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Journal of Spices and Aromatic Crops (1992-2023)

Indian Society for Spices (ISS)
ICAR-Indian Institute of Spices Research
Kozhikode-673 012, Kerala, India

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Compiled and Edited by
C N Biju
Mohammed Faisal Peeran
Lijo Thomas
P V Alfiya
A Jeevalatha
S Mukesh Sankar
Sharon Aravind
K Kandiannan

Editorial Assistance
P Rajaneesh Chandra
K S Reshma

Design & Print
Overlap Designs

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PREFACE

It is time to celebrate three decades of the *Journal of Spices and Aromatic Crops*, on this momentous occasion to reflect on the significant strides made in this vital field, a compilation is worthwhile for reminiscence. This journal has not only been a platform for ground-breaking research but also a catalyst for innovation and sustainable practices in the global spice and aromatic crop industry.

With the inception of Indian Society for Spices (ISS), the society launched the *Journal of Spices and Aromatic Crops* (JOSAC) to support spice researchers, filling a gap in specialized publications. The response for submissions was encouraging, and the first issue was published during 1992. Dr. P N Ravindran was the founder Editor, who was instrumental in naming of JOSAC and contributed significantly in growth of the Society and JOSAC. Over the past three decades, the journal has consistently published high-quality research articles, reviews, and short communications, covering a wide range of topics, from traditional cultivation practices to cutting-edge biotechnology with a rating of 5.11 by NAAS. It has been instrumental in disseminating knowledge and fostering collaboration among researchers, policymakers, farming community, and industry stakeholders worldwide.

The journal's commitment to excellence is evident in its rigorous peer-review process, ensuring that only the most impactful research finds its way into its pages. By providing a platform for open access, it has made invaluable contributions to the global scientific community, empowering researchers and practitioners to access the latest advancements in the field.

The editors have compiled a rich collection of research and reviews published from 1992 to 2023. This compilation reflects the diverse and complex world of spices and medicinal plants. Each section has been thoughtfully curated to provide readers with comprehensive insights into the latest developments in this vibrant field.

The entries are organized into 12 sections: Black pepper, Small cardamom, Large cardamom, Ginger, Turmeric, Vanilla, Tree spices (including nutmeg, clove, cinnamon, allspice, Garcinia, tamarind), Seed spices (such as coriander, cumin, fennel, fenugreek, ajwain etc.), Chilli, Medicinal, aromatic and miscellaneous crops, Multiple crops and bioagents (research on major spices and bioagents), and Reviews (including book reviews). For major spices, abstracts are further categorized into four key thematic sections *viz*., Crop Improvement, Crop Production and Postharvest Technology, Crop Protection, and Social Sciences. This approach ensures that readers can easily navigate through relevant studies and advancements in each area.

Our aim is to provide valuable insights that not only inform but also inspire further research and exploration, contributing to the growth and sustainability of spice cultivation, medicinal plant industries, and associated sectors. The curated content from JOSAC serves as a vital resource for advancing knowledge, fostering innovation, and promoting the global importance of spices and aromatic crops.

Currently, the *Journal of Spices and Aromatic Crops* (JOSAC) is available in both printed and online formats, making it more accessible to researchers globally. The online platform enables wider reach, allowing researchers to easily access the recent findings in the field of spices and aromatic crops. This dual format ensures that both print-oriented readers and those who prefer digital access can stay updated with the journal's content. Additionally, the online presence facilitates faster dissemination of research, promotes greater international collaboration, and provides a platform for spice researchers to publish and share their work with a broader audience.

As we look to the future, the *Journal of Spices and Aromatic Crops* remains dedicated to its mission of promoting sustainable and ethical practices in the spice and aromatic crop industry. It will continue to play a pivotal role in addressing global challenges such as climate change, food security, and biodiversity conservation.

Kozhikode **Editors**

07.01.2025

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BLACK PEPPER

Crop Improvement and Biotechnology

Induced polyploidy in black pepper (*Piper nigrum* L.). 1 (2): 151-153 (1992)
R R Nair & P N Ravindran
Induced polyploidy in a hybrid cultivar of black pepper Panniyur 1 is reported. Open pollinated seeds were used for polyploidy induction. One tetraploid of Panniyur I with 104 chromosomes in somatic cells was recovered from plants raised from seeds treated with 0.05% colchicine. The plant was vigorous and possessed all the polyploid syndromes.

Pournami - A high yielding black pepper selection tolerant to root-knot nematode (*Meloidogyne incognita*). 1 (2): 136-141 (1992)
P N Ravindran, K V Ramana, M K Nair, K Nirmal Babu & C Mohandas
A high yielding selection (Coll. 812) from the germplasm, named Pournami, was tolerant to root-knot nematode (*Meloidogyne incognita*), damaging roots of black pepper and causing yellowing of leaves and significant yield decline. This selection when tested for its comparative yield performance, was on par with Karimunda and Panniyur-I and was recommended for release.

Variability in open pollinated seedlings of black pepper (*Piper nigrum* L.). 2 (1&2): 60-65 (1993)
P N Ravindran & B Sasikumar
Highly heterogeneous variances were observed for plant height, leaf number, leaf width, internode length and stem girth in open pollinated seedlings of three black pepper (*Piper nigrum*) cultivars. Collection 1344 had maximum range and coefficient of variation for all the characters followed by Panniyur 1 and a Karimunda Selection KS-27. Eighteen distinct morphological variants were also recorded in the progeny of Coll. 1344. In some of the progenies, the initial variation sustained with growth for most of the morphological

features. No such morphological variants were observed in the progenies of Panniyur 1 and KS-27. The reason for this behaviour of the cultivar is discussed.

Kanamycin sensitivity of cultured tissues of *Piper nigrum* L. 3 (2): 158-160 (1994)
B Sasikumar & K Veluthambi
The kanamycin sensitivity for callus growth was studied *in vitro* in a cultivar of black pepper (*Piper nigrum*) using cotyledons as explants to investigate the suitability of kanamycin resistance as a selectable marker for *Agrobacterium* mediated transformation. Callus formation was completely inhibited at 50 μg ml^{-1} and above concentrations of kanamycin suggesting that 50 μg ml^{-1} is the minimum concentration needed to select the transformed tissues.

Morphometrical studies on black pepper (*Piper nigrum* L.). I. Cluster analysis of black pepper cultivars. 6 (1): 9-20 (1997)
P N Ravindran, R Balakrishnan & K Nirmal Babu
Forty four cultivars and seven wild black pepper (*Piper nigrum*) accessions (51 Operational Taxonomic Units) were subjected to single linkage and centroid linkage cluster analysis. The 22 characters employed in the study resolved into two distinct sets. Based on character correlations, six clusters were recognised while certain characters did not show correlation with others. Centroid clustering led to the grouping of the Operational Taxonomic Units into 11 clusters. Among these, four groups had one cultivar, four had two cultivars, one had four cultivars, one had seven cultivars and one had 28 cultivars each. The cultivars that were unique and did not cluster with any other are Karimunda, Panniyur 1, Vadakkan and Kuthiravally. The inclusion of 28 cultivars in one group also shows that a majority of common cultivars resemble one another closely and probably had a common origin. The study is useful in establishing the relative resemblances of major black pepper cultivars grown in Kerala and Karnataka of India.

Morphometrical studies on black pepper (*Piper nigrum* L.). II. Principal component analysis of black pepper cultivars. 6 (1): 21-29 (1997)

P N Ravindran, R Balakrishnan & K Nirmal Babu

Forty four cultivars and seven wild accession of black pepper (*Piper nigrum*) (51 Operational Taxonomic Units) were analysed adopting Principal Component Analysis to determine the nature and extent of divergence among them. Eight principal components emerged from the analysis and the dispersion pattern of Operational Taxonomic Units between the principal components (in principal component plots) showed the characters involved in the divergence of various cultivars. Dispersion of Operational Taxonomic Units between principal components showed that certain cultivars remain as independent entitles thereby indicating their divergence from other cultivars. The majority of cultivars are distributed around the central point, and this group is comparable to the group D obtained by the centroid clustering. Computation of inter and intracluster-D^2 helped to establish further the extent of relationships among the clusters.

Varietal evaluation of black pepper (*Piper nigrum* L.) for yield, quality and anthracnose disease resistance in Idukki District, Kerala. 11 (2): 122-124 (2002)

P Sainamole Kurian, S Backiyarani, A Josephrajkumar & M Murugan

Fourteen accessions of black pepper were evaluated at the Cardamom Research Station, Pampadumpara for yield, quality and disease resistance. Out of the fourteen cultivars, CuI. 239 (Panniyur-5) recorded the highest wet (906.5 g) and dry (310.1 g) yield of berries per plant. The maximum volatile oil (5.06%) and oleoresin (9.4%) contents in dry berries were observed in CuI. 5128 and Panniyur 1, respectively. A positive correlation existed between the number of spikes and berries per plant and yield. However, yield and quality characters are negatively correlated, though not significant. The results showed that Panniyur 5 is the most suitable black pepper variety for high range conditions of Idukki District.

Clonal variability in black pepper hybrid Panniyur 1. 12 (2): 154-157 (2003)

T Pradeepkumar, D Sajith Babu, K C Aipe & Samuel Mathew

Forty two clones of twenty year old Panniyur 1 plants, grown as a monocrop of black pepper, were analyzed for variations in yield contributing factors as well as quality parameters over a period of three years. The analysis of the data has revealed that the plants exhibited considerable amount of variability for characters under study and the standard deviation was more for berries spike^{-1} and yield. Among the quality characteristics, oleoresin exhibited more variability than piperine. From the non-hierarchical Euclidean cluster analysis it is observed that the plants can be clustered ideally in to five clusters based on their mean performance. The intra and inter cluster distance was more for cluster number 4, which later culminated in maximum number of plants (13) having high yield and oleoresin.

IISR Thevam', 'IISR Malabar Excel' and 'IISR Girimunda' - Three new black pepper (*Piper nigrum* L.) clones. 13 (1): 1-5 (2004)

B Sasikumar, P Haridas, J K George, K V Saji, T J Zachariah, P N Ravindran, K N Babu, B K Moorthy, P A Mathew & V A Parthasarathy

Based on 7 years performance at Valparai (Tamil Nadu) (3000 ft MSL), and 2 years performance at Peruvannamuzhi (Kerala) and quality evaluation, three black pepper lines namely, Coll. 1041, HP-813 and HP-I05 were superior and proposed for release as 'IISR Thevam', 'IISR Malabar Excel' and 'IISR Girimunda', respectively. These lines were superior to at least one of the controls for more than one character at one or both the locations. Trials laid out at farmer's fields in four northern districts of Kerala also indicated the superiority of these lines. Coll. 1041 besides out-yielding control, exhibited a high degree of field tolerance to foot rot disease, whereas HP-813 had oleoresin content as high as 12%.

Molecular and morphological characterization of new promising black pepper (*Piper nigrum* L.) lines. 14 (1): 1-9 (2005)
M Sreedevi, S Syamkumar & B Sasikumar
Seven high yielding, new, promising lines of black pepper (*Piper nigrum*) were characterized using molecular markers (randomly amplified polymorphic DNA) and morphological features. Out of the 14 random decamer primers studied, 9 could generate unique bands in 6 lines. Maximum unique bands of the primers were observed in the line OPKM followed by HP-1411 and HP-105. HP-780 could not be discriminated by any of the primers. Sixteen unique bands were produced by the nine primers making an average of 1.7 bands per primer. The lines OPKM, HP-1411 and HP-105 exhibited distinct morphological features also.

A method for isolation and reverse transcription of high-quality RNA from *Piper* species. 14 (1): 10-14 (2005)
K Johnson George, R Sandeep Varma, G Ganga, M Anandaraj & V A Parthasarathy
A rapid and efficient protocol for isolation of RNA from *Piper* leaves is described. RNA was extracted from two *Piper s*pecies namely, *P. nigrum* and *P. colubrinum* using strong denaturing buffer containing guanidinum thiocyanate and polyvinylpyrollidone followed by precipitation with pre-cooled sodium acetate and extraction with phenol: chloroform: isoamyl alcohol (25:24:1). RNA was precipitated with isopropanol. The extraction procedure reliably yielded high quality RNA suitable for reverse transcription experiments.

Performance, diversity analysis and character association of black pepper (*Piper nigrum* L.) accessions in the high altitude of Idukki district, Kerala. 27 (1): 17-21 (2018)
T T Preethy, T S Aswathy, T Sathyan, M K Dhanya & M Murugan
The experiment was conducted to evaluate black pepper accessions for growth parameters, yield attributing characters and yield. Out of the ten accessions tested, Karimunda recorded the highest fresh (1.61 kg) and dry (508.7 g) yield of berries plant^{-1}. Fresh weight showed significant positive genotypic correlation to dry weight and while negative correlated to 100 berry volume, 100 berry weight and

number of berries spike^{-1}. Hence, selection based on number of berries spike^{-1}, 100 berry volume and 100 berry weight may not lead to the high yielding black pepper variety. The results showed that Karimunda is the most suitable black pepper variety for high altitude areas of Idukki district.

Association and path coefficient analysis among yield attributes and berry yield in black pepper (*Piper nigrum* L.). 28 (2): 106-112 (2019)

M S Shivakumar & K V Saji

Eighty two germplasm accessions of black pepper aggregated from pepper cultivating tracts of Karnataka, Kerala, Goa and Maharashtra were characterized for 17 quantitative traits as per the IPGRI descriptors during 2018-19 at the field gene bank of ICAR-Indian Institute of Spices Research, Experimental Farm, Kozhikode. Wide range and high coefficient of variation (CV) were recorded for dry berry weight, fresh berry weight and number of spikes vine^{-1} whereas, lower CV was observed for berry size. Fresh berry weight showed significant positive correlation with dry berry weight followed by number of spikes vine^{-1} whereas, number of immature berries spike^{-1} and berry size showed significant negative association with setting percentage. High positive direct effect of fresh berry weight on dry berry weight was observed during path analysis. Both fresh rachis weight and number of spike vine^{-1} had indirect positive effects on dry berry weight through fresh berry weight. Residual effect was meagre suggesting that the 17 quantitative traits explained 99% variability. Traits like number of spikes vine^{-1} and fresh berry weight are the important traits that need to be augmented during improvement of black pepper for yield.

Characterization of black pepper (*Piper nigrum* L.) varieties and landraces/farmers selections for spike and berry traits. 31 (2): 134-142 (2022)

M S Shivakumar, S Aarthi, H J Akshitha, K V Saji, K S Krishnamurthy & B Sasikumar

Statistical tools such as analysis of variance, correlation, path coefficient analysis, Scott-Knott test and principal component analysis

were used in the present study to characterize black pepper verities/hybrids for spike and berry traits. ANOVA indicated that fifteen traits under study were statistically significant. Traits like fresh pericarp weight and dry pericarp weight showed high positive correlation (>0.95) with spike weight. Path coefficient analysis revealed that berry weight and seed size are contributing directly to spike weight. Scott-Knott test identified Panniyur 1 and Nedumchola as the most contrasting genotypes for most number of traits studied. Based on Principal Component Analysis (PCA), first three principal components had an eigen value above unity and explained 88 per cent of cumulative variation. Principal component PC-1 accounted for maximum variation of about 42.4 per cent which discriminated the genotypes based on fresh berry weight, dry seed weight and fresh pericarp weight. These traits serve as the selection criteria for improvement of yield in black pepper.

Genetic variability analysis in elite black pepper genotypes using morpho physiological and yield-attributing traits. 32 (2): 107-119 (2023)

A P Theertha, M S Shivakumar & K S Krishnamurthy

The genetic variability in selected 21 black pepper accessions was analyzed based on desirable drought-tolerant and susceptible characteristics using principal component and cluster analyses. The experiment was conducted at ICAR-Indian Institute of Spices Research, Experimental farm, Peruvannamuzhi, Kozhikode using a randomized block design with four replications. Morphological, physiological and yield contributing traits were studied. The traits examined showed a comprehensive range of variability. The principal component and UPGMA clustering analyses were employed to assess the proportional contribution of various traits and grouped the genotypes, respectively. The first principal component was responsible for the highest variation (30.87%) in the yield-related characteristics, which were positively correlated with each other and correlated negatively with the morphological characteristics and stomatal frequency. Separate clusters were formed for the genotypes that displayed drought-tolerant characteristics (cluster 2 and 3) and those that showed susceptible characteristics (cluster 1). The results

indicated that the analysed black pepper genotypes have significant genetic variability among them which may be helpful for identification of genotypes with desirable drought tolerant characteristics. Accessions 7211 (cluster 2), 1495, 1343 and 4132 (cluster 3) showed characteristics that make them potentially drought tolerant while the accessions 5717 and 4064 (cluster 1) showed drought susceptible traits.

Crop Production and Postharvest Technology

Effect of vesicular arbuscular mycorrhiza on rooting of black pepper (*Piper nigrum* L.). 3 (1): 39-42 (1994)
M Anandaraj & Y R Sarma
Incorporation of vesicular arbuscular mycorrhiza (VAM) fungus *Glomus fasciculatum* in the rooting medium of sand enhanced rooting of black pepper (*Piper nigrum*) cuttings. The rooting was reduced when the commercial rooting hormone (Ceradix B) was also added in addition to VAM. Rooting enhancement could be used as a criterion to identify efficient strains of VAM for black pepper.

Effect of application of organic materials on growth and foliar nutrient contents of black pepper (*Piper nigrum* L.) 3 (2): 135-141 (1994)
C Siva Kumar & P A Wahid
The effect of soil application of organic materials (leaves of *Erythrina indica, Garuga pinnata, Grevilea robusta, Piper nigrum* and *Coffea arabica*) on growth and nutrition of black pepper vines (*Piper nigrum*) was studied in pot culture experiments. A substantial increase in growth and biomass production was noticed in vines treated with organic materials as compared to control. However, application of leaves of *C. arabica* and *P. nigrum* at higher rates suppressed growth of vines probably due to allelopathic effects of the decay products of these materials in the soil. The rates of decomposition of leaf materials in the soil varied considerably. Leaves of *C. arabica* and *G. robusta* were the most persistent while that of *G. pinnata* was least resistant to decomposition.

An approach into the detection of authenticity of black pepper (*Piper nigrum* L.) oleoresin. 5 (1): 64-67 (1996)
Milind M Madan, Rekha S Singhal & Pushpa R Kulkarni
Investigations on authenticity of black pepper (*Piper nigrum*) oleoresin indicated that saponification value, iodine value and ratio of saponification value to iodine value are useful indicators. The presence of papaya seeds in black pepper used to prepare the oleoresin could be detected at 15 per cent levels using these indices. The advantages of these indices over piperine as an indicator are discussed.

Performance of black pepper (*Piper nigrum* L., var. Panniyur 1) trained on different shade trees as live standards. 8 (1): 97 (1999)
V S Korikanthimath & S J Ankegowda
In the present investigation the yield of black pepper vines (Panniyur-1) at eighth year of planting (mix cropped with robusta coffee) was recorded in four species of standards. The standards include, *Erythrina lithosperma* Bl. ex Miq, an evergreen fast growing tree which has a uniform small trunk diameter (30-40 cm); *Ficus glomerata* Roxb, a fast growing tree of medium height with medium trunk diameter (40-60 cm) with comparatively smooth surface and with well distributed branches; silver oak (*Grevillea robusta* A. Cunn.), a tall tree with very rough trunk surface with 40-50 cm diameter and small leaves helping in adequate transmission of light and thanimara *(Terminalia bellerica* Roxb.), a very huge tree with 95 cm trunk diameter with 3-4 main branches with good light transmission The data indicated that the total surface area available for the vine to cling to the support trees and the distribution of sunlight under them are important factors for yield of black pepper vines on the standards. Vines trailed on *G. robusta* yielded 19.16 kg/vine-green berries indicating that it is a suitable standard in high ranges and also for high density planting of black pepper.

Growth of bush pepper (*Piper nigrum* L.) plants as influenced by light and nutrients. 9 (2): 105-109 (2000)
Madhura Devadas and S Chandini
Experiments conducted at Sadanandapuram (Kerala, India) to study the influence of nutrients under different light intensities on growth of bush pepper (*Piper nigrum*) plants indicated that better expression of growth characters was observed at 50% light intensity in plants given 37.5 g each of nitrogen and phosphorus and 50.0 g of potassium per year.

Growth and nutrient content of black pepper (*Piper nigrum* L.) cuttings as influenced by inoculation with biofertilizers. 9 (2): 145-147 (2000)
K Kandiannan, K Sivaraman, M Anandaraj & K S Krishnamurthy
Experiments conducted to test the effect of *Azospirillum*, phosphobacteria and vesicular arbuscular mycorrhiza on growth and nutrient content of black pepper (*Piper nigrum*) cuttings indicated that growth parameters were on par with control when these three biofertilizers were applied individually, but their combination enhanced growth significantly over control. Inoculation with a combination of two/three biofertilizers enhanced plant height, leaf area, biomass and dry matter production and nutrient content significantly over uninoculated control.

Effect of plant growth regulators on yield parameters, yield and quality of black pepper (*Piper nigrum* L.) variety Panniyur-1. 11 (2): 125-128 (2002)
A Ramesh Kumar, S Sathiamoorthy & A Subbiah
Experiments conducted at Horticultural College and Research Institute, Periyakulam and Horticultural Research Station, Thadiankudisai (TNAU) to study the effect of different plant growth regulators (NAA, GA3, BA and 2,4-D) indicated that spraying NAA (50 ppm) has improved many commercially desirable parameters like number of berries per spike, volume and weight of berries and yield in black pepper (Piper nigrum L.). Benefit cost ratio, however, was the highest in the treatment 2,4-D (10 ppm). The high cost of chemicals outweighed the yield except in the case of 2,4-D.

Influence of different phosphorus sources and zinc spray on yield and quality of black pepper (*Piper nigrum* L.) under acid soils. 12 (1): 15-18 (2003)
D Muthumanickam
Trials were conducted to identify the suitable form of phosphorus and optimum spray concentration of zinc for increasing yield of black pepper under acid soil conditions of Yercaud (Tamil Nadu, India). The results indicated that soil application of 40 g P_2O_5 vine^{-1} as rock phosphate along with spraying of $ZnSO_4$ (0.5%) increased dry pepper yield (9.21 kg vine^{-1}) and oleoresin content (12.34%).

Influence of soil physico-chemical properties on productivity of black pepper (*Piper nigrum* L.). 13 (1): 6-9 (2004)
S Hamza, A K Sadanandan & V Srinivasan
Soil surveys were conducted to study the physico-chemical characteristics of major black pepper (*Piper nigrum*) growing soils in Kerala and their relationship with black pepper productivity. Soil samples were collected from four major black pepper growing districts, namely, ldukki, Wayanad (high elevation), Kozhikode and Kannur (low elevation) and were classified based on yield as high, moderate and low yielding gardens. The relationships between elevations, physico-chemical properties and black pepper productivity were studied. The investigation revealed that soils of high yielding gardens were high in sand and low in clay fractions. These soils had high pH, base saturation, canon exchange capacity, organic carbon, phosphorus, potassium, calcium, magnesium and zinc status compared to low yielding gardens. These factors favoured good growth of black pepper vines with higher productivity.

Studies on rapid multiplication of black pepper (*Piper nigrum* L.) on soil mound. 13 (1): 34-36 (2004)
R G Khandekar, P M Haldankar, V S Pande, G D Joshi, D S Bagade, D B Malve, N R Bhagwat, A D Rangwala, N D Jambhale & K V Ramana
An experiment was conducted to study rapid multiplication of black pepper (*Piper nigrum*) on soil mound at Dapoli (Maharashtra). The black pepper plants were planted at the base of soil mound (2.5 m

width, 0.60 m height at centre, 18 m length, 45° angle slope) at various spacings (15.0, 22.5, 30.0 and 37.5 cm) and compared with cuttings raised by bamboo and traditional methods. The vines in soil mound method exhibited superior performance with respect to length and root production node^{-1}. The availability of cuttings from soil mound method was also the highest. The rooting percentage of cuttings obtained from soil mound and bamboo methods were significantly superior over traditional method of propagation. The B:C ratio for marketable black pepper cuttings by soil mound method was the best (2.1:1.0). Planting base material at 15 cm spacing on soil mound was the best and produced more runners per unit area as compared to other spacing treatments and traditional method.

Evaluation of composted coir pith with chemical and biofertilizers on nutrient availability, yield and quality of black pepper (*Piper nigrum* L.). 14 (1): 15-20 (2005)
V Srinivasan, S Hamza & A K Sadanandan
Composted coir pith was evaluated at Madikeri (Karnataka) under integrated plant nutrient management system to substitute chemical input of fertilizers for improving the yield and quality of black pepper (*Piper nigrum*). Application of composted coir pith (CC) @ 2.5 t ha^{-1}with full recommended dose of NPK (100:40:140 kg ha^{-1} of N, P_2O_5 and K_2O) yielded the highest (4.18 kg vine^{-1}) which was on par with 1.25 t ha^{-1} CC + full NPK, 2.5 t ha^{-1} CC + ½ NPK + *Azospirillum* sp., 1.25 t ha^{-1} CC + ½ NPK + Azospirillum sp. and 2.5 t ha^{-1} CC alone. The levels of composted coir pith application were on par with regard to quality (piperine and oleoresin contents) of black pepper. The highest benefit-cost ratio of 1.94 was recorded in the treatment with composted coir pith @ 1.25 t ha^{-1} + *Azospirillum* sp.

Effect of *Pseudomonas fluorescens* (IISR-6) and *Trichoderma harzianum* (P-26) on growth of black pepper (*Piper nigrum* L.) in the nursery. 14 (2): 112-116 (2005)
C K Thankamani, K Sreekala & M Anandaraj
Experiments conducted to study the effect of *Pseudomonas fluorescens* (IISR-6) and *Trichoderma harzianum* (P-26) on growth of black pepper (*Piper nigrum*) rooted cuttings in the nursery indicated that

maximum height and leaf area of cuttings were obtained with application of *P. fluorescens* thrice, which was on par with raising cuttings in *T. harzianum* applied potting mixture and application of *P. fluorescens* thrice. Number of roots and biomass production were higher with combined application of *P. fluorescens* (thrice) and *T. harzianum* which was on par with application of *P. fluorescens* thrice.

Effect of source and method of application of zinc on yield and quality of black pepper (*Piper nigrum* L.). 14 (2): 117-121 (2005)
S Hamza & A K Sadanandan

Experiments were conducted in the green house at Peruvannamuzhi (Kerala) and also in the field at Madikeri (Karnataka) to compare the effect of zinc sources, zinc sulphate (ZnSO4) and zinc ethylenediaminetetraacetic acid chelate (Zn-EDTA) and methods of application (soil and foliar) to black pepper (*Piper nigrum*) in a zinc deficient soil. The results showed that with regard to soil availability of zinc, application of zinc as Zn-EDTA chelate @ 2.5 mg kg^{-1} soil in green house and 2.5 kg ha^{-1} in field conditions recorded maximum values. Leaf and berry zinc and pepper yield were maximum due to 0.5% $ZnSO_4$ foliar spray. Irrespective of sources and methods, Zinc application significantly increased oleoresin and piperine contents. With regard to benefit:cost ratio, 0.5% foliar spray of $ZnSO_4$ resulted in maximum value in green house, whereas soil application of 2.5 kg Zn ha^{-1} as $ZnSO_4$ resulted in maximum value in field condition.

Nutrient diagnosis of black pepper (*Piper nigrum* L.) gardens in Kerala and Karnataka. 16 (2): 77-81 (2007)
S Hamza, V Srinivasan & R Dinesh

Diagnosis and Recommendation Integrated System (DRIS) indices were worked out for soil and leaf nutrient status of black pepper (*Piper nigrum*) at Calicut (Kerala). The nutrient analysis data obtained from extensive (130 samples) surveys of major black pepper growing tracts of Kerala and Karnataka was compared with already worked out soil and leaf nutrient DRIS indices values to find out the deviation of nutrients from the corresponding critical concentrations. The results revealed that the soils in most of the gardens were acidic (pH 4.4 to 6.7). Soil sample analysis showed that 88% gardens had organic

carbon (OC) status below the critical values, 74% gardens had Zn and 36% gardens had P and 28% gardens had Ca status below the required levels. Leaf analysis results showed that 46% samples had Mg, 39% samples had Cu and 12% samples had P, K and Zn status below the required critical values. The order of limiting nutrients was: OC > Zn > P > Ca > K > Mg for soil and Mg > Cu > P=K=Zn > Mn for leaf samples. The study revealed the importance of manuring black pepper gardens with organic manures supplemented with secondary and micronutrients.

Study on grinding of black pepper and effect of low feed temperature on product quality. 16 (2): 82-87 (2007)
Santhi Mary Mathew & V V Sreenarayanan

The effect of feed temperature on grinding of black pepper (*Piper nigrum*) in a hammer mill was studied at Coimbatore (Tamil Nadu). Variation in temperature was attained by keeping black pepper in a refrigerator maintained at 4°C (low temperature sample) to attain a feed temperature of 7.9 to 21.2°C and by mixing with dry ice at different ratios (ultra-low temperature sample) to get temperatures from -3.33 to 12.86°C. On the basis of volatile oil content, oleoresin, piperine and volatile components, a feed temperature of -3.33 to -1.25°C was optimized. The volatile oil content of the product indicated an increase of about 17% retention of oil for ultra-low temperature and 15% for low temperature compared to the ambient condition (control). Gas chromatographic analysis of the oil showed higher retention of monoterpenes under ultra-low temperature condition compared to ambient and low temperature conditions of grinding. An increase of 1% to 3% moisture was observed for the ultra-low temperature sample for a feed temperature of -3.33 to -1.25°C, which helped to increase 2% to 3% oleoresin yield. The volume surface mean diameter of black pepper powder showed an increasing trend of 0.15 mm to 0.18 mm with an increase in feed temperature from-3.33 to 12.86°C for ultra-low temperature sample. The specific energy consumption varied from 24.79 to 46.62 kJ $(kg°C)^{-1}$ with increase in grinding temperature.

Evaluation of nursery mixture for planting material production in black pepper (*Piper nigrum* L.). 16 (2): 111-114 (2007)

C K Thankamani, V Srinivasan, S Hamza, K Kandiannan & P A Mathew

An experiment was conducted at Peruvannamuzhi (Kerala) to study the feasibility of using soil-less medium containing coir pith compost and granite powder for raising black pepper (*Piper nigrum*) cuttings in the nursery. Plant height, leaf production, leaf area and total dry matter production were significantly higher in the medium consisting of coir pith compost and granite powder in 1:1 proportion along with *Azospirillum* sp. and phosphobacteria as nutrient sources whereas, the cost of production of rooted cuttings was cheaper in the medium consisting of coir pith compost, granite powder, and farmyard manure in 2:1:1 proportion compared to conventional potting mixture (soil:sand:farmyard manure in 2:1:1 proportion).

Effect of solarized potting mixture on growth of black pepper (*Piper nigrum* L.) rooted cuttings in the nursery. 17 (2): 103-108 (2008)

C K Thankamani, R Dinesh, S J Eapen, A Kumar, K Kandiannan & PA Mathew

Solarized potting mixture in combination with nutrients and biocontrol agents was evaluated for production of vigorous disease-free rooted cuttings of black pepper. Plants raised in solarized potting mixture had better growth than plants raised in non-solarized potting mixture (soil, sand, and farm yard manure 2:1:1 proportion). Among the various treatments, plants raised in solarized potting mixture with recommended nutrients (urea, superphosphate, potash and magnesium sulphate 4:3:2:1) showed significant increase in number of leaves (5.3), length of roots (20 cm), leaf area (177 cm^2), nutrient contents and biomass (3.7 g pl^{-1}). The results indicated the superiority of solarized potting mixture for reducing the incidence of diseases besides yielding vigorous planting material. Cost of production of rooted cuttings with biocontrol agents was found to be cheaper in the case of rooted black pepper cuttings raised in solarized potting mixture. Bio control agents or biofertilizers can be mixed with solarized potting mixture.

Evaluation of indigenous *Azospirillum* isolates for growth promotion in black pepper (*Piper nigrum* L) rooted cuttings. 17 (2): 128-133 (2008)

K P Sangeeth, R Suseela Bhai & V Srinivasan

The aim of the present work was to evaluate the inoculation effects of indigenous *Azospirillum* spp. selectively isolated from various black pepper growing locations of Kerala and Karnataka in enhancing the growth and nutrient uptake of black pepper cuttings. *Azospirillum* isolates BPaz4 and BPaz9 recorded 67% more plant height in rooted cuttings than untreated cuttings. The nitrogen, phosphorus and potassium uptake and total dry weight were significantly superior in treated plants. Increase in the uptake of iron, manganese, zinc and copper was found in BPaz9 treatment. Colonization of rhizosphere soil and non-rhizosphere by these isolates was found to be high. The N_2 fixation capacity of the isolates BPaz4 and BPaz9 showed 8.68 and 8.52 mg g^{-1} malate. Thus the application of these inoculants *viz*., BPaz4 and BPaz9 is suggested for the ecofriendly production of rooted cuttings of black pepper.

Ideotype concept in black pepper (*Piper nigrum* L.). 19 (1&2): 1-13 (2010)

K S Krishnamurthy, V A Parthasarathy, K V Saji & B Krishnamoorthy

An attempt has been made to describe the crop ideotype characteristics for black pepper (*Piper nigrum*). It is proposed that the black pepper ideotype should have acute branch angles (45^0) at the top and more wider branch angles at the bottom (60^0). The fruiting branches should be well spread from top to bottom of the canopy. To harvest maximum light especially by the bottom canopy, the leaf angle should be more at the bottom ($130\text{-}140^0$) compared to the top ($100\text{-}110^0$). It is desirable that within a branch, the bottom leaves have lengthier petioles than the top leaves. The vine should have a high photosynthetic rate (minimum of 3.0-3.5 μ moles), more than 90% bisexual flowers with >95% self pollination, increased spike length (≥12 cm) and more number of berries spike-1 (≥70). Fruit set should be ≥80% and should yield at least 2.5-3.0 kg dry berries $vine^{-1}$. Among the cultivars/varieties studied, Panniyur 1 was found to possess more

number of traits for the proposed ideotype compared to other cultivars/varieties.

Effect of *Azospirillum* sp. and nutrients on yield of black pepper (*Piper nigrum* L.).
20 (1): 9-13 (2011)
C K Thankamani, V Srinivasan, K S Krishnamurthy & K Kandiannan
An experiment was conducted at Peruvannamuzhi (Kerala) to study the effect of *Azospirillum* sp. along with nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), boron (B) and molybdenum (Mo) on yield of black pepper (*Piper nigrum*). Maximum fresh yield (2207 g vine^{-1}) was recorded in the treatment *Azospirillum* sp. + 50% recommended N + Mg followed by application of NPK alone. Significantly higher N, K and Mg content in the soil and N and Ca content in the leaf was observed in the treatment, 50% recommended N + Mg. Application of *Azospirillum* sp. increased the population of bacteria and a final population of 10^6 x 10^5 cfu (colony forming units) in the soil was recovered in the treatment 50% recommended N + Mg (0.2 kg ha^{-1}) compared to uninoculated control.

Feasibility of intercropping medicinal plants in black pepper garden. 21 (2): 113-117 (2012)
C K Thankamani, K Kandiannan, M S Madan, V K Raju, S Hamza & K S Krishnamurthy
The feasibility of cultivating medicinal plants in black pepper (*Piper nigrum* L.) plantation was studied at Ambalavayal (Kerala). The plants tested were *Adhatoda beddomei*, *Desmodium gangeticum*, *Pseudarthria viscida*, *Ayapana triplinervis*, *Pogostemon cablin* and *Plumbago rosea* in a fifteen-year-old black pepper plantation. The results indicated that black pepper yield (2100 kg ha^{-1}) was higher under intercropping situation compared to sole crop (1675 kg ha^{-1}). Among the medicinal plants, maximum black pepper equivalent yield (PEY) (2100 kg ha^{-1}) was recorded in *P. rosea* followed by *P. cablin* (2000 kg ha^{-1}). Maximum net return was obtained from black pepper + *P. rosea* followed by *P. cablin*. The benefit: cost ratio was highest for inter

cropping P. rosea (3.5) followed by *P. cablin* (3.3) and *A. triplinervis* (3.3).

Paenibacillus glucanolyticus, a promising potassium solubilizing bacterium isolated from black pepper (_Piper nigrum_ L.) rhizosphere. 21 (2): 118-124 (2012)

K P Sangeeth, R Suseela Bhai & V Srinivasan

A bacterium possessing high ability to solubilize potash was isolated from the rhizosphere of black pepper. On the basis of biochemical and 16S rDNA sequence analysis, the bacterium was identified as *Paenibacillus glucanolyticus* strain IISRBK2. The optimal medium composition and cultural conditions for the isolation of *P. glucanolyticus* were sucrose 5.0 g, Na_2HPO_4 2.0 g, $MgSO_4.7H_2O$ 2.0 g, $FeCl_3$ 0.005 g, $CaCO_3$ 0.1 g and wood ash 1.0 g at pH 7.5 at 30°C. The strain was also evaluated for plant growth and potassium (K) uptake of black pepper in soil artificially treated with 0.5,1 and 1.5g K kg^{-1} soil in the form of wood ash. In this study, wood ash was used as a source of K which contained 53.1 g kg^{-1} K of which 4.5% was in insoluble form. Inoculation with strain *P. glucanolyticus* was found to increase tissue dry mass (ranging from 37.0% to 68.3%) of black pepper in 1g K kg^{-1}wood ash amended soil. In the soil treated with 0.5 -1.5 g K kg^{-1}, K uptake in live bacterium inoculated black pepper plants increased by 125.0-184.0% compared to uninoculated control.

Efficiency of sulphate of potash (SOP) as an alternate source of potassium for black pepper (_Piper nigrum_ L.). 22 (2): 120-126 (2013)

V Srinivasan, K Kandiannan & S Hamza

Field experiments were conducted at two locations, *viz*., Kannur (Kerala) and Chettalli (Kodagu, Karnataka) for evaluating the efficacy of sulphate of potash (SOP) as a source of potassium (K) on black pepper. There were nine treatment combinations *viz*., T_1 - Control, T_2 - Recommended (Rec.) K as muriate of potash (MOP), T_3 - Rec. K as SOP, T_4 - 125% of Rec. K as SOP, T_5 - T_3 + SOP 2% foliar spray, T_6 - 50% of Rec. K as SOP + SOP 2% foliar spray, T_7 - 50% of Rec. K as SOP, T_8 - T_2 + Mg @ 25 kg ha^{-1} as $MgSO_4$ and T_9 - T_3 + Mg @ 25 kg ha^{-1} as $MgSO_4$ laid out in a randomized block design with three replications. The

results showed that soil nutrient status in treatment with 25.0% higher recommended K as SOP recorded significantly higher concentrations of soil organic carbon, K, Ca, S, Zn and Cu. The study further revealed that for economic yield of high quality black pepper, 50% of recommended dose of K as SOP for soils of high K status and 100% recommended K as SOP + 2% foliar spray of SOP for soil of low K status can be recommended.

Development of a black pepper harvester. 22 (2): 127-130 (2013)

K S K Aneeshya, G K Krishnanunni & V Ganesan

Three models of pepper harvester were fabricated and evaluated on the basis of efficiency in the cutting action and easiness in operation. All the three models basically consisted of a mild steel cutting unit, aluminium conveying pipe and a collecting basket. The main concepts adopted for the fabrication were impact, shear and pulling action for the proper insertion and cutting of the spikes and collection. The test was conducted for Panniyur variety out of which, the most efficient and user friendly was the second model due to its light weight, easiness in operation and minimum loss. The main advantages accounted for this model were simultaneous cutting and collection of spikes without heavy loss.

Physico-mechanical properties of black pepper (*Piper nigrum* L.). 22 (2): 131-137 (2013)

S Balasubramanian, R Kumar, K K Singh, T John Zachariah & Vikram

The physical and mechanical properties of black pepper were determined as a function of moisture content in the range of 3.3% to 18.1% (d.b.). The average axial dimensions, major, medium and minor increased linearly from 4.92 mm to 5.37 mm, 4.59 mm to 5.08 mm and 4.42 mm to 4.89 mm, respectively. The geometric mean diameter, sphericity, unit volume, surface area and thousand seed weight increased from 4.63 mm to 5.10 mm, 0.94 mm^3 to 0.95 mm^3, 53.06 mm^3 to 70.35 mm^3, 67.65 mm^2 to 81.87 mm^2 and 42.82 g to 56.04 g, respectively with increase in moisture content from 3.3% to 18.1%. The true density increased linearly from 987.7 to 1012.2 kg m^{-3}, while

the bulk density decreased linearly from 556.8 to 542.7 kg m^{-3} and the porosity increased linearly with increase in moisture content. The angle of repose increased linearly from 22.30° to 33.66° and the coefficient of friction increased linearly from 0.705 to 0.936 with increase in moisture content. The coefficient of friction was found to be maximum against plywood. The force and energy absorbed at rupture point decreased non-linearly from 74.6 N to 50.1 N and 42.9 kJ to 32.8 kJ while the deformation increased non-linearly from 0.575 mm to 0.650 mm with increase in moisture content.

Size reduction characteristics of black pepper. 22 (2): 138-147 (2013)

S Balasubramanian, R Kumar, K K Singh, T J Zachariah & Vikram

Black pepper corn at three moisture contents (5.5%, 11.4% & 17.6%, d.b.) was subjected to size reduction using micro pulverizer with screen aperture size (0.5 mm, 1.0 mm & 1.5 mm) and feed rate (8, 16 & 24 kg h^{-1}) at constant rotor speed (3000 rpm). It was found that the specific energy consumptions showed a decreasing trend (310.71-30.55 kJ kg^{-1}) with increase of feed rate but increasing trend with moisture content and screen openings. Maximum specific energy consumption was recorded for 11.4% moisture content and 8 kg h^{-1} feed rate with 1.0 mm screen aperture size. The average particle size increased from 0.21 mm to 0.29 mm with increase of moisture content and screen opening. The Bond's work index (0.086-0.312 kWh kg^{-1}) and Kick's constant (0.68 to 20.33 kWh kg^{-1}) showed direct motion with moisture content feed rate and screen aperture size. Size reduction ratio and grinding effectiveness of black pepper seed decreased from 25.42 to 14.57 and 0.077 to 0.008 with the increase in moisture content, feed rate and screen aperture size. The loose and compact bulk densities varied in the range of 322.8 to 1408 kgm^{-3} and 346.2 to 1760 kg m^{-3}, respectively for various mass fractions of sieve analysis. Bond's work index and Kick's constants were affected significantly ($P<0.05$) by moisture content but not feed rate for all screen aperture size.

Thermal properties of cryo-ground powder of black pepper (Panniyur 1). 22 (2): 148-153 (2013)

P Barnwal, K K Singh, R Kumar & T J Zachariah

The thermal properties of black pepper powder, namely specific heat, thermal conductivity and thermal diffusivity were investigated. The specific heat increased from 225.68 to 4479.53 J kg^{-1} K^{-1} with increase in temperature from -150 to 100°C and moisture content from 3.3% to 18.2% dry basis and it showed a second order polynomial relationship with temperature and moisture content. The thermal conductivity increased non-linearly from 0.1161 to 0.1844 W m^{-1} K^{-1} with increase in moisture content from 3.3% to 18.2% dry basis at 30°C. The thermal diffusivity increased non-linearly from 10.86×10^{-6} to 17.36×10^{-6} m^2 s^{-1} with increase in moisture content from 3.3% to 18.2% dry basis at 30°C. The thermal conductivity and thermal diffusivity showed quadratic relationships with moisture content. The specific heat was affected significantly with moisture content and temperature ($P<0.01$). The thermal conductivity and thermal diffusivity were affected significantly by moisture content.

Standardization of soil-less nursery mixture for black pepper (*Piper nigrum* L.) multiplication using plug-trays. 23 (1): 1-9 (2014)

D Prasath, K B Vinitha, V Srinivasan, K Kandiannan & M Anandaraj

Availability of quality planting material of high yielding varieties is a major production constraint in all black pepper (*Piper nigrum* L.) growing countries, and hence there is a need for technology that boosts production of quality planting material. An investigation was carried out to study the effect of different combinations of soil-less coir pith based nursery mixtures on rooting and growth of black pepper cuttings in the nursery. Among the different nursery media combinations, coir pith with *Trichoderma* and vermicompost recorded significantly higher growth parameters. The study confirmed that composted coir pith with vermicompost and *Trichoderma* is an ideal potting medium for black pepper nursery. In the second experiment, among the single node cuttings with three different maturities (collected from the serpentine method runners), maximum nursery

growth, was recorded in the terminal portion of the runners (11-15th nodes). Similarly, higher growth parameters were recorded in the cuttings planted with full leaf compared to half leaf cuttings. The study indicated that the rooted cuttings with full leaf from middle and top portions recorded higher growth parameters. Use of *Trichoderma* and vermicompost enriched coir pith in black pepper nurseries minimizes chemical fungicides besides *Trichoderma* that colonizes the root system of seedlings will help in preventing the infection by pathogens in the main field. Since there is no high additional cost involved, the use of *Trichoderma* enriched coir pith can also be adopted by commercial nurseries.

Effect of biofertilizers and organic supplements on the growth of black pepper rooted cuttings (*Piper nigrum* L.). 27 (1): 54-58 (2018)

T S Aswathy, M K Dhanya, J Jintu, T Sathyan, T T Preethy & M Murugan

An experiment was conducted at the Cardamom Research Station, Kerala Agricultural University, Pampadumpara (Kerala) with an objective to study the effect of different biofertilizers (Phosphorus solubilizing bacteria, *Azospirillum* and Plant Growth Promoting Rhizobacteria Mix I) and organic supplements (fish extract and humic acid) on the growth of black pepper rooted cuttings. The results of the experiment indicated that application of Phosphorus solubilizing bacteria (5 g) along with *Azospirillum* (5 g), humic acid (0.2%) and fish extract (0.5%) was the best combination for the production of black pepper rooted cuttings with improved vegetative characters (plant height, number of leaves, number of roots, length of roots and leaf area) compared to their individual inoculation. This innovative information can be effectively utilized and advocated for the commercial production of black pepper rooted cuttings with lusty growth.

Effect of biocontrol agents on production of rooted back pepper cutting in serpentine method. 27 (1): 59-65 (2018)

R S Bhai, K P Subila, S J Eapen, A Reshma, R Pervez, A I Bhat & V Srinivasan

Availability of disease-free quality planting material is a major limiting factor in black pepper cultivation. In order to meet the increasing demand and also to create awareness on good agricultural practices for healthy disease-free planting material production to farmers, a nursery experiment was started with improved varieties of black pepper by adopting a non-chemical bio-intensive management strategy. Here solarization of potting mixture was the main concern followed my amending the solarized potting mixture with potential bioagents. The experiment was designed in a two factor CRD with four improved varieties and five treatments. Each treatment contains a combination of two bioagents with antifungal and nematicidal properties respectively. The common recommended fungicide metalaxyl-mancozeb (0.125%) and nematicide carbsosulfan (0.1%) was used as control. The treatments were incorporated individually into solarized potting mixture and planted with improved varieties used *viz*., IISR Girimunda, Malabar Excel, Shakthi and Thevam. The plants in each treatment were kept for multiplication by serpentine method with proper irrigation and phytosanitation. The results of plant growth and establishment in different treatments, showed that fortification of solarized potting mixture with *Trichoderma harzianum + Pochonia chlamydosporia* combination or combination of *Streptomyces* strains (Act 2+9) are significantly superior (35.46% and 21% respectively) for the production of healthy rooted planting material. IISR Malabar Excel and IISR Thevam produced the maximum number of plants from a single node cutting in treatment with *T. harzianum + P. chlamydosporia* (T1) (59 nos. and 51 nos., respectively) followed by Malabar Excel with Act 2+9 and Act 5+9 (45 nos. each). So an average of 6-7 plants/month/cutting was produced in the potential treatment while it was only 3-4 plants in control. The advantage of the method is that, after solarization and fortification with respective bioagents, there is no need for further application of any fungicides, insecticides or any other nutrient spray as usually done. Thus the method of soil solarization followed by fortification of

either *T. harzianum + P. chlamydosporia* or combination of *Streptomyces* strains *viz.*, *Ketasatospora setae* (Act 2) and *S. tauricus* (Act9) is found suitable for the production of healthy quality planting material of high yielding varieties to meet the increasing demand of planting material with a C:B ratio of 1:2.

Morphological characterization and secondary metabolites profile of black pepper (*Piper nigrum* L.) genotypes from Sikkim. 29 (2): 98-104 (2020)

K Gurung & S Manivannan

Quantification of volatile oil and analysis of four major metabolites using HPLC was done in 24 black pepper genotypes collected from south Sikkim. The amount of volatile oil ranged from 2.01% to 0.022%. Secondary metabolites like piperine ranged from 2.75-0.022%, myrcene from 2.094-0.022%, alpha-phellandrene from 1.373-0.008% and linalool from 0.834-0.012%. Genotype 23 had the highest amount of myrcene and linalool, genotype 13 had the highest quantity of piperine and genotype 8 had high amount of alpha-phellandrene. The principal component analysis (PCA) of analyzed metabolites grouped the genotypes into four categories. The study revealed that some of the genotypes were as good as pepper varieties grown in traditional areas. These genotypes will be useful in crop improvement strategies and suitable for Sikkim Himalaya.

Response of black pepper varieties for propagation by serpentine layering. 30 (2): 196-199 (2021)

A Thapa, S Datta & U Rai

In the present study response of light black pepper verities for propagation through serpentine layering was studied. Verities showed significant variations with respect to growth attributing parameters, survivability and numbers of layers per year. Maximum survivability (93.00% and 88.33%) at 30 and 90 days after cutting was found in Panniyur-1. Maximum planting material production per year was achieved in Panniyur-1 (51.17) which was higher than the rest of the varieties but was statistically at par with Panniyur-2 (50.50) and Pournami (50.17). These three varieties may be

considered for higher production of planting materials through serpentine layering method.

Productive and profitable black pepper based mixed cropping systems involving tuber crops. 32 (2): 120-128 (2023)
B Sudha, C K Airina, C K Yamini Varma, C K Thankamani, K S Krishnamurthy & Sharon Aravind
An experiment on pepper based mixed cropping systems involving tuber intercrops was carried out at Pepper Research Station (Kerala Agricultural University), Panniyur, Kannur during 2013-14 to 2022-23. Five different black pepper based mixed cropping systems which accommodated five different tropical tuber crops were experimented. The data pertaining to 2020-21, 2021-22 and 2022-23 were separately recorded and the pooled mean worked out for individual crop yields as well as equivalent yields and economics of cultivation of the different systems. The pooled equivalent yield for black pepper + greater yam and black pepper + elephant foot yam mixed cropping systems were recorded in terms of base crop black pepper as 1239.28 and 1214.25 kg ha^{-1} respectively, significantly superior to all other mixed cropping systems. The equivalent yield recorded for black pepper sole cropping was 561.73 kg ha^{-1} only. The pooled data revealed higher profitability for black pepper + greater yam mixed cropping system with gross returns, net returns and B:C ratio of Rs. 619637 ha^{-1}, Rs.440043 ha^{-1} and 3.45 respectively. For black pepper + elephant foot yam system, the respective values were Rs. 607126 ha^{-1}, Rs. 440043 ha^{-1} and 3.57. The soil properties were also favourably maintained under mixed cropping as that in sole cropping of black pepper as indicated by soil nutrient analysis conducted at the end of the field experiment.

Crop Protection

Natural enemies of major insect pests of black pepper (*Piper nigrum* L.) in India. 3 (1): 50-55 (1994)
S Devasahayam & K M Abdulla Koya
The natural enemies recorded on major insect pests of black pepper (*Piper nigrum* L.) in India including new records are given. The

potential of utilising them in biological control programmes are discussed.

Efficacy of *Paecilomyces lilacinus* (Thorn.) Samson in suppressing nematode infestations in black pepper (*Piper nigrum* L.). 3 (2): 130-134 (1994)
K V Ramana
The efficacy of *Paecilomyces lilacinus* in suppressing root-knot nematode (*Meloidogyne incognita*) and burrowing nematode (*Radopholus similis*) infestations in black pepper (*Piper nigrum*) was studied. Though the fungus could not effect absolute control of nematodes, it significantly suppressed nematode infestation and increased total root mass production. The fungus was more effective in suppressing *M. incognita* than *R. similis*.

Management of Phytophthora foot rot and nematode diseases in black pepper (*Piper nigrum* L.). 4 (1): 61-63 (1995)
M S Lokesh & P M Gangadharappa
Phytophthora foot rot and nematode diseases of black pepper were managed effectively by following cultural practices; neem cake and phorate application; spraying, drenching and pasting of Bordeaux mixture (1%) before onset of monsoon and Akomin (0.04%) and Ridomil MZ 72 WP (100 ppm) as spraying and drenching during second week of July and September, respectively, as second and third round application.

A simple method for indexing *Phytophthora* and nematode infections in black pepper (*Piper nigrum* L.). 5 (1): 68-71 (1996)
Jose Abraham, M Anandaraj, K V Ramana & Y R Sarma
A simple method for indexing Phytophthora foot rot disease of black pepper (*Piper nigrum*) caused by the fungus *P. capsici* and the nematodes *Radopholus similis* and *Meloidogyne incognita* was derived. The index is based on foliar yellowing and defoliation which are the predominant aerial symptoms of the disease.

Occurrence of *Verticillium chlamydosporium* Goddard in a black pepper (*Piper nigrum* L.) garden in Kerala, India. 5 (2): 143-147 (1996)

T P Sreeja, Santhosh J Eapen & K V Ramana

Verticillium chlamydosporium was isolated and identified for the first time from cases of a semi-endoparasitic nematode, *Trophotylenchulus piperis*, from an infested black pepper (*Piper nigrum*) garden in Calicut District of Kerala, India. The fungus suppressed hatching of root knot nematode (*Meloidogyne incognita*) eggs by 41.4 per cent within 5 days in an *in vitro* bioassay and appears promising for the control of root knot nematodes of spice crops.

Compatibility of phorate and chlorpyriphos with *Trichoderma harzianum* (Rifai.) applied for integrated disease management in black pepper (*Piper nigrum* L.). 9 (2): 111-115 (2000)

R Stephen Jebakumar, M Anandaraj & Y R Sarma

The compatibility of the biocontrol agent, *Trichoderma harzianum* utilized for the management of Phytophthora foot rot of black pepper (*Piper nigrum*), with phorate and chlorpyriphos applied for the management of nematodes and mealybugs respectively, was studied. The experiments were conducted in vitro and in soil at different concentrations for each chemical considering the recommended dose (6-36 ppm ai for phorate and 10-40 ppm ai for chlorpyriphos). The, in vitro studies indicated that phorate at 6-36 ppm did not affect radial growth and sporulation of *T. harzianum*, whereas, chlorpyriphos at 10-40 ppm retarded radial growth up to 50% at 24 hand 48 h but not at 72 h, and retarded sporulation. In soil, there was no significant difference in the number of viable colonies of *T. harzianum* at 1% concentration for phorate concentrations of 1000 and 2000 ppm. However, incorporation of chlorpyriphos into soil resulted in increase in number of viable colonies of *T. harzianum*. The study indicated that phorate and chlorpyriphos could be safely applied with *T. harzianum* for the management of Phytophthora foot rot, nematodes and mealybugs on black pepper.

Survival of *Colletotrichum gloeosporioides*, the causal organism of anthracnose disease of black pepper. 11 (2): 129-131 (2002)
Anoop Sankar and P Santha Kumari
Survival of *Colletotrichum gloeosporioides* (Penz) Penz., & Sacco the causal organism of anthracnose disease of black pepper was studied at the College of Agriculture, Vellayani, Trivandrum, Kerala. The naturally infected black pepper leaves and spikes of the variety Karimunda collected from black pepper gardens were buried in soil and another set kept in brown paper bags under laboratory conditions to study the mode of survival of the fungus. Samples were taken from these two sets periodically and plated on PDA. Viable colonies of *C. gloeosporioides* were obtained up to 90 days in the case of infected plant parts buried in the soil and up to 150 days in the case of infected materials kept in paper bags. The results indicate that the black pepper anthracnose fungus can survive on the infected leaves and spikes or in the soil and hence warrants strict phytosanitation to reduce the disease incidence.

Absorption of soil-applied carbofuran by black pepper (*Piper nigrum* L.) plants in laterite soil. 13 (1): 10-15 (2004)
Betty Bastin and P A Wahid
The effect of organic matter on availability of soil-applied carbofuran and its absorption by black pepper (Piper nigrum) plants were studied in a pot culture experiment employing 14C_labelled carbofuran. Absorption of carbofuran from soil was inversely related to the organic matter content of the soil. This was attributed to the enhanced degradation of the insecticide with increasing soil organic matter resulting in its reduced availability, rather than its adsorption in the soil. The absorbed carbofuran was mainly translocated to the leaf (64.0%) and stem (33.5%) and to a lesser extent to the berries (1.5%). The results also indicated that carbofuran had no phytotonic effect on black pepper plants but retarded root production.

Purification, production of antiserum and development of enzyme linked immunosorbent assay-based diagnosis for *Cucumber mosaic virus* infecting black pepper (*Piper nigrum* L.). 13 (1): 16-21 (2004)

A I Bhat, T H Faisal, R Madhubala, P S Hareesh & R P Pant

Cucumber mosaic virus (CMV) infecting black pepper (*Piper nigrum*) in India was propagated on *Nicotiana benthamiana* and *N. glutinosa*, and purified by differential and sucrose density gradient centrifugation. The purified virus preparations showed the presence of typical isometric particles of about 28 nm diameter. Polyclonal antiserum against the virus was produced in New Zealand white rabbits. Immunoglobulin G was purified from the crude antiserum and coupled with the enzyme, alkaline phosphatase. 'Double antibody sandwich-enzyme linked immunosorbent assay method was standardized for detection of CMV in diseased black pepper samples collected from different regions of Karnataka, Kerala and Tamil Nadu. The virus infection was also detected on other Piper species such as *P. chaba*, *P. colubrinum* and *P. longum* and a few of the common weeds such as *Ageratum conyzoides*, *Colacasia esculanta*, *Synedrella nodiflora*, *Cynodon dactylon* and *Sonchus oleraceus* found in and around black pepper gardens. The utility of the method developed in diagnosis, epidemiology and management of the disease is discussed.

Antagonistic mechanisms of fluorescent pseudomonads against *Phytophthora capsici* in black pepper (*Piper nigrum* L.). 14 (2): 122-129 (2005)

Diby Paul, M Anandaraj, A Kumar & Y R Sarma

Fluorescent pseudomonads were selectively isolated from black pepper (*Piper nigrum*) roots and screened for volatile and non-volatile metabolite production and inhibition in growth of *Phytophthora capsici*, the causal organism of foot rot disease. Among the isolates tested, the inhibition of *P. capsici* varied from 36.3% to 70.0% by non-volatile metabolites and from 2% to 23% by volatile-metabolites. Isolate IISR-51 caused maximum inhibition of *P. capsici* by production of non-volatile and volatile metabolites. Many of the isolates produced hydrogen cyanide, which limited the growth of *P. capsici*. The study indicated the involvement of siderophore-mediated antagonism in

fluorescent pseudomonads. The fluorescent pseudomonads could systemically invade black pepper cuttings upon root bacterization.

Variability in *Phytophthora capsici* (Leonian) isolates of black pepper (*Piper nigrum* L.) based on nutritional preferences and isozyme profiles. 15 (2): 81-87 (2006)
Shamina Azeez & Y R Sarma
Experiments were conducted to study the intraspecific variability among five isolates of black pepper (*Piper nigrum*) foot rot pathogen, *Phytophthora capsici*, in its nutritional preferences and isozyme profiles. The carbon sources most suited for the vegetative growth of the isolates were sucrose and glucose, followed by starch, fructose, cellulose and maltose. Among the nitrogen sources, the L-isomers of the amino acids, glutamate, proline, aspartate, asparagine, histidine, serine, arginine and glycine, and also the organic sources of nitrogen, urea, yeast extract, casein hydrolysate, peptone and tryptone supported good growth. Among the vitamins studied, only thiamine was essential for vegetative growth of *P. capsici*. A considerable degree of variation was observed among the five isolates in their preferences for nutrient sources for their optimal growth. From the isozyme profiles of esterase, acid phosphatase, superoxide dismutase and catalase systems, the similarity between the isolates ranged between 25.0%-44.7%.

An improved method for selection of antagonistic bacteria against *Phytophthora capsici* Leonian infections in black pepper (*Piper nigrum* L.). 16 (1): 1-7 (2007)
A Dinu, A Kumar, R Aravind & S J Eapen
An improved and rapid method for selection of bacteria primarily based on its inhibitory effect on pathogenesis of *Phytophthora capsici* on black pepper (*Piper nigrum*) was developed. Reductions in mycelial growth of P. capsici in dual plating assay and inhibition of lesion on excised black pepper shoots in planta assay were calculated. The inhibition ranged from 0.0%to 92.8% among the 19 bacterial isolates tested against *P. capsici* in the *in planta* assay where the bacterized shoots were challenge inoculated with P. capsici. The *in planta* assay could select only two bacterial strains among the 19 isolates as

effective against *P. capsici* whereas, four and six bacterial strains in the in planta assays I and II, respectively. The dual plate method, where only two-way interaction between the pathogen and antagonist was studied, could select four bacterial strains as effective ones. The *in planta* selected bacterial strains could protect the black pepper plants from foot rot infection when tested in the nursery. The in planta assay based on this three-way interaction among black pepper (host)-*P. capsici* (pathogen)-candidate bacterial strains (antagonist) was found to be an effective method to select antagonistic bacteria against the foot rot pathogen.

Screening of black pepper (*Piper nigrum* L.) germplasm for resistance to foot rot disease caused by *Phytophthora capsici* Leonian. 16 (2): 115-117 (2007)

R Suseela Bhai, M Anandaraj, Y R Sarma, S S Veena & K V Saji

Studies were conducted at Calicut (Kerala) to locate sources of resistance among 491accessions of cultivars, 691 hybrids, 124 wild accessions and 182 Karimunda and 60 Kottanadan selections of black pepper (*Piper nigrum*) using stem inoculation technique against foot rot disease caused by *Phytophthora capsici*. One hybrid (Acc. 1375), two wild accessions (Accs. 3160 and 3260) and four Kottanadan selections (2466, 2471, 2515 and 2433) were promising with disease index 1 and no external lesion after inoculation of the pathogen under greenhouse conditions.

Management of anthracnose disease (*Colletotrichum gloeosporioides* (Penz) Penz & Sac.) of black pepper (*Piper nigrum* L.) in the high ranges of Idukki District, Kerala. 17 (1): 21-23 (2008)

P Sainamole Kurian, G Sivakumar, A Josephrajkumar, S Backiyarani, M Murugan & K N Shiva

Evaluation of contact and systemic fungicides for the management of anthracnose disease(caused by *Colletotrichum gloeosporioides*) on black pepper (*Piper nigrum*) at Idukki District (Kerala) indicated that the incidence of the disease on leaves and spikes was significantly lower in vines treated with a combination fungicide containing carbendazim + mancozeb 0.1% followed by carbendazim 0.1%. The

dry berry yield was also significantly highest (742.7 g vine^{-1}) in vines treated with carbendazim + mancozeb 0.1%.

Efficacy of systemic fungicides and antagonistic organism for the management of Phytophthora foot rot of black pepper in arecanut cropping system. 17 (2): 114-121 (2008)
M S Lokesh, H G Hegde & Nagesh Naik

Black pepper vines were less affected when the vines were treated either with metalaxyl gold MZ 64 WP (Ridomil gold) @ 2.5 g/vine or potassium phosphonate (0.5 per cent) as spray (@ 2 l/vine) and drench twice (@ 3 l/vine) during before on set of monsoon and second application in the month of August coupled with soil application of antagonistic organism i.e., *Trichoderma harzianum* @ 50 g (cfu 10^7) along with 1 kg of neem cake to the root zone of the vine. Application of systemic fungicides alone i.e., metalaxyl MZ 68 WP (Ridomil gold) @ 2.5 g/vine or potassium phosphonate (0.5 per cent) as spray (@ 2 l/vine) and drench twice (@ 3 l/vine) also showed effectiveness in the combating the disease.

Variation in the concentration and indexing black pepper plants for PYMoV and CMV through DAS-ELISA. 17 (2): 197-201 (2008)
V Bhadramurthy, A I Bhat, Jasmine George, C K Thankamani & P A Mathew

Variation in concentration of Piper yellow mottle virus (PYMoV) and Cucumber mosaic virus (CMV) in stunted disease infected black pepper plants from different varieties/cultivars during different months of a year was studied by DAS-ELISA. Higher A_{405} values were recorded from October to February in four varieties/cultivars of black pepper tested and Panniyur-1 had the highest concentration of both the viruses. Results on distribution of the viruses within a plant from three varieties/cultivars showed that young leaf contained highest concentration of both the viruses while root region recorded the least. A total of 2186 black pepper nursery plants from eleven varieties were indexed by DAS-ELISA for the presence of viruses. Of these, 714 plants were found infected with either of the two viruses. Among these, IISR-Sreekara had the highest number of infected plants followed by IISR-Subhakara while Panniyur-5 had the least number of

infected plants. Of the 714 plants tested positive, 390 plants exhibited no visible external symptoms indicating the necessity for sensitive diagnosis in identifying virus-free planting material.

Development of SCAR marker for *Phytophthora* resistance in black pepper (*Piper nigrum* L.). 17 (3): 215-222 (2008)
M Anandaraj, Sheji Chandran, Renu Susan George, A Ishwara Bhat & R Suseela Bhai
Foot rot disease caused by *Phytophthora capsici* is one of the major production constraints in black pepper (*Piper nigrum*) in India. RAPD profile of moderately resistant and susceptible lines indicated the presence a unique band of 360 base pair in moderately resistant lines with the primer OPA-01. The DNA fragment associated with these lines was cloned, sequenced and converted into a SCAR marker. The SCAR primer was tested on plants that were classified as moderately resistant and susceptible. SCAR primers amplified DNA invariably from resistant plants only. The sequence of the unique band matched with stress related gene sequences reported in several eukaryotes including *Arabidopsis thaliana.*

Polymerase chain reaction (PCR) based indexing of black pepper (*Piper nigrum* L.) plants against *Piper yellow mottle virus*. 18 (1): 28-32 (2009)
A I Bhat, A Siljo, M V Jiby, C K Thankamani & P A Mathew
A polymerase chain reaction (PCR) based method was used for indexing 845 plants representing 14 popular varieties of black pepper (*Piper nigrum*) showing no visible external symptoms (apparently healthy) for *Piper yellow mottle virus* (PYMoV), among which 694 plants were positive (82%) for PYMoV. The percentage of infected plants ranged from 59% to100% in different varieties; 100% of the tested plants of Panniyur-6 were infected with PYMoV and Sreekara had the least number of infected plants (59%). Some of the indexed PCR positive plants exhibited visible symptoms such as mild chlorosis, yellow specks and mottling in 1-3 months after testing. The study showed that indexing by PCR successfully detected PYMoV in infected black pepper plants showing no visible symptoms. The method can

be used in certification programmes to identify PYMoV-free plants for further propagation.

Native multi-trait rhizobacteria promote growth and suppress foot rot in black pepper. 23 (2): 156-163 (2014)
R Dinesh, M Anandaraj, A Kumar, K P Subila, Y K Bini & R Aravind
In this study, 74 PGPR isolates from different varieties of black pepper were characterized for morphological, biochemical and nutrient mobilization traits as well as inhibition of *Phytophthora capsici* (causing foot rot) under *in vitro* conditions. Based on the multiple traits, two PGPR [(*Micrococcus luteus* Schroeter (1872) Cohn 1872 (BRB3) and *Enterobacter aerogenes* Hormaeche and Edwards 1960 (AL) (BRB13)] were shortlisted for further growth promotion studies. For biocontrol studies, three PGPR [(*Burkholderia cepacia* (Palleroni & Holmes 1981) Yabuuchi *et al*. (1993) (BRB21), *Pseudomonas aeruginosa* Schröter (1872) Migula 1900 (BRB28) and *Serratia marcescens* Bizio 1823 (AL) (BRB49)] which showed >70% inhibition of P. capsici were shortlisted. The results from green house study on growth promotion indicated that application of M. luteus (BRB3) + 75% recommended dose (RD) of N + 100% RD of PK produced taller plants, longer roots, greater fresh biomass, more number of leaves and nodes in black pepper. This suggested a 25% reduction in chemical N fertilizer in the presence of M. luteus (BRB3). In the green house study on biocontrol, lowest foot rot (32.77%) and taller plants (332.0 cm) were observed with *B. cepacia* (BRB 21), which was on par with chemical treatment. This is the first report on the potential of PGPR like M. luteus for growth promotion and *B. cepacia* for management of *P. capsici* in black pepper.

Evaluation of strobilurin fungicides Ergon 44.3% (w/w) [Kresoxim methyl 500 g L^{-1} SC] and RIL-070/FI (72WP) against *Phytophthora capsici* infection in black pepper. 24 (2): 73-82 (2015)
R S Bhai & C R Anjali
Two new strobilurin fungicides *viz*., Ergon 44.3% (w/w) [Kresoxim methyl 500 g L^{-1} SC] and RIL-070/FI (72WP) were evaluated *in vitro* and in planta against Phytophthora capsici causing foot rot disease of

black pepper and ED_{50} and ED_{90} values were calculated based on the in vitro efficacy. The chemicals were tested in planta using the maximum concentration found effective in vitro. Ergon when tested from 10-6000 ppm of the product *in vitro*, showed complete inhibition of mycelial growth and sporulation at 6000 ppm. But the zoospore germination was completely inhibited at 2000 ppm. The average ED_{50} and ED_{90} values of Ergon were 845.51 and 1740.71, respectively. Foliar spray of the chemical followed by challenge inoculation showed an overall reduction of lesion development by 44.83% over control and maximum inhibition (57.12%) was observed at five days after spraying at a concentration of 7000 ppm. Soil application of Ergon at different concentrations from 6000-8000 ppm showed no infection or mortality at 7000 ppm. RIL-070/FI at different concentrations from 10-500 ppm of the product when tested in vitro against *P. capsici* showed 100% mycelial inhibition at 50 ppm with ED_{50} and ED_{90} values of 22.85 and 45.71, respectively. For inhibition of sporulation, the maximum concentration required was 100 ppm. However, zoospore germination showed 100% reduction at 200 ppm. Foliar spraying of the RIL at concentrations from 100-600 ppm showed lesion development from 0.71 to 100%. When *P. capsici* was challenged five days after spraying of the chemical, 600 ppm showed 100% inhibition of lesion development.

Cross species amplification of microsatellite loci from *Phytophthora* spp. to assess genetic diversity among the *Phytophthora* isolates from black pepper. 25 (2): 104-112 (2016)
J Cissin, R S Bhai, K B Vinitha, K N Babu & M Anandaraj

Phytophthora capsici is one of the most destructive pathogens of black pepper in India and the world over. Diversity of 114 *Phytophthora* isolates obtained from leaf, stem, root and soil of different agro climatic areas was studied using 25 SSR primers that were previously described. twenty primers were successfully amplified. Of these, 15 were polymorphic among the *Phytophthora* isolates and altogether 37 loci were detected. Of the 37 bands generated from 20 primers, 75.67% were polymorphic. Cluster analysis using the unweighted pair-group method with arithmetic averages divided the isolates into seven major groups. The

dendrogram generated showed that all the isolates were separated at similarity coefficient between 57-95%. Group 7 with a single isolate stood as an out group. Clustering did not follow the pattern of geographical origin or plant part from where the isolates were obtained.

In vitro evaluation of fungal endophytes of black pepper against _Phytophthora capsici_ and _Radopholus similis._ 25 (2): 113-122 (2016)

K Sreeja, M Anandaraj & R S Bhai

Experiment on *in vitro* screening of 125 endophytic fungi of black pepper against *Phytophthora capsici* indicated that 23 isolates showed more than 50% inhibition. The nematicidal activity of metabolites from endophytic fungi was also tested on *Radopholus similis* and the isolate BPEF73 (*Daldinia eschscholtzii*) showed highest mortality up to 60%. The isolates showing biocontrol potential were characterized based on internal transcribed spacer (ITS1 and ITS2) regions of rDNA. The sequence analysis of the isolates showed maximum identity with *Annulohypoxylon nitens* (BPEF25 and BPEF38), *Daldinia eschscholtzii* (BPEF41 and BPEF73), *Fusarium* spp. (BPEF72 and BPEF75), *Ceriporia lacerata* (BPEF81), *Diaporthe* sp. (BPEF11) and *Phomopsis* sp. (BPEF83). This is first report of endophytic association of above fungi in black pepper and the exploitation of their biocontrol potential against the major black pepper pathogens *P. capsici* and *R. similis*.

Detecting and monitoring endophytic colonization by _Pseudomonas putida_ BP25 in black pepper (_Piper nigrum_ L.) using quantitative real-time PCR. 26 (1): 1-7 (2017)

V N Agisha, S J Eapen, R S Bhai & A Kumar

A quantitative real-time PCR assay was developed to quantify *Pseudomonas putida* BP25, an antagonistic endophyte against a broad range of pathogens in black pepper such as *Phytophthora capsici, Colletotrichum gloeosporioides, Rhizoctonia solani, Gibberella moniliformis, Athelia rolfsii* and a plant parasitic nematode, *Radopholus similis*. The real-time PCR primers were designed based on the16S rRNA sequences of *P. putida* strains and

specificity of the primers was confirmed. The detection limit of the assay was found to be 1 pg. The assay detected and quantified the bacterial colonization in the roots at weekly intervals after inoculation. The *P. putida* DNA was quantified to be 0.4 ng in roots corresponding to 5.4 $\log_{10}$ CFU g^{-1} at 7th and 14th day after inoculation (DAI). A decline in endophyte population was observed during 21st and 28th DAI and the DNA concentration ranged from 3.7-4.6 pg corresponding to 3.4-3.5 $\log_{10}$ CFU g^{-1} of root. No amplification could be obtained in stem and leaf samples. The newly developed real-time PCR could be useful for detection, quantification and monitoring of endophytic *P. putida* BP25 in different plant tissues.

Mitigating Phytophthora foot rot and slow decline diseases of black pepper through the deployment of bacterial antagonists. 26 (2): 69-82 (2017)

R S Bhai, S J Eapen, A Kumar, R Aravind, R Pervez, E M Varghese, P B Krishna & K Sreeja

Field trial was conducted at ICAR-IISR Experimental Farm, Peruvannamuzhi, Kozhikode district, Kerala, during 2008-2013 using IPM modules. Planting materials of black pepper were produced by raising two node runners cuttings treated with chemicals and bioagents. A plot having non-living standards in 3 x 2 m spacing was selected. Pits of 50 cm^3 were made and buffered with lime and cow dung. Planting was done with three month old rooted plants where roots were primed with respective bacterium/chemical. The experiment was in RCBD with eight treatments *viz*., *Pseudomonas aeruginosa* (Bp 35) + Phorate, *P. putida* (Bp 25) + Phorate, *P. fluorescence* (IISR 6) (later identified as *P. aeruginosa*) + Phorate, *Bacillus megaterium* (Bp 17) + Metalaxyl Mz, *Curtobacterium luteum* (TC10) + Metalaxyl Mz, *P. aeruginosa* (IISR 853) + Metalaxyl Mz and Phorate + Metalaxyl Mz (chemical check) and an absolute control having no treatments. The differential treatments were imposed at planting in May and subsequent application in September and thereafter every year. Initial two years, plants were maintained weed free by plastic mulching. Commonly, shade and irrigation were provided during summer in the first two years and thereafter only mulching and irrigation were continued. All the plants were sprayed

with $ZnSO_4$ (0.25%), DAP (0.5%) and $MgSO_4$ (0.25%) during May and September from second year onwards. For controlling 'Pollu' beetle (*Longitarsus nigripennis*) and anthracnose (*Colletotrichum gloeosporioides*), quinalphos (0.075%) + Bordeaux mixture (1%) was sprayed twice during September and November. Soil biological properties and pathogen population were monitored regularly. No foot rot incidence due to *Phytophthora* spp. could be noticed in any of the treatments till the end of the experimental period. However, nematode infection, manifested as yellowing of the vines, as well as nematode population showed a gradual increase. Among the treatments, *C. luteum* (TC 10) with Metalaxyl- Mz showed significant reduction in nematode population and also showed better performance in growth and yield.

Development of diagnostic assays for rapid and sensitive detection of *Phytophthora* infecting major spices and plantation crops. 27 (2): 119-130 (2018)

R T P Pandian, A I Bhat, C N Biju & S Sasi

Phytophthora, the ubiquitous stramenopile phytopathogen is a major threat to several economically important horticultural crops including spices and plantation crops. Trans-seasonal survival of *Phytophthora* in plant debris and soil continuum has considerable epidemiological significance as the quiescent propagules often serve as primary foci of infection with inherent potential to trigger epiphytotics in the succeeding season favoured by conducive environmental conditions. Hence, early and rapid detection of over summering propagules is highly imperative to manage *Phytophthora*-induced diseases efficiently and economically. Twelve isolates representing different species of *Phytophthora* (*P. capsici*, *P. tropicalis*, *P. palmivora*, *P. citrophthora* and *P. meadii*) representing hosts such as black pepper, cardamom, nutmeg, coconut, arecanut and cocoa were used to develop nucleic acid-based diagnostic tools *viz*., polymerase chain reaction (PCR), real-time PCR, loop-mediated isothermal amplification (LAMP) and real-time LAMP. *Phytophthora* genus-specific primers were designed from the conserved region of nuclear ribosomal DNA. Each of the assays was specific and detected different species of *Phytophthora* and not other pathogens (*Rhizoctonia solani*, *Pythium*

vexans, *Fusarium oxysporum* and *Colletotrichum gloeosporioides*) and plant samples. Sensitivity assays indicated that, real-time PCR detected *Phytophthora* up to 1.3 fg, followed by LAMP (13 fg) and PCR (13 pg).

Development of a real-time PCR based protocol for quantifying *Radopholus similis* in field samples. 28 (1): 52-60 (2019)
P B Krishna & S J Eapen
The burrowing nematode, *Radopholus similis*, is an obligate migratory endoparasite. Currently detection of this nematode is carried out mostly by physically extracting them from soil and then observing under a light microscope. To identify this nematode, a thorough knowledge about their morphological features is quite indispensable. Developing a DNA based detection technique makes it more convenient and accurate in detection. Though PCR based methods have been reported by earlier workers, developing a real-time PCR based method will enable estimating their population in field samples. In this study, real-time PCR primers were designed using the DNA sequences from the ITS region of *R. similis*. It can detect *R. similis* up to the limit of 100 fg μL^{-1} DNA. The real-time PCR based detection serves as an efficient tool for the detection and estimation of this nematode from soil samples.

Documentation of fungal endophytes of black pepper (*Piper nigrum* L.) and their seed transmission studies. 28 (2): 113-121 (2019)
K Sreeja, M Anandaraj & R Suseela Bhai
The present study envisaged to document the endophytic fungal association with black pepper through a series of *in vitro* and *in planta* investigations. Black pepper was found to harbour endophytic fungal flora belonging to the genera *Alternaria*, *Acremonium*, *Aspergillus*, *Cladosporium*, *Chaetomium*, *Curvularia, Colletotrichum*, *Fusarium*, *Humicola*, *Paecilomyces*, *Rhizoctonia*, *Phoma* and non-sporulating forms. Further, it was found that the endocarp of black pepper seed is free from culturable endophytic fungi. This was evident from the absence of culturable fungi in *in vitro* grown black pepper seedlings. The growth of fungi from the

seedlings grown under greenhouse conditions reveal that the fungal endophytes establish from fungal propagules falling on the (test) plants that may enter the plant tissues as back ground inoculum and grow as endophyte. This was also supported by the study that the type of endophytic fungi that harbour black pepper plants varied with geographical locations from where the samples were collected.

Occurrence of teleomorphic phase of *Colletotrichum gloeosporioides sensu lato*, the incitant of black pepper anthracnose. 29 (1): 48-58 (2020)

C N Biju, R Praveena, M F Peeran, A M Sujatha & S J Ankegowda

Anthracnose caused by *Colletotrichum gloeosporioides sensu lato*, the ascomycetous pathogen is a major constraint in black pepper cultivation. In the present study, surveys carried out in black pepper cultivating regions of Karnataka, India revealed the prevalence of anthracnose disease manifested as diverse array of foliar symptoms. An atypical foliar symptom was also noticed in the black pepper nurseries, characterized by grayish necrotic lesions with brown-blackish margins and randomly distributed blackish structures of pin-head size in the lesion area manifested particularly on the older leaves. The pin-head structures produced orangish exudation embedded with asci, ascospores and perithecia, when incubated under high humid conditions. Typical anthracnose symptoms were developed on susceptible host in pathogenicity studies and subsequent isolation yielded two distinct colonies designated as black and orange. The perithecia were induced artificially under *in vitro* conditions, which retained fertility and infectivity more than three months. Alternation of generation was observed when the perithecia were cultured on potato dextrose medium which resulted in the formation of acervuli with abundant conidiation. The results of present investigation shed light into the occurrence and potential role of perithecial (teleomorphic) phase in the survival of *C. gloeosporioides s. l*. infecting black pepper.

Screening of black pepper varieties against anthracnose under nursery conditions. 31 (1): 86-91 (2022)

Rajshree Verma, Apurba Das, P R Narzary, D K Sarmah, R C Boro, P K Kaman & Sanjib Sharma

Pathogen causing anthracnose of black pepper was isolated from symptomatic leaf sample and was identified as *Colletotrichum gloeosporioides* on the basis of morphological, cultural and molecular characterization. Later, pot culture experiment was conducted in greenhouse (year 2020-21) to determine resistance/susceptibility of seven different black pepper varieties *viz*., Arakkulamunda, Doddigya, Karimunda, Malligesara, Panniyur-1, Poonjarmunda and Uddagare, against anthracnose in nursery condition. It was observed that no variety was resistant but Karimunda variety was found to be highly tolerant against the disease. Whereas, Poonjarmunda and Panniyur-1 were classified as susceptible and highly susceptible, respectively.

Multiplex PCR assay for simultaneous detection of *Phytophthora*, *Pythium* and *Fusarium* associated with foot rot and yellowing diseases of black pepper. 31 (1): 92-96 (2022)

A Jeevalatha, Fathimath Zumaila, C N Biju & Mohammed Faisal Peeran

In this study, a multiplex PCR assay was developed to detect *Phytophthora*, *Pythium* and *Fusarium* infecting black pepper. Genus-specific primers were designed from the conserved region of ITS and a multiplex PCR was optimized by manipulating the annealing temperature and primer as well as $MgCl_2$ concentrations. The black pepper 18S rRNA gene-specific primers were also included in the multiplex PCR assay as internal control. The assay successfully detected the pathogens from artificially inoculated black pepper roots and did not show any cross amplification with other fungal pathogens of black pepper such as *Rhizoctonia solani*, *Sclerotium rolfsii* and *Colletotrichum* sp. Hence, the developed multiplex PCR assay will help in early diagnosis of the cause of black pepper yellowing leading to timely adoption of management strategies.

Virus-mealybug relationship in the transmission of piper yellow mottle virus. 32 (2): 214-221 (2023)
P Malavika, A Lijisha & A I Bhat
In the current study, the piper yellow mottle virus (PYMoV)-mealybug (*Ferrisia virgata*) relationship in the transmission of PYMoV in black pepper was determined. The mealybug *F. virgata* collected from healthy black pepper plants was reared on pumpkin in the laboratory and used to determine the acquisition access period (AAP), retention period (RP) and inoculation access period (IAP) for the transmission of PYMoV. The crude extracts isolated from black pepper plants and mealybugs were tested through PCR using PYMoV-specific primers. The study determined 30 min, 8 h, and 30 min as the AAP, RP, and IAP respectively, indicating the semipersistent type of transmission of PYMoV.

Social Sciences

Quantitative determination of loss in yield of black pepper (*Piper nigrum* L.) in Kannur District (Kerala, India). 6 (1): 31-36 (1997)
P V Prabhakaran
A method for estimation of yield loss (including stand loss) in black pepper (*Piper nigrum*) due to various factors was developed. The method was applied for estimating the loss in yield of black pepper due to incidence of pests, diseases and drought in Kannur District (Kerala, India) during 1989-1992. The average annual yield loss in Introduction black pepper due to these factors was around 33 per cent. The major contributors towards stand loss, was foot rot caused by *Phythopthora capsici* contributing to 9 per cent loss followed by drought. Among the causal factors contributing to yield loss the most disastrous was incidence of pollu beetle (*Longitarsus nigripennis*) which accounted for about 13 per cent loss followed by fungal poilu caused by *Colletotrichum gleosporioides*. The percentage avoidable loss in yield by adopting plant protection measures was estimated to be around 43 per cent.

Price behaviour of black pepper in Indian and international markets: a comparative analysis. 28 (1): 27-33 (2019)
S S Sabu, A Kuruvila & K Manojkumar
Black pepper, being a trade dependent commodity, shows high degree of price fluctuations. The present study examined the price behaviour of black pepper in the pre-liberalisation and post liberalisation periods. The study revealed that the variation in prices increased in the post liberalisation period. Seasonal nature was evident in prices and the harvesting period was found to be coinciding with the trough phase in the price cycle, while the off-season synchronized with the peak phase. The prices exhibited cyclical behaviour and the periods of low prices endured longer than that of the price spikes. The occurrence and amplitude of random factors exhibited in the prices of black pepper were more in the pre-liberalisation period.

ALLIED SPECIES OF BLACK PEPPER

Cytological studies on *Piper barberi* - A rare species endemic to Western Ghats. 1 (1): 81-84 (1992)
P J Mathew & P M Mathew
Piper barberi, a rare species of *Piper* from Western Ghats, is having a somatic chromosome number of 2n=52. The meiosis is normal, pollen fertility is high.

***Piper barberi* Gamble - A redescription of the species with a note on the karyotype. 1 (1): 88-93 (1992)**
K Nirmal Babu, R Ramakrishnan Nair, Johnson K George & P N Ravindran
P. barberi was described by Gamble (1924) based on the male plants only. Here the species is being redescribed based on the female plant characters as well. *P. barberi* is a unique species among the *Piper* taxa occurring in South India. The somatic chromosome number of *P. barberi* was determined to be 2n=52.

Micropropagation of betel vine (*Piper betle* L.). 1 (2): 160-162 (1992)
K Nirmal Babu, J Rema, Geetha S Pillai, Minoo Divakaran, P N Ravindran & K V Peter
Betel vine (*Piper betle* L,) cv. Lakkuvalli was successfully micropropagated on Woody Plant Medium (WPM). Different explants from shoot, leaf and root tissues developed multiple shoots and regenerated into plantlets either directly or through intervening callus phase on WPM supplemented with 3 mgl^{-1} benzyladenine and 1 mgl^{-1} kinetin. The excised shoots developed good root system on growth regulator free medium of the same composition. The plantlets were transferred to soil with 80% success.

The success story of betelvine cultivation in Mahoba, Uttar Pradesh. 1 (2): 163-166 (1992)
V R Balasubrahmanyam, R S Chaurasia & J K Johri
The story of this successful fight against problems of betelvine cultivation is a gripping story of onward march in the face of many obstacles. There might have been failures and much remains to be accomplished. Some betelvine diseases still resist efforts for their control. Though methods were developed for prevention of diseases, they are costly for the cultivators as 90% of them are marginal farmers or landless. The cost of establishment of a betelvine conservatory is quite high-as much as Rs. 1 1akh per acre. Marketing is quite unorganised and middlemen exploit the cultivators as betel leaves are a highly perishable commodity. But as the grower grapples with these problems, he will have in the background, scientists working with him with the knowledge he needs to lighten his economic load and permit him to produce betel leaves economically and efficiently.

Two new taxa of *Piper* (Piperaceae) from Kerala, India with a note on their origin and interrelationship. 2 (1&2): 26-33 (1993)
K Nirmal Babu, V Girish Naik & P N Ravindran
Two new taxa of *Piper*, *P. sugandhi* and *P. sugandhi* var. *brevipilis* are described from Sugandhagiri project area of Western Ghats in South India. They are related to *Piper nigrum*, *P. galeatum* and *P.*

trichostachyon. Morphological and ecological evidences point to their origin through hybridisation involving these three species. Their inter-relationships are discussed.

Plant regeneration in *Piper longum* L. (Piperaceae) through direct and indirect adventitious shoot development. 2 (1&2): 34-40 (1993)

V Sarasan, Elizabeth Thomas, Beena Lawrence & G M Nair

Methods for large scale multiplication of *Piper longum* are reported. Shoot tips cultured on Murashige & Skoog's medium supplemented with 0.5 mgl^{-1} benzyl adenine or kinetin in combination with 0.5 mgl^{-1} 1-naphthalene acetic acid developed multiple shoots at very low frequency. Multiple shoots originated in large numbers, only from nodes of vertically planted explants, while shoots developed *de novo* from all over the surface, when planted horizontally in the same medium containing 2-5 mg l^{-1} benzyl adenine. Leaf segments also developed adventitious buds in large numbers in Murashige & Skoog's medium containing 3 mg l^{-1} benzyl adenine, 1 mg l^{-1} kinetin and 10% (v/v) coconut water. Callus induced from leaf and stem explants in Murashige & Skoog's medium with 1-2 mg l^{-1} 2, 4-dichlorophenoxy acetic acid in combination with 1 mg l^{-1} benzyl adenine developed shoot buds when transferred to medium containing 3 mg l^{-1} benzyl adenine. All the shoots were rooted in Murashige & Skoog's basal medium. The isolated plantlets, hardened in vermiculite were transferred to pots containing garden soil and sand.

Chemotaxonomy of South Indian *Piper*. 3 (1): 6-13 (1994)

P N Ravindran & K Nirmal Babu

A chemotaxonomical study was carried out on South Indian taxa of *Piper* to understand their interrelationships. Fourteen taxa were analysed for their flavonoids and based on presence or absence of these compounds, percentage similarity indices were calculated. The results in general supported the species delimitation and taxonomical relationships arrived at by conventional taxonomy using morphological characters. A chemical dichotomy was evident between the two sub genera-*Pipali* (having erect spikes) and

Maricha (having pendant spikes) thereby supporting the validity of the sectional classification.

In vitro culture of _Piper attenuatum_ Ham. (Piperaceae): Callus induction and plant regeneration. 5 (2): 127-130 (1996)
K Madhusudhanan, B A Rahiman & B Sandhya
Callus induction and plant regeneration of *Piper attenuatum* was achieved from stem explants in Murashige and Skoog and Gamborg's basal media supplemented with 2,4-dichlorophenoxyacetic acid, indole-3-acetic acid, Kinetin, benzyladenine and palmyarh (*Borassus flabellifer*) endosperm extract. Root induction was obtained from stem explants in Murashige and Skoog medium supplemented with *α*-naphthaleneacetic acid, *β*-naphthoxyacetic acid, indole-3-acetic acid, benzyladenine, kinetin and coconut water. Shoot development was achieved in *in vitro* rooted stem segments planted in Murashige and Skoog's medium supplemented with indole-3-acetic acid, benzyladenine and also in indole-3-acetic acid and kinetin. The plantlets were successfully established in soil. This is the first report of *in vitro* culture of *P. attenuatum*.

Anatomy of _Piper colubrinum_ Link. 7 (2): 111-123 (1998)
P N Ravindran & A B Remashree
Piper colubrinum exhibits dimorphic branching (orthotropic and plagiotropic shoots) as in many other *Piper* species. The stem exhibits anomalous secondary growth. The number and size of peripheral and medullary bundles show variations in the two types of shoots. Secondary growth occurs only in the peripheral bundles. In a mature stem (7 mm thickness), the average length and width of xylem vessel is 258 µm and 73.8 µm respectively, in peripheral bundles, whereas in medullary bundles it is 195 µm and 81.5 µm, respectively. Vessels are pitted with simple perforation plates. Tracheids have scalariform and annular thickening. Libriform unseptate fibres are also present. Comparative stem anatomy of *P. nigrum* and *P. colubrinum* shows similarities. However, the aerial and underground roots show variations especially in the number of vascular elements. Secondary thickening in root is comparable to

that in dicots. The aerial roots undergo transformation in internal structure when they enter soil and grow as underground roots.

Effect of low temperature stress on betel vine (*Piper betle* L.) types, Bangla and Desavari. 9 (2): 141-143 (2000)
Rajesh Tripathi, Garima Khare & Nikhil Kumar
The effect of low temperature stress was studied in two types (Bangla and Desavari) of betel vine (*Piper betle*). Among the two types, Desavari showed better performance under cold stress and had significantly higher leaf thickness, levels of total thiols and peroxidase activity and lower lipid peroxidation.

***Piper hapnium*: A rare *Piper* species from Peruvannamuzhi, Kerala - A new report. 10 (1): 63-64 (2001)**
K V Saji, B Sasikumar, K Johnson George & S Biju
Recently a small population of *P. hapnium* (both male and female) trailing on *Ailantus* sp., *Aporosa lindleyana* and other trees was located in the Peruvannamuzhi forest (10 m to 60 m MSL) in Calicut District, Kerala along with other species of *Piper* such as *P. nigrum*, *P. attenuatum* etc. Male plants were observed for the first time, which were rare compared to female plants.

Sex change in *Piper thomsoni* Hook. (Piperaceae). 14 (1): 39-41 (2005)
K V Saji, B Sasikumar, K Johnson George & V A Parthasarathy
Piper thomsoni, a dioecious *Piper* species endemic to north eastern India, was collected from Totopara forests (New Jalpaiguri District, West Bengal), multiplied and maintained at the Germplasm Conservatory, Experimental Farm, Indian Institute of Spices Research, Peruvannamuzhi (Kerala). The male plants conserved under partial shade exhibited sex change and a few berries developed on the spike. This appears to be the first report of sex change in the genus *Piper*.

Evaluation of betelvine (*Piper betle* L.) cultivars in the Gangetic alluvial plains of West Bengal, India. 21 (1): 1-8 (2012)
Anupam Pariari & Munsi Nasir Imam
Evaluation of 14 cultivars of betelvine (*Piper betle*) in the Gangetic alluvial plains of West Bengal indicated that there was wide variation among them for growth, yield and quality parameters. Cultivar Simurali Sanchi showed superior performance with respect to increment in vine length (145.37 cm during June to August), fresh (364.38 g) and dry weight (52.29 g) of 100 leaves (depetiolated) and total chlorophyll content in leaves (2.45 mg g^{-1} tissue). Leaf production was also maximum (58.56 $vine^{-1}$ $year^{-1}$) in cv. Simurali Deshi.

Antioxidant capacity, radical scavenging ability, total phenols and flavonoids in three types of betelvine (*Piper betle* L.). 21 (1): 64-67 (2012)
K S Shivashankara, T K Roy & G A Geetha
Betelvine (*Piper betle* L.) leaves from female (Bengaluru local), male (Madras type) and meeta paan (sweet type) were analysed for antioxidant capacity (FRAP) and radical scavenging ability (DPPH) using acidic methanol extracts. FRAP and DPPH values were higher in the leaves of Bengaluru local followed by Madras type and were lowest in sweet type of betelvine. However, chlorophyll was higher in female and sweet betelvine when compared to Madras type. Bengaluru local also recorded higher total phenols and flavonoids followed by Madras type and sweet betelvine recorded lowest phenols and flavonoids. Higher antioxidant and radical scavenging capacities of female and male types was mainly due to the higher phenols and flavonoids and not due to total chlorophyll content. The study indicated that the total phenol content of betelvine is comparable with that of tea powder.

Keeping quality of betel leaves (*Piper betle* L.) as influenced by different methods and seasons. 21 (2): 106-112 (2012)
M N Imam & A Pariari
The objectives of the study were to assess the keeping quality under different seasons and methods of storage to suggest the best method

and season for betel leaves storage. In all the treatments, leaves in two forms i.e. petiolated and depetiolated were included. The result showed that December-January i.e. winter season was the best for longer storage of betel leaves in any form and method. Among method of storage, zero energy cool chamber was the best for longest period of storage followed by packing with banana leaves in bamboo basket. Depetiolated condition was always better than petiolated condition for enhancing storage life. Chlorophyll degradation was minimum in petiolated condition either in packing with banana leaves or in treatment with Benzylaminopurine (BA) @ 30 ppm compared to depetiolated condition. Ascorbic acid content was more in sterilized paddy straw packing and in hessian cloth lined with mustard seed and ice pieces compared to other treatments.

Genetic divergence in betelvine (*Piper betle* L.). 22 (1): 1-5 (2013)

B T Priya, P R Devi & P Sunitha

Genetic divergence was assessed in a population of 51 genotypes of betelvine (*Piper betle*) for seven characters using Mahalanobis D^2 technique. The genotypes were grouped into six clusters. The clustering pattern of the genotype was random and did not follow geographical origin, indicating that geographical isolation may not be the only factor causing genetic diversity. Leaf area contributed maximum towards genetic diversity in betelvine. Cluster analysis revealed wide genetic distance between Cluster V and Cluster VI followed by Cluster IV and Cluster VI, and Cluster III and Cluster V. Thus, selections of parents from the clusters with high inter and intra cluster distance will help to obtain substantial heterosis in respect of economic traits during hybridization programme.

Thin layer drying of long pepper (*Piper longum* L.). 22 (1): 31-37 (2013)

P Bhagyashree, B Vanita & D Sneha

The effect of drying air temperatures on the drying kinetics of long pepper was investigated during 2010 using a hot-air tray dryer. In order to select the appropriate drying model, twelve mathematical drying models were fitted to the experimental data. Result indicated

that the drying took place in the falling rate period. Considering the statistical criteria such as coefficient of determination (R^2), Chi square (X^2), sum of square error (SSE) and root mean square error (RMSE), Midilli *et al*. model was found to fit well to describe the drying behaviour of long pepper. Multiple regression analysis was used to find the correlation of the model coefficients with temperatures. Model coefficient equations predicted the moisture ratio (MR) well at various drying temperatures for long pepper with an $R^2 = 1$ and SE = 0. Effective moisture diffusivity (D_{eff}) was observed in the range of 1.397×10^{-10} to 6.190×10^{-10} m^2s^{-1} for the temperature range of 40° to 80°C. The overall acceptability (OA) (90%) was highest in tray drying method at 60°C air temperature and the drying time was reduced to 50% against sun drying. This study will be useful to optimize drying process parameters for commercial production of dried long pepper.

Betel leaf yield in relation to soil fertility in Guntur district (Andhra Pradesh). 22 (1): 62-64 (2013)
B T Priya, P R Devi & K Sireesha
An attempt was made to survey betelvine gardens in Guntur district of Andhra Pradesh to ascertain soil fertility status and its impact on growth and yield of betelvine. All the soils were clay loam in texture. The pH of the soil was alkaline (7.1 to 8.4) and EC ranged from 0.35 to 1.61 dSm^{-1}. The organic carbon (OC) content of the soil was in the range of 0.55 to 1.24%. The available nitrogen (N), phosphorus (P) and potassium (K) status ranged from 201 to 313, 10 to 60, 337 to 840 kg ha^{-1}, respectively. Correlation indicated that the growth parameters *viz*., number of laterals, intermodal length, petiole length and soil parameter *viz*., pH, EC and P were positively correlated with betel leaf yield but relations were not significant, whereas, plant height and soil nutrients *viz*., OC content, N and K were significantly and positively correlated with leaf yield.

Genetic diversity study in *Piper* spp. using inter simple sequence repeat (ISSR) markers. 22 (2): 111-119 (2013)
T E Sheeja, G Uma, B Sasikumar, K V Saji & P R Rahul
Genetic diversity analysis of 27 *Piper* species using ISSR (Inter Simple Sequence Repeat) markers indicated that the analysis placed them in

six clusters in the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) dendrogram. The molecular marker based clustering of the species gave supporting evidence to the earlier groupings proposed by the taxonomists using traditional tools. We have identified 35 species specific bands from different species. *P. galeatum* had a maximum number of four unique bands.

Diversity study of leaf volatile oil constituent of *Piper* species based on GC/MS and spatial distribution. 23 (1): 10-16 (2014)
P Utpala, G R Asish, K V Saji, Johnson K George, N K Leela & P A Mathew

Ten wild *Piper* species of Western Ghats were studied for leaf volatile oil constituents using GC/MS. The total number of major components (≥ 1%) in different species varied from 5 to 10. The leaf oil was rich in sesquiterpenoids. The most abundant compounds in *Piper* leaf oil of Western Ghats were β-Caryophyllene, Nerolidol and β-Elemene. Different accessions of *P. nigrum* collected from different parts of Western Ghats were used to study the spatial diversity of aroma with the help of DIVA GIS. The results indicated that the latitudinal influence was strong in aroma diversity. Total number of components varied from 17 to 73, while the major components found were 10 in *P. nigrum* leaves. The diversity index of the total component was 2.87.

Phenolic profiling of *Piper* species by Liquid Chromatography-Mass Spectrometry. 25 (2): 123-132 (2016)
D Sruthi & T J Zachariah

In the present study, phenolic compounds from four *Piper* species *viz*., *P. nigrum* (black pepper), *P. longum*, *P. chaba* and *P. colubrinum* were identified by LC-MS analysis. The identified phenolic compounds mainly include phenolic acids and flavonoids. Thirteen compounds were identified in black pepper which mainly included hydroxybenzoic acids (syringic acid, protocatechuic acid etc.), hydroxycinnamic acids (caffeic acid, ferulic acid and 4-coumaric acid) and flavonoids (luteolin-8-C-glucoside and apigenin). Among the six compounds identified in *P. longum*, three belonged to hydroxybenzoic acid and the other three belonged to hydroxycinnamic acid category. Seven compounds were identified from *P. chaba* which comprised of

hydroxybenzoic acids, phenolic aldehydes and hydroxycinnamic acids. In *P. colubrinum*, ten compounds were identified and majority were flavonoids like kaempferol-5-glucoside and apigenin-7-galactoside. Hydroxybenzoic acids like protocatechuic acid and phenolic aldehyde like vanillin were also identified in *P. colubrinum*. Salicylic acid, a monohydroxybenzoic acid was identified in all the four species.

SMALL CARDAMOM

Crop Improvement and Biotechnology

Preliminary evaluation of elite clones of cardamom (*Elettaria cardamomum* Maton) for yield and yield parameters in clonal nursery. 6 (1): 37-41 (1997)
V S Korikanthimath, Ravindra Mulge & M M Hosmani
Twelve elite clones of cardamom (*Elettaria cardamomum*) were assessed for yield and yield parameters at Appangala (Karnataka, India) in the clonal nursery in two batches of planting. Among them, Sel. 9, Sel. 7 and Sel. 4 were significantly superior for yield and yield parameters, with higher number of panicles and capsules per plant, wet weight of capsules per plant and dry capsule yield per hectare. Early planting of clones was ideal for better establishment, suckering and yield under irrigated conditions.

Studies on multiple branching panicles in cardamom (*Elettaria cardamomum* Maton). 7 (2): 125-127 (1998)
V S Korikanthimath, M N Venugopal, Rajendra Hegde & S J Ankegowda
Field investigations were carried out at Kodagu (Karnataka, India) to study the nature of branching of panicles in 49 entries of cardamom (*Elettaria cardamomum*) of Malabar type (CI-37, prostrate type). Considerable variations in the nature of branching and basal branching, terminal branching and uniform branching throughout the length of the main axis of the panicle were observed. The pattern of branching was secondary and tertiary in nature. The 49 entries were also assessed for growth and panicle characters and considerable variations were observed for number of tillers, number of bearing tillers, number of panicles per plant and number of branches per panicle. The number of panicles per plant ranged from 12-148 and number of branches ranged from 17-31 per panicle.

Studies on selection of elite lines of CI-37 seedling progenies of cardamom (*Elettaria cardamomum* Maton). 8 (1): 57-61 (1999)
V S Korikanthimath, M J Mathew, Ravindra Mulge, Rajendra Hegde & M M Hosmani

Studies were carried out at Chettalli (Karnataka, India) to select high yielding accessions (lines) of cardamom (*Elettaria cardamomum*) from seedling progenies of CI-37 in a cardamom plantation and also to identify plants for earliness (yielding) coupled with high yield potential. Among the 275 high yielding accessions selected, 49 entries (17.8% of total entries) were classified as high yielders with a mean yield of 6537.01 g wet capsules/clump. High variability for total yield and Bartlet Index of earliness for yield was observed. The yield per clump varied from 325 to 7555 g wet capsules/clump. Entry No. 186 was identified to be a high yielding early type having the highest Bartlet Index of 0.7084950 with a total yield of 5156 g wet capsules/clump.

Studies on crossability between elite types of cardamom (*Elettaria cardamomum* Maton). 8 (2): 185-187 (1999)
M N Venugopal & K Padmini

A 8 x 8 set of crosses including reciprocals were made between elite Malabar selections of cardamom (*Elettaria cardamomum*) namely, CCS-1 and RR-1 and six cardamom mosaic disease (*katte*) resistant lines (NKE-12, NKE-27, NKE-34, NK3,9, NKE-3 and NKE-19) to incorporate desirable characters in the hybrids. All the elite selections were compatible with each other; however, the degree of compatibility varied with the parents selected for hybridisation. The crossability was highest and significant in the cross NKE-19 x NKE-34 (92%) followed by NKE-12 x NKE-19 (77%) and NKE-12 x RR-1 (69%). The crossability in CCS-1 x RR-1, NKE-27 x CCS-1, NKE-12 x RR-1, NKE-9 x RR-1 and NKE-3 x RR-1 was high (>50%) indicating the scope for combining yield and disease resistance in these crosses.

Evaluation of cardamom (*Elettaria cardamomum* Maton) germplasm. 9 (1): 55-56 (2000)
N Miniraj, M Murugan & Carmel Rani Joseph
Seventy two cardamom (*Elettaria cardamomum*) accessions were evaluated for 5 years at Pampadumpara (Kerala, India) for vegetative and economic characters and susceptibility to insect pests. Nine accessions recorded a dry capsule yield of above 150 g per clump. Among these nine promising accessions, S-1 appeared to be the best for further breeding programmes in view of its higher yield, moderate incidence of insect pests and higher quality parameters compared to other entries. Accessions MBP (Multiple Branching Panicle) and CP (Compound Panicle) can also be used in breeding programmes in view of their higher yield potential. The entries PS-12 and PS-5 offer great scope in breeding for quality.

Heterosis for seedling characters in cardamom (*Elettaria cardamomum* Maton). 9 (2): 149-153 (2000)
K Padmini, M N Venugopal & S J Ankegowda
A study was conducted to assess the nature and extent of relative heterosis, heterobeltiosis and economic heterosis in cardamom (*Elettaria cardamomum*) hybrids under nursery conditions. Among the 54 cardamom hybrids evaluated for seedling characters, NKE-9 x NKE-34, NKE-19 x NKE-12, NKE-3 x RR-1 and NKE-34 x NKE-12 were the best for plant height, number of leaves per plant, leaf length and leaf breadth, respectively. No positive and significant economic heterosis was observed in the hybrids for number of leaves per plant. Nine hybrids exhibited significantly higher and positive heterobeltiosis and economic heterosis for all the characters studied except number of leaves per plant.

Association of yield attributes among quantitative characters of cardamom (*Elettaria cardamomum* Maton). 9 (2): 155-156 (2000)
V S Korikanthimath, D Prasath & A A Mohamed Sayed
The correlation between quantitative characters of cardamom (*Elettaria cardamomum*) on number of capsules per plant and fresh weight of capsules per plant was estimated. The number of capsules

per plant had significant positive correlation with total number of tillers, bearing tillers and total panicles per plant, and fresh weight of capsules had significant positive correlation with number of tillers per plant and number of panicles per plant.

Evaluation of high yielding accessions of small cardamom (*Elettaria cardamomum* Maton) for suitability in the high ranges of Idukki District. 11 (2): 93-96 (2002)

S Backiyarani, P Sainamole Kurian, A Josephrajkumar & M Murugan

Ten high yielding small cardamom accessions were collected from RRS, Mudigere; ICRI, Saklespur and CRS, Pampadumpara and evaluated for their suitability in Idukki District, Kerala. M-1 and PV-1 were found to be high yielding varieties since both of them recorded the highest yield consistently for four consecutive years. M-l was relatively tolerant to thrips infestation. The biometrical traits such as plant height, tiller number, panicle number, panicle length and seed number showed high positive correlation with yield. These characters are likely to be the ideal selection criteria in small cardamom.

Factor analysis in cardamom (*Elettaria cardamomum* Maton). 13 (1): 37-39 (2004)

V V Radhakrishnan, Priya P Menon, K J Madhusoodanan, K M Kuruvilla & J Thomas

A pooled factor analysis of 17 variables representing morphological, yield contributing and qualitative characters of 90 genotypes of cardamom (*Elettaria cardamomum*) was carried out at Myladumpara (Kerala), for identifying marker characters which accommodate the inheritance of associated characters. Among the 17 characters subjected to the analysis, 6 factors were identified as having maximum influence on growth, yield and quality of cardamom. Among the six factors identified, three factors controlled yield and yield contributing characters, two factors controlled qualitative characters and one factor controlled growth characters. The characters identified with maximum factor loadings in each group include bearing tillers clump^{-1}, seeds capsule^{-1}, internodal length, racemes panicle^{-1}, leaf

breadth and capsules (dry) kg^{-1}. The six principal components or factors accounted for 78.09% of the total variance.

Screening small cardamom (*Elettaria cardamomum* Maton) field gene bank accessions for phenotypic characters, yield potential and disease resistance. 29 (2): 105-112 (2020)
A Sharon, C N Biju, S J Ankegowda, M S Shivakumar, R Senthil Kumar & M F Peeran
Evaluation of 117 field gene bank accessions of small cardamom for phenotypic characters along with yield potential and disease resistance (rhizome rot and leaf blight) at ICAR-Indian Institute of Spices Research Regional Station, Appangala revealed significant variation with respect to phenotypic characters. The highest plant height (350 cm) and number of bearing tillers (36.4) were recorded in the accessions, field gene bank (FGB) 65 and FGB 16, respectively. The highest fresh weight of capsules (399.61 g) and maximum number of capsules (244.20) $plant^{-1}$ were recorded in the accession, FGB 13. Further, based on screening for disease resistance, 35 and 15 accessions of cardamom were identified as resistant to leaf blight and highly resistant to rhizome rot, respectively. Based on the multivariate cluster analysis, 117 FGB accessions were classified into 5 clusters *viz*., clusters 1 and 2 encompassing equal number of accessions (44), cluster 3 with one accession (FGB 10), clusters 4 and 5 with 8 and 20 accessions, respectively.

Crop Production and Postharvest Technology

Effect of biostimulants on the growth and biomass of secondary nursery seedlings of cardamom. 1 (1): 75-80 (1992)
B A Vadiraj, K V V Rama Rao & R Naidu
A nursery experiment was undertaken at the Indian Cardamom Research Institute, Myladumpara to understand the effect of biostimulants on the growth and biomass of secondary nursery cardamom seedlings. Five biostimulants at different concentrations were sprayed at 30-day intervals for a period of 120 days. The results indicated that biostimulants such as vipul (a tricontanol-containing commercial product), Ergostim (N-acetyl thiazolidne-4-carboxylic

acid & folic acid-containing commercial product), pure folic acid, low levels of simazine and 2,4-D significantly increased the growth and dry matter production. The results suggest, that application of biostimulants not only reduces the nursery period but also helps in getting vigorous seedlings for better establishment in the field.

Effect of seed size and incubation temperature on seed germination of cardamom (*Elettaria cardamomum* Maton). 2 (1&2): 47-52 (1993)
Siddagangaiah, K Srinivasan, M R Sudharshan & R Naidu
An experiment was conducted to find out the optimal incubation temperature and ideal season for sowing cardamom (*Elettaria cardamomum*) seeds to achieve better and uniform germination. Germination parameters were studied during September-October, December-January and February-March 1989-91. An incubation temperature of 30°C recorded good germination during all the three seasons. However, seeds kept at ambient temperature during September-October resulted in best germination compared to 30°C. There was no significant difference in germination between seed sizes used.

Effect of Chloromequat, Daminozide, Ethepon and Maleic hydrazide on certain vegetative characters of cardamom (*Elettaria cardamomum* Maton) seedlings. 2 (1&2): 53-59 (1993)
Siddagangaiah, V Krishna Kumar & R Naidu
The effect of application of growth regulators such as Maleic hydrazide, Daminozide (Alar), Chloromequat (Cycocel) and Ethepon (Ethrel) on growth and development of cardamom (*Elettaria cardamomum*) seedlings of various age groups was studied. Maleic hydrazide (250 ppm), Daminozide (500 ppm), Chloromequat (250 ppm) and Ethepon (100 ppm) significantly enhanced tiller production and other vegetative characters when applied on 7 month old seedlings. These treatments were economical based on cost-benefit ratios that were worked out.

Effect of pruning mother suckers on daughter sucker production in cardamom (*Elettaria cardamomum* M.) seedlings. 2 (1&2): 68-70 (1993)

Siddagangaiah, V Krishna Kumar & M R Sudharshan

The effect of pruning mother suckers on daughter sucker production, growth and development of nursery seedlings of cardamom (*Elettaria cardamomum*) is reported. The number of suckers produced was significantly higher in seedlings pruned at 5 months of age followed by seedlings pruned at 3 months of age. The study indicated that pruning was not helpful in increasing biomass and hence it may not be necessary to remove apical meristem (mother sucker pruning) before transplanting of nursery seedlings.

Effect of growth regulators and spacing on multiplication of planting units in cardamom (*Elettaria cardamomum* Maton). 6 (1): 49-50 (1997)

S M Shanthaveerabhadraiah, H M Chandrappa & M Thimmarayappa

Experiments on multiplication of planting units in cardamom (*Elettaria cardamomum*) under uniform shade revealed that growth regulators (Etherel 250 ppm and Cycocel 2000 ppm) did not influence proliferation of planting units whereas closer spacing (0.9 m x 0.3 m) resulted in significantly higher number of planting units.

Response of cardamom (*Elettaria cardamomum* Maton) to NPK under uniform shade. 6 (2): 115-118 (1997)

S M Shanthaveerabhadraiah, H M Chandrappa & B Jagannath

Experiments conducted during 1987-94 at Mudigere (Karnataka, India) to study the response of different levels of N, P and K on the yield of cardamom (*Elettaria cardamomum*) under uniform shade indicated that increasing N up to 100 kg/ha resulted in a significant increase in capsule yield. Application of P at 50 kg/ha had a positive effect on yield; further increase of P up to 100 kg did not give significant results. In the case of K, significant increase in yield was observed up to 100 kg/ha. The effect of NPK levels on yield component factors such as suckers and panicles varied from year to year.

Influence of sowing methods on production of seedlings in cardamom (*Elettaria cardamomum* Maton). 6 (2): 137-139 (1997)

Siddagangaiah, Koshy John & M R Sudharshan

The effect of different methods of seed sowing in cardamom (*Elettaria cardamomum*) was studied in relation to germination and growth of seedlings in the nursery at Mudigere (Karnataka, India). Seed requirement was less and germination percentage was significantly higher in dibbling hill method of sowing compared to drilling line method. Height of seedlings, number of leaves, leaf area, number of tillers, fresh weight, dry weight per seedling and percentage of standard seedlings (4-5 tillers/seedling) obtained at transplantable age were also significantly higher in dibbling hill sowing method.

Cultivation of cardamom (*Elettaria cardamomum* Maton) in homesteads. 7 (1): 1-6 (1998)

V S Korikanthimath, G M Hiremath & M M Hosmani

Trials on cultivation of cardamom (*Elettaria cardamomum*) in homesteads conducted during 1991-93 in an area of 0.05 ha under controlled shade at Chettalli (Karnataka, India) resulted in a yield of 103 kg of dry cardamom within 30 months and an actual gross return of Rs. 47,388, net return of Rs. 26,175 and benefit-cost ratio of 2. It also generated employment of 380 labour days for effective utilisation of spare time besides productive utilisation of backyards for profitable cultivation of cardamom.

Growth and yield parameters of cardamom (*Elettaria cardamomum* Maton) as influenced by nutrition and planting density. 7 (1): 39-42 (1998)

V S Korikanthimath, Rajendra Hegde, Ravindra Mulge & M M Hosmani

Investigations carried out on cardamom (*Elettaria cardamomum*) at Appangala, Karnataka, India) to assess the effect of NPK nutrient combinations and planting densities on growth and yield parameters indicated that, increasing nutrient levels as well as planting density resulted in increased plant height at early stages of plant growth. Increased fertilizer levels increased number of leaves and panicles,

but increased planting density had adverse effect on these characters. A fertilizer combination of 50:75:300 kg NPK/ha and 5000 plants/ha planted at 2 m x 1 m spacing was comparatively optimum for satisfactory growth of cardamom.

Effect of different methods of planting and spacing on growth and yield of cardamom (*Elettaria cardamomum* Maton). 7 (2): 81-84 (1998)
Siddagangaiah, V Krishnakumar & M R Sudharshan
Experiments conducted at Sakaleshpur (Karnataka, India) to study the effect of different methods of planting and spacing on growth and yield of cardamom (*Elettaria cardamomum*) indicated that trench method of planting (60 cm x 30 cm) at 2 m x 1 m spacing resulted in significantly better growth and yield.

Response of cardamom (*Elettaria cardamomum* Maton) seedlings to vesicular arbuscular mycorrhizal fungi. 7 (2): 89-94 (1998)
K R Sreeramulu & D J Bagyaraj
The growth response of cardamom (*Elettaria cardamomum*) seedlings (cv. Malabar) to 13 different vesicular arbuscular mycorrhizal fungi was tested under mat house conditions at Bangalore, India, In general, seedlings inoculated with the fungi grew taller, had more number of leaves and tillers, increased seedling biomass and uptake of nutrients compared to control seedlings, Among the various mycorrhizal fungi tested, seedlings inoculated with *Gigaspora margarita* and *Glomus monosporum* exhibited significantly higher growth with increased uptake of nutrients,

Effect of light intensity on leaf scorching in nursery seedlings of cardamom (*Elettaria cardamomum* Maton). 7 (2): 129-131 (1998)
K C Ravindran & G Kulandaivelu
Studies on leaf scorching in nursery seedlings of cardamom (*Elettaria cardamomum*) grown at Thadiyankudisai (Tamil Nadu, India) indicated that total biomass, chlorophyll and protein contents, and photochemical activities were adversely affected in leaf scorched seedlings grown under full light (100% of total sunlight), when

compared to healthy seedlings grown under medium light (45-55% of total sunlight).

Microclimatic and physiological analysis in coffee-cardamom mixed cropping system. 7 (2): 133-135 (1998)
V S Korikanthimath, S J Ankegowda, N Yadukumar, Rajendra Hegde & M M Hosmani
Experiments were conducted at Chettalli (Karnataka, India) to study microclimatic and gas exchange parameters in coffee (*Coffea robusta*) and cardamom (*Elettaria cardamomum*) mixed cropping system. Coffee in monocrop and mixed cropping systems recorded higher light interception, photosynthetically active radiation, net photosynthetic rate and transpiration rate compared to cardamom. In the mixed cropping system, cardamom received 57.8% light and almost equal amount of photosynthetically active radiation.

Adoption of recommended practices for cultivation of cardamom (*Elettaria cardamomum* Maton) in the Hill Zone of Karnataka, India. 7 (2): 137-139 (1998)
D Raghupathi & R Venkatappa
A study was conducted in the Hill Zone of Karnataka, India, to find out the relationship of selected independent variables with dependent variables on adoption of improved practices for cultivation of M-1 variety of cardamom (*Elettaria cardamomum*). The study indicated that experience had a positive significant relationship with adoption of improved practices and education and land holding had no significant relationship with the same.

Effect of organic manure and inorganic fertilizers on growth, yield attributes and yield of cardamom (*Elettaria cardamomum* Maton). 9 (1): 57-59 (2000)
M Thimmarayappa, K T Shivashankar & S M Shanthaveerabhadraiah
Experiments conducted at Mudigere (Karnataka, India) to study the effect of organic manure and inorganic fertilizers alone and in combination in cardamom (*Elettaria cardamomum*) indicated that application of 100% inorganic fertilizers increased the number of

bearing suckers. Application of 100% inorganic fertilizers resulted in highest panicle production per clump (23.15) and green capsule yield (707 kg/ha). Though 100% inorganic fertilizers gave maximum yield which gave a higher benefit cost ratio of 4.19, integrated nutrient management with 25% organic manure + 75% inorganic fertilizers and 50% organic manure + 50% inorganic fertilizers also recorded yields at par with this treatment (609 and 602 kg/ha, respectively) with benefit cost ratios of 3.22 and 3.04, respectively.

Microclimatic and photosynthetic characteristics in arecanut and cardamom mixed cropping system. 9 (1): 61-63 (2000)
V S Korikanthimath, S J Ankegowda, N Yadukumar, Rajendra Hegde & M M Hosman
The microclimatic and photosynthetic characteristics of arecanut (*Areca catechu*) and cardamom (*Elettaria cardamomum*) mixed cropping system were studied at Sirsi (Karnataka, India). Arecanut canopy received higher amount of light and also photosynthetically active radiation. Arecanut also recorded higher photosynthetic rate, transpiration rate, stomatal conductance, intercellular CO_2 concentration, carboxylation efficiency and water use efficiency at gas exchange level.

Status of major nutrients in soils of cardamom (*Elettaria cardamomum* Maton) plantations in Kodagu District, Karnataka, India. 9 (2): 117-122 (2000)
V S Korikanthimath, A V Gaddi & S J Ankegowda
Soils were collected from various cardamom (*Elettaria cardamomum*) plantations in Kodagu District (Karnataka, India) and assessed for nutrient status. The soils were acidic (5.0 to 6.6 pH) in nature with high organic carbon content, which decreased with depth of the soil. The soils were medium (56.82%) to high (43.18%) in available nitrogen, low (79.55%) in available phosphorus and low (38.63%) to medium (52.27%) in available potassium. The soil profile collected from cardamom fields indicated relatively higher level of available nitrogen and organic matter than from uncultivated area due to recycling of organic materials in the former. The organic carbon

content was correlated positively and significantly with available nitrogen content.

Changes in climatic elements and their impact on production of cardamom (*Elettaria cardamomum* Maton) in the Cardamom Hills of Kerala, India. 9 (2): 157-160 (2000)
M Murugan, N Mini Raj and Carmel Rani Joseph
The change in climatic elements namely, temperature and precipitation in Cardamom Hills (Kerala, India) was studied by analysing the weather data for 20 (temperature) and 40 years (precipitation). Minimum temperature exhibited drastic variation over the years. The difference between the warmest and coolest month had narrowed considerably and the days have become warmer markedly. Except during 1967-76 (Decade-II) the total annual average precipitation received was more or less equal. Even though the total number of rainy days has increased, the distribution pattern was erratic during the last decade. The rainfall parameters had positive correlation with production of cardamom (*Elettaria cardamomum*) with significant relationship for number of rainy days.

Soil-site suitability evaluation for cardamom - A case study. 10 (2): 99-103 (2001)
C R Shivaprasad, V S Korikanthimath, A V Gaddi, K V Niranjan, D H Venkatesh & P Krishnan
Nineteen soil profiles representing seven soil series with sixteen mapping units were collected, described and mapped at Indian Institute of Spices Research, Cardamom Research Centre, Appangala, Madikeri, Karnataka for evaluating their suitability for cardamom cultivation. Soil and site properties such as climate, depth, slope, elevation, shade, texture, drainage, etc were compared with suitability criteria and the soils were assessed for growing cardamom. It is indicated that the well distributed rainfall of 1500-2000 mm with well drained conditions, a soil depth of more than 80 cm and 900-1200 m elevation support good crop of cardamom. The critical limit of Available Water Capacity was found to be 100 cm. Of the total area of the research station, 42 per cent area is highly suitable for cardamom

cultivation. About 53 per cent of the area is moderately suitable and about 4 per cent is marginally suitable.

Yield forecasting in cardamom (*Elettaria cardamomum* Maton) plantations under intensive management. 12 (1): 55-56 (2003)
Priya P Menon, V V Radhakrishnan, K J Madhusoodanan & K M Kuruvilla
A study was undertaken to develop a model for forecasting the yield in cardamom plantations under intensive management. Thirteen biometrical characters namely tillers per clump, tiller height leaves per tiller, vegetative buds per clump, bearing tillers per clump, panicles per clump, panicle length, racemes per panicle, capsules per raceme, seeds per capsule, leaf length, leaf breadth and recovery percentage were chosen as explanatory variables and they exhibited a precision of about 82%. Step down regression resulted in the retention of only four characters namely, panicles per clump, racemes per panicle, capsules per raceme and leaf breadth with which yield can be estimated with around 77% precision.

Evaluation of small cardamom accessions for moisture stress. 17 (2): 172-176 (2008)
S J Ankegowda & K S Krishnamurthy
High biomass and high yielding cardamom genotypes *viz*., Green gold, Mysore-2, APG 277, Malabar-18, Compound panicle 7 (CP 7) and Hybrid 36 were screened for moisture stress tolerance. Clonally propagated seedlings were planted in cement pots and grown for one and a half year with recommended package of practices under rainout shelter with three replications and two treatments (control and moisture stress). Moisture stress was imposed by withholding irrigation for two months. Data on morphological and physiological parameters related to drought tolerance were recorded at the initiation, middle and end of stress. Plant height and number of leaves per clump did not record significant variation among the accessions at the initiation of stress. Number of dried leaves increased under stress in all genotypes at the middle of stress. Compound panicle 7 recorded higher reduction in biomass at end of stress period compared to all other accessions. Variation in relative water content between the

treatments was non-significant. Chlorophyll florescence yield reduced significantly under moisture stress treatment compared to control. Results indicate that genotypes Mysore 2, Green gold and Malabar 18 have better adaptability to drought conditions.

Essential oil content of cardamom (*Elettaria cardamomum* Maton) by Hand-held Electronic Nose. 26 (2): 125-129 (2017)
N K Leela, A M Muneeb, S Mukherjee, D Ghosh & N Bhattacharya
Cardamom (*Elettaria cardamomum* Maton.) is one of the most expensive spices in the world. Essential oil is the most functionally important component of cardamom and is described as sweet, spicy, warm, camphoraceous and citrusy. The quality of cardamom is assessed by the essential oil content and its composition. Design of hand-held E-nose and evaluation of quality of cardamom in terms of its essential oil content is reported here.

Crop Protection

Preliminary screening of cardamom (*Elettaria cardamomum* Maton) elite clones for thrips (*Sciothrips cardamomi* Ramk.) damage in the field. 2 (1&2): 81-82 (1993)
C Parvathi & H M Chandrappa
Seventy three elite cardamom (*Elettaria cardamomum*) clones were screened for tolerance to thrips (*Sciothrips cardamomi*) damage under natural infestation. Three clones, *viz*., D-514, D-769 and Cl-754 were promising with least damage to capsules.

Record of soft scale (*Coccus hesperidium* Linn.) and its parasite (*Coccophagus ceroplastae* (Howard) on cardamom (*Elettaria cardamomum* Maton). 3 (1): 36-38 (1994)
Jasvir Singh, Tamil Selvan & D Kumaresan
A soft scale (*Coccus hesperidium*) is reported to occur on cardamom (*Elettaria cardamomum*) for the first time from Saklespur, Karnataka, India. The pest was parasitised by a hymenopteran, *Coccophagus ceroplastae* in the field.

A new genus and three new species of whiteflies (Aleyrodidae: Homoptera) from the cardamom eco system, South India. 5 (1): 58-63 (1996)
S Selvakumaran & B Vasantharaj David
Small cardamom (*Elettaria cardamomum* Maton) is affected by many diseases which have been identified as a major production constraint. Among the viral diseases 'katte' or mosaic is the major viral disease causing severe yield losses to an extent of 68 per cent. In addition, Nilgiri necrosis, infectious variegation virus and 'kokke kandu' diseases are gaining importance in recent years. The present paper reviews the information available on distribution of viral diseases, symptomatology, crop loss, transmission, etiology, host range and disease management. The future plan of work on aspects such as breeding for disease resistance through genetic engineering, virus characterization and early detection methods are indicated.

Is the cardamom whitefly *Kanakarajiella cardamomi* (David and Subramaniam) a vector of Nilgiri Necrosis Virus disease of cardamom *Elettaria cardamomum* Maton? 6 (1): 55-56 (1997)
S Selvakumaran, B Vasantharaj David & D Kumaresan
The vector and mode of transmission of the Nilgiri Necrosis Virus (NNV) disease affecting cardamom. *Elettaria cardamomum* Maton is unknown so far. More than 70 whitefly borne viral diseases have been reported on cultivated plants and weeds from tropical and subtropical regions (Cohen 1990). Muniappa (1980) in his critical review listed 65 viral diseases transmitted by whiteflies. The present studies were carried out to determine whether the cardamom whitefly, *Kanakarajiella cardamomi* (David and Subramaniam), an important pest on cardamom, acts as a vector of the NNV disease.

Efficacy of entomogenous fungi on biological suppression of *Pentalonia nigronervosa* f. *caladii* Van der Goot of cardamom (*Elettaria cardamomum* Maton). 7 (1): 43-46 (1998)
M J Mathew, K A Saju & M N Venugopal
Experiments were conducted in the laboratory on the biological suppression of the aphid *Pentalonia nigronervosa* f. *caladii* of cardamom (*Elettaria cardamomum*) using four entomogenous fungi

namely, *Beauveria bassiana*, *B. brongniartii*, *Verticillium chlamydosporium* and *Metarhizium anisopliae,* fungal spore suspensions (l x10^7 spores/ml) when applied on the aphid colonies caused mortality to both apterous adults and nymphs ranging from 37.0 to 96.6 per cent and 32.5 to 75.4 per cent, respectively. *B. bassiana* was the most potent biocontrol agent effecting 96.6 and 75.4 per cent mortality for adults and nymphs, respectively, in the indirect exposure method and 65.9 and 70.9 per cent, respectively, in the direct exposure method.

Evaluation of *Trichoderma* spp. for the control of seedling rot disease of cardamom (*Elettaria cardamomum* Maton). 7 (2): 85-88 (1998)

R Suseela Bhai & Joseph Thomas

Trichoderma viride and *T. harzianum* were evaluated as seed dressing prior to sowing of seeds and as soil application in nursery beds at the time of transplanting cardamom (*Elettaria cardamomum*) seedlings for the control of seedling rot or damping off caused by *Pythium vexans*. Coating of seeds with *Trichoderma* spp. did not alter the percentage of germination but reduced the percentage of damping off in sick soil. Soil drenching of *Trichoderma* spp. macerates 1 week prior to transplanting of seedlings in sick soils was effective in reducing seedling mortality compared to *Trichoderma* application after transplanting or as seedling dip.

***Chrysoperla carnea* Stephens (Chrysopidae: Neuroptera) - A potential biocontrol agent of cardamom aphid (*Pentalonia nigronervosa* f. *caladii* van der Goot). 7 (2): 155-156 (1998)**

M J Mathew, K A Saju & M N Venugopal

The mean aphid population in the leaf funnels with the predators was reduced to 18.7 (81.3% predation), 3 days after release, while in control, the mean population increased to 146 aphids. The per cent inhibition of population growth was 87.2. The study indicated the possibility of utilizing *C. carnea* for the control of *P. nigronervosa* on cardamom in an environment-friendly way.

Seasonal population of cardamom thrips (*Sciothrips cardamomi* (Ramk.) on three cultivar types of cardamom (*Elettaria cardamomum* Maton). 8 (1): 19-22 (1999)
Jasvir Singh, M R Sudharshan & M Tamil Selvan
The seasonal population of cardamom thrips (*Sciothrips cardamomi*) and its damage to capsules was assessed on three cultivar types (Malabar, Vazhukka and Mysore) of cardamom (*Elettaria cardamomum*) at Saklespur (Karnataka, India) during 1990-92. Thrips population was high during pre-and post-monsoon periods in all the cultivar types. There were significant differences in thrips damage on the capsules in the three cultivar types. There was no significant correlation between abiotic factors and thrips population. The cultivar type Malabar, mainly grown in Karnataka, recorded about 50% less damage than the other cultivar types. Mean thrips damage on capsules during the three years of study in Malabar, Vazhukka and Mysore cultivar types were 28.44%, 57.92% and 62.55%, respectively.

Influence of abiotic factors on population build up of cardamom whitefly *Kanakarajiella cardamomi* (David and Subramaniam) on cardamom (*Elettaria cardamomum* Maton). 8 (1): 67-71 (1999)
S Selvakumaran, B Vasantharaj David & D Kumaresan
The seasonal occurrence and influence of abiotic factors on population build up of cardamom whitefly *Kanakarajiella cardamomi* on cardamom (*Elettaria cardamomum*) was assessed during 1989-1990 at Lower Pulneys in Tamil Nadu (India). *K. cardamomi* persisted throughout the year with a maximum egg population of 9.09 per leaf during October 1989 and a minimum of 0.33 per leaf during June and August 1990; maximum nymphal population was 8.66 per leaf during October 1989 and minimum was OA9 per leaf during August 1990. Maximum temperature and relative humidity exhibited a significant negative association with population build up of eggs and nymphs; however, none of the abiotic factors had significant partial correlation coefficient with egg. and nymphal population. From the multiple regression equation constructed with R' value, it was attributed that the abiotic components had only 24 and 43% influence on the population build up of *K. cardamomi* eggs and nymphs, respectively.

Effect of washing on persistence of residues of mancozeb in cardamom (*Elettaria cardamomum* Maton) capsules. 8 (1): 73-76 (1999)
Thomas Biju Mathew, Naseema Beevi, K Sudharma, Nalinakumari & Maickutty P Mathew
Experiments on degradation of the fungicide mancozeb on cardamom (*Elettaria cardamomum*) capsules by processing techniques indicated that thorough washing had a profound influence on the removal of surface residues. A waiting period of 8 to 14 days in the case of fresh capsules could be brought down to 3 to 4 days by washing.

Natural disease escapes as sources of resistance against cardamom mosaic virus causing *katte* disease of cardamom (*Elettaria cardamomum* Maton). 8 (2): 145-151 (1999)
M N Venugopal
Resistant sources to cardamom mosaic virus causing katte disease of cardamom (*Elettaria cardamomum*) were identified by collecting 134 disease escapes from hot spots of virus infection in South India and screening them in greenhouse, sick plot and hot spots. Testing of promising collections in four hot spots and also against natural infection confirmed the resistant nature of the collections.

Breeding potential of *Pentalonia nigronervosa* f. *caladii* Van der Goot (Homoptera: Aphididae) on *katte* escape cardamom (*Elettaria cardamomum* Maton) plants. 8 (2): 189-191 (1999)
M N Venugopal, M J Mathew & M Anandaraj
Two viral diseases of cardamom (*Elettaria cardamomum*) namely, mosaic or katte disease and vein clearing or *kokke kandu* disease are transmitted by the cardamom aphid, *Pentalonia nigronervosa* f. *caladii*. The breeding potential of this vector on 17 mosaic disease escape accessions of cardamom was compared with, those of a local susceptible check. The aphids colonised and multiplied on all test accessions at a rate of multiplication ranging from 1.77 to 3.93, on the 5th day after introduction, On the 10th day after introduction, the local check recorded the highest multiplication rate (5.88) followed by NKE-5 (5.63); NKE-27 recorded the lowest rate of multiplication

(2.31). Colonisation of aphids on all *katte* escape lines indicates that the resistance of cardamom accessions to *katte* virus is not due to deterrence to vector but due to some other host factors.

Studies on honeybee foraging and pollination in cardamom (*Elettaria cardamomum* Maton). 9 (1): 37-42 (2000)
O P Chaudhary & Rakesh Kumar

Studies on floral biology, foraging behaviour and honeybee pollination in cardamom (*Elettaria cardamomum*) were conducted at Kadasikadavu (Idukki District, Kerala, India) during 1993 to 1995. Anthesis commenced around 0500 h and dehiscence occurred at 0600 h. The styles with receptive stigmas emerged at 0900 h and flowers withered after 12-13 h. Apoidea were the predominant flower visitors (more than 99% of all visitors), the Indian hive bee (*Apis cerana indica*) being the major visitor (95.8%) followed by *Trigona iridipennis* (2.2%). *A. cerana* indica foraging for nectar and pollen peaked from'0700 to 0900 and 0800 to 0900 h, respectively with no bee record after 1300 h. A*. cerana indica* spent more time collecting nectar (12.4 sec) than pollen (7.4 sec) and the proportion of nectar foragers was more (101.7/day) than pollen gatherers (61.6/day). The number of flower visits was minimum (6.6/min) at 0600 h which increased progressively to 14.9 min at 1100 h. The number of capsules/10 panicles, number of seeds, number of seeds/capsule, seed weight and 1000-seed weight were higher in open pollination than without insect pollination. Bee pollination resulted in better quality capsules of uniform shape and bigger size.

Evaluation of biorationals against thrips (*Sciothrips cardamomi* Ramk.) and shoot and capsule borer (*Conogethes punctiferalis* Guen.) in cardamom. 11 (2): 132-134 (2002)
A Joseph Rajkumar, P Sainamole Kurian, S Backiyarani & M Murugan

A field experiment was conducted to evaluate the efficacy of biorationals in the management of thrips and shoot and capsule borer of cardamom. Among the biorationals evaluated, fish oil insecticidal soap (FOIS) (Na) 2.5% + tobacco extract 2.5% significantly reduced the damage caused by thrips. None of the treatments is effective for

the control of shoot and capsule borer infestation on the capsules and all the treatments were on par with the control. Spraying quinalphos (0.05%) reduced the damage caused by thrips (6%) and increased the yield (391 g plant-I). Foraging activity of honey bees was highest in control plots.

Pigmentation and growth-temperature response of *Phytophthora meadii* and *P. nicotianae* var. *nicotianae* infecting cardamom (*Elettaria cardamomum* Maton). 12 (2): 158-161 (2003)
R Suseela Bhai & Y R Sarma
Capsule rot ('*Azhukal*') and leaf blight are two major *Phytophthora* diseases of small cardamom (*Elettaria cardamom* Maton). Variability among the *Phytophthora* isolates causing these diseases were studied using *Phytophthora* cultures isolated from rot affected plant parts such as capsules, rhizomes, leaf and also from blight affected leaves collected from different locations. Detailed studies on growth of these cultures in different media and at different temperatures showed significant difference between these isolates. *P. meadii* did not cause any pigmentation in casein hydrolysate tyrosine agar (Timmer's medium) and the fungus did not grow at high temperature while *P. nicotianae* var. *nicotianae* showed chocolate reddish brown pigmentation in casein hydrolysate tyrosine agar and did grew at high temperature. Therefore pigmentation in casein hydrolysate tyrosine agar and growth at high temperature were found ideal for differentiating *Phytophthora* isolates infecting cardamom.

IISR Avinash - A rhizome rot resistant and high yielding variety of cardamom (*Elettaria cardamomum* Maton). 15 (1): 14-18 (2006)
M N Venugopal, D Prasath & Ravindra Mulge
The cardamom (*Elettaria cardamomum*) variety, IISR Avinash (RR-1) was developed at the Indian Institute of Spices Research, Cardamom Research Centre, Appangala (Karnataka), through clonal selection and recommended for release for its resistance to rhizome rot dis-ease and high yield. The average yield of IISR Avinash was 643 kg ha^{-1} (dry) with a potential yield of 979 kg ha^{-1} (dry) with good quality dark green capsules.

Evaluation of bacterial antagonists for the management of rhizome rot of cardamom (*Elettaria cardamomum* Maton). 21 (1): 9-15 (2012)

Sivakumar G, Josephrajkumar A & Dhanya M K

Among the 90 rhizobacterial isolates screened against rhizome rot pathogens (*Pythium* vexans, *Fusarium oxysporum* and *Rhizoctonia solani*) of cardamom (*Elettaria cardamomum*) two bacterial strains viz., *Pseudomonas fluorescens* Pf 51 and *Bacillus subtilis* B45 were highly inhibitory. *P. fluorescens* Pf 51 exhibited highest inhibition (42.5%, 44.2% and 41.4%, respectively) against *P. vexans*, *F. oxysporum* and *R. solani*. *B. subtilis* B45 also exhibited highest inhibition (43.2%, 41.2% and 42.4% respectively) against these three pathogens. *P. fluorescens* Pf51 was compatible with *B. subtilis* Bs 45. Peat formulation supported the survival of both the strains up to 270 days with a viable population of 4.3 × 107 cfu g^{-1} and 6.2 × 107 cfu g^{-1}, respectively. Application of antagonists in combination with rhizome bacterization and soil application resulted in 54.0% reduction in rhizome rot over control as compared to single method such as rhizome bacterization (43.0%) or soil application (39.0%). Application of copper oxychloride and carbendazim resulted in 68.0% reduction of rhizome rot. Maximum height (167.21 cm) and number of tillers (30.14) were recorded due to the application of mixture of both the strains through rhizome bacterization and soil application.

Residue estimation of chlorpyriphos and lambda cyhalothrin in cardamom [*Elettaria cardamomum* (L.) Maton]. 22 (1): 65-69 (2013)

T George & N P Kumar

The aim of the study was to validate the method for estimation of residues of chlorpyrifos and lambda cyhalothrin in cardamom. Accordingly, the limit of detection (LOD) arrived at was 0.005 µg kg^{-1} and the limit of quantitation (LOQ) arrived at was 0.01 mg kg^{-1}. Chlorpyriphos and lambda cyhalothrin residues showed a linear response in the range of 0.005-5.0 µg kg^{-1} and the mean recovery obtained was 97.3% for chlorpyriphos and 98.9% for lambda cyhalothrin with satisfactory RSD values. The initial residues of chlorpyriphos applied at a concentration of 0.05% in cardamom was

1.6 µg kg^{-1} and the residue was 5.64 µg kg^{-1} after processing, with a processing factor of 3.53, while the lambda cyhalothrin when applied at 0.0025% resulted in initial residues of 0.26 µg kg^{-1} which got magnified to 1.19 µg kg^{-1}, with a processing factor of 4.58. The processing factor obtained in this study led to the conclusion that the residues of chlorpyriphos were magnified 3.53 times and that of lambda cyhalothrin were magnified 4.58 times of initial residues, mainly due to loss of weight of cardamom due to dehydration during curing.

Analysis of variability in *Cardamom mosaic virus* isolates occurring in India using symptomatology and coat protein gene sequence. 22 (1): 70-75 (2013)
A Siljo, A I Bhat & C N Biju
Coat protein (CP) gene from six symptomatologically distinct isolates of Cardamom mosaic virus (CdMV) causing mosaic disease of cardamom collected from different geographical areas were amplified, cloned, sequenced, compared among themselves and with other CdMV isolates available in the GenBank. Identity of coat protein sequence among the isolates varied from 74.8%-99.3% and 80.9%-99.2% at nucleotide and amino acid levels, respectively. Based on the identity, isolates were classified into three distinct groups. All isolates from Karnataka (except Sirsi) belonged to one group, while isolates from Kerala and Tamil Nadu belonged to the other group. Multiple sequence alignment and phylogenetic analyses confirmed grouping of isolates based on percent identities.

Dissipation of flubendiamide (480 SC) in cardamom [*Elettaria cardamomum* (L.) Maton]. 24 (1): 7-11 (2015)
T George, S N Beevi, T B Mathew, N Pratheeshkumar & G Xavier
Insecticide flubendiamide was sprayed thrice at 21 days interval between December-February on cardamom at two concentrations, i.e. 0.72 g a.i. 10 L^{-1} (X), and 1.44 g a.i. 10 L^{-1} (2X). Samples of capsules were collected at regular intervals for 15 days after application of the insecticide for residue analysis. The initial deposit of flubendiamide in capsules was 0.42 and 0.60 mg kg^{-1} for X and 2X treatments, respectively that dissipated with a half-life of 1.25 and 2.53 days,

respectively. No residue of des-iodo flubendiamide (the metabolite of flubendiamide) was detected in any of the samples up to 15 days. The limit of quantification (LOQ) of the method was 0.05 mg kg^{-1}, for both flubendiamide and des-iodo flubendiamide.

Induced defense response in small cardamom plants by *Bacillus subtilis* strain Bs against capsule rot pathogen, *Phytophthora meadii.* 24 (1): 12-17 (2015)

G Sivakumar, M K Dhanya & M Murugan

The objective of this study was to investigate the mechanism by which *Bacillus strains* confer plant protection. *Bacillus subtilis* strain Bs was identified as potential bacterial antagonist against cardamom capsule rot pathogen, *Phytophthora meadii*. This strain was tested for its ability to induce defense related enzymes *viz*., peroxidase (PO), polyphenol oxidase (PPO) and total phenols against P. meadii in cardamom plants. Cardamom plants treated with bacterial antagonist and challenge inoculated with P. meadii showed higher levels of defense related enzymes and phenols compared to antagonist alone, pathogen alone and untreated plants. *B. subtilis* strain Bs induced higher activities of total phenols (182 µg g^{-1} of tissue), PO (2.81 change in OD min^{-1} g^{-1} of tissue) and PPO activity (1.01 change in OD min^{-1} g^{-1}) in cardamom plants treated with *P. meadii.* The present study clearly indicated that the bacterial antagonist *B. subtilis* has the ability to induce defense related enzymes in cardamom plants against *P. meadii*.

Evaluation of insecticides and natural products for their efficacy against cardamom thrips (*Sciothrips cardamomi* Ramk.) (Thysanoptera: Thripidae) in the field. 24 (2): 133-136 (2015)

T K Jacob, C M Senthil Kumar, Sharon D'Silva, S Devasahayam, H R Ranganath, E S Sujeesh, C N Biju, R Praveena & S J Ankegowda

Eleven insecticides and natural products were evaluated in the field at Appangala (Karnataka) for their efficacy against cardamom thrips (*Sciothrips cardamomi*) for three years. Combined analysis of three years data indicated that all the treatments were significantly effective in reducing the damage caused by thrips on capsules compared to control when sprayed during February-March, March-

April, April-May and September and October. Fipronil 0.005% treated plots recorded the lowest percentage of damage (6.5%) that was on par with imidacloprid 0.0089%, thiamethoxam 0.0075% and spinosad 0.0135%. The trials indicated that spinosad can substitute synthetic insecticides for thrips control in cardamom, due to their less adverse effects on the environment.

Degradation of monocrotophos in cardamom under field conditions and during processing. 25 (2): 195-199 (2016)
X Reivax, M Oommen, J J Varghese, P Natarajan & J Thomas
The degradation pattern of monocrotophos (Dimethyl (E)-1-methyl-2-(methyl carbamoyil) vinyl phosphate) in small cardamom (*Elettaria cardamomum*) under field conditions and during processing were studied. Monocrotophos 36% SL was sprayed at the recommended dose of 0.072% as per standard foliar application procedures. The residues were determined by gas chromatography with flame photometric detector. The degradation of monocrotophos followed first order kinetics and the half-life of monocrotophos in fresh cardamom capsules was found to be five days. Due to dehydration during processing of fresh cardamom capsules, monocrotophos residue in cardamom capsule was found to be magnified by 3.5 times. Monocrotophos residue was reduced by 11.5% on curing and 29.5% on polishing.

Epidemiological parameters to delineate weather-disease interactions and host plant resistance against leaf blight in small cardamom (*Elettaria cardamomum* Maton). 27 (1): 22-31 (2018)
C N Biju, M F Peeran, R Gowri, R Praveena, A Sharon & S J Ankegowda
Small cardamom, the versatile spice of Zingiberaceae is cultivated in diverse agro-climatic regions of India especially in South India. Leaf blight incited by *Colletotrichum gloeosporioides sensu lato* is one among the major challenges encountered across different cardamom growing tracts. In the present investigation, epidemiology of cardamom leaf blight was studied and an attempt was made to decipher the resistant nature of Malabar, Mysore and Vazhukka genotypes based on epidemiological parameters. The average percent

disease index recorded in Malabar, Mysore and Vazhukka varied from 23.41 to 27.72, 18.79 to 20.34 and 18.74 to 20.38, respectively. The disease exhibited a positive correlation with respect to T_{max} and T_{min} in all the genotypes, however, significant correlation was observed only in Malabar and Mysore with respect to T_{max}. Whereas, rainfall and rainy days had negative correlation with leaf blight in all genotypes however found to be non-significant. The average infection rate was maximum (0.000429) in Malabar, whereas it was 0.000124 and 0.000186 in Mysore and Vazhukka, respectively. The area under disease progress curve registered the highest for Malabar (8814.15) and lowest in Vazhukka (6531.02) while, Mysore type recorded 6612.96 indicating that, Vazhukka and Mysore types might possess horizontal resistance and Malabar with vertical resistance. In the light of above results, plant protection measures could be scheduled based on the take-off level and genotypes with horizontal resistance could be promising candidates in resistance breeding programmes.

Interactive effect of biocontrol agents in the management of Fusarium rot in cardamom and its impact on plant defense mechanism. 30 (1): 50-57 (2021)

K C Veny Krishna, M K Dhanya, M Joy, N S Radhika & B Aparna

Cardamom plantations are subjected to constant threat due to the *Fusarium* rot disease caused by *Fusarium oxysporum* Schlecht which is pronounced during summer months. The current study deals with the identification of an effective and ecofriendly management practice for the disease through the use of biocontrol agents. Survey conducted between February and May 2019 revealed maximum disease severity and incidence in Pampadumpara panchayat of Nedumkandam block (84.40% and 100%) and minimum in Erattayar panchayat of Kattappana block (50.40% and 60.00%). A pot culture experiment was conducted to study the effect of three bioagents (*Glomus fasciculatum*, *Trichoderma asperellum* and *Pseudomonas fluorescens*) individually as well as in combinations. Root inoculation of *G. fasciculatum* with basal application and spray with *P. fluorescens* as well as root inoculation of *G. fasciculatum* along with basal application of *T. asperellum* and *P. fluorescens* spray were identified to be effective against the disease. Disease suppression by the above

bioagents was facilitated by reduced pathogen antagonist ratio in the soil, high level of mycorrhizal colonization in the roots and enhanced biochemical activity of defense enzymes like peroxidase, poly phenol oxidase and phenylalanine ammonia lyase in the plants.

Social Sciences

Price structure of cardamom in India - An analysis. 1 (1): 65-71 (1992)
Tomy Joseph & R Naidu
The seasonal phenomenon in the price of small cardamom along with the seasonality in related variables like sales at auction centres, export and export price are analysed. The interrelationship between market price and these variables is also studied. The analysis shows that the seasonal index of price was the highest in January and the lowest in July, while the seasonal index of market sales was the highest in November and lowest in July. The extent of seasonality was more in sales compared to prices. Compared to export price, sales price showed more marked seasonality. An attempt is made to quantify the extent of relationship between yearly sales price and variables like production, quantity of sales at auction centres, export and export price by employing multiple regression analysis. The analysis shows that around 97% variation in yearly price can be explained by the two variables namely export and export price. The compound growth rates in production, export and prices during the period are also worked out.

Economics of sustained production of cardamom (*Elettaria cardamomum* M.). 4 (2): 119-128 (1995)
V S Korikanthimath
Large scale field trials were conducted by adopting High Production Technology at Chettalli (Coorg District, Karnataka, India) to study labour utilisation, input requirement and economics of cultivation of cardamom (*Elettaria cardamomum*). A highest yield of 1625 kg/ha (dry) was recorded during the fourth year after planting. The average of nine crop seasons - 695.66 kg/ha (dry) obtained in the trials was 12 times more than the national average yield of 58 kg/ha. Cultivation of

cardamom was highly labour intensive. Out of 747.42 labour days required per ha/year during bearing period, the requirement of women labourers was higher (64.05 per cent); 63 per cent of the labour requirement was for harvesting and processing alone. The annual maintenance cost was Rs. 35,148.00/ha. Partitioning of various inputs indicated that maximum expenditure was incurred towards labour (including supervisory charges) i.e., Rs. 19,574.50/ha (55.69 per cent). A net income of Rs. 1,09,967.11/ha (average of nine crop seasons) was obtained with a production cost of Rs. 57.22/kg (dry).

Economics of mixed cropping of cardamom (*Elettaria cardamomum* Maton) in arecanut (*Areca catechu* L.) gardens. 6 (2): 107-113 (1997)
V S Korikanthimath, V Kiresur, G M Hiremath, Rajendra Hegde, Ravindra Mulge & M M Hosmani
A study carried out for 8 years (1986-87 to 1993-94) on mixed cropping of arecanut (*Areca catechu*) with cardamom (*Elettaria cardamomum*) in comparison to mono cropping of arecanut indicated that the cost of cultivation was higher (Rs.40,683/ha) in mixed cropping than under mono cropping system (Rs.27,571/ha). The net returns of Rs.1,61,837/ha realised in mixed cropping was 1.56 times higher over mono cropping (Rs.1,03,626/ha). The incremental net gain in mixed cropping was Rs.58,211/ha (56.21 per cent over mono cropping). Net Present Worth and Benefit Cost Ratio were higher by 1.48 and 1.01 times respectively, under mixed cropping compared to mono cropping.

Generation of employment potential in coffee-cardamom based cropping systems.
8 (1): 29-34 (1999)
V S Korikanthimath, G M Hiremath & M M Hosmani
Studies carried out at Chettalli (Karnataka, India) on mixed cropping of coffee (*Coffea robusta*) with cardamom (*Elettaria cardamomum*) in comparison with mono cropping of coffee indicated greater potential of labour employment in mixed cropping system compared to mono cropping system. The mixed cropping system required 237 men and

710 women labourers per ha per year (9 years average) to carry out various operations which was 1.67 times higher than the mono cropping system. The correlation coefficient of yield and labour requirement in both mono and mixed cropping systems were high and significant.

Mixed cropping systems in cardamom (*Elettaria cardamomum* Maton) - An analysis. 8 (1): 63-66 (1999)
K Srinivasan, Siddagangaiah, A K Biswas & V Krishnakumar
Surveys and economic analyses conducted in various cardamom (*Elettaria cardamomum*) plantations adopting mixed cropping systems in Kerala and Karnataka, India indicated that inclusion of black pepper (*Piper nigrum*) or coffee (*Coffea arabica*) and arecanut (*Areca catechu*) was highly remunerative giving high cost-benefit ratios.

Performance and economics of replanted cardamom (*Elettaria cardamomum* Maton) plantation. 9 (1): 31-36 (2000)
V S Korikanthimath
The performance and economics of replanting of cardamom (*Elettaria cardamomum*) was studied at Chettalli (Kodagu District, Karnataka, India). An average yield of 749 kg (dry)/ha of cardamom was obtained for five crop seasons which was 5.35 times higher than the national average yield of 140 kg/ha. A highest yield of 1775 kg/ha (dry) was recorded during the second year after replanting. Out of 869.8 labour days required per ha per year during the bearing period, the requirement of women labourers was higher (87.4%); 57.8% labour requirement was for picking only. Maximum expenses (69.45%; Rs. 57,230.80/ha) was incurred on labour charges. A net income of Rs. 1,96,986.20/ha (average of five crop seasons) was obtained with a production cost of Rs. 130.97/kg (dry). The discounting cash flow measures namely, Net Present Value (NPV) of Rs. 5,09,296.45, Benefit Cost Ratio (BCR) of 2.78 and Pay Back Period (PBP) of 2.15 years indicated that replanting of cardamom is an economically viable and financially feasible proposition.

Trade competitiveness and export performance of Indian cardamom. 28 (1): 34-42 (2019)
L Thomas, P Rajeev & P C Sanil
India is one of the major producers and consumer of cardamom. The export performance of cardamom has witnessed several changes over the past few decades. This paper analyses the trends and performance of cardamom commodity from India. Using secondary data from the Spices Board and the Ministry of Commerce along with international trade data from the United Nations International Trade Statistics Database, the trend in the domestic production and export markets is clearly drawn out. The changes in Revealed Comparative Advantage in cardamom exports over the years is used to study the level and changes in the export competitiveness of the commodity. The study identifies a revival in export competiveness in the recent years along with an increase in the share of global cardamom exports. The highly concentrated production of cardamom, the preference for Indian cardamom in Middle East economies and the revival of export competitiveness can benefit the Indian cardamom producers. The study argues for strengthening research investments in cardamom for sustaining and enhancing the benefits from cardamom exports from the country.

Price transmission and supply response : The case of Indian small cardamom. 30 (1): 34-41 (2021)
A Indhushree & A Kuruvila
Market price volatility, the major challenge faced by the cardamom exporters greatly hinders the investment and destabilizes the earning of small holders. The present study attempted to analyse the price transmission between Indian and international markets and study the supply response of small cardamom to changes in price. The co-movement of prices of small cardamom exist between the Indian and international markets after trade liberalisation and the price transmission has been from the international market to the Indian market. The short-run disequilibrium has been found between the Indian and international prices of cardamom, which got corrected with varying speed of adjustment. The positive and significant elasticity of supply of small cardamom with respect to its own two

year lagged price has been established. Crop specific price stabilization mechanism would help to overcome the wide fluctuations in prices of small cardamom.

LARGE CARDAMOM

Crop Improvement and Biotechnology

A note on large cardamom (*Amomum subulatum* Roxb.) germplasm collection. 2 (1&2): 77-80 (1993)
Y S Rao, U Gupta, Anand Kumar & R Naidu
Eleven accessions (SBLC 1-11) of large cardamom (*Amomum subulatum*) collected from Sikkim and Darjeeling district of West Bengal, India were studied for some morphological attributes. SBLC 11 (Barlanga variety) had superior yielding characters like 4 spikes per tiller and bold size of capsules with 45-46 seeds.

Micropropagation of large cardamom (*Amomum subulatum* Roxb.). 6 (2): 145-148 (1997)
A Sajina, P M Mini, C Z John, K Nirmal Babu, P N Ravindran & K V Peter
A method for micropropagation of large cardamom (*Amomum subulatum*) is reported. Rhizome buds were activated to grow in Murashige and Skoog basal medium supplemented with 3% sucrose and 0.5 mg l^{-1} kinetin. The sprouted buds were multiplied at the rate of 5-10 shoots per culture in Murashige and Skoog medium supplemented With 1.0 mg l^{-1} benzylaminopurine and 0.5 mg l^{-1} indole-3-butyric acid. The shoots rooted in the same medium. The *in vitro* regenerated plantlets could be established in the soil with 90 per cent success.

Growth and yield of native germplasm of large cardamom in the wild habitat of Arunachal Pradesh. 11 (2): 148-150 (2002)
A K Dubey & D S Yadav
Surveys were made during 1998 and 1999 to identify and evaluate in situ the germplasm of large cardamom available in natural forests of Arunachal Pradesh. It was observed that eight distinct types of large cardamom were present in this state, which differ significantly in their morphological characteristics. Boklok, a high altitude accession, had the highest plant height, number of tillers and panicles, maximum yield and dry weight of fruits. However, fruits panicle^{-1} was found to

be highest in Bebo light red. Jaker green has larger capsules with highest fresh weight of fruits, while Belak had the highest number of seeds fruit^{-1}. The germplasm collected provides good scope for the crop improvement through breeding.

Multivariate analysis in large cardamom (*Amomum subulatum* Roxb.) 15 (2): 133-135 (2006)
U Gupta, K M Kuruvilla, Priya P Menon, K J Madhusoodanan & J Thomas
The variability in large cardamom (*Amomum subulatum*) germplasm was studied by application of multivariate methods such as principal component analysis, discriminant function analysis and Hotelling's T^2 statistic. Variables such as girth of the clump, number of bearing tillers, number of spikes clump^{-1}, number of capsules spike^{-1}, capsule length, capsule diameter and capsule weight recorded in 40 accessions belonging to two cultivars of large cardamom namely, Ramsey and Sawney were used in the study. Principal component analysis resulted in the identification of three components, which could explain 73% of variability in large cardamom. Discriminant function analysis brought about a discriminant function to distinguish between the two cultivars of large cardamom. Among the variables, capsule weight, girth of the clump, capsules spike^{-1} and number of bearing tillers contributed maximum towards yield and hence such characters can be effectively exploited in crop improvement programmes.

Crop Production and Postharvest Technology

Curing of large cardamom (*Amomum subulatum* Roxb.): Fabrication of a new dryer and a comparative study of its performance with existing dryers. 5 (2): 105-110 (1996)
Johny Joseph, B Raghavan, G Nanjundaiah & M L Shankaranarayana
A simple natural convection dryer that could be easily dismantled and transported was designed, fabricated and field tested in a large cardamom (*Amomum subulatum*) plantation in Sikkim, India. The thermal efficiency of the dryer (5.2%) was much higher compared to

the traditional curing house dryer (1.8%) thus saving substantial fuel. The dryer had a capacity of 300 kg of fresh cardamom capsules which was adequate for most of the plantations in the region. The time taken for drying the fresh capsules to a moisture content of about 10% was 24 h which was much less compared to conventional bhatti drying (55 h) and curing house drying (42 h). The quality of the dried product with respect to flavour and colour was also superior to that obtained from the other two methods of drying.

Comparative performance of different varieties of large cardamom (*Amomom subulatum* Roxb.) under mid altitude of Arunachal Pradesh. 10 (2): 119-122 (2001)
A K Dubey & D S Yadav
Studies were conducted to assess the performance of eight varieties of large cardamom at mid altitudes (660 meters MSL) in Arunachal Pradesh. Out of the eight varieties tested, Ramla, Sawney, Madhusey and Ramsey performed better and can be introduced for commercial cultivation at mid altitude region of Arunachal Pradesh.

Efficacy of microbial inoculants and organic fertilizer for establishing large cardamom (*Amomum subulatum* Roxb.) sucker nursery. 23 (1): 138-142 (2014)
S S Mahesh, K A Saju, B A Vadiraj, J Thomas & T N Deka
An experiment was conducted to evaluate the effectiveness of various microbial inoculants on large cardamom suckers. The study demonstrated the beneficial effect of microbial inoculants, *viz*., *Azospirillum*, *Pseudomonas fluorescens*, *Trichoderma harzianum*, phosphate solubilizing bacteria (PSB) and Arbuscular Mycorrhizal Fungi (AMF) on plant growth. Application of farm yard manure (FYM) + *Azospirillum* + *P. fluorescens* + *T. harzianum* + AMF recorded significantly higher number of tillers and plant height as compared to other treatments. Hence, using the above microbial inoculants may facilitate better establishment and growth for planting material in the nursey.

Volatile oil composition of four popular varieties of large cardamom (*Amomum subulatum* Roxb.). 26 (1): 37-43 (2017)
A K Vijayan, N K Leela, M Dhanalakshmi, H J Akshitha, R Rahul, P Utpala & K N Babu
In the present study volatile oil profile of the four popular varieties of large cardamom (*Amomum subulatum* Roxb.) namely Sawney, Varlangey, Ramla and Ramsey were studied in detail. The capsules contained 58.1-68.1% seeds and 1.2-2.8% essential oil. By GC-MS analysis 23 constituents of the oil were identified with 1,8-cineole as the chief component. Major constituents of the oil were α-pinene (1.7-6.5%), β-pinene (4.0-11.1%), 1,8-cineole (63.2-73.4%) and α-terpineol (5.6-7.6%). The oil contained high level of 1,8-cineole when compared to small cardamom (*Elettaria cardamom* Maton). α-terpinyl acetate, the chief component of small cardamom oil was not detected in large cardamom.

Crop Protection

Incidence of *Phoma* leaf spot disease of large cardamom (*Amomum subulatum* Roxb.) and *in vitro* evaluation of fungicides against the pathogen. 20 (2): 86-88. (2011)
K A Saju, T N Deka, M R Sudharshan, U Gupta & A K Biswas
Surveys conducted in 17 locations in North East India indicated that the incidence of *Phoma* leaf spot disease of large cardamom (*Amomum subulatum*.) caused by *P. hedericola* ranged from 5% to 15%. Six fungicides were evaluated *in vitro* against the pathogen and carbendazim 50WP was significantly effective at all concentrations (0.05% - 0.15%) tested followed by carbendazim + mancozeb 75WP (0.1%-0.4%).

***In vitro* evaluation of biocontrol agents, botanicals and fungicides against *Pestalotiopsis* sp. infecting large cardamom (*Amomum subulatum* Roxb.). 20 (2): 89-92 (2011)**
K A Saju, Smrita Mech, T N Deka & A K Biswas
Commercially available biological control agents (*Trichoderma harzianum*, *T. viride*, *Pseudomonas fluorescens* and *Bacillus subtilis*), aqueous extracts of plant species (*Artemisia vulgaris* and *Schima*

wallichi) and four fungicides were screened in vitro at Tadong (Sikkim), against *Pestalotiopsis* sp. infecting large cardamom (*Amomum subulatum*). *B. subtilis* showed significantly high inhibition (62.6%) of the pathogen followed by *T. viride* (50.9%). Inhibition of mycelial growth of *Pestalotiopsis* sp. by combined aqueous extract of *A. vulgaris* and *S. wallichi* varied from 12.2% to 74.5% and was significantly higher at 15% concentration. Inhibition of the pathogen increased with increase in concentration of the extract. The growth inhibition of the pathogen increased with increase in concentration of all fungicides tested. Carbendazim 50WP was significantly effective at all concentrations tested (0.05%-0.15%). The study indicated the potential of using biocontrol agents and botanicals for eco-friendly management of Pestalotiopsis sp. infecting large cardamom and fungicides in case the incidence is severe.

Hail injury in large cardamom (*Amomum subulatum* Roxb.) at high altitudes of Sikkim. 20 (2): 93-95 (2011)
K A Saju, T N Deka, S S Mahesh, N K Bhattarai, U Gupta, A K Biswas & M R Sudharshan
Hail injury as an abiotic stress factor affecting large cardamom (*Amomum subulatum*) in Sikkim during February-May and its implications are described. Hail damage to foliage appeared as bruising, shredding or physical mangling and on the pseudostem as open, ragged-edged wounds. In addition to direct damage caused by hails the wounds also served as infection court for fungal pathogens. Since hail occurred at flowering stage (February-May) of large cardamom, it resulted in physical damage of floral parts too and thus affected the yield.

Chilling injury of large cardamom (*Amomum subulatum* Roxb.) in high altitudes of Sikkim and Darjeeling, India. 21 (1): 78-81 (2012)
K A Saju, T N Deka, U Gupta, A K Biswas & M R Sudharshan
Manifestations of cold temperature damage on large cardamom (*Amomum subulatum* Roxb.) was monitored at Pangthang (2160 m MSL), East Sikkim during the winter seasons (October–March) of 2006–10. Damage to plant tissues, mainly leaves, occurred during

prolonged cold wave conditions (below 6°C) that prevailed during December–February. Tiny pin prick like water soaked lesions appeared on the lamina, coalescing to form a large patch that died and turned pale brownish and served as infection court for fungal pathogens. Extreme frosting on leaves was more common in exposed areas without shade trees.

Identity of *Colletotrichum* infections in large cardamom (*Amomum subulatum* Roxb.). 22 (1): 101-103 (2013)
K A Saju, T N Deka, U Gupta, A K Biswas, M R Sudharshan, A K Vijayan & J Thomas
The pathogen causing blight and severe devastation of large cardamom in Sikkim and Darjeeling Hills was isolated and identified as *Colletotrichum gloeosporioides* (Penz.) Sacc. {perfect state *Glomerella cingulata* (Stoneman) Spauld. & Schrenk}. We propose the name, *Colletotrichum* blight for the disease.

Yield loss of large cardamom (*Amomum subulatum* Roxb.) due to *Colletotrichum* blight in Sikkim. 22 (2): 215-218 (2013)
K A Saju, S Mech, T N Deka, U Gupta, A K Biswas & M R Sudharshan
Large cardamom (*Amomum subulatum* Roxb.) is affected by various fungal diseases. Of these, blight caused by *Colletotrichum gloeosporioides* (Penz.) Sacc. (perfect state *Glomerella cingulata* (Stoneman) spaulding & Schrenk) is one of the major production constraints. In order to assess the loss due to Colletotrichum blight, yield of affected plants of two cultivars, Varlangey and Sawney was recorded. Yields were also recorded from healthy plants of the same cultivars for comparison. There was 46.8% reduction in the dry yield of infected plants of Varlangey and 34.5% reduction in dry yield of Sawney as compared to healthy plants. The infected plants of Varlangey were found dead in the first year itself causing 100% loss. Lack of maturity of seeds, increased husk weight of fresh capsules and decreased weight of dried capsules were observed in the infected plants.

***Colletotrichum* blight control in large cardamom (*Amomum subulatum* Roxb.) nursery. 22 (2): 219-221 (2013)**

K A Saju, R Kuldeep, T N Deka, U Gupta, A K Biswas & M R Sudharshan

Experiments were conducted in large cardamom (*Amomum subulatum* Roxb.) nursery using bioagents and chemicals to produce healthy planting materials free from blight caused by *Colletotrichum gloeosporioides* (Penz.) Sacc. The results indicated that selection of apparently disease-free mother plants and treating the rhizome and pseudostem (planting unit) with carbendazim + mancozeb (0.3%) or copper oxychloride (0.3%) would help in reducing the disease incidence in the nursery. Since Sikkim is an organic state, use of copper oxychloride can be recommended.

Prevalence of insect pests in large cardamom (*Amomum subulatum* Roxb.) and evaluation of bio-rationals for the management of major pests under organic agro-ecosystem of Sikkim. 30 (1): 42-49 (2021)

C Raj, S Singh, H Kalita, R K Avasthe, R Gopi, M Singh, C Kapoor, R Kumar & N J Singh

Large cardamom (*Amomum subulatum* Roxb.) is one of the important cash crops of Sikkim and Darjeeling areas of West Bengal. In this study, a fixed plot survey on insect pests of large cardamom was conducted and found that stem borer (*Glyphipterix* spp., Lepidoptera: Glyphiperidae), shoot fly (*Merochlotops dimorphus* Cherian, Diptera: Chlororpidae), leaf eating caterpillar (*Artona chorista* Jordon, Lepidoptera: Zygaenidae) and tea mosquito bug (*Helopeltis theivora* Waterhouse, Hemiptera: Miridae) are the major pests of the crop. Eco-friendly organic treatments like neem-based oil, petroleum-derived horticultural oil, spinosad and different formulations of entomopathogens were tested against these major insects. Among all, application of spinosad 45 SC @ 0.3 ml L^{-1} was found effective followed by neem-based oil (Azadirachtin 0.15% EC) 1500 ppm @ 3 ml L^{-1} at three different time intervals (first application in February-March, second application in June-July and third application in October-November) against all insects. Moreover, entomopathogenic bio-control agents (*Bacillus thuringiensis* @ 2 ml L^{-1}, *Metarhizium*

anisopliae @ 5 ml L^{-1} and *Beauveria bassiana* @ 5 ml L^{-1}) were on par with neem-based oil for the management of stem borer. Considering the economic importance of the crop and absence of valid technology for management of insect pests in large cardamom through organic options, application of either of them could be helpful in organic management of insect pests in Sikkim.

Report on association of plant parasitic nematodes in large cardamom (*Amomum subulatum* Roxb.) at Sikkim, Himalaya region of India. 32 (1): 94-97 (2023)

S S Bora, Debanand Das, Binita Basumatary, D Ajay, T N Deka, S L Bhutia, L O Pakhrin & A B Remashree

Large cardamom (*Amomum subulatum* Roxb.), is a major cash crop grown in Sikkim Himalaya region. The crop is found to be affected by many pests (insects and diseases); which hinders the production, productivity as well as quality of the produce. Based on symptoms in this crop, similar to nematode infestation, soil and root samples were collected from the rhizosphere of different large cardamom fields and analyzed for presence of nematodes. Laboratory analysis revealed the association of six nematode species with large cardamom *viz*., *Meloidogyne incognita*, *Helicotylenchus* spp., *Hoplolaimus* sp., *Tylenchorhynchus annulatus*, *Pratylenchus* sp. and *Macroposthonia* spp., of which *Meloidogyne incognita* and *Pratylenchus* sp. were recorded in roots also and the percentage of occurrence was 59.09. Apart from *Meloidogyne incognita*, all other five nematode species were recorded for the first time in large cardamom. *Helicotylenchus* spp. was the dominant genera among the six genera with 50% occurrence, 61.56% relative abundance and 60 nematodes per 200 cc soil.

GINGER

Crop Improvement and Biotechnology

Induced tetraploids of ginger (*Zingiber officinale* Rosc.). 1 (1): 39-42 (1992)
K Ramachandran & P N Chandrasekharan Nair
Autotetraploids were produced in a clone of ginger by treating sprouting buds on the rhizome with 0.25% colchicine solution. The tetraploid was more vigorous in growth, had larger rhizomes and high yield. Oil content of rhizomes, however, was lower in the tetraploid than in the original diploid cultivar.

Direct regeneration of plantlets from immature inflorescence of ginger (*Zingiber officinale* Rosc.) by tissue culture. 1 (1): 43-48 (1992)
K Nirmal Babu, K Samsudeen & P N Ravindran
Immature inflorescences of ginger when cultured on MS revised medium supplemented with 10 mg l^{-1} BA and 0.2 mg l^{-1} 2,4-D resulted in the conversion of floral buds into vegetative buds and these later developed into plantlets directly without intervening callus phase. About 38% of the buds produced multiple shoots ranging from 5-25. When individual flowers were cultured separately on the same medium plantlets developed from the ovary in 45% of cases. These plantlets were made to develop good root system on MS medium with 1 mg l^{-1} NAA. These rooted plantlets established easily in the soil. In some of the cultures the ovaries developed into fruits.

***In vitro* formation of roots and rhizomes from anther explants of ginger (*Zingiber officinale* Rosc.). 1 (1): 72-74 (1992)**
K Ramachandran & P N Chandrasekharan Nair
Anther explants produced callus and profuse roots when cultured in a modified MS Medium containing 2,4-D, and coconut milk and incubated in darkness.

Cytological studies on diploid and autotetraploid ginger (*Zingiber officinale* Rosc.). 1 (2): 125-130 (1992)
K Ramachandran & P N Chandrasekharan Nair
Cytology of diploid and induced autotetraploid of ginger (*Zingiber officinale* Rosc.) was studied. The diploid (2n=22) showed one or two associations of four chromosomes at first metaphase. The tetraploid formed a high frequency of quadrivalents at first metaphase. Both showed bridge-fragment configurations at first anaphase. Pollen fertility was 13% in the diploid and 85% in the tetraploid.

Yield and quality of ginger (*Zingiber officinale* Rosc.) varieties grown in Assam. 1 (2): 131-135 (1992)
L Saikia & A Shadeque
Twenty indigenous and exotic varieties of ginger were evaluated for yield and quality. Significant variations in yield were observed among the varieties. Nadia yielded the highest (67.0 q/ha fresh ginger) followed by Chekerella (57.0 q/ha). Growth attributes like leaves per clump, tillers per clump and shoot height were positively correlated with yield. Moran, Jorhat hard, Thinladium and Wynad were fibrous. Moran and Jorhat hard yielded higher volatile oil and acetone extract. The fibrous varieties Moran and Jorhat hard were suitable for extraction of oleoresin and volatile oil.

Genetic variability, character association and path analysis for yield components in ginger (*Zingiber officinale* Rosc.). 2 (1&2): 16-20 (1993)
G Pandey & V K Dobhal
Twenty nine collections of ginger (*Zingiber officinale*) were studied for variability, character association and path analysis for yield and its 10 component characters. Wide range of variability was observed for most of the characters studied. Rhizome yield per plant was positively associated with plant height, number of fingers per plant, weight of fingers and weight of primary rhizome. Plant analysis revealed that weight of fingers, width of fingers and leaf width were the strongest forces influencing yield.

A note on a ginger (*Zingiber officinale* Rosc.) type collected from Western Ghats, South India. 4 (2): 160-161 (1995)
B Sasikumar, K Johnson George & T John Zachariah
Even though South East Asia is considered to be the centre of origin of ginger (*Zingiber officinale* Rosc.) (Bailey 1949), there are very few reports of ginger occurring in the wild state. Fisher (1921) recorded that ginger was seen apparently in wild conditions in the Anamalais at about 2300 ft elevation. Muralidharan and Velayudhan (1983) also indicated the possibility of ginger growing as a component of natural vegetation in pockets of Western Ghats at higher altitudes.

IISR Varada - A new high yielding ginger (*Zingiber officinale* Rosc.) variety. 5 (1): 34-40 (1996)
B Sasikumar, Johnson K George & P N Ravindran
IISR Varada (Acc. 64) developed at the Indian Institute of Spices Research, Calicut and recommended for release by the All India Coordinated Research Project on Spices, is a good quality, high yielding, ginger (*Zingiber officinale*) variety developed through germplasm selection. Maturing in 200 days, the variety has an average yield of 22.66 t/ha (fresh), low fibre and dry recovery of 20.7 per cent. The dry ginger of this variety is less prone to storage insect damage.

Embryogenesis and plant regeneration from ovary derived callus cultures of ginger (*Zingiber officinale* Rosc.). 5 (2): 134-138 (1996)
K Nirmal Babu, K Samsudeen, M J Ratnambal & P N Ravindran
Ovary explants from 1-2 week old flowers of ginger (*Zingiber officinale*) developed profuse callus in Murashige and Skoog medium supplemented either with 2,4-dichlorophenoxyacetic acid (1 mg l^{-1}) alone or with 2,4-dichlorophenoxyacetic acid (0.5 mg l^{-1}) and benzyladenine (1 mg l^{-1}). The callus later turned embryogenic and produced white globular embryoid like structures when cultured on modified Murashige and Skoog medium supplemented with benzyl adenine (10 mg l^{-1}) and 2,4-dichlorophenoxyacetic acid (0.2 mg l^{-1}). The embroyoid formation was more pronounced when growth regulators were removed from the culture medium after initial embryogenesis. Some of the embryoids developed into complete

plantlets. The primary embryoids directly produced secondary embryoids in subsequent cultures on growth regulator free medium. The individual embryoids developed into plantlets with better rooting when α-naphthalene acetic acid (1 mgl^{-1}) was added to the culture medium. About 80 per cent of these plantlets were established in soil.

Genetic variability in ginger (*Zingiber officinale* Rosc.). 8 (1): 81-83 (1999)
R K Yadav
The coefficient of variation, heritability and expected genetic advance for 18 important horticultural traits was estimated in 26 accessions of ginger (*Zingiber officinale*) at Raigarh District, Madhya Pradesh. The genotypic coefficient of variation was high for length and weight of secondary rhizome, weight of primary rhizome, number of secondary and primary rhizomes and rhizome yield per plant. High heritability coupled with high genetic advance as percentage of mean was observed for plant height, leaf length, suckers per plant, number of mother and secondary rhizomes, weight of primary rhizome and rhizome yield per plant indicating that desirable improvement in these traits can be brought about through straight selection.

Development of oil cells and ducts in ginger (*Zingiber officinale* Rosc.). 8 (2): 163-170 (1999)
A B Remashree, K Unnikrishnan & P N Ravindran
The development, distribution and structure of oil cells, development of secretory ducts and diffusion of oil in ginger rhizomes (*Zingiber officinale*) were studied. Oil cell differentiation initiate from a group of meristematic cells before the development of primary vascular tissue. Oil cells are present in leaf, shoot apex, root apex and are more or less spherical and contain stored volatile oil. The number of oil cells is higher in the apical and nodal regions than in the internodal region and the size of oil cells is dependent on their number. Secretory ducts develops schizogenously and lysigenously. The former type is present in the primary tissues while the latter type is found throughout the developmental stages.

Genetic diversity in ginger (*Zingiber officinale* Rosc.) with reference to essential oil content. 9 (2): 161-164 (2000)
P P Singh, V B Singh, H P Singh & S Rajan
D^2 analysis was carried out on a set of 18 genotypes of ginger (*Zingiber officinale*) involving 8 metric traits, at Nagaland, India. The genotypes could be grouped into three clusters and while inter cluster D^2 values ranged from 338.99 to 2029.63, intra cluster D^2 values ranged from 18.41 to 45.05. The major forces for divergence were rhizome yield per plant, oleoresin and fibre contents.

Stability analysis of ginger (*Zingiber officinale* Rosc.) genotypes. 9 (2): 165-167 (2000)
T P Manomohan Das, T Pradeepkumar, P Mayadevi, K C Aipe & K Kumaran
Ten genotypes of ginger (*Zingiber officinale*) were subjected to stability analysis based on their evaluation for 6 years at Regional Agricultural Research Station, Ambalavayal (Kerala, India). All the genotypes differed significantly for tiller number, leaf number and yield. Stability analysis revealed the superiority of Ernadan and Kuruppampady as they expressed high mean yield, non-significant S^2di values and a regression nearing unity.

IISR Mahima and IISR Rejatha - Two high-yielding and high-quality ginger (*Zingiber officinale* Rosc.) varieties. 12 (1): 34-37 (2003)
B Sasikumar, K V Saji, Alice Antony, Johnson K George, T John Zachariah & S J Eapen
IISR Mahima (Acc. 117) and IISR Rejatha (Acc. 35), developed through selection from germplasm at the Indian Institute of Spices Research, Calicut are good quality, high yielding ginger varieties. Maturing in 200 days, IISR Mahima has given an average yield of 23.2 t ha^{-1} (fresh) with a dry recovery of 23%, essential oil 1.72%, oleoresin 4.48% and fibre content 3.26%. Rhizomes of Mahima are bold and this variety is resistant to root-knot nematode also. IISR Rejatha is a medium duration, bold variety with an average yield of 22.4 t ha^{-1} (fresh), dry recovery 19%, essential oil 2.36%, oleoresin 6.34% and fibre content 4.0%.

Correlation and path analysis in ginger (*Zingiber officinale* Rosc.). 12 (2): 187-189 (2003)
Z Abraham & M Latha
Twelve morphological characters recorded from 40 genotypes of ginger were subjected to correlation and path analysis. The results revealed that all characters studied have positive correlation with yield and direct selection based on leaflet number, rhizome length and thickness of secondary rhizome could help to improve the yield. The lowest residual effect indicates the optimistic nature of the characters taken for the study.

Diversity of ginger cultivation in India - A GIS study. 15 (2): 93-99 (2006)
P Utpala, A K Johny, V A Parthasarathy, K Jayarajan & M S Madan
The climatic conditions of important ginger (*Zingiber officinale*) growing states of India wereanalysed with the help of Geographic Information System (GIS). The Eco-crop model of DIVA-GIS indicated that Orissa, West Bengal, north eastern States and Kerala are environmentally most suitable for ginger cultivation.

Identification of suitable areas and effect of climate change on ginger - A GIS study. 17 (2): 61-68 (2008)
Utpala Parthasarathy, K Jayarajan, A K Johny & V A Parthasarathy
Secondary data on the area, production, and productivity of ginger over the past three decades reveal a consistent increasing trend. However, the increase in area is not always proportional to the increase in production. A comparison of 30 years area and production data from key ginger-growing states with the Eco-crop suitability model demonstrated that suitability directly influences production. States such as Orissa, West Bengal, Mizoram, and Kerala are classified as highly suitable, while northwestern states like Gujarat, Rajasthan, Uttar Pradesh, and Madhya Pradesh are marginally suitable or unsuitable. Northeastern and southwestern states are identified as highly suitable for ginger cultivation. The Eco-crop model's future predictions indicate that a temperature rise of 1.5 to 2°C could significantly reduce the suitability of Orissa and West Bengal from

highly suitable to marginally suitable, highlighting the impact of climate change.

Molecular characterization of primitive, elite, and exotic ginger genotypes to protect the biowealth of elite ginger accessions. 17 (2): 85-90 (2008)
Jithin Prem, Jaleel Kizhakkayil, Elizabeth Thomas, K Dhanya, S Syamkumar & B Sasikumar
Molecular fingerprints of elite, exotic, and primitive ginger genotypes were developed using RAPD and ISSR markers to characterize and conserve these accessions. Out of 30 molecular markers studied, 13 effectively discriminated the genotypes. Cluster analysis using UPGMA dendrogram classified the ginger genotypes into four distinct groups. The clustering of elite genotypes with putative wild types suggests a phylogenetic relationship between the putative wild types and modern cultivars. An exotic ginger type from Japan, resembling putative types in rhizome features, exhibited high similarity with four indigenous putative types.

Ginger (*Zingiber officinale* Rosc.) germplasm evaluation for yield and quality in southern West Bengal. 22 (1): 88-90 (2013)
T Chongtham, R Chatterjee, V Hnamte, P K Chattopadhyay & S A Khan
The experiment was conducted to assess ginger (*Zingiber officinale*) germplasm for yield and quality at Nadia (West Bengal). The experiment with 10 treatments was laid out in a Randomized Block Design with three replications. Ginger germplasm namely Suprabha, Suruchi, Suravi, V3S1-8, Himgiri, IISR Varada, IISR Mahima, IISR Rejatha, Gorubathan (local *cv.*) and Sambuk (local *cv.*) were selected for the study. The investigation indicated Gorubathan as the most promising germplasm in terms of growth and yield. The yield attributes like length of primary fingers (2.28 cm), diameter of secondary fingers (1.95 cm), rhizome yield plant^{-1} (0.201 kg) were highest with Gorubathan. The projected fresh yield was maximum (18.27 t ha^{-1}) in Gorubathan but dry recovery was maximum with Sambuk (33.48%) and maximum oleoresin was with Suravi (10.25%).

Evaluation of ginger (*Zingiber officinale* Rosc.) varieties in high altitude and tribal zone of Srikakulam district of Andhra Pradesh. 23 (2): 258-261 (2014)
R Rajyalakshmi & K Umajyothi
The yield performance and simple association between yield and its components were studied in eight varieties of ginger during *kharif* 2007 and 2008. The variety *Suprabha* was taller and recorded more number of leaves, tillers plant^{-1} and number of finger rhizomes plant^{-1}. It produced significantly more fresh rhizome yield of 21.71 t ha^{-1} than all the other the varieties tested. Among the varieties *Chintapalli local* produced more number of mother rhizomes plant^{-1}. Number of tillers plant^{-1}, number of mother and finger rhizomes plant^{-1} and fresh rhizome yield showed high GCV, PCV, heritability and genetic advance as per cent mean. The simple correlation studies indicated that number of tillers plant^{-1}, number of mother and finger rhizomes plant^{-1} recorded highly significant association with yield.

Yield attributes and yield in somaclones of ginger (*Zingiber officinale* Rosc.). 25 (1): 49-55 (2016)
A Dev, A Kurian & M A Sankar
Twenty five somaclones derived from two induced polyploids (Z-0-78 and Z-0-86) and diploid cultivar 'Himachal Pradesh' were field evaluated and subjected to yield and yield attribute analyses. Somaclones were highly variable in the yield and yield attributes. Extent of variation was more in somaclones when compared to check varieties (Karthika and IISR-Varada) rather than parent cultivars (Z-0-78, Z-0-86 and HP). Somaclones derived from Z-0-86 recorded superiority in rhizome characters over those derived from 'Himachal Pradesh' and Z-0-78. About 92% of somaclones showed higher yield over parent cultivars while 84% of somaclones showed higher rhizome yield over check varieties. Somaclones derived from Z-0-86 alone recorded higher driage and dry yield.

Yield and quality evaluation of ginger (*Zingiber officinale* Rosc) genotypes under high rainfall zone of Tamil Nadu. 26 (2): 135-140 (2017)
R Balakumbahan & J P Joshua
An experiment on ginger was undertaken with an objective to identify suitable ginger cultivar or accession with higher yield and quality attributes suitable for high rainfall zone of Tamil Nadu. Twenty four ginger genotypes, local strains and varieties were collected from different ginger growing tracts of India and evaluated for their performance in high rainfall region. Among the twenty four genotypes tested, the accession Z. O-4 recorded higher fresh rhizome yield (22.16 ha^{-1}) than other genotypes whereas Z. O-6 recorded highest dry recovery per cent (22.47%). Higher oleoresin and fibre content was recorded in genotypes Z. O-5 (9.56%) and Z. O-17 (11.20%) respectively.

Crop Production and Postharvest Technology

Influence of decreasing minisett weight and intra-row spacing on the coated ginger cv. Taffin-giwa. 1(1): 59-64 (1992)
P A Okwuowulu
The influence of varying minisett weights, intra-row spacing, sites and weather on yield of the ginger cv. Taffin giwa is discussed. Yield of fresh ginger at increasing minisett weights has the same effects as decreasing intra-row spacing, both factors inversely related to seed harvest multiplication ratio. Off-shoots (seed pieces= s3 g) are potential setts. Using reduced minisetts stimulates complete harnessing of food reserve in mother setts during crop growth. The level of sunshine and heat radiation during crop growth and drastic/erratic changes in ambient soil temperature in the tuberous stem deposition zone cause significant (< 30%) yield losses.

Ginger (*Zingiber officinale* Rosc.) in South Eastern Nigeria. II. The field response of the uncoated ginger Yatsun-biri for rapid seed ginger production. 3 (1): 1-5 (1994)
P A Okwuowulu
Sett weights (9, 7, 5 and 3 g) were assessed for rapid seed ginger (*Zingiber officinale*) multiplication at varying intra-rows (20, 15 and 10 cm) at two locations in South Eastern Nigeria. Establishment counts increased with larger setts but sowing off-sized setts (~ 3 g) offers potential for rapid seed harvest and multiplication ratio. Close planting (10 cm within-row spacing) and larger setts produced significantly higher yields of rhizomes but not seed harvest multiplication ratio.

Yield and quality of ginger (*Zingiber officinale* Rosc.) grown in Nagaland, India. 6 (1): 43-47 (1997)
P B Kanjilal, M N Sarma, I H Siddque, R Kotoky, M G Pathak & R S Singh
Multilocational trials conducted at Nagaland, India, in ginger (*Zingiber officinale*) indicated significant differences in growth characteristics and yield components among the cultivars at various locations. The yield was very low (4.8-9.3 t/ha) and fibre content high (6.7-9.6%) at all locations. Yield and quality of ginger grown in Wokha, Mon, Mokokchang and Tuensang districts were superior to the ginger from other districts of Nagaland.

Biochemical variability in selected ginger (*Zingiber officinale* Rosc.) germplasm accessions. 6 (2): 119-127 (1997)
A Shamina, T John Zachariah, B Sasikumar & Johnson K George
Twenty five accessions of ginger (*Zingiber officinale*) germplasm were studied for variations in total free amino acids, proteins, total phenols and isozymes. Considerable variations were observed for total free amino acids, proteins and total phenols. The variability for the isozyme loci in the population was generally low. Dendrograms were prepared based on the average similarity of the accessions with respect to the isozyme profiles and accessions collected from the same geographical area had a tendency to cluster together.

Mulch requirement of ginger (*Zingiber officinale* Rosc.) under shade. 6 (2): 141-143 (1997)
P Babu & B K Jayachandran
Field experiments conducted at Vellayani (Kerala, India) to study the mulch requirement of ginger (*Zingiber officinale*) under various shade levels indicated that under 25 per cent shade, one-fourth quantity (7.5 t/ha) of green leaf mulch could be saved.

Mixed cropping of ginger (*Zingiber officinale* Rosc.) and maize (*Zea mays* L.). 8 (2): 219-220 (1999)
K Kandiannan, K M Abdulla Koya & K V Peter
The trial indicated that maize can be grown with ginger for grain and fodder or for more returns without affecting crop growth and yield of ginger under Kerala conditions also.

Optimum dose of nitrogen and potassium for ginger in Wynad, Kerala. 10 (1): 7-11 (2001)
T Pradeepkumar, P Mayadevi, K C Aipe, T P Manomohandas, M P Giridharan, K N Satheesan & K Kumaran
Study on nutrient requirement of ginger in Wynad, Kerala showed the positive effect of higher, doses of N and K on the yield. Among the 16 levels of N and K, 3 combinations *viz*., 150 kg N, 50 kg K; 150 kg N, 100 kg K and 75 kg N, 150 kg K ha^{-1} were found to be significantly superior with respect to yield. Among the vegetative characters, plant height was found to be significantly influenced by nitrogen. The optimum dose of N and K derived from the quadratic equation was 144 kg and 109 kg ha^{-1}, respectively.

Effect of mulching on yield of ginger (*Zingiber officinale* Rosc.). 10 (1): 13-16 (2001)
Ram Chandra & Sheo Govind
Field experiments were conducted at Barapani, Meghalaya to evaluate the response of ginger to the application of locally available organic mulches. Five treatments namely, paddy straw mulch, *Schima wallichii* dry leaf mulch, *Eupatorium odoratum* green stem and leaf mulch, *Pinus kesia* dry leaf mulch and unmulched control were compared in the present study. Use of organic mulches enhanced the sprouting,

reduced the dry matter accumulation by weeds and improved the growth and yield of ginger significantly. Paddy straw and *Schima* leaves were superior as these mulches increased the yield by 43.6% and 39.7% over control, respectively.

Effect of major nutrients on yield of ginger (*Zingiber officinale* Rosc.) intercropped in coconut garden. 10 (1): 17-23 (2001)
K Ajithkumar & B K Jayachandran
The effect of different levels of nitrogen, phosphorus and potassium on the yield of ginger (*Zingiber officinale* Rosc.) grown as an intercrop in a coconut garden was studied in a field experiment conducted at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala. Significant increases in leaf production, leaf area index and dry matter production, crop growth rate and uptake of nutrients were resulted from higher dose of fertilizers. Fertilizer recommendation for ginger grown under open condition (N:P:K @ 75:50:50 kg ha^{-1}) is insufficient for ginger intercropped in coconut gardens. A higher fertilizer dose of N:P:K @ 150:100:100 kg ha^{-1} is necessary for increasing the yield of ginger grown as an intercrop in coconut garden.

Influence of shade regimes on the photosynthetic rate and stomatal characters of ginger. 11 (1): 26-29 (2002)
K Ajithkumar, B K Jayachandran & V Ravi
The study conducted on the influence of shade regimes on photosynthetic rate and stomatal characters of ginger (*Zingiber officinale* R.) indicated that the highest photosynthetic rate was in plants grown under open condition followed by plants grown at 20 and 40 per cent shade levels. Regression coefficient analysis demonstrated that photosynthetic rate, stomatal conductance, transpiration rate, stomatal index and stomatal frequency significantly reduced linearly with increasing level of shade, whereas stomatal resistance increased linearly with increasing level of shade. The enhanced rhizome yield under low levels of shade (20 and 40 per cent) compared to open condition (where photosynthetic rate was maximum) may be mainly due to the higher leaf area resulted in the plants grown under 20 and 40 per cent shade levels.

Influence of shade regimes on the physiological parameters of ginger (*Zingiber officinale* Rosc.). 11 (1): 30-34 (2002)
G S Sreekala & B K Jayachandran

A study was carried out at College of Agriculture, Vellayani to determine the relation of various physiological parameters on the yield of ginger under different shade levels. The experimental design was a completely randomized design with five treatments (0, 20, 40, 60 and 80 per cent shade levels) and four replications. Higher dry matter production (DMP), leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR) were observed in low shade level (20 per cent). The higher yield at this shade level may be due to the higher values of these physiological parameters. The results suggest a positive response of shade on the physiological parameters and yield of ginger, provided the intensity of shade is low. Regression equation fitted showed the influence of shade on DMP, NAR and yield, while no significant relation was observed with regard to LAI.

Influence of shade regimes on yield and quality of ginger (*Zingiber officinale* Rosc.). 12 (1): 29-33 (2003)
K Ajithkumar & B K Jayachandran

The effect of different levels of shade on yield and quality of ginger (*Zingiber officinale* Rosc.) was studied during two seasons at Coconut Research Station, Thiruvananthapuram, Kerala Agricultural University, Kerala. The shade levels 20 and 40 per cent were favourable for obtaining higher dry ginger yield. Volatile oil content showed an increasing trend with increasing levels of shade. Maximum NVEE was recorded in the plants grown under 20 and 40 per cent shade levels. Higher starch content was observed in plants grown under 20 per cent shade level. Crude fibre content gradually reduced as the intensity of shade increased. The results indicate the possibility of utilizing existing shaded situations in coconut gardens and under other perennial crops for the production of ginger.

Response of ginger (*Zingiber officinale*) to methods of planting and levels of phosphorus in a rehabilitated forest developed on sodic land. 12 (1): 63-66 (2003)
Ajai Singh, Bajrang Singh, Achal Singh & Pushpendra Singh
Experiments were conducted during 1999 and 2000 at Banthra Research Station of NBRI, Lucknow (UP) to standardize agro-techniques of ginger cultivation in forest gaps. The response of three methods of planting and three levels of phosphorus was studied, which revealed that the flat bed followed by earthing and application of P_20_5 50 kg ha^{-1} recorded the maximum growth and yield (7.88 t ha^{-1}). These treatments also influenced the bio-chemical composition positively showing greatest values of crude protein (9%), crude fibre (5.15%) and volatile oil (1.45%). The study showed a modest potential of ginger cultivation in a semi-reclaimed sodic soils through afforestations.

Threshold level of soil zinc for optimum production of ginger (*Zingiber officinale* Rosc.). 13 (1): 55-57 (2004)
V Srinivasan, S Hamza, K S Krishnamurthy & C K Thankamani
A field experiment was conducted at Peruvannamuzhi (Kerala), for two years to evaluate the optimum level of zinc (Zn) content in soils for maximizing production of ginger (*Zingiber officinale*) on an *Ustic Humitropept* with varying levels of Zn fertilizer. The mean rhizome yield of two years was higher in plots where Zn @ 5 kg ha^{-1} was applied. A cubic model described satisfactorily the relationship between mean rhizome yield and fertilizer application rate. The optimum fertilizer dose for obtaining maximum rhizome yield was determined as 6 kg ha^{-1} of Zn. The maximum limit of soil DTPA-Zn for obtaining higher rhizome yield was 3.4 mg kg^{-1}.

Influence of nitrogen, *Azospirillum* sp. and farm yard manure on the yield, rhizome rot and quality of ginger (*Zingiber officinale* Rosc.). 17 (2): 177-179 (2008)
D K Dash, N C Mishra & B K Sahoo
The influence of nitrogen fertilizer, *Azospirillum* sp., farm yard manure and their combinations on ginger (*Zingiber officinale* Rosc) was studied at Pottangi (Orissa). The highest fresh rhizome yield (18.70

q/ha), lowest rhizome rot (11%) and quality ginger (5.82% oleoresin content) with B:C ratio of 2:4 could be obtained in recommended dose of fertilizers 100% combined with *Azospirillum* sp. 10 kg/ha and FYM 10 t/ha. *Azospirillum* has a prominent role in increasing productivity and quality of ginger while reducing the most challenging disease i.e. the rhizome rot of ginger. In some situations, inorganic N level can be reduced to 30% level in presence of bio-fertilizers to obtain economic return. In all organic farming situations, addition of *Azospirillum* to package of practices will enhance the production of ginger.

Physical and biochemical parameters of fresh and dry ginger (*Zingiber officinale* Roscoe). 20 (1): 14-21 (2011)
E Jayashree & R Visvanathan

The physical and biochemical properties of fresh and dry ginger (*Zingiber officinale*) (cv: Himachal) obtained from Nemmara (Palakkad District, Kerala), useful for the design of processing machineries, were determined. The average moisture content of fresh and dry rhizomes were 81.70% and 8.85%, respectively. The average length, width and thickness of fresh rhizome were 14.99 cm, 8.17 cm and 4.49 cm, respectively and the corresponding values for dry rhizome were 9.74 cm, 5.56 cm and 4.49 cm. The mean values of cylindricity for primary, secondary and tertiary finger rhizomes were 0.46, 0.51 and 0.56, respectively and the corresponding values for dry finger rhizomes were 0.48, 0.53 and 0.58. The average mass, volume and surface area of fresh rhizomes were 103.45 g, 85.0 cm^3 and 194.52 cm^2, respectively and the corresponding values for dry rhizomes were 31.62 g, 22.10 cm3 and 65.84 cm^2. The bulk density, true density and porosity for fresh rhizomes were determined as 471.49 kg m^{-3}, 1107.01 kg m^{-3} and 66.80%, respectively, and for dry rhizomes the values were 460.09 kg m^{-3}, 1013.22 kg m^{-3} and 54.09%. The angle of repose increased from 34.6° to 39.5° after drying. Mild steel surface offered more frictional resistance than other surfaces and the coefficient of friction for fresh and dry ginger against mild steel was 0.74 and 0.54, respectively. The average meat: peel ratio of the whole fresh rhizome was 10.7:1. The average recovery of dry ginger was 23.01%. The dry ginger obtained had 1.6% essential oil, 3.5% oleoresin and 2.7% crude fibre.

Mechanical and thermal properties of ginger (*Zingiber officinale* Rosc.). 20 (2): 60-65 (2011)
E Jayashree & R Visvanathan
Mechanical properties of fresh and stored (under ambient conditions for 2 months) ginger rhizomes (*Zingiber officinale*) (cv. Himachal) necessary for the design of processing machineries, were determined. Thermal properties were determined for fresh and dry ginger. Mechanical properties like peel penetration force for primary, secondary and tertiary finger rhizomes increased from 0.45 N, 0.52 N and 0.51 N to 0.60 N, 0.70 N and 0.65 N, respectively; the peel compressive force at rupture increased from 20.12 N, 19.86 N and 17.56 N to 22.58 N, 21.21 N and 19.67 N, respectively, and the cutting force required to penetrate through peel increased from 31.56 N, 27.68 N and 26.57 N to 32.71 N, 28.93 N and 28.16 N, respectively, in fresh and stored ginger rhizomes. Thermal properties like specific heat, thermal conductivity and thermal diffusivity for fresh ginger were 3566.87 J kg^{-1} K^{-1}, 0.2916 W m^{-1} K^{-1} and 0.8609 x 10^{-7} m^2 s^{-1} and the corresponding values for dry ginger at 10% moisture content were 1918.81 J kg^{-1} K^{-1}, 0.0760 W m^{-1} K^{-1} and 1.7339 x 10^{-7} m^2 s^{-1}, respectively.

Characterization of polyphenol oxidase in ginger (*Zingiber officinale* R.). 21 (1): 33-41 (2012)
Ancy Joseph, B Thayumanavan & Pournami R Panicker
A polyphenol oxidase (PPO) isoform that showed expression at all developmental stages of rhizomes in 13 ginger (*Zingiber officinale* R.) accessions and the only one observed at full maturity of rhizome was characterized. The isoform is a non-covalent homo-dimeric protein of 66 kDa subunits. The native molecular mass was estimated at ~127 kDa using non- reducing SDS-PAGE (10%). Its activity after purification was confirmed by substrate staining both in native gel (7%) and non-reducing SDS gel (10%). The N-terminal amino acid sequence of the subunit of ginger rhizome polyphenol oxidase is 'Glu-Gln-Gly-Val-Gly-Gly-Asp-Asp-Gly-Leu-.' The enzyme showed maximum activity at pH 4.5 and 60°C. The PPO is thermo-tolerant and active in a broad pH range (pH 3.5 to 8). Heat inactivation studies showed a decrease in enzyme activity at 75°C and above. Lower

concentrations of $MgCl_2$ (1 mM) and $CaCl_2$ (0.5 mM) activated the enzyme whereas higher concentrations (10 mM) reduced the activity. L-Cysteine HCl, L-ascorbic acid, potassium metabisulfite and NaCl inhibited PPO strongly. Western blot analysis of crude leaf extracts with polyclonal antiserum raised against purified PPO confirmed absence of its expression in leaves at different stages of development. Polyclonal anti-PPO antiserum cross reacted with *Solanum tuberosum*, *Raphanus sativus* and *Dioscorea esculenta* tuber extracts and *Solanum melongena*, *Malus sylvestris* and *Musa paradisiaca* fruit extracts but no cross reactivity was observed with *Curcuma amada* and *Ipomoea batatas* extracts.

Mathematical modelling for thin layer sun drying of ginger (*Zingiber officinale* Rosc.). 22 (1): 24-30 (2013)
E Jayashree & R Visvanathan

Trials on drying of ginger were conducted during the month of April, 2009 at Agricultural Engineering College and Research Institute, Coimbatore (Tamil Nadu). Ginger rhizomes were mechanically washed, partially peeled, spread in single layer on cemented yard and dried from initial moisture of 594.01% (d.b.) (dry basis) to a final moisture content value of 9.82% (d.b.). Drying of ginger was completed in eight days. Drying characteristics curves, showed no constant rate period and all the drying process occurred in the falling rate period. Thin layer modeling of drying data showed that diffusion approximation model best described the drying process. The effective moisture diffusivity for drying of ginger was calculated as 1.91×10^{-7} $m^2 s^{-1}$. Sun dried ginger rhizomes were evaluated for its quality and it was found that the essential oil, oleoresin, moisture and crude fibre contents were 2.0%, 4.6%, 9.82% and 2.5%, respectively.

Influence of zinc on yield and quality profile of ginger (*Zingiber officinale* Rosc.). 22 (1): 91-94 (2013)
S Hamza, N K Leela, V Srinivasan, C R Nileena & R Dinesh

Field experiments were conducted for three consecutive years (2008-09, 2009-10, 2010-11) in a Zn deficient soil to study the variation in quality and oil composition of ginger due to incorporation of Zn in the fertilizer schedule. The treatments consisted of recommended

package of practice (POP) without zinc, POP + 5 kg Zn ha^{-1}, POP + 10 kg Zn ha^{-1} as zinc sulphate. The results showed that application of Zn increased the fresh yield of ginger from 7.72 to 9.57 $kg^3 m^{-2}$ indicating an increase of 23%. Zinc application also increased the oil, oleoresin, β-sesquiphellandrene, farnesene, camphene and Z-citral contents of ginger oil. Contrarily, Zn application decreased zingiberene, α-pinene, α-curcumene and 1, 8 cineol contents of ginger oil. The quality components such as fiber content varied from 3.05% to 3.43%, oil content from 1.33% to 1.73%, oleoresin from 3.35% to 5.41%, zingiberene from 13.1% to 21.8%, α-pinene from 0.67% to 2.23%, β-sesquiphellandrene from 5.92% to 10.20%, farnesene from 5.58% to 11.1%, camphene from 3.06% to 5.36%, Z-citral from 3.73% to 6.54%, α-curcumene from 5.32% to 7.70%, 1,8 cineol from 2.70% to 5.29%, β-phellandrene from 1.87% to 4.18% and citral contents from 5.03% to 6.54%.Keywords: ginger, ginger quality, zinc deficiency, zinc nutrition.

Development of a hand-operated diamond cut mesh drum abrasive ginger peeler. 22 (2): 174-180 (2013)
E Jayashree & R Visvanathan

Peeling of fresh ginger is an important operation done before drying to enhance the drying process and is generally done manually. A mechanical ginger peeler was developed with its peeling drum made of diamond cut mesh. Peeling trials were conducted for varying drum loads (5 kg, 6 kg and 7 kg), for varying drum speeds (20 rpm, 25 rpm and 30 rpm) and for different peeling durations (5 m, 10 m and 15 m) to determine the peeling efficiency and material loss in the developed peeler. It was found that peeling of ginger was associated with the material loss. The optimum machine parameters for maximum peeling with minimum loss was obtained at a drum load of 7 kg per batch, operated at a drum speed of 30 rpm for a peeling duration of 15 min, to produce sufficiently peeled ginger. The peeling efficiency and material loss at the optimum conditions were determined as 59.43% and 4.76%, respectively. The ginger obtained after mechanical peeling was dried and the quality was determined. It was found to have essential oil of 2.0%, oleoresin of 4.6%, moisture content of 9.82% and crude fibre content of 2.5%.

Effect of dates of planting and spacing on growth and yield characteristics of ginger (*Zingiber officinale* Rosc.) var. IISR Mahima. 22 (2): 209-214 (2013)

A R Yadav, R N Nawale, G N Korake & R G Khandekar

A field trial was carried out with an objective to determine the optimum date of rhizome planting and spacing to obtain good growth and yield of ginger var. 'IISR Mahima' at Dapoli (Maharashtra). The experiment was laid out in split plot design with planting dates as main plot treatments (15th April, 1st May, 15th May, 30th May and 15th June) and intra row spacing as sub plot treatments (25 cm × 15 cm, 25 cm × 25 cm and 25 cm × 35 cm) in three replications. It is evident from the results that dates of planting had significant effect on almost all the characters under study. Planting of rhizomes on 15th April showed better growth, yield and yield attributing characters. Among spacing levels, the closer spacing of 25 cm × 15 cm recorded significantly higher plant height, green and dry ginger yield. The interaction treatments showed significant effect for most of the characters except for number of days required for sprouting, per cent sprouting and finger characters. Among the various treatment combinations planting on 15th April and 25 cm × 15 cm spacing exhibited higher plant height, yield of green (40.16 t ha^{-1}) and dry ginger (8.58 t ha^{-1}). Planting after 15th May with wider spacing 25 cm × 35 cm resulted in lower yield.

Effect of dates of planting on growth, yield and quality of ginger (*Zingiber officinale* Roscoe). 23 (1): 59-63 (2014)

A R Yadav, R G Khandekar, G N Korake, P M Haldankar & R N Nawale

The trial was carried out during 2008-09 to study the ideal date of planting and spacing to obtain better growth, yield and quality of ginger crop var. 'IISR Mahima'. The experiment was laid out in Split Plot Design with dates of planting as main plot treatment (15th April, 1st May, 15th May, 30th May and 15th June) and three treatments of spacing as sub plot treatment (35 cm × 25 cm, 25 cm × 25 cm and 15 cm × 25 cm) with three replications. The observations were recorded on dry recovery (%), harvest index, oil and crude fibre content. Dates of planting had significant effect on all the characters studied. April

15th planting showed better oil content. Among spacings, the spacing of 35 cm × 25 cm gave highest dry recovery. The closer spacing of 15 cm × 25 cm recorded higher harvest index. It was observed that spacing had no significant effect on quality attributes *viz*., oil and crude fibre content. The treatment combination of 15th April planting and 35 cm × 25 cm spacing exhibited higher dry recovery. The treatment combination of 15th April planting and 15 cm × 25 cm spacing showed maximum harvest index. Economics of interactions revealed maximum net returns of Rs. 5,59,690.1 ha^{-1} with benefit cost (B:C) ratio of 2.67 for the treatment combination of 15th April planting and 15 cm × 25 cm spacing.

Effect of organic manures on the performance of ginger under Northern Dry Zone of Karnataka. 23 (1): 121-124 (2014)
M V Sharath Pal, N K Hegde, S I Hanamashetti & M S Kulkarni
A field trial was conducted to assess the effect of different organic manures on the performance of ginger cv. Humnabad. Higher growth, yield and quality attributes were observed in the treatment receiving FYM (25 t ha^{-1}) along with recommended dose of fertilizer (RDF) (100: 50: 50 kg NPK ha^{-1}) followed by poultry manure (5 t ha^{-1}) along with RDF. Among the treatments, significantly higher fresh rhizome yield was recorded in FYM + RDF (16.52 t ha-1) followed by poultry manure (5 t ha^{-1}) + RDF (16.23 t ha^{-1}) and press mud (10 t ha^{-1}) + RDF (15.47 t ha^{-1}). Net returns per ha ranged between Rs. 1.30 lakh (FYM+RDF) and Rs. 0.48 lakh (Neem cake @ 2 t ha^{-1}).

Quality profile of ginger under different management systems. 23 (1): 125-129 (2014)
C R Nileena, V Srinivasan, S Hamza, N K Leela & C K Thankamani
Field experiments were conducted to find out the variation in yield, and quality profile of ginger under organic, inorganic and integrated management systems for three consecutive years (2007-2009). Ginger varieties, IISR Varada, IISR Mahima and IISR Rejatha were used for the experiment. Results showed that among the treatments, the yield was on par in organic and integrated management system. The oil content was significantly higher in integrated and inorganic management systems and oleoresin in inorganic system. The essential

oil constituents *viz.,* zingiberene, farnesene, α-pinene, citral, 1,8 cineole, z-citral and camphene contents were highest in integrated management system. β-Sesquiphellandrene content was highest under inorganic management and ar-curcumene content was highest under organic management system. Among the three varieties, IISR Mahima recorded significantly higher yield, oleoresin, β-Sesquiphellandrene and ar-curcumene contents. In the case of oil and zingiberene content, there was no significant difference among the varieties. IISR Varada recorded maximum oleoresin, α-pinene, citral, 1,8 cineole, z-citral and camphene content while IISR Rejatha recorded the highest farnesene and ar-curcumene content.

Biennial harvest reduces rhizome multiplication rate and provides no yield advantage in ginger (*Zingiber officinale* Roscoe). 25 (1): 79-83 (2016)

K Kandiannan, D Prasath & B Sasikumar

A study was conducted during 2009-10 and 2010-11 under rainfed condition to observe the sprout emergence, tiller production and yield when the ginger was allowed to grow in the second season/year without harvest in first year/season. First generation ginger was not harvested and allowed to emerge on the same container and harvested in subsequent year in second generation in the month of January 2011. After harvesting, fresh rhizome was cleaned and sorted into first year produce and second year produce based on their appearance and texture and weighed separately, their proportion was estimated and multiplication rate from first generation crop to second generation crop was calculated. The mean shoot emergence and tiller production were five and 19, respectively. Average yield in first, second years and total yield were 209, 566 and 775 g plant^{-1}, respectively. The share between first and second year yield were 27.8 and 72.2%, respectively and mean multiplication rate was 3.5 times. Although, yield levels tend to increase in second season, the multiplication rate was much reduced. Hence, the practice of biennial harvest may not have clear yield advantage over regular annual harvest.

Growth, nutrient uptake, and yield of ginger as impacted by potting media, foliar nutrition, and microbial inoculants. 29 (2): 113-121 (2020)

B Sudha, J John, A V Meera & A Sajeena

Experiments were conducted during 2017-19 at the Integrated Farming System Research Station, Karamana, Kerala Agricultural University for assessing the impact of quantity of potting media, foliar application of multinutrient mixture IISR Power Mix G and microbial inoculants Arbuscular Mycorrhizal Fungi (AMF) and *Trichoderma* on the growth, nutrient uptake and yield of ginger variety Karthika grown as pot culture. The study revealed that 12 and 15 kg of potting media filled grow bags could produce comparable yields of ginger significantly higher than that obtained with 9 kg of potting media. Application of IISR Power Mix G @ 0.5% at 2 and 3 months of planting enhanced the yield of ginger to the tune of 11 per cent in comparison to control. Microbial inoculants AMF (5 g plant^{-1}) and *Trichoderma* (1 kg mixed with 90 kg FYM and 10 kg neem cake and 250 g of the mixture used) applied at planting time followed by *Trichoderma* at 1 month after planting resulted in higher fresh ginger yield of 596.67 g bag^{-1} and was comparable to 550 g of fresh ginger obtained with application of AMF and *Trichoderma* at planting.

Effect of foliar application of micronutrients on ginger productivity. 30 (2): 200-203 (2021)

Nagarajappa Adivappar & M K Naik

Ginger (*Zingiber officinale* Rosc) is cultivated in different agro-climatic zones of Karnataka. Correction of deficiency of nutrients through foliar application of micronutrients is imperative to maintain the growth and development of the crop. Hence, large scale demonstrations were conducted and the impact analysis of crop specific ICAR-Indian Institute of Spices Research, Kozhikode-micronutrient formulation (released as "Ginger Special") on productivity and profitability of ginger in Southern Transitional Zone of Karnataka was carried out during 2016- 19 by involving 429 farmers in an area of 133.20 ha. Foliar application of ginger special (5 gl^{-1}), 45 days after planting up to six months at an interval of 45 days showed significant increase in fresh yield (23.94 t ha^{-1}), higher

returns ha^{-1} (Rs. 9,80,300) and higher BCR (2.89). The test farmers who used ginger special obtained a mean additional fresh yield (2.44 t ha^{-1}), additional return (Rs. 99,500 ha^{-1}) besides providing additional employment to the farm workers (12 ha^{-1}). Use of ginger special, created a good impact on productivity and profitability of ginger cultivation and the technology has spread in an area of 500 ha in Shivamogga district of Karnataka.

Drying kinetics and activation energy for solar drying of ginger slices. 31 (1): 15-24 (2022)
N C Shahi, Deepika Kohli, Pradeep Kumar, Mohit Tamta & Pooja Arya

Drying is one of the oldest and most important preservation method for food in which by reducing the water activity the shelf life can be increased. In the present investigation, fresh ginger was pretreated in calcium oxide solution at different concentrations. Solar drying at three temperature levels *viz*., 55, 65 and 75°C at loading densities of 0.147 g/cm^2, 0.176 g/cm^2, 0.206 g/cm^2 respectively were used for the investigation. Results of study revealed that the total time required for ginger drying in solar dryer curtails with rise in drying air temperature and increased as loading density increased. The activation energy was observed to be 20.45 kJ mol^{-1}, 29.06 kJ mol^{-1} and 17.6 kJ mol^{-1} for 0.147 g/cm^2, 0.176 g/cm^2 and 0.206 g/cm^2 loading density respectively. Also, the diffusivity increased with increase in temperature from 45 to 65°C.

Evaluation of phytochemical and nutritional composition of Boriavi ginger variety. 31 (2): 194-198 (2022)
Hemrajsinh Chhasatiya & Govind Tagalpallewar

The "Boriavi" variety of ginger was evaluated for its phytochemical and nutritional composition. The proximate composition was found to be 86.30 ± 0.11% moisture content (% wet basis), 2.70 ± 0.06% protein content, 0.60 ± 0.01% fat content, 1.30 ± 0.07% fibre content, 1.88 ± 0.02% ash content, and 7.20 ± 0.11% carbohydrate content. The ascorbic acid content was found to be 6.55 ± 0.26 mg per 100 g, antioxidant activity was found to be 86.94 ± 0.16% by DPPH method, and total phenolic content was found to be 41.45 ± 0.17 mg GAE per

100ml. The mineral composition in fresh ginger was also evaluated in which phosphorus (10955 ± 2.00 mg kg^{-1}) was found to be the highest among all minerals.

Crop Protection

Integrated management of root knot nematode in ginger (*Zingiber officinale* Rosc.). 4 (1): 70-73 (1995)
K C Mohanty, S Ray, S N Mohapatra, P R Patnaik & Pratima Ray
Pre-planting application of neem cake (1 t/ha) followed by post-planting application of carbofuran (1 kg ai/ha) 45 days after planting gave the best result in terms of suppression of root knot nematode population, disease intensity and increased yield of ginger (*Zingiber officinale* Rosc.) closely followed by application of carbofuran first followed with neem cake.

Detection of *Ralstonia solanacearum* in ginger rhizomes using post-enrichment NCM-ELISA. 11 (1): 35-40 (2002)
A Kumar, Y R Sarma & S Priou
Bacterial wilt, caused by *Ralstonia solanacearum*, is an important production constraint in ginger. The pathogen is seed rhizome borne and the low level of inoculum is very difficult to be detected and monitored by conventional methods. Pathogen detection and selection of healthy planting material is an important prerequisite for the production of a healthy crop of ginger in the field. In the present work we have evaluated the suitability of NCM-ELISA kit, developed at International Potato Centre (CIP), Lima, Peru, for detecting bacterial wilt pathogen in ginger. The result indicated that the antibodies developed at CIP for potato strain of *R. solanacearum* was sensitive enough to detect *R. solanacearum* from ginger, chilli, *Chromolaena* and tomato. The sensitivity of the kit was determined to be 42 cells per ml of ginger extract when ELISA was performed after enrichment in selective medium. We have also tested the specificity of antibodies and found that the antibodies were specific for *R. solanacearum*. The extraction protocol (citrate buffer at pH 5.6) developed for potato was found to be suitable for ginger also.

Screening of rhizobacterial isolates against soft rot disease of ginger (*Zingiber officinale* Rosc.). 14 (2): 130-136 (2005)
R S Bhai, V K Kishore, A Kumar, M Anandaraj & S J Eapen
Twenty rhizobacterial cultures including *Pseudomonas fluorescens*, *Enterobacter agglomerans* and *Bacillus* sp. were tested under *in vitro* and *in vivo* conditions to evaluate their efficacy in inhibiting *Pythium myriotylum* and reducing the incidence of soft rot disease in ginger (*Zingiber officinale*). Under *in vitro* conditions, 19 of the tested rhizobacterial cultures significantly inhibited *P. myriotylum*. Evaluation of these cultures under *in vivo* conditions indicated that seven of the isolates were effective in suppressing the pathogen. Five of the isolates when inoculated along with *Glomus* sp. (vesicular arbuscular mycorrhizae) also enhanced root development without disease incidence.

Distribution of *Pythium gisiotylum* Drechsler causing soft rot of ginger. 17 (1): 5-10 (2008)
A Kumar, S T Reeja, R Suseela Bhai & K N Shiva
Fourteen of the 29 *Pythium* isolates pathogenic to ginger (*Zingiber officinale*) collected from various parts of India such as Assam, Karnataka, Kerala, Sikkim and Uttar Pradesh were identified as *Pythium myriotylum* based on the size of the species-specific amplicon (150 bp) using the oligo primers Pmy5 and ITS2. The suitability of the primer combination Pmy5 (5'-gTC gCT gTT ATg gCg gAg-3') and ITS2 (5'-gCT gCg TTC TTC ATC gAT gC-3') (Wang *et al*. 2003) at the species level identification of *P. myriotylum* was further confirmed through this study.

PCR-based detection of bacterial wilt pathogen, *Ralstonia solanacearum*, in ginger rhizomes and soil collected from bacterial wilt-affected fields. 17 (2): 109-113 (2008)
A Kumar & S Abraham
A PCR-based method for detecting the bacterial wilt pathogen, *Ralstonia solanacearum*, in ginger rhizomes and soil is described. The pathogen was detected in apparently healthy rhizomes and soil samples collected from fields in endemic areas. This protocol provides

an indexing tool for identifying bacterial wilt pathogens in seed rhizomes and soil. The findings underscore the importance of restricting the movement of rhizomes from endemic regions to non-traditional areas to prevent disease spread.

Field tolerance of ginger (*Zingiber officinale*) genotypes to soft rot under rainfed upland conditions. 17 (2): 202-204 (2008)
A Mishra, S K Mohanty, B Behera & D K Dash
Eleven ginger genotypes were evaluated for their reaction to soft rot and rhizome yield during 2006-07 at the AICRP on Dryland Agriculture, OUAT, Phulbani, Orissa. The trial, arranged in a randomized block design (RBD) with three replications, was conducted under rainfed upland conditions. Soft rot incidence was monitored at 60, 75, 90, and 135 days after planting (DAP). High soft rot incidence (>8%) was observed in ACC-35, ACC-117, and SG-666 at 60 DAP, with severe progression recorded by 135 DAP. Genotypes Suprabha, Phulbani Local, and VIC-8 exhibited minimal soft rot incidence. ACC-117 experienced complete crop failure due to severe soft rot, while VIC-8 recorded the highest rhizome yield (46.27 q ha^{-1}). The yields of Suprabha, VIC-8, and Phulbani Local were statistically at par. Poor genotype performance was attributed to dry weather during the peak growth stage and soft rot incidence.

Morphological variability, mycelial compatibility and fungicidal sensitivity of *Colletotrichum gloeosporioides* causing leaf spot of ginger (*Zingiber officinale* Rosc.). 23 (2): 211-223 (2014)
C N Darshana, R Praveena, S J Ankegowda & C N Biju
Colletotrichum gloeosporioides isolates causing leaf spot of ginger were collected from diverse agroecological regions of Kodagu, Hassan, Shimoga and Chikmagalur districts of Karnataka (KAG 1-6) and Idukki and Wayanad districts of Kerala (KLG 1-3). Diversity analysis of the isolates revealed existence of considerable variability in the field populations of the leaf spot pathogen. Colour of the colony varied from white to dull grey and considerable variation was observed in the growth rate of the isolates. The conidial shapes varied with regions and were cylindrical with tapering ends, cylindrical, elliptical or dumbbell, whereas, most of the isolates belonged to cylindrical

with tapering ends category. The appressoria were either unlobed, single lobed or multilobed. The size of conidia and appressoria ranged from 12.2-18.3 × 6.1-6.9 μM and 9.0-14.8 × 6.2-11.0 μM, respectively. Mycelial compatibility studies among the nine isolates revealed that, the isolate, KLG 3, originating from Kerala was most compatible with other isolates, while KLG 1 and KAG 6 exhibited a highly incompatible reaction. Microscopic observations to study the process involved in compatible reaction showed the aggregation of hyphae at region of contact, fusion of hyphae (formation of 'H'-like structure) and subsequent generation and growth of new hyphae from the point of contact. Among the fungicides tested at recommended dosages, propiconazole was found to be promising followed by carbendazim + mancozeb. The present study indicated that leaf spot caused by *C. gloeosporioides* is emerging as a major foliar disease in the ginger growing tracts.

Effect of storage methods and seed rhizome treatment on the field performance of ginger. 24 (1): 51-55 (2015)
A Shadap, N K Hegde & Y A Lyngdoh

An experiment was conducted to evaluate the effect of different storage methods and seed rhizome treatment on the field performance of ginger var. Humnabad. Four storage methods were selected for the study *viz*., rhizomes kept in sand layers (indoor), 250 gauge polyethylene bag with 0.5% vents (indoor), Zero energy cool chamber (ZECC) either in open condition or in polyethylene bag with 0.5% vents. The seed rhizomes were treated with fungicide *viz*., Ridomil MZ (3 g L^{-1}), biocontrol agent *Trichoderma harzianum* (5 g kg^{-1} seed rhizome) and no seed treatment as the control. Highest germination (98.89%), plant height (52.3 cm), leaf area index (25.75), number of tillers $clump^{-1}$ (19.7), pseudostem girth (3.41 cm) and fresh rhizome yield (22.35 t ha^{-1}) were recorded in rhizome stored in ZECC treated with *T. harzianum* whereas, the rhizome stored in sand layer with no seed treatment recorded the lowest levels of germination (75.56%), plant height (33.6 cm), leaf area index (9.73), number of tillers $clump^{-1}$ (12.6), pseudostem girth (2.32 cm) and fresh rhizome yield (11.84 t ha^{-1}).

Evaluation of insecticides and a natural product for their efficacy against shoot borer (*Conogethes punctiferalis* Guen.) (Lepidoptera: Crambidae) infesting ginger (*Zingiber officinale* Rosc.). 26 (2): 91-94 (2017)

C M Senthil Kumar, T K Jacob & S Devasahayam

Nine insecticides and a natural product were evaluated in the field at Peruvannamuzhi (Kerala) for their efficacy against shoot borer (*Conogethes punctiferalis*), a serious insect pest of ginger (*Zingiber officinale*) for two years. Pooled analysis of two years data indicated that chlorantraniliprole 0.01% was the best treatment with a mean pseudostem damage of 2.6% which was on par with flubendiamide 0.02% (4.1%), spinosad 0.0225% (6.5%) and cyantraniliprole 0.005% (8.8%), when sprayed at 15 day intervals during the second fortnight of July to the first fortnight of November. The trials indicated that that these low-risk insecticides and natural product can be utilized for the management of *C. punctiferalis* in ginger with reduced risk to the environment.

Impact of water activity and temperature on the growth and aflatoxin production by two toxigenic isolates of *Aspergillus flavus* on ginger. 29 (1): 72-77 (2020)

V C Okereke

Ginger may be affected by aflatoxin-producing *Aspergillus flavus* during storage. This study evaluated the interaction between different temperatures and water activity (a_w) levels on the growth and aflatoxin production (AFB_1) of two toxigenic isolates of *A. flavus* previously isolated from ginger (AFg) and turmeric (AFt) on ginger medium over a 10-day period. Results showed that regardless of the temperature, no growth was observed at 0.85 a_w and at 20°C and 0.9 a_w suggesting limits for growth could vary. *A. flavus* had optimum conditions for growth at 0.98-0.995 a_w and 30-35°C in both isolates, while the level of AFB_1, production varied considerably among the isolates. Generally, AFt isolate produced higher concentration of toxins than AFg. Maximum AFB_1 production by both isolates was at 0.98 a but at different temperatures This result could therefore be useful in the post-harvest handling of ginger and ginger-based

products in stores against *A. flavus* colonisation and subsequent AFB_1 production.

Microbial inoculants and *Trichoderma viride* consortia for growth promotion and disease management in ginger. 30 (1): 58-68 (2021)

T R Haritha & K S Gopal

A study was conducted to evaluate the effect of microbial inoculants consortia on ginger under field conditions. Three biofertilizers comprising of *Azospirillum lipoferum* (nitrogen fixer KAU-AZO), *Bacillus megaterium* (phosphate solubilizer KAU-PSB), *Bacillus sporothermodurans* (potash solubilizer KAU-KSB) and two biocontrol agents namely, *Pseudomonas fluorescens* (KAU-PF) and *Trichoderma viride* (KAU-TV) were used in the study. Compatibility studies revealed that all the isolates were compatible with each other. However, *P. fluorescens* and *T. viride* were incompatible with each other under in vitro. Under field evaluation, consortia of microbial inoculants performed better than the single inoculants in terms of yield and disease management. The organic Adhoc package recorded the minimum incidence of rhizome rot (2.09 %) among all the treatments. However, KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV recorded the minimum rhizome rot (5.23%) incidence among the consortia. In the case of Rhizoctonia leaf blight disease, consortia of KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF showed the minimum incidence (5.21%). In general, consortium of *A. lipoferum*, *B. megaterium* (PSB), *B. sporothermodurans* (KSB) and *T. viride* was the most efficient for plant growth promotion and disease management in ginger.

Biocontrol of *Pythium aphanidermatum* causing soft rot in ginger with biosurfactant produced by a rhizospheric *Bacillus* species. 30 (1): 69-80 (2021)

D Goswami & M B Syiem

Plant growth-promoting rhizobacteria benefit plants by producing phytohormones and acquiring vital nutrients from soil. They also form a shield against potential phytopathogens with the production of antimicrobial compounds such as bacteriocin, biosurfactants etc. In

the present study, among various rhizobacteria isolated from ginger rhizosphere, the isolate identified as *Bacillus altitudinis* VS7 that showed a potent biosurfactant producing ability in the preliminary tests was selected for the further study. Compositional analyses indicated that the biosurfactant produced by VS7 was a surfactin like compound, a cyclic lipopeptide. In both microtitre plate and mycelium growth inhibition studies, the biosurfactant showed dose dependent antagonistic activities against *Pythium aphanidermatum* that causes soft rot in ginger. Although there are reports of biocontrol activity of various rhizobacteria against soft rot in ginger, this is the first information regarding biocontrol activity of a biosurfactant produced by the rhizobacterium *B. altitudinis* VS7 against *P. aphanidermatum*.

Social Sciences

Yield and quality of ginger (*Zingiber officinale* Rosc.) grown in Nagaland, India. 6 (1): 43-47 (1997)
P B Kanjilal, M N Sarma, I H Siddque, R Kotoky, M G Pathak & R S Singh
Multilocational trials conducted at Nagaland, India, in ginger (*Zingiber officinale*) indicated significant differences in growth characteristics and yield components among the cultivars at various locations. The yield was very low (4.8-9.3 t/ha) and fibre content high (6.7-9.6%) at all locations. Yield and quality of ginger grown in .Wokha, Mon, Mokokchang and Tuensang districts were superior to the ginger from other districts of Nagaland.

Economics of ginger (*Zingiber officinale* Rosc.) production in Amravati District (Maharashtra, India). 7 (1): 7-11 (1998)
S H Gaikwad, P V Thorve & B D Bhole
The economics of production of ginger (*Zingiber officinale*) in Anjangaon Surji Taluka of Amravati District (Maharashtra, India) was studied during 1995-96. The study indicated that cost of cultivation and gross returns were positively related with size of the holding. The overall cost of cultivation was Rs. 1,32,415.63 per ha and Rs. 1012.04 per qtl. The overall net returns at cost C (which included all costs) was

Rs. 50,399.23 per ha. However, net returns decreased with size of holdings. The overall input-output ratio at cost C was 1.38.

Adoption of recommended cultivation practices in ginger (*Zingiber officinale* Rosc.) at Koraput District, Orissa. 15 (2): 130-132 (2006)
S C Mohapatra & P Acharya
A study was conducted in Koraput District (Orissa) for determining the level of adoption and constraints in adoption of recommended cultivation techniques in ginger (*Zingiber officinale*) among farmers. The overall adoption level of improved cultivation techniques was low (44.1%) and the major constraints in their adoption was lack of technical guidance (39%), ignorance (38.4%) and high cost of inputs (36.2%).

Impact of cluster-based technology transfer on profitability of ginger cultivation by small hill farmers of Shivalik region of Haryana. 31 (1): 25-33 (2022)
S S Grewal & J S Kanwar
Ginger (*Zingiber officinale*) is an important commercial crop of Morni hills of Haryana Shivaliks. There was considerable gap between the actual yield and income than the potential indicated by successful growers. In an attempt to bridge this gap by adopting a cluster development approach, 32 ginger growers of a hill village were formed as a common group to implement the recommended package of practices based on soil test analysis and adopted over one bigha (1/12th of hectare) of 32 demonstration plots and one bigha was kept as untreated control with farmers' normal practice. The beneficiary farmers were provided trainings, exposure visits and interaction with agricultural experts. The average fresh ginger rhizome production in treated plots was 11.19 t ha^{-1} as against 6.97 t ha^{-1} in control plots. While 84 percent farmers obtained an yield of 11 to 12 t ha-1, yield recorded by remaining farmers ranged from 7.44 to 9.63 t ha^{-1} thus indicating scope of further increase in production. The ratio between seed used and rhizome yield was taken as an indicator of yield potential and this was 4.04 in case of treated plots and 2.65 in case of control thus registering overall increase of 52.4 percent. The total

gross and net returns were Rs. 9,96,678 and Rs. 3,95,925 ha^{-1} and the average cost of cultivation was Rs. 6,00,753 ha^{-1}. The overall benefit cost ratio was 1.66. However, in case of control plots, the average gross and net returns were Rs. 5,32,800 and Rs. 1,06,972 with a benefit cost ratio of 1.22. In the cluster based approach, reduction in input costs and collective marketing resulted in better dividends.

TURMERIC

Crop Improvement and Biotechnology

Performance of turmeric (*Curcuma longa* L.) varieties in the hill zone of Karnataka, India. 3 (2): 161-163 (1994)
S Sheshagiri & B C Uthaiah
A field experiment was conducted at Mudigere (Karnataka, India) to assess the yield performance of six elite turmeric (*Curcuma longa*) varieties under rainfed conditions. The yield of fresh turmeric was maximum in BSR-1 (16.57 t/ha) followed by Waigon (15.45 t/ha). BSR-1 was also superior in growth attributes.

Performance of turmeric (*Curcuma longa* L.) cultivars in open and partially shaded conditions under coconut. 4 (2): 139-144 (1995)
P Latha, M P Giridharan & B Jayaprakash Naik
The performance of 15 turmeric (*Curcuma longa*) cultivars grown under open and partially shaded conditions (25-30 per cent shade intensity) as an intercrop in a coconut (*Cocos nucifera*) garden was evaluated at Pilicode (Kerala State, India). Plant height, number of secondary fingers and total weight of fresh rhizomes were higher in all the cultivars under partially shaded conditions. However, curing percentage was higher under open conditions. The cultivar Chayapasupu recorded the highest yield (43.73 t ha^{-1} of fresh rhizomes) followed by VK-31 (42.42 t ha^{-1}) under partially shaded conditions. The yield of cured rhizomes was highest in VK-116 (5.74 t ha^{-1}) followed by VK-77 (5.63 t ha^{-1}) under the same conditions. As pure crop, VK-31 (35.06 t ha^{-1}) and VK-55 (34.66 t ha^{-1}) were the high yielders in terms of fresh yield and VK-77 recorded the highest yield (6.96 t ha^{-1}) of cured rhizomes followed by VK-114 (6.87 t ha^{-1}). The study indicated the need for standardising optimum light requirement for each cultivar for maximum production of cured rhizomes.

Performance of turmeric (*Curcuma longa* L.) varieties in lower Pulney hills of Tamil Nadu, India. 4 (2): 156-158 (1995)
D V Patil, K M Kuruvilla & K J Madhusoodanan
Eight turmeric (*Curcuma longa*) varieties were evaluated under rainfed conditions for two crop seasons at lower Pulney hills, Tamil Nadu, India. The varieties differed among themselves with regard to yield and growth characters such as plant height, number of tillers per plant, leaves per tiller, leaf length and breadth and curing percentage. Suvarna (PCT-8) had maximum number of tillers per plant but was inferior to others in relation to other growth traits. The highest yield (t/ha - fresh rhizomes) was recorded in BSR-l (20.88), followed by Suvarna (19.32) and Suroma (19.04).

IISR Prabha and IISR Prathibha - Two new high yielding and high quality turmeric (*Curcuma* longa L.) varieties. 5 (1): 41-48 (1996)
B Sasikumar, G K Johnson, T John Zachariah, M J Ratnambal, K Nirmal Babu & P N Ravindran
IISR Prabha (Acc. 360) and IISR Prathibha (Acc. 361), developed at the Indian Institute of Spices Research, Calicut and recommended for release by the All India Coordinated Research Project on Spices are two valued added turmeric (*Curcuma longa*) varieties, developed for the first time through open pollinated progeny selection. These varieties surpassed most of the existing varieties including Alleppey in terms of curcumin content and oleoresin percentage. Maturing in 205 days under rainfed conditions, IISR Prabha has an average yield of 37.47 t/ha (fresh) with a dry recovery of 19.5 per cent, curcumin 6.52 per cent, oleoresin 15.0 per cent and essential oil 6.5 per cent. IISR Prathibha matures in about 225 days under rainfed conditions and has an average yield of 39.12 t/ha (fresh) with a dry recovery of 18.9 per cent, curcumin 6.2 per cent, oleoresin 16.2 per cent and essential oil 6.2 per cent.

Bud and root development of turmeric (*Curcuma longa* L.) rhizome. 8 (1): 49-55 (1999)
K K Sherlija, K Unnikrishnan & P N Ravindran
The structure and organization of axillary bud and adventitious root in turmeric (*Curcuma longa*) rhizome was studied. The mother rhizome is bulbous with smaller internodes compared to branches (fingers) which have long internodes. The axillary buds develop from the axile of scale leaf of the rhizome. The secondary branches of the rhizome develop from the primary branches. Roots originate from the intermediate zone of the rhizome. The root apical meristem is of the open type the three sets of structural initials and possess a distinct quiescent center.

Evaluation and selection of turmeric (*Curcuma longa* L.) genotypes. 10 (1): 33-36 (2001)
K A Shanmugasundaram, T Thangaraj, R S Azhakiamanavalan & M Ganga
Fifteen genotypes of turmeric (*Curcuma longa* L.) from five states of India were evaluated for yield and curcumin content. Among them, PTS-43 yielded 33.86 t ha^{-1} fresh rhizome, 7.17 t ha^{-1} cured rhizome, 5.36% curcumin and 21.17% recovery of cured rhizome as against 28.00 t ha^{-1}, 4.48 t ha^{-1}, 3.56% and 16.00% respectively in BSR-2, the local check and 26.69 t ha^{-1}, 5.69 t ha^{-1} 4.84% and 21.33%, respectively in the national check (var. Roma).

Correlation and path analysis in turmeric (*Curcuma longa* L.). 11 (1): 70-73 (2002)
B Panja, D K De, B Basak & S B Chattapadhyay
Studies on nineteen characters of eight turmeric (*Curcuma longa* L.) genotypes revealed that plant height, leaf number, number of primary fingers, number and weight of secondary fingers had positive genotypic correlation while length of primary fingers, internode length and ratio of outer and inner core of primary fingers had significant negative association with rhizome yield. The number and weight of secondary rhizomes exhibited higher positive correlation with yield than other characters. Path analysis indicated higher direct positive effect of weight of primary and mother rhizomes but

insignificant correlation with rhizome yield due to higher indirect negative effect of some of the component characters. On the contrary, the number of primary fingers had the highest direct negative effect on rhizome yield, but significantly positive correlation with it, apparently due to high positive indirect effect via weight of primary and mother rhizomes and number of secondary rhizomes. The importance of plant height, leaf number, number of primary fingers, number and weight of secondary fingers as criteria for selection of bitter turmeric genotypes has been indicated.

Preliminary evaluation of turmeric (*Curcuma longa* L.) varieties at Konkan region of Maharashtra. 14 (1): 28-33 (2005)
P V Sinkar, P M Haldankar, R G Khandekar S A Ranpise, G D Joshi & B B Mahale
The performance of 21 varieties of turmeric (*Curcuma longa*) for rhizome characters, yield and curcumin content was studied at Konkan region (Maharashtra). Salem was found to be the best variety, which recorded significantly higher weight of primary fingers (208.92 g), secondary fingers (243.75 g), yield plot' (11.99 kg) and yield hectare" (44,395 kg). The curcumin content was significantly higher in CA-71 (4.87%). The phenotypic and genotypic coefficient of variation, heritability and genetic advance on mean basis were appreciably high for yield and curcumin content. The magnitude for environmental coefficient of variation was very low.

Two new high yielding, high 'curcumin, turmeric (*Curcuma longa* L.) varieties- 'IISR Kedaram' and 'IISR Alleppey Supreme'. 14 (1): 71-74 (2005)
B Sasikumar, K Johnson George, K V Saji & T John Zacharia
Two turmeric (*Curcuma longa*) varieties, IISR Kedaram (Acc. 126) and 'IISR Alleppey Supreme (Acc. 585) were developed at the Indian Institute of Spices Research, Calicut, through selection and recommended for release for their high yield and curcumin content. llSR Kedaram, matures in 215 days and has an average yield of 5.28 t ha^{-1} (dry rhizome) and 301.10 kg ha^{-1} curcumin whereas, IISR Alleppey Supreme, an Alleppey finger turmeric selection, matures in

220 days and yields 5.58 t ha^{-1} (dry rhizome) and 309.69 kg ha^{-1} curcumin.

Character association and path analysis for yield components in turmeric (*Curcuma longa* L.). 14 (1): 75-77 (2005)
N S Tomar, S K Nair & C R Gupta
Correlation and path analysis of 11 characters of turmeric (*Curcuma longa*) were carried out using 22 genotypes at Raigarh (Chhattisgarh). Plant height, leaf length, thickness of primary and secondary rhizomes and number of secondary rhizomes revealed significant positive associations with rhizome yield. Path analysis showed positive direct effect of plant height, leaf length and thickness of primary and secondary rhizomes on rhizome yield. These traits may be given due emphasis while making selections for improvement in rhizome yield of turmeric.

Genetic divergence in germplasm collections of turmeric (*Curcuma longa* L.). 14 (2): 165-168 (2005)
A Manohar Rao, P Venkat Rao, Y Reddy & M Ganesh
Fifty four turmeric (*Curcuma longa*) cultivars were evaluated at Jagtial (Andhra Pradesh) by subjecting to D^2 statistic to assess the genetic diversity available in the cultivars. The D^2 analysis showed wide diversity among the cultivars and they were grouped into six clusters. Inter-cluster distance values also showed wide genetic divergence among the cultivars. Based on cluster-mean values, the cultivars PTS-38 and Duggirala in cluster I (high cured yield), PCT-5 and PCT-8 in cluster III (high curcumin, essential oil and oleoresin contents) and PCT-13, PCT-14 and PCT-10 in cluster IV (short duration, medium yield with good curcumin content) were identified as potential parents for future breeding programmes.

Growth analysis and curcumin content of long, medium and short duration turmeric (*Curcuma longa* L.) genotypes. 15 (1): 42-47 (2006)
A Manohar Rao, P Venkat Rao & Y Narayana Reddy
Six turmeric (*Curcuma longa*) genotypes, two genotypes each from long (Armoor and Duggirala), medium (CLI-317 and CLI-330) and

short (PCT-13 and PCT-14) duration were evaluated at Jagtial (Andhra Pradesh). Long duration genotypes accumulated more dry matter and maintained leaf area index, chlorophyll content and cumulative growth rate for longer period up to 210 days, resulting in higher yield and curing percentage over medium and short duration genotypes. The long duration genotype Duggirala produced highest fresh rhizome yield (168 g plant^{-1}) and Armoor had highest curing percentage (20.26). Curcumin content was higher in short duration genotypes over medium and long duration genotypes. Maximum curcumin content was recorded in short duration genotype PCT-14 (4.06 %).

Genetic variability, correlation and path coefficient analysis in turmeric (*Curcuma longa* L.). 22 (1): 104-107 (2013)
R Rajyalakshmi, L N Naidu, M Rajasekhar & V Sudhavani
Eight turmeric genotypes were raised in a randomized block design to study the variability, heritability with genetic advance, correlation, direct and indirect effects of characters on rhizome yield for a period of four year. Variability accompanied by higher values for genetic coefficient of variation was recorded for rhizome yield. Heritability and genetic advance were high for rhizome yield and number of tillers per plant. In general, genotypic correlations were higher than phenotypic correlations for all the characters studied. Rhizome yield was positively and significantly correlated with plant height, number of tillers plant^{-1} and number of leaves plant^{-1}. Number of tillers plant^{-1} followed by plant height exerted the highest positive direct effect on rhizome yield, which indicated that selection for these characters would directly improve the yield in turmeric.

Evaluation of turmeric (*Curcuma longa* L.) genotypes for yield attributes, yield and reaction to foliar diseases. 22 (2): 238-240 (2013)
A K Singh
An experiment was conducted during 2005-06 to 2008-09 at Raigarh (Chhattisgarh) to assess the variability of thirteen genotypes of turmeric for yield and disease resistance. The results indicated that entries TCP-11 and TCP-82 produced maximum yield i.e, 20.3 and

18.8 t ha^{-1}, respectively. Entry TCP-11 showed resistance to leaf spot and blotch while TCP-82 was found to be moderately resistant to Colletotrichum leaf spot and resistant to Taphrina leaf blotch. The check variety IISR Prabha showed moderate resistance to both the diseases and yielded 14.4 t ha^{-1}.

Comparative gene expression study between two turmeric (*Curcuma longa* L.) cultivars. 27 (2): 131-137 (2018)
D K Ayer, K G Modha, V B Parekh, R K Patel, V Ramtekey & A P Bhuriya
Two turmeric (*Curcuma longa* L.) cultivars differing in curcumin content viz GNT-2 (4.6 % curcumin) and NDH-98 (1.6% curcumin) were selected for comparative gene expression study in association with total curcumin contents. Sampling was done at six months after planting in open field condition. Differential gene expression patterns were observed between two cultivars by reverse transcription quantitative real time polymerase chain reaction (RT-qPCR), and total curcumin contents were quantified using high performance liquid chromatography (HPLC). Low curcumin yielding cultivar, NDH-98, exhibited higher expression of *DCS* and *CURS3* whereas lower expression of *CURS1* and *CURS2*. However, opposite pattern was observed in a high curcumin yielding cultivar, GNT-2, where *DCS* and *CURS3* expressions were lower but *CURS1* and *CURS2* expressions were higher. *CURS3* showed similar expression between both cultivars. *CURS1* and *CURS2* expression patterns showed more closer association than *DCS* and *CURS3* gene expression patterns with each other. Differential gene expression patterns could be predictively associated with differential curcuminoids concentrations in turmeric cultivars.

Comprehensive assessment of phytometabolites and health benefits of Geographical Indication turmeric in India. 31 (1): 45-55 (2022)
Dona Ann Jose, N M Bhabhina, N K Leela, M Vishudha, S Aarthi & D Prasath
The interest and demand for the Geographical Indication (GI) turmeric have increased significantly in recent years as research

unfolds their unique benefits. Still, their comprehensive and comparative metabolite profile remains to be analysed in detail from a nutritional perspective. This investigation reports phytochemical constituents, nutraceuticals, and bioactivities of four GI turmeric (Erode turmeric, Kandhamal haldi, Waigaon turmeric and Sangli turmeric) in India. The results revealed considerable differences in major quality parameters *viz*., essential oil (4.00-5.60%), oleoresin (8.36-18.12%) and curcuminoids (2.23-5.50%). Among the GIs, Waigaon turmeric was superior in terms of quality parameters and rhizome traits. The Erode turmeric contained significantly high protein (4.64%) and several minerals (K, Ca, Fe and Mg). The IC50 values of DPPH scavenging assays (160.72-194.25 µg ml^{-1}) and α-glucosidase inhibitory assays (126.50-146.57 µg ml^{-1}) ensured the potent antioxidant and anti-diabetic activities of GI turmeric. The GC-MS profile of essential oil unveiled six major compounds such as, ar-turmerone, β-sesquiphellandrene, α-zingiberene, α-curcumene, α-turmerone, and curlone. The brightest yellow colour was observed in Sangli turmeric and dark orange in Waigon turmeric, based on L*, a* and b* values. All the four GI turmeric varieties are good sources of spice for people to consume but Waigaon turmeric was found to be superior among them.

Estimates of genetic variability, inter character association and path analysis in turmeric over environments. 31 (1): 56-64 (2022)

S Aarthi, J Suresh & D Prasath

Pooled data of 27 traits, including quantitative and qualitative, from 15 turmeric varieties grown in three locations over two years were used to estimate the genetic parameters of variability and path analysis. High genotypic coefficient of variation (GCV) combined with high phenotypic coefficient of variation (PCV) was observed for collar girth, length of mother rhizome, number of mother rhizomes, weight of mother rhizome, weight of primary rhizome, number of secondary rhizomes, primary rhizome inter-nodal length, bisdemethoxycurcumin (BDMC), demethoxycurcumin (DMC), curcumin (CUR) and yield. High heritability coupled with high genetic advance as per cent mean (GAM) was recorded for plant height,

number of shoots, leaf petiole length, leaf length, collar girth, length of mother rhizome, girth of mother rhizome, primary rhizome inter-nodal length, dry recovery, oleoresin, BDMC, DMC and curcumin. Correlation coefficients showed that yield was significantly associated with collar girth, weight of mother rhizome, number of primary rhizomes, weight of primary rhizome and number of secondary rhizomes. Path coefficient analysis at phenotypic level revealed that, positive direct effect was high for length of mother rhizome followed by number of mother rhizomes, weight of primary rhizome and curcumin content. The study confirmed that characters such as weight of mother rhizome, girth of mother rhizome, weight of primary rhizomes, number of primary rhizomes and curcumin content can be relayed upon to form selection criteria in turmeric.

Patterns in genetic variation and character association of yield components in turmeric (*Curcuma longa* L.). 32 (1): 14-22 (2023)
Raghuveer Silaru, Yuvaraj Kotha Madduri, Aarthi Sounderarajan & Prasath Duraisamy

Understanding genetic variability patterns of turmeric yield traits is essential to develop new genotypes with improved traits. The objective of the present study was to investigate the genetic variability, heritability, genetic advance and association of various yield components in turmeric genotypes. The experiment was conducted for two seasons during 2021-22 and 2022-23 using 21 turmeric genotypes at ICAR-IISR, Experimental farm, Peruvannamuzhi, Kerala. The results indicate that the genotypes exhibited significant variation across two seasons for most traits, with the exception of collar girth, weight of primary rhizomes per clump, and number of primary rhizomes per clump, which suggests the presence of genetic variability in the genotypes. Maximum fresh rhizome yield per clump was recorded in the genotype, IISR Pragati. The Genotypic Coefficient of Variation (GCV) was found to be moderate to high for most of the traits except plant height, leaf lamina length, collar girth and fresh rhizome yield per plant, whereas, Phenotypic Coefficient of Variation (PCV) was found to be moderate to high for all the traits except plant height. Heritability was observed moderate to high for all the traits except collar girth, number of

primaries per clump, weight of primary rhizomes per clump and fresh rhizome yield per plant. The petiole length, total leaf area, weight of mother rhizomes per clump and number of mother rhizomes per clump showed high heritability along with genetic advance. Correlation analysis suggested that weight of mother rhizomes per clump had a strong positive association with plant height, number of leaves, leaf lamina length, leaf lamina width, leaf area, total leaf area, and collar girth and had a weak positive relationship with fresh rhizome yield per plant and petiole length. The path analysis revealed, total leaf area, fresh rhizome yield per plant and number of primaries per clump have high direct positive effects with weight of mother rhizomes per clump. The high heritability and genetic advance observed for above mentioned traits suggest that exercising a simple selection could indirectly improve the low heritable, low genetic advance traits such as fresh rhizome yield per plant as indicated by correlation and path analysis.

Identification of drought tolerant turmeric (*Curcuma longa* L.) genotypes with sustainable yield. 32 (2): 129-147 (2023)
C V Nazmin Banu & K S Krishnamurthy

Turmeric (*Curcuma longa* L.) (Zingiberaceae), is native to south west India. Water stress is the most common adverse environmental condition which severely affects crop productivity. Here we have analysed morphology, stomatal density, relative water content, electrolyte leakage, epicuticular wax content and rhizome yield of 50 elite turmeric genotypes for identification of genotypes with differential response (tolerance and susceptibility) to water stress. Results showed that water stress during rhizome development stage (90-120 days after planting) significantly decreased the leaf relative water content and increased membrane permeability. Epicuticular wax content varied significantly among the genotypes. Genotypes with lower leaf area, higher relative water content, lesser electrolyte leakage, higher wax content and fewer stomata than other genotypes were shortlisted as tolerant. From among these shortlisted ones, four tolerant genotypes (IISR Pragati, SL 5, Suguna, and Suvarna) with higher yield, along with two susceptible genotypes (IISR Alleppey Supreme and IISR Kedaram), were further evaluated in field

conditions. The results indicated that, in terms of yield and physiological parameters, the tolerant genotypes significantly outperformed the susceptible ones, showcasing superior drought tolerance traits. These genotypes with contrasting characters can be used for further studies to elucidate the mechanism of drought tolerance.

Crop Production and Postharvest Technology

Effect of storage of fresh turmeric rhizomes on oleoresin and curcumin contents. 1 (1): 55-58 (1992)
T John Zachariah & K Nirmal Babu
The turmeric varieties Suvarna (PCT-8), Suguna (PCT-13) and Sudarshana (PCT-14), were harvested and stored for a period of nine months. Samples were analysed for curcumin and oleoresin at monthly intervals. Curcumin and oleoresin levels were not affected by storage. The marginal increase in these constituents after sprouting is only relative as the nutrients like carbohydrates get progressively depleted with the progress of sprouting and growth of the sprout. The distribution of curcumin in mother rhizomes and fingers are also discussed.

Estimation of leaf area in turmeric (*Curcuma longa* L.) under two agroecological conditions. 3 (1): 14-18 (1994)
K V Satheesan, M V George, K Vijayakumar & A Ramadasan
The total leaf area (TLA) at different stages of growth of tillers or clumps of turmeric (*Curcuma longa*) varieties raised under two agro-ecological conditions *viz*., in the open as a pure crop and in association with coconut, can be estimated using the regression equation TLA = b_1 nB + b_2 L. The total leaf area of the tiller or clump can be computed by taking the linear measurements ('L' and 'B') of only one leaf i.e., median leaf of the tiller or those of the median leaf of the tiller having maximum number of leaves, respectively, and counting the total number of leaves ('n') in the respective tiller or clump. Under both the ecological conditions studied and between the same, the regression coefficients were not homogenous over various stages of growth and for different varieties. Hence common mathematical formulae were

not attempted to, with regard to varieties, age of the plant or ecological conditions.

Effect of nitrogen, phosphorus and potassium levels on growth and yield of turmeric (*Curcuma longa* L.) in the hill zone of Karnataka. 3 (1): 28-32 (1994)
K S Sheshagiri & B C Uthaiah
A nutritional trial on turmeric (*Curcuma longa*) variety CO-1 conducted for three seasons at Regional Research Station, Mudigere, Karnataka indicated that a nutrient level of 120:60:120 kg NPK/ha is optimum for growth and yield of the crop in the hill zone of Karnataka.

Response of turmeric (*Curcuma longa* L.) to nitrogen in relation to application of farm yard manure and straw mulch. 8 (2): 211-214 (1999)
B S Gill, R S Randhawa, G S Randhawa & J Singh
Experiments were conducted during *kharif* 1995 and 1996 at Ludhiana, India, to study the response of turmeric (*Curcuma longa*) to nitrogen in relation to application of farm yard manure and wheat straw mulch. The treatments consisted of two levels of mulch (0 and 6 t/ha), four levels of farmyard manure, (0, 20, 40 and 60 t/ha) and three levels of nitrogen (0, 60 and 120 kg/ha). The study revealed that application of wheat straw mulch improved growth and yield of turmeric significantly. Rhizome yield increased significantly with each increase in farm yard manure level during 1996 with a maximum yield of 365.4 q/ha with 60 t/ha of farm yard manure. Nitrogen levels did not affect growth and yield of turmeric significantly.

Effect of rate and time of nitrogen application on growth and yield of turmeric (*Curcuma longa* L.). 10 (2): 123-126 (2001)
B S Gill, R Krorya, K N Sharma & S S Saini
An experiment was conducted to study the response of turmeric to rate and time of N application. The treatments consisted of three levels of nitrogen (60, 120 and 180 kg ha^{-1}) as main plot treatments and number of applications (nitrogen applied in equal splits of one, two, three, four and five) as sub-plot treatments. The results showed

that 60 kg N ha^{-1} produced maximum fresh rhizome yield. Turmeric yield at 60, 120 and 180 kg N ha^{-1} did not differ significantly. Nitrogen applied in three equal splits produced maximum fresh rhizome yield and it was significantly superior to application of whole N at planting and in two splits. N content in leaf, rhizome and available nitrogen in soil increased with increase in the level of nitrogen and number of split application.

Studies on stomatal frequency and its relationship with leaf biomass and rhizome yield of turmeric (*Curcuma longa* L.) genotypes. 10 (2): 127-134 (2001)
B Panja & D K De

Stomatal frequencies of twelve turmeric (*Curcuma longa* L.) genotypes were recorded from different locations of both surfaces of the fourth, sixth and eighth nodal leaves. Turmeric leaves were amphistomatous having lower stomatal frequency in the upper surface (426.6-1773.7 sq. cm^{-1}) and higher in the lower surface (7131.5-12,270.9 sq. cm^{-1}) of the leaves. With a few exceptions, stomatal frequency of the leaves of the genotypes tested increased from fourth to eighth nodal position. The stomatal frequency of the genotypes either at the same location within leaf, at different locations within leaf or both leaf surfaces taken together did not vary significantly. The genotype TCP-9 had the highest stomatal frequency. However, stomatal frequency increased from base towards tip on both surfaces of the leaf, irrespective of the position of the leaf in all the genotypes. The stomatal frequency appeared significant and more positively correlated with rhizome yield than leaf dry weight in genotypes resistant to leaf blotch disease while in susceptible types it exhibited significant and negative correlation with leaf dry weight and rhizome yield.

Delineation of turmeric zones in Tamil Nadu. 10 (2): 153 (2001)
K Kandiannan, K K Chandaragiri, N Sankaran & T N Balasubramanian

The districts with RYI and RSI more than 90 are considered as efficient zones and accordingly Erode, Coimbatore and Salem are efficient with RYI 101.81, 105.26, 95.57 and RSI 874.50, 391.78,

121.39, respectively. The identification of efficient zones will help the traders, policy makers and other developmental agencies to concentrate on that particular zone for setting up industry, trade centres etc.

Influence of different levels of nitrogen and phosphorus on growth and yield of turmeric (*Curcuma longa* L.). 11 (1): 74-77 (2002)

Annie Thomas, Swati Barche & D B Singh

A nutritional trial on turmeric (*Curcuma longa* L.) variety Suvarna, conducted with three levels of nitrogen (45, 60 and 75 kg ha^{-1}) and three levels of potassium (90, 120 and 150 kg ha^{-1}) at Horticulture Research Farm, Allahabad Agricultural Institute, indicated that the growth and yield potential of the crop under Allahabad agro climatic condition can be increased by applying NPK at the rate of 75:60:150 kg ha^{-1}.

Analysis of spatial variability of turmeric (*Curcuma longa* L. syn. *C. domestica* Val.) yield in India. 11 (2): 155-159 (2002)

K Kandiannan, K K Chandaragiri, M Govindaswamy, P Subbian & N Sankaran

This paper examines the yield variability of turmeric in India. The data on maximum, minimum and mean fresh rhizome yield of 200 experiments from secondary sources of published research papers/reports were collected. These data were utilized with an objective to calculate summary statistics and to identify maximum and minimum yields and yield differences obtained in each state. The summary statistics indicated that in India maximum yield ranged between 4.59 and 95.0 t ha^{-1} with a mean of 28.48 ± 14.29 t ha^{-1}. The minimum yield ranged between 1.34 and 56.25 t ha^{-1} with a mean of 13.73 ± 18.60 t ha^{-1} and the mean yield ranged from 3.09 to 72.68 t ha^{-1} with a mean of 22.99 ± 11.60 t ha^{-1}. The maximum yield obtained in all the cases was due to adoption of improved production techniques such as variety, manure and better crop management practices compared to minimum yield of control treatment. The yield differences between maximum and minimum ranged from 6.69 to 93.50 t ha^{-1}.

Effect of rock phosphate, single super phosphate and their mixtures with FYM on yield, quality and nutrient uptake by turmeric (*Curcuma longa* L.) in acid alfisol of Meghalaya. 12 (1): 47-51 (2003)

M S Venkatesh, B Majumdar & Kailash Kumar

A field experiment was conducted for two years on a P deficient Typic Hapludlalf Meghalaya to study the effectiveness of rock phosphate (RP), Single Super Phosphate (SSP) and their mixtures along with FYM on turmeric. Application of P as RP or SSP alone or their mixtures with FYM significantly increased the rhizome yield over control. There was a 50 per cent increase in rhizome yield due to FYM application. Maximum N and P uptake, curcumin content and Phosphorus use efficiency (PUE) were recorded in RP + SSP (1:3) + FYM treatment. Postharvest analysis of soil samples indicated that soil pH was marginally reduced with FYM application while organic carbon, ECEC and available P contents increased turmeric.

Effect of nitrogen levels on growth and yield of turmeric. 12 (1): 77-79 (2003)

S K Attarde, B J Jadhao, R M Adpawar & A D Warade

An experiment was conducted during 2000-2001 to study the response of two turmeric varieties (Krishna and Selam), five levels of nitrogen (0, 40, 80, 120, 150 kg ha^{-1}) on growth and yield. The results indicated that variety Krishna responded favourably for all the characters to the application of 120 kg N ha^{-1}. The maximum rhizome yield of 277.87 and 225.43 q ha^{-1}, respectively was harvested by the application of 120 kg N ha^{-1} with turmeric variety Krishna. The interaction of nitrogen x variety was significant only for fresh weight of fingers per plant.

Influence of planting methods, spacing and farmyard manure on growth, yield and nutrient content of turmeric (*Curcuma longa* L.). 13 (2): 117-120 (2004)

B S Gill, Simerjit Kaur & S S Saini

Investigations carried out at Ludhiana (Punjab), with different methods of planting (flat and ridge), spacings (60 cm x 10 cm and 60

cm x 15 cm) and farmyard manure levels (0, 30 and 60 t ha^{-1}) on turmeric (*Curcuma longa*) revealed that fresh rhizome yield was significantly higher in ridge method of planting than flat method of planting with significantly taller plants and more number and weight of primary and secondary rhizomes. Farmyard manure application significantly improved plant height, number and weight of mother, primary and secondary rhizomes and fresh rhizome yield. Plant spacing did not influence growth and yield. Nitrogen, phosphorus and potassium contents in leaf and rhizome improved with farmyard manure application.

Effect of humic acid (potassium humate) on growth and yield of turmeric (*Curcuma longa* L.) in an alfisol. 14 (1): 34-38 (2005)
K Baskar & K Sankaran
A field experiment was conducted at Mattuvarayapuram (Coimbatore District, Tamil Nadu) to evaluate the effect of lignite humic acid (HA) on growth and yield of turmeric (*Curcuma longa*) in an alfisol. The study revealed that application of 100% NPK 150:60:108 kg ha^{-1}) with HA applied to soil 10 kg ha^{-1}) + foliar spray (HA 0.1%) + rhizome dipping (HA 0.1%) significantly enhanced the growth and yield attributes, fresh and cured rhizome yield of turmeric.

Impact of planting geometry on productivity and profitability of turmeric (*Curcuma longa*) and pigeonpea (*Cajanus cajan*) intercropping under rainfed condition. 17 (2): 154-157 (2008)
B Behera, S K Mohanty, A Mishra & D K Dash
Six planting patterns of turmeric and pigeonpea intercropping compared with sole turmeric and sole pigeonpea at Phulbani, Orissa during 2005-06 and 2006-07 under organic environment. Turmeric cv. Lakadong (200 days) and pigeonpea cv. Asha (225 days) were selected for the experiment. Well-decomposed FYM @ 20 t/ha was applied as the source of nutrient for the system. Over seasons, sole turmeric gave the maximum dry rhizome equivalent yield of 21.19 q/ha closely followed by turmeric and pigeonpea (10:2) planting in replacement series with dry rhizome equivalent yield of 19.91 q/ha. Sole turmeric gave the maximum gross return of Rs. 61,319/ha, but turmeric and pigeonpea (10:2) intercropping proved the most

remunerative with net return of Rs. 17,884/ha due to lower cost of cultivation as compared to sole turmeric.

Effect of method of planting and harvesting time on growth, yield and quality of turmeric (*Curcuma longa* L.). 18 (1): 22-27 (2009)
Balwinder Kumar & B S Gill

An experiment was conducted at Ludhiana (Punjab) to study the influence of method of planting (flat and ridge planting) and harvesting time (10 November-12 March) on growth, yield and of quality turmeric (*Curcuma longa*). Planting methods did not influence growth, yield and quality of turmeric significantly. Harvesting on 12th March produced maximum fresh rhizome yield of 28.94 t ha^{-1} (mean yield) of turmeric which was statistically on par with 20th February (27.61 t ha^{-1}) and 30th January (26.78 t ha^{-1}) harvesting, but was significantly better than all the earlier harvesting dates. A similar trend was observed in processed turmeric yield. The number and weight of rhizomes improved significantly with delay in harvesting. The oil and curcumin content also increased with delay in harvesting.

Growth and yield of turmeric (*Curcuma longa* L.) intercropped in poplar (*Populus deltoides* Bartram ex Marshall) plantation at Punjab. 18 (1): 40-42 (2009)
B S Gill, A Singh, Devinder Singh, N Gandhi & Jaspreet Kaur

The effect of planting dates and methods of planting of turmeric (*Curcuma longa*) intercropped in poplar (clone Udai) (*Populus deltoides*) plantation was studied at Ludhiana (Punjab, India). The treatments consisted of three planting dates namely, 20th March, 20th April and 20th May and two methods of planting, namely, ridge and flat method (60 cm x 10 cm) in poplar plantation. The study revealed that in first year of plantation (2004-05), a fresh rhizome yield of 9.96 t ha^{-1} was obtained in 20th April planting which was significantly more than that of 20th May planting (9.45 t ha^{-1}). During 2005-06, a fresh rhizome yield of 8.15, 11.61and 13.95 t ha^{-1} was produced in 20th March, 20th April and 20th May planting dates, respectively. During 2006-07, the yields were lower and the differences in fresh rhizome yield due to 20th May (6.33 t ha^{-1}) and 20th April (6.43 t ha^{-1}) planting were not significant but both the planting dates were

significantly better than 20th March (5.6 t ha^{-1}) planting. The ridge method of planting produced 8.0%, 11.0% and 9.8% more yield which was significantly higher than flat method of planting during 2004-05, 2005-06 and 2006-07, respectively.

Growth, yield and quality of turmeric (*Curcuma longa* L.) as influenced by planting method, plant density and planting material. 19 (1&2): 42-49 (2010)

Balwinder Kumar & B S Gill

A study was carried out at Ludhiana (Punjab) to evaluate the effect of planting method, plant density and planting material on growth, yield and quality of turmeric (*Curcuma longa*). The experiment consisted of two planting methods (flat and ridge), three plant densities(1,66,667; 1,11,111 and 83,333 plants ha^{-1}) and three types of planting material (mother, primary and secondary rhizomes). Fresh rhizome yield of 164.8 and 160.3 q ha^{-1} (pooled data) was produced in flat and ridge method of planting but the differences were non-significant. Closer plant spacing or higher plant density produced highest fresh, dry and processed turmeric yield and it decreased with decrease in plant density; whereas, number and weight of rhizomes increased with decrease in plant density. Use of mother rhizome as planting material resulted in better emergence (86.6% and 83.1%), taller plants (49.6 and 50.0 cm) with more number of leaves and leaf area index (4.4 and 3.8), more tillers $plant^{-1}$ (2.7 and 3.1), higher number (17.09 and 23.89) and weight (136.96 and 227.66 g) of total rhizomes $plant^{-1}$ as compared to use of primary and secondary fingers as planting material during 2003-04 and 2004-05, respectively. Planting of mother rhizomes produced highest fresh (207.7 q ha^{-1}), dry (46.0 q ha^{-1}) and processed (44.1 q ha^{-1}) turmeric yield and it decreased significantly with decrease in seed size. Curcumin content did not change due to different planting methods, plant densities and planting materials.

Effect of phosphorus levels on growth and yield of turmeric (*Curcuma* longa L.). 19 (1&2): 76-78 (2010)
Rakesh Banwasi & Ajit Kumar Singh
A field experiment was conducted at Raigarh (Chattisgarh) to study the effect of five levels of phosphorus (0, 50, 100, 150 and 200 kg P_2O_5 ha^{-1}) on growth and yield of turmeric (*Curcuma longa*) (var. TCP-1). A common dose of N @ 150 kg ha^{-1} and K_2O @ 120 kg ha^{-1} was applied in all the treatments. Application of phosphorus significantly influenced various growth characters and yield. The highest yield of fresh rhizome (156.3 q ha^{-1}) was recorded with application of 150 kg P_2O_5 ha^{-1} followed by 149.2 and 147.9 ha^{-1} rhizomes with application of100 and 200 kg P_2O_5 ha^{-1}, respectively. These treatments were significantly superior over other treatments and on par with each other. However cost:benefit ratio was highest in the treatment with application of 150 kg P_2O_5.

Influence of sodicity on growth, yield, quality and ionic composition of turmeric (*Curcuma longa* L.). 20 (1): 22–29 (2011)
V K Garg
The influence of sodicity on growth, yield and curcumin content of turmeric (*Curcuma longa*) grown in Typic Natrustalfs soil at Banthra, Lucknow (Uttar Pradesh) was studied. The experiments were laid out in a split plot design with five levels of soil exchangeable sodium percentage (10, 20, 30, 40 and 50) as main plot treatments and four varieties (Local BRS, KTS-1, Rajendra Sonia and Meducar) as sub-plot treatments with three replications. The results showed that emergence of rhizomes was marginally affected due to sodicity. However, an adverse effect of sodicity on number of tillers $clump^{-1}$ rather than plant height and number of leaves was observed. The estimated fresh rhizome yield on sodic soil followed the order of Meducar (4.8 t ha^{-1})>Local BRS (4.4 t ha^{-1})>KTS-1 (4.29 t ha^{-1})>Rajendra Sonia (3.68 t ha^{-1}). The highest cured rhizome yield (0.96 t ha^{-1}) was obtained in Meducar followed by Local BRS>KTS-1>Rajendra Sonia. The curcumin content was higher in Local BRS (9.6%) and Meducar (10.5%) than other genotypes grown in sodic soil. An accumulation of nutritionally adequate amount of potassium

(K) and calcium (Ca) besides maintenance of greater K/Na (5.9) and Ca/Na (5.6) ratios in the foliage at ESP 20 indicated the potential of turmeric to withstand mild sodicity.

Effect of organic manures and microbial inoculants on yield, root colonization and total bacterial population in turmeric (*Curcuma longa* L.) intercropped in arecanut (*Areca catechu* L.) garden. 20 (2): 66-71 (2011)
S S Roy & J K Hore
The effect of combination of organic manures namely, compost, vermicompost, phosphocompost and mustard cake and microbial inoculants namely, *Azospirillum brasilense* and arbuscular mycorrhiza (*Glomus fasciculatum*) were evaluated for the organic production of turmeric (*Curcuma longa*) (cv. Suguna) grown as intercrop in arecanut (*Areca catechu*) (cv. Mohitnagar) plantation at Mondouri (Nadia, West Bengal) A significant difference in rhizome yield was noticed when organic manure-microbial inoculant combination was applied when compared with recommended dose of fertilizers (inorganic). Among different treatment combinations tried, the most effective treatment was vermicompost + *Azospirillum* sp. + *Glomus* sp. (28.94 t ha^{-1}), followed by compost + *Azospirillum* sp. + *Glomus* sp. (26.93 t ha^{-1}), as compared to recommended inorganic NPK (24.11 t ha^{-1}). Maximum root colonisation (74%) with microbial inoculants at 180 days after planting was observed with vermicompost + *Azospirillum* sp. + *Glomus* sp. Maximum bacterial population (105.25 x 10^5 CFU g^{-1} soil) at harvest was noticed in compost + *Azospirillum* sp. + *Glomus* sp., as compared to lowest population with recommended NPK (56.35 x 10^5 CFU g^{-1} of soil).

Effect of different cultural practices on production of turmeric (*Curcuma longa* L.) in Punjab. 21 (1): 53-58 (2012)
S S Manhas & B S Gill
Field experiments were conducted at Ludhiana (Punjab) to study the effect of different cultural practices on production of turmeric (*Curcuma longa* L.). Number of tillers, dry matter accumulation, number of rhizomes $plant^{-1}$ and yield were significantly higher when mother rhizomes were used as planting material as compared to

primary and secondary fingers. Quality parameters and nutrient uptake also increased with increase in planting material size. Number of tillers, dry matter accumulation, number of rhizomes plant^{-1} and yield decreased significantly with delay in planting from 25th April to 25th May. Quality parameters and nutrient uptake were also better with 25th April planting. Rhizomes plant^{-1}, yield, quality parameters and nutrient uptake were not affected by different harvesting dates. Mother rhizomes as planting material and 25th April planting resulted in maximum net return and benefit:cost ratio.

Physical properties of turmeric (*Curcuma longa* L.) 21 (2): 178-181 (2012)

S Balasubramanian, A M Mohite, K K Singh, T John Zachariah & T Anand

Turmeric (*Curcuma longa*) rhizome (var. IISR Alleppey Supreme) sample was divided into three grades (I: 25-35 mm, II: 35-45 mm, III: 45-55 mm) according to its major dimension to study its physical properties. The average values of geometric property *viz*., length (30.38-50.60 mm), breadth (9.77-10.64 mm), thickness (5.18-6.44 mm), arithmetic mean diameter (15.82-21.91 mm), geometric mean diameter (12.77-13.76 mm), square mean diameter (24.24-28.58 mm), equivalent diameter (17.61-21.41 mm), sphericity (0.27-0.42), aspect ratio (0.20-0.35), unit volume (1641-2901 mm^3), surface area (771-1265 mm^2) and shape factor (1.63-1.77) for grades I, II and III are reported. The gravimetric property *viz*., bulk density (260-348 kg/m^3), true density (1341-1354 kg/m^3) and porosity (74.53-80.93%), and frictional property *viz*., angle of repose (37.57-38.90°) and coefficient of friction with respect to different surface *viz*., aluminium sheet, mild steel sheet and plywood sheet for grades I, II and III were found to range between of 0.69-0.81, 0.84-0.94, 0.80-0.86, respectively.

Growth, yield and quality of turmeric (*Curcuma longa* L.) as influenced by planting time and fertility levels. 23 (1): 64-70 (2014)

S K Tiwari, J K Tiwari & M K Pathak

This study was carried out to evaluate the growth, yield and quality of turmeric as influenced by dates of planting and fertility levels. The experiment was laid out in split plot design with four dates of planting (first fortnight of May (D_1), second fortnight of May (D_2), first fortnight of June (D_3) and second fortnight of June (D_4) in main plots, four fertility levels (NPK @ 0:0:0 kg ha^{-1} (F_0), NPK @ 125:25:30 kg ha^{-1} (F_1), NPK @ 150:50:60 kg ha^{-1} (F_2) and NPK @ 175:75:90 kg ha^{-1} (F_3) in sub plots and two varieties [Rajendra Haldi-5 (V_1) and Rajendra Sonia (V_2)] in ultimate plots. Yield attributes i.e. weight of primary, secondary and mother rhizomes, number of primary and secondary rhizomes, fresh rhizome yield $clump^{-1}$ and yield ha^{-1} were found to be significantly higher when planted during first fortnight of June. Fertility levels imparted significant effect on plant height, number of tillers $clump^{-1}$, weight of primary, secondary and mother rhizomes, length of mother rhizome, number of primary and secondary rhizomes, fresh weight of rhizome $clump^{-1}$ and yield. These parameters were significantly higher in F_2. Among the varieties, Rajendra Sonia performed better with regard to plant height, number of tillers $clump^{-1}$, weight of mother, primary and secondary rhizomes, length of mother rhizomes, number of primary and secondary rhizomes, fresh rhizome weight $clump^{-1}$ and yield. Among the interactions, Rajendra Sonia supplied with NPK @ 175:75:90 kg ha^{-1} produced higher yield and was at par with F_2V_2 (NPK @ 150:50:60 kg ha^{-1} + Rajendra Sonia).

A study on curcuminoid profile of *Curcuma longa* L. varieties as affected by processing method. 25 (1): 26-33 (2016)

R Priyanka, M Vasundhara, A Jayaram & D Nuthan

An attempt was made to understand the variation in the curcuminoid profile of turmeric varieties. Eight cultivars namely, Local (check), IISR Alleppey Supreme, IISR Kedaram, IISR Prabha, IISR Prathibha, Suvarna, Suguna and Sudharshana were utilized for the study. Curcuminoid content of fresh, dried and cured varieties after

methanolic extraction and quantification through HPLC revealed that Local (check) turmeric in fresh form was significantly superior in curcuminoid content. IISR Prabha and IISR Prathibha in dry and cured form respectively, also exhibited high curcuminoid content.

Nutrient management in turmeric (*Curcuma longa* L.) in an integrated farming system in southern Kerala. 25 (2): 206-209 (2016)

S R Isaac & J Varghese

A field trial was conducted to assess the effect of different organic manures produced *in situ* in an integrated farming system at Farming Systems Research Station, Sadanandapuram during 2012-13 on the performance of turmeric, variety Suguna, grown as component crop in the system under nutrient recommendation of 30:30:60 kg NPK ha^{-1}. Higher plant growth was recorded in the treatment integrating 75% recommended dose nitrogen as organic manures and remaining 25% as inorganic fertilizers. Rhizome yields were significantly highest (42.71 t ha^{-1}) in the treatment receiving vermicompost along with chemical fertilizers followed by poultry manure substitution (33.08 t ha^{-1}) and sole organics-integration of vermicompost enriched with PGPR Mix I with poultry manure and goat manure (31.61 t ha^{-1}). Net returns per ha ranged between Rs. 1.82 lakh (inorganic fertilizers alone) and Rs. 5.8 lakh (vermicompost + inorganic fertilizers) and benefit cost ratios between 1.76 and 3.19.

Effect of scheduling of drip irrigation on growth, yield and water use efficiency of turmeric (*Curcuma longa* L.) var. CO 2. 26 (1): 8-15 (2017)

R Chitra, R M Havaraddi, S Subramanian & J Suresh

Field experiments were conducted during 2012-13 and 2013-14 at Horticulture College and Research Institute, Coimbatore (Tamil Nadu) on black clay loam soil to study the effect of scheduling of drip irrigation on the growth, yield and water use efficiency of turmeric (cv. CO 2). The experiment included two intervals and three levels of irrigation with surface irrigation as control. Significantly higher rhizome yield was recorded in one day interval of irrigation at 80% PE (T_2) (42.79 t ha^{-1}) which was on par with two days interval of

irrigation at 80% PE (T_3) (42.51 t ha^{-1}). Significantly higher number of leaves, leaf area, number of tillers, plant height and dry matter production were recorded in T_2 and T_3 compared to flood irrigation. Both one day and two days interval of irrigation and 40% PE recorded significantly higher WUE. The intervals and levels of irrigation were significantly superior for WUE, compared to surface irrigation.

Effect of intercrops on growth and yield of turmeric (*Curcuma longa* L.). 26 (1): 51-54 (2017)
R Chitra & P Hemalatha
The initial growth of turmeric is rather slow and takes about 4-5 months to cover the inter space. Therefore, the available space between the rows of turmeric could be effectively utilized by growing short duration crops like, vegetables, cereals etc. Hence, it is worthwhile to explore the possibilities of growing compatible crops with turmeric. With this background the experiment on effect of intercrops on growth and yield of turmeric was conducted at Agricultural Research Station, Bhavanisagar. Among the different intercrops, turmeric with cowpea recorded the maximum fresh rhizome yield per hectare (30.78 t ha^{-1}) while turmeric + bhendi registered the maximum B:C ratio (2.68:1). Monocropping of turmeric recorded the lowest B:C ratio (1.67:1) among all the treatments.

Addressing the problem of sub-optimal productivity and curcumin content of turmeric in low input rainfed agricultural system. 26 (2): 114-124 (2017)
A Mishra, A Mishra, B S Rath, S K Mohanty & B Behera
Field experiments were conducted at AICRP for Dryland Agriculture, Orissa University of Agriculture and Technology, Phulbani, Odisha (India) to study the yield performance of 10 important turmeric genotypes, and the effect of five different nutrient management practices on four outstanding varieties in order to address the problem of low rhizome yield and curcumin content of the zone. Based on yield data of 10 turmeric varieties over two years (2007 and 2008) evaluated in RBD with three replications, highest rhizome yield of 21.7 t/ha was observed in Lakdong followed by Rajendra Sonia (16.0 t/ha). The second experiment was laid out in factorial design

involving four varieties and five nutrient treatments with 3 replications. The yield data over five years (2009-10 to 2012-13 and 2014-15) shows Lakdong (9.14 t/ha) to be the best among varieties and lime @ 10% LR + 50% organic + 50% inorganic (9.15 t/ha) among nutrient treatments. Significant variety × nutrient interaction was observed with respect to rhizome yield. Highest rhizome yield was obtained from turmeric variety Lakdong with 100% organic treatment (11.1 t/ha). While two varieties, Lakdong and Phulbani Local exhibited highest yield with 100% organic treatment, performance of Rajendra Sonia was the best with 50% organic + 50% inorganic + lime @ 10% LR and Roma with 50% organic + 50% inorganic. Significant variation was observed among nutrient treatments of all four turmeric varieties for NPK content in shoot and rhizome. The interaction between varieties and nutrient management practices for curcumin content was significant.

Comparison of quality of dry turmeric (*Curcuma longa*) produced by slicing and other curing methods. 27 (2): 138-144 (2018)
E Jayashree, T J Zachariah & R Rakhi

The study determines the effect of slicing and curing turmeric (var. Alleppey Supreme) on the quality of dry turmeric rhizomes produced. The turmeric rhizomes were sliced to 5 mm and the curing methods followed were steam curing in TNAU model turmeric boiler for 60 min and traditional water boiling for 60 min. The drying characteristics curves obtained indicated that the time required for drying was significantly reduced by slicing to 127 h (5 days) and the maximum time of 288 h (12 days) was required for complete drying of steam cured turmeric in TNAU boiler. Quality analysis of the dried turmeric samples indicated that the maximum retention of primary metabolites i.e. carbohydrates, proteins, fat and starch was found in turmeric samples cured by water boiling method for 60 min corresponding to 53.15, 3.16, 2.72 and 49.14%, respectively and the maximum retention of secondary metabolites i.e. essential oil, oleoresin and curcumin content were observed in sliced samples and the values corresponded to 6.23, 10.51 and 3.74%, respectively.

Intercropping summer moong (*Vigna radiata*) in turmeric (*Curcuma longa* L.) - A feasibility study at Punjab. 27 (2): 145-150 (2018)

B Kaur & P K Sraw

On farm trial on the effect of intercropping of summer moong (*Vigna radiata*) on growth, yield, and economics of turmeric (*Curcuma longa* L.) was conducted at farmer's fields in adopted villages of Krishi Vigyan Kendra *viz*., Kandola Kalan, Kaimwala, Mehsampur and Fatehpur in Jalandhar district during 2012 and 2013. The experiment was laid out in randomized complete block design with nine treatments. The treatments were T_1 - sole turmeric flat (30 cm x 20 cm), T_2 - sole turmeric ridge (45 x 15 cm), T_3 - sole turmeric ridge (60 x 10 cm), T_4 - sole turmeric bed (67.5 cm), T_5 - turmeric : summer moong (1:1) flat, T_6 -turmeric : summer moong (1:1) ridge 45 x 20 cm, T_7 – turmeric : summer moong (1:1) ridge 60 x 20 cm, T_8 -turmeric : summer moong (2:1) bed 67.5 cm and T_9 - turmeric : summer moong (2:2) bed 67.5 cm. In intercropping treatments, the planting of turmeric was done on the top of ridge and bed and summer moong was sown in furrows. The data on emergence count (30 and 60 DAS), plant height, tillers plant^{-1} (No.), dry matter accumulation, number of rhizomes (mother, primary, secondary), total rhizomes plant^{-1}, rhizome yield (q ha^{-1}) (fresh, dry and processed) were recorded. The treatments T_8 and T_9 where turmeric was planted on bed with summer moong in the furrow were found to be better for all the characters under study. The highest net returns of Rs. 2.27 x 10^5 ha^{-1} with B:C ratio 4.89 was obtained in T_9 - turmeric : summer moong (2:2) bed 67.5 cm followed by T_8 -turmeric : summer moong (2:1) bed 67.5 cm and recorded lowest net returns of Rs. 1.58 x 10^5 ha^{-1} with benefit: cost ratio 3.51 in T_5 - turmeric : summer moong (1:1) flat. The study revealed that summer moong can be a better option as intercrop in turmeric than the sole turmeric crop for proper utilization of all resources.

Comparative analysis of nutraceutical potential of turmeric grown in different areas of Almora, Uttarakhand. 30 (2): 163-174 (2021)

Vasudha Agnihotri, Smita Rana & Sofiya Anjum

Curcuma longa (Turmeric) is an important medicinal condiment, which is known for its unique phytochemicals and biological activities. Seven turmeric powder samples obtained from five different locations of Almora District, Uttarakhand were compared for their nutraceutical potential in terms of proximate composition, phytochemical constituents such as phenolics and flavonoids, along with their antioxidant potential, curcumin, minerals etc. The commercial brand was taken for comparison purposes. Total fat was found highest in Jamradi sample (10.07%) while lowest was found in commercial sample (2.72%). The curcumin (5.13%), total phenolic (2.12 mg GAE 100 mg^{-1} DW) and flavonoid contents (5.43 mg QE 100 mg^{-1} DW) were highest in the Tani turmeric sample. DPPH activity of Dharad and market samples were quite comparable (0.24 mg AAE 100 mg^{-1} DW), and FRAP activity was highest for Hawalbagh sample (0.44 mg AAE 100 mg^{-1} DW). Total fat, total moisture, phytic acid and oxalate content were identified as main factors causing difference among the turmeric samples.

Phytochemical profiling of petroleum ether and chloroform extracts of *Curcuma caesia* rhizome by GC-MS and comparing their bioactivities. 30 (2): 183-195 (2021)

Rameshor S Atom, Shaukat Ali M Shaikh, Warjeet S Laitonjam, Raghumani S Ninghthoujam & Amit Kunwar

The objective of this study was to characterise the putative phytochemical constituents from petroleum ether (CC-P) and chloroform (CC-C) extracts of *Curcuma caesia* rhizome by GC-MS analysis and to compare their bioactivities. GC-MS analysis facilitated the documentation of a total of 16 and 20 volatile constituents in CC-P and CC-C extracts respectively. Of these the major constituents present in CC-P were cycloisolongifolence, 8, 9-dehydro-9 formyl- (19.64%), 4-oxo β-isodamascol (16.05%), 6,10-dimethyl-3- (1-methylethyl) -6-cyclodecene-1,4-dione (13.80%), 2H-cyclohepta[b]furan-2-one, 6-[1-(acetyloxy)-3-oxobutyl]-3,3a,4,7,8,8a-

hexahydro-7-methyl 3-methylene- (9.08%), tricycle [5.1.0.0(2,4)]oct-5-ene-5-propanoic acid,3,3,8.8-tetramethyl- (6.39%), 2(3H)-benzofuranone,6-ethenylhexahydro-3,6-dimethyl-7-(1-methylethenyl)-, [3S-(3α,3aα,6α,7β,7aβ) (4.18%) and 7a-isopropenyl-4,5-dimethyloctahydroindene-4-carboxylic acid (4.01%). Similarly, the major constituents present in CC-C were cycloisolongifolence,8,9 dehydro-9-formyl-(15.69%), 6,10-dimethyl-3-(1-methylethyl)-6-cyclodecene-1, 4-dione (13.38%), 2H-cyclohepta[b]furan-2-one,6-[1-(acetyloxy)-3-oxobutyl]-3,3a,4,7,8,8a-hexahydro-7-methyl 3-methylene- (4.55%), tricycle [5.1.0.0(2,4)] oct-5-ene-5-propanoic acid,3,3,8.8-tetramethyl- (7.50%), 2(3H)-benzofuranone,6-ethenylhexahydro-3, 6-dimethyl-7-(1-methylethenyl)-[3S(3α,3aα,6α,7β,7aβ) (6.15%), 7a-isopropenyl-4,5-dimethyloctahydroindene-4-carboxylic acid (6.43%) and 2-(4a,8-Dimethyl-6-oxo-1,2,3,4-4a,5,6,8a-octahydro-naphthalen-2-yl) ropionaldehyde (6.57%). The extracts, CC-P and CC-C exhibited almost similar antibacterial and antifungal potentials but differed with respect to antioxidant activity. The IC_{50} values of CC-P and CC-C extracts for DPPH scavenging were 0.68±0.02 mg ml^{-1} and 0.13±0.01 mg ml^{-1}, respectively. Together, above results provide an important basis for the isolation of bioactive compounds from *C. caesia* rhizome extract and their use as traditional medicine.

Quality variation of turmeric during polishing in a power operated turmeric polisher. 31 (1): 34-44 (2022)
E Jayashree & Nejma Basheer

Polishing of turmeric is an important post harvest operation done after drying to improve the surface colour and to obtain a smooth surface finish. Turmeric (variety IISR Prathiba) was cleaned and cured for 1 h in a steam operated turmeric boiler and one batch was dried in a solar tunnel drier of size 9 m × 4 m × 2.6 m and the other batch was sun dried on cemented concrete floor until constant weight was obtained. The turmeric obtained by both the methods were subjected to polishing in a power operated turmeric polisher to obtain clean and yellow coloured turmeric. Based on the physical appearance and surface finish, it was revealed that turmeric polished for 30 min was optimum to obtain turmeric rhizomes of marketable acceptance and

the degree of polishing for solar tunnel dried turmeric was 5.45% and for sun dried turmeric it was 5.20%.

Effect of curing methods on quality and drying characteristics of turmeric. 31 (1): 65-74 (2022)
Tshering Ongchu Lepcha, Shrilekha Das, Babli Dutta & P S Medda
Turmeric rhizomes of Suranjana cultivar were cured by traditional and microwave methods in water and sodium bicarbonate solution and dried in hot air dryer. Effect of curing methods on moisture content, hardness, colour, curcumin content, essential oil content, total phenolic content and drying rate were investigated. Curing methods did not have significant effect on moisture content of cured rhizomes. Hardness of turmeric rhizomes decreased as curing duration increased. Microwave curing in sodium bicarbonate solution for 6 min resulted in maximum value of the colour indices, highest curcumin content (5.20%) and essential oil content (4.38%) in turmeric powder and highest dry recovery (24.20%). Curing caused significant reduction in drying time. Minimum drying time (20.84 h) was required in microwave curing in water for 8 min, whereas, uncured samples took longest time (29 h) for drying. Drying of all the turmeric rhizomes cured by different methods occurred in falling rate period.

Physical and functional properties of low temperature ground turmeric (*Curcuma longa*) powder. 32 (1): 23-31 (2023)
P S Sapariya, N U Joshi & M N Dabhi
Turmeric (*Curcuma longa*) rhizome (var. Salem) sample was ground according to two different grinding parameters *viz*., four grinding methods and two feed temperatures. The effect of grinding methods and feed temperature on some functional and physical properties was evaluated. The average values of the flow property *viz*., bulk density (506.78 to 537.94 kg/m^3), tapped density (611.35 to 635.72 kg/m^3), Hausner ratio (1.150 to 1.225) and compressibility index (13.07 to 18.34%) and functional property *viz*., water absorption index (3.88 to 4.46), water solubility index (16.17 to 26.51%), water holding capacity (268.40% to 307.19%) and oil absorption index (210.57% to 258.04%) with respect to different grinding methods and feed

temperatures varied. The ground sample with chilled water circulation method with the ambient temperature feed (L_2T_0) was found the most suitable for better flow parameters and functional properties.

Crop Protection

Variability in *Colletotrichum curcumae*, the incitant of leaf spot of turmeric (*Curcuma longa* L.) in Vidarbha, Maharashtra, India. 4 (1): 74-77 (1995)
M Y Palarpawar & V R Ghurde
Colletotrichum curcumae, the incitant of leaf spot of turmeric (*Curcuma longa* L.) was found to exist in the form of three different strains in Vidarbha region of Maharashtra, India which could be distinguished by their symptom expression on Waigaon variety of turmeric. These strains differ in their cultural, morphological and physiological characters. Strains 1 and 3 were more virulent than Strain 2. Strain 1 produced symptoms on turmeric flowers also.

Incidence of insect pests of turmeric (*Curcuma longa* L.) in northern Karnataka, India. 9 (1): 51-54 (2000)
Y K Kotikal & K A Kulkarni
A roving survey conducted during 1996-97 at three phases of crop growth in turmeric (*Curcuma longa*) in northern districts of Karnataka (India) revealed the incidence of major insect pests like rhizome fly (*Mimegralla coeruleifrons*), shoot borer (*Conogethes punctiferalis*), lacewing bug (*Stephanitis typicus*), leaf roller (*Udaspes folus*), thrips (*Panchaetothrips indicus*) and scale insects (*Aspidiotus curcumae*) in all the areas and minor pests like various species of leaf beetles, caterpillars and grasshoppers. The population of rhizome fly was high (up to 0.88 adults per m^2) in Raibag, Athani, Mudhol, Indi, Chincholli and Basavakalyan taluks at all stages of crop growth. However, most of the rhizomes that contained maggots of rhizome fly were rotten. Shoot borer was predominant in early vegetative phase (45-60 days) and grand growth stage (100-120 days) of the crop in Raibag, Chikodi, Jamakhandi, Indi and Humanabad taluks.

Evaluation of fungicides for the management of Taphrina leaf blotch of turmeric (*Curcuma longa* L.). 9 (1): 69-71 (2000)
A K Singh, S Edison & Shashank Singh
Evaluation of six fungicides for the management of leaf blotch disease of turmeric (*Curcuma longa*), caused by *Taphrina maculans*, at Madhya Pradesh, India, indicated that all the fungicides reduced the disease severity significantly over control. Lowest disease severity and highest fresh rhizome yield was recorded in Ridomil (500 ppm) which was on par with thiophanate methyl (0.1%), carbendazim (0.1%), Blitox (0.3%) and Antracol (0.3%). Apparent rate of infection was lowest in thiophanate methyl spray followed by Ridomil spray.

Preliminary screening of indigenous collections of turmeric against shoot borer (*Conogethes punctiferalis* Guen.) and scale insect (*Aspidiella hartii* Sign.). 12 (1): 72-76 (2003)
K C Velayudhan & R S Liji
The incidence of shoot borer (*Conogethes punctiferalis* Guen.) and scale insect (*Aspidiella hartii* Sign.) was scored subjectively on 0-9 scale in an indigenous collection of 489 accessions under field epiphytotic conditions at Vellanikkara, Thrissur during 2001 cropping season. The collections belonged to 21 morphotypic groups of turmeric from different agroclimatic conditions in India. Morphotypic group wise incidence of shoot borer indicated that the lowest incidence of mean score 2 was observed in morphotype 2 followed by 2.6 in morphotype 14. Lowest scale insect incidence of 0.5 was scored in morphotype 6. Eighty accessions were free of scale insect but were susceptible to shoot borer. Maximum susceptibility to the scale insect was noticed in the case of IC 137023 and IC 88895. A total of 22 accessions were tolerant to shoot borer with <3 score.

Management of leaf spot of turmeric (*Curcuma longa* L.) incited by *Colletotrichum capsici* through fungicides. 21 (2): 151-154 (2012)
S Narasimha Rao, K Ravindra Kumar & M Anandaraj
An experiment was conducted at Kammarpally (Andhra Pradesh) to evaluate the efficacy of four fungicides *viz*., propiconazole (0.1%), hexaconazole (0.1%), tricyclazole (0.1%) and carbendazim +

mancozeb (0.1%) for the management of leaf spot disease (*Colletotrichum capsici*) of turmeric (*Curcuma* longa L.). Rhizome treatment with carbendazim + mancozeb (0.1%) gave the best results for germination (90.52%) and rhizome treatment and foliar application of propiconazole (0.1%) at 45 and 90 days after planting (DAP) were significantly superior in reducing the disease index (20.01%) of leaf spot disease and increasing the fresh rhizome yield (17.13 t ha^{-1}) as compared to other fungicides tested. The high cost-benefit ratio was achieved in rhizome treatment and foliar application of carbendazim + mancozeb at 45 and 90 DAP (1:1.92).

Penetration and infectivity of entomopathogenic nematodes against *Lema* sp. (Chrysomelidae: Coleoptera) infesting turmeric (*Curcuma longa* L.) and their multiplication. 23 (1): 71-75 (2014)
R Pervez, T K Jacob, S Devasahayam & S J Eapen

Penetration and infectivity of eight native isolates of entomopathogenic nematodes (EPNs), *Heterorhabditis* sp. (IISR-EPN 01); *Steinernema* sp. (IISR-EPN 02); *S. ramanai* (IISR-EPN 03); *S. carpocapsae* (IISR-EPN 06), *Oscheius gingeri* (IISR-EPN 07) and *Oscheius* spp. (IISR-EPN 04, 05 and 08) were evaluated against larvae of leaf feeder (LF) *Lema* sp. infesting turmeric. Among the tested EPNs, *Steinernema* sp. (IISR-EPN 02) and *O. gingeri* (IISR-EPN 07) were more pathogenic to LF larva as they brought about 100% mortality to the insect within 48 h post exposure, followed by *Heterorhabditis* sp. (IISR-EPN 01) and *Oscheius* sp. (IISR-EPN 08) after 72 h of exposure. *S. ramanai* (IISR-EPN 03) and *Oscheius* spp. (IISR-EPN 04 and 05) took 96 and 120 h, respectively, to kill the test insect. *Lema* sp. larva was the most suitable host for multiplication of infective juveniles (IJs) of *O. gingeri* (IISR-EPN 07), which yielded 11, 480 IJs $larva^{-1}$, followed by *Steinernema* sp. (IISREPN 02) (8, 658 IJs $larva^{-1}$) and *S. carpocapsae* (IISR-EPN 06) (6, 810 IJs $larva^{-1}$), however, *Heterorhabditis* sp. (IISR-EPN 01) less multiplied. The maximum number of *Steinernema* sp. (IISREPN 02) IJs penetrated into test larva (17.5 IJs $larva^{-1}$), followed by *S. carpocapsae* (IISR-EPN 06) (10.2 IJs $larva^{-1}$) and the fewest (2.8 IJs $larva^{-1}$) were of *Oscheius* sp. (IISR-EPN 08). The infectivity of the above EPNs against LF is being reported for

the first time which opens up a new hope of utilizing them in insect pest management in turmeric.

Management of leaf spot of turmeric (*Curcuma longa* L.) caused by *Colletotrichum capsici* through fungicides. 24 (1): 66-69 (2015)
R S Mishra & V P Pandey
An experiment was conducted to evaluate the efficacy of four fungicides *viz*., hexaconazole (0.1%), propiconazole (0.1%), tricyclazole (0.1%) and carbendazim + mancozeb (0.1%) for the management of leaf spot disease of turmeric through rhizome treatment + foliar spray and foliar spray alone at 45 and 90 days after planting (DAP). Rhizome treatment with carbendazim + mancozeb gave the best results for rhizome germination (91.13%) followed by propiconazole (88.40%) and hexaconazole (87.33%). Foliar application of propiconazole (0.1%) at 45 and 90 DAP was significantly superior in minimizing percent disease intensity (27.61) with increased fresh rhizome yield (33.96-34.33 t ha^{-1}). C:B ratio was the highest (1:2.65) with foliar spray of propiconazole.

Management of Colletotrichum leaf spot of turmeric through fungicides. 24 (2): 153-156 (2015)
R S Mishra & V P Pandey
The major foliar diseases of turmeric (*Curcuma longa* L.) reported in Uttar Pradesh are leaf spot caused by *Colletotrichum capsici* and leaf blotch caused by *Taphrina maculans*. Leaf spot generally appears in September and October, which can reduce rhizome yield up to 62.5%. Therefore, the experiment was conducted to evaluate the efficacy of four fungicides *viz*., hexaconazole (0.1%), propiconazole (0.1%), tricyclazole (0.1%) and carbendazim + mancozeb (0.1%) for the management of leaf spot disease of turmeric through rhizome treatment + foliar spray and foliar spray alone at 45 and 90 days after planting (DAP). Rhizome treatment with carbendazim + mancozeb (0.1%) gave the best results for rhizome germination (91.13%) followed by propiconazole (88.40%) and hexaconazole (87.30). Foliar application of propiconazole (0.1%) at 45 and 90 DAP was significantly superior in minimizing per cent disease intensity (27.61

PDI) in comparison to foliar spray + rhizome treatment with hexaconazole (28.50 PDI) and tricyclazole (33.73 PDI). The fresh rhizome yield ranged from 33.96-34.33 t ha^{-1} with propiconazole and 31.15-33.22 t ha^{-1} with hexaconazole as compared to the control (28.17 t ha^{-1}). C:B ratio was found to be highest (1:2.65) with foliar spray of propiconazole.

Efficacy of new generation insecticides for the management of shoot borer (*Conogethes punctiferalis* Guen.) (Lepidoptera: Crambidae) of turmeric (*Curcuma longa* L.). 28 (1): 70-73 (2019)
C M Senthil Kumar, T K Jacob & S Devasahayam
The efficacy of nine insecticides and a natural product was evaluated in the field at Peruvannamuzhi (Kerala) for the management of shoot borer (*Conogethes punctiferalis*), a major insect pest on turmeric (*Curcuma longa*). Pooled analysis of data for two years showed that chlorantraniliprole 0.01% treatment had the lowest mean pseudostem damage (0.3%) that was on par with lambda-cyhalothrin 0.01% (1.0%) and flubendiamide 0.02% (1.8%), when these insecticides were sprayed at fortnightly intervals from the second fortnight of July to the first fortnight of November. Fresh rhizome yield was highest in plots treated with lambda-cyhalothrin 0.01% (9.7 kg bed^{-1}) that was on par with flubendiamide 0.02% (9.5 kg bed^{-1}), chlorantraniliprole 0.01% (9.0 kg bed^{-1}) and spinosad (9.0 kg bed^{-1}). The trials indicated that reduced-risk/low-toxic insecticides such as chlorantraniliprole and flubendiamide can be utilized for the management of the pest with less hazard to the environment.

Social Sciences

Instability in turmeric (*Curcuma longa* L.) production in India. 7 (1): 19-22 (1998)
N Ajith Kumar & P G Sankaran
The factors responsible for the instability in turmeric (*Curcuma longa*) production in India were studied. Instability analysis showed that yield instability increased marginally in the eighties. However, the decrease in area instability more than compensated for the increase in yield instability resulting in reduction of production instability.

Decomposition analysis showed that yield instability was the dominant factor affecting production instability. Therefore future development programmes should envisage stabilisation of yield which will stabilise production. The yield instability could be reduced by investing on research towards evolving of cultivars suitable for existing agro-climatic conditions.

ALLIED SPECIES OF TURMERIC

Micropropagation of *Curcuma amada* (Roxb.). 1 (2): 154-156 (1992)
M (Phukan) Barthakur & D N Bordoloi
Rhizome explants of *Curcuma amada* (Roxb.) produced shoots and roots simultaneously when cultured in B_6 medium containing NAA and BAP. This technique would be suitable for field propagation and conservation.

Comparative rhizome anatomy of four species of *Curcuma*. 7 (2): 103-109 (1998)
K K Sherlija, A B Remashree, K Unnikrishnan & P N Ravindran
The anatomy of rhizomes of four economically important species of Curcuma namely, *C. longa* (turmeric), *C. aromatica* (Kasthuri turmeric), *C. amada* (mango-ginger) and *C. zedoaria* (yellow zedoary) were studied, Though all the species basically had similar anatomical characters, variations were noticed in the number and arrangement of primary and secondary vascular bundles, orientation of endodermoid layer, number and shape of starch grains and curcumin cells. Maximum number and. size of curcumin cells were found in *C. longa*. The endodermoid layer formed a continuous ring along with the pericycle in C, longa and was more or less circular in *C. amada*. But in *C. aromatica* and C. *zednaria*, Uris layer was discontinuous and wavy in nature, In C, long14 the meristematic layer was associated with true cambium with ray and fusiform initials, Apart from this, the number of companion cells was directly proportional to metabolic translocation and deposition of reserve substances which can be considered as identifying characters among the species.

Performance of mango-ginger (*Curcuma amada* Roxb.) under different levels of shade. 7 (2): 145-146 (1998)
B K Jayachandran & G Sreekandan Nair
Field trials on the performance of mango-ginger (*Curcuma amada*) conducted at Vellayani (Kerala, India) for two seasons under varying levels of shade revealed that rhizome yield under open and 25 per cent shade were on par indicating that the crop is shade tolerant and is suitable for intercropping situations.

Major nutrient requirement of mango-ginger (*Curcuma amada* Roxb.). 8 (1): 85-88 (1999)
K R Mridula & B K Jayachandran
Field trials conducted at Vellayani (Kerala, India) with factorial combinations of three levels each of nitrogen (15, 30 and 45 kg N ha^{-1}), phosphorus (15, 30 and 45 kg P_2O_5 ha^{-1}) and potassium (30, 60 and 90 kg K_2O ha^{-1}) revealed that N, P_2O_5 and K_2O @ 30 : 30 : .60 kg ha^{-1} was optimum for obtaining maximum net returns and benefit-cost ratio in mango-ginger (*Curcuma amada*).

Empirical model for turmeric (*Curcuma domestica* Val.) yield prediction. 10 (1): 59-61 (2001)
K Kandiannan, K K Chandaragiri, N Sankaran, T N Balasubramanian & C Kailasam
The mean weather variables namely maximum (TMAX) and minimum (TMIN) temperature, maximum (RHMAX) and minimum (RHMIN) relative humidity, rainfall (RAINF), rainy days (RAIND), evaporation (EVPN), wind speed at 8 feet height (WINDS), sunshine hours per day (SUNSH) and total solar radiation (RADN) of different months of turmeric crop season for twenty years (1979-80 to 1998-99) were correlated with yield (dry) in Coimbatore District, Tamil Nadu. Out of the ten variables studied, three variables (TMAX, RHMAX and RADN) did not show significant relationship with yield while the remaining seven variables had significant correlation with yield. These significant variables were further subjected to stepwise regression analysis and those variables, which could be related to yield variability reasonably (EVPN, RHMIN, RAINF, TMIN) were used in the final regression model. This model was used to estimate turmeric

yield in Coimbatore District and it was found that the estimated and observed yields did not differ. This model (Y= -11675.5119 - 591.0617 $EVPN_3$ + 810.3569 $TMIN_5$ + 12.1481 $RAINF_2$ + 91.7499 $RHMIN_9$) can be used to predict the yield of turmeric and total production in Coimbatore District, Tamil Nadu, India.

Response of turmeric (*Curcuma domestica* Val.) to *in vivo* and *in vitro* pollination. 10 (2): 135-139 (2001)
D Renjith, P A Valsala & E V Nybe
Seed set and development were obtained through *in vivo* pollination in three combinations of short duration turmeric cultivars and these were not observed in crosses of medium duration cultivars and short x medium duration cultivars. The fruit developed after *in vivo* pollination was a thick walled trilocular capsule. It took 20-22 days for development and ripening. Arilled seeds are triangular with two seed coats. The seeds are filled with massive endosperm and the embryo is seen oriented towards the chalazal end of the seed. In the *in vitro* pollination studies, culture establishment and ovule development were obtained in half strength MS + NAA 0.5 mg l^{-1} with BAP and kinetin at 1 mg l^{-1} each. Among the various methods of pollination tried, ovule $seed^{-1}$ development was observed in the intra ovarian, placental and modified placental pollination techniques. In the *in vitro* developed seed, the endosperm development was not complete. The aforesaid *in vitro* techniques need refinement with respect to medium and other requirements for the germination of *in vitro* produced seeds.

Studies on the essential oils of *Curcuma haritha* Mangaly & Sabu and *C. raktakanta* Mangaly & Sabu. 11 (1): 78-79 (2002)
Mathew Dan, V George & P Pushpangadan
The essential oils obtained by hydrodistillation from the fresh rhizomes of two endemic species of *Curcuma viz*., *C. haritha* and *C. raktakanta* were studied by GLC analysis. Eleven components were identified from *C. haritha* of which camphor (21.24%) was the major component and ten components were identified from *C. raktakanta* of which ethyl p-methoxycinnamate (16.57%) was the major

component. ά-pinene, ß-pinene, camphor, terpinyl acetate, turmerone and ethyl p-methoxycinnamate were common to both the species.

Rapid multiplication of Kasthuri turmeric (*Curcuma aromatica* Salisb.) through minisett technique and nursery management. 26 (1): 47-50 (2017)

T S Aswathy & P C Jessykutty

The experiment was conducted at Vellayani (Kerala) during 2014 with an objective to standardize minisett method of propagation and nursery techniques for rapid mass multiplication of Kasthuri turmeric. The investigation was taken up as two experiments. In experiment I best pre-sprouting treatments for rhizomes and in experiment II best soil-less coir pith based nursery mixtures for growth of Kasthuri turmeric seedlings were studied. The result indicated that rhizome bits with three node (approximate weight-7g) subjected to pre-treatments with benzyl adenine 100 ppm for 24 hrs was recorded the highest sprouting (95.60%). The improved method of protray seedling production using sprouted rhizome bits and coirpith + vermicompost + *Trichoderma* (1:25) media in 1:1 combination resulted in sturdy, uniform and healthy seedlings for transplanting in the main field.

Evaluation of the antibacterial activity of mango ginger rhizome extracts against bacterial wilt pathogen *Ralstonia solanacearum*. 26 (2): 95-100 (2017)

R Karthika, D Prasath, N K Leela, R Suseela Bhai & M Anandaraj

The Indian mango ginger (*Curcuma amada* Roxb.) is a perennial rhizomatous herb with a raw mango flavour. It is resistant to bacterial wilt disease. In order to understand the disease resistance mechanism of mango ginger the hexane, chloroform and methanol extracts (5, 10, 25, 50 and 100 mg mL^{-1}) and essential oils (1%, 5% and 10%) were tested against the bacterial wilt pathogen *Ralstonia solanacearum* by agar well diffusion method. The hexane, chloroform and methanol extracts showed more or less the same level of antimicrobial activity with a zone of inhibition ranging from 3-9 mm. The essential oils exhibited a zone of inhibition ranging from 3-7 mm. The major constituents of the essential oils were β-myrcene and β-pinene. The

results indicated that the rhizome of mango ginger may contain compounds that are toxic to the pathogen. The extracts of mango ginger could be explored further for developing a natural bactericide against *R. solanacearum*.

Morpho-anatomical characterisation of the rhizomes of ten species of *Curcuma* L. (Zingiberaceae) from South India. 29 (1): 38-47 (2020)

S Anu, M Navas & M Dan

The morphological and anatomical characterisation of ten medicinally and economically important species of *Curcuma* L. from South India namely, *C. aeruginosa* (neela-kua), *C. amada* (manga-inchi), *C. aromatica* (kasturi-manjal), *C. aurantiaca*, *C. caesia* (kari-manjal), *C. haritha* (karpura-kua), *C. longa* (manjal), *C. montana*, *C. zanthorrhiza* (manja-kua) and *C. zedoaria* (chenthandan-kua) were studied and compared. Even though, all the species show similarity in their characters, striking differences were noticed with respect to morphological characters such as shape and size of mother rhizome and lateral branches, colour of the cut surface, aroma and taste of rhizomes etc. Differences were also observed in some anatomical characters such as nature of endodermoid layer, size and shape of starch grains, oil cells and curcumin cells, etc. Based on the distinct morpho-anatomical features, an artificial dichotomous key was proposed for taxonomic delimitation of the species with their rhizome.

VANILLA

Crop Improvement and Biotechnology

Correlations between biometrical characters in vanilla (*Vanilla planifolia* Andrews). 3 (2): 155-157 (1994)
P G Sankaran, K M Kuruvilla & K J Madhusoodanan
A study was undertaken to find out the extent of association among growth attributes of vanilla (*Vanilla planifolia*) and to develop a model for determination of vine length based on biometrical observations. The characters, number of nodes, number of leaves and internodal length were significantly and positively correlated with vine length. The multiple regression equation derived exhibited a precision of 82.5 per cent.

Flowering and fruit set in vanilla (*Vanilla planifolia* Andr.). 5 (2): 148 (1996)
Y G Shadakshari, H M Chandrappa & K Umesha
Cultivation of vanilla (*Vanilla planifolia* Andr.) is becoming increasingly popular in recent years in the hill zone of Karnataka, India. However, information on duration of flower opening and the ideal period for hand pollination is not available for this region. Hence studies on anthesis, stigma receptivity and hand pollination were conducted during March 1992 at the Regional Research Station, Mudigere (Karnataka, India).

Pollen viability and stigma receptivity in vanilla (*Vanilla planifolia* Andrews). 12 (2): 194-196 (2003)
Y G Shadakshari, D Madaiah, M Dinesh Kumar, K V Shivakumar & K H Bhagavantha Goudra
Pollen viability and stigma receptivity period before and after complete flower opening was studied by hand pollinating the flowers/flower buds with its own pollen and fresh viable pollen. Based on the results, the pollen viability periods were 23 h before complete flower opening and 16 h 30 min after complete flower opening. The stigma receptivity periods were 41 h before complete

flower opening and 17 h after complete flower opening under hill zone conditions.

Crop Production and Postharvest Technology

Standardization of rooting media for propagation of vanilla (*Vanilla planifolia* Andr.). 5 (2): 131-133 (1996)
Siddagangaiah, B A Vadiraj, M R Sudharshan & V Krishnakumar
Evaluation of various rooting media indicated that vermicompost and decomposed coir pith were ideal for rooting and multiplication of vanilla (*Vanilla planifolia*).

Processing of vanilla (*Vanilla planifolia* Andrews) beans - Influence of storing fresh beans, killing temperature and duration of killing on quality parameters. 16 (1): 31-37 (2007)
V Krishnakumar, G P Bindumol, S N Potty & C Govindaraju
Experiments were conducted at Myladumpara (Kerala) to study the effect of storing fresh vanilla (*Vanilla planifolia*) beans before killing, killing temperature and duration of killing and further curing on quality parameters. The study indicated that storing of fresh beans for a maximum of 3 days after harvest and before killing is advisable and the vanillin content of such beans was the highest (2.51%) when compared to longer duration of storage. Killing of beans in hot water maintained at 65°C for 3 min or at 63°C for 5 min was on par. Immediate wrapping of killed beans with woolen cloth and storing in sweating box was the ideal method for obtaining optimum weight and vanillin content of beans. A higher percentage of beans (71 to 84) became ready for conditioning within 15 days of slow drying by this method. Interactions of killing temperature and exposing beans either directly or the next day as well as killing temperature and duration of killing were significant.

Crop Protection

Phytophthora rot - A new disease of vanilla (*Vanilla planifolia* Andrews) in India. 9 (1): 73-75 (2000)
R Suseela Bhai & Joseph Thomas
A severe rot disease affecting beans, leaves and stems of *Vanilla planifolia* was observed during the South West monsoon season at Koothattukulam and surrounding areas (Ernakulam District, Kerala, India). The causal organism was identified as *Phytophthora meadii* and its pathogenicity was proved. This is the first report of *Phytophthora* disease of vanilla in India.

Sclerotium rot - A new disease of vanilla (*Vanilla planifolia* Andrews) in India. 9 (2): 175-176 (2000)
Joseph Thomas & R Suseela Bhai
A new type of bean rot affecting vanilla beans was observed in vanilla (*Vanilla planifolia*) growing tracts of Moovattupuzha in Ernakulam District (Kerala, India). The disease was characterized by rotting of bean bunches and subsequent development of thick fungal mat over the bean surface. The causal organism was identified as *Sclerotium rolfsii*; the fungus was brought into pure culture and its pathogenicity was proved. This is the first report of the fungus on vanilla from India.

Mosaic disease of vanilla (*Vanilla planifolia* Andrews) - The first report from India. 12 (1): 80-82 (2003)
R Suseela Bhai, Joseph Thomas, S N Potty, L Geetha & J J Solomon
Recent disease surveys revealed the occurrence of a mosaic disease in vanilla. The infected plants showed mosaic symptoms, distortion of leaves, leaf curling etc. which are typical symptoms of viral infection. Negative staining of the leaf sap with potassium phosphotungstic acid, uranyl acetate and ammonium molybdate revealed the presence of flexuous rod shaped viral particles. This is the first report of occurrence of viral disease in vanilla from India.

Occurrence and distribution of viral diseases on vanilla (*Vanilla planifolia* Andrews) in India. 13 (2): 143-148 (2004)
A I Bhat, M N Venugopal, R P Pant & R Suseela Bhai
Sixty five vanilla (*Vanilla planifolia*) plantations in 28 locations of Karnataka and Kerala were surveyed for the occurrence and distribution of viral diseases. Two viral diseases namely, mosaic and stem necrosis with an average incidence ranging from 0% to 5% and 0% to 10%, respectively, in various locations were noticed. The distribution of the diseases was random and not restricted to any particular region or locality. Electron microscopy of leaf dip preparations of the diseased plants showed three kinds of flexuous particles resembling *Potexvirus*, *Potyvirus* and *Closterovirus*, and an isometric particle.

Brown spot - A new disease of vanilla (*Vanilla planifolia* Andrews) from India. 15 (2): 139-140 (2006)
R S Bhai & M Anandaraj
A new disease characterized by the appearance of small water-soaked spots which later developed into characteristic brownish sunken lesions on vanilla beans (*Vanilla planifolia*) was noticed during September 2004 in Kozhikode District (Kerala) where vanilla is grown as an intercrop with coconut, arecanut and clove. Studies on the causal organism and pathogenicity tests showed that the disease is caused by the fungus *Cylindrocladium quinqueseptatum*.

Occurrence of fungal diseases in vanilla (*Vanilla planifolia* Andrews) in Kerala. 17 (2): 140-148 (2008)
R Suseela Bhai & Jithya Dhanesh
A study was carried out to evaluate the distribution and incidence of various fungal diseases on vanilla (*Vanilla planifolia* Andrews) in major vanilla growing tracts of Kerala. The study included both survey and assessment of diseases as and when reported by farmers. Survey was conducted during April, May and August 2003, March 2004 and November 2005. A total of 111 locations (72 locations during survey and 39 locations from farmer's reports) distributed in six districts were subjected for the study. The major disease noticed in survey during April-May 2003 was yellowing and premature bean shedding

(YPBS). The disease was found associated with *Colletotrichum vanillae* Massae, predisposed by high temperature and low relative humidity. During August 2003, *Phytophthora* incited stem and bean infection was noticed in isolated areas in Kozhikode and Idukki districts. Survey during March 2004 at Kozhikode revealed the recurrence of flower shedding and YPBS, besides root rot caused by *Fusarium oxysporum* f. sp. *vanillae*. Survey during November 2005 in Wayanad area revealed the prevalence of stem and root rot incited by *Fusarium* species along with leaf axil rot incited by *Colletotrichum* sp. In addition, *Rhizoctonia solani*, *Cylindrocladium quinqueseptatum* and *Mucor racemosus* were also isolated as pathogens from different symptomatic parts. Other minor infections noticed were leaf rot, bean rot and brown rot. *Fusarium* and *Colletotrichum* sp. were the predominant pathogens found to be associated with most of the infections on vanilla. The association of *Mucor* sp. with leaf and bean rot and *C. quinqueseptatum* with brown rot were observed as new reports of its kind on vanilla.

ALLIED SPECIES OF VANILLA

Natural fruit set in *Vanilla wightiana* Lindl., an endangered species from Andhra Pradesh, India. 9 (1): 77 (2000)
Y S Rao, K Mary Mathew, K J Madhusoodanan, M R Sudharshan, V Krishna Kumar & S N Potty

Flowers are white and smaller when compared to those of *V. planifolia*. Sepals are oblong and lanceolate and the upper two petals resemble sepals in the case of cultivated species. Likewise, the lower petal is modified as the labellum. Gynostemium which is attached to the labellum as well as the flab like rostellum are much reduced in size when compared to that in *V. planifolia*. Black ants and butterflies frequently visited the flowers, which indicated the possibility of insect pollination directly or indirectly. The mature processed beans had vanillin comparable to that of *V. planifolia*.

***In vitro* propagation of *Vanilla tahitensis* Moore. 9 (2): 171-173 (2000)**

K Mary Mathew, Y S Rao, Gilu Lizy George, R Lakshmanan & K J Madhusoodanan

A commercially viable protocol for mass propagation of *Vanilla tahitensis*, a cultivated species of vanilla, was standardized. A multiplication ratio of 1:4.7 was observed over a culture period of 60-70 days on benzylaminopurine (1 mg l^{-1}) and α-naphthaleneacetic acid (0.1 mg l^{-1}).

TREE SPICES

NUTMEG

Crop Improvement and Biotechnology

***In vitro* proliferation of nutmeg aril (mace) by tissue culture. 1 (2): 142-147 (1992)**
K Nirmal Babu, T John Zachariah, Minoo Divakaran, K Samsudeen & P N Ravindran
Mace from *Myristica fragrans* Houtt. is one of the most expensive of spices. Mace tissue could be successfully multiplied on Mc Cown's Woody Plant Medium (WPM) supplemented with 0.5 mg l^{-1} of IBA. The multiplied tissue retained both the colour and flavour components even after 2 months of culture indicating that their biosynthesis is continuing in culture. Gas chromatographic analysis of the mace oil extracted from the cultured tissue was similar to that of original mace in its qualitative profile.

Effect of packing materials and storage of scions on graft success in nutmeg (*Myristica fragrans* Houtt.). 7 (2): 147-148 (1998)
J Rema & B Krishnamoorthy
Evaluation of various packing materials and storage of nutmeg (*Myristica fragrans*) scions indicated that storage of scions in sealed polythene bags and in moist coir dust in sealed polythene bags were the best and 63.7% and 62.2% graft success respectively, was obtained up to 10 days of storage.

Somatic chromosome number in nutmeg (*Myristica fragrans* Houtt.). 8 (2): 205-206 (1999)
K P M Dhamayanthi & B Krishnamoorthy
The somatic chromosome number in nutmeg (*Myristica fragrans*) was determined to be 38 in root tips, using squash technique.

Repeatability of nut yield in nutmeg. 12 (1): 38-42 (2003)
P M Haldankar, G D Joshi, B P Patil & B M Jamdagni
An investigation was made to study the repeatability of nut yield in 34 nutmeg genotypes under Maharashtra conditions. Remarkable

variation for nut yield was recorded among genotypes. The mean sum of squares of variation between genotypes was predominantly larger than within genotypes. The magnitudes of repeatability were relatively low but the upper confidence limits were reasonably high. The study suggested that, in nutmeg yield recorded over a wider period is more consistent than single yield records at early stages. The genotypes N42, N72, N41 and N37 were found to have potential for nut yield.

Studies on genotypic response of nutmeg to softwood grafting. 12 (2): 139-145 (2003)
P M Haldankar, G D Joshi, B M Jamadagni, B P Patil, A J Kelaskar & V S Sawant
An experiment was conducted to study the success rate of softwood grafting in 22 female, 12 hermaphrodite and 5 male nutmeg genotypes. The variation among genotypes for sprouting, survival and growth parameters was statistically significant. The magnitudes of GCV, PCV, habitability and genetic advance were low for sprouting and survival of nutmeg grafts. The graft survival has strong negative correlation with leaf width. Maximum graft sprouting was associated with the faster production of new leaves with less breadth and longer petiole. The genotypes, N66, N24, N61, N1, N5, N29, N38 and N49 gave the best response to grafting.

Variability for growth, flowering and fruit set in seedling progenies of nutmeg (*Myristica fragrans* Routt.). 13 (1): 28-33 (2004)
P M Haldankar, G D Joshi, B P Patil & P C Haldavnekar
The variability in growth, flowering and fruit set of 39 seedling progenies of nutmeg (*Myristica fragrans*) was studied at Ratnagiri (Maharashtra). Growth was cyclic with two peaks, one in January-February and the second in May. Shoot elongation was rapid during 150-270 days after shoot emergence during first peak. Considerable variation among the genotypes with respect to growth parameters was noticed. Duration of anthesis was short in female flowers and long in male flowers. Significant variations were noticed among genotypes for duration of anthesis and fruit set. Environmental

coefficient of variation was very low for fruit set and duration of anthesis. Higher magnitudes of phenotypic coefficient of variation and genotypic coefficient of variation indicated good amount of variation among the genotypes for these characters. High estimates of heritability and genetic advance for fruit set suggested that it is under the control of additive gene action.

Studies on germination and seedling vigour characters for genotype selection in nutmeg (*Myristica fragrans* Houtt.). 14 (2): 137-144 (2005)

P M Haldankar, G D Joshi, B M Jamadagni, V S Sawant & A J Kelaskar

An experiment was conducted at Ratnagiri (Maharashtra) to study the regeneration ability and variability of 34 nutmeg (*Myristica fragrans*) seedling genotypes. The variations recorded for germination percentage, period required for germination and seedling growth parameters were significant. Higher magnitudes of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance on per cent mean basis were recorded for fresh seed weight, germination percentage, days for germination and root length. The selection of nutmeg genotypes at seedling stage on the basis of vigour of the characters such as number, length and breadth of leaves, collar thickness and petiole length would help to identify genotypes for propagation. Among the genotypes studied, N22, N24, N26, N29, N34, N37, N38, N42, N43, N51, N63 and N72 were promising.

IISR Keralashree - A high yielding and high quality nutmeg (*Myristica fragrans* Houtt.). 25 (1): 56-59 (2016)

P A Mathew, B Krishnamoorthy, J Rema, T John Zachariah & B Sasikumar

An accession of nutmeg IC-537218 derived from an open pollinated seedling progeny of a high yielding tree from Burliar, Nilgiris, Tamil Nadu, was evaluated under a farmer participatory mode at three locations in two states, Kerala and Tamil Nadu, for yield characters, for 13 years and this accession was found superior for mace and nutmeg yield over the existing variety, IISR Vishwashree, in all the

yield parameters studied. The tree is a pure female which flowers profusely and bears oblong shaped yellow fruits. The aril is thick and covers the entire seed and is dark red in colour. The nut is bold and brownish black in colour. The mace and nut of the new variety is rich in sabinene.

Variability in fruit characteristics of nutmeg (*Myristica fragrans* Houtt.) under Kerala conditions. 25 (2): 187-194 (2016)

H C Vikram, N Mini Raj, K T Presanna Kumari, E V Nybe & D Mathew

Forty one accessions of nutmeg collected from diverse locations of Kerala of age 15 years were evaluated at Kerala Agricultural University, Thrissur during 2012-14. Among these accessions, 38 were females and three were monoecious. The accessions were evaluated based on 17 fruit characters recorded from two trees per accession during two consecutive bearing seasons. The statistical parameters *viz*., mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (H^2), genetic gain (GG) and genotypic correlation coefficients were calculated. High PCV and GCV were observed for the characters such as fruit weight, mace weight, mace volume, dry nut weight, kernel weight, fruit volume and number of fruits per tree. Heritability was high for all the characters except shell thickness. High GCV coupled with high heritability in the characters indicated the scope for yield improvement through selection based on these characters. Genetic gain was the highest for number of fruits per tree (144.3%) followed by mace characters *viz*., fresh and dry weight as well as volume of nut. Fruit weight was also significantly and positively correlated with fruit breadth, fruit volume and thickness of pericarp. Based on the results, accessions such as Acc. 9, Acc. 8 and Acc. 22 were found promising with respect to the economic characters *viz*., mace weight, nut weight, kernel weight and number of fruits per tree. These accessions can be used in further crop improvement programmes on nutmeg.

A note on a seed sterile nutmeg from the secondary centre of domestication. 26 (1): 44-46 (2017)
B Sasikumar, K V Saji & J Rema
A unique nutmeg accession having normal fruit, but with rudimentary, sterile seed and finely packed mace having a human brain like appearance was collected from a farmer's garden from the secondary centre of domestication of the crop and characterized. Seed (female) sterility in a dioecious or emerging monoecious plant like nutmeg is hitherto not recorded and is a novelty. This unique accession is conserved at the germplasm conservatory of tree spices at the ICAR-Indian Institute of Spices Research, Kozhikode, Kerala.

Diversity in floral characters of monoecious nutmeg (*Myristica fragrans* Houtt.). 27 (1): 66-70 (2018)
S Aarthi, J Rema, B Sasikumar, K V Saji & M Anandaraj
Floral diversity in monoecious type nutmeg reveals three types of flowers namely; pistillate, staminate and hermaphrodite flowers. The structure of hermaphrodite flowers in nutmeg is reported for the first time. The flowers are borne on the leaf axil, flowering habit of the three types of flowers are seen in cymes as well solitary in the same tree. The gynoecium consists of single ovary with bifid stigma in the pistillate flowers and the androecium of staminate flowers has adnate 7-13 anthers. Intra flower variability is evident in case of hermaphrodite flowers. In hermaphrodite flower the androecium ranges with 1-4 anthers, in the form of fused filament or free filament or both; some anthers are fused with the gynoecium. Besides remnants of the stamen in the developed fruits of hermaphrodite flowers, staminodes are also observed in the flowers. Colour of all the three types of flowers are light creamy yellow, with thick gamosepalous perianth which bursts as bilobed, trilobed, tetralobed and pentalobed lobes during anthesis. Analysis of variance of trees for flower types and floral attributes like flower type, number of anthers, length of anthers, length of filaments and length of ovary are found to be highly significant. High coefficient of variation is recorded for hermaphrodite (183.84) and pistillate (171.71%) flowers. The pollen viability of the hermaphrodite flowers are found less as compared to the staminate flowers. The percentage of pollen viability is 79.74%

and 90.77% in hermaphrodite and male flower respectively. In the population studied, the occurrence of hermaphrodite flower in monoecious tree ranged from 0-10%.

Air layering in nutmeg (*Myristica fragrans* Houtt.). 28 (1): 66-69 (2019)

V A M Nissar, B Sasikumar, S Aarthi & J Rema

Nutmeg is an important perennial spice crop, which is dioecious in nature. Vegetative propagation is the norm in commercial propagation of the tree. The existing practice of propagation is grafting and budding which needs good skill and expertise for reasonable success. As an alternative to these two methods, air layering was attempted in matured trees for the first time in the country. Air layering was successful in plagiotropic and orthotropic shoots with 100 per cent survival. This method is cost effective and is easy for adoption.

High yielding nutmeg (*Myristica fragrans* Houtt.) varieties : A farmer-centric research approach to select superior trees. 32 (2): 148-160 (2023)

N Miniraj, H C Vikram, E V Nybe & Manu Philip

A comprehensive survey was conducted in the nutmeg-growing region of Kerala state to locate superior clones of nutmeg, by employing Participatory Varietal Selection (PVS) method. Twenty nine superior accessions were identified through mother tree characterization for four consecutive years. The characterized clones were female and produced fruits ranging from 628 to 2250 tree^{-1} year^{-1}, dry nut weight varied from 3.27 g to 15.37 g, and assorted dry mace weight varied from 0.35 g to 4.80 g. Genetic variability analysis revealed high heritability with high genetic advance as *per se* mean (dry mace weight 76.30%, dry kernel weight 71.37% and the number of fruits tree^{-1} 73.24%) which signifies the advantage of simple selection method of breeding. Based on the economic importance of yield contributing characteristics, five superior clones out of twenty nine mother trees evaluated have been released as KAU-farmer's varieties. All the superior trees identified based on yield traits had appreciable quantities of volatile oil (1.63-12.25% in nut; 3.31-

16.97% in mace), oleoresin (17.60-41.77% in nut; 13.00-30.50% in mace) and fixed oil (22.45-40.70% in nut) in their nuts and maces as well as myristicin, elemicin, safrole and sabinene in the volatile oils. The characteristic features of mother trees and released varieties are discussed in this paper, and further, these varieties are recommended for commercial cultivation under tropical moist, humid climate conditions.

Crop Production and Postharvest Technology

Chemical composition of nutmeg and mace. 1 (1): 49-54 (1992)
M Gopalakrishnan
The proximate analysis of nutmeg and mace, unlike in earlier reports, has been carried out using the raw spices. The major hallucinogenic principle in Indian nutmeg/mace oils appears to be myristicin which is present in good amount. GC profiles of the oils compared very well with reports in literature. The rind of the nutmeg fruit contain good quality pectin upto 14%.

Effect of chemical treatment on germination of nutmeg (*Myristica fragrans* Routt.) seeds. 10 (1): 57-58 (2001)
M Gunasekaran, D Prasath & V Krishnasamy
Studies were undertaken to evaluate the influence of pre-sowing treatment of nutmeg (*Myristica fragrans*) seeds with various chemicals on the viability of seeds and seedling vigour. Among the various chemicals evaluated, gibberellic acid (100 ppm) was most effective and resulted in significantly higher germination (85%) and vigour index value (3945).

Chemical composition of essential oil of nutmeg (*Myristica fragrans* Houtt.) accessions. 13 (2): 135-139 (2004)
K M Maya, T John Zachariah & B Krishnamoorthy
Sixty five nutmeg (*Myristica fragrans*) germplasm accessions from Indian Institute of Spices Research, Experimental Farm, Peruvannamuzhi (Kerala), were evaluated for chemical composition of essential oil of nutmeg and mace and variability was observed among the accessions. The major constituents of significance in the

essential oil were sabinene, safrole, myristicin and elemicin. Among the accessions, A9/71 and A9/95 had high sabinene and low hallucinogens namely, myristicin, elemicin and safrole, in both nutmeg and mace oils.

Effect of rooting media on germination and seedling growth of nutmeg (*Myristica fragrans* Houtt.). 15 (2): 100-104 (2006)
R G Khandekar, L K Dashora, G D Joshi, P M Haldankar, U A Gadre, M C Jain, P C Haldavnekar & V S Pande
Experiments conducted on germination of nutmeg (*Myristica fragrans*) seeds at Dapoli (Maharashtra) indicated that there were significant differences in germination of seeds sown in different media. The mean germination was significantly higher in seeds sown in rice bran (82.3%) which was on par with sand (82.0%) and sand + rice bran (81.7%). These media also recorded significantly lesser time for first emergence namely, 27.17 days (rice bran), 28.10 days (sand + rice bran) and 28.50 days (sand), respectively. The time taken for final emergence was also significantly lower in seeds sown in rice bran (80.83 days), sand + rice bran (81.60 days) and sand (82.17 days), respectively. The vegetative growth of seedlings namely, shoot length, shoot diameter, number of leaves and leaf area were also significantly higher in these media namely, rice bran, sand + rice bran and sand at 30, 90 and 180 days after germination.

Chemical composition of nutmeg and mace (*Myristica fragrans* Houtt.) from Tellicherry and Kannur regions, Kerala. 18 (2): 108-110 (2009)
K M Abdurrasheed & C Janardanan
The chemical composition of nutmeg and mace of *Myristica fragrans* collected from Tellicherry and Kannur areas (North Kerala) was studied. The study indicated that the nutmeg and mace obtained from these areas is comparable in quality (with minor variations) to that reported from other areas.

Pulsed microwave assisted hot air drying of nutmeg mace for better colour retention. 25 (1): 84-87 (2016)

J N Meetha, P Muhammadali, M I Joy, R Mahendran & A Santhakumaran

A study was conducted on application of novel drying technology for better colour retention of mace. Pulsed microwave assisted hot air drying was investigated at three different power levels 0.5 kW, 1 kW and 1.445 kW with 30 seconds pulsation at a hot air temperature of 45°C and the colour values of mace were compared with the market and fresh sample using colourimeter. Further, the major flavour compound, myristicin in mace was analyzed.

Nutmeg with yellow arils - Potential tree spice with high essential oil content. 31 (1): 100-106 (2022)

M G Govind, **R Ananthakrishnan**, **Mathew Dan**, **M Madhukrishnan**, **K V Radhakrishnan & K B Rameshkumar**

The mace derived from the arils of *Myristica fragrans*, is red in colour, whereas the present study reports the evaluation of *Myristica fragrans* with yellow arils. Morphological features of fruits of *M. fragrans* with yellow arils and that of common red aril variant from cultivated locations in Kerala, South India, were similar. The average mace yield was higher for the yellow arils (2.5 kg plant^{-1}) than the red arils (2.0 kg plant^{-1}). The volatile chemical profiling revealed that the essential oil yield of the yellow mace (19.3% v/w) was more than two fold higher than standard red mace (9.2% v/w). GC-MS analysis showed that the distribution of monoterpenoids, sesquiterpenoids, and phenylpropanoids were similar in both the varieties, except for the percentage distribution. The major constituents of mace of both the red and yellow types were α-pinene, and sabinene followed by elemicin and safrole. Though an exotic species, *M. fragrans* has been naturalized in South India, and several high-yielding varieties have been reported from the region. The present study highlights nutmeg with yellow arils as a potential spice crop with high oil yield.

Physicochemical quality evaluation and drying characteristics of nutmeg (*Myristica fragrans*) dried in a solar tunnel dryer with biomass backup. 31 (2): 166-176 (2022)
E Jayashree & Desmond Joseph
Experiments on drying of nutmeg was performed in a solar tunnel dryer with biomass back up and in a mechanical dryer under three varying temperatures of 45°C, 50°C and 55°C. Drying of nutmeg in solar tunnel dryer was completed in 147 h, while in a mechanical dryer, drying was completed in 105 h, 102 h and 78 h at drying temperatures of 45°C, 50°C and 55°C, respectively. Solar tunnel dried nutmeg had maximum physical quality retention of bulk density (484.88 kg m^{-3}) and kernel recovery (70.63%) whereas dry recovery of nut (61.88%) and shell recovery (31.55%) were maximum in mechanically dried samples at 55°C and 45°C, respectively. Secondary metabolites like essential oil (10.67%) and oleoresin (23.25%) were higher in mechanically dried nutmeg at a drying temperature of 45°C. Volatile oil constituents like β-pinene, safrole, terpineol, γ-terpinene, α-thujene, α-terpinene and myristicin content were highest in solar tunnel dried nutmeg.

Crop Protection

A new record of horse hair blight on nutmeg (*Myristica fragrans* Houtt.) from India. 9 (2): 169-170 (2000)
Baby P Skaria, Sajitha Kumari, J Thomas, Samuel Mathew & P P Joy
A new record of horse hair blight disease caused by *Marasmius equicrinis* on nutmeg (*Myristica fragrans*) observed at Rayamangalam Panchayat of Ernakulam District in Kerala, India, is reported. The formation of mycelial hairs on the plant caused drying of leaves and branches getting themselves hung on the mycelial network giving a 'bird's nest' appearance.

ALLIED SPECIES OF NUTMEG

Pollen viability, germination and pollination in *Myristica fatua* Houtt. var. *magnifica* (Beddome) Sinclair - A threatened taxon of Western Ghats, India. 4 (2): 135-138 (1995)
P Rama Bhat & K M Kaveriappa

A study of anthesis, pollen viability and pollination in *Myristica fatua* var. *magnifica* showed that anthesis took place early in the morning and anther dehiscence about 36-48 h prior to anthesis. The pollen grains held inside the flower get released as a cloud at the time of anthesis. Male flowers are shed 36-48 h after anthesis. The pollen grains are sticky, pilated in sculpture, spherical and without any visible aperture. Pollen germination commenced 2 h after dusting the grains on slides containing sucrose solution and was completed in about 6 h. Maximum germination (67.3 per cent) was obtained in 5% sucrose solution and the length of pollen tube was also maximum in this concentration. The stained and unstained pollen grains varied in size and the former measured more than the latter. The viability of freshly collected pollen as determined by their stainability in acetocarmine was 94.3 per cent. Among the 10 species of insects collected from trees during flowering, *Cremastogaster* sp., *Sima nigra* and *Syrphis* sp. were most common.

Chemical composition of leaf oils of *Myristica beddomeii* (King), *Myristica fragrans* (Houtt.) and *Myristica malabarica* (Lamk.). 17 (1): 10-15 (2008)
T John Zachariah, N K Leela, K M Maya, J Rema, P A Mathew, T M Vipin & B Krishnamoorthy

Essential oil constituents of leaves of three *Myristica* species namely, *Myristica beddomeii*, *M. fragrans* and *M. malabarica* were determined by gas chromatography and gas chromatography-mass spectrometry. *M. fragrans* was dominated by monoterpenes (91%), *M. beddomeii* contained mono-(48%) and sesquiterpenes (35%) whereas *M. malabarica* was dominated by sesquiterpenes (73%). The leaf oil of *M. beddomeii* was dominated by α-pinene (19.59%), t-caryophyllene (14.63%) and β-pinene (12.46%). The leaf oil of *M. fragrans*

contained sabinene (19.07%), α-pinene (18.04%), 4-terpineol (11.83%), limonene (8.32%) and β-pinene (7.92%) as major compounds, while t-caryophyllene (20.15%), α-humulene (10.17%), nerolidol (9.25%) and δ-cadinene (6.72%) were predominant in the oil of *M. malabarica*. Linalool, α-terpineol, t-caryophyllene, β-elemene and γ -elemene were present in all the three species. This is the first report on the essential oil composition of *M. beddomeii* leaves.

Optimization of DNA isolation and PCR parameters in *Myristica* sp. and related genera for RAPD and ISSR analysis. 17 (2): 91-97 (2008)

T E Sheeja, K Johnson George, Jessy Jerome, R Sandeep Varma, S Syamkumar, B Krishnamoorthy & V A Parthasarathy

An efficient protocol for isolation of DNA from wild and related genera of *Myristica* rich in polysaccharides and polyphenols was developed. The protocol utilizes CTAB (3%), 1.5% PVP and 0.3% β-mercaptoethanol for isolation and RNase and phenol chloroform extraction for purification. The yield of DNA ranged from 25-175 μg/g of fresh leaf tissue, with *Knema andamanica* giving the highest yield. The present method yielded 10 times higher than the old methods. Characteristic patterns were generated on digestion of DNA by Ecor I and Hind III restriction enzymes. PCR parameters were optimized using random primers (OPERON Technology, USA). DNA concentration at 20 ng/reaction, annealing temperature of 45°C, 0.3 mM dNTP in presence of 0.5 U of Taq DNA polymerase, and 2.0 mM $MgCl_2$ and MJ Research Gene Thermocycler was best. Successful amplification by ISSR and RAPD primers indicated that DNA is of good quality and free of polysaccharides and polyphenols.

Genetic diversity analysis of *Myristica* and related genera using RAPD and ISSR markers. 22 (1): 38-46 (2013)

T E Sheeja, C Sabeesh, O V Shabna, R S Shalini & B Krishnamoorthy

Genetic diversity among seven species of *Myristica*, two of its related genera and an unidentified species was analyzed using 46 PCR markers (30 RAPD and 16 ISSR). This is the first study on molecular genetic diversity of the rare, endangered and endemic *Myristica*

species and its related genera. RAPD and ISSR analyses yielded 497 and 262 bands with 98.1% and 97.3% polymorphism, respectively. By combining markers, a total of 759 bands were detected of which 743 (97.8%) were polymorphic with an average of 16.1 bands per primer. High level of existing genetic variability was evident from the high percentage of polymorphism. Combined analysis of RAPD and ISSR markers resulted in better distinction of species. The mean polymorphic information content (PIC) indicated that both the marker systems are effective in detecting polymorphism either individually or in combination. Similarity coefficient (Jaccards) varied from 0.22 to 0.62 when markers were combined and the pattern was similar to RAPD with a high Mantel matrix correlation (r = 0.95). Principal Coordinates Analysis (PCA) conformed to cluster analyses. First three most informative PC components explained 51.1%, 49.3% and 46.5% of total variation. A maximum similarity of (63%) was observed between *Gymnocranthera canarica* and the unidentified species of *Myristica*. *Knema andamanica* and *Myristica prainii* were found to be the most distinct (17.7%). Similarities at molecular level were close to either the morphological traits (mace and fruit/seed characters) or the geographical location. Species specific bands could be identified from all the accessions under study, which has the potential for development into SCAR (Sequence Characterised Amplified Region) markers for genotype fingerprinting or development of specific DNA probes for identification and authentication.

DNA barcoding to resolve phylogenetic relationship in *Myristica* spp. 28 (2): 131-140 (2019)

V P Swetha, T E Sheeja & B Sasikumar

Myristica is the largest and primitive genus of the taxonomically complex family Myristicaceae. DNA barcoding was used to study the evolutionary relationship between Myristica spp. and other genera of Myristicaceae. The barcoding loci namely, rbcL, matK, psbA-trnH, ITS and multilocus combinations were tested to assess their phylogenetic relationship. psbA-trnH locus revealed information regarding the relationship of species in *Myristica* genus. *M. fragrans* was found to be closely related to *M. beddomei*, *M. amygdalina*, *M. andamanica*,

whereas *M. fatua* was found to be distinct from *M. malabarica*. *Gymnocranthera* and *Knema* species were found to share sister relation with other *Myristica* spp.

CLOVE

Crop Improvement and Biotechnology

Three promising morphological variants in clove (*Syzygium aromaticum* (L.) Merr. & Perry) from Tamil Nadu, India. 3 (2): 168 (1994)
B Krishnamoorthy & J Rema
The oldest clove plantation in India is in Ashamboo hills (Kanyakumari district), the southernmost hills of the country. Surveys were undertaken in these hills from 1992 onwards for identification of elite clove trees and variant types. Three distinctly different morphological variants located during the surveys are reported here.

Soft wood grafting in clove (*Syzygium aromaticum* (L.) Merr. & Perry) on related species. 8 (2): 215 (1999)
P A Mathew, J Rema & B Krishnamoorthy
The study indicated that the number of successful unions in various species is very poor indicating incompatibility barriers between clove and the related species. Clove survived only on *S. heynianum* root stock after 2 years of observation and the survival percentage was only 3.6. The shoot growth of these plants were normal without any dwarfing effect. On other species of *Syzygium*, yellowing of leaves was observed akin to nitrogen deficiency before mortality.

Reversal of dwarfness in a short-statured variant of clove (*Syzygium aromaticum* (L.) Merr. & Perry) by approach grafting. 15 (1): 57-58 (2006)
P A Mathew, J Rema & B Krishnamoorthy
Approach grafting of short-statured variant (dwarf) of clove (*Syzygium aromaticum*) was successful on ordinary clove rootstock

and the graft union was obtained in 6-8 months with 64% success and 100% field establishment. The resultant graft had the appearance of ordinary clove with increase in internodal length of the scion shoot. But when ordinary clove was approach grafted to dwarf clove rootstock the internodal length of the scion was reduced. The study indicated that the rootstock had a definite influence on the scion, with regard to growth in clove.

Crop Production and Postharvest Technology

Nutrient management in clove (*Syzygium aromaticum* L.) for sustainable production. 17 (2): 194-196 (2008)
R Swarna Piria & M Jayasekhar
An experiment was carried out to formulate nutrient management for sustainable production on 10-year-old trees of clove. Both organic and NPK fertilizers were used in 6 combinations. Though no marked difference between treatments were observed, the combination of 5 kg of vermicompost, 150: 300: 900 g NPK and a foliar spray of 2% panchkavya recorded the highest yield.

Variation in the oil content in different parts of clove bud and from different geographical regions. 31 (1): 97-99 (2022)
Riya Bhosle, Shraddha Dighe, Drushti Kute, Gopaal Ahuja, Ganesh Ahuja & Kirti Laddha
This study determined the difference in oil content from separated parts of clove buds, full bud with crown, clove bud without crown and dust (stamen and style), and only crown along with dust from market sample. Results showed that the highest oil content in clove bud without a crown. Oil yield varied in clove buds from different geographical regions wherein, Madagascar showed the highest amount of oil.

Social Sciences

The economic landscape of clove production in India: Challenges and opportunities. 32 (2): 161-169 (2023)

Lijo Thomas, K Anees & V A Muhammed Nissar

Clove is a valuable spice commodity with high demand in India, yet domestic production has remained stagnant, leading to import dependency. This study analyzed the clove economy in India, focusing on production trends, trade patterns, cost of production, and returns from clove farming. The data from primary survey of 40 clove plantations from five clove growing regions of Kerala (Idukki, Kozhikode and Kollam districts) and Tamil Nadu (Kanyakumari and Tenkasi districts) were used to estimate the cost of production and profitability of clove farming. The cost of production was estimated to be Rs. 581 per kilogram of dry clove. The study reveals that clove cultivation faces challenges such as low genetic variability, poor agronomic practices, inadequate soil fertility management, biotic stress factors, senile plantations, unorganized markets, and labour shortages during harvest. These challenges constrain domestic production and hinder profitability. Intervention opportunities include developing high yielding, disease resistant varieties, enhancing extension services and training, strengthening disease and pest control measures, encouraging replanting and rejuvenation of senile plantations, establishing organized markets and price stabilization mechanisms, and addressing labour shortages during harvest. Addressing these challenges and implementing suggested interventions can increase domestic clove production, reduce import dependency, and improve the profitability and sustainability of clove farming in India.

CINNAMON

Crop Improvement and Biotechnology

Variability and association studies in cinnamon (*Cinnamomum verum*). 1 (2): 148-150 (1992)
B Krishnamoorthy, B Sasikumar, J Rema, A Gopalam & Jose Abraham
Seventy one *cinnamon* accessions studied for variability and association revealed high coefficient of variation for dry and fresh bark yield, bark oleoresin, leaf oil, bark oil, leaf size index and percentage recovery of bark. Association analysis revealed significant correlation of fresh weight of bark and leaf oil with dry hark yield. Bark oil was negatively associated with leaf oil.

Rooting response of elite cinnamon (*Cinnamomum verum* Bercht & Presl.) lines. 2 (1&2): 21-25 (1993)
J Rema & B Krishnamoorthy
Rooting of terminal cuttings of cinnamon (*Cinnamomum verum*) with indole butyric acid 2000 ppm was standardized. Nine elite lines of cinnamon superior in their yield and quantity were studied for variability in their rooting capacity. Cinnamon line SL-5 was the best with high rooting percentage and good development of primary and secondary roots.

Navashree and Nithyashree - Two new high yielding and high quality cinnamon (*Cinnamomum verum* Bercht & Presl.) selections. 5 (1): 28-33 (1996)
B Krishnamoorthy, J Rema, T John Zachariah, Jose Abraham & A Gopalam
Nine elite cinnamon (*Cinnamomum verum*) lines were evaluated for their yield and quality during 1990-95 at the Experimental Farm of Indian Institute of Spices Research at Peruvannamuzhi (Kerala State, India). Two lines, namely, SL 63 and In 189 yielding 55.6 kg and 54.2 kg dry bark/ha per year, respectively, were selected based on their regeneration capacity, yield and quality. These two lines named Navashree and Nithyashree also had higher bark and leaf oil and

oleoresin contents and have been recommended for cultivation in all cinnamon growing areas in India.

Air layering in *cinnamon* (*Cinnamomum verum* L.) under wet humid tropical conditions. 27 (1): 71-73 (2018)
A A Waman & P Bohra
Cinnamon is a cross pollinated species and seed propagation has resulted in development of considerable variability in growth, yield and quality among the populations. Air layering has been considered as one of the efficient methods of multiplication in cinnamon. However, the success of layering varies greatly depending on the local environmental conditions. In the present investigation, air layering was performed at 20 days interval during rainy season (July 3rd to October 11th) of two consecutive years in Bay islands. Result revealed that first week of July was the most suitable time for air layering in cinnamon as it supported better rooting percentage (87.5%).

Crop Production and Postharvest Technology

Quality attributes of cinnamon (*Cinnamomum verum* Bercht & Presl.) accessions grown at Shevroys (Tamil Nadu, India). 9 (2): 177 (2000)
R Richard Kennedy, K Nageswari & G Balakrishnamoorthy
The quality of bark and leaf of cinnamon (*Cinnamomum verum* Bercht & Presl.) is determined by their oil and oleoresin contents. The quality of cinnamon is known to vary depending on the region where they are grown (Pruthi 1979). Five accessions of *cinnamon* collected from Indian Institute of Spices Research, Calicut, are being maintained at Horticultural Research Station, Yercaud (Tamil Nadu, India) (1450 m<MSL). The quality parameters of these accessions were analysed and are reported here.

Effect of short and long-term storage on essential oil content and composition of cinnamon (*Cinnamomum verum* Bercht. & Presl.) leaves. 15 (1): 19-24 (2006)
B R Rajeswara Rao, D K Rajput, P N Kaul, A K Bhattacharya & A A Naqvi
The effect of duration of storage of cinnamon (*Cinnamomum verum*) leaves on the content and chemical composition of essential oil was studied. The results revealed that neither the essential oil content (1.9%-2.2%), nor the chemical composition of essential oil (eugenol 87.1%-90.7%; eugenyl acetate 2.9%-5.5%; linalool 0.8%-1.2%; benzyl benzoate 0.3%-0.6%) was affected during the storage of leaves for up to 15 months.

Essential oil composition of petiole of *Cinnamomum verum* Bercht. & Presl. 16 (1): 38-41 (2007)
B R Rajeswara Rao, D K Rajput & A K Bhattacharya
Essential oil isolated from the petiole of *Cinnamomum verum* was analysed by gas chromatography and gas chromatography-mass spectrometry. Twenty five compounds accounting for 87.31% of the total essential oil were identified. (E)-Cinnamaldehyde (33.04%) followed by eugenol (17.32%), linalool (16.85%) and (E)-cinnamyl acetate (11.78%) were the main components of the essential oil. This is the first report on the composition of essential oil of petiole of *C. verum*.

Effect of time of pruning and peeling on the bark yield of cinnamon (*Cinnamomum verum* J. Pres.) in Andaman and Nicobar Islands. 19 (1&2): 50-52 (2010)
I Jaisankar, V Damodaran, D R Singh & R Sudha
An experiment was conducted at Port Blair, Andaman and Nicobar Islands, to study the effect of time of pruning and peeling on the yield of cinnamon (*Cinnamomum verum*) intercropped in an arecanut (*Areca catechu*) garden. Pruning and peeling was carried out at 20 days interval from first week of June to August during both the years. The number of branches (31) and girth (19.98 cm) were significantly higher in 10th July pruning. Bark yield tree^{-1} (both fresh and dry weight) was also significantly higher during 10th July (4.03 kg fresh

and 1.22 kg dry weight) pruning indicating that this period is ideal for pruning and peeling cinnamon in Andaman and Nicobar Islands.

Physical properties of cinnamon bark. 21 (2): 161-163 (2012)
S Balasubramanian, K K Singh, Ashish M Mohite & T John Zachariah

Physical properties of cinnamon (*Cinnamomum verum* J. Pres) bark (var. Nityashree) were determined by dividing into three grades (I, II and III) according to their size at 10.15% (db) moisture content. The values of length, breadth and thickness for grade I were 48.38 mm, 7.34 mm and 1.37 mm; for grade II were 71.81 mm, 8.45 mm and 1.00 mm; for grade III were 104.95 mm, 8.15 mm and 0.98 mm, respectively. Unit volume and surface area for grade I were 214.80 mm^3 and 159.68 mm^2; for grade II were 364.92 mm^3 and 226.33 mm^2; for grade III were 409.85 mm^3 and 242.85 mm^2, respectively. Bulk density and true density for grade I were 144.56 kgm^{-3} and 177.60 kgm^{-3} for grade II were 148.44 kgm^{-3} and 186.87 kgm^{-3} for grade III were 132.08 kgm^{-3} and 202.91 kgm^{-3}, respectively. Porosity, angle of repose for grade I was 14.20% and 40.69°; for grade II were 20.95% and 41.56°; for grade III were 37.72% and 42.30°, respectively. The coefficient of static friction with respect to different surfaces *viz*., plywood, galvanized iron and aluminium sheet for grade I were 0.86, 0.94 and 0.80; for grade II were 0.84, 0.89 and 0.79; for grade III were 0.80, 0.81 and 0.70, respectively. Standardization of stem thickness

Standardization of stem thickness and length for harvesting cinnamon (*Cinnamomum verum* J. Pres.) bark. 21 (2): 164-168 (2012)
R G Khandekar, U B Pethe, R N Nawale, P M Haldankar, B B Jadhav & M Anandaraj

An experiment was conducted during 2008-09, 2009-10 and 2010-11 at Dapoli (Maharashtra) to study the effect of stem thickness and stem length for harvesting cinnamon bark. Twelve treatment combinations *viz*., two genotypes; Konkan Tej (G_1), ACC-11 (G_2), two lengths of stem; 50 cm (L_1), 100 cm (L_2) and three thicknesses of stem; 1-2 cm (T_1), 2-3 cm (T_2), 5-6 cm (T_3) were used for experimentation. There were no significant differences in bark thickness before and after drying, fresh

and dry weights of quill in the genotypes studied and length of cinnamon stem selected for bark extraction. Significantly highest bark thicknesses before (1.14 mm) and after (0.82 mm) drying and fresh (111.21 g) and dry (56.64 g) weights of quill were recorded in T_3 (5-6 cm thick stem) treatment. Interaction effect of genotype, length and thickness of stem selected for coppicing indicate significant differences in bark thickness before and after drying and fresh and dry weights of quill. Significantly maximum bark thickness before drying (1.74 mm) was recorded in treatment combination $G_2L_1T_3$, which was at par with $G_1L_2T_3$ (1.72 mm), $G_2L_2T_3$ (1.71 mm) and $G_1L_1T_3$ (1.67 mm). The treatment combination $G_1L_2T_3$ produced significantly highest bark thickness after drying (1.33 mm), fresh (223.31 g) and dry (117.28 g) weights of quill, respectively. Significantly low bark thickness before drying (1.00 mm), fresh (49.13 g) and dry (22.92 g) weights of quill were recorded in treatment combination $G_1L_1T_1$, which were at par with treatment combination $G_2L_1T_1$. Higher oil percentage was observed in 5-6 cm thick stem i.e. Konkan Tej (3%) and ACC-11 (2.50%), respectively. Thus for coppicing of cinnamon for extraction of bark, harvesting of 5-6 cm thick stem is recommended.

Determination of thermal properties of cryo-ground cinnamon powder. 23 (2): 262-267 (2014)

P Barnwal, K K Singh, A Mohite, A Sharma & T J Zachariah

In this study, thermal properties, *viz*., specific heat, thermal conductivity and thermal diffusivity, of cryo-ground cinnamon powder (var. Navasree) were investigated. Cinnamon samples were ground using a cryogenic grinder at low temperature (generally below -50°C) using liquid nitrogen (LN_2), having a grinder speed of 12000 rpm and 1 kg h^{-1} feed rate. The specific heat varied from 46.60-58.04 kJ kg-^{1}°C within the temperature and moisture ranges of -100-100°C and 6.4-19.0% dry basis, respectively. Thermal conductivity and thermal diffusivity varied from 0.055 to 0.884 Wm^{-1}°C and 0.35×10^{-8} - 7.23×10^{-8} m^2 s^{-1}, respectively in the temperature and moisture ranges of -40-60°C and 6.4-19.0% db. The specific heat, thermal conductivity and thermal diffusivity showed quadratic relationships

with temperature and moisture content and were significantly affected by moisture and temperature at 5% level of significance.

Crop Protection

Grey blight disease of cinnamon (*Cinamomum verum* Bercht & Presl.) leaves. 2 (1&2): 66-67 (1993)
P Karunakaran, M C Nair & Lulu Das
A survey on diseases affecting cinnamon (*Cinnamomum verum*) revealed the occurrence of grey blight of leaves caused by *Pestalotiopsis palmarum* in several parts of Kerala, India.

ALLIED SPECIES OF CINNAMON

Bark anatomy of four species of *Cinnamomum* (Lauraceae) from Kerala. 1 (1): 84-87 (1992)
M Shylaja & K S Manilal
Bark anatomy of four species of *Cinnamomum*-three cultivated (*C. verum, C. cassia, C. camphora*) and the most common wild cinnamon (*C. malabatrum*) are reported here. They differ with regard to many characters such as the nature of the sclerenchymatous groups in the pericyclic region, nature of the phloem rays, distribution of phloem fibres and in the presence of crystalline inclusions. The differences in the bark structure are useful in distinguishing the genuineness of the true cinnamon (*C. verum*) bark and also in the taxonomy of the genus.

Essential oil of leaves of *Cinnamomum tamala* Nees. & Eberm. from North East India. 3 (1): 33-35 (1994)
S C Nath, A K Hazarika & R S Singh
An essential oil (0.7%) having n_D^{28} = 1.4791 obtained by hydro distillation of fresh leaves of *Cinnamomum tamala* cultivated in North Cacher Hills of North East India was examined by gas chromatography. Fourteen oil components were identified which constituted 93.44% of the oil. Linalool was the main component (60.73%), whereas eugenol and cinnamic aldehyde were detected in trace amounts (<1%). Other components of significant occurrence

(3%) in the oil were α-pinene (10.54%), β-pinene (10.42%), limonene (3.21%) and camphene (3.06%).

Air layering in cassia (*Cinnamomum aromaticum* Nees.). 3 (1): 48-49 (1994)
B Krishnamoorthy & J Rema
Air layering in 2-year-old cassia plants (*Cinnamomum aromaticum*) is reported for the first time. A success of 87.5 and 50.0% rooting was obtained when carried out during July and November, respectively, with 100% field establishment.

Evaluation of selected Chinese cassia (*Cinnamomum cassia* Blume) accessions for chemical quality. 8 (2): 193-195 (1999)
B Krishnamoorthy, T John Zachariah, J Rema & P A Mathew
Twenty five Chinese cassia (*Cinnamomum cassia*) accessions were analysed at 15% moisture level for bark oil, bark oleoresin and leaf oil percentages. Bark oil ranged from 1.2 to 4.9%, leaf oil 0.4 to 1.6% and bark oleoresin 6.0 to 10.5%. Cinnamaldehyde was the major constituent in both leaf and bark oils. Accessions A_1 and C_1 had high bark oleoresin and D_1, D_3 and D_5 high bark oil and cinnamaldehyde contents.

Panicle and bark oils of a variant of *Cinnamomum bejolghota* (Buch-Ham) Sweet. from North East India. 11 (2): 135-137 (2002)
Akhil Baruah & Subhan C Nath
Essential oils obtained by hydro-distillation of panicle and bark of *Cinnamomum bejolghota* (Buch-Ham) Sweet. Variant II, growing in Upper Brahmaputra valley region in Assam, India were investigated by GC and GC-MS. Twenty seven and 23 components accounting 98.52% and 81.60% in the oils of panicle and bark, respectively, were identified. Linalool (65.00%) was the major component in the panicle oil. The predominant components in the bark oil were α-terpineol (23.30%), linalool (14.40%) and *p*-cymene (13.90%). The chemical composition of the oils, on comparison with those reported for *C. bejolghota*, exhibited the natural existence of four chemotype sources for the species from North East India.

Leaf anatomy and essential oil characters of *Cinnamomum pauciflorum* Nees. - A potential spice crop from North-East India. 15 (1): 52-56 (2006)

Akhil Baruah & Subhan C Nath

The anatomy and essential oil characters of leaf of *Cinnamomum pauciflorum*, a new promising source of cinnamon was studied. Eighteen components accounting for 99.8% of the total oil were identified by GC analysis of the oil. Cinnamaldehyde was the major component in the oil.

Performance of cassia [*Cinnamomum cassia* (Blume)] genotypes under high rainfall and high altitude Kodagu region of Karnataka. 18 (1): 37-39 (2009)

R Senthil Kumar, D Prasath, N K Leela, B Krishnamoorthy & M N Venugopal

Fifteen cassia (*Cinnamomum aromaticum*) genotypes were evaluated for their performance for growth and yield characters under high rainfall and high altitude Kodagu region of Karnataka. Analysis of fresh and dry bark yield plant^{-1} after 7 years of planting showed significant variation among the genotypes. Among the genotypes, IC 370405 exhibited superiority in terms of dry weight (1083 g plant^{-1}) and IC 370408 was superior in quality.

Evaluation of coumarin content and essential oil constituents in *Cinnamomum cassia* (Nees & T. Nees) J. Presl. 28 (1): 43-51 (2019)

A J Jose, N K Leela, T J Zachariah & J Rema

The use of cinnamon bark from commercial sources has raised concerns globally, as it is widely adulterated with *Cinnamomum cassia* which possesses coumarin that is established as a hepatotoxic chemical in animal trials. The current study reveals the availability of *C. cassia* trees with high levels of cinnamaldehyde but low in coumarin. The estimated level of coumarin in three trees by HPLC analysis was found to be <100 mg kg^{-1} of dry bark which is below the stipulated upper levels put forth by the European Food Safety Authority and Food Safety Standards Authority of India. Considering the internationally accepted flavour of cassia oleoresin and the low

coumarin levels, the *C. cassia* of Indian origin can be widely propagated and may be popularized along with *C. verum.*

ALLSPICE

Crop Improvement and Biotechnology

Seedling variants in allspice (*Pimenta dioica* (L.) Merr.). 8 (1): 93-94 (1999)
P A Mathew, B Krishnamoorthy & J Rema
A distinctly variant type of seedling was identified in a seedling population maintained in the nursery at the Experiment Farm of Indian Institute of Spices Research at Peruvannamuzhi (Kerala) during 1996 and is reported here. The variant types had a dwarf/semi-dwarf habit with short internodes and bushy nature possessing a large number of branches. The leaves were smaller (about 1/3 the size) when compared to that of normal leaves. The variants were multiplied clonally through grafting and all the clones exhibited the parental character.

Crop Production and Postharvest Technology

Increase in fruit and seed size, and seeds per fruit in allspice (*Pimenta dioica* L. Merr.) by hormonal application. 4 (2): 162-163 (1995)
B Krishnamoorthy, K S Krishnamurthy & J Rema
Though innumerable reports are available on increase in fruit and seed size, and number of seeds per fruit due to hormonal application in various horticultural crops, this is the first such report in allspice opening up new vistas for future research on this important spice crop.

TAMARIND

Genetic diversity analysis in tamarind (*Tamarindus indica* L.). 22 (1): 55-61 (2013)
S Gangaprasad, Rajkumar, R L Ravikumar, M H Savitha, K Krishnamurthy & S Hittalamani
The present study conducted at Shimoga (Karnataka) during 2005-2008 is an attempt to examine genetic relatedness and genetic diversity among 13 Indian collections of Tamarind. Twenty eight selected arbitrary primers were used for characterization using RAPD that generated 131 fragments, of which 116 (88.54%) were polymorphic. Two genotypes, NTI62 and NTI84 were distinguished by unique band specific to them. The genetic similarity coefficient values suggested a wide genetic base for genotypes considered for the study. Cluster analysis based on unweighted pair group method using arithmetic average (UPGMA) clearly indicated that genotypes did not cluster according to their site of collection. This could be attributed to highly cross pollinating nature, small distribution area and that most tamarind genotypes grown in India are from seed source.

Studies on preparation and storage of tamarind squash. 24 (1): 37-42 (2015)
P Archana & K Laxman
An attempt was made to standardize the protocol for the preparation of tamarind squash. The chemical composition of tamarind squash and changes in chemical constituents during storage at ambient temperature were studied. Results showed that higher amount of mean TSS (54.13%), reducing sugar (9.51%) and total sugar (30.25%) were noticed in recipe having 30% juice + 50% TSS + 1% acidity, whereas higher retention of ascorbic acid (3.68 mg 100 g^{-1}) was observed in recipe having 30% juice + 40% TSS + 1% acidity. However, minimum TSS (40.48%), reducing sugar (8.82%) and total sugar (22.77%) were noticed in recipe having 25% juice + 40% TSS + 1% acidity and titrable acidity in the recipe having 30% juice + 50% TSS + 1% acidity. Among the recipes the tamarind squash prepared from 30% juice + 50% TSS + 1% acidity was found superior to other

recipes. The beverage retained its characteristic colour, aroma and taste up to 3 months of storage at room temperature.

Genetic variability, correlation and path analysis in tamarind (*Tamarindus indica* L.). 29 (2): 133-139 (2020)
C Rajamanickam
The present study was conducted at the Horticultural College and Research Institute, Periyakulam with the objective to estimate the extent of genotypic and phenotypic coefficient of variation, correlation and path analysis among tamarind genotypes. A remarkable variability was observed among the tamarind collections for all the characters. In all the cases, phenotypic variance was higher than the genotypic variance. Also, phenotypic coefficient of variation was found higher than genotypic coefficient of variation for all the traits. The high heritability coupled with high genetic advance as per cent over mean was observed in the traits such as pod yield plant^{-1} (98.07%; 76.103%), fruit weight (89.11%; 63.668%), fibre weight (89.95%; 91.967%), shell weight (86.19%; 58.534%) and pulp weight (74.13%; 51.533%) whereas the lowest values were recorded for pod length (34.91%; 13.945%) and tree circumference (20.34%; 8.198%). Thus, it indicated better scope for improvement of these traits through selection programme. Pod yield tree^{-1} was significantly and positively correlated with pod width, tree circumference and pulp weight. Path coefficient analysis showed that pod yield tree^{-1} contributed the maximum positive direct effect.

GARCINIA AND ALLIED SPECIES

Multiple shoot regeneration in kokum and camboge. 10 (2): 151-152 (2001)
K Mary Mathew, Y S Rao, K M Kuruvilla, R Lakshmanan, Gilu Lizy George, K J Madhusoodanan & S N Potty
The present paper deals with development of tissue culture protocols for multiplication of kokum and camboge. The present report on *Garcinia*, which is a first account, could be used as a basis for further research on micropropagation of this tree spice.

Variability of fruit characters in kokum (*Garcinia indica* Choisy). 14 (1): 65-70 (2005)
V N Kore, S R Nimbalkar & P M Haldankar
The fruit characters of 22 genotypes of kokum (*Garcinia indica*) were studied at Dapoli (Maharashtra). The genotypes exhibited significant variation for all the fruit characters and the environmental coefficient of variation recorded for all the fruit characters was very low. The higher magnitudes of phenotypic and genotypic coefficient of variations indicated good amount of variation among the genotypes. Estimates of heritability and genetic advance were relatively higher for length, weight and volume of fruit, fresh rind weight, pulp weight and dry seed weight. The genotypes K-29, K-32, K-146, KN-1, KN-3, KN-4 and KN-5 were promising.

Soft wood grafting of *Garcinia xanthochymus* (Hook. f.) [Syn. *G. tinctoria* (Wight)]. 15 (1): 63-64 (2006)
B Krishnamoorthy, P A Mathew, J Rema, Minoo Divakaran & K Jayarajan
Soft wood grafting of *Garcinia xanthochymus* was standardized on 9-month-old rootstocks of the same species with 90% success. The grafted plants flowered within 3 years after grafting and set fruits in the fourth year, while seed propagated plants did not flower even 6½ years after planting in the field.

Seed germination studies in *Garcinia* spp. 16 (2): 118-121 (2007)
Ancy Joseph, K N Satheeshan & T G Jomy
Germination studies conducted at Padannakad (Kerala) on *Garcinia gummi-gutta* and *Garcinia cowa* indicated that soaking seeds in hydrogen peroxide (30%) for 30 min and overnight soaking in cow milk and kinetin (500 ppm) were effective in breaking the dormancy of seeds and resulted in 60.05%, 39.96% and 34.41% germination, respectively in *G. gummi-gutta* and 65.33%, 69.33% and 54.67% germination in *G. cowa* at 7 months after sowing. In *Garcinia tinctoria*, soaking in hydrogen peroxide (30%) for 30 min and overnight soaking in kinetin (500 ppm) and gibberellic acid (500 ppm) induced early germination resulting in 78.6%, 93.3%, and 64.0% germination respectively, at 2 months after sowing.

Isozyme diversity of *Garcinia gummigutta* (L.) N. Robson in Western Ghat region, South India. 19 (1&2): 29-33 (2010)
Utpala Parthasarathy, G R Asish, K Jayarajan, R Aravind, B Krishnamoorthy & P A Mathew
Isozyme genetic markers are efficient tools to study genetic variations within and between populations of less known wild species as well as for studies on spatial distribution of genetic variation. A study was conducted with four important isozyme markers namely, peroxidase, polyphenol oxidase, esterase and superoxide dismutase in *Garcinia gummigutta* population collected from Western Ghats in South India. The cluster analysis of the marker bands showed that most of the population from similar geographic locations was the first one to group themselves, though a significant pattern was not noticed. The mean percentage of polymorphic loci was 52.5%. Total heterozygocity was 0.97 which is consistent with the average of tropical tree species.

Economic viability of production of kokum (*Garcinia indica* Choicy) in Maharashtra, India. 19 (1&2): 34-41 (2010)
P J Kshirsagar, J M Talathi, H K Patil & S R Torane
Financial feasibility analysis of capital investment in kokum (*Garcinia indica*) in South Konkan (Sindhudurg and Ratnagiri districts in Maharashtra) revealed profitability of the enterprise. The initial investment for establishing orchards raised from seedlings and grafts were Rs. 38,877 ha^{-1} and Rs. 69,196 ha^{-1}, respectively. The total cost of production and gross returns were Rs. 26,417 ha^{-1} and Rs. 42,820 ha^{-1} and Rs. 44,931 ha^{-1} and Rs. 45,572 ha^{-1}, respectively for orchards raised from seedlings and grafts, with a benefit:cost ratio of 1.11 and 1.70, respectively. The net present value for both the types of orchards were positive with a payback period of 7-8 years.

Effect of post-flowering foliar sprays of nutrients on fruit growth of kokum (*Garcinia indica* Choisy). 21 (1): 48-52 (2012)
A V Somavanshi, P M Haldankar & V S Dandekar
A study was undertaken at Dapoli (Maharashtra) to find out the effect of application of post-flowering foliar nutrients on growth of kokum (*Garcinia indica* Choisy) fruits. Various concentrations and combinations of urea 1.0%, potassium nitrate 3.0%, monopotassium

phosphate 0.5% and 19 N:19 P:19 K (1.0%) were applied at fruit set and repeated 20 days after fruit (DAF) set. The results indicated that weight of fruit increased consistently up to 90 days of fruit set and decreased slightly at harvest irrespective of treatments. The increase in fruit length and fruit circumference was linear till harvest. All foliar nutrient treatments improved the growth rate over control with respect to fruit weight, fruit length and fruit circumference at all stages of fruit growth. T_4 [potassium nitrate 3.0% twice], T_5 [potassium nitrate 3.0% + monopotassium phosphate 0.5%] and T_6 [19 N: 19 P: 19 K (1.0%) twice] were at par with each other and recorded significantly higher yield over control. Among the treatments T_2 [Urea 1.0% + potassium nitrate 3.0%] was the best for improvement in fruit weight and fruit circumference of kokum fruit. All foliar nutrient sprays improved the quality of kokum fruit with respect to total soluble solids, acidity, ascorbic acid and sugar content. Among the treatments, T_4 and T_5 were at par with each other and significantly improved acidity and sugar content.

SEED SPICES

CORIANDER

Crop Improvement and Biotechnology

Variability in a collection of coriander (*Coriandrum sativum* L.) germplasm. 8 (1): 99 (1999)
R K Yadav
Surveys were conducted for collection of coriander (*Coriandrum sativum* L.) germplasm from Jabalpur (Madhya Pradesh, India) during 1996-97. The collections were sown at Regional Agricultural Research Station, Raigarh, Madhya Pradesh for evaluation and some of their morphological attributes are presented.

Genetic distance in coriander (*Coriandrum sativum* L.) for essential oil yield and yield traits. 11 (2): 101-105 (2002)
H P Singh, N K Patra, A Kalra, H B Singh, B Kumar, S P Singh & A K Singh
Genetic association and distances were assessed in a collection of 15 Indian accessions of coriander, consisting of 8 land races and 7 cultivars, on the basis of seven economic plant traits including essential oil content and oil yield. The study revealed that genetic distance in the material was substantial with the D^2 values ranging from 37.4 (between the genotypes C-2 and DH-5) to 1309 (between the genotypes C-1 and RCr-20). The genotypes clubbed into 8 clusters. The genetic diversity was found to be independent of the geographical diversity of the genotypes. Considered together, the results of genetic association and D^2 analysis revealed that the variation in seed yield was the most prominent force accounting for both variations in oil yield and genetic distance in the material. The study suggested that improvement in this crop would be possible by exercising selection for oil yield, seed yield and their associated traits *viz*. oil content and umbellets per umbel. The results of D^2 values and cluster means permitted rational selection of S-33 and C-1, RCr-41 and PD-1, potent genotypes with complementary characters in morphological fitnesses for yield and its associated traits, for effective cross hybridization programme.

Variability in coriander (*Coriandrum sativum* L.) for yield and yield components. 12 (2): 162-164 (2003)
S S Rajput and Dhirendra Singh
Studies on variability in twenty genotypes of *Coriandrum sativum* L. indicated higher estimates of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance for seed yield, umbels plant^{-1}, seeds umbeI^{-1} and plant height, suggesting probable role of additive gene effects on character expression. Superior genotypes for different, traits identified in the study could be exploited for inter varietal hybridization (reciprocal recurrent selection method) for evolving a high yielding variety with other desirable traits.

Stability analysis for seed yield, its contributing traits and oil content in coriander (*Coriandrum sativum* L.). 12 (2): 165-170 (2003)
D P Singh & M A Shah
Twenty genetically different genotypes of coriander were evaluated for their stability with respect to their seed yield, its contributing traits and oil content. Environments differed significantly as revealed by significant mean square due to environment (linear) for all the traits studied. The genotype x environment interactions was found significant for days to flowering, plant height, 1000 seed weight, harvest index and oil content. Whereas non-significant mean square genotype x environment interaction for remaining traits showed linear response of genotypes to varying environments. Both linear and non-linear interactions were significant for plant height, 1000 seed weight, harvest index and oil content, whereas for seed yield only linear component was significant. The genotypes with good yield potential, average plant height and medium maturity were G.Cori-1, RCr-20, UD-262, RCr-446, UD-744, CS-2, RCr-41 and G.Cori-2 suited for favourable environment, while Patan mandi-1 and UD-447 with regression coefficient (bi) <1.0 could be suitable for low yielding environment.

Yield stability in coriander (*Coriandrum sativum* L.). 13 (2): 124-125 (2004)
N S Tomar, P Singh, S K Nair & C R Gupta
The yield stability of eight elite accessions of coriander (*Coriandrum sativum*) was estimated under Chattisgarh plains condition at Raigarh (Chattisgarh). The accession JCO-387 yielded the highest, exhibiting above average response but unstable reaction (high S^2di) while UD-744, DH-246 and UD-743 were promising and suitable for favourable environment.

Genetic variation for seed yield and its components and their association in coriander (*Coriandrum sativum* L.) germplasm. 15 (1): 25-29 (2006)
Dhirendra Singh, U K Jain, S S Rajput, V Khandelwal & K N Shiva
Evaluation of 360 lines of coriander (*Coriandrum sativum*) at Jobner (Rajasthan) indicated high variability for seed yield (22.82%), umbels plant^{-1} (28.65%) and seeds umbel^{-1} (21.63%)and low variability for days to 50% flowering (12.39%) and umbellets umbel^{-1} (13.30%). High broad sense heritability (91.94%) and genetic advance (56.55%) were obtained for umbels plant^{-1} and seeds umbel^{-1}. Correlation and path coefficient analysis indicated that umbels plant^{-1} and branches plant^{-1} were the most important traits as they exerted positive direct effect on seed yield.

Effect of water stress on seed quality of coriander (*Coriandrum sativum* L.). 19 (1& 2): 53-56 (2010)
S N Saxena, R K Kakani, R Saxena & M M Anwer
Twelve coriander (*Coriandrum sativum*) accessions comprising of released varieties, advanced breeding material, regional and exotic collections were evaluated at Ajmer (Rajasthan) for effect of water stress on seed quality parameters including total oil, essential oil, test weight and seed size. All the recorded parameters showed significant genotypic variation as well as significant interaction of genotype with environment. Mid-term water stress did not have adverse effect on the studied quality parameters while terminal water stress resulted in reduction in quality parameters in most of the accessions.

Genetic variability analysis in coriander (*Coriandrum sativum* Linn.). 22 (1): 81-84 (2013)
S J Singh & S K Singh
The investigation was undertaken to assess the genetic parameters in respect of yield and yield determining characters of nine genotypes namely 2007, 8918, 2002, 9903, 9106, 9807, 2015, 2108 (germplasm lines) including check variety Azad Dhania-1 of coriander (*Coriandrum sativum*). The maximum genotypic coefficient of variability (18.39%), broad sense heritability (93.5%) and genetic advance over mean (36.60%) were obtained for umbels plant^{-1}. Seed yield was positively associated with several characters such as plant height, number of primary branches plant^{-1}, number of secondary branches plant^{-1}, number of umbels plant^{-1}, number of umbellets plant^{-1}, number of seeds umbel^{-1} and umbel diameters. Quantitative traits like plant height, number of secondary branches plant^{-1}, number of primary branches plant^{-1}, number of umbel plant^{-1}, number of umbellets umbel^{-1} and number of seeds umbel^{-1} exhibited wide range of variability, maximum genotypic and phenotypic coefficient of variability, broad sense heritability and genetic gain (as per cent of mean). It was found that the genotypes 9106, 2007, 2108 and 2015 were promising.

Crop improvement of coriander (*Coriandrum sativum* L. subsp. *indicum* var. *indicum*.) through crossing. 25 (1): 1-6 (2016)
K Giridhar, S Suryakumari, C Sarada & L N Naidu
Coriander is the most important seed spice crop in India. Selection is the most common breeding procedure used in coriander and crossing is non-existent. The present study was conducted to promote crossing as a breeding technique in coriander. It was found that coriander was protandrous and the sex ratio was 1.75 to 2.07. The stigma was receptive from the 3rd day to 6th day of anthesis indicating that artificial pollination on emasculated florets must be done repeatedly on 3rd and 4th day of anthesis. Pollen was viable for two days in the field. Fresh pollen can be stored in incubator at 25°C for three weeks with 88% retention of viability. Emasculation of florets was carried out with the help of binocular loupe. Emasculation either in the morning before anthesis or previous day evening was found to be

suitable. For demonstrating the technique, four parents were reciprocally crossed. Only three crosses were successful indicating the differences in combining ability of the parents. Mean success among the crosses was 23%, fruit set among the florets varied from 9.52-83.3% depending on the cross combination.

Evaluation of coriander (*Coriandrum sativum* L.) cultivars for yield and yield contributing characters in Gujarat. 25 (1): 7-12 (2016)

A K Phurailatpam, K A Geetha, R S Meena & S Maiti

Nineteen cultivars of coriander (*Coriandrum sativum* L.) from diverse sources were evaluated in semi-arid conditions of Gujarat for observing the various morphological and yield characters. The highest plant height was found in Pant Haritama (97.27 cm) which was at par with RCr 435, ACr 209, JD 1, Co 4, RCr 20 and Sadhana. There were no significant differences in number of primary and secondary branches in all the cultivars. Highest seed yield plant^{-1} were observed in JD 1 (10.78 g) which was at par with Sudha, Sindhu and RCr 41. The lowest yield plant^{-1} were observed in RCr 20 (1.81g). The minimum time taken for 50% flowering was observed in Sudha and RCr 41 (42.67 days) which were at par with that of Sindhu. The maximum time taken for 50% flowering was by RCr 20 (68.67 days). It was also observed that the time taken for days to full flowering in an umbel ranges between 8-14 days and the days to complete complete fruit formation in an umbel ranges from 14-20 days. It might be concluded from the study that the cultivars differed significantly in most of the parameters and offer a good scope of selection of cultivars for desired traits.

Evaluation of coriander germplasm for yield and powdery mildew resistance. 25 (1): 70-72 (2016)

A K Singh & S S Rao

An experiment was conducted during *rabi* to identify coriander lines resistant to powdery mildew and high yield. Twelve entries were included for evaluation with one each of national check as well as local check. The result showed that out of 12, four lines were found susceptible to disease and remaining were moderately resistant. In

the present study coriander line Cor-31 (DH220) produced the highest yield 1021.53 kg ha^{-1} with moderate resistant reaction against powdery mildew. The area under disease progress curve (AUDPC) and apparent rate of infection (r) values were 502.24 and 0.035, respectively.

Stability analysis of seed yield in coriander based on non-parametric methods. 25 (2): 133-140 (2016)
E V D Sastry & S S Rajput
The present study consisted of evaluation of 42 genotypes in two environment-with full irrigations (called irrigated) and with half the number of normal irrigations (called drought) over three years. ANOVA has indicated significant influence of environments on the expression of seed yield. All types of interactions with genotypes were significant indicating non-linear response of genotypes to environments. Stability analysis indicated significant differences among the ranks of stability of the genotypes. Significant positive correlations were noted among the different non parametric statistics and between corrected and uncorrected seed yield. Similarly there was good correspondence between the scatters of the genotypes obtained with $S_i^{(1)}$, $S_i^{(2)}$, $S_i^{(3)}$ as well as between the scatters of AMMI (mean vs IPCA 1).

Evaluation of coriander (*Coriandrum sativum* L.) genotypes for resistance to stem gall disease and seed yield. 26 (1): 33-36 (2017)
R S Mishra & V P Pandey
A field experiment was conducted during three consecutive *Rabi* seasons (2002-03 to 2004-05) at Kumarganj, Faizabad, (UP). The coriander genotypes, received from All India Coordinated Research Project on Spices, were tested for resistance against stem gall disease and powdery mildew under natural condition. The promising genotypes were also tested at Dholi (Bihar), Hissar (Hariyana) and KVK and farmers field in Uttar Pradesh. The data on coriander genotypes revealed that genotype K. Selection showed lowest disease severity of stem gall 6.4% in 2002-03, 6.7% in 2003-04 and 6.8% in 2004-05. Whereas, pooled disease severity of stem gall in K.

Selection during 2005-08 was 8.62% as compared with Pant Haritma (11.78%), UD-118 (18.78%), RD-154 (33.33%) and LCC-174 (37.46%). The yield performance of K. Selection in coordinated varietal trials at Kumarganj was significantly higher over the national check Pant Haritma. K. Selection also recorded higher seed yield at farmer's field (10.9%) and Krishi Vigyan Kendra (23.5%).

Genotype x environment interaction and stability of indigenous coriander (*Coriandrum sativum* L.) genotypes for seed yield in different agro-climatic zones of Chhattisgarh. 28 (2): 122-130 (2019)

S L Sawargaonkar, A K Singh, J Tiwari, K P Singh, A Sao, P M Paraye, S K Painkra, G R Rathia, S Sahu, S S Rao, A K Sarawagi, R N Sharma, R K Bajpai & K Nirmal Babu

The present study was conducted to find out the stability and yield performances of 13 genotypes of indigenous coriander (*Coriandrum sativum* L.) evaluated in different agro climatic zones of Chhattisgarh. The trials were laid out in a Randomized Block Design (RBD) with three replications at three locations for three years resulting in nine environments (Genotype × year interactions). The genotypes and G × E interactions revealed significant differences at $p < 0.01$ for seed yield indicating varieties and testing environments were distinct from each other. Additive main effects and multiplicative interaction analysis (AMMI-biplot) indicated that the yield performances of indigenous coriander genotypes were highly affected by the environments. The first two principal component axes (PCA 1 and PCA 2) were significant and they explained 67% of the total genotype x environment interaction of which 42.4% and 24.6% were represented by PCA 1 and PCA 2, respectively. A biplot generated using genotypic and environmental scores of the first two AMMI components demonstrated that genotype with larger PCA 1 and lower PCA 2 scores were high yielding and stable genotypes and genotypes with lower PCA 1 and larger PCA 2 scores were low yielding and unstable cultivars in tested locations. The genotype GC 5 C-101 (ICS 4) showed higher grain yields (16.35 q ha^{-1}) over grand mean (13.03 q ha^{-1}) and also had the minimum PCA 1 score, minimum AMMI stability value (ASV) and yield stability index (YSI). Therefore genotype ICS 4

(Chhattisgarh Shri Chandrahasini Dhaniya-2) showed wider stability across different agro-climatic environments of Chhattisgarh.

Growth and yield of AGCr-1 coriander affected by plant geometry and nutrition. 31 (2): 199-205 (2022)
G Lal, M K Choudhary, S S Meena & N Kumar
A study was conducted during *Rabi* season of 2015-16 and 2016-17 at the Research Farm of ICAR-NRC on Seed Spices, Ajmer, Rajasthan to assess the influence of plant geometry and different levels of nutrition on vegetative growth and yield of coriander variety Ajmer Green Coriander-1 (AGCr-1). The treatments comprised of three crop geometry (25 cm x 5 cm, 25 cm x 7.5 cm and 25 cm x 10 cm) and three levels of NPK (40:25:20 kg ha^{-1}, 50:35:25 kg ha^{-1} and 60:45:30 kg ha^{-1}) laid out in Randomized Factorial Block Design. The vegetative growth attributes *viz*., plant height at different growth stages, length of first leaf, length of second leaf, number of basal leaves $plant^{-1}$, primary branches $plant^{-1}$ and secondary branches $plant^{-1}$ recorded the highest level with the application of 60:45:30 kg ha^{-1} NPK combined with (25 cm x 7.5 cm) crop geometry. Similarly, yield parameters like number of umbel $plant^{-1}$, number of umbellates $umbel^{-1}$ and seed yield (1253.0 kg ha^{-1}) were also maximum with the same treatment.

Crop Production and Postharvest Technology

Response of coriander (*Coriandrum sativum* L.) cultivars to graded levels of vermicompost. 7 (2): 141-143 (1998)
B A Vadiraj, Siddagangaiah & S Narayana Potty
A field study was undertaken at Sakaleshpur (Karnataka, India) to study the response of three cultivars of coriander (*Coriandrum sativum*) to graded levels of vermicompost in comparison with chemical fertilization (NPK). The study indicated that application of vermicompost significantly increased herbage and seed yield and was comparable to chemical fertilization. The herbage yield was maximum in Rcr-41 (6067.5 kg/ha) at 60th day after sowing when 15 t/ha of vermicompost was applied. Seed yield was maximum in Rcr-41 (1314 kg/ha) in plants treated with 20 t/ha vermicompost.

The study also showed that vermicompost can be used as an alternative nutrient source for coriander cultivation.

Influence of sowing date, nitrogen and plant growth regulators on growth and yield of coriander (*Coriandrum sativum* L.). 15 (2): 88-92 (2006)
S S Meena, N L Sen & S K Malhotra
Field experiments conducted at Udaipur (Rajasthan) indicated that coriander (*Coriandrum sativum*) crop sown on 15th October resulted in significantly higher growth and yield as compared to 15th November sown crop. Higher levels of nitrogen fertilization did not show any significant influence on growth and yield. Foliar spray of naphthalene acetic acid (25 ppm) at 30 days after sowing resulted in significantly higher growth and seed yield which was on par with gibberellic acid (50 ppm) spray at 30 days after sowing.

Influence of nitrogen, *Azospirillum* sp. and farmyard manure on growth, yield and incidence of stem gall disease in coriander (*Coriandrum sativum* L.). 15 (2): 115-117 (2006)
S K Malhotra, B B Vashishtha & V V Apparao
The influence of *Azospirillum* sp. (biofertilizer), nitrogen fertilizer, farmyard manure and their combinations on coriander (*Coriandrum sativum*), was studied at Ajmer (Rajasthan). *Azospirillum* sp. inoculation along with nitrogen and farmyard manure increased plant height and number of primary branches plant^{-1} as compared to *Azospirillum* sp. alone and absolute control. Number of umbels plant^{-1} and number of grains umbel^{-1} increased significantly when *Azospirillum* sp. was applied in combination with 100% nitrogen + 5 t farmyard manure, 75% nitrogen + 5 t farmyard manure and 50% nitrogen + 5 t farmyard manure ha^{-1}. Higher seed yield was recorded in *Azospirillum* sp. + 100% nitrogen + 5 t farmyard manure (10.8 q ha^{-1}) followed by *Azospirillum* sp. + 75% nitrogen + 5 t farmyard manure (10.2 q ha^{-1}) and *Azospirillum* sp. + 50% nitrogen + 5 t farmyard manure ha^{-1} (9.7 q ha^{-1}). The use of *Azospirillum* sp. + 50% nitrogen + 5 t farmyard manure ha^{-1} was the most economical treatment for obtaining higher seed yield. The *Azospirillum* sp. treatment

combinations also reduced the incidence of the seed-borne stem gall disease of coriander.

Effect of plant growth regulators on vegetative growth and seed yield of coriander (*Coriandrum sativum* L.) cv. RCr - 435. 15 (2): 118-122 (2006)
Piyush Verma & N L Sen
A field experiment consisting of nine levels of plant growth regulators (indole acetic acid, naphthalene acetic acid and gibberellic acid, each at 10, 25 and 50 ppm concentration) and three modes of application (soaking of seeds, spraying 20 days after sowing and soaking + spraying) was conducted at Udaipur, Rajasthan, to study their effect on growth and yield of coriander (*Coriandrum sativum*). The results revealed that application of gibberellic acid 50ppm by soaking + spraying resulted in maximum number of nodes on main shoot (7.60), number of branches plant^{-1} (9.51), number of umbels plant^{-1} (25.36), biological yield (1.274 q ha^{-1}) and seed yield (0.432 q ha^{-1}).

Efficacy of biofertilizers on the performance of rainfed coriander (*Coriandrum sativum*) in vertisols. 17 (2): 98-102 (2008)
Giridhar Kalidasu, C Sarada & T Yellamanda reddy
Biofertilizers are cheap, eco-friendly, improve soil fertility and plant nutrition within short time, and are effective components in organic farming. The present study was undertaken with nine treatment combinations containing *Azospirillum* sp., *Azatobactor* sp. and PSB and combination of *Azospirillum* and PSB, *Azatobactor* and PSB, Vermicompost, *Trichoderma viride*, 100% inorganic nitrogen and control in RBD with three replications. Inoculation of microorganisms and FYM @ 5 t/ha applied along with recommended dose of inorganic nitrogen @ 100% N had shown significant influence on growth parameters when compared with absolute control. However, the influence of microorganisms is significant only on number of secondary branches and number of umbels per plant when compared to 100% N. Plant height, number of primary and secondary branches were significantly more in treatment with 100% N in combination with *Azospirillum*, PSB and FYM @ 5 t/ha (66.4 cm, 6.2 and 15.4, respectively) than control (58.3 cm, 4.4 and 8.7, respectively). Among

all the treatment combinations, 100% N in combination with *Azospirillum*, PSB and FYM @ 5 t/ha recorded highest seed yield (1004.0 kg/ha) which is significantly superior to 100% N alone (877.7 kg/ha). In addition to the increase yield, the treatment recorded an incremental Benefit Cost Ratio of 1.63. The increase in yield in treatments with *Azospirillum*, PSB and FYM along with 100% RDF may be due to better uptake of nitrogen and phosphorous and enhanced food accumulation.

Threats in production of coriander (*Coriandrum sativum*) in Andhra Pradesh. 17 (2): 158-162 (2008)
C Sarada & Giridhar Kalidasu
Andhra Pradesh ranks first in the southern states of the country in production and productivity of coriander and ranks second in country. Coriander is cultivated in nearly 31298 hectares in Andhra Pradesh with a production of 37548 metric tonnes. The productivity of the crop increased from 275 kg/ha in 1990 to 1200 kg/ha by 2005-06. The reduction in crop coverage has become a serious concern for the Department of Horticulture and as well as farmers. The major factors that affected the shift were cultivation of alternate crops and changing cropping patterns, vagaries in climate, non-availability of quality seed, terminal moisture stress and fluctuations in market prices. This study also focuses on achievements of the state in crossing the average national productivity of the crop through strong research by AICRP on Spices and efforts of Department of Horticulture in extension programmes.

Effect of different levels of nitrogen and leaf cutting on leaf and seed yield of coriander (*Coriandrum sativum*). 17 (2): 180-182 (2008)
S K Tehlan & K K Thakral
The effect of different levels of nitrogen (30, 60, 90 and 120 kg N/ha) and leaf cutting (no cutting, one cutting at 45 days after sowing) and two cuttings at 45 and 60 days after sowing of coriander (*Coriandrum sativum* L.) cv. DH-228 was studied during 2003-04 and 2004-05. Both green leaf yield and seed yield increased with the increase in N levels up to 90 kg/ha. Single leaf cutting at initial vegetative growth

stage did not much affect the later vegetative and reproductive growth. Maximum seed yield was recorded with 90 kg N/ha (14.6 q/ha) without leaf cutting which was at par with 90 kg N/ha and one cut (14.2 q/ha). The green leaf yield was recorded highest with 90 kg N/ha and two cutting (186.4 q/ha).

Effect of bio-regulators and their time of application on growth and yield of coriander (*Coriandrum sativum*). 17 (2): 183-186 (2008)

C Sarada, K Giridhar & T Yellamanda Reddy

The effect of plant growth regulators and their time of application on growth and yield of coriander was studied during 2004-06 at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh. Bio-regulators used were NAA (10 & 50 ppm) and triacontonol (e 0.5 ml and 1 ml/litre). Triacontanol @ 1.0 ml/l recorded maximum plant height, more number of branches and more number of umbellets per umbel. NAA 10ppm recorded more number of umbels per plant and increased crop duration. Maximum seed yield was recorded with NAA 10 ppm followed by Triacontanol @ 1.0 ml/l. With regard to number of sprays, two sprays at 40 and 60 DAS recorded maximum seed yield, compared to one spray at 40 DAS or three sprays at 40, 60 and 80 DAS.

Influence of micronutrients on growth and yield of coriander (*Coriandrum sativum*) in rainfed vertisols. 17 (2): 187-189 (2008)

Giridhar Kalidasu, C Sarada & T Yellamanda Reddy

Coriander crop is grown as a rainfed *rabi* crop in vertisols of Andhra Pradesh. The crop generally suffers from periods of moisture stress from the flowering to maturity stage depending on precipitation during November and December months. During these stress periods, the crop shows deficiency symptoms of micronutrients such as copper, manganese, zinc and iron. The foliar application of $ZnSO_4$ 0.5%, $FeSO_4$ 0.5% and combination of $ZnSO_4$ + $FeSO_4$ + $CuSO_4$ + $MnSO_4$, all at 0.5%, had significant positive influence on all growth parameters and yield of coriander crop. Among the treatments, $ZnSO_4$ + $FeSO_4$ + $CuSO_4$ + $MnSO_4$ all at 0.5% recorded maximum plant height,

number of primary branches and secondary branches, umbels per plant and umbellets per umbel, which are significantly superior to control. Crop maturity differed significantly among the treatments though the difference between the maximum and minimum days was only 3.3 days. The treatments, $ZnSO_4$ + $FeSO_4$ + $CuSO_4$ + $MnSO_4$, all at 0.5%, recorded significantly highest yield (940 kg/ha) followed by $FeSO_4$, 0.5% (927 kg/ha) and $ZnSO_4$, 0.5% (922 kg/ha) which are on par with each other and significantly superior over control (801 kg/ha).

Effect of irrigation and nitrogen on water use, moisture extraction pattern, nitrogen uptake and yield of coriander (*Coriandrum sativum* L.) in north-western irrigated plains of Rajasthan. 18 (2): 88-91 (2009)

S R Bhunia, S D Ratnoo & S M Kumawat

An experiment was conducted at Sriganganagar (Rajasthan) to study water use, water use efficiency, nitrogen uptake, yield and economics of coriander (*Coriandrum sativum*) cultivars (RCr 41, RCr 435) under various levels of nitrogen (20, 40 and 60 kg ha^{-1}) and irrigation (IW/CPE ratios 0.6, 0.8 and irrigation at branching + flowering + seed formation stages). The highest seed yield (10.98 q ha^{-1}), yield attributes and benefit: cost ratio (2.65) were recorded with 60 kg nitrogen ha^{-1}. Increasing levels of nitrogen also recorded higher consumptive use of water and nitrogen uptake. Plants under higher levels of nitrogen (60 kg ha^{-1}) extracted more water from the lower depth (60-90 cm) than lower level of nitrogen (20 kg ha^{-1}). Increase in irrigation frequency significantly enhanced the yield and yield attributes of both the cultivars. Similarly, water use, nitrogen uptake and benefit: cost ratio were also higher with higher levels of irrigation.

Effect of vermicompost and chemical fertilizers on growth, yield and quality of coriander (*Coriandrum sativum* L.) in a semi-arid tropical climate. 20 (1): 30-33 (2011)

Munnu Singh

Field experiments were conducted at Bangalore (semi-arid tropical climate) to study the influence of vermicompost and chemical

fertilizers (NPK and sulphur) on growth, seed and oil yield and oil quality of coriander (*Coriandrum sativum).* The results of the study showed that application of vermicompost (7.5 t ha^{-1}) + 25% recommended NPK (25: 12.5: 12.5 kg ha^{-1}) produced maximum biomass (28.2 q ha^{-1}), seed (10.82 q ha^{-1}) and oil yield (6.53 kg ha^{-1}) of coriander which was at par with other treatments except full organic manure and control which indicated that 75% NPK requirement can be supplemented through vermicompost without loss of yield. The oil content and quality were not influenced by the treatments tested.

Effect of thiourea on yield and nutrient uptake of coriander (*Coriandrum sativum* L.) varieties under normal and late sown conditions. 20 (1): 34-37 (2011)
L R Balai & G L Keshwa
A field experiment was conducted on loamy sand soil at Jobner (Rajasthan) during *rabi* season to study the effect of thiourea on yield and nutrient uptake of coriander (*Coriandrum sativum*) varieties under normal and late sown conditions. The crop sown at normal sowing time (last week of October) produced significantly higher seed yield (14.2 q ha^{-1}), straw yield (23.9 q ha^{-1}) and total uptake (14.2 kg ha^{-1}) of phosphorus (P) as compared to late sown crop. The concentration of nitrogen (N) and potassium (K) in seed and straw were significantly higher under late sown condition over normal sowing. The variety RCr-435 gave higher seed and straw yield, N and K concentrations in seed and straw and total uptake of N, P and K as compared to RCr-41. Application of thiourea (1000 ppm) at vegetative and flowering stages significantly increased the seed (24.6%) and straw yields (25.8%), N (25.6% and 27.3%) and K (25.2% and 26.0%) concentrations in seed and straw and total uptake of N, P and K as compared to water sprayed control.

Arsenic intake and dietary risk assessment of coriander (*Coriandrum sativum* L.) leaves in the Gangetic basin of West Bengal. 21 (2): 125-129 (2012)
R Kundu, K Bhattacharyya & S Pal
Field experiments were conducted at farmers' field in Nadia district of West Bengal during winter seasons of 2008-09 and 2009-10 to

evaluate the varietal tolerance and arsenic (As) accumulation of different coriander cultivars and As intake and dietary risk assessment of leaves. Results revealed that As accumulation in different plant parts was in the order, root > leaf > stem. Ingestion of significant proportion of inorganic As through consumption of coriander was observed which posed a risk of 36.0% of Provisional Tolerable Weekly Intake.

Effect of weed and nitrogen management on coriander (*Coriandrum sativum* L.) yield and economics. 23 (1): 38-44 (2014)

I Choudhary, S S Yadav, L R Yadav, O P Sharma & B L Yadav

Field experiments were carried out during *rabi* 2007-08 and 2008-09 to evaluate the effect of different weed management measures and nitrogen (N) application on yield and economics of coriander. Results revealed that two hand weedings (HW) at 20 and 40 days after sowing (DAS) produced the highest seed and straw yields (13.71 and 25.83 q ha^{-1}). The highest net returns (Rs. 55,841 ha^{-1}) and B:C ratio (2.39) were also obtained under this treatment. However, it was found to be at par with pendimethalin at 1.0 kg ha^{-1} + HW at 40 DAS, wherein seed and straw yields of 13.61 and 25.57 q ha^{-1}, respectively were obtained. The highest harvest index of 35.01% as well as the lowest mean weed index of 0.7%, were also observed under pendimethalin at 1.0 kg ha^{-1} + HW at 40 DAS. Results further revealed that application of N at 75 kg ha^{-1} significantly increased the seed yield to the extent of 11.9%, 32.7% and 84.3% and net returns by Rs. 7,915, Rs. 18,366 and Rs. 34,536 ha^{-1} over 50, 25 kg N ha^{-1} and control, respectively. Correlation studies revealed that seed yield of coriander was significantly and positively correlated with growth and yield attributing characters and nutrient uptake by crop. Based on the response studies, 64.75 kg ha^{-1} was found to be the optimum level of N for coriander.

Selected thermal properties of cryo-ground coriander powder (var. RCR-41). 23 (1): 45-50 (2014)
P Barnwal, K K Singh, R Kumar & S N Saxena
Thermal properties of cryo-ground coriander powder (var. RCR-41) such as specific heat, bulk thermal conductivity and bulk thermal diffusivity were investigated. It was observed that the specific heat increased from 347.63 to 3700.31 J kg^{-1} K^{-1} with increase in temperature from -150°C to 100°C and moisture content from 3.5% to 17.7% (db) and it showed a second order polynomial relationship with moisture content and temperature. The thermal conductivity increased nonlinearly from 0.0884 to 0.1340 Wm^{-1} K^{-1} with increase in moisture content from 3.5% to 17.7% (db) at 30°C. Thermal diffusivity varied non-linearly from 12.63×10^{-6} to 19.89×10^{-6} m^2s^{-1} with increase in moisture content from 3.5% to 17.7% (db) at 30°C. Both thermal conductivity and thermal diffusivity showed quadratic relationships with moisture content. The specific heat was affected significantly with moisture content and temperature ($P \leq 0.01$) and both thermal conductivity and thermal diffusivity were affected significantly by moisture content.

Use of plant growth regulators for yield improvement in coriander (*Coriandrum sativum* L. 23 (2): 192-199 (2014)
S N Saxena, R K Kakani, S S Rathore & B Singh
Two genotypes of coriander viz., ACr 1 and RCr 41 were sown during *rabi* season in three consecutive years (2009-10, 2010-11 and 2011-12) and plant growth regulators (PGRs) viz., abscisic acid (ABA), betaine, acetyl salicylic acid (ASA) (1, 3, 5 and 7 µM) and proline (200, 400, 600 and 800 µM) were sprayed at flowering stage. Morphological parameters in terms of fresh: dry weight, shoot: root weight, shoot root length and seed yield was significantly increased by application of proline, betain and ASA from 1 to 7 µM. Effective concentration of PGRs was influenced by climatic conditions during growth period. In genotype ACr 1, yield was maximum (6.29 and 5.92 g $plant^{-1}$) in the treatments involving betain at 1 and 5 µM while ASA at 3 and 5 µM resulted in seed yield of 4.96 and 4.97 g $plant^{-1}$, respectively. Maximum seed yield (5.41 and 5.17 g $plant^{-1}$) of genotype RCr 41 was recorded in the treatment involving proline at 200 and 400 µM,

respectively. It is suggested that exogenous application of proline (200-800 µM), betain and ASA (1-5 µM) at flowering stage in both the genotypes will be useful to enhance the yield.

Effect of FYM, foliar feeding of nitrogen and deficit irrigation on drip irrigated coriander (*Coriandrum sativum* L.). 24 (2): 98-101 (2015)

I M Verma, S R Bhunia, N C Sharma, K Balai & M P Sahu

A field experiment was conducted to study the water use, nitrogen (N) uptake and economics of coriander (*Coriandrum sativum* L.) under organic enrichment, foliar feeding of N and fertigation. Drip irrigation at 80% ETc + foliar spray of 25% N (15 kg ha^{-1}) + fertigation (45 kg ha^{-1}) gave the highest plant height, branch $plant^{-1}$, umbel $plant^{-1}$, umbelets $umbel^{-1}$, seed $umbel^{-1}$, and test weight compared to irrigation at 80% ETc and at 60% ETc (up to flowering stage) + 80% ETc (reproductive stage) with or without foliar spray. Increased yield parameters were attributed to the highest seed yield and B:C ratio of 1.90 using 265.74 mm water. Water use efficiency (WUE) was also the highest. This treatment also recorded the highest N uptake of 52.6 kg ha^{-1}. Further, addition of 10 t ha^{-1} FYM in addition to recommended nitrogen dose (60 kg ha^{-1}) gave higher yield attributes *viz*., branch $plant^{-1}$, umbel $plant^{-1}$, seed $umbel^{-1}$ and test weight as compared to recommended level of fertilizers. Enhanced yield attributes thus increased seed yield, N removal, WUE and B:C ratio.

Influence of plant growth regulators on growth, seed yield, quality and economics of coriander (*Coriandrum sativum* L.) cv. Sudha. 25 (1): 13-17 (2016)

V Yugandhar, P S S Reddy, G Thanuja Sivaram & D S Reddy

A field experiment was conducted to study the effect of plant growth regulators (PGRs) on growth, seed yield, quality and economics of coriander (*Coriandrum sativum* L.) cv. Sudha. The seven treatments included in the experiment are two concentrations each of GA_3 (50 and 75 ppm), NAA (10 and 25 ppm), Cycocel (100 and 250 ppm) and control (water spray), as pre-soaking, foliar spray at 30 and 60 DAS. Among different PGRs applied, spray of 75 ppm GA_3 resulted in significant maximum plant height. However, maximum number of

primary branches and secondary branches plant^{-1}, number of umbels plant^{-1}, number of umbellets umbel^{-1}, number of seeds umbel^{-1}, seed yield and B:C ratio was maximum with 250 ppm Cycocel. Minimum number of days to 50% flowering and maturity and maximum carbohydrate content and protein content were noticed with 75 ppm GA_3. Similarly, lowest moisture content in seeds was also observed with 75 ppm GA_3, while, the essential oil content in seeds was maximum with 50 ppm GA_3.

Weed management in coriander (*Coriandrum sativum* L.) at varying levels of nitrogen. 25 (1): 18-25 (2016)
S S Yadav, I Choudhary, L R Yadav and O P Sharma

A field experiment was conducted to study the effect of weed control treatments and nitrogen (N) levels on weed dynamics, weed control efficiency, nutrient depletion by weeds, yield of coriander and weed competition index. All the weed control treatments significantly reduced the density and dry weight of weeds and nutrient depletion as compared to weedy check. Oxadiargyl at 0.06 kg ha^{-1} + hand weeding (HW) at 40 days after sowing (DAS) represented the lowest weed density and controlled the weeds to the extent of 94.9%. Two hand weedings done at 20 and 40 DAS and pendimethalin at 1.0 kg ha^{-1} + HW at 40 DAS were found to be the most superior treatments in reducing density, intensity and dry weight of weeds and increasing weed control efficiency. These treatments controlled the weeds to the extent of 95.1% and 95.4%, respectively at harvest stage than weedy check and showed lower weed infestation of 17.4 and 18.1%, respectively. The lowest nutrient depletion due to weeds was obtained with pendimethalin at 1.0 kg ha^{-1} + HW at 40 DAS treatment which saved 54.80 kg N, 8.31 kg P and 49.22 kg K ha^{-1}, respectively than weedy check. Two HWs at 20 and 40 DAS and oxadiargyl at 0.06 kg ha^{-1} + HW at 40 DAS also reduced the nutrient depletion to the extent of 94.8 and 94.5% of N; 95.0 and 94.7% of P and 94.9 and 94.6% of K, respectively in comparison to weedy check. Two hand weeding treatment gave the highest seed yield (1.37 t ha^{-1}) among all the treatments and was closely followed by pendimethalin at 1.0 kg ha^{-1} + HW at 40 DAS which also increased the seed yield by a margin

of 0.84 t ha^{-1} over weedy check, and registered the lowest weed competition index of 0.7%.

Analysis of medicinally important compounds and anti-oxidant activity in solvent extracts of coriander (*Coriandrum sativum* L.) plant parts. 25 (1): 65-69 (2016)

S N Saxena, S S Rathore, G Maheshwari, R Saxena, L K Sharma & J K Ranjan

Total phenolic, flavonoid content and antioxidant activity of crude extract of seeds, roots, stem and leaves of coriander plant were determined. Maximum phenolic content (62.6 and 50.141 mg gallic acid equivalents (GAE) g^{-1} extract) was observed in distilled water extract of fresh and dried roots followed by methanol extract (49.53 and 47.32 mg in green and dried stem respectively). Ethyl acetate extract showed more phenolics in dried stem (12.734 mg GAE g^{-1} extract) and leaves (8.62 mg GAE g^{-1} extract) as compared to green stem and leaves (1.808 and 5.433 mg, respectively). Distribution of flavonoids content in different green as well as dried plant parts and different solvents showed less variation in phenolic and flavonoid contents which ranged from a maximum of 9.843 mg quercetin equivalents (QE) g^{-1} extract in green seeds to a minimum of 4.40 mg in green stem. 1, 1-Diphenyl-2-picrylhydrazin scavenging as a measure of antioxidant capacity was more in distilled water extract of green stem (94.49%) followed by methanol crude extract (76.256%) and ethyl acetate extract (59.706%).

Effect of seed treatments, spacing and season of sowing on yield and quality of coriander (*Coriandrum sativum* L.) under rain shelter. 30 (1): 90-99 (2021)

V U Anjukrishna, N Mini Raj, P Anitha & A K Aneesha

Coriander is an important herb & seed spice. The yield of coriander is influenced by the agronomic practices adopted during cultivation. This study was carried out in the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Kerala Agricultural University from July 2019 to March 2020 to analyse the effect of seed treatments, spacing and growing season on yield and quality of coriander leaves under rain shelter. The experiment was laid out in

factorial completely randomized design (FCRD) with three replications. The study revealed that, pre-sowing seed treatments improved the growth and yield of coriander than untreated seeds. The impact of seed treatments was conspicuous at the time of harvest on growth, yield and quality parameters. Hydropriming for 24 h was found to be the best pre-sowing seed treatment followed by seed treatment with GA_3 50 ppm for 8 h. A closer spacing of 10 x 10 cm which accommodated more plants per unit area recorded the highest biomass and herbage yield plot^{-1}. October-December season was found to be the best for obtaining better growth and yield in leaf coriander. Hence, the study concluded that, hydropriming for 24 h or seed treatment with GA_3 50 ppm for 8 h, a closer spacing of 10 x 10 cm and October-December season are the ideal combination for the best performance of variety CO-4 for leaf purpose under rain shelter in the tropical moist humid climate.

Crop Protection

Management of coriander wilt using biocontrol agents. 11 (2): 138-140 (2002)

P Muthulakshmi, N Chezhiyan, K Muthukrishnan & Sabitha Doraisamy

A replicated field trial on biocontrol of coriander wilt caused by *Fusarium oxysporum* f., sp. *corianderi* was conducted in *kharif* season during 1995-96, 1996-97 and 1997-98 in the Department of Spices and Plantation Crops, Horticultural College and Research Institute, TNAU, Coimbatore. Seed treatment with *Trichoderma viride* at 4 g kg^{-1} of seed was found to be more effective in reducing the wilt incidence to 5.3 per cent as against 28.3 per cent recorded in untreated, control plots in all the three years. The mean yield (387.5 kg ha^{-1}) for all the three years was also significantly higher in seed treatment with *T. viride* as against very low yield (162 kg ha^{-1}) obtained in untreated plots. The cost benefit ratio was also enhanced with the same treatment.

Evaluation of fungicides for the control of powdery mildew disease in coriander (*Coriandrum sativum* L.). 15 (2): 123-124 (2006)

A K Singh

Six fungicides were evaluated at Raigarh (Chhattisgarh), for the control of powdery mildew disease of coriander (*Coriandrum sativum*), caused by *Erysiphe polygoni*. All the fungicide reduced the disease severity significantly, over control, with maximum reduction in hexaconazole (0.1%) that was on par with propiconazole (0.1%) and wettable sulfur (0.3%). Yield of coriander was higher 2.54, 2.00 and 2.20 times, over control, in hexaconazole (0.1%), propiconazole (0.1%) and wettable sulfur (0.3%), respectively. Cost-benefit ratio was 1:5.3,1:4.0 and 1:4.5 in hexaconazole (0.1%), propiconazole (0.1%) and wettable sulfur (0.3%), respectively.

Diversity, temporal abundance, foraging behaviour of floral visitors and effect of different modes of pollination on coriander (*Coriandrum sativum* L.). 16 (1): 8-14 (2007)

O P Chaudhary & Jage Singh

Studies on spatial distribution, foraging behaviour of pollinators and effect of different modes of pollination on yield of coriander (*Coriandrum sativum*) were undertaken at Karnal (Haryana). Coriander flowers were visited by 34 species of insects belonging to 18 families and 8 orders. Apoidea (35.9%), diptera (47.8%) and other hymenoptera (13.2%) were the three major groups comprising 96.9% of the total visitors. Italian honey bee, *Apis mellifera* was the most prominent species (31.1%) followed by *Episyrphus balteatus* (19.2%) and unidentified Hymenoptera species (10.2%). Honey bees foraged both for nectar and pollen whereas, dipterans and other species for nectar alone. *A. mellifera* started foraging early at 09.05 h, peaked from 11.00 to 16.00 hand declined drastically thereafter. *A. dorsata* peaked at 11.00 h and was not recorded after14.00 h. *A. cerana* population peaked from 10.00 to 14.00 h and was not recorded after 15.00h. The syrphid and other dipteran flies were present throughout the day with two peaks, first from 07.00 to 11.00 h and another minor peak late in the afternoon from 15.00 to 18.00 h. *A. cerana* had higher foraging rate (15.2 flower^{-1}) than *A. mellifera* (13.1) and *A. dorsata*

(10.6) and likewise visited more number of plants per minute (3.6, 2.7 and 2.1 min^{-1}, respectively). A meagre yield of 6.3 g $plant^{-1}$ was recorded in caged plots without honey bees (control). Yields in open and honey bee pollinated plots were 14.0 g each, with an increase of 122.2% over without insect pollinated plots. Maximum yield was in plots treated with bee attractant Bee-Q (18.1 g $plant^{-1}$) which was 187.3% higher over without insect pollinated plots and 30.0% higher over open pollinated or bee pollinated plots.

Efficacy of plant extracts for the control of powdery mildew of coriander (*Coriandrum sativum* L.). 17 (1): 24-25 (2008)
A K Singh
Evaluation of five plant extracts namely, *Andrographis paniculata*, *Azadirachta indica*, *Polyalthia longifolia*, *Saraca indica* and *Adina cardifolia* for the control of powdery mildew of coriander (*Coriandrum sativum*), in comparison with wettable sulfur 0.3% indicated that *A. paniculata* and *A. indica* were significantly superior in reduction of disease severity and increase ingrain yield over control indicating their potential for use as a component in integrated management of the disease.

Evaluation of fungicides and bio-agents on powdery mildew of coriander (*Coriandrum sativum* L.). 21 (1): 76-77 (2012)
Ajit Kumar Singh & Rakesh Banwasi
Various fungicides and biocontrol agents were evaluated for the management of powdery mildew of coriander (*Coriandrum sativum* L.) at Raigarh (Chhattisgarh). The results showed that minimum disease intensity (20.6%) and maximum yield (810 kg ha^{-1}) were obtained with application of carbendazim as soil drench and 0.1% spray at 60 days after sowing which was on par with spray of wettable sulphur 0.2% at 60 days after sowing (T6). Cost:Benefit ratio (2.08) was highest with wettable sulphur 0.2% spray at 60 days after sowing.

Studies on management of powdery mildew in coriander using new generation fungicides. 26 (1): 59-62 (2017)
C Ushamalini & S Nakkeeran
Coriander is an important spice crop, affected by powdery mildew caused by *Erysiphe polygoni*. The present study was conducted to test the efficacy of new generation fungicides i.e., azole compounds for the management of powdery mildew in coriander. Two sprays of propiconazole (0.15%) at 15 days interval i.e. on 30 and 45 days after sowing (DAS) were found to be effective in reducing powdery mildew incidence, which also recorded the highest seed yield.

***Bacillus subtilis*, a potential biocontrol agent for the management of coriander wilt. 26 (2): 130-134 (2017)**
S Aswathi & C Ushamalini
Coriander is an important spice crop affected by wilt caused by *Fusarium oxysporum* f. sp. *corianderi.* Two trials were conducted to evaluate the efficacy of *Bacillus subtilis* for the management of wilt under glass house condition. The results of the trials indicated that, among the various treatments, seed treatment with talc formulation of *Bacillus subtilis* (10g/kg of seed) along with soil application (2.5 kg/ha) as basal and top dressing at 30 and 45 days after sowing was effective in reducing the wilt incidence (14.59%) compared to control (32.68%).

CUMIN

Crop Improvement and Biotechnology

Studies on variability in cumin (*Cuminum cyminum* L.) on normal and saline soil. 8 (2): 197-199 (1999)
L S Dhayal, S C Bhargava & S C Mahala
Studies on variability in nine genotypes of cumin (*Cuminum cyminum*) (UC-217, UC-198, UC-216, UC-209, Local, UC-218, UC-89, RS-1 and UC-208) conducted at Jobner, India, indicated higher estimates of genotypic coefficient of variance, phenotypic coefficient of variance, heritability and genetic advance for plant height, number of umbels per plant, number of grains per umbel, test

weight, grain yield per 10 plants, on normal soil and number of grains per umbel and test weight on saline soil, suggesting the probable role of additive gene effects on character expression.

Genotypic differences in seed yield, K: Na ratio and leaf metabolism of cumin (*Cuminum cyminum* L.) under salt stress. 12 (2): 113-119 (2003)
B K Garg, U Burman & S Kathju
Responses of five genotypes (UC-198, UC-220, UC-223, RZ-19 and RZ-209) of cumin (*Cuminum cyminum* L.) irrigated with water having two levels of salinity (0.2 and 10 dSm^{-1}) on shoot dry weight, seed yield, K : Na ratio and leaf metabolism at the flowering stage were studied. Increased salinity significantly reduced seed yield and shoot dry matter in all the genotypes. However, RZ-19 displayed higher salt tolerance than UC-198 and RZ-209 whereas UC-220 and UC-223 showed intermediate tolerance to salinity in terms of seed weight and shoot dry matter. Adverse effects of salinity on the levels of total chlorophyll, soluble protein, free amino acids, starch, reducing sugars and nitrate reductase activity were consistently less in tolerant genotype RZ-19 as compared to sensitive genotypes, UC-198 and RZ-209. Moreover sensitive genotypes had higher concentration of Na and lower concentration of K and consequently lower K:Na ratio under salt stress as compared to the tolerant genotype. These differential genotypic responses have been discussed in the light of the present knowledge.

Genetic diversity studies of cumin (*Cuminum cyminum* L.) genotypes in western plains of Rajasthan. 29 (1): 67-71 (2020)
S R Kumhar, B R Choudhary, Ramesh & M L Mehriya
Genetic diversity was studied in fifty four genotypes of cumin, *Cuminum cyminum* L. at "Agricultural Research Station, Mandor, Jodhpur" during *rabi* season 2017-18. The mean squares were found significantly different for all the characters under study, depicting the variability among the study materials. The high magnitude of phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV) for seed yield, primary branches per plant and number of umbels per plant depicted the presence of vast amount of variation

for the character along with high heritability (68-97%) combined with higher genetic advances as percentage of means for seed yield. The highest intra-cluster distance was recorded in cluster VI (11.8) along with cluster VII (11.33) and cluster VIII (8.29) depicting large genetic variability among the genotypes of these three clusters. The highest inter-cluster distance was reported among cluster III and VIII (51.97) followed by cluster III and VII (40.07) and cluster IV and cluster VIII (34.77), suggesting wide range of diversity between genotypes of the clusters. Amongst the characters, seed yield contributed the highest towards genetic divergence (47.80%) followed by number of umbels plant^{-1} (25.65%), branches per plant (8.60%) and 1000 seed weight (6.64%).

Biochemical composition, oil profiling and elemental analysis of different cumin (*Cuminum cyminum* L.) genotypes. 32 (1): 32-45 (2023)

N S Gamit, N S Litoriya, A S Thounaojam & P K Patel

Cumin (*Cuminum cyminum* L.) is an annual plant of the family Apiaceae and the genus *Cuminum* has a single species *Cyminum*, native from the east Mediterranean to east India. In India, Gujarat and Rajasthan are the major producing states. After black pepper, cumin is the second most popular spice in the world. The present research work was carried out to study the nutritional quality parameters, oil profiling and element composition of fifteen cumin genotypes. The results showed that the moisture content was found to vary from 6.22 to 8.15 %. The carbohydrate content was higher in Kushalpura-1 (46.14%), while the crude protein was highest in Indawar followed by GC-2 and Merta-2. Total protein content was highest in Lampolai (18.24%) and lowest in GC-2 (11.36%). In Lamba Jatan, highest content of non-reducing sugars (8.35%) and total soluble sugars (9.11%) were observed. Reducing sugars was detected in the range of 0.72-1.53%. Highest amount of total free amino acids and crude fibre were found in Gawardi and Kushalpura-1, respectively. The total oil (20.27%) and volatile oil (3.99%) content were highest in GC-4. The petroselinic acid and linoleic acid were observed as primary fatty acids in all tested genotypes. However, Lampolai, Merta-1, GC-2 and GC-4 were good sources of both fatty acids among all the genotypes.

The elemental analysis showed that the GC-2 has a high overall amount of macronutrients, while micronutrients was highest in Piplon-5.

Crop Production and Postharvest Technology

Response of cumin (*Cuminum cyminum* L.) to row spacing and seed rate. 8 (2): 159-162 (1999)
G R Chaudhary
A field trial was conducted at Jobner (Rajasthan, India) to study the response of cumin to row spacing and seed rate. Row spacing of 15.0, 22.5 and 30.0 cm recorded significantly higher mean seed yields (2.69-2.85 q/ha) over broadcast sown crop (2.45 q/ha) and were on par. Seed rate of 12 and 14 kg/ha produced significantly higher mean seed yield (3.01 and 3.00 q/ha) over 8, 10 and 16 kg/ha seed rate. Row spacing of 22.5 cm with 14 kg/ha seed rate gave the highest mean seed yield of 3.55 q/ha. Maximum net returns of Rs. 9656 and Rs. 1l, 088/ha with B:C ratios of 2.46 and 2.77 were obtained with the row spacing of 22.5 cm and seed rate of 12 kg/ha, respectively.

Salinity tolerance of cumin (*Cuminum cyminum* L.) genotypes during germination. 10 (2): 145-146 (2001)
L S Dhayal, S C Bhargava & M L Jakhar
A laboratory experiment was conducted to identify cumin (*Cuminum cyminum* L.) genotypes tolerant to salt at germination stage. Four salinity levels having electrical conductivity of 2.61 (control), 5.17 (low), 8.10 (medium) and 12.15 (high) dSm^{-1} were tested. There is an increase in the suppression of seed germination with increase in salinity in all the genotypes tested. The genotype UC-208 showed maximum salt tolerance, followed by UC-209 and UC-218.

Effect of weed control and nitrogen on yield, nutrient removal and quality parameters of cumin (*Cuminum cyminum* L.). 13 (1): 22-27 (2004)
S S Yadav, O P Sharma, P D Kumawat & R D Yadav
A field experiment was conducted at Jobner (Rajasthan), to evaluate the effect of different weed control measures and levels of

nitrogen on yield, nutrient uptake and quality parameters of cumin (*Cuminum cyminum*). The results showed that two hand weedings at 25 and 50 days after sowing was the most effective treatment that increased the seed yield by 292.9% over weedy check. Among the herbicides, pre-plant trifluralin @ 1.08 kg ha^{-1} was the best treatment (4.94 q ha^{-1}) that was comparable to trifluralin @ 2.16 kg ha^{-1} and pendimethalin @ 1.00 kg ha^{-1}. Nitrogen content in seed and straw of cumin and uptake of nitrogen and phosphorus also significantly improved by different weed control treatments. Maximum protein content (17.60%) was recorded with trifluralin @ 1.08 kg ha^{-1} and essential oil content (2.52%) with pendimethalin @ 1.00 kg ha^{-1}. The study also revealed that application of nitrogen @ 30 kg ha^{-1} which was on par with 45 kg ha^{-1} significantly increased seed and straw yield, nutrient uptake and protein content in cumin in comparison to application of nitrogen @ 15 kg ha^{-1}.

Growth analysis in cumin (*Cuminum cyminum* L.) under different weed control methods and nitrogen levels. 13 (2): 92-96 (2004) S S Yadav & O P Sharma

A field experiment was conducted at Jobner (Rajasthan) to evaluate the effect of weed control and nitrogen application on growth and yield of cumin (*Cuminum cyminum*). The study revealed that two hand weedings done at 25 and 50 days after sowing (DAS) yielded maximum seeds (5.50 q ha^{-1}) which was 292.7% higher over control (with weeds). This treatment also attained maximum harvest index (40.7%), crop growth rate during 40-70 DAS and 70 DAS and relative growth rate during 40-70 DAS phase. Trifluralin @ 1.08 kg ha^{-1} (pre-plant incorporation) also increased seed yield by 252.9% which was the next superior herbicidal treatment with regard to yield and physiological parameters. Application of 45 kg N ha^{-1} was the most effective dose with regard to seed yield, crop growth rate and relative growth rate and was on par with 30 kg N ha^{-1}. Seed yield had a significant and positive association with growth, yield attributes and nutrient uptake by the crop.

Influence of varieties, sheep manure and nitrogen on yield of cumin (*Cuminum cyminum* L.). 13 (2): 126-128 (2004)
M Patidar, Balak Ram, M P Singh & Gopal Singh
The performance of three varieties (Local, RZ-19 and RZ-209) of cumin (*Cuminum cyminum*) and the effect of sheep manure (0 and 5 t ha^{-1}) and nitrogen levels (20 and 40 kg N ha^{-1}) on the yield of the crop was evaluated at Jodhpur (Rajasthan). Growth and yield attributes, seed yield and net returns were significantly higher in improved varieties compared to local variety. Maximum seed yield (580 kg ha^{-1}) and net returns (Rs. 32,400 ha^{-1}) were obtained with RZ-19. Application of sheep manure increased seed yield by 5.2% over no manure; however, net returns were not increased. Nitrogen @ 40 kg ha^{-1} significantly increased seed yield by 26 kg ha^{-1} and net returns by Rs, 1,850 ha^{-1} with benefit-cost ratio of 2.19 over 15 kg N ha^{-1}.

Response of cumin (*Cuminum cyminum* L.) cultivars to nutrient management practices in arid zone of Rajasthan, India. 15 (1): 30-33 (2006)
Raj Singh & A V Rao
A field study was conducted at Satheen Village (Rajasthan) to investigate different nutrient management practices on the production of two cultivars of cumin (*Cuminum cyminum*) in arid zone. Cultivar RZ-19 was superior to local cultivar with respect to seed yield (21.5% higher) and its attributes. The net returns and benefit:cost ratio obtained with RZ-19 was much higher compared to that of local variety. All the nutrient management practices recorded significantly higher yield and its attributes over control. However, the maximum seed yield of 586 kg ha^{-1} was recorded with integrated nutrient management practices involving tumba cake (*Citrullus colocynthis*) with 50% recommended dose of fertilizers and application of bio-fertilizer (*Azotobacter chroococcum* + phosphate solubilizing bacteria), whose yield was at par with that of integrated nutrient management practices involving application of 5 t farm yard manure. Maximum returns (Rs. 20,300) and benefit:cost ratio (2.51) was obtained in integrated nutrient management practices involving application of 5 t of farm yard manure.

Economic feasibility of weed management practices in cumin (*Cuminum cyminum* L.). 18 (1): 9-12 (2009)
S S Meena, R K Kakani & R S Mehta
Field experiments conducted at Ajmer (Rajasthan), to find out the economic feasibility of weed management practices in terms of weed control efficiency and performance of cumin (*Cuminum cyminum*) indicated that weed-free treatments resulted in maximum vegetative growth and seed yield (6.03 q ha^{-1}) followed by pre-emergence application of oxadiargyl @ 75 g ha^{-1} + hand weeding at 45 days after sowing (DAS). Maximum net returns (Rs. 46,365 ha^{-1}) and highest cost: benefit ratio (1:3.48) was also obtained in pre-emergence application of oxadiargyl @ 75 g ha^{-1} + hand weeding at 45 DAS.

Response of cumin (*Cuminum cyminum* L.) to 'panchgavya' and plant leaf extracts in arid western Rajasthan. 18 (2): 92-99 (2009)
R N Kumawat, S S Mahajan & R S Mertia
A field experiment was conducted at Jaisalmer (Rajasthan) to study the effect of foliar applied neem (*Azadirachta indica*), datura (*Datura metel*) and tumba (*Citrullus colocynthis*) leaf extracts in 1:1 combination with 'panchgavya' on growth and yield of cumin (*Cuminum cyminum*). The results revealed that synthesis of chlorophyll and activity of nitrate reductase in fresh leaves increased significantly with application of neem + panchgavya compared to control at 55 and 80 days after sowing. Dry matter accumulation, branches $plant^{-1}$, umbels $plant^{-1}$, seeds $umbel^{-1}$ and 100-seed weight also recorded significant increase with application of neem + 'panchgavya'. Compared to control, neem + 'panchgavya' increased grain, straw and biological yield by 58%, 72% and 65%, respectively. The content and uptake of N and P in seed and straw also recorded significant increase with application of neem + 'panchgavya'. Application of foliar sources both at branching and flowering stages recorded significantly higher accumulation of dry matter, yield and yield attributes, content and uptake of N and P in seed and straw compared to single application at branching or flowering.

Influence of sheep manure, vermicompost and biofertilizer on growth, yield and profitability of cumin (*Cuminum cyminum* L.) production. 21 (1): 16-19 (2012)
R S Mehta, M M Anwer & S K Malhotra
A field study on effect of various sources of organic manure (sheep manure and vermicompost) with and without biofertilizer (*Azotobacter* sp.) on performance of cumin (*Cuminum cyminum* L.) was conducted at Ajmer (Rajasthan) during *rabi* 2003, 2004 and 2005. Application of biofertilizer alone as well as in combination with sheep manure, vermicompost and recommended doses of fertilizer resulted in higher growth, yield attributes and yield over absolute control. The association of biofertilizers with all sources of nutrients proved beneficial and resulted in higher growth and yield. Application of recommended doses of fertilizer with seed inoculation by biofertilizer proved to be superior for realizing higher net return and benefit:cost ratio.

Weed dynamics and critical period of crop weed competition in cumin (*Cuminum cyminum*) under arid region of Rajasthan. 22 (2): 165-169 (2013)
R Singh & A Saxena
A field experiment was conducted to assess the effect of crop weed competition on yield and monetary benefit in cumin under arid conditions of Rajasthan. In the first year of the study *Heliotropium oralifolium* was the most dominating weed species with a relative density, relative frequency and importance value index (IVI) of 24.7, 23.5 and 48.2, respectively, while *Chenopodium murale* dominated during second year with a relative density, relative frequency and importance value index (IVI) of 47.8, 21.8 and 69.6, respectively. Weed competition index decreased with increasing weed free check period. However, weed competition index in weed free check maintained from 30 to 60 days after sowing (DAS) varied from 10.52 and 5.26, while it was 44.76 under weed free check up to 15 DAS. No significant difference in the growth, yield attributes and seed yield was recorded in weed free condition maintained beyond 30 DAS, but differed significantly over weed free check up to 15 DAS. Allowing weeds to compete with crop after 30 DAS and up to harvest

significantly reduced yield attributes and seed yield compared to weedy check up to 15 DAS. The highest mean seed yield (437 kg ha^{-1}) was recorded in season long weed free check, but net monetary benefit was highest (Rs. 19,520 ha^{-1}) with weed free check up to 30 DAS. Thus, the crop should be weed free for at least initial 30 DAS.

Crop Protection

Management of wilt of cumin (*Cuminum cyminum* L.) by organic amendments. 4 (1): 80-81 (1995)
P K Diyora & R R Khandar
Among the various organic amendments used, mustard cake was the best followed by groundnut cake for the management of wilt of cumin (*Cuminum cyminum*) caused by *Fusarium oxysporum* f. sp. *cumini* in pot culture.

Chemical control of *Alternaria* blight of cumin (*Cuminum cyminum* L.). 4 (1): 82-83 (1995)
L F Akbhari & I U Dhruj
Attempts were made to control *Alternaria* blight of cumin (*Cuminum cyminum* L.) caused by *Alternaria burnsii* Uppal, Patel and Kamat. Out of nine fungicides evaluated, three sprays of mancozeb (0.2%) or propiconazole (0.025%) at 12 days interval at initiation of disease was the best for controlling the disease and increasing grain yield.

***In vitro* and field evaluation of biocontrol agents and fungicides against wilt of cumin caused by *Fusarium oxysporum* f. sp. *cumini*. 16 (2): 88-92 (2007)**
P K Bardia & P K Rai
Fungal antagonists and fungicides were evaluated for the management of wilt of cumin (*Cuminum cyminum*) caused by *Fusarium oxysporum* f. sp. *cumini* at Jobner (Rajasthan). On the basis of *in vitro* studies, *Trichoderma harzianum* isolate I_6 and carbendazim were the best treatments in inhibiting the growth of the pathogen. The promising fungal antagonist and fungicides were tested in the field at different combinations and the most effective combination was seed treatment with carbendazim (2 g kg^{-1} seed) in combination

with *T. harzianum* isolate I_6 (10^8 spores ml^{-1}). This treatment combination resulted in significantly lowest disease incidence (11.7%) and highest yield (6.17 q ha^{-1}).

In vitro evaluation of plant extracts and bioagents against _Alternaria burnsii_ Uppal, Patel & Kamat causing blight of cumin (_Cuminum cyminum_ L.). 17 (1): 26-28 (2008)
K B Jadeja & B H Pipliya
Laboratory evaluation of 14 plant extracts for growth inhibition of *Alternaria burnsii*, the causal organism of blight disease of cumin (*Cuminum cyminum*) indicated that 5% and 10% extract of garlic cloves and ginger rhizomes were most effective resulting in 78.52% and 72.96% mean inhibition, respectively. Evaluation of 11 isolates of *Trichoderma* spp. against the pathogen in the laboratory indicated that *T. harzianum* 360 and *T. viride* Anand were most effective resulting in 100% inhibition of *A. burnsii*.

Integrated management of wilt of cumin (_Cuminum cyminum_ L.). 17 (3): 223-229 (2008)
K B Jadeja & D M Nandoliya
Four components of integrated management namely, soil solarization, crop rotation, chemicals and biocontrol agents were tested under field condition at Junagadh (Gujarat) for the management of wilt of cumin (*Cuminum cyminum*) caused by *Fusarium oxysporum* f. sp. *cumini*. Growing of sorghum (*Sorghum bicolor*) or maize (*Zea mays*) during *kharif* season did not reduce wilt incidence during the following *rabi* season. Soil solarization with 25 µm LLDPE plastic cover for 15 days in summer proved most effective in reducing wilt incidence to 26.27% as against 44.90% in non-solarization and increasing yield to 396 kg ha^{-1} as against 286 kg ha^{-1} in non-solarized plots. Application of carbendazim granules 10 kg ha^{-1} one month after sowing or *Trichoderma viride* in organic carrier @ 62.5 kg ha^{-1} at sowing time were also effective. Integrating soil solarization followed by growing of sorghum in *kharif* and application of either carbendazim granules 10 kg ha^{-1} one month after sowing or application of *T. viride* in organic carrier 62.5 kg ha^{-1} was effective for the management of cumin wilt

Integrated strategy to control wilt disease of cumin (*Cuminum cyminum* L.) caused by *Fusarium oxysporum* f. sp. *cumini* (Schlecht) Prasad & Patel. 18 (1): 13-18 (2009)
Deepak & G Lal
Various fungicides, oilcakes and fertilizers were evaluated at Jaipur (Rajasthan) for the management of cumin (*Cuminum cyminum*) wilt caused by *Fusarium oxysporum* f. sp. *cumini*. Trimethyl thiuram disulphide (0.1 g g^{-1} seeds) was the best fungicide which was on par with propiconazole, carbendazim and copper oxychloride (0.1 g g^{-1} seeds) for the control of wilt. The disease incidence was minimum under the soil treatment with neem cake (30 q ha^{-1}) which was on par with sesamum cake (25 q ha^{-1}). Among the chemical and non-chemical manures, application of NPK 40 kg ha^{-1} was most suitable to control the disease which was on par with *Azotobacter* 40 kg ha^{-1}. The disease incidence was also significantly lower in plants grown in solarized soil. The yield was significantly higher in all treatments as compared to control. The highest cost benefit ratio was obtained (1:40) in thiophanate methyl treatment followed by carbendazim. Among the combined treatments, minimum disease incidence was recorded with solarized soil + sesamum cake 25 q ha^{-1} + seed treatment with carbendazim @ 0.1 g g^{-1} seeds followed by solarized soil + sesamum cake 25 q ha^{-1} + *Azotobacter* @ 40 q ha^{-1}. However, the highest cost benefit ratio (1:10.6) was obtained with solarized soil + sesamum cake 25 q ha^{-1} + *Azotobacter* (biofertilizer) 40 kg ha^{-1}. The integrated treatments recorded the highest grain yield and low disease incidence over control as compared to individual application.

Evaluation of *Trichoderma* spp. along with farm yard manure for the management of Fusarium wilt of cumin (*Cuminum cyminum* L.). 19 (1&2): 57-60 (2010)
S Gangopadhyay & Ram Gopal
The efficacy of *Trichoderma harzianum* and *T. viride* used as seed treatment and soil application with and without farm yard manure in controlling wilt of cumin (*Cuminum cyminum*) caused by *Fusarium oxysporum* f. sp. *cumini* was studied at Bikaner (Rajasthan) in pathogen inoculated soil under greenhouse condition. The two antagonists were evaluated as seed treatment @ 4, 6 and 8 g kg^{-1} seed;

in case of soil application, these were evaluated @ 5 g kg^{-1} soil. Among the 12 combinations tested, maximum reduction in disease incidence was recorded when *T. harzianum* was used as seed treatment 4 g kg^{-1} seed + soil application @ 5 g kg^{-1} soil along with soil amendment of farm yard manure @ 10 kg^{-1} soil. This treatment also resulted in highest dry weight of cumin plants.

Efficacy of indigenous *Trichoderma* isolates for the management of cumin wilt (*Fusarium oxysporum* f. sp. *cumini*) in Rajasthan. 23 (2): 268-271 (2014)

Y K Sharma, K Kant, S Sriram & B Ramanujam

Sixteen *Trichoderma* isolates from soils under cumin, identified as *Trichoderma harzianum*, *T. koningiopsis* and *T. asperllum* showed variation in their colony morphology as well as degree of inhibition of *Fusarium oxysporum* f.sp. *cumini*. In the field experiment, all *Trichoderma* isolates were tested as seed treatment and soil application on cumin cultivar RZ 209. The result showed that *T. asperllum* (CuTa7-02, CuTa3-01), *T. koningiopsis* (CuTk7-01) and *T. harzianum* (CuTh9-02, CuTh3-03, CuTh8-01) significantly reduced wilt incidence (58-85%) and can be used as biological components in integrated management of cumin Fusarium wilt.

Comparative efficacy of biological control agents for the management of cumin wilt caused by *Fusarium oxysporum* f.sp. *cumini*. 24 (1): 18-22 (2015)

Y K Sharma, S K Lodha , S Sriram & B Ramanujam

Field experiments were conducted during *rabi* 2008-09 and 2009-10 for the management of cumin wilt caused by *Fusarium oxysporum* f.sp. *cumini*. The results showed that seed treatment with *Trichoderma viride* (10 g kg^{-1} of seed) and soil application (2.5 kg ha^{-1}) recorded minimum per cent disease incidence (PDI) of 18.5 (disease reduction of 51.8%) versus 38.4 in the control. It was on par with seed treatment and soil application with *Aspergillus versicolor* at 10 g kg^{-1} of seed and 2.5 kg ha^{-1}, respectively which reduced the disease incidence by 45.4%. The chemical treatment i.e. seed treatment with carbendazim at 2.5 g kg^{-1} seed recorded PDI of 23.9 with 37.7% disease reduction. Among different treatments seed treatment and

soil application with *A. versicolor* gave a seed yield of 246 kg ha^{-1} followed by *P. fluorescens* (222.6 kg ha^{-1}). Treatment *T. viride*, recorded the highest yield of 258.2 kg ha^{-1}. Hence, seed treatment at 10 g kg^{-1} and soil application at 2.5 kg ha^{-1} of *T. viride* was the most effective, eco-friendly disease management.

Bioefficacy of different insecticides against aphid (*Myzus persicae*) in cumin (*Cuminum cyminum* L.). 26 (2): 83-85 (2017)
N L Dangi, M K Mahla, K C Ahir & H Swami
A field trial was conducted in Udaipur to the evaluate efficacy of carbosulfan 25% EC at 250, 312.5 and 375 g a.i. ha^{-1} along with thiamethoxam 25% WG at 25 g a.i. ha^{-1}, imidacloprid 17.8 SL at 25 g a.i. ha^{-1} and acetamiprid 20% SP at 10 g a.i. ha^{-1} against aphid (*Myzus persicae*) in cumin during *Rabi*, 2013-14 and 2014-15. The result revealed that two sprays of carbosulfan 25% EC at 375 g a.i. ha^{-1} was found effective against aphid. It caused maximum mean reduction in aphid population after second spray at 10 days after application, which was 87.52% and 88.45% during 2013-14 and 2014-15, respectively. It was followed by carbosulfan 25% EC at 312.5 g a.i. ha^{-1}. The maximum yields were recorded in case of carbosulfan 25% EC at 375 g a.i. ha^{-1}, which were 622.3 and 456.7 kg ha^{-1} during 2013-14 and 2014-15, respectively.

Biology of aphid, *Aphis gossypii* Glover in cumin. 32 (1): 98-103 (2023)
Sarita Dadhich, Shalini Pandey, M M Kumawat & M M Sundria
The experiment on biology of aphid, *Aphis gossypii* infesting cumin crop was conducted under ambient conditions in the Entomology Laboratory, Agricultural Research Station, Mandor, Jodhpur. The study was conducted on potted plants of cumin variety GC-4. The aphid, *A. gossypii* nymphs were moulted four times before attaining the adult stage. The mean body length, width, antennal length and cornicle length of first, second, third and fourth instar nymphs were 0.50 ± 0.04, 0.28 ± 0.03, 0.28 ± 0.02 and 0.036 ± 0.01 mm; 0.90 ± 0.04, 0.38 ± 0.04, 0.40 ± 0.03 and 0.065 ± 0.01 mm; 1.11 ± 0.05, 0.49 ± 0.04, 0.54 ± 0.03 and 0.095 ± 0.01 mm and 1.31 ± 0.06, 0.65 ± 0.05, 0.64 ± 0.04 and 0.175 ± 0.01 mm, respectively. The mean body length, width,

antennal length and cornicle length of adult aphid were 1.68 ± 0.06, 0.71 ± 1.53, 0.88 ± 0.02 and 0.266 ± 0.01 mm, respectively. The mean duration of first, second, third and fourth instar nymphs were 1.30 ± 0.42, 2.05 ± 0.62, 2.40 ± 0.52 and 1.45 ± 0.45 days, respectively. The total nymphal duration was 7.75 ± 1.61 days. The mean longevity of adult aphid was 9.65 ± 1.75 days with an entire life span of 17.75 ± 2.91 days. The pre-reproductive, reproductive and post-reproductive periods were 1.35 ± 0.56, 7.20 ± 1.47 and 1.75 ± 0.71 days, respectively. The fecundity of the adult female was 24.45 ± 6.21 nymphs per female and the intrinsic rate of single female was an average of 4.80 ± 2.01 nymphs/day.

Social Sciences

Adoption of cumin (*Cuminum cyminum* L.) production technology in arid zone of Rajasthan. 14 (2): 148-151 (2005)
Bhagwan Singh
A study was conducted in four districts of Rajasthan, namely, Jodhpur, Pali, Bikaner and Jaisalmer, to determine the extent of adoption of various technologies in cumin (*Cuminum cyminum*) by farmers in the arid zone of the state. The study revealed that a majority (62.5%) of the farmers had adopted various production technologies to a medium level. Out of 16 variables, 5 variables, namely, education, occupation, irrigation facilities, sources of information and knowledge were positively and significantly correlated with overall adoption whereas, age and farming experience were negatively and significantly correlated with overall adoption of production technologies. The 16 independent variables taken together explained 59.9% of the variation in adoption of cumin production technology.

Constraints in adoption of production technologies in cumin (*Cuminum cyminum* L.). 16 (1): 42-45 (2007)
Bhagwan Singh
A study was conducted in four districts of Rajasthan, namely, Jodhpur, Pali, Bikaner and Jaisalmer, to study the constraints in adoption of production technologies in cumin (*Cuminum cyminum*). The study revealed that non-availability of seeds of high yielding varieties at

proper time, lack of knowledge and interest, high cost of seeds, fertilizers and pesticides, lack of technical guidance and lack of finance were perceived by farmers as main constraints in adoption of improved technologies.

Performance of improved varieties and technological interventions at farmers' fields for cumin cultivation. 24 (2): 145-148 (2015)

G Lal, R S Mehta, P Chand , A S Godara & H Cheriyan

Front line demonstrations on cumin consisting of two improved varieties (GC-4 and RZ-209) with scientific interventions *viz*., seed treatment (Bavistin @2.5 g kg^{-1} seed and *Trichoderma viride* @ 4 g kg^{-1} seed), and pre-emergence application of oxadiragil (Raft) @ 75 g a.i. ha^{-1} for effective weed management and application of recommended doses of nutrients (40:40:0 kg ha^{-1} NPK) for balanced nutrition and appropriate plant protection schedule [(two sprays of malathion (0.2%), two sprays of Dithan M-45 (0.2%) and one spray of karathan (0.1%) for the control of aphids, blight and powdery mildew, respectively)] were carried out at farmer's fields in two villages (Kajipura and Bhadal) of Jaipur and one village (Karad) of Sikar district of Rajasthan during *Rabi* season of 2011-12 and 2012-13. Study revealed that overall yield was increased by 21.09% over farmer's practice due to the technological interventions with average yield of 536.50 kg ha^{-1}. Overall extension gap of 112.50 kg ha^{-1} and technical gap of 463.50 kg ha^{-1} were recorded in the study with 46.35% technology index. Maximum additional return (Rs. 15,875 ha^{-1}) with highest effective gain (Rs. 10,775 ha^{-1}) and incremental B:C ratio (3.11) were obtained in the year 2011-12. However, the overall average additional return was Rs. 14,601 ha^{-1} with effective gain of Rs. 9,401 ha^{-1} and incremental B:C ratio of 2.81.

FENNEL

Crop Improvement and Biotechnology

Variability, correlation and path analysis in fennel (*Foeniculum vulgare* Mill.). 6 (1): 51-54 (1997)
Puneet Agnihotri, S L Dashora & R K Sharma
Forty eight collections of fennel (*Foeniculum vulgare*) showed significant variability for days to flowering, plant height, branches per plant, umbels per plant, umbellets per umbel, grains per umbel, 1000 seed weight, yield per plant and yield per plot at Jobner, India. The broad sense heritability was high for 1000 seed weight, umbels per plant and grain yield per plant while genetic advance was high for umbels per plant, yield per plant and yield per plot. Grain yield per plot was significant and positively associated with yield per plant, grains per umbel and umbels per plant. Branches per plant showed a high positive, direct effect on yield per plot followed by grains per umbel and plant height.

Varietal diallel analysis for yield and yield related traits in fennel (*Foeniculum vulgare* Mill.). 11 (1): 18-21 (2002)
Abhay Dashora, R K Sharma, E V D Sastry & D Singh
A half diallel of nine genetically diverse varieties was made and resulting 36 F_1 populations along with the parents were evaluated during *rabi* 1997-98. The analysis of variance indicated that heterosis was significant for all the characters, except for branches per plant. The heterosis components were also significant for most of the traits studied. Specific heterosis component accounted for more than 50% of the overall heterosis, indicating complex type of inheritance for seed yield and its component traits. The crosses UF (M)-l x UF-134, RF-125 x JF-29 and UF-90 x HF-71 exhibited significant and positive heterobeltiosis for seed yield per plant.

Genetic association in fennel grown on sodic soil. 12 (2): 171-173 (2003)
V K Garg, Sudhir Shukla & P K Singh
Correlation and path analysis of 30 genotypes of fennel (*Foeniculum vulgare* Mill.) grown in sodic soils of Banthra Research Station of NBRI, Lucknow, India, were worked out. Results showed significant genotypic association of seed yield with plant height and stover yield. The stover yield had a positive direct path with seed yield followed by branches plant^{-1}. Plant height exhibited significant positive genotypic association with all the traits, which suggests that plant height is mainly responsible for increase of each trait, ultimately contributing in the enhancement of seed yield. The plant height, number of branches per plant and stover yield were found important components to build an ideal plant type to increase seed yield. Hence selection should be based on these traits.

Mass, full and half sib-selection for genetic improvement in fennel (*Foeniculum vulgare* Mill.). 12 (2): 179-182 (2003)
V V Singh & E V Divakara Sastry
A study was conducted to estimate genetic variances and heritability for yield and yield attributes in fennel UF-143 population using North Carolina Design-I. The dominance component was high for days to 50% flowering, branches per plant, umbels per plant, seeds per umbel, seed yield, harvest index and test weight. Preponderance of additive gene action was observed for plant height, umbellets per umbel and biological yield. The heritability in narrow sense was high for biological yield. Among the various methods for which theoretical responses were calculated, mass selection appeared suitable for the improvement of biological yield, harvest index, test weight, seed yield, umbellets per umbel, umbels per plant and branches per plant.

Assessment of S_1 progenies in two diverse populations of fennel (*Foeniculum vulgare* Mill.). 13 (1): 40-43 (2004)
V V Singh, E V D Sastry & D L Singhania
An investigation was conducted at Jobner (Rajasthan) to estimate variability, heritability and expected selection gain among S_1

progenies generated from RF-125 and UF-143 populations of fennel (*Foeniculum vulgare*). The inter-family variance was higher in comparison to intra-family variance in both the populations for most of the characters studied. The estimates of heritability (narrow sense) were high only for plant height in RF-125. For rest of the characters, the heritability was medium to low. The expected genetic gain was medium to low in both the populations and was highest in umbels plant^{-1} in RF-125. The study suggests that significant inter-family variance is still present in these populations which can be exploited.

Comparison of full sib, half sib and S_1 progenies in fennel (*Foeniculum vulgare* Mill.). 13 (2): 129-131(2004)
V V Singh, E V Divakara Sastry & D L Singhania
A field experiment was conducted at Jobner (Rajasthan), to compare different population improvement methods in a fennel (*Foeniculum vulgare*) population namely, UF-143. Estimates of genotypic coefficient of variation and phenotypic coefficient of variation were higher in full sib than S_1 and half sib progenies for most of the traits. Heritability estimate was higher in full sib progenies for days to 50% flowering, seeds umbel^{-1} and test weight, while half sib showed maximum heritability for branches plant^{-1}, umbels plant^{-1} and umbelletes umbel^{-1}. S_1 progenies recorded maximum heritability and genetic gain for seed yield plant^{-1}. For most of the traits, full sib progenies recorded maximum genetic gain except plant height, umbellets umbel^{-1} and seed yield plant^{-1}.

Combining ability in fennel (*Foeniculum vulgare* Mill.) for yield and quality. 14 (1): 42-46 (2005)
S S Rajput, D L Singhania, D Singh & R S Raje
Twelve genetically diverse varieties of fennel (*Foeniculum vulgare*) were evaluated at Jobner (Rajasthan) following diallel mating design for determining their utility as parents in the development of hybrids and/or high yielding composites. The analysis of variance indicated that varieties and heterosis were significant for most of the characters studied, indicating complex type of inheritance involving additive, dominance and epistatic components. The heterosis sum of squares

accounted for more than 75% of the entries sum of squares. Partitioning of overall heterosis variation indicated that contribution of specific heterosis was the highest (>50%) among the three components. Estimates of genetic constants indicated that varietal heterosis effects were significant for all the traits except days to 50% flowering and test weight, while specific heterosis effects were significant for most of the characters. The cross RF-101 x JF-25 showed the highest positive specific heterosis effect for seed yield plant^{-1} along with high specific heterosis effects for umbels and biological yield plant^{-1}. These two parents represented a good choice to initiate inter-population improvement.

Studies on variability of some morphological characters in fennel (*Foeniculum vulgare* Mill.). 17 (1): 29-32 (2008)
D G Patel, P S Patel & I D Patel

Analysis of variability carried out for 15 characters in 36 diverse genotypes of fennel (*Foeniculum vulgare*) at Jagudan (Gujarat) revealed highly significant differences among genotypes for all the characters studied. High genotypic and phenotypic variances were observed for days to 50% flowering, days to 50% maturity, plant height, plant height up to main umbel, total branches plant^{-1}, number of seeds main umbel^{-1} and seed yield plant^{-1}. The highest genotypic coefficient of variation was observed for volatile oil content in seed followed by total branches plant^{-1} and number of seeds main umbel^{-1}. Heritability estimates were high for seed yield plant^{-1}, days to 50% flowering, number of primary branches plant^{-1}, total branches plant^{-1}, test weight and volatile oil content. High genetic advance as percentage of mean was recorded for seed yield plant^{-1}, days to 50% flowering, primary branches plant^{-1}, total branches plant^{-1}, effective umbels plant^{-1}, number of umbellates umbel^{-1}, number of seeds main umbel^{-1}, test weight and volatile oil content, suggesting that phenotypic selection for these traits would be effective. Overall, it is suggested that for improving yield in fennel, more emphasis should be given to plant height, primary branches plant^{-1}, total branches plant^{-1} and effective umbels plant^{-1}.

Genetic evaluation for biometrical traits in fennel (*Foeniculum vulgare* Mill.). 22 (1): 85-87 (2013)
S K Rawat, S Kumar & Y C Yadav
The genetic variability, heritability, genetic advance, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) of 13 diverse genotypes of fennel were studied. Considerable amount of variation was recorded for all the characters. The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) in all the characters. The maximum genotypic coefficient of variation (GCV) was recorded for yield plant^{-1} (40.27) followed by seed yield (32.40 q ha^{-1}), weight of seed umbel^{-1} (27.12), number of umbellets umbel^{-1} (17.47) and number of seeds umbel^{-1} (16.88). High heritability coupled with high genetic advance were recorded for number of seeds umbel^{-1}, yield plant-^{1}, plant height, number of umbel plant^{-1} and number of branches plant^{-1}.

On-farm assessment of fennel varieties in Rajasthan. 22 (2): 200-202 (2013)
M L Meena & D Singh
Fennel varieties *viz*., RF-205, RF-125, RF-145, RF-178 and NRCSS-AF1 with the recommended package of practices were evaluated in 120 farmers' field from eight adopted villages of Pali district of Rajasthan. The results of the study indicated that under diversified agro-climatic conditions, three varieties of fennel *viz*., NRCSS-AF1, RF-205 and RF-125 were promising over local check with higher B:C ratio of 2.21, 2.02 and 1.63, respectively.

Variability studies in fennel (*Foeniculum vulgare* Mill.). 22 (2): 203-208 (2013)
P S Yadav, V P Pandey & Y Yadav
Analysis of variability carried out for nine characters in 25 diverse genotypes of fennel (*Foeniculum vulgare*) revealed high genotypic and phenotypic coefficient of variations for seed yield plant^{-1}, weight of grains umbel^{-1}, number of umbels plant^{-1}, number of branches plant^{-1}, number of umbellet umbel^{-1} and plant height. Heritability estimates were high for test weight, weight of grains umbel^{-1}, seed yield plant^{-1}, number of umbel plant^{-1}, plant height and number of umbelletes

umbel^{-1}. Higher genetic advance as per percentage of mean was recorded for seed yield plant^{-1}, weight of grains umbel^{-1}, number of umbels plant^{-1}, number of branches plant^{-1}, number of umbelletes umbel^{-1}, plant height and test weight. The plant height, days to 50% flowering, number of branches plant^{-1}, number of umbels plant^{-1}, number of umbellets umbel^{-1} and weight of grains umbel^{-1} exhibited positive and significant correlation with seed yield. Path coefficient analysis revealed that days to maturity had highest direct effect on seed yield followed by days to 50% flowering and number of umbels plant^{-1}. Therefore, greater emphasis should be given on these characters while selecting for higher yield and related traits.

Stability analysis for seed yield and yield attributing traits in fennel (*Foeniculum vulguare* Mill.). 27 (1): 74-80 (2018)
S L Sawargaonkar, A K Singh & S Sahu

Study was carried to evaluate phenotypic stability of 13 genotypes of fennel for seed yield and yield attributing traits. Out of 13 genotypes, three were checks (RF 205, RF 201 and Local fennel) grown in Randomized Block Design (RBD) with three replications in each year. The significant genotypic differences were observed for all the characters suggesting differential responses of genotypes to the environmental changes. The results showed that among 13 genotypes RF 205 and Local fennel were found stable for seed yield plant^{-1}, FNL 69 for days to flower, FNL 70 and RF 101 for primary branches plant^{-1}, FNL 74 for umbels umbellet^{-1} and FNL 71 for umbels plant^{-1}. The results revealed that some reliable predictions about G x E interaction as well as its unpredictable components contributed significantly in determining the stability of genotypes. The wider stability recorded by RF 205, RF 201 and Local fennel during all the three years which will be useful for development of high yielding varieties of fennel.

Crop Production and Postharvest Technology

Dodder (*Cuscuta reflexa* Roxb.), a severe parasitic weed on fennel (*Foeniculum vulgare* Mill.). 3 (2): 152-154 (1994)
D S Bhati
A survey on weed infestation in fennel (*Foeniculum vulgare*) undertaken in Tonk District of Rajasthan, India during *rabi* season of 1986-87, indicated that the parasitic weed *Cuscuta reflexa* was observed in 6 fields among the 11 fields surveyed. In infested fields, 70.70 to 23.04 per cent plants were parasitised. The seed yield was 25.27 to 11.32 g/plant in healthy plants and 10.18 to 4.47 g/plant in infested plants. The reduction in estimated seed yield due to infestation by *C. reflexa* ranged from 14.04 to 30.07 per cent. One hundred per cent infestation reduced the seed yield by 31.21to 71.52 per cent.

Chemical composition of the essential oil of bitter fennel (*Foeniculum vulgare* subsp. *piperitum*). 10 (1): 49-50 (2001)
M Ozcan & A Akgul
The composition of the essential oil obtained by steam distillation from seeds of bitter fennel (*Foeniculum vulgare* subsp. *piperitum*) was analysed by GC/MS. The presence of at least seventeen compounds was demonstrated. They correspond to 99.95% of the oil. Methyl chavicol was the main constituent of the oil (47.09%), followed by limonene (29.07%), fenchone (13.43%), α-terpinene (2.5%), fenchyl acetate (exo) (1.95%) and *cis*-β-ocimene (1.41%). *Trans*-anethole was not detected. Therefore, it is concluded that the oil of Turkish bitter fennel is rich in methyl chavicol.

Evaluation of fennel (*Foeniculum vulgare* Mill.) germplasm for production and quality. 12(2): 174-178 (2003)
Sanjeev Agrawal, Dhirendra Singh & S S Rajput
Seventy four fennel (*Foeniculum vulgare* Mill.) accessions along with check varieties RF-101 and RF-125 were evaluated for yield and yield attributing characters. Eight promising accessions for seed yield were then evaluated for volatile oil content. The oil content of three most promising accessions along with check varieties were

analyzed on a GLC. The accession, UF-178, exhibited superiority over other accessions in respect of yield attributing characters such as branches plant^{-1}, seeds umbel^{-1} and seed yield. UF-177 was found to be superior with respect to volatile oil content as well as volatile oil yield. UF-177 has the least fenchone content among the three. UF-179 was having maximum anethole content, which was found to be at par with variety-RF-101. These three accessions may be exploited in breeding programmes for production and quality.

Maximization of seed yield in transplanted fennel (*Foeniculum vulgare* Mill.). 16 (1): 46-49 (2007)
B L Menaria & P L Maliwal

A field experiment was conducted at Udaipur (Rajasthan) to study the effect of three plant densities, four fertilizer treatments and two growth regulators on yield maximization of transplanted fennel (*Foeniculum vulgare*). Planting of fennel at a density of 27,770 plants ha^{-1} recorded significantly higher yield attributes (umbels plant^{-1}, seed yield plant^{-1} and test weight), while seed yield ha^{-1} was higher with a density of 55,550 plants ha^{-1} (20.89 q ha^{-1}). Application of 90 kg N + 40 kg P_2O_3 + 20 kg K_2O + 20 kg S + 5 kg Zn ha^{-1} recorded significantly higher yield attributes and yield of fennel during both the years. Application of naphthalene acetic acid 100 ppm recorded significantly higher yield attributes and seed yield.

Effect of non-symbiotic microbial inoculants on growth, yield and quality of fennel (*Foeniculum vulgare* Mill.) grown in sodic soil. 16 (2): 93-98 (2007)
V K Garg

The response of non-symbiotic microbial inoculants on growth, yield and quality of fennel (*Foeniculum vulgare*) grown in partially reclaimed sodic soils was studied at Lucknow (Uttar Pradesh). The results revealed that inoculation of phosphate solubilizing bacteria or in combination with *Azotobacter chroococcum* was superior resulting in 14%-15% increase in seed yield. Application of fertilizers (80 kg ha^{-1} N + 25 kg ha^{-1} P) with inoculants had an additive effect on plant growth. An increase in availability of soil P (41%-44%) and essential oil content (10%-14%) was also noticed.

Effect of chemical fertilizers on growth, yield and quality of fennel (Foeniculum vulgare Miller). 17 (2): 134-139 (2008)
Hans Raj & K K Thakral
A field experiment was conducted to study the effect of nitrogen (N), phosphorus (P) and potash (K) on growth, seed yield and quality of fennel at the vegetable research farm, Department of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar during 2002-2003 and 2003-2004. The experiment consisted of 16 treatment combinations with four levels each of N (25, 50, 75 & 100 kg ha^{-1}), P (25 & 50 kg ha^{-1}) and K (25 & 50 kg ha^{-1}). The experiment was laid out in randomized block design with three replications. The results revealed significant differences in growth and yield parameters among the treatments. Application of N at 100 kg ha^{-1}, P at 50 kg ha^{-1} and K at 50 kg ha^{-1} recorded the maximum values of plant height, flowering, umbels per plant and umbellets per umbel, while seeds per umbel, seed yield (q ha^{-1}) and harvest index was found maximum at 75 kg nitrogen, 50 kg phosphorus and 50 kg potash per hectare. However a dose of 75 kg N, 50 kg P_2O, and 25 kg K_2O per hectare was found economical.

Growth and yield of fennel (*Foeniculum vulgare* Mill.) as influenced by irrigation, nutrient levels and crop geometry. 20 (2): 77-80 (2011)
R S Mehta, M M Anwer & O P Aishwath
A field experiment was conducted during 2003-06 at Ajmer (Rajasthan) to study the growth, profitability and productivity of fennel (*Foeniculum vulgare*) as influenced by irrigation (12, 15 and 18 days interval), nutrients levels (N and P_2O_5 each at 60/30, 90/40 and 120/50 kg ha^{-1}) and crop geometry (40 cm x 25 cm, 50 cm x 25 cm and 60 cm x 25 cm). Significantly higher yield attributes, seed yield and N, P and K uptake was obtained with 15 days irrigation interval. Growth parameters, yield attributes, yield and N, P and K uptake were significantly higher with application of 120 kg N and 50 kg P_2O_5 ha^{-1}. Crop geometry of 60 cm x 25 cm resulted in significantly higher seed yield. Thus, irrigation at 15 days interval with 120 kg N and 50 kg P_2O_5 ha^{-1} at 60 cm x 25 cm was optimum for realizing higher yield, profitability and productivity of fennel.

Sodicity affects growth, yield and cation composition of fennel (*Foeniculum vulgare* Mill.). 21 (2): 130-135 (2012)
V K Garg
Field trials were conducted at Banthra, Lucknow, (Uttar Pradesh) to study the effect of sodicity on growth, yield and cation composition of fennel (*Foeniculum vulgare* mill.) grown in a Typic Natrustalf. The treatments included five exchangeable sodium percentage (ESP) levels (10, 20, 30, 40 and 50) and four genotypes *viz*., HF-107, NDF-9, Local BRS and NDF-7. An adverse effect of sodicity was observed on emergence of secondary branches and seed setting causing decrease in seed yield. The variety HF-107 produced the highest seed yield (1956 kg ha^{-1}) followed by Local BRS (1709 kg ha^{-1}), NDF-9 (1577 kg ha^{-1}) and NDF-7 (1078 kg ha^{-1}). The cation composition of stover revealed Na inclusion mechanism with narrow K/Na and Ca/Na ratios. The study further revealed that the crop can tolerate medium level of sodicity (ESP 30).

Standardization of primary processing of fennel (*Foeniculum vulgare* Mill.) in tribal area of Sirohi (Rajasthan). 22 (1): 11-19 (2013)
R L Bhardwaj, U Nandal, D K Sarolia & L Vyas
An experiment was conducted in a farmer's field at Sirohi (Rajasthan) during 2009-10 and 2010-11. Five separate experiments on (i) harvesting time (ii) umbels drying structure (iii) fennel threshing floor (iv) grading stages and (v) packing material of fennel, were laid out in a completely randomized design with four treatments replicated five times. The results revealed that different treatments had significant effect on sensory attributes, geometry and economics of fennel seed quality. The fennel umbels which were harvested at post maturity stage [31-40 days after flower initiation (DAFI)] were superior to rest of the harvesting stages and recorded maximum sensory scores, seed dimensions and highest yield (17.35 q ha^{-1}), maximum market rate (Rs. 150.24 kg^{-1}) and B:C ratio (4.62). Results also showed that drying of fennel umbels in modified locally made structures gave better quality of seed over other structures, giving good market price (Rs. 135.74 kg^{-1}). Threshing on RCC floor was found to be better for maintaining good quality of seed. The grading

and packing also improved the quality of seed. The fennel seed which was packed in polyethylene lined gunny bag was found to be better because the quality of seed did not deteriorate in terms of taste, colour, and flavour for longer time. Maximum shelf life of produce along with better quality and higher market price was also obtained in this treatment.

Effect of irrigation and crop geometry on growth, yield, quality and profitability of transplanted fennel (*Foeniculum vulgare* Mill.). 23 (1): 51-58 (2014)

R L Bhardwaj & S K Agrawal

Field experiments were conducted in two adjoining farmer's field in a tribal area of district Sirohi (Rajasthan) during two successive seasons from July to March, 2011 and 2012 to study the impact of varied crop geometry and irrigation methods on production, quality and profitability of fennel. The trench method of irrigation exhibited significantly higher plant height, number of branches, number of roots plant^{-1}, root length, fresh weight of shoot and roots plant^{-1}, maximum number of umbels plant^{-1}, umbellate umbel^{-1}, number of seed umbel^{-1}, highest seed yield (26.52 q ha^{-1}) with maximum gross return (Rs. 3,05,714.15), net return (Rs. 2,66,314.15) and benefit:cost ratio (6.75). Comparatively less time (26.25 h) was required for one hectare irrigation in the same treatment in both the years. The crop planted in paired row (210 cm/120 cm × 25 cm) significantly influenced crop growth, yield and profitability of fennel. In this treatment, highest plant height, number of branches plant^{-1}, number of roots plant^{-1}, root length, fresh weight of shoot and root, maximum number of umbel plant^{-1}, umbellate umbel^{-1}, number of seed umbel^{-1}, highest seed yield (28.55 q ha^{-1}) with maximum gross return (Rs. 3,36,940.80), net return (Rs. 2,94,670.80) and benefit:cost ratio (6.97) was observed in both the years. Lower growth, yield and profitability were found in border strip method of irrigation and single row (90 cm × 45 cm) method of planting.

Response of fennel (*Foeniculum vulgare*) to irrigation and mulching. 23 (1): 106-109 (2014)
M Meena, L R Yadav, S S Yadav, O P Sharma, G L Choudhary & P Choudhary
A field experiment was conducted to find out the effect of irrigation levels and mulching on performance of fennel. Results indicated that application of six irrigations significantly increased the plant height, number of branches plant^{-1}, total chlorophyll content, dry matter accumulation per metre row length, number of umbels plant^{-1}, umbellets umbel^{-1}, seeds umbellet^{-1} as well as seed, stover and biological yield of fennel compared to four and five irrigations. However, it remained at par with seven irrigations. Results further revealed that application of straw mulch significantly increased number of branches plant^{-1}, dry matter accumulation per metre row length, number of umbellets umbel^{-1} and yields (seed, stover and biological) over control, dust and plastic mulches. Plant height and number of umbels plant^{-1} increased significantly with straw mulch as compared to control and dust mulch, but remained at par with plastic mulch. However, in respect of number of seeds umbellet^{-1}, straw, plastic and dust mulch gave similar results.

Influence of organic and inorganic sources of fertilizers on growth, yield and economics of fennel (*Foeniculum vulgare* Mill.) cultivation under semi-arid conditions. 23 (2): 200-204 (2014)
A S Godara, U S Gupta, G Lal & R Singh
The experiment was conducted with eight treatments (absolute control and varying proportions of organic and inorganic sources of nutrients *viz*., 100% recommended dose of nitrogen (RDN) through fertilizers (90:45:0), 100% RDN through farm yard manure, 100% RDN through poultry manure, 100% RDN through vermicompost, 50% RDN through fertilizers + 50% RDN through farm yard manure, 50% RDN through fertilizers + 50% RDN through poultry manure and 50% RDN through fertilizers + 50% RDN through vermicompost). Results revealed that RDN through fertilizers and combinations of different organic and inorganic sources produced significantly higher grain yield over absolute control. RDN (100%) applied through fertilizers exhibited highest vegetative growth and yield attributes

with maximum yield (2325 kg ha^{-1}), net returns (Rs. 62,091 ha^{-1}) and benefit cost ratio (3.01), closely followed by 50% RDN through fertilizers + 50% RDN through vermicompost.

Response of fennel (*Foeniculum vulgare* Mill.) to phosphorus and zinc fertilization in a loamy sand soil. 24 (1): 23-27 (2015)
S K Kumawat, B L Yadav & S R Kumawat

The field experiment was conducted with four levels of phosphorus (0, 20, 40, and 60 kg ha^{-1}) and four levels of $ZnSO_4$ (0, 15, 30 and 45 kg ha^{-1}) to study their effects on growth and yield of fennel. Application of P up to 40 kg ha^{-1} significantly increased days to 50% flowering, plant height, number of branches, number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, seeds $umbel^{-1}$, seed and stover yield, net return and B:C ratio. The delay in 50% flowering, plant height, number of branches $plant^{-1}$, number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$ and seeds per $umbel^{-1}$, seed and stover yield, net return and B:C ratio increased significantly up to 30 kg $ZnSO_4$ ha^{-1}. The combined application of P @ 40 kg ha^{-1} and Zn @ 30 kg $ZnSO_4$ ha^{-1} was significantly superior with respect to umbels $plant^{-1}$, seed and stover yield as compared to other combinations of P and $ZnSO_4$. The economic optimum dose of P and $ZnSO_4$ was computed as 53.85 kg ha^{-1} with response of 1245.66 kg ha^{-1} and 39.03 kg ha^{-1} with the response of 1255.94 kg ha^{-1}, respectively.

Effect of varying levels of nitrogen on growth, yield, quality and profitability of transplanted fennel (*Foeniculum vulgare* Mill.). 25 (2): 141-148 (2016)
R L Bhardwaj & D Kumar

Field experiments were conducted at two adjoining farmer's field in tribal area of district Sirohi (Rajasthan) during two successive seasons from July 2012 to March 2013 and July 2013 to March 2014 to study the impact of varied levels of nitrogen (60, 90, 120 and 150 kg N ha^{-1}) on production, quality and profitability of transplanted fennel (*Foeniculum vulgare*). Application of nitrogen @120 kg ha^{-1} recorded the highest stem girth, number of roots $plant^{-1}$, root length, fresh weight of root and root:shoot ratio. The maximum value of number of umbels $plant^{-1}$, umbellate $umbel^{-1}$, number of seeds $umbel^{-1}$, test

weight, seed yield, straw yield, harvesting index was also reported in same treatment. Similarly, volatile and total oil content, soluble sugar, total carbohydrate and overall quality of seeds were also higher with application of 120 kg N ha^{-1}, whereas, disease incidence significantly increased with application of higher dose of nitrogen (150 kg N ha^{-1}). The maximum net return and highest benefit:cost ratio was also recorded with application of 120 kg N ha^{-1}. However, some of the growth parameters (plant height, number of primary and secondary branches $plant^{-1}$, number of leaves, fresh weight of shoot and duration of flowering, protein and nitrogen content in seed were more with 150 kg N ha^{-1}.

Response of transplanted fennel (*Foeniculum vulgare* Mill.) to potassium fertilization. 25 (2): 149-158 (2016)
R L Bhardwaj

This study presents the results of farmer's field experiment on the effects of potassium (K) fertilization on transplanted fennel (*Foeniculum vulgare* Mill.) production. Four treatments (K_1 = 20 kg K ha^{-1}, K_2 = 40 kg K ha^{-1}, K_3 = 60 kg K ha^{-1}, K_4 = 80 kg K ha^{-1}) were compared using four replications under Completely Randomized Design. Application of potassium @ 60 kg ha^{-1} recorded highest value of plant height primary branches $plant^{-1}$, secondary branches $plant^{-1}$, number of leaves, number of roots $plant^{-1}$, tap root length, fresh weight of shoot, fresh weight of root and minimum root:shoot ratio. The maximum value of number of umbels $plant^{-1}$, umbellate $umbel^{-1}$, number of seeds $umbel^{-1}$, test weight, seed yield, straw yield and harvest index was also observed in same treatment. All the quality parameters like, volatile and total oil content, soluble sugar, total carbohydrate, crude protein, potash content of seed and soil and overall quality of seeds were higher with application of 80 kg K ha^{-1}, whereas disease incidence was significantly reduced with application of higher dose of K. The maximum gross return, net return and highest benefit:cost ratio was also recorded with application of 60 kg K ha^{-1}.

Effect of spacing and fertilizer levels on yield, quality and nutrient uptake of fennel (*Foeniculum vulgare* Mill.) under northern dry zone of Karnataka. 31 (2): 206-211 (2022)

M Rajeshwari, Y C Vishwanath, B Vijayakumar Narayanapur, Itigi Prabhakar, Vijaymahantesh & R Anita Ghandhe

An experiment was carried out on effect of spacing and fertilizer levels on yield, quality and nutrient uptake of fennel (*Foeniculum vulgare* Mill.) under northern dry zone of Karnataka. Among various spacing levels, 60 x 30 cm spacing recorded highest seed yield. The highest essential oil content and essential oil yield was obtained in 60 x 40 cm spacing. Nutrient uptake was found maximum in 60 x 30 cm spacing. The maximum seed yield, essential oil content, oil yield and total nutrient uptake was obtained by supplying 100:50:40 NPK kg ha^{-1} and it was at par with 90:40:30 N, P_2O_5, K_2O kg ha^{-1}, respectively.

Effect of seed pelleting on yield and storage quality in fennel (*Foeniculum vulgare* Mill.). 32 (1): 46-51 (2023)

Prashant H Nikumbhe & C S Shantharaja

The current investigation on the effect of seed pelleting on germination, plant establishment and seed yield in fennel was carried out in two seasons during *Rabi* 2017 and 2018. The experiment consisted of 17 seed pelleting treatments along with the control. Field emergence (93.1%), umbels per plant (26.61) and seed yield (1376 kg ha^{-1}) were highest in seeds pelleted with Lignite + *Azospirillum* and higher number of seeds per plant (397) was obtained in Lignite + Gum Arabic, whereas, days to 50% field emergence, plant height and test weight showed non-significant differences among the treatments. Lignite + Gum Arabic pelleting recorded maximum seed germination (65%) at the end of six months storage period. In general, seeds pelleted with Lignite and coated with *Azospirillum* showed better performance both in terms of yield and storability.

Crop Protection

Influence of management practices on the incidence of *Systole albipennis* Walker in fennel (*Foeniculum vulgare* Mill.) seeds. 3 (2): 124-129 (1994)
R K Kashyap, O P Chaudhary & K K Thakral
The chalcid wasp *Systole albipennis* Walker (Hymenoptera : Eurytomidae) was observed as the most important pest of fennel (*Foeniculum vulgare* Mill.) seeds under field conditions in Haryana State, India. Studies on influence of management practices on pest infestation indicated that sowing the crop in December-January resulted in maximum seed infestation (up to 17 per cent) and minimum yields (1.1 q/ha) as against October sown crop which resulted in minimum (4 per cent) seed infestation and higher yields (32 q/ha). Plant population per unit area did not affect wasp infestation, though total yield was significantly affected. The loss of seed weight due to wasp infestation was higher in October sown crop, as seeds from this sowing are well developed and infestation of even a single seed amounts to increased loss of seed weight.

Yield loss estimation in fennel (*Foeniculum vulgare* Mill.) due to root knot nematode. 4 (1): 84-85 (1995)
D J Patel, S K Patel & H V Patel
Meloidogyne javanica (Pathotype 3) is a serious pest of fennel (*Foeniculum vulgare*) in Gujarat and can cause up to 28 per cent loss in grain yield. Application of carbofuran (Furadan 3 G) is effective in reducing the nematode infestation.

Integrated management of root-knot nematode *Meloidogyne javanica* (Treub) Chitwood in fennel (*Foeniculum vulgare* Mill.). 14 (2): 152-154 (2005)
S K Patel, H V Patel, A D Patel & D J Patel
Evaluation of organic cakes and nematicides for the management of root-knot nematode (*Meloidogyne javanica*) on fennel (*Foeniculum vulgare*) at Kapadvanj (Gujarat) indicated that all the treatments including organic amendments and nematicide either alone or in combination significantly reduced root-knot disease and increased

the grain yield over control. Maximum grain yield (2762 kg ha^{-1}) was obtained with the treatment neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}, which was on par with Neemguard 20 kg ha^{-1} + phorate 1 kg ha^{-1} (2566 kg ha^{-1}). Minimum root-knot index (1.64) was recorded in the combined treatment of neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}, which was on par with castor cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}. Maximum net returns (Rs. 22,775 ha^{-1}) was obtained in the treatment neem cake 1000 kg ha^{-1} + phorate 1 kg ha^{-1}.

Diversity, foraging behaviour of floral visitors and pollination ecology of fennel (*Foeniculum vulgare* Mill.). 15 (1): 34-41 (2006) O P Chaudhary

A study on floral visitors of fennel (*Foeniculum vulgare*) conducted at Karnal (Haryana) indicated that 39 species visited the crop among which, hymenopterans (47.1%) and dipterans (50.3%) were the most prominent groups. Six Apoidea species contributed 39.5% of the total visitors and Italian honeybee, *Apis mellifera* was the most prominent species (32.5%). Among the dipteran species, *Episyrphus balteatus* was the most prominent species (24.7%). *A. mellifera* was most abundant with 15.7 bees m^{-2} observation $interval^{-1}$ followed by *E. balteatus* (11.9 bees m^{-2} observation $interval^{-1}$). All the *Apis* species started foraging late (09.00 h) and *A. mellifera* had longer foraging period (spread up to 18.00 h), whereas, *A. cerana* foraged up to 16.00 h and *A. dorsata* till 14.00 h. Peak activity of dipterans and other hymenopterans was during morning and late afternoon hours. Bee-Q application increased Apoidea population by 29.1%, other hymenopterans by 12.6% and had no effect on dipteran population (3.0%). Mean seed yield of fennel in caged plots was 5.2 g $plant^{-1}$ compared to 29.7 g $plant^{-1}$ in open pollinated and 26.6 g $plant^{-1}$ in bee pollinated crop (an increase of 474.7% and 413.5%, respectively). Bee-Q treated plots gave the highest yield of 33.8 g $plant^{-1}$ (increase of 553.4%). Yields in bee pollination were at par with open pollination signifying the role of insect pollinators other than honeybees, especially dipterans like *E. balteatus*, *Eristalis arvorum*, *Eristalis* sp. and *Musca* sp.

Management of phyllody in fennel by intercropping and insecticide use. 22 (1): 6-10 (2013)
R K Jaiman, N R Patel, K D Patel & A V Agalodiya
Experiments were conducted during 2007-08 to 2010-11 at Centre for Research on Seed Spices, S.D. Agricultural University, Jagudan (Gujarat) for management of phyllody disease in fennel. Minimum incidence (9.80%) of phyllody with highest fennel equivalent yield (3035.28 kg ha^{-1}) was observed in fennel inter cropped with green gram (1:1). Maximum income Rs. 1,53,632.60 ha^{-1} was observed in fennel + green gram intercropping. Minimum incidence of phyllody (9.19%) with highest yield (1947.17 kg ha^{-1}) was recorded in seedling root dip in 0.04% Imidacloprid plus one spray of 0.005% Imidacloprid after one month of transplanting followed by seedling grown in 40 mesh nylon cloth net.

Social Sciences

Impact of technology transfer for fennel primary processing on income and employment opportunities for tribal women in district Sirohi (Rajasthan). 23 (2): 205-210 (2014)
R L Bhardwaj, U Nandal & L Vyas
Krishi Vigyan Kendra organized a set of need based skill oriented training programmes for selected 500 tribal women (fennel producers) in small groups (25-30 trainees) during last four years (2008 to 2012) with an aim to develop their skills regarding harvesting of umbel at post-mature stage, grading of produce (A, B, C and D grades), drying of fennel in modified shade house made up of local indigenous material, threshing on RCC floor or polyether sheet and packaging in polythene lined bags and marketing of the final produce. The skill-oriented trainings had a positive impact on tribal women and about half of the total area (50%) has been transformed in primary processing. By primary processing of fennel, additional employment of about one lakh man days have been generated in district Sirohi. By this intervention, additional monetary returns of around Rs. 29.0 crores have been generated in the district. In the district, trained tribal women are getting Rs. 200-250 day^{-1} for harvesting and primary processing of fennel, whereas other unskilled

women are getting only Rs. 100-150 day^{-1}. This intervention has not only improved the living standards of the rural and tribal households but also increased the socio-economic status by providing self-employment opportunities and livelihood security.

FENUGREEK

Crop Improvement and Biotechnology

Variability in a collection of fenugreek (*Trigonella foenum-graecum* L.) germplasm. 8 (2): 217 (1999)
R K Yadav
Promising characters like maximum number of 8 primary branches in RFS-1 and RFS-8, maximum pod length of 12.7 cm and seeds/pod in RFS-1, maximum number of 150 and 140 seeds/plant in RFS-l and RFS-8 respectively, maximum 1000 seed weight of 25 g and 21.9 g in RFS-5 and RFS-8 respectively, indicated the germplasm collected had a vast potential for improvement of fenugreek.

Variability assessment in M_7-lines of fenugreek (*Trigonella foenum-graecum* L.). 10 (1): 45-47 (2001)
Surendra Kumar Kaushik & S L Dashora
The variability in 29 M-lines derived from gamma radiation at 10, 20, 30, 40 and 50 Kr dose along with three checks namely, RMt-1, RMt-143 and a local cultivar of fenugreek (*Trigonella foenum-graecum*) was estimated. Significant variability was recorded for days to flowering, plant height, pods per plant, seeds per pod, test weight, seed yield per plot, protein content and the incidence of powdery mildew disease. High genotypic and phenotypic coefficients of variation were observed for protein content, pods per plant, seed yield per plot and branches per plant. High broad sense heritability (>74%) coupled with high genetic advance (>31 %) was recorded for protein content and pods per plant. Among the 29 M_7-lines, No. 20 (551-1) exhibited superiority over all the three checks and other lines, indicating the necessity for further evaluation of this line.

An induced determinate mutant in fenugreek (*Trigonella foenum-graecum* L.). 10 (1): 51-53 (2001)
A K Choudhary & V V Singh
A determinate mutant was isolated from a population of 400 plants of fenugreek (*Trigonella foenum-graecum* L.) in the M_2 generation raised from 200 seeds of Rmt 1 (indeterminate variety) treated with ethyl methane sulphonate (EMS) 0.10% for 4 h. Random samples from all M_2 populations (except the mutant) were advanced to M3 generation. The appearance of one determinate type in a sample of 798 plants indicated that the trait is monogenic. This mutant was grown along with Rmt 1 and UM 305 (spontaneous mutant for similar growth habit). There were significant differences among genotypes for plant height, number of pods per plant, seed yield per plant and aphid infestation. The study indicated that the performance of the mutant could be brought on par with the checks following selection for desired economic traits.

Inheritance of giant mutant plant type in fenugreek (*Trigonella foenum-graecum* L.). 11 (2): 141-142 (2002)
R S Raje, D Singh & D L Singhania
The inheritance of giant mutant plant type was worked out by evaluating F_1, F_2 and F_3 generations in a cross (RMt-1 x Mutant) of fenugreek. On the basis of plant type in F_1 and the segregation ratios in F_2 and F_3, it was concluded that the normal plant type of RMt-1 was controlled by a single dominant gene and mutant plant type by its recessive allele.

Inheritance of determinate growth habit in fenugreek (*Trigonella foenum-graecum* L.). 11 (2): 146-147 (2002)
Ram Avtar & B S Jhorar
Inheritance of determinate growth habit in fenugreek (*Trigonella foenum-graecum* L.) was examined in six generations of the reciprocal crosses of HM 350 with NLM and HM 65. All the F_1 plants had indeterminate growth habit in both the crosses. In F_2, segregation was observed in 3:1 ratio for indeterminate and determinate plant types revealing that determinate habit was under the control of a single

recessive gene. The results were further confirmed by observing 1:1 ratio in back crosses involving HM 350 as one of the parents.

Studies on genetic variability and selection criteria in F^3 generation of a cross in fenugreek (*Trigonella foenum-graecum* L.). 12 (1): 19-28 (2003)
J Mahey, R S Raje & D L Singhania
Thirty F_3 families of the cross UM - 305 x UM - 117 in fenugreek were evaluated for seed yield and other component characters. Substantial amount of genetic variability was observed at inter as well as intra-family levels for all the observed characters. Plant height and number of pods per plant, having true positive association with seed yield per plant, were mainly under the control of additive gene action and thus, direct selection for these characters would be effective for the improvement of seed yield per plant. Genetic variability at the intra-family level could be exploited by further selection for plant height and number of pods per plant. Superior families with respect to high mean performance for seed yield and its components were also identified. these families will be useful in developing high yielding fenugreek genotypes.

Genetics of earliness in fenugreek under powdery mildew inoculated and natural environments. 12 (1): 57-59 (2003)
R Avtar, A S Rathi & D S Jatasra
Inheritance of days to flower and maturity in fenugreek (*Trigonella foenum-graecum* L.) was studied using six generations (P_1, P_2, F_1, F_2, B_1 and B_2) of a cross between HM 350 (early) and HM65 (late) in two different environments i.e. inoculated with conidia of powdery mildew disease (E_1) and normal (E_2). Partial dominance was observed for both the traits under both the environments. The variances of F_2 and backcross generations revealed the predominance of non-additive gene action. Genetic analysis suggested that generally all types of epistatic effects were significant for both the traits studied in one environment or another. Intermating of selects in early generations has been suggested for further improvement in these traits.

Genetic variability in fenugreek (*Trigonella foenum-graecum* L.) grown under mid-hills of Himachal Pradesh. 12 (1): 60-62 (2003)
Rakesh Verma & B N Korla

Thirty nine accessions of fenugreek (*Trigonella foenum-graecum* L.) were collected from different parts of the country and evaluated under mid-hill conditions of Himachal Pradesh. The coefficient of variation was high for economic yield and biological yield in these accessions. Heritability in broad sense was high for plant height, seed vigour and pods plant^{-1} while moderate for 1000-seed weight, branches plant^{-1}, total seedling length and germination percentage. Economic yield, biological yield and pod length exhibited low heritability. Genetic advance as percentage of mean was comparatively high for biological yield, economic yield and pods plant^{-1}.

Inheritance of powdery mildew resistance and growth habit in fenugreek (*Trigonella foenum-graecum* L.). 12 (2): 120-126 (2003)
R S Raje, D L Singhania & D Singh

Inheritance of resistance to powdery mildew was studied by evaluating parents, F_1 and F_2 generations of cross UM-305 x UM-117 along with susceptible check varieties over the years for powdery mildew reaction. The F_3 and F_4 families of the cross were also evaluated along with the F_1, parents and the check varieties for powdery mildew' reaction to confirm the results. X^2 test was applied to test the fitness of assumed ratio. The inheritance pattern suggested resistance to powdery mildew was monogenic recessive. Results indicated that gene for powdery mildew resistance and gene for determinate growth habit assort independent of each other.

Evaluation of early generation progenies (F_2) of fenugreek (*Trigonella foenum-graecum* L.) crosses for seed yield and yield related characters. 12 (2): 127-134 (2003)
R S Raje, D L Singhania & D Singh

F_2 generation of five crosses of fenugreek were evaluated for seed yield and its components along with parents. F_2 generation had wider range than the parents for most of the characters in the crosses. Genetic parameter of variation also indicated that substantial amount

of variability was generated in F_2 of all the crosses which will be very useful in fenugreek improvement. Pods per plant had high PCV, GCV, heritability and genetic advance as percentage of mean in all the five crosses. Association analysis indicated that pods per plant had positive association with seed yield plant in all the five crosses. On the basis of the present study, selection for pods per plant in F_2 generation of fenugreek crosses will be useful for improvement in seed yield.

Genetic variability, correlation and path analysis in fenugreek (*Trigonella foenum-graecum* L.). 13 (1): 44-48 (2004)
Ananya Banerjee & P C Kole
Genetic variability was studied in a population of 22 genotypes of fenugreek (*Trigonella foenum-graecum*) at Sriniketan (West Bengal). Phenotypic and genotypic coefficients of variability were high for stem weight; moderate for plant height, branches plant^{-1}, days to flowering, duration of flowering, shelling per cent and test weight; and low for pod length. High to moderate estimates of heritability coupled with moderate to high genetic advance were recorded for plant height, days to flowering, duration of flowering, shelling per cent and test weight indicating the predominance of additive gene action. Grain yield was positively correlated with branches plant^{-1}, pods plant^{-1}, pod length, seeds pod^{-1}, pod weight, biological yield, shelling per cent and harvest index at both phenotypic and genotypic levels. Results of path analysis revealed that days to flowering, pods plant^{-1}, pod length and seeds pod^{-1} are the important characters determining seed yield in fenugreek.

Analysis of genetic divergence in fenugreek (Trigonella foenum-graecum L.). 13 (1): 49-51 (2004)
Ananya Banerjee & P C Kole
Genetic divergence among 22 genotypes of fenugreek (*Trigonella foenum-graecum*) was estimated for 8 quantitative characters using Mahalanobis's D^2 statistic and the genotypes were grouped into 6 clusters. Cluster I consisted of maximum number of 13 genotypes followed by 4 and 2 genotypes in clusters II and III, respectively. Three clusters were monogenotypic. Clustering pattern of genotypes was not related to geographical differentiation. Inter-cluster distance

was highest between clusters III and VI and lowest between clusters II and VI while, intra-cluster distance was highest in cluster III. Plant height, pods plant^{-1}, days to flowering and test weight were the major forces for divergence.

Stability analysis for seed yield and its component characters in fenugreek (*Trigonella foenum-graecum* L.). 14 (1): 47-50 (2005)
P C Kole
Fourteen genotypes of fenugreek (*Trigollella foenum-graecum*) were grown at Sriniketan (West Bengal) in four different environments during winter season for three consecutive years. Genotype x environment (G x E) interaction was studied for seed yield and its component characters namely, pods plant^{-1}, seeds pod^{-1} and test weight. G x E interactions were highly significant for all the characters. Both linear and non-linear components of G x E interactions were highly significant, non-linear component being predominant for seeds pod^{-1} and seed yield plant^{-1}, while linear component was predominant for test weight. However, both linear and non-linear components were equally important for pods plant^{-1}. The genotypes UM-129, UM-301 and UM-302 were stable.

Genetic divergence in fenugreek (*Trigonella foenum-graecum* L.) germplasm. 15 (1): 59-62 (2006)
U K Jain, Dhirendra Singh, O P Balai & K N Shiva
Thirty six genotypes of fenugreek (*Trigonella foenum-graecum*) were studied at Jobner (Rajasthan) for their genetic divergence following D^2 analysis. The study indicated that the genotypes were grouped into six clusters and there was lack of parallelism between genetic and geographic diversity. Intra cluster distance was highest in cluster I followed by cluster II. Inter cluster distance was maximum between cluster IV and II followed by III and II. Among the 10 characters studied for genetic divergence, fat content contributed the maximum accounting for 70.3% of total divergence, followed by plant height (8.6%). The study indicated that for obtaining heterotic response as well as better segregants, inter-mating between genotypes of diverse clusters may be undertaken in breeding programmes for improving yield and quality traits.

Correlation and regression analysis of yield components between F_3 and F_4 generations in fenugreek (*Trigonella foenum-graecum* L.). 17 (1): 33-35 (2008)
M K Yadav &R S Raje
Evaluation of 21 F_4 progeny families and the corresponding F_3 parent families of fenugreek (*Trigonella foenum-graecum*) at Jobner (Rajasthan) indicated that the value of r_{op} (correlation between offspring and parents) and b_{op} (regression of offspring on parents) were low for primary branches plant^{-1}, when primary branches plant^{-1} was taken as selection criterion. Low r_{op} and b_{op} values were also recorded for pods plant^{-1} and seeds pod^{-1} when pods plant^{-1} and seeds pod^{-1} were taken as selection criterion. Whereas, highly significant r_{op} and b_{op} values were recorded for other parameters that were not taken as selection criterion for each of the three traits namely, pods plant^{-1}, primary branches plant^{-1} and seeds pod^{-1}. This indicated that there was more resemblance between parents and offsprings for these characters and selection did not have much effect on these characters.

Path analysis for seed yield and its component characters in fenugreek (*Trigonella foenum-graecum* L.). 17 (2): 69-74 (2008)
K C Sharma & E V D Sastry
Fenugreek (*Trigonella foenum-graecum* L.) is an important spice crop of Rajasthan. A vast germplasm collection is maintained at S.K.N. College of Agriculture, Jobner. Two hundred forty lines from this germplasm along with five promising varieties namely RMt-1, RMt-143, UM-144, UM-303 and local check were evaluated in an augmented block design at the research farm of S.K.N. College of Agriculture, Jobner on light textured soil. Results indicate that the genotypes showed significant differences for all the characters under study. All the character had more than 80% broad sense heritability but only seed yield per plant, biological yield and pods per plant had above 50% genetic advance expressed as % of mean. The association analysis revealed that the seed yield per plant was significant and positively associated with plant height, primary branches per plant, pods per plant, pod length, seeds per pod and biological yield at both

phenotypic and genotypic levels and with test weight at phenotypic level. Further path coefficient analysis revealed that characters such as biological yield, pods per plant and primary branches per plant were the important characters for the selection of high yielding genotypes as they exerted positive direct effect as well as showed positive correlation with seed yield at both genotypic and phenotypic levels.

Studies on character association in fenugreek (*Trigonella foenum-graecum* L.). 17 (2): 82-84 (2008)
C Sarada, K Giridhar & N Hariprasada Rao

The investigation was carried out with twelve genotypes of fenugreek obtained from different coordinating centres of AICRP on Spices at Regional Agricultural Research Station, Lam during 1998-1999, 1999-2000, 2000-2001 and 2001-2002 to estimate the correlation coefficients for yield and yield components. The mean data over four years was subjected to statistical analysis for estimating correlation coefficients both at phenotypic and genotypic level. In general the phenotypic correlation coefficients were smaller than genotypic correlation coefficients for majority of the characters. Seed yield showed highly significant positive association with plant height (0.907** and 0.967**), number of pods per plant (0.876** and 0.952**), pod length (0.839** and 1.005*") and number of seeds per pod (0.905** and 0.984**) both at phenotypic and genotypic level, respectively. Among the yield component characters plant height with number of pods per plant (0.961** and 0.971**), pod length (0.818** and 0.939**), number of seeds per pod (0.982 and 0.994); number of pods per plant with pod length (0.743**, 0.932**), number of seeds per pod (0.979**, 0.994**) and pod length with number of seeds per pod (0.815**, 0.979**) showed significant positive association both at phenotypic and genotypic level. The phenotypic and genotypic correlation studied showed that association of seed yield with plant height, number of pods per plant, pod length and number of seeds per pod was appreciable, indicating the importance of these traits as components for seed yield.

Studies on genetic variability, heritability and genetic advance in fenugreek (*Trigonella foenum-graecum* L.). 17 (2): 163-166 (2008)

C Sarada, K Giridhar & N Hariprasada Rao

The present investigation was carried out with fenugreek genotypes obtained from different coordinating centres of AICRP on Spices. Pods per plant (36.5 and 34.61), number of seeds per pod (22.86 and 21.20) and seed yield (22.09 and 17.21) recorded highest coefficients of variation (both phenotypic and genotypic), while it was low for pod length (11.43 and 7.32). Heritability estimates were high for plant height (83.10), pods per plant (89.90) and seeds per pod (86.00). Seed yield (60.70) and branches per plant showed moderate estimates of heritability. The characters *viz*. plant height, pods per plant, seeds per pod and seed yield which recorded high heritability also showed high genetic advance indicating operation of additive gene action in the inheritance of these traits. These studies indicated that selection may be worthwhile in fenugreek for number of pods per plant, seeds per pod besides plant height for achieving higher yields.

Genetic variation in fenugreek (*Trigonella foenum-graecum* L.) for phosphorus utilization under Aridisol. 18 (2): 104-107 (2009)

Indira Rathore, O P Aishwath Poonam Joshi & J C Tarafdar

An experiment was conducted at Ajmer (Rajasthan) to investigate the genetic variation of seven fenugreek (*Trigonella foenum-graecum*) genotypes for phosphorus utilization under typical Aridisol. The result showed that cv. Rajendra Kranti was superior and could utilize about 71% of the rhizosphere phosphorus. A strong positive correlation between plant phosphorus concentration and alkaline phosphatase ($r = 0.51$, $P < 0.05$) as well as dehydrogenase activity($r = 0.62$, $P < 0.01$) in the rhizosphere was observed. Labile phosphorus showed a strong negative correlation with plant phosphorus concentration ($r = -0.70$, $P < 0.01$) and total phosphorus uptake ($r = -0.62$, $P < 0.01$). Higher phosphorus concentration (3.36 mg g^{-1}), total phosphorus uptake (87.4 mg plant $^{-1}$) and dry biomass (26.0 g plant^{-1}) at critical growth stage was observed in Rajendra Kranti. A strong

correlation (r = 0.98, P <0.001) was also found with dry biomass and total phosphorus uptake.

Genetic variability and character association in fenugreek (*Trigonella foenum-graecum* L.). 19 (1&2): 61-64 (2010)
D B Prajapati, Y Ravindrababu & B H Prajapati
Sixty four genotypes of fenugreek (*Trigonella foenum-graecum*) were evaluated for genetic variability, correlation and path coefficient analysis at Jagudan (Gujarat). Phenotypic and genotypic coefficients of variability were high for grain yield plant^{-1}, number of pods plant^{-1} and number of primary branches plant^{-1}. Moderate heritability estimates along with high genetic advance as percentage of mean were recorded for number of pods plant^{-1}. High heritability estimates along with moderate to low genetic advance as percentage of mean were recorded for days to maturity and plant height. Grain yield was positively correlated with number of pods plant^{-1}, number of seeds pod^{-1} and 1000 seed weight. Results of path analysis revealed that number of pods plant^{-1}, days to 50% flowering and test weight had highest positive direct effects on grain yield. It was concluded that improvement of seed yield in fenugreek is possible through selection for number of pods and seed weight through number of grains and length of pods.

Variability, correlation and path coefficient analysis in fenugreek (*Trigonella foenum- graecum* L.) under water limited conditions. 20 (1): 38-42 (2011)
Abhay Dashora, S R Maloo & L K Dashora
Genetic variability, character association and path analysis between yield and its component traits were carried out in 48 genotypes of fenugreek (*Trigonella foenum graecum*) at Udaipur (Rajasthan). Highly significant differences between genotypes were recorded for all the characters studied. High phenotypic and genotypic coefficient of variation coupled with high heritability and high genetic advance was observed for seed yield plot^{-1}, biological yield plot^{-1}, harvest index and pods plant^{-1} indicating the importance of additive gene effects for these traits. Biological yield plot^{-1} and harvest index exhibited positive and significant correlation with seed yield while days to 50%

flowering exhibited negative and significant association with seed yield. Path coefficient analysis revealed that biological yield plot^{-1} had highest positive direct effect on seed yield followed by branches plant$^{-1,}$ pod length and test weight. It was concluded that improvement in the seed yield of fenugreek is possible through selection for biological yield plot^{-1}, harvest index, branches plant^{-1}, pod length and test weight.

Genotype and phenotype variability studies in fenugreek (*Trigonella foenum-graecum* L.) accessions in Kaffa Zone, South West Ethiopia. 25 (2): 159-168 (2016)

A A Wojo, S Alamerew, A Nebiyu & T Menamo

The present investigation was conducted on 36 geographically diverse Ethiopian accessions of fenugreek with an objective to study the extent of genetic and phenotypic variation among yield and its related traits. The accessions differed significantly for most of the characters and exhibited a relatively wide range. These characters indicated existence of variation among the tested accessions. High GCV was only observed in number of secondary branches per plant. High PCV were observed in number of primary and secondary branches per plant, number of seeds per pod, and 1000-seeds weight. High heritability values were observed in the number of seed per pod (63.1%), plant height (65.3%), biological yield per plot (80.1%), seed yield per plot (89.0%), day to maturity (80.8%), and day to flowering (71.4%). High genetic advance was observed for days to maturity, number of pod per plant, number of secondary branches per plant, biological yield and seed yield per plot. Seed yield per plot had positive and significant genotypic correlations with all traits except days to 50% flowering and plant height. Seed yield per plot had positive and significant phenotypic association with number of primary branches and plant height at maturity. This study revealed that there is good scope of concurrent improvement in yield by exploiting the Ethiopian germplasm of fenugreek.

Crop Production and Postharvest Technology

Influence of sowing time and phosphorus on phenology, thermal requirement and yield of fenugreek (*Trigonella foenum-graecum* L.) genotypes. 9 (1): 43-46 (2000)
R S Sheoran, H C Sharma, P K Panuu & Ram Niwas
Experiments were conducted at Hisar (Haryana, India) to study the effect of sowing time and phosphorus on phenology, thermal requirement and yield of two genotypes of fenugreek (*Trigonella foenum-graecum*). Genotype HM-65 performed better than T-8 with respect to yield and was more efficient in utilizing heat units. Delayed sowing resulted in significant reduction in time taken for initiation of flowering and maturity in both the genotypes. Thermal requirement decreased with delay in sowing in both the genotypes. Increasing levels of phosphorus up to 60 kg/ha significantly enhanced the yield but heat unit consumption slightly declined in both file genotypes.

Growth analysis of fenugreek (*Trigonella foenum-graecum* L.) under various levels of farmyard manure and phosphorus. 10 (2): 105-110 (2001)
K D Khiriya, R S Sheoran & B P Singh
Field investigations were carried out during winter (*rabi*) season of 1996-97 and 1997-98 to study the effect of different levels of farmyard manure and phosphorus on growth of two fenugreek genotypes in sandy loam soils. The results indicated that genotype NLM was significantly superior to HM-65 in terms of plant height, LAI, LAD CGR and dry matter accumulation at all stages of crop growth, except at 30 DAS. These growth parameters in the genotype NLM resulted in higher seed yield. Plant height, LAI, LAD, CGR and dry matter accumulation were significantly higher with increase of FYM upto 15 t ha^{-1} at all stages of crop growth, except at 30 DAS. Seed yield was also enhanced significantly with the FYM up to 15 t ha^{-1}. Increasing levels of phosphorus up to 40 kg ha^{-1} significantly increased the growth parameters and yield of fenugreek.

Performance of fenugreek (*Trigonella foenum-graecum* L.) genotypes under new alluvial zone of West Bengal. 13 (2): 132-134 (2004)

S Datta & R Chatterjee

Eight fenugreek (*Trigonella foenum-graecum*) genotypes namely, RMt-1, Rajendra Kranti, J. Fenu-195, HM-350, HM-346, Pusa Early Bunching, RMt-143 and UM-303 were evaluated against local cultivar for growth, yield and incidence of root rot disease at Mondouri under the new alluvial zone of West Bengal. All characters, except primary branches plant^{-1} showed significant variation. Among the different genotypes, Rajendra Kranti exhibited superiority in terms of seed yield (10.67 q ha^{-1}). Pusa Early Bunching was resistant to root rot disease.

Effect of irrigation regimes on moisture extraction pattern, evapotranspiration and yield of fenugreek (*Trigonella foenum-graecum* L.). 15 (2): 125-129 (2006)

S Datta & R Chatterjee

A field experiment was undertaken at Nadia (West Bengal) to study the effect of irrigation on moisture extraction pattern, evapotranspiration and yield of fenugreek (*Trigonella foenum-graecum*). The study revealed that irrigation influenced the moisture extraction pattern of the crop and higher amount of moisture was extracted from surface layer irrespective of irrigation treatment and depletion of soil moisture increased with increasing level of irrigation. Seed yield and water use efficiency were influenced by different levels of irrigation. The highest water use efficiency was recorded in no irrigation and it was lowest in higher level of irrigation at IW/CPE at 1.0. The highest seed yield, gross return, net return and benefit:cost ratio were recorded at IW/CPE ratio 1.0. Scheduling of irrigation at IW/CPE ratio 1.0 was most beneficial followed by IW/CPE ratio 0.8 and irrigation at branching + flowering + seed development stages with respect to yield and return.

Studies on nutrient management and seed rate on growth and herbage yield of fenugreek (*Trigonella corniculata* L.) cv. Kasuri in Rajasthan. 18 (1): 19-21 (2009)

N S Deora, Jitendra Singh & M L Reager

A field experiment was conducted at Bikaner and Jalore (Rajasthan) to study the effect of fertilizer and vermicompost and four levels of seed rate on growth attributes of fenugreek (*Trigonella corniculata*) cv. Kasuri. The results showed that application of fertilizer (20 kg N+ 4 kg P_2O_5 ha^{-1}) increased plant height, number of branches $plant^{-1}$, dry matter accumulation and number of root nodules over control. Vermicompost @ 4 t ha^{-1} significantly improved growth attributes. Growth parameters such as plant height, herbage yield and dry weight of leaves, increased significantly with increasing levels of seed rate up to 7.5 kg ha^{-1}, whereas, nodules $plant^{-1}$, fresh root weight and number of branches $plant^{-1}$ decreased significantly up to 7.5 kg ha^{-1}.

Effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum* L.). 18 (1): 33-36 (2009)

Ruchita Gour, I S Naruka, P P Singh, S S Rathore & R P S Shaktawat

A field experiment was conducted at Mandsaur (Madhya Pradesh) to find out the effect of phosphorus and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum-graecum*). The results indicated that significantly higher growth and yield (17.62 qha^{-1}) were observed with application of 60 kg phosphorus ha^{-1}. Foliar spray of naphthaleneacetic acid (NAA) 20 ppm at 25 days after sowing (DAS) and 55 DAS resulted in significantly higher growth and seed yield (17.41 q ha^{-1}). The highest benefit:cost ratio (4.20:1) was observed for the treatment, 60 kg phosphorus ha^{-1} + NAA 20 ppm.

Growth and yield of fenugreek (*Trigonella foenum-graecum* L.) as influenced by irrigation levels and weed management practices. 19 (1&2): 14-22 (2010)

R S Mehta, B S Patel, R K Singh, S S Meena & S K Malhotra

A field experiment on effect of irrigation levels and weed management practices on growth and yield of fenugreek (*Trigonella foenum-graecum*) was conducted at Sardarkrushinagar (Gujarat). The study

indicated that irrigation at IW/CPE ratio 1.0 gave significantly higher plant height, dry matter accumulation plant^{-1}, leaf area plant^{-1} and leaf area index at all the growth stages and seed, haulm and biological yields over IW/CPE ratios 0.8 and 0.6. Number of branches, number of nodules and their dry weight plant^{-1} were also highest with irrigation at IW/CPE ratio 1.0. Days to 50% flowering and maturity significantly increased with increasing levels of irrigation from IW/CPE ratio 0.6 to 1.0. Besides weed free treatment, higher plant height, dry matter accumulation plant^{-1}, number of nodules and their weight plant^{-1}, number of branches plant^{-1}, days to 50% flowering and maturity were recorded with weed control by pre-emergence application of Pendimethalin @ 0.75 kg ha^{-1} + Inter-culturing at 40 days after sowing (DAS) and hand weeding at 20 and 40 DAS which were significantly superior over rest of treatments. Application of irrigation at IW/CPE ratio 1.0 along with weed control by pre-emergence application of Pendimethalin @ 0.75 kg ha^{-1} + Inter-culturing at 40 DAS is beneficial for realising better growth and productivity of fenugreek.

Influence of nitrogen, phosphorus and bio-fertilizers on growth characters and yield of fenugreek (*Trigonella foenum-graecum* L.). 19 (1&2): 23-28 (2010)

R S Mehta, B S Patel, S S Meena & R S Meena

A field experiment was carried out at Sardarkrushinagar (Gujarat) to find out the optimum levels of nitrogen and phosphorus with bio-fertilizers for obtaining higher yield in fenugreek (*Trigonella foenum-graecum*). Sixteen treatment combinations of two nitrogen levels (10 and 20 kg N ha^{-1}), two phosphorus levels (20 and 40 kg P_2O_5 ha^{-1}) and four bio-fertilizer levels (Control, *Rhizobium* sp., Phosphate solubilizing bacteria (PSB) and *Rhizobium* sp. + PSB) were evaluated in the experiment. Application of 20 kg N and 40 kg P_2O_5 ha^{-1} produced higher plant height, dry matter and leaf plant, leaf area index and seed and straw yields over 10 kg N and 20 kg P_2O_5 ha^{-1}. Individual and combined application of both *Rhizobium* sp. and PSB was at par with each other with respect to plant height but significantly better over control during both the years. Dry matter accumulation, leaf area index, seed and straw yields were higher with inoculation of seed with *Rhizobium* sp. and PSB over their individual

application as well as control at all growth stages during both the years. Thus, application of 20 kg N and 40 kg P_2O_5 ha^{-1} with seed inoculation by *Rhizobium* sp. and phosphorus solubilizing bacteria is better for higher growth and yield of fenugreek.

Growth, yield and profitability of fenugreek (*Trigonella foenum-graecum* L.) as influenced by varying levels of growth regulators and vermin-wash. 19 (1&2): 65-67 (2010)
Khushbu Gour, B S Patel & R S Mehta
A field experiment was conducted at Sardarkrushinagar (Gujarat) to study influence of growth regulators (naphthalene acetic acid (NAA) and ethephon) on growth, yield and profitability of fenugreek (*Trigonella foenum-graecum*). Dry matter accumulation, crop growth rate, relative growth rate, seed, straw and biological yields, net realization and benefit:cost ratio were significantly higher with foliar spray of NAA 30 ppm, followed by ethephon 150ppm and NAA 20 ppm.

Integrated nutrient management in fenugreek (*Trigonella foenum-graecum* L.). 19 (1&2): 68-70 (2010)
B S Patel, S G Patel, S P Patel & A U Amin
A field experiment was conducted at Jagudan (Gujarat) to study the effect of integrated nutrient management (INM) practices in fenugreek (*Trigonella foenum-graecum*). Growth and yield attributes as well as seed and straw yields of fenugreek were significantly influenced by INM treatments. Application of recommended dose through inorganic form with phosphate solubilizing bacteria @ 5 kg ha^{-1} gave higher growth and yield attributes and was at par with recommended dose of fertilizer + *Azotobacter* sp. @ 5 kg ha^{-1} + 5 t farm yard manure ha^{-1} and recommended dose of nitrogen + phosphate solubilizing bacteria @ 5 kg ha^{-1} which were significantly superior to other treatments except test weight. This treatment also recorded significantly the highest grain and straw yields. The maximum net realization and benefit:cost ratio were obtained when the crop was fertilized with full dose of nitrogen and phosphorus with phosphate solubilizing bacteria @ 5 kg ha^{-1}.

Response of fenugreek (*Trigonella foenum-gracecum* L.) to sodicity. 21 (1): 25-32 (2012)
V K Garg
Field trials were conducted at Lucknow (Uttar Pradesh) to study the effect of sodicity on growth, yield and cation composition of fenugreek (*Trigonella foenum-graecum* L.). The treatments included five exchangeable sodium percentage (ESP) levels (10, 20, 30, 40 and 50) and four varieties namely, HM-346, RMt-1, Hissar Sonali and Kalyanpur Selection. The results showed that the crop was able to endure sodicity at germination stage but an adverse effect was noticed on emergence of branches plant^{-1} rather than plant height. The yield attributes were unaffected up to ESP 30. The variety Kalyanpur Selection produced greater biomass and seed yield than other genotypes up to ESP 30. The cation composition of plant revealed Na inclusion mechanism and showed narrow K/Na and Ca/Na ratio in the foliage indicating the potential of fenugreek crop to withstand medium level of sodicity.

Irrigation water quality and zinc on growth and yield of fenugreek (*Trigonella foenumgraecum* L.). 22 (2): 170-173 (2013)
R K Jakhar, B L Yadav & M R Choudhary
A pot experiment was carried out to find out the influence of different Residual Sodium Carbonate (RSC) water and zinc (Zn) levels on growth and yield of fenugreek. The study involved 12 treatment combinations of four RSC levels of irrigation water (W_1=1, W_2=2.5, W_3=5.0 & W_4=7.5 mmol L^{-1}) and three Zn levels (Z_0=control, Z_{10}= 10 & Z_{20}= 20 mg kg^{-1} soil). Results revealed that the plant height, number of pods plant^{-1}, number of seeds pod^{-1}, test weight, seed yield and straw yield of fenugreek significantly decreased with all levels of RSC water and increased with increasing levels of Zn. Thus, application of 20 mg kg^{-1} Zn under 2.5 mM L^{-1} of RSC water was found to be superior with respect to growth and yield of fenugreek.

Response of *Trigonella foenum-graecum* to organic manures and *Rhizobium* inoculation in a Typic Haplustept. 23 (1): 110-114 (2014)

Naimuddin, O P Aishwath, G Lal, K Kant, Y K Sharma & S F Ali

Field experiments carried out to study the effect of organic manures and *Rhizobium* on performance of fenugreek (*Trigonella foenum-graecum*) revealed that germination was hastened by the application of organic manures [Vermicompost (VC), Sheep manure (SM) and Farmyard manure (FYM)] and seed inoculation with *Rhizobium*. Plant height and number of branches were higher with FYM. However, there was no significant variation in days to flower initiation and complete flowering. Yield and yield attributes i.e. number of pods plant^{-1}, number of seeds pod^{-1} and seed test weight were maximum with FYM. Application of manures and *Rhizobium* inoculation enhanced the seed yield. Per cent seed yield increase with *Rhizobium* inoculation, sheep manure, vermicompost and FYM was 11.45, 22.91, 20.83 and 35.41, respectively. Harvest Index and protein content were highest with FYM.

Thermal properties of cryo-ground fenugreek powder. 24 (1): 28-32 (2015)

P Barnwal, K K Singh, R Kumar & S N Saxena

Thermal properties, *viz*., specific heat, thermal conductivity and thermal diffusivity of fenugreek (cv. AM-2) powder were determined. Specific heat increased from 295.9 to 5794.4 J kg^{-1} K^{-1} with increasing temperature from -150°C to 100°C and moisture content from 5.5% to 25.2% d.b. and exhibited second order polynomial relationship. Thermal conductivity and thermal diffusivity ranged from 0.140-0.186 W m^{-1} K^{-1} and 8.13 × 10^{-6}-11.38 × 10^{-6} m^2 s^{-1}, respectively with increasing moisture content. Thermal conductivity and thermal diffusivity showed quadratic relationships with moisture content. Specific heat of fenugreek powder was significantly affected by moisture content and temperature ($P<0.01$), while thermal conductivity and thermal diffusivity were significantly affected by moisture content ($P<0.01$).

Influence of gibberellic acid on growth and quality of fenugreek (*Trigonella foenum-graecum* L.). 24 (1): 56-57 (2015)
C Tania, J N U Kumara, R Chatterjee & P K Chattopadhyay
Gibberellic acid (GA_3) at 50 ppm, 75 ppm, 100 ppm and 125 ppm was sprayed to fenugreek at 40 and 60 days after sowing. GA_3 @ 100 ppm promoted growth and produced highest yield (12.60 q ha^{-1}), followed by GA_3 @ 75 ppm (12.05 q ha^{-1}) which, however, was at par with GA_3 @ 100 ppm. Among quality parameters, carbohydrate was highest (45%) with GA_3 @ 125 ppm whereas, crude protein content was highest (29.33%) with GA_3 @ 75 ppm. The highest oleoresin content (0.3%) and highest essential oil content (2.8%) was recorded with GA_3 @ 100 ppm.

Effect of drip irrigation and bioregulators on yield, economics and water use of fenugreek (*Trigonella foenum-graecum*). 24 (2): 102-105 (2015)
S R Bhunia, I M Verma, M P Sahu, N C Sharma & K Balai
The field experiment was conducted during winter seasons of 2009–10 and 2010–11 to assess the effect of drip irrigation levels and bioregulators (thiourea and Thioglycollic acid) on fenugreek. Increasing levels of drip irrigation from 0.6 to 1.0 ETc enhanced yield attributes *viz*., branches $plant^{-1}$, pods $plant^{-1}$, pod length, seeds pod^{-1} and test weight. Increased yield attributes with 1.0 ETc thus, enhanced seed yield (15.53 q ha^{-1}) and stover yield (31.54 q ha^{-1}). However highest B:C ratio (2.11) was recorded with 0.8 ETc irrigation level and highest water use efficiency of 4.83 kg ha^{-1} mm with 0.6 ETc. Recommended surface irrigation treatment recorded 13.02 q ha^{-1} seed yield with using 540 mm of water. Whereas, fenugreek under drip irrigation at 0.6, 0.8 and 1.0 ETc used 278.16, 370.88 and 463.60 mm of water, respectively. Seed treatment of fenugreek before sowing with bio-regulator thiourea (500 ppm) for 4 h recorded higher yield attributes *viz*., pods $plant^{-1}$, pod length and test weight, as well as, seed yield of 14.85 q ha^{-1} against 14.36 q ha^{-1} where no seed treatment was done. Thus, in turn fetched higher water use efficiency (4.00 kg ha^{-1} mm) and B:C ratio (2.08). Further, foliar spray with 200 ppm thioglycollic acid at vegetative and seed formation stages recorded highest seed yield of 15.01 q ha^{-1} over 100 ppm thioglycollic acid

spray (14.59 q ha^{-1}) or no spray treatment (14.21 q ha^{-1}). Increased yield thus enhanced water use efficiency (3.93-4.05 kg ha^{-1} mm) and B:C ratio (2.06-2.11) in thioglycollic acid treated crop.

Influence of different plant growth regulators and zinc levels on growth and quality aspects of fenugreek (*Trigonella foenum-graecum* L.) under semi-arid conditions. 24 (2): 149-152 (2015)
A Singh, S P Singh, A K Mahawar & T V Yadav
The experiment was conducted to study the influence of different plant growth regulators and zinc (Zn) levels on growth and quality attributes of fenugreek (*Trigonella foenum-graecum* L.). The results revealed that foliar application of triacontanol and NAA increased the growth attributes and uptake of N, P and Zn significantly over control and thiourea application. Growth regulator sprays were superior to control with regard to N, P and Zn concentration in seed & straw and protein content in seed. Application of Zn @ 4 kg ha^{-1} significantly increased the growth and quality attributes compared to 0 and 2 kg Zn ha^{-1}.

Evaluation of nutrient management for better growth, yield and economics of fenugreek. 25 (1): 34-40 (2016)
M Anitha, D V Swami, B P Kumar and D R S Suneetha
A field experiment was conducted to study the effect of nutrient management combinations in fenugreek (*Trigonella foenum-graecum*). Growth as well as seed and straw yields of fenugreek were significantly influenced by different treatments. Application of recommended dose through inorganic form (50%) + neem cake @ 638 kg ha^{-1} + *Rhizobium melilotii* + phosphate solubilising bacteria (PSB) recorded the highest plant height of 34.98 cm, leaves of 82.35 and branches of 5.5 at the final harvest stage. This treatment also recorded significantly highest straw yields. The maximum seed yield, net returns and benefit cost ratio were obtained in the combination of 50% recommended dose of fertilizer (RDF) + poultry manure (PM) @1000 kg ha^{-1} + *Rhizobium melilotii* + phosphate solubilising bacteria (PSB).

Influence of pinching and plant growth regulators on flowering, yield and economics of fenugreek (*Trigonella foenum-graecum* L.). 25 (1): 41-48 (2016)

V Krishnaveni, T Padmalatha, S S V Padma & A L N Prasad

A field experiment was conducted to evaluate the effect of pinching and plant growth regulators on flowering and seed yield of fenugreek cv. *APHU Methi*-1. Minimum time to 50% flowering and seed maturity and maximum test weight were recorded with no pinching (P_0) treatment. Single pinching at 25 days after sowing (DAS) (P_1) recorded significantly maximum number of pods, length of pod, number of seeds pod^{-1} and seed yield. Among the plant growth regulators, foliar spray of GA_3 50 ppm (G_1) thrice (25, 45 and 65 DAS) resulted in best performance of the yield parameters like number of pods plant^{-1}, length of pod, number of seeds pod^{-1} and seed yield plant^{-1}. Early flower initiation and early maturity was observed with application of GA_3 75 ppm (G_2). Among the interactions of pinching and plant growth regulators (PGRs), the treatment combination of no pinching with application of GA_3 50 ppm (P_0G_1) resulted in maximum test weight. Maximum yield attributes like number of pods plant^{-1}, length of pod and seed yield plant^{-1} were recorded with single pinching at 25 DAS and application of GA_3 50 ppm (P_1G_1). However, pinching at 25 DAS with application of NAA 50 ppm (P_1G_3) gave highest B:C ratio (1.88).

Effect of cryogenic grinding on phenolic compounds and antioxidant properties of fenugreek (*Trigonella foenum-graecum* L.) seed extract. 25 (1): 73-78 (2016)

S N Saxena, P Saxena, S S Rathore, L K Sharma, R Saxena & P Barnwal

Effect of cryogenic grinding on oil content, total phenolics, flavonoid content and anti-oxidant properties of seed extract of three fenugreek (*Trigonella foenum-graecum*) genotypes AM 1, RMt 1 and RMt 305 have been analyzed. Oil content was 37.36% more in cryogenically ground sample of genotype AM 1. Yield of methanol crude seed extract was 76.75% more in cryo ground sample of genotype AM 1. Total phenolic content (TPC) was also high in cryo ground samples of all three genotypes. It ranged from a minimum of 75.72 mg in RMt 1 to

a maximum of 94.03 mg gallic acid equivalent (GAE) g^{-1} crude seed extract in genotype AM 1. Similarly total flavanoid content (TFC) was also increased in all cryogenically ground samples and ranged from 17.75 mg in RMt 305 to 26.37mg quercetin equivalents g^{-1} crude seed extract in genotype AM 1. Methanol crude seed extract of all genotypes were evaluated for its antioxidant activity in terms of total antioxidant content (AOC), 1,1-Diphenyl-2-picrylhydrazin (DPPH) free radical scavenging % and EC50 value. The amount of total antioxidant content in cryo ground seeds was significantly high in all genotypes ranging from 9.32 mg in genotype RMt 1 to 11.08 mg butyl hydroxyl toluene (BHT) Equivalent g^{-1} crude seed extract in RMt 305. DPPH scavenging % was invariably more in cryo ground seeds in all three genotypes. Higher concentration of antioxidant content and DPPH scavenging % suggested high antioxidant activity in cryo ground samples.

Response of fenugreek (*Trigonella foenum-graecum* L.) to plant growth regulators and their time of application. 25 (2): 169-174 (2016)

A C Shivran, N L Jat, D Singh, E V D Sastry & S S Rajput

The effect of plant growth regulators and their time of application on growth, yield and economics of fenugreek were studied during three winter seasons (*Rabi*) of 2005-06 to 2007-08. Plant growth regulators used were Naphthalene Acetic Acid (NAA) 50 ppm, Triacontanol 1000 ppm and Triacontanol 500 ppm with three times of spray *viz*., one (40 DAS), two (40 and 60 DAS) and three (40, 60 and 80 DAS) along with absolute control laid out in factorial randomized block design replicated thrice. Based on three years study it was observed that growth regulator treatments significantly influenced growth, yield attributes, yield and economics of fenugreek. The highest pods $plant^{-1}$, test weight, seed yield (1494 kg ha^{-1}), straw yield (3381 kg ha^{-1}), gross returns (Rs. 51,582 ha^{-1}), net returns (Rs.35,586 ha^{-1}) and benefit:cost ratio (2.25) were recorded with NAA 50 ppm which was significantly superior to Triacontanol 1000 ppm and 500 ppm and water spray. The seed yield was increased by 27.80%, 23.70% and 16.08% and net returns by 44.20%, 36.71% and 25.25% with application of NAA 50 ppm, Triacontanol 1000 ppm and 500 ppm over spray of water,

respectively. Further, significantly maximum number of branches plant^{-1}, test weight, seed yield (1409 kg ha^{-1}), gross returns (Rs. 48,546 ha^{-1}), net returns (Rs. 32,331 ha^{-1}) and benefit:cost ratio (1.99) were recorded with three sprays at 40, 60 and 80 DAS closely followed by two sprays at 40 and 60 DAS over single spray at 40 DAS. Hence, the application of NAA 50 ppm twice at 40 and 60 DAS or thrice at 40, 60 and 80 DAS was found beneficial in terms of increased growth, yield and monetary returns of fenugreek.

Determination of grinding parameters of fenugreek seed. 26 (1): 16-26 (2017)

S Balasubramanian, Rajkumar & K K Singh

Experiment to identify ambient grinding conditions and energy consumed was conducted for fenugreek. Fenugreek seeds at three moisture content (5.1%, 11.5% and 17.3%, d.b.) were ground using a micro pulverizer hammer mill with different grinding screen openings (0.5, 1.0 and 1.5 mm) and feed rate (8, 16 and 24 kg h^{-1}) at 3000 rpm. Physical properties of fenugreek seeds were also determined. Specific energy consumptions were found to decrease from 204.67 to 23.09 kJ kg^{-1} for increasing levels of feed rate and grinder screen openings. On the other hand specific energy consumption increased with increasing moisture content. The highest specific energy consumption was recorded for 17.3% moisture content and 8 kg h^{-1} feed rate with 0.5 mm screen opening. Average particle size decreased from 1.06 to 0.39 mm with increase of moisture content and grinder screen opening. It has been observed that the average particle size was minimum at 0.5 mm screen opening and 8 kg h^{-1} feed rate at lower moisture content. Bond's work index and Kick's constant were found to increase from 8.97 to 950.92 kWh kg^{-1} and 0.932 to 78.851 kWh kg^{-1} with the increase of moisture content, feed rate and grinder screen opening, respectively. Size reduction ratio and grinding effectiveness of fenugreek seed were found to decrease from 4.11 to 1.61 and 0.0118 to 0.0018 with the increase of moisture content, feed rate and grinder screen opening, respectively. The loose and compact bulk densities varied from 219.2 to 719.4 kg m^{-3} and 137.3 to 736.2 kg m^{-3}, respectively.

Response of fenugreek (*Trigonella foenum-graecum*) to bio-regulators TGA and N-acetyl cystein under drip irrigation levels. 26 (1): 55-58 (2017)

S R Bhunia, I M Verma & M Arif

Field experiments were conducted during winter seasons of 2010-11 and 2011-12 at Bikaner (Rajasthan) to study the effect of bioregulators *viz*., TGA and N-acetyl cystein under different drip irrigation levels on yield, yield attributes, water use and water use efficiency of fenugreek. The highest plant height (69 cm) and yield attributes *viz*., branches plant^{-1} (7.6), pods plant^{-1} (46.3), pod length (13.5 cm), seed pod^{-1} (16) and test weight (12.7 g) were recorded with 100% ETc + TGA (200 ppm). Further, 80% ETc + TGA (200 ppm), and 100% ETc + N-acetyl cystein (both 10 and 20 ppm) and 100% ETc + TGA (both 100 and 200 ppm) produced comparable plant height. However, 80% ETc + N-acetyl cystein (both 10 and 20 ppm), 80% ETc + TGA (both 100 and 200 ppm), 100% ETc + N-acetyl cystein (both 10 and 20 ppm), 100% ETc + TGA (100 ppm) and 100% ETc + TGA (200 ppm) recorded at par branches plant^{-1}, pods plant^{-1}, pod length and test weight of fenugreek. Highest seed and biological yield of fenugreek were recorded with 100% ETc + N-acetyl cystein (20 ppm), which was at par with 100% ETc + N-acetyl cystein (10 ppm) and 100% ETc + TGA (both 100 and 200 ppm). Maximum water use recorded at 100% ETc with or without bioregulators, whereas maximum water use efficiency was recorded with 60% ETc + N-acetyl cystein (20 ppm) followed by 60% ETc + N-acetyl cystein (10 ppm).

Effect of low temperature grinding on phytochemicals profile of fenugreek seed powder. 31 (2): 177-186 (2022)

Prakash M Sirwani, Mukesh N Dabhi and Pankaj J Rathod

The grinding of spices at ambient temperature causes the loss of valuable heat-sensitive constituents. While higher investment and maintenance of cryogenic grinding make it prohibitive for small-scale industries. So, the present study was carried out to check the effects of low-temperature grinding on various phytochemicals of ground powder of fenugreek seeds. Water at ambient temperature, chilled water and coolant were circulated around the grinding chamber to lower the grinding temperature. Additionally, fenugreek seeds were

fed at ambient and low temperatures (-10^{0}C). The temperature inside the grinding chamber at the end of grinding for three kg of fenugreek seeds ranged from 91.33^{0}C–53.33^{0}C for different treatments. A fall in grinding temperature resulted in the retention of a higher quantity of total phenol (7.71 mg g^{-1}), total flavonoid (12.08 mg quercetin equivalent/g extract), antioxidant activity (21.29%) and volatile components in powder of fenugreek seeds ground by coolant circulation with low-temperature feed.

Crop Protection

Yield losses due to powdery mildew disease in fenugreek (*Trigonella foenum-graecum* L.). 11 (2): 143-145 (2002)
A S Rathi, P P Gupta & B S Jhorar
A field experiment was conducted at Hisar during winter (*rabi*) of 1998-99 and 1999-2000 to assess the reduction in growth and yield parameters of two susceptible fenugreek (*Trigonella foenum-graecum* L.) varieties (HM 65 and T 8) due to powdery mildew disease caused by *Erysiphe polygoni* DC. and *Leveillula taurica* (Lev.) Arnaud. The disease had no significant effect on plant height and number of branches even at more than 80 per cent disease intensity. However, more than 60 per cent disease intensity significantly reduced the number of pods per plant, number of seeds per pod and test weight. Reductions of 22.8-25.6, 16.2-18.8 and 14.3-17.2 per cent pods per plant, seeds per pod and test weight, respectively were recorded in both the varieties when disease intensity was more than 80 per cent.

Management of root rot disease of fenugreek. 24 (1): 58-60 (2015)
A K Singh and S S Rao
Field experiments were conducted for two years for the management of root rot of fenugreek and it was found that maximum reduction in disease incidence (14.52% and 11.4%, respectively) was observed in the treatment where seeds were treated with carbendazim (2 g kg^{-1}) + spray at 45, 60 and 75 days after sowing during both the years. This treatment also registered maximum seed yield of 7.3 q ha^{-1} and 7.9 q ha^{-1}, respectively during the two years. The next best treatment was

seed treatment with hexaconazole (2 mL kg^{-1}) + spray (0.2%) at 45, 60 and 75 DAS with disease incidence of 16.41% and 13.7%, respectively and yield of 6.8 and 7.5 q ha^{-1}, respectively.

Effect of sowing dates, crop geometry and host range on powdery mildew (*Erysiphe polygoni*) of fenugreek, *Trigonella foenum graecum* L. 26 (2): 86-90 (2017)
R Kumawat, K S Shekhawat & K Kumawat
In Rajasthan, fenugreek crop is attacked by a number of diseases. Powdery mildew of fenugreek is an important and serious disease caused by *Erysiphe polygoni.* Date of sowing and crop geometry greatly influenced the disease intensity of powdery mildew on fenugreek during the two consecutive years 2012-13 and 2013-14. Early sown crop exhibited more disease development as compared to late sown crop. November 30th sown crop recorded minimum per cent disease intensity, whereas 10th October sown crop recorded maximum per cent disease intensity and minimum seed yield. The crop was sown on 30th October registered maximum seed yield (16.48 q/ha) with 61.10 per cent disease intensity. The wider spacing of 15 x 45 cm, 15 x 30 cm and 10 x 45 cm between rows and within rows recorded minimum per cent disease intensity (36.11, 39.66 and 45.39), respectively. However, closer spacing 5 x 15 cm recorded maximum seed yield and per cent disease intensity. Out of fifteen host species powdery mildew symptoms were observed on *Pisum sativum, Cuminum cyminum, Coriandrum sativum, Calendula officinalis, Lathyrus odoratus* and *Foeniculum vulgure* under caged conditions.

AJWAIN

Crop Improvement and Biotechnology

Evaluation of ajowan (*Trachyspermum ammi* L.) introductions for growth, yield and quality. 10 (1): 37-39 (2001)
S Datta, R Chatterjee, P S Medda & P K Chattopadhyay
Five ajowan (*Trachyspermum ammi* L.) introductions (RA-6, HAJ-S-I, RA-2, RA-7 and RA-4) and a local cultivar were evaluated for their growth, yield and quality under alluvial zone of West Bengal (India).

Among the introductions, RA-2 exhibited superiority over other introductions in respect of morphological characters such as plant height, number of primary branches per plant and number of leaves per plant and seed yield. The essential oil content was significantly higher in local cultivar (4.53%), while essential oil yield per hectare was significantly higher in RA-7 (14.50 kg) which was on par with RA-4 (14.13 kg).

Genetic divergence analysis in ajowan [*Trachyspermum ammi* (L.) Sprague]. 15 (2): 105-107 (2006)
R V Paliwal & Umesh Kumar Jain

Fifty eight genotypes of ajowan (*Trachyspermum ammi*) were subjected to multivariate analysis using D^2 statistics at Pratapgarh (Rajasthan). The characters studied were days to 50% flowering, days to maturity, umbels plant^{-1}, umbellets umbel^{-1}, 1000-seed weight, fatty oil content of seed and seed yield plant^{-1}. The study indicated that the genotypes grouped into seven clusters depending on similarities of their D^2 values and lack of parallelism between genetic and geographic diversity. The inter cluster D^2 values ranged from 16.41 to 45.23, suggesting considerable diversity among the groups of the genotypes. Among the seven characters studied for genetic divergence, fatty oil contributed the maximum accounting for 56.29% of total divergence followed by seed yield plant^{-1}. Based on cluster means, characters such as umbels plant^{-1} and umbellets umbel^{-1} were major factors of differentiation among genotypes, which may be taken into account while selecting parents for hybridization programmes.

Evaluation of ajowain (*Trachyspermum ammi* L.) genotypes suitable for semi-arid regions. 17 (2): 167-171 (2008)
Dhirendra Singh & S P Choudhary

Forty two genotypes of ajowain collected from various sources were planted in Randomized Block Design in three replications at Research Farm, S.K.N. College of Agriculture, Jobner to assess the degree of genetic variability, heritability and genetic advance for seed yield per plant in ajowain (*Trachyspermum ammi* Linn.). The analysis of variance revealed significant differences among the genotypes for all the characters studied *viz*., day to 50% flowering, plant height,

branches per plant, umbels per plant, umbellets per umbel, seeds per umbel, 1000-seed weight, harvest index and seed yield per plant. The estimates of heritability (broad sense) were high for plant height, umbels per plant, harvest index and seed yield per plant whereas, it was moderate for days to 50% flowering, branches per plant, umbellets per umbel, seeds per umbel and 1000-seed weight. The genotypic coefficient of variation and genetic advance expressed as percentage of mean were high for harvest index and seed yield per plant and moderate to low for umbels per plant, seeds per umbel, branches per plant, plant height, days to 50% flowering, umbellets per umbel and 1000-seed weight, respectively.

Assessment of genetic variability, correlation and path analysis for yield and its components in ajwain (*Trachyspermum ammi* L.). 24 (1): 43-46 (2015)

Ghanshyam, N S Dodiya, S P Sharma, H K Jain & A Dashora

Genetic variability, heritability, correlation and path analysis were estimated among 28 germplasm for 10 characters in ajwain (*Trachyspermum ammi* L.). Analysis of variance revealed significant differences among the germplasm lines for number of secondary branches plant^{-1}, number of umbels plant^{-1}, number of umbellets umbel^{-1}, seed yield plant^{-1}, harvest index and oil content, suggesting sufficient amount of variability in the experimental material. The estimates of genotypic coefficient variation (GCV) and phenotypic coefficient variation (PCV) indicated the existence of fairly high degree of variability for seed yield plant^{-1}, oil content, number of umbels plant^{-1} and harvest index. Lower values of GCV and PCV were recorded in number of umbellets umbel^{-1} indicating the important role of environment in the expression of the characters. High heritability associated with moderate genetic advance was recorded in traits like harvest index and seed yield plant^{-1}. The association study among characters revealed that seed yield was positively and significantly correlated with number of umbellets plant^{-1}. Path coefficient analysis revealed that number of umbellets plant^{-1} had maximum positive direct effect on seed yield plant^{-1}.

Genetic variability studies in ajwain (*Trachyspermum ammi* L.). 24 (2): 119-123 (2015)
S S Meena, R K Solanki, R K Kakani & S Kumari
In ajwain (*Trachyspermum ammi* L.) extent of variability was assessed in eighty four genotypes using augmented design. The analysis of variance indicated presence of considerable amount of variability. Genetic coefficient of variation (GCV) was high for plant height, seed yield plant^{-1}, length of internodes, and number of secondary branches, test weight, number of umbels plant^{-1} and number of seeds umbel^{-1}. High heritability and genetic advance was found for number of seed umbel^{-1}, number of secondary branches and seed yield plant^{-1}. Hence, in ajwain ample amount of variability exists for the important component traits like number of secondary branches, harvest index, number of seed umbel^{-1} and number of umbellate umbel^{-1} thus the scope of improving the crop by selection in the available variability is high.

Crop Production and Postharvest Technology

Effect of interaction of nitrogen and phosphorus on seed and essential oil yield of ajowan (*Trachyspermum ammi* L.) genotypes. 9 (2): 137-139 (2000)
V Krishnamoorthy & M B Madalageri
Field experiments conducted at Dharwad (Karnataka, India), to study the effect of interaction of nitrogen and phosphorus on seed yield and essential oil yield of ajowan (*Trachyspermum ammi*) genotypes, revealed that number of tertiary branches increased significantly with increasing levels of interaction of phosphorus and nitrogen in the genotypes BEN-l and BEN-2. The number of umbels increased significantly with increasing levels of phosphorus and nitrogen combinations. Significantly higher number of seeds was recorded in BEN-l at P_{50} + N_{100} and at P_{50} + N_{25} in BEN-2. Thousand seed weight significantly decreased in BEN-l with increasing levels of phosphorus and nitrogen combination, whereas in BEN-2 it increased with increasing levels of phosphorus and nitrogen combinations. Seed yields were significantly higher at P_{50} + N_{100} in BEN-l (20.50 q ha^{-1}) and BEN-2 (14.61 q ha^{-1}), respectively. Essential

oil yields were significantly higher at P_{50} + N_{100} in BEN-l (82.04 kg ha^{-1}) and BEN-2 (26.30 kg ha^{-1}), respectively.

Effect of date of sowing, nitrogen levels and spacing on growth and yield of ajwain (*Trachyspermum ammi* (L.) Sprague). 17 (1): 1-4 (2008)

Prem Nath, R C Jaiswal, R B Verma & G C Yadav

The effect of three dates of sowing (15th October, 30th October and 14th November), four levels of nitrogen (0, 20, 40 and 60 kg ha^{-1}) and three spacings (30 cm x 10 cm, 30 cm x 20 cm and 30 cm x 30 cm) on growth and yield of ajwain (*Trachyspermum ammi*) was studied at Kumarganj (Uttar Pradesh). Sowing on 30th October significantly increased plant height, number of primary and secondary branches $plant^{-1}$, plant spread, number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, number of seeds $plant^{-1}$ and yield of seeds $plant^{-1}$ and ha^{-1}. Maximum values of all the parameters were obtained with application of 60 kg N ha^{-1}. Wider spacing (30 cm x 20 cm and 30 cm x 30 cm) was found to be effective for all the characters except seed yield, which was higher at the closest spacing (30 cm x 10 cm). The interaction of dates of sowing and nitrogen levels significantly increased primary and secondary branches $plant^{-1}$ as well as seed yield ha^{-1}.

Influence of sheep manure, vermicompost and *Azotobactor* sp. on growth and yield of ajowan (*Trachyspermum ammi* Sprague). 18 (2): 100-103 (2009)

S S Meena, R S Mehta & B B Vashishtha

A field experiment was conducted at Ajmer (Rajasthan) to study the influence of sheep manure, vermicompost and bio-fertilizer on growth and yield of ajowan (*Trachyspermum ammi*). The experiment consisted of 16 treatments comprising of three levels of sheep manure (5.0, 7.5, and 10.0 t ha^{-1}), three levels of vermicompost (2, 3, and 4 t ha^{-1}) and recommended fertilizer dose (90 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1}) with and without *Azotobacter* sp. and control. The results revealed that application of *Azotobacter* sp. alone and with sheep manure, vermicompost and recommended fertilizer dose resulted in higher growth parameters, yield attributes and yield of ajowan over control. Increasing levels of sheep manure (5.0, 7.5 and 10.0 t ha^{-1})

and vermicompost (2, 3, and 4 t ha^{-1}) exhibited higher yield over their respective lower doses. The highest seed (16.35 q ha^{-1}), stover (33.14 q ha^{-1}) and biological yield (49.49 q ha^{-1}) of ajowan was obtained with application of sheep manure @ t 10 ha^{-1} with *Azotobactor* sp.

Seed germination and seedling physiology of ajowan (*Trachyspermum ammi* L.) under chloride salinity. 23 (1): 102-105 (2014)

R Yogita, T D Nikam & K N Dhumal

Seed germination and seedling physiology of ajowan (*Trachyspermum ammi*) was investigated under salinity induced by NaCl. Five different salinity levels (0, 25, 50, 100 and 150 mM) were used. The results revealed that seed germination and seedling growth were significantly retarded due to salinity. Significant accumulation of various osmolytes like reducing sugars and total sugars, proline, glycine, betaine and total free amino acids was recorded with increasing salinity. The reduction in protein and starch content of seedlings under stress condition was concentration dependent. The studies suggested that ajowan is moderately tolerant to salt stress at seed germination stage.

Weed management in ajwain (*Trachyspermum ammi* L.). 24 (2): 124-128 (2015)

R L Meena, S S Meena, R S Mehta & R D Meena

A field experiment was conducted to find out a suitable and economical method of weed management in ajwain. The experiment was laid in randomized block design with three replications. Based on the two year study, it was found that besides weed free treatment, significantly higher plant height, number of primary, secondary branches, number of leaves, number of nodes and dry matter accumulation $plant^{-1}$ at (60 DAS, 90 DAS and at harvest) were recorded with the pre-emergence application of oxadiargyl @75 g ha^{-1} + one hand weeding at 45 days after sowing (DAS) and pendimethalin @1 kg ha^{-1} + one hand weeding at 45 DAS. Yield attributes like number of umbels $plant^{-1}$, number of umbellate $plant^{-1}$, number of seeds $umbel^{-1}$, umber of seed $umbellate^{-1}$ and test weight as well as seed and straw yields of ajwain were also higher with the above two

treatments. After weed free treatment, the lowest dry weight of weed at harvest, weed index and highest weed control efficiency were obtained with pre-emergence (PE) application of oxadiargyl @75 g ha^{-1} + one hand weeding at 45 DAS. The highest gross returns and net returns per hectare were obtained in weed free treatment. This was followed by pre-emergence application of oxadiargyl @75 g ha^{-1} + one hand weeding at 45 DAS, which recorded the highest B:C ratio (2.62).

Essential oil and thymol extracted from ajwain as effective antioxidant agents. 28 (2): 141-146 (2019)
J Gaba, S Sharma, P Kaur & S Joshi
Ajwain is an essential herbal plant with many health and medicinal values. Quantitative phytochemical analysis of ajwain was carried out to determine total phenolic compounds, flavonoids, saponins and tannin content. The phytochemical contents were in the order saponins>tannins>flavonoids>phenolics. Essential oil was extracted and chromatographed for the major constituent thymol which was further characterized with spectral techniques. Further, role of essential oil of ajwain seeds and its major compound thymol for antioxidant activity in respect of total antioxidant capacity and free radical scavenging potential were worked out. Out of thymol and ajwain oil, former was found to be more effective antioxidant at all tested concentrations. Inhibition concentrations (IC_{50}) of oil, thymol and ascorbic acid were found to be 1.87, 1.46 and 0.01 mg mL^{-1}, respectively. Results suggest that ajwain and thymol can be used as natural substitutes to synthetic antioxidants in preservation of various food products.

Effect of organic manures, PGPR and micronutrients on yield and quality enhancement in ajwain (*Trachyspermum ammi* L). 30 (1): 100-106 (2021)
G S Thanuja, B Srinivasulu, K M Yuvaraj & K Giridhar
Experiments were conducted for two consecutive years during 2017-19 to study the effect of organic manures, PGPR and micronutrients on yield and quality of ajwain seed. Farm yard manure (FYM) and vermicompost (VC) were used as organic sources at 50% and 75% recommended dose of nitrogen (RDN) as basal dose. PGPRs namely

Azospirillum lipoferum, *Bacillus megaterium* and *Frateuria aurantia* were used for seed priming. Micronutrients namely $ZnSO_4$ and Fe_2SO_4 were applied thrice as foliar application @ 0.5% first before flowering, second at 50% flowering and third during grain formation. The results revealed that highest number of umbels plant^{-1}, umbellets umbel^{-1}, number of fruits umbellet^{-1}, seed yield plant^{-1}, seed yield hectare^{-1}, straw yield, biological yield, test weight of seeds and essential oil yield were recorded with the application of 50% RDN through VC, which was on par with 50% RDN through FYM, seed priming with *Azospirillum* and foliar application of zinc with respect to their individual effect. Maximum essential oil content, fixed oil content and thymol content were also observed in case of application of 50% RDN through VC, seed priming with *Azospirillum* and foliar application of zinc individually. Highest Benefit Cost Ratio (BCR) of 3.33 was recorded with combined application of 50% of RDN through FYM along with seed priming with *Azospirillum* and foliar spray of Zn at 0.5%.

Ajwain (*Trachyspermum ammi* L. Sprague) based intercropping for higher system productivity of semiarid tropics of Northern Karnataka. 32 (2): 186-193 (2023)

Honnappa Asangi, K N Kattimani, A B Mastiholi, R Siddappa & C B Harisha

Field trials were executed at the University of Horticultural Sciences, Bagalkot, Karnataka during the *kharif* season of 2016 and 2017 to study the growth and productivity of ajwain and leafy vegetables under intercropping system including economic profitability of such cropping systems in Northern Karnataka. The experiments were carried out with thirteen treatments comprising sole ajwain and sole crops of leafy vegetables (fenugreek, coriander, dill and amaranthus) and various combinations of ajwain and leafy vegetables in 1:1 and 1:2 ratios adopting randomized complete block design with three replications. Results showed that the sole crop of ajwain exhibited superior growth and yield. However, in intercropping systems, the combination of ajwain and coriander at a 1:1 ratio demonstrated the highest growth and yield parameters. The sole crop of ajwain recorded the maximum plant height (84.64 and 84.55 cm), number of

branches per plant (52.38 and 52.19), number of umbels per plant (166.54 and 164.93), number of umbellates per umbel (12.44 and 12.34), and seed yield (12.95, 12.88 q ha^{-1} during both the years, respectively). This performance was comparable to intercropping with ajwain + coriander (1:1). Sole crops of fenugreek, coriander, dill, and amaranthus yielded higher fresh market yields compared to different intercropping systems. Notably, growing ajwain as an intercrop with coriander at 1:1 ratio resulted in a significantly higher land equivalent ratio (1.61) and a higher benefit–cost ratio (2.99) followed by ajwain + fenugreek (1:1) and (2.98), respectively.

NIGELLA

Influence of nitrogen, phosphorus and potassium on growth and yield of black cumin (*Nigella sativa* L.). 12 (1): 51-54 (2003)
A Nataraja, A A Farooqi, B S Sreeramu & K N Srinivasappa
A field experiment was conducted to study the influence of nitrogen, phosphorus and potassium on growth and seed yield of black cumin at Sanjivini Vatika, University of Agricultural Sciences, Bangalore during 2000-2001. The experiment consisted of twenty seven treatment combinations with three levels each of nitrogen (0, 50 and 100 kg ha^{-1}), phosphorus (0, 20 and 40 kg ha^{-1}) and potassium (0. 30 and 60 kg ha^{-1}), and was laid out in factorial randomized block design with three replications. The results revealed significant differences in growth and yield parameters among the treatments. Application of nitrogen at 100 kg ha^{-1} recorded the maximum values for plant spread (427.75 cm^2) and number of seeds (57.52) per pod. Significant differences were also observed with the interaction of NPK at 50:40:30 kg ha^{-1} producing pods of good size (3.84 cm^2), higher test weight of 1000 seeds (2.38 g) and seed yield (17.45 q ha^{-1}).

Response of nigella (*Nigella sativa* L) variety NRCSS AN 1 to different agro-techniques. 17 (2): 190-193 (2008)
S K Malhotra & B B Vashishtha
A field study was conducted during the winter seasons of 2002-2003 and 2003-2004 to study the response of nigella (*Nigella sativa* L.) variety NRCSS AN-1 to different agro-techniques under semi-arid

conditions. The yield attributes *viz*., number of capsules/plant, number of seeds/capsule and 1000 seed weight were significantly high when crop was sown on 15 October followed by 1 October sowing. Significantly higher seed yield of 8.84 q/ha was recorded when crop was sown on 15 October. The seed yield of 7.86 q/ha was significantly higher with row spacing of 30 cm. The plant height and number of branches/plant were more at seed rate of 7 and 8 kg/ha and were noticed significantly high as compared to seed rate treatment of 9 kg/ha. However, the seed yield attributes and seed yield (8.24 q/ha) were significantly high at seed rate of 8 kg/ha. The fertilizer dose of 50 kg N, 25 kg P_2O, and 20 kg K_2O /ha was found optimum and produced higher seed yield of 7.87 q/ha. The days to 50% flowering was not affected considerably with different treatments. The essential oil content increased significantly when crop was sown at wider spacing of 40 cm and with application of fertilizer dose of 50 kg N, 25 kg P_2O, and 20 kg K_2O/ha.

Economic feasibility of weed management practices in nigella (Nigella sativa L.). 23 (2): 224-228 (2014)
S S Meena, R S Mehta, R D Meena, R L Meena & D K Sharma

A field experiment was conducted to find out the suitable and economical method of weed control in nigella. Based on two year study, it was found that besides weed free treatment, significantly higher plant height, number of primary and secondary branches, number of leaves, number of nodes and dry matter accumulation plant^{-1} (at 60 days after sowing (DAS), 90 DAS and at harvest) were recorded with the pre-emergence application of oxadiargyl @ 75 g ha^{-1} + one hand weeding at 45 DAS and pendimethalin @ 1 kg ha^{-1} + one hand weeding at 45 DAS. Similarly, yield attributes like number of siliqua plant^{-1}, number of seeds siliqua^{-1}, siliqua size and test weight as well as seed and straw yields of nigella were also higher with these two treatments. Besides weed free treatment, lower dry weight of weed at harvest, weed index with highest weed control efficiency was obtained under pre-emergence (PE) application of oxadiargyl @ 75 g ha^{-1} + one hand weeding at 45 DAS. The highest gross returns and net returns were obtained in weed free treatment followed by effective control of weed with pre-emergence application of oxadiargyl @ 75 g

ha^{-1} + one hand weeding at 45 DAS but highest B:C ratio (2.62) was recorded with pre-emergence application of oxadiargyl @ 75 g ha^{-1} + one hand weeding at 45 DAS.

Effect of integrated nutrient management on growth, yield and quality attributes of black cumin (*Nigella sativa* L.) var. Rajendra Shyama grown under terai region of West Bengal. 28 (1): 61-65 (2019)

A Sen, S D Khade, J C Jana & P Choudhury

A field experiment was conducted during *rabi* seasons of 2014-15 and 2015-16 to study the effects of various combination of different levels of inorganic, organic and bio-fertilizers (Azophos) on the vegetative growth, yield contributing attributes and quality of seeds of black cumin. The results showed that the combination of 100% RDF (Recommended Dose of Fertilizer) + 15 t ha^{-1} FYM (Farm Yard Manure) + 4 kg ha^{-1} Azophos significantly improved most of the parameters related to growth of plant, seed yield and net returns. However, for production of seed oil, 75% RDF of chemical fertilizers + FYM + bio-fertilizer was recorded was the best. Most of the soil properties were improved by application of 100% RDF + FYM. Therefore from the results, it could be suggested that inclusion of organic manure and bio-fertilizer along with 100% (RDF) is the best combination for seed production of black cumin whereas for better quality seed oil 25% RDF can be substituted with FYM and bio-fertilizer (Azophos) in terai region of West Bengal.

DILL

Effect of irrigation, nutrient levels and crop geometry on growth and yield of dill (*Anethum sowa* L.). 21 (1): 20-24 (2012)

R S Mehta, M M Anwer & Y K Sharma

A field experiment was conducted during *rabi* season at Ajmer (Rajasthan) to study the growth, profitability and productivity of dill (*Anethum sowa* L.) as influenced by irrigation and nutrient levels with varying crop geometry. Three irrigation levels (12, 15 and 18 days interval) in main plot, three nutrient levels (N and P_2O_5 each at 60 + 30, 90 + 40 and 120 + 50 $kgha^{-1}$, respectively) in sub plot and three

crop geometry patterns (40 × 25 cm, 50 × 25 cm and 60 × 25 cm) in sub-sub plot were studied. The highest plant height at all the growth stages was recorded with irrigation at 12 days interval but higher branches plant^{-1}, dry matter plant^{-1}, yield attributes, seed yield, straw and biological yield of 1.2, 2.1 and 3.3 t ha^{-1} respectively, as well as net return (Rs. 15,428 ha^{-1}) and benefit:cost ratio (0.74) was recorded with irrigation at 15 days interval. Higher plant height, dry matter accumulation at all growth stages, yield attributes, seed yield (1.2 t ha^{-1}), straw (2.1 t ha^{-1}) and biological yield (3.3 t ha^{-1}) as well a net return (Rs. 14,464) and benefit:cost ratio (0.69) were obtained with application of 90 kg N and 40 kg P_2O_5 ha^{-1} being at par with 120 kg N and 50 kg P_2O_5 ha^{-1}. Crop geometry of 50 × 25 cm resulted in higher seed (1.2 t ha^{-1}), straw (2.1 t ha^{-1}) and biological yield (3.3 t ha^{-1}) over 60 × 25 cm. Thus, application of irrigation at 15 days interval with 90 kg N and 40 kg P_2O_5 ha^{-1} at 50 × 25 cm crop geometry was optimum for realizing higher yield, profitability and productivity of dill.

Influence of irrigation and nitrogen levels on yield attributes, yield and water use efficiency in dill (*Anethum graveolens* L.) cultivation. 32 (2): 194-201 (2023)

R C Bairwa & S R Bhunia

The field experiments were conducted during three consecutive *Rabi* seasons during 2016-19 at Agricultural Research Station, SKRAU, Bikaner to study the influence of irrigation and nitrogen levels to growth, yield attributes, yield and water use efficiency of dill (*Anethum graveolens* L.) under drip irrigation system. The experiment consisted of sixteen treatment combinations of four irrigation levels (ETc-0.4, ETc-0.6, ETc-0.8 and ETc-1.0), and four nitrogen levels (control, 120% RDN in 4 splits, 100% RDN in 4 splits and 80% RDN in 4 splits). The treatments were laid out in a split plot design with three replications. Results revealed that irrigation at ETc 1.0 with application of nitrogen at 120% of RDN in four splits recorded significantly higher crop yield as compared to the remaining treatments. The water use efficiency decreased with increased irrigation and nitrogen levels.

KALA ZEERA

Genetic divergence and path co-efficient analysis in kala zeera (*Bunium persicum* Boiss. Fedtsch.). 22 (1): 95-100 (2013)
S K Gupta, S Kumar & M Sharma

Genetic variation and path coefficient analysis was carried out in seven genotypes of kala zeera (*Bunium persicum*). The genotypic, phenotypic and environmental correlations were calculated by applying the technique of variance-covariance analysis in which total variability was split into treatments, replication and error. The results indicated that the values of genotypic correlation coefficients were higher in general, than the phenotypic ones. Number of seed umbellet^{-1}, number of seed plant^{-1}, umbel diameter, number of secondary and tertiary branches plant^{-1}, number of umbellets umbel^{-1} and number of seed umbel^{-1} recorded significant positive association with seed yield ha^{-1} at the genotypic level. However, at phenotypic level, number of primary, secondary and tertiary branches plant^{-1}, umbel diameter, number of umbellets umbel^{-1}, number of umbels plant^{-1}, number of seed umbellet^{-1}, number of seed umbel^{-1}, number of seed plant^{-1} and 1000 seed weight were strongly associated with seed yield ha^{-1}. The characters such as number of umbels plant^{-1}, number of seed umbel^{-1}, umbel diameter and number of primary branches plant^{-1} contributed directly as well as indirectly in the expression of seed yield ha^{-1}. Residual effects was found to be significantly low (0.055) indicating that the number of primary branches plant^{-1} was the most reliable trait for improving the seed yield of *Bunium persicum* through selection.

Price transmission behaviour of major seed spices in Rajasthan. 32 (1): 52-65. (2023)
Kailash Chand Bairwa, G L Meena, Hari Singh, Harkesh Kumar Balai, Anju Yadav & P C Meena

The present study was based on secondary price information. The study period from January, 2011 to December, 2021 was chosen to analyse the price behaviour of major seed spice markets in Rajasthan. The data was analysed using the Augmented Dickey Fuller (ADF) test and Vector Error Correction Model to accomplish the objectives of the

study. ADF test results showed that price data for coriander, cumin, fenugreek, and fennel were non-stationary at the level and stationary at the first difference level. Values of trace and maximum Eigen of Johansen multiple co-integration tests revealed three co-integration equations in cumin and coriander crops, but only one co-integration equation in fennel prices. Prices of coriander, cumin, and fennel in selected KUMS (Krishi Upaj Mandi Samiti) were primarily influenced by the one-month and two-month lag prices of respective markets in the long run. The prices of coriander, cumin and fennel demonstrated one-way co-integration in KUMS, Merta City→KUMS, Jodhpur and Ramganj Mandi→Baran while combination of Baran↔Kota, Ramganj Mandi↔Kota and Merta City↔Niwai showed bi-directional co-integration. Fenugreek prices in selected KUMS did not move in tandem over a long period of time. We find that the prices of coriander, cumin and fennel in Rajasthan's selected markets moved in lockstep over time and were influenced by one month or two months lag price of other respective markets.

CHILLI

Crop Improvement and Biotechnology

Multivariate analysis in chilli (*Capsicum annum* L.). 2 (1&2): 71-74 (1993)
G Pandey & V K Dobhal
Thirty genotypes of chilli (*Capsicum annum*) were studied for genetic divergence for eight characters utilizing Mahalanobis D^2 statistics. The genotypes were grouped into seven clusters. The genotype GP-65(A) was quite different and formed cluster VII. Variability in this material was limited and was mainly due to a few extreme types. The genotype(s) in clusters II, V and VII had the highest dry yield per plant and higher values for fruits per plant, fruit length and days to flower and could be utilized in breeding programmes.

Diversity and horticultural grouping in *Capsicum* spp. 7 (1): 27-33 (1998)
K P Sunil & Rasheed Ahmad
One hundred and sixty chilli (*Capsicum*) accessions maintained at Chalode (Kerala, India) were assigned to five species. The 128 *C. annuum* lines identified were assigned to 3 varietal groups and 12 horticultural groups. The characteristics and importance of the taxonomic groups identified are discussed in respect to selection, and intervarietal and interspecific hybridisation in chilli.

Cross compatibility in five species of *Capsicum*. 7 (1): 35-38 (1998)
K P Sunil & Rasheed Ahmad
Evaluation of 160 accessions of *Capsicum* which included five species and their inter specific hybrids at Chalode (Kerala, India) indicated that *C. chinense* (110.3 ASTA unit colour and 186.2 g per plant yield) and the hybrid *C. annuum* x *C. chinense* (58.6 ASTA unit colour and 190.3 g per plant yield) were the most promising and can be used as sources of colour for improving the present day chilli cultivars.

Transfer of clustered and upright fruit characters into two popular chilli cultivars of Tamil Nadu. 10 (1): 41-43 (2001)
K P M Dhamayanthi & V R K Reddy
Transfer of two agronomically desirable characters from CA-33 and CA-219 to two popular chilli cultivars, G-4 and CO-2, was attempted. The F_1 hybrids and their segregating population, F_2, BC_1, and BC_2 were raised to determine the gene action in respect of the fruit orientation and clustered fruit character. The results revealed that genes responsible for the clustered fruit character are monogenic while, the upright fruit character is digenic, controlled by two genes with dominant and recessive epistasis.

Breeding derivatives with desirable traits using chilli (*Capsicum annuum* L.) stocks and popular varieties. 12 (2): 107-112 (2003)
K P M Dhamayanthi & V R K Reddy
In chilli, four agronomically desirable characters *viz*., compact plant type, cluster fruit character, upright fruit position and destalkness were transferred from three chilli stocks using as male parent to four popular South Indian varieties using as female parent. The genes controlling the above four characters known to be monogenic and recessive in nature were transferred by selfing and screening the backcross progenies. The rate of expression of the genes responsible for the upright fruit position and clusterness were higher than the compact plant type and destalkness. Inheritance pattern of the four characters was studied to confirm the genes transferred from the chilli stocks to the popular varieties.

Random amplified polymorphic DNA technique for detection of plant based adulterants in chilli powder (*Capsicum annuum*). 17 (2): 75-81 (2008)
K Dhanya, S Syamkumar, K Jaleel & B Sasikumar
The present study reports a modified protocol for isolation of good quality DNA from chilli powder and its probable adulterants (dried red beet pulp, almond shell dust and powdered *Ziziphus nummularia* fruits) and the utility of RAPD primers for detection of adulterants in marketed chilli powder. Selected RAPD primers, which produced adulterant specific bands in simulated samples were used for

analyzing market samples of chilli powder. Out of the six market samples analyzed, one sample amplified *Z. nummularia* specific band indicating the occurrence of adulteration in market samples. All the market samples tested were free from dried red beet pulp or almond dust adulteration.

Variability and genetic divergence in paprika (*Capsicum annuum* L.). 19 (1&2): 71-75 (2010)

S Surya Kumari, K Uma Jyothi, D Srihari, A Siva Sankar & C Ravi Sankar

Ninety four paprika (*Capsicum annuum*) accessions were evaluated for 17 characters for variability, heritability, genetic advance and genetic divergence at Lam, Guntur (Andhra Pradesh). Higher phenotypic and genotypic coefficient of variation (PCV and GCV) and heritability coupled with high genetic advance was observed for number of fruits plant^{-1}, fresh fruit yield plant^{-1}, dry fruit yield plant^{-1}, 100 seed weight, number of seeds fruit^{-1} and capsanthin, capsaicin and oleoresin contents indicating the higher magnitude of variability for these traits and consequently more scope for their improvement through selection. Plant height, plant spread and fruit diameter exhibited moderate PCV and GCV estimates suggesting the possible role of environment in expression of these characters. Cluster analysis through Mahalanobis D^2 analysis classified the 94 genotypes into 10 clusters indicating considerable genetic diversity in the material studied.

Character association in paprika (*Capsicum annuum* L.). 20 (1): 43-47 (2011)

S Surya Kumari, K Uma Jyothi, V Chenga Reddy, D Srihari, A Siva Sankar & C Ravi Sankar

Correlation studies conducted in 94 diverse genotypes of paprika (*Capsicum annuum*) grown at Lam (Andhra Pradesh) indicated that dry fruit yield plant^{-1} showed significant and positive association with plant height, plant spread, number of fruits plant^{-1}, fruit girth, seeds fruit^{-1} and capsanthin content. Path coefficient studies revealed that number of fruits plant^{-1} had the highest positive direct effect on dry fruit yield plant^{-1}. Number of fruits plant^{-1}, plant height, plant spread,

number of seeds fruit^{-1}, days to maturity and capsanthin content (in the given order) were important yield and quality components having direct bearing on dry fruit yield and hence can be considered while breeding for improved yield in paprika.

Heterosis and inbreeding depression in chilli (*Capsicum annuum* L.). 20 (2): 72-76 (2011)
D B Prajapati & A V Agalodia
Investigations were carried out at Jagudan (Gujarat) to study the extent of heterosis and inbreeding depression through six generation mean analysis for yield and yield attributing characters in chilli (*Capsicum annuum*). The magnitude of heterosis and heterobeltiosis was significant in desired direction with moderate to high for green fruit yield, secondary branches, fruit length; high for number of fruits plant^{-1}, ripe/dry fruit weight and seed to pericarp ratio and low for flowering and ripening of fruit. The cross combinations JCh-676 x JCh-659 showed the highest estimate of relative heterosis and heterobeltiosis for dry fruit yield. All the crosses also revealed inbreeding depression for most of the characters. These traits can be improved effectively through pedigree method of selection. In general, the crosses JCh-730 x JCh-725 and JCh-676 x JCh-659 were identified as promising hybrids since they depicted significant heterosis for green and dry fruit yield and its important yield contributing characters

Identification of fertility restorer and sterility maintainer lines in chilli (*Capsicum annuum* L.). 21 (1): 68-70 (2012)
B V Tembhurne & S K Rao
Three cytoplasmic geneic male sterile lines of chilli (*Capsicum annuum* L.) namely, JNKVVA1, ACBGA1 and ACBGA2 showed 100% male sterility when tested with 1% acetocarmine solution. Among the 50 chilli lines crossed with the three male sterile lines, 36 lines were stable for fertility restoration (Rf) while, two lines namely, AVNPC131 and X235 were identified as sterility maintainers (rf).

Stability of chilli genotypes for different seasons at terai zone of West Bengal. 21 (1): 71-75 (2012)
S Datta & J C Jana
The stability of 15 chilli (*Capsicum annuum* L.) genotypes, was studied during *rabi* (winter) and *kharif* (rainy) seasons of 2005-06 and 2006-07 at Pundibari, Cooch Behar (West Bengal). Pooled analysis of variance revealed the presence of significant genetic variability among the genotypes. With respect to different growth, yield and quality characters, significant differences were also found in all the characters except ascorbic acid, indicating the effect of environment on the performance of the genotypes. Ulka-686 showed supremacy in yield in both *rabi* and *kharif s*easons but its magnitude of yield for *kharif* season was about half of that of *rabi* season. CA-29 exhibited better performance under *rabi* season and Jwalan, Tejaswini and Pusa Sadabahar were adapted for *kharif* season.

Genetic analysis for earliness under varying environments in chilli (*Capsicum annum* L.). 21 (2): 155-160 (2012)
D B Prajapati & A V Agalodiya
Six generations P_1, P_2, F_1, F_2, BC_1 and BC_2 of six families were developed in chilli (*Capsicum annum* L.) from 11 inbreds and were used to apply A, B, C and D scaling tests in the attributes of earliness *viz*., days to 50.0% flowering (DTF) and days to fruit ripening (DTFR) in different environments at Jagudan (Gujarat). The experiment was conducted in *Kharif* 2007 under high fertility condition (E_1), *Kharif* 2007 under low fertility condition (E_2) and summer 2007 under high fertility condition (E_3). For DTFR in *Kharif*, low fertility and summer grown conditions enhanced the expression of dominant/partially dominant genes. Whereas, DTF in low fertility as well as late sowing conditions depressed the expression of dominant/partially dominant genes. Detection of epistasis in a cross in one environment and not in the other emphasized the influence of environment on interaction parameters. High role of epistasis for ripening and flowering in all the three environments was observed. In general, for inheritance of days to flowering preponderance of dominance gene effects or due weightage of additive and dominance epistasis and dominance × dominance gene effects were noticed. For improvement of this trait,

heterosis breeding was fruitful, where importance of non-additive gene effects with greater influence of dominance gene effects was estimated. The parents GVC-111, Junagadh Gholar, JCh-730 and JCh-725 contributed desirable genes for imparting earliness.

Performance of paprika and paprika alike chillies (*Capsicum annuum* L.) under warm humid tropics. 22 (2): 222-227 (2013)
K N Shiva, T J Zachariah, N K Leela & P A Mathew
A study was conducted to evaluate the performance of 21 paprika alike chillies (indigenous germplasm) and nine paprika lines (exotic collections) under rain-shelter. Highly significant variation was recorded among the genotypes for all the characters. The results indicated that Kt-Pl-19 variant-I, ICBD-6, ICBD-12, ICBD-13, ICBD-11 were promising for yield and yield attributing characters, while ICBD-12, ICBD-11, ICBD-2, ICBD-13, Kt-Pl-19 variant-I proved to be better for high seed numbers. With respect to total extractable colour, ICBD-5, ICBD-7, ICBD-4, ICBD-1, ICBD-18 were measured with high colour value, among the indigenous germplasm. Among the exotic collections, PBC-171, SSP-1999, EC-18, EC-45, EC-71 proved better for yield and yield attributing characters. The genotypes, Paprika King, EC-45, PBC-171, EC-43 produced maximum number and weight of seeds, whereas PBC-171, IMI-5, EC-71, EC-45 were found promising for high colour value. Based on these observations, the genotypes Kt-Pl-19 variant-I, ICBD-6, ICBD-12, PBC-171, SSP-1999 and EC-18 were found suitable for high yield, whereas ICBD-12, ICBD-11, Paprika King, EC-45 and PBC-171 for high seed numbers and ICBD-5, ICBD-7, ICBD-4, PBC-171, IMI-5, EC-71 for high colour value in Kerala. Among the various traits, wide range of variation was recorded for number of seeds per fruit and narrow range of variation for fruit length.

Studies on stability of chilli genotypes at different fertility levels under terai zone of West Bengal. 23 (1): 26-31 (2014)
S Datta & J C Jana
An experiment was carried out to study the stability of 15 chilli genotypes at five fertility levels (0%, 50%, 100%, 150% and 200% of recommended dose of fertilizer) during *rabi* season of 2006-07 and *kharif* season of 2007. Pooled analysis of variance showed the

presence of significant genetic variability among the genotypes for all the characters studied. Among the different early flowering genotypes, 'CA-29' and 'CA-30' were specifically adapted to the unfavourable environment and 'Diamond F1' and 'Pusa Sadabahar' were adapted to the favourable environment. None of the genotypes showed absolute stability with respect to fruit length under different environments. With respect to number of fruits, 'Pusa Sadabahar' was stable under different environments. With respect to yield, 12 genotypes showed S^2di value significantly greater than zero which indicated the unstability for this trait. Among the high yielding genotypes, 'Ulka 686 F1', 'Jwalan', 'CA-29', 'CA-48' and 'CA-47' and low yielder genotype had regression value of >1 which indicated that they showed better response under favourable environment. However, deviation from regression value (S^2di) was significant which indicated that their performance among the environment was unpredictable. 'Chilli Philhal' and 'Pusa Jwala' produced lower yield but these genotypes were adapted to unfavourable environment. The *rabi* crop showed its superiority over *kharif* crop with respect to yield and its attributing characters.

Genetic variability and correlation studies for growth and yield characters in chilli (*Capsicum annuum* L.). 23 (2): 170-177 (2014)
K Amit, I Ahad, V Kumar & S Thakur

Twenty three genotypes were used to study the genetic variability, heritability, genetic advance and correlation for growth and yield contributing characters in chilli under Kashmir conditions. Significant variations were observed for all the characters studied except for days to flowering and crop duration [mature (green) as well as dry (red)]. High Phenotypic Coefficient Variation (PCV) and Genotypic Coefficient Variation (GCV) were recorded for number of fruits plant^{-1}, fruit weight and dry (red) yield. All the characters showed high heritability estimates. However, number of the fruits plant^{-1}, green fruit yield plant^{-1}, dry (red) yield plant^{-1}, number of seeds plant^{-1} and plant height exhibited high genetic advance as percentage of mean indicating additive gene effect. Fruit yield (green and red) plant^{-1} was positively and significantly correlated with number of fruits plant^{-1} and fruit length. It revealed that the characters *viz*., plant height, fruit

length, number of fruits plant^{-1}, fruit weight and fruit yield (green and red) are the most important traits for genetic improvement of chilli.

Heterosis in mild pungent chilli (*Capsicum annuum* L.). 23 (2): 178-185 (2014)
A L Patel, K B Kathiria & B R Patel
Field experiment was carried out to study heterosis for green fruit yield and its components of 28 F_1 hybrids generated by half diallel crosses of eight diverse mild pungent chilli cultivars. Among 28 F_1 hybrids, hybrids IVPBC-535 X SG-5, IVPBC-535 X ACS-03-14 and IVPBC-535 X ACS-03-13 were found to be most promising for green fruit yield and other desirable traits. Hence, they could be further evaluated to exploit the heterosis or utilized in future breeding programmes to obtain desirable segregants for the development of superior genotypes.

Performance of chilli (*Capsicum annuum* L.) genotypes for growth and yield parameters in eastern dry zone of Karnataka. 23 (2): 250-253 (2014)
H M Vijaya, A P M Gowda, S D Nehru & K Jyothi
The present experiment was undertaken to evaluate 24 chilli genotypes for different growth and yield parameters. The genotype 'Chikballapur Local' was found to have maximum plant height (118.6 cm) and plant spread (0.481 m^2) while, genotype 'Sankeshwar' recorded higher number of primary branches plant^{-1} (7.47) and maximum fruit length (14.61 cm). Genotype 'Byadgi Dabbi' registered maximum fruit diameter (1.60 cm), pericarp weight (0.80 g), stalk weight (0.14 g) and number of seeds fruit^{-1} (98.42). The higher number of fruits plant^{-1} (186.30) and dry fruit yield (97.33 g plant^{-1}) were recorded in the genotype 'Sankeshwar' followed by genotype LCA-206.

Variability and character association in paprika and paprika alike chillies. 24 (1): 61-65 (2015)
K N Shiva, D Prasath, P Gobinath, N K Leela & T John Zachariah
An experiment was conducted to estimate variability and character association in a set of 25 indigenous (paprika alike chillies) and 18

exotic (paprika) germplasm of paprika. Wide range of variation was observed for all the characters except for capsaicin content, weight of seeds, fruit girth and length. The maximum range of variation was recorded for yield plant^{-1} followed by colour value, plant height and number of seeds fruit^{-1}. Among the various traits, maximum coefficient of variation was observed for capsaicin content, followed by weight of pericarp fruit^{-1}, yield plant^{-1} and weight of seeds fruit^{-1}in the indigenous lines of paprika. Similarly, in the exotic and combined germplasm of paprika and paprika alike chillies, maximum range of variation was registered with yield plant^{-1}, followed by colour value, number of seeds fruit^{-1} and plant height and narrow range of variation was observed with capsaicin content. In the combined germplasm, maximum coefficient of variation was recorded with capsaicin content, followed by weight of pericarp fruit^{-1}, yield plant^{-1} and colour value. Weight of pericarp, number and weight of seeds fruit^{-1} were identified as important yield components and selection should be focused on these traits for improvement of paprika and paprika alike chillies.

Growth and yield of elite genotypes of chilli (*Capsicum annuum* L.) in diverse agroclimatic zones of Punjab. 24 (2): 83-91 (2015)
M S Dhaliwal, N Garg, S K Jindal & D S Cheema

Eleven elite genotypes of chilli along with one check (Punjab Surkh) were evaluated at two diverse locations of Punjab, India. The G × E interaction was significant for red ripe fruit yield, fruit width and fruit weight and genotype Acc-33-1 was the most stable across locations. The pooled analysis showed that the genotype, SD 463 had the maximum red ripe fruit yield (0.586 kg plant^{-1}) and fruit weight (4.1 g); Mehma Sarja had the highest plant height (93.5 cm) and fruit width (13.4 mm); Selection 7 exhibited the lowest plant height (37.6 cm) and fruit width (7.0 mm); PC-6-1 had the longest fruits (8.6 cm); DCL 524 possessed maximum number of seeds fruit^{-1} (43.5); Selection 36-1 produced the maximum seed weight (0.211 g fruit^{-1}). The low broad sense heritability (h^2) for number of seeds fruit^{-1} and dried seed weight fruit^{-1} revealed that these traits were highly influenced by environment. High heritability coupled with high genetic advance for

red ripe fruit yield, fruit weight, plant height, fruit length and fruit width indicated the important role played by additive gene effects.

Genetic analysis of paprika genotypes for dry fruit yield in chilli. 25 (2): 200-205 (2016)

S Srikanth, V Kanthaswamy and S Ramesh Kumar

Ten genotypes of paprika were evaluated for mean performance, variability parameters and association of characters towards dry fruit yield. Based on mean performance, genotype C-6 ('U.S.609') was the best for all characters except number of seed fruit^{-1}, ascorbic acid, oleoresin content, capsaicin and capsanthin content. High estimates of genotypic coefficients of variation for numbers of primary branches, dry fruit yield plant^{-1}, fresh ripe fruit yield plant^{-1} and fruit length indicated that the major part of variability was due to genetic makeup for these traits. Fruit length, fresh ripe fruit yield plant^{-1} and dry fruit yield plant^{-1} had higher genetic advance coupled with high heritability indicates the additive gene action. Among the characters analyzed for association it could be concluded that number of fruit plant^{-1}, fruit length, plant height, days from anthesis to harvest and number of primary branches plant^{-1} would be appropriate selection parameters for improvement of fresh fruit yield.

Performance of chilli (*Capsicum annuum* L.) hybrids for yield and quality traits. 31 (2): 157-165 (2022)

Vinay Verma, Amit Vikram, Yash Pal Sharma, Ramesh K Bhardwaj, Rajesh K Dogra, Meenu Gupta and Shalini Singh

Twenty-eight F1 combinations of chilli (*Capsicum annuum* L.) obtained from half-diallel cross along with eight diverse parents were evaluated in a field study to elucidate the information on the extent of mean performance of various horticultural traits. The analysis revealed that all the genotypes possessed wide spectrum of variability and showed significant differences for parents and hybrids for the traits studied. For parents UHF CHI 13 (216.20), UHF CHI 15 (193.80), UHF CHI 5 (139.00) and for hybrids H1 (182.60), H9 (181.40) and H7 (172.80) hold highest fruit count per plant. The parents UHF CHI 5 (1047.13 g), UHF CHI 15 (949.62 g) and UHF CHI 7 (912.61 g) and cross combinations H17 (1535.10 g), H8 (1320.00), H6 (1229.76) and

H18 (967.60) recorded the high ripe fruit yield per plant. As for earliness, parents UHF CHI 5 (43.33), UHF CHI 11 (45.00), UHF CHI 7 (45.33) and hybrids H27 (42.67), H26 (43.00) and UH28 (43.00) took minimum days for flowering. For pungency UHF CHI 12 (0.28%), UHF CHI 13 (0.26%), DKC-8 (0.24%) and H23 (0.33%), H5 (0.31%), H26 (0.26%) recorded high capsaicin content.

Crop Production and Postharvest Technology

Effect of spacings and fertilizers on growth, yield and physical fruit quality of chilli (*Capsicum annuum* L.) cultivars. 8 (1): 23-27 (1999)

J P S Pundir & R Porwal

The effect of spacings and fertilizers on growth, yield and fruit quality (physical) of chilli (*Capsicum annuum*) cultivars was studied at Bikaner (Rajasthan, India). The cultivar Local Desi recorded significantly higher plant height, dry weight per plant, weight and volume per fruit. However, cultivar NP 46 produced maximum number of fruits per plant, fruit yield per plant and fruit yield per hectare. Application of 100 kg N in combination with 25 kg P and 50 kg K per ha recorded highest fruits per plant. Maximum plant height, fresh weight and dry weight per plant, number of fruits and yield of fruits per plant were recorded in the widest spacing (55 cm x 55 cm); closest spacing (25 cm x 25 cm) produced highest fruit yield per hectare. The quality of fruits was affected by spacings. Interaction effect of spacings, fertilizers and cultivars was non-significant to affect growth, yield and fruit quality attributes.

Quality of chilli (*Capsicum annuum* L.) variety Co-3 as influenced by levels and sources of phosphorus and levels of nitrogen. 10 (1): 1-5 (2001)

M Murugan

Nitrogen and phosphorus application increased the ascorbic acid content and capsaicin content in green, ripe and dry chilli. Sources of phosphorus did not have any significant effect on the ascorbic acid content. The maximum ascorbic acid content was recorded in green fruit which decreased gradually with maturity of fruit, recording the

lowest value in dry pod, while capsaicin content was lowest in green fruit and maximum in dry pod.

Storage studies of chilli (*Capsicum annuum* L) cultivars on germination and vigour index. 17 (2): 149-153 (2008)
K Uma Jyothi, S Surya Kumari, P Venkata Reddy & C Ravi Shankar
The experiment was conducted at the Chillies Improvement Project, Regional Agricultural Research Station, Lam, Guntur and in the Priyanka Cold Store, Chilakaluripet Road, Guntur during the year 2001-2002. The fresh ripe chilli cultivars *viz*., LCA 334, LCA 357, LCA 206,LCA 235, Paprika type, Guntur Grand and Wonder Hot were collected and Sun dried both moisture lend of 10-11 per cent. Then the dried chilli was packed in gunny bags in two sets. One set was kept in cold store and the other set at ambient condition. Samples were drawn at monthly intervals and subjected to seed germination and seedling vigour index. The seeds of cultivars LCA 235, LCA 206, LCA 334 and LCA 357 recorded higher germination percentage and vigour index at different intervals of storage. The chilli stored in cold store proved superior to ambient storage even for good quality seed.

Study of drying methods and chemical treatments on quality aspects of chilli cv. LCA 334. 17 (2): 205-208 (2008)
K Uma Jyothi, S Surya Kumari, P Venkata Reddy & C Ravi Shankar
The experiment to using chilli Cv. LCA 334 was conducted at Regional Agricultural Research Station. Lam, Guntur during the year 2003-2004. The results revealed significant differences among different drying methods and chemical treatments and their interactions on quality constituents of chilli *viz*., oleoresin, capsanthin and capsaicin. Among the drying methods, Tobacco barn drying gave the highest oleoresin content of 10.5% and was found superior to the other methods of drying *viz.,* ground, tarpaulin and mechanical drying. However, the chemicals *viz*., BHA (Butylated Hydroxy Anisole), potassium carbonate and dipsol used for drying did not exert significant influence on oleoresin content. Among the interactions, chilli treated with dipsol and dried in tobacco barn recorded the highest oleoresin content of 10.7% followed by chilli treated with BHA and dried in tobacco barn (10.5%). With regard to capsanthin

content, the chilli dried in mechanical drier recorded the highest value (14503EOA colour value) followed by tobacco barn drying (13893 EOA colour value) and were found superior to chilli dried on ground/ tarpaulin. Among the chemical treatments, chilli treated with dipsol recorded the highest capsanthin content (13923 EOA colour value) and found significantly superior to all the other treatments tried. With regard to the capsaicin content, chilli dried in tobacco barn recorded the highest capsaicin content (0.502%), closely followed by chilli dried on ground (0.498%) and were found on par with each other and significantly superior to tarpaulin and mechanical drying. Among the chemicals, BHA significantly increased the capsaicin content (0.508%) and found superior to check (0.468%) and also the other chemicals tried. Among the interactions, chilli treated with BHA and dried in tobacco barn recorded the highest capsaicin content (0.576%) and found significantly superior to all other interactions.

Biochemical evaluation of chilli (*Capsicum annuum* L) cultivars suitable for export. 17 (2): 209-211 (2008)

K Uma Jyothi, S Surya Kumari, K V Siva Reddy, T Vijayalakshmi & P Venkata Reddy

Chilli, an important spice of India is cultivated in all the states and Union territories of the country. Some varieties are famous for typical red colour and others are known for pungency. A study was conducted on biochemical constituents *viz*., oleoresin, capsanthin and capsaicin for two consecutive years *viz.,* 2005-06 and 2006-07. Twenty three cultivars collected from the coordinated centres of All India Co-ordinated Vegetable Improvement Project from all over the country were used in this study. Among the cultivars studied, PC-7 and PC-6 from Pantnagar recorded the highest colour value of 50782 and 49456 EOA colour value respectively and the lowest colour value was recorded by DCL-352 (19932 EOA colour value). The highest oleoresin content was recorded by DCL 352 (13.82%) of IARI and the lowest was recorded byPC-7 (6.91%). The capsaicin content among the entries was in the range of 0.256 % (SKAU-C-101) to 0.528% (BC-40-2). From the above study, it was concluded that the cultivars *viz*., PC-7, PC-6 of Pantnagar and Sel 11 of Ludhiana had high colour value and similarly BC-40-2 of Bhubaneshwar had high pungency and

suitable to catch high market price both in domestic and export market.

Influence of sodicity on cation composition, growth, yield and quality of chilli (*Capsicum annuum* L.). 18 (1): 1-8 (2009)
V K Garg
Field trials conducted at Lucknow (Uttar Pradesh) to study the performance of chilli (*Capsicum annuum*) in sodic soil with four genotypes (Jwala, PC-1, KDCS-810 and LCA-235) and five levels of exchangeable sodium percentage (ESP) (10, 20, 30, 40 and 50) indicated the adverse effect of sodicity and hence picking of red ripe fruits may be stopped after the sixth one when there is about 25% reduction in fruit size. Maximum mean yield (fresh) was obtained in LCA-235 (16.2 t ha^{-1}) followed by KDCS-810 (13.1 t ha^{-1}), PC-1 (12.0 t ha^{-1}) and Jwala (10.3 t ha^{-1}). There was less reduction in yield of LCA-235 and KDCS-810 than Jwala and PC-1 at higher sodicity level (ESP=40) revealing greater sodicity tolerance. Cation composition of different plant parts indicated salt (Na) exclusion mechanism and higher K/Na and Ca/Na ratio supporting the potential of chilli crop to endure greater degree of sodicity. Physical fruit quality with respect to length, diameter and pod weight were affected by soil sodicity and decreased with increase in soil sodicity. Oleoresin and capsaicin contents did not vary with increase in sodicity, whereas, ascorbic acid content was reduced.

Stability analysis in chilli (*Capsicum annuum* L.) under open and mahogany (*Swietenia mahagoni* L.) based agroforestry system. 18 (2): 84-87 (2009)
L S Datta & A N Dey
Eight chilli genotypes (*Capsicum annuum*) were evaluated for yield and yield parameters under open and mahogany (*Swietenia mahagoni*) based agroforestry system for stability analysis at northern West Bengal. Genotype and environment interactions for plant height, primary and secondary branches, plant spread, stem girth, fruit length and diameter and yield were significant indicating differential response of genotypes under different environments. Significant linear and nonlinear components of genotype-

environments were recorded for plant height, fruit length and yield. The chilli genotype CA-5 may be adopted for cultivation under favourable (open) conditions in view of its stability. Though CA-12 and Bhaghyalakshmi recorded lower yield than the mean yield, these two genotypes were stable. Bhaghyalakshmi was stable under open and agroforestry condition and CA-12 was specifically adapted under agroforestry condition.

Stability analysis in chilli (*Capsicum annuum* L.). 22 (2): 154-164 (2013)

B V Tembhurne & S K Rao

Twenty cytoplasmic genetic male sterility (CGMS) based F_1 hybrids, three promising genotypes and a check were evaluated in three different environments for stability analysis. The correlation and path coefficient analysis were studied in 75 genotypes for 18 and 12 different quantitative characters, respectively. Variance due to genotypes × environment interactions were significant for all the characters except number of fruits plant^{-1} and fresh fruit weight plant^{-1}. Considering all the stability parameters, JCH-47, BCH-24 and BVC-37 exhibited wider stability for dry fruit yield plant^{-1}, JCH-01 had stability for favourable environment and JCH-05, JCH-14, JCH-23, JCH-24, JCH-54 and RCH-23 showed below average stability. Highest performing F_1 hybrid JCH-54 was identified as stable performer under unfavourable environment for dry fruit yield. The highest correlations were found with dry fruit weight plant^{-1} and fresh fruit weight plant^{-1} (r=1.00), number of fruits plant^{-1} (r=0.63), dry fruit weight fruit^{-1} (r=0.44), number of seeds fruit^{-1} (r=0.35), fresh fruit weight fruit^{-1} (r=0.32) and fruit length (r=0.28). Path analysis indicated that the number of fruits plant^{-1} and fresh fruit weight fruit^{-1} were the two factors that exerted the greatest influence both directly and indirectly upon the dry fruit yield. These two traits were the most important components that involved dry fruit yield plant^{-1}.

Performance of paprika and paprika alike chillies (*Capsicum annuum* L.) under warm humid tropics. 22 (2): 222-227 (2013)
K N Shiva, T J Zachariah, N K Leela & P A Mathew
A study was conducted to evaluate the performance of 21 paprika alike chillies (indigenous germplasm) and nine paprika lines (exotic collections) under rain-shelter. Highly significant variation was recorded among the genotypes for all the characters. The results indicated that Kt-Pl-19 variant-I, ICBD-6, ICBD-12, ICBD-13, ICBD-11 were promising for yield and yield attributing characters, while ICBD-12, ICBD-11, ICBD-2, ICBD-13, Kt-Pl-19 variant – I proved to be better for high seed numbers. With respect to total extractable colour, ICBD-5, ICBD-7, ICBD-4, ICBD-1, ICBD-18 were measured with high colour value, among the indigenous germplasm. Among the exotic collections, PBC-171, SSP-1999, EC-18, EC-45, EC-71 proved better for yield and yield attributing characters. The genotypes, Paprika King, EC-45, PBC-171, EC-43 produced maximum number and weight of seeds, whereas PBC-171, IMI-5, EC-71, EC-45 were found promising for high colour value. Based on these observations, the genotypes Kt-Pl-19 variant-I, ICBD-6, ICBD-12, PBC-171, SSP-1999 and EC-18 were found suitable for high yield, whereas ICBD-12, ICBD-11, Paprika King, EC-45 and PBC-171 for high seed numbers and ICBD-5, ICBD-7, ICBD-4, PBC-171, IMI-5, EC-71 for high colour value in Kerala. Among the various traits, wide range of variation was recorded for number of seeds per fruit and narrow range of variation for fruit length.

Variability in quality attributes of paprika and paprika alike chillies (*Capsicum annuum* L.). 23 (1): 17-25 (2014)
K N Shiva, P Gobinath, T J Zachariah & N K Leela
An investigation was carried out to assess the variability in paprika alike chillies (26 indigenous germplasm) and paprika lines (18 exotic collections) for yield and quality attributing parameters, which would in turn help in identifying and utilizing the promising lines for crop improvement. Highly significant variation was recorded among the genotypes for yield and quality contributing characters. Kt-Pl-19, Kt-Pl-19 variant-I, ICBD-10, ICBD-8, SSP-1999 and PBC-171, were found promising, while ICBD-10, ICBD-8, ICBD-1, ICBD-11, ICBD-6, ICBD-19, CC-1, EC-171, EC-490, EC-18, EC-6, EC-45, EC-71 and EC-14 proved to

be ideal for quality attributes. Based on yield and quality parameters, the genotypes ICBD-10, ICBD-8 and EC-18 were found suitable for paprika industry with high yield (> 850 g plant^{-1}) and high-quality attributing characters (>200 ASTA units and <0.5% capsaicin). Among the various characters, maximum coefficient of variation (15.25%) was recorded for capsaicin content in both indigenous and exotic germplasm and minimum variation for colour value (0.46%) in the indigenous germplasm and weight of pericarp (6.78%) in the exotic collections.

Wax coating affects postharvest shelf-life of non-cooled sweet pepper. 23 (1): 98-101 (2014)
V Arumugam & T N Balamohan
Investigations were carried out to determine the effect of wax coating on physical and quality parameters in sweet pepper (*Capsicum annuum*) cv. Indra under ambient storage (25±5°C). Wax coating with carnauba wax at 2% produced the lowest physiological loss of weight (PLW), and increased shelf-life, total soluble solids (TSS), total sugar content and ascorbic acid. Wax concentration of >2% coating had little or no effect, on physical and biochemical characters. This suggested that 2% wax coating increased the shelf life, while concentration of >2% did not enhance its shelf life.

Cluster analysis based on biochemical constituents in paprika like chillies (*Capsicum annuum* L.). 23 (2): 164-169 (2014)
P Gobinath, T J Zachariah, K N Shiva, N K Leela, K Jayarajan & Kiptoo Geoffry
Chillies and paprika like chillies (*Capsicum annuum* L.) belonging to Solanaceae, is a source of natural colour, widely used in the food industry and is in great demand in the international market. Twenty four accessions belonging to Indigenous Collections of Byadagi Dabbi (ICBD) and others were analyzed for biochemical constituents from leaf. Biochemical constituents studied were total carbohydrate, starch, reducing sugars, total free amino acids, phenol and protein. The accessions were compared for the isozymes *viz*., peroxidase, superoxide dismutase and polyphenol oxidase in the leaf, besides, leaf protein using SDS-PAGE. The dendrogram showing the relationship

among the accessions for leaf biochemical constituents and colour value of fruits formed six clusters. Colour value ranged from 109 to 353 ASTA units. The accessions ICBD-11 and ICBD-19 possessed highest colour value. Accession ICBD-24 was distinctly different from others. Accessions in each cluster had almost uniform colour value and uniform isozyme profile. The accession ICBD-24 was a Coorg collection and ICBD-11 and ICBD-19 were from Dharwad district of Karnataka. Significant positive correlation was observed between colour value and total free amino acids, total protein, total phenol and polyphenol oxidase in paprika like chillies.

Integrated nutrient management on growth, yield and quality of paprika alike chillies (*Capsicum annuum* L.). 24 (2): 92-97 (2015)
K N Shiva, V Srinivasan, T J Zachariah & N K Leela
The experiment was conducted for two seasons to study the effect of organic nutrient sources and inorganic sources of nutrients combined with biofertilizers on growth, yield and quality of paprika alike chillies (indigenous germplasm of paprika). The results revealed that application of vermicompost (250 g plant^{-1}) combined with neem cake (100 g plant^{-1}) recorded higher growth parameters, yield and quality attributes, which was comparable with inorganic fertilizers at the recommended levels. Under integrated nutrient management, application of 75% N (8 g plant^{-1}) + *Azospirillum* spp. (5 g plant^{-1}) + 75% P (1.7 g plant^{-1}) + Phosphobacteria (5 g plant^{-1}) + 100% K (2.5 g plant^{-1}) improved the growth, yield and quality parameters of paprika alike chillies as compared to recommended NPK through fertilizers indicating a saving 25% of both inorganic N and P through biofertilizers.

Effect of nitrogen and potassium sources on yield attributes and yield of chilli (*Capsicum annuum* L.). 24 (2): 137-140 (2015)
S Suryakumari, S Bharathi, K U Jyothi & P V Reddy
In a field experiment the comparative efficacy of three sources of nitrogen *viz*., urea, calcium ammonium nitrate and ammonium sulphate and two sources of potassium *viz*., muriate of potash and sulphate of potash on yield attributes and yield in chilli cv. LCA 353 was evaluated. Among the treatments tested the highest number of

fruits per plant and yield was recorded in the treatment where the recommended nitrogen of 300 kg ha^{-1} was given 50% as urea and remaining 50% as CAN and recommended potassium of 120 kg ha^{-1} as 50% MOP and remaining 50% as SOP (228.4 fruits $plant^{-1}$ and 48.85 q ha^{-1}). However, in the treatment where the recommended nitrogen of 300 kg ha^{-1} was given 50% as urea and remaining 50% as AS/CAN and recommended potassium of 120 kg ha^{-1} as 50% MOP and 50% SOP were economical with C:B ratio of 1:1.95 as against control with 1:1.64 where split application of recommended N and K was given in single source as urea and muriate of potash.

Effect of irrigation methods and mulching on growth and yield parameters of chilli (*Capsicum annum* L.) in arid condition. 27 (1): 81-87 (2018)

R L Bhardwaj, M M Sundria, S R R Kumhar & N Kumar

The research work was carried out to study the impact of various irrigation methods and mulching on plant growth, production and profitability of chilli cv. R.Ch. 1 at Agricultural Research Station, Mandor, Jodhpur during July, 2016 to February, 2017. The results of surface irrigation were compared with drip irrigation system under no mulch and in conjunction with plastic mulch. The results revealed that the crop was irrigated by drip irrigation on raise bed with 100 micron Linear Low Density Poly Ethylene plastic mulch (T_8 treatment) exhibited significantly higher seedling survival at 15 and 30 days after transplanting (95.16% and 91.70%), highest plant height (47.10 cm at 45 DAT and 54.60 cm at harvest), highest number of branches (14.93) $plant^{-1}$, maximum stem girth (2.32 cm) number of roots $plant^{-1}$ (138.5), highest fruit set (38.47%), length of fresh fruit (12.56 cm), diameter of fruit (3.52 cm) and fresh weight of $fruit^{-1}$ (8.42 g) was observed. The maximum number of fruits $plant^{-1}$ (125), highest yield $plant^{-1}$ (1052.5 g), yield ha^{-1} (337.63 q) and premier fruit quality score (9.11) with maximum net return (Rs. 3,26,407.28) and benefit:cost ratio (3.41) was also reported in same treatment. Comparatively minimum time (15 hours) required for one hectare irrigation was also reported in drip irrigation on raise bed with plastic mulch. This led to lower population of white fly $plant^{-1}$ (4.53), minimum weed infestation (1.53 weed m^{-2}), leaf curl (5.50%) and

fruit rot (5.0%) incidence than other treatment combinations. The minimum growth, yield and profitability were reported in check basin method of irrigation without mulch (T_1 treatment).

Crop Protection

Seasonal occurrence of chilli (*Capsicum annuum* L.) diseases in Kerala, India. 4 (1): 86-87 (1995)
Sally K Mathew, M Abdul Wahab & S Nirmala Devi
Observations on the seasonal occurrence of chilli (*Capsicum annuum* L.) diseases in Vellanikkara, Trichur, India during 1989 to 1991 showed that *Alternaria* leaf blight, die back and fruit rot diseases were serious problems during rainy season. Incidence of leaf blight (*Phytophthora capsici*) and bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*) were also observed in this area.

Reaction of detached fruits of chilli (*Capsicum annuum* L.) varieties to isolates of *Colletotrichum capsici* (Syd.) Butler and Bisby. 14 (2): 145-147 (2005)
T Vanan, S K Khirbat & R Mehra
Investigations on the pathogenic potential of nine isolates of *Colletotrichum capsici* on four chilli (*Capsicum annuum*) varieties revealed variations in their incubation period and lesion size induced on inoculated fruits. The isolates CC-1, CC-2, CC-3, CC-4, CC-5 and CC-7 gave resistant reaction in all the four varieties. Isolate CC-9 gave susceptible reaction in all the four varieties. Isolate CC-8 induced susceptible reaction in Hisar Shakti and resistant reaction in Hisar Vijay whereas, CC-6 gave susceptible reaction in Hisar Vijay and resistant reaction in Hisar Shakti.

Reaction of chilli (*Capsicum annuum* L.) genotypes and hybrids against Fusarium wilt (*Fusarium solani*). 23 (2): 186-191 (2014)
T B Maruti, B V Tembhurne, R L Chavan & Y S Amaresh
Field experiment was conducted to evaluate chilli (*Capsicum annuum* L.) genotypes and hybrids against *Fusarium solani*. About 56 restorer lines and 38 F_1 hybrids were evaluated for resistance to *Fusarium solani* under laboratory conditions. Among the 56 genotypes, none of

them were immune or resistant. However, only one genotype *viz*., P3 was found moderately resistant in both seed inoculation and rapid root dip transplanting techniques. However, out of 38, two hybrids, *viz*., JNA2 × ACB1 × 9608D and Rajaput × P3 showed resistance under sick pot culture condition.

Effective inoculation technique for identification of resistance source in chilli (*Capsicum annuum* L.) against aflatoxin and management through *Trichoderma* species. 24 (1): 1-6 (2015)
K K Pandey, R C Gupta & K K Mishra
The present study was carried out to develop an effective inoculation technique for screening chilli fruits against *Aspergillus flavus* and to identify the most effective bioagents against *A. flavus* to integrate them into management strategies. The study revealed that dipped method is better than pin-pricked method for creating maximum infection pressure on fruits and can be successfully utilized for screening against the pathogen. Artificial screening revealed that chilli varieties Tabasco, PBC-535, IIHR-10 and LCA-429 were resistant to *A. flavus*. Among three tested species of *Trichoderma*, *T. viride* was comparatively more effective against 21 isolates of *A. flavus*. All the *Trichoderma* species showed fungistatic behaviour against *A. flavus* even after 14 days of incubation. Differential response of *Trichoderma* species against *A. flavus* indicated distinct variability among the isolates of *A. flavus* collected from different regions of the country.

Management of anthracnose (*Colletotrichum capsici*) in chilli (*Capsicum annum* L.) through fungicides, bioagents and hand picking methods. 24 (2): 141-144 (2015)
K K Pandey & R C Gupta
Field trials were conducted on chilli variety LCA-355 for management of anthracnose (*Colletotrichum capsici*) through fungicides, bioagents and hand picking of initial set of green fruits. The pooled data of two year trials revealed that, minimum per cent disease index (PDI) of anthracnose (13.33%) on red chilli fruits was recorded in thrice hand picking of initial set of green chilli fruits. The data also indicated that foliar spray of bioagent *Aspergillus niger*-V @ 0.5% with sticker @ 0.1% resulted in 29.83 PDI which proved to be the second effective

treatment. However, highest total yield (1947.95 g plot^{-1})) as well as healthy red chilli fruits (1286.66 g plot^{-1}) was recorded in foliar sprays with mancozeb @ 0.3% followed by azoxystrobin @ 0.1% (1125.00 g plot^{-1})) and lowest yield in control (550 g plot^{-1}). The highest PDI (59%) of anthracnose on dry red chilli fruits with lowest total yield (1068.97 g plot^{-1}) was recorded in control. The pooled data of field trials revealed that, the thrice hand picking of initial set of green chilli fruits performed better with lowest PDI and proved that hand picking is an effective method for management of anthracnose.

Biocontrol activity of *Streptomyces* isolate SDSRO-13 against *Colletotrichum* spp. causing anthracnose disease of chilli (*Capsicum annuum* L.). 32 (2): 170-185 (2023)

D S Savita & R Onkarappa

A total of 18 *Streptomyces* species were isolated from the rhizospheric soil of maize. Among 18 isolates, SDSRO-13 showed strong inhibition against *Colletotrichum* spp. of chilli. SDSRO-13 was identified as *Streptomyces* sp. based on morphological, biochemical and 16SrRNA partial gene sequence analysis. In this study, two strains of *Colletotrichum* sp. were used for pathogenicity test. For *in vivo* antifungal activity, spore suspension of the test pathogens were used on the fresh chilli fruit by making a small puncture on the fruit, in completely sterile conditions and incubated for up to 21 days. The chilli fruits treated with SDSRO-13 and test pathogens showed no disease symptoms. The infected fruits were subjected for Koch's postulate test and they showed the similar morphological features compared to the pure cultures of the pathogens. We conclude that actinomycetes, especially members of the genus *Streptomyces* are potential biocontrol agents which offer safer alternative management strategy to control the chilli fungal pathogens.

Social Sciences

A study on growth, instability and direction of chilli trade in India. 22 (1): 76-80 (2013)
N Ashoka, C Kuldeep, V A Ramachandra & R A Yeledhalli
This study was aimed at studying growth, instability in area, production and productivity and direction of trade of chilli from India. Compound growth rate analysis, Instability analysis and Markov chain analytical tools were used for the study. The results indicated that the growth in area under chilli was negative, while production showed increasing growth due to increased productivity. The sources of instability in chilli production were found to be change in area variance and change in yield variance. Malaysia, Sri Lanka, United Arab Emirates and Indonesia were found to be the loyal markets for Indian chillies. The influence of export price and production on the changes in export of chilli was positive, but the influence of domestic price was negative.

Resource use efficiency and economics of marketing of green chilli. 23 (1): 32-37 (2014)
P P Jagtap, U S Shingane & K P Kulkarni
The study was conducted in Achalpur tahsil of Amravati district of Maharashtra with a sample of 80 farmers selected randomly from four villages with twenty farmers from each village. Data used were pertaining to the period 2009-10. Production function analysis of data indicated that, among various resources selected, human labour, bullock labour and machine power in small farmers, seed, bullock labour and fertilizers and manures in medium farmers and the fertilizers and manures in large farmers were statistically significant. The ratio of marginal value product to its acquisition cost per unit was found to be greater than unity for the variables plant protection chemicals and fertilizers and manures in small farmers, variables human labour and fertilizers and manures in medium farmers and the variables seed, human labour and fertilizers and manures in large farmers. Also economic analysis of data indicated that majority of farm produce was routed through two marketing channels, Channel-I (Producer-commission agent-retailer consumer) and Channel-II

(Producer-commission agent-Wholesaler-retailer-consumer). Producer's share in consumer's rupee was found to be 56.31%, 40.59% and price spread was Rs. 655.35 Rs. 891 q^{-1} for Channel-I and Channel-II, n growth, yield and quality of ginger respectively.

KING CHILLI

Effect of pre- and post-harvest treatments on yield, quality and post-harvest shelf life of king chilli (*Capsicum chinense* Jacquin) under foothill conditions of Nagaland (India). 21 (1): 42-47 (2012)

I Rongsennungla, S P Kanaujia, V B Singh and C S Maiti

Field and laboratory experiments were carried out at Medziphema (Nagaland) to evaluate the effect of pre- and post-harvest treatments on yield, quality and post-harvest life of King chilli (*Capsicum chinense* Jacquin) under foothill conditions of Nagaland. Highest fresh yield (13.65 t ha^{-1}) and capsaicin content (819421.13 SHU) of fruits were recorded with application of Naphthalene Acetic Acid (40 ppm). Maximum vitamin C content (115.67 mg 100 g^{-1} of fruit) was recorded with application of Ethrel 250 ppm. Lowest physiological loss in weight (2.55%) and change in fruit colour (10%), highest value of ascorbic acid content (120.5 mg 100 g^{-1} of fruit) and longest shelf life (9 days) were recorded at 9th day after storage in calcium chloride (0.5%) treated fruits, packed in non-perforated bags and stored under refrigeration at 5°C.

MEDICINAL, AROMATIC AND MISCELLANEOUS CROPS

GARLIC AND ALLIED SPECIES

Embryogenesis and plantlet formation in garlic (*Allium sativum* L.). 3 (1): 43-47 (1994)
Sushma Koul, Manju Sambyal & S Grewal
An *in vitro* method for propagation of garlic (*Allium sativum*) *via* somatic embryogenesis is described. Complete plantlets were obtained by a sequential supply of different basal media and growth hormones. Murashige & Skoog's medium with kinetin (5.0 ppm) and 2,4-dichlorophenoxy acetic acid (0.5 ppm) promoted embryogenic callus formation. Shoot regeneration was achieved by transferring embryogenic callus to Gamborg's B_5 medium with kinetin and indole acetic acid whereas root formation occurred in same basal medium supplemented with α-naphthalene acetic acid (0.1 ppm). Sucrose at a higher concentration (10%) had stimulatory effect on shoot regeneration potential of embryoids. A characteristic garlic odour developed in this culture.

Chemical composition of essential oils of garlic (*Allium sativum* L.). 8 (1): 41-47 (1999)
P G Prabhakara Rao, L Jaganmohan Rao & B Raghavan
Six varieties of garlic grown in different geographical locations in Gujarat, India were analysed for their proximate composition including volatile oil content. Twenty nine compounds were identified in the volatile oils by gas chromatography and gas chromatography-mass spectrometry, among which 15 were new compounds hitherto not reported to be components of garlic. The relative concentrations of 13 major components in the volatile oils of all six varieties are also presented.

Effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic (*Allium sativum* L.) cultivars. 10 (2): 111-117 (2001)

I S Naruka & R S Dhaka

The field experiment to study the effect of row spacing and nitrogen fertilization on growth, yield and composition of bulb in garlic cultivars was conducted during *rabi* in 1998-99 and 1999-2000. All growth parameters, yield attributing traits, bulb yield and contents of the bulb increased significantly with the increasing level of nitrogen application and row spacing and these were maximum with nitrogen application of 200 kg ha^{-1} and a row spacing of 15 cm. However, the T.S.S. was higher in closer row spacing (10 cm). The cultivar, Jajavar local was significantly superior over the other two cultivars in all these characters. The interaction studies showed that the treatment combination of $N_4S_2V_2$, (Nitrogen @ 200 kg ha^{-1}, row spacing of 15 cm and cultivar Jajavar local) gave higher bulb yield (128 q ha^{-1}) with maximum net returns (Rs. 77,236 ha^{-1}) and a B:C ratio (3.06:1).

Response of garlic (*Allium sativum* L.) to phosphorous and sulphur application in acid alfisol of Meghalaya. 12 (2): 183-186 (2003)

B Majumdar, M S Venkatesh, Kailash Kumar & Patiram

In a field experiment with three levels of P (0, 50 and 100 kg P_2O, ha^{-1}) and four levels of S (0, 10, 15 and 20 kg S ha^{-1}) on a P and S deficient Typic Hapludalf of Meghalaya, the bulb and straw yield, nutrient uptake and protein content of garlic increased significantly with increasing levels of P and S application. The available P and S content in postharvest soil increased significantly with P and S application. The interaction effects of P and S were significant for bulb yield, N, P and S uptake and available P and S in postharvest soil and their highest values were recorded with $P_{100}S_{20}$ treatment combination. P use efficiency increased with S levels and was higher at P_{50} as compared to P_{100} level. S use efficiency increased with increasing levels of P and S. Maximum P and S use efficiency were recorded with $P_{50}S_{20}$ and $P_{100}S_{20}$ treatment combinations, respectively.

Genotype x environment interactions and stability analysis in elite lines of garlic (*Allium sativum* L.). 14 (1): 21-27 (2005)
A Khar, A Asha Devi, V Mahajan & K E Lawande
Thirty five elite lines and three released varieties of garlic (*Allium sativum*) were evaluated for their stability, with respect to yield and its contributing traits, for three years at Rajgurunagar (Maharashtra) during *rabi* season. Analysis of variance for stability of different characters indicated that mean differences for varieties and environments (years) were significant for all the characters except for number of leaves, indicating that the performance with respect to number of leaves in different years was not stable. Genotype 50 gave stable performance for higher plant height, clove weight, total yield and marketable yield, while genotypes 74 and 163 gave better yield under adverse situations. Genotype 117 had stability for dwarf plant height, less number of leaves and more equatorial diameter. Genotype 58 had stability in desired direction for less number of leaves and lesser neck thickness. Genotype 52 showed stability for higher plant height, greater neck thickness and average number of cloves with less number of leaves. Variety G-41 was stable for marketable yield only. In genotypes 52, 58, 117, 163, 200, 229 and variety G-41, the yield was more in favourable environmental conditions.

Callus culture and regeneration from root tip of garlic (*Allium sativum* L.). 14 (1): 51-55 (2005)
Anil Khar, A Asha Devi & K E Lawande
Callus induction and subsequent plant regeneration was studied in a commercial Indian cultivar of garlic, cv. G-41 (short-day type). 2,4-dicholorophenoxyacetic acid at lower concentration (0.25 mg l^{-1}) and picloram at higher concentration (1.0 mg l^{-1}) were suitable for efficient callus formation from the root tips. Callus was obtained only from the apical portions of root tips treated with 2,4-dicholorophenoxyacetic acid whereas picloram led to callus formation throughout the root segment except the non-apical (subjacent) portion. Callus obtained from induction medium containing both auxins and cytokinins responded well to regeneration. The average shoot regeneration frequency ranged from 16.7% to 50.0%. The best combination for callus culture and regeneration was callus formation

in root tip medium 2 (CRT 2) (2,4-dicholorophenoxyacetic acid 0.25 mgl^{-1} + 6-benzylaminopurine 1.0 mg l^{-1}) induction medium followed by garlic regeneration medium 3 (GR 3) (kinetin 1.0 mg l^{-1}) as the regeneration medium. In other regeneration media, profuse root formation and appearance of dark green callus was also observed.

Genotypic response of short day garlic (*Allium sativum* L.) accessions to shoot multiplication. 16 (1): 15-21 (2007)
A Asha Devi, A Khar & K E Lawande
A simple protocol for *in vitro* shoot multiplication of 10 accessions including 8 varieties and 2 advanced lines of short day Indian garlic (*Allium sativum*) is described. Two shoot multiplication media (Murashige and Skoog 1 and Murashige and Skoog 2) were tried using basal plate explant from mature cloves for multiple shoot induction. The medium (Murashige and Skoog 2) consisting of 6-(γ,γ-dimethylallylamino)-purine (3 mg l^{-1}) was the best for induction of multiple shoots. Although genetic variability existed among the genotypes, shoot multiplication was obtained in all the accessions in Murashige and Skoog 2 medium along with almost 100% bulb formation in the shoots produced.

Effect of γ-ray irradiation on storage behaviour in garlic (*Allium sativum* L.). 16 (1): 22-26 (2007)
P C Tripathi & K E Lawande
Experiments conducted at Rajgurunagar (Maharashtra) to study the effect of γ-ray irradiation and cold storage on storage losses in garlic (*Allium sativum*) indicated that cold storage of garlic reduced physiological weight loss and infection due to diseases. These losses were lower than ambient stored garlic even after 5 months of storage. Un-irradiated cold stored garlic showed rapid sprouting during post cold storage period but this low temperature induced sprouting was not noticed in γ-ray irradiated cold stored garlic after storage period. Overall, γ-ray irradiation followed by cold storage minimized the storage losses by 15% to 20% and increased the shelf life of garlic.

A note on frost induced garlic (*Allium sativum* L. var. *sagitatum* Kuz.) mutant with larger aerial bulbils. 16 (2): 122-124 (2007)
Deepu Mathew
A natural frost induced mutant of garlic (*Allium sativum* L. var. *sagitatum* Kuz. cv. Agri Found Parvati), producing normal clove-sized aerial bulbils, was isolated from extreme cold-arid trans-Himalayan deserts of Ladakh (9,000-18,500 ft above MSL), India. The yield after a season's growth from mutated bulbils (42.3 g) was slightly less than that realized from second season's growth in conventional bulbils (46.7 g) and greater than that from normal cloves (39.3 g). This mutant, ensuring commercial garlic production from aerial bulbils within a single season itself, was stable over two successive generations.

Effect of micro irrigation practices on growth and yield of garlic (*Allium sativum* L.) var. G. 41. 17 (3): 230-234 (2008)
V Sankar, K E Lawande & P C Tripathi
An experiment was conducted at Pune (Maharashtra) to study the feasibility of micro irrigation on growth, yield and yield contributing characters of garlic (*Allium sativum*) under Western Maharashtra conditions. Both drip and sprinkler irrigation systems improved growth, yield and yield contributing parameters of garlic. Among the different irrigation methods and levels tested, drip irrigation at 100% PE recorded the highest marketable bulb yield of garlic followed by sprinkler irrigation at 100% PE. The study indicated that in the best treatment compared to surface method of irrigation, a saving of 37.9% irrigation water in drip and 36.4% in sprinkler system can be achieved.

Correlation and path coefficient studies in garlic (*Allium sativum* L.). 20 (2): 81-85 (2011)
R K Singh, B K Dubey, S R Bhonde & R P Gupta
Correlation and path coefficient analysis were studied in 32 promising germplasm lines of garlic (*Allium sativum*) at Karnal (Haryana). Marketable yield was positively and significantly correlated with leaves plant^{-1}, bulb diameter, bulb size index, weight of 20 bulbs and cloves bulb^{-1} at genotypic and phenotypic levels and negatively

correlated with weight of 50 cloves at both levels. Gross yield was positively and significantly correlated with plant height, neck thickness and negatively correlated with clove diameter and clove size index at genotypic and phenotypic levels, indicating that selection based on these traits will help in increasing the yield. At genotypic level, traits such as leaves plant^{-1}, clove diameter, cloves bulb^{-1} and weight of 50 cloves showed a positive direct effect on yield. Clove diameter had maximum positive direct effect (0.744) followed by weight of 50 cloves (0.547), cloves bulb^{-1} (0.313) and leaves plant^{-1} (0.288). The highest negative direct effect was noted for clove size index (-0.874), followed by neck thickness (-0.341), weight of 20 bulbs (-0.264) and plant height (-0.057). The estimates of direct and indirect effect on yield were more pronounced in genotypic path than phenotypic path coefficient. The study thus indicated that weight of 20 bulbs, bulb size index, weight of 50 cloves and cloves bulb^{-1} produced higher positive direct effect on yield and should be given emphasis during selection for improvement of garlic.

Studies on variability and genetic divergence in elite lines of garlic (*Allium sativum* L.). 21 (2): 136-144 (2012)
R K Singh, B K Dubey & R P Gupta

The study was conducted during 2006-07 to 2007-08 at Karnal (Haryana), to identify suitable genotypes of garlic for cultivation. The results revealed that a wide range of variability was recorded for gross yield, marketable yield, weight of 50 cloves, number of cloves per bulb, plant height and clove size index. Genotypic and phenotypic coefficients of variations were high for weight of 50 cloves, number of cloves per bulbs, marketable yield and clove size index. Heritability in broad sense ranged from 43.9 to 95.0%. High value of heritability was recorded for plant height followed by cloves per bulb, leaves per plant, weight of 50 cloves, weight of 20 bulbs, marketable yield, bulb size index, and neck thickness. A high estimate of genetic advance was showed by cloves per bulb followed by weight of 50 cloves, marketable yield and weight of 20 bulbs. High values of heritability, GCV and genetic advance as per cent of mean were observed for cloves per bulb, weight of 50 cloves, marketable yield, and weight of 20 bulbs. The analysis of variance revealed significant divergence

among the thirty two garlic advance lines for different traits, indicating sufficient genetic diversity among the cultivars. The cluster VII had highest value of plant height (109.11 cm), gross yield (239.19 q ha^{-1}) and minimum *Stemphylium* intensity (2.08%). Cluster VI was promising for leaves per plant (9.51), bulb size index (15.88 cm^2), weight of 20 bulbs (0.696 g) and marketable yield (159.05 q ha^{-1}). Cluster X was observed to be promising for bulb diameter (4.63 cm), clove diameter (1.33 cm), clove size index (3.58 cm^2) and weight of 50 cloves (85.0 g). Therefore, it is suggested that selection of genotypes based upon the large cluster distances from all the clusters may lead to broad spectrum favourable genetic variability for bulb yield improvement.

Influence of vermicompost and sulphur on growth and yield of garlic (*Allium sativum* L.) under semi-arid climate. 22 (1): 20-23 (2013)

S Verma, M R Choudhary, B L Yadav & M L Jakhar

A field experiment was conducted during *rabi* season of 2010-2011 to find out the suitable dose of vermicompost (VC) and sulphur (S) to obtain high yield and net returns in garlic (*Allium sativum*). Sixteen treatment combinations with four levels of VC (control, 2.5, 5.0 and 7.5 t ha^{-1}) and four levels of S (control, 30, 60 and 90 kg ha^{-1}) were evaluated. Application of 7.5 t ha^{-1} VC and 90 kg ha^{-1} S individually produced maximum plant height, number of leaves per plant, chlorophyll content in leaves, fresh weight of leaves, neck thickness, number of cloves per bulb, weight of bulb, bulb diameter and bulb yield, whereas, the combined application of 5.0 t ha^{-1} VC along with 60 kg ha^{-1} S was found to be significantly superior with respect to weight of bulb (34.55 g), bulb yield (199.18 q ha^{-1}) and net returns of garlic.

Genetic diversity of pran (*Allium cepa* var. *prolliferum*) in Kashmir. 22 (2): 194-199 (2013)

J I Mir, N Ahmed, S Wajida, R Rizwan, K A Mir, M A Sheikh, M H Khan, Z F Shafia & U Noor

Ten pran genotypes were evaluated using RAPD markers to determine the genetic relationships among genotypes showing

morphological variations. Forty three decamer primers were used in this study. Genetic diversity in the genotypes studied was analyzed using several variability parameters. Genotypes were grouped into two main clusters based on Jaccard similarity coefficient. A dendrogram based on UPGMA analysis grouped the ten genotypes into two main clusters. Genotypes representing cluster-I are superior over genotypes in cluster-II with respect to yield attributes. Some genotypes did not show any similarity with either cluster, depicting their diverse nature. The grouping that was obtained with the RAPD analysis was at par with the morphological grouping based on yield attributes. The results of Principal Co-ordinate (PCO) analysis were comparable to the cluster analysis. Finally, the investigation of the genetic variation of pran with RAPD indicated that this marker is a suitable tool for assessing polymorphism and estimating the genetic similarity.

Management of purple blotch (*Alternaria porri*) disease of garlic (*Allium sativum* L.). 23 (1): 115-118 (2014)
R C Gupta, N K Pandey & R P Gupta

Field trials were conducted for the management of purple blotch disease of garlic during *Rabi* 2008-11. Six fungicides *viz*., tebuconazole @ 0.1%, azoxystrobin @ 0.1%, hexaconazole @ 0.1%, sectin (fenamidone + mancozeb) @ 0.2%, propineb @ 0.2% and mancozeb @ 0.25% and a control formed the treatments. The pooled data of three years indicated that purple blotch incidence ranged from 10% to 33.33% and intensity from 0.44% to 4.71%. Significantly lower incidence (21.11%) as well as intensity (1.78%) were recorded with spray of mancozeb @ 0.25% followed by tebuconazole @ 0.1% and azoxystrobin @ 0.1%. The highest gross yield (86.49 q ha^{-1}) and marketable yield (86.07 q ha^{-1}) were also recorded with spray of mancozeb @ 0.25% followed by azoxystrobin @ 0.1% and tebuconazole @ 0.1%. It was evident from the data that 1.73% intensity with 21.11% incidence of purple blotch at 45 days after planting (DAP) caused economic yield losses and it is considered as threshold value of purple blotch in garlic. The higher incidence (33.33%) and intensity (4.71%) of the disease as well as lowest gross yield (62.18 q ha^{-1}) and marketable yield (61.87 q ha^{-1}) were recorded

in untreated control. The present study revealed that contact fungicide mancozeb and systemic fungicides namely tebuconazole and azoxystrobin spray after 30 DAP and subsequent sprays at fortnightly intervals were ideal for the management of purple blotch disease and increased garlic yield.

Response of garlic to integrated nutrient management practices in a sodic soil of Uttar Pradesh, India. 24 (1): 33-36 (2015)
R C Nainwal, D Singh, R S Katiyar, L Sharma & S K Tewari
An investigation was carried out to study the combined effect of biofertilizers *viz*., phosphate solubilizing bacteria (PSB) and *Trichoderma* supplemented with FYM and chemical fertilizers on plant growth and bulb yield of garlic (*Allium sativum*) under degraded land condition. Significantly higher values of plant growth and yield parameters were obtained with the application of 100% recommended dose of NPK supplemented with FYM along with seed treatment with *Trichoderma* and PSB. Seed treatment with PSB was effective for all the parameters. However, PSB and *Trichoderma* were more effective when applied along with 100% NPK and FYM @ 20 t ha^{-1}. It can, therefore, be concluded that for sustainable production of garlic, application of recommended dose of inorganic fertilizer (NPK) supplemented with 20 t ha^{-1} of FYM coupled with inoculation of PSB and *Trichoderma* can enhance yield and profitability of garlic.

Effect of pre-harvest sprays of growth regulators and chemicals on storage life of garlic (*Allium sativum* L.). 24 (1): 47-50 (2015)
B R Kumara & S Patil
The effect of pre-harvest treatments involving combinations of different chemicals and growth regulators *viz*., maleic hydrazide (MH), MH + carbendazim, MH + dithane M-45, cycocel (CCC), CCC + carbendazim, CCC + dithane M-45, borax, borax + carbendazim on storage life of garlic was studied. Among the treatments, minimum physiological loss in weight (30.67%) was recorded with the pre-harvest spray of MH (2500 ppm) + carbendazim (1000 ppm), three weeks prior to harvest followed by MH (2500 ppm) three weeks prior to harvest. Application of CCC (1000) ppm + dithane M-45 (1000

ppm) showed maximum recovery of healthy cloves (41.04%) at the end of 180 days of storage.

Studies on the performance of some garlic genotypes (Allium sativum L.) under subtropical conditions of Himachal Pradesh. 24 (2): 106-111 (2015)

D Sharma, S K Banyal & K Jarial

Twenty six genotypes of garlic collected from commercial garlic growing pockets of Himachal Pradesh were evaluated for two consecutive years. Observations were recorded on various horticultural traits. The analysis of data revealed that the germplasm differed significantly for morphological attributes, yield and storage performance. The height of the plants varied from 39.70 cm to 76.71 cm. Length and width of the individual bulb ranged from 3.69 cm to 4.96 cm and 4.00 cm to 5.33 cm, respectively. The number of cloves/bulb and individual bulb weight also varied significantly. Per hectare yield of garlic genotypes varied from 0.92 t ha^{-1} to 2.60 t ha^{-1}, lowest yield was recorded in NG-12 and highest in Agrifound Parvati. NG-25 had minimum storage loss (5.79%) after three months of storage. Considering yield and other parameters, the lines NG-1, NG-11, NG-25 and Agrifound Parvati were found promising.

Genotype x environment interaction and stability analysis for yield and its attributes in garlic (*Allium sativum* L.). 25 (2): 175-181 (2016)

R K Singh, B K Dubey & R P Gupta

Genotype environment interaction is very important to the plant breeder in developing improved varieties. The present investigation was carried out at National Horticultural Research and Development Foundation, Karnal to identify the suitable and stable genotypes for *Rabi* season with higher yield and others horticultural attributes. It is concluded from present investigation that the genotypes G-384, G-324, G-378, G-376 and check Yamuna Safed-3 (G-282) performed well in favourable environment for gross as well as marketable yield and considered as most stable and responsive genotype as it possesses higher yield along with the bi=one or near one and non-significant S^2di values and hence could be recommended for adoptability. These

above genotypes can be further exploited in breeding programme for increasing the production of garlic.

Earliness, yield and bulb parameters of hardneck garlic (*Allium sativum* L.) as influenced by leaf knotting and scape removal in north Indian plains. 25 (2): 182-186 (2016)
N Garg & K S Sekhon
The present study was conducted during *Rabi* 2012-13 and 2013-14 to estimate the effect of scape removal, leaf knotting 4 weeks before harvest and leaf knotting 2 weeks before harvest on earliness, yield and bulb parameters of hardneck garlic cultivar 'PG-17' in north western plains of India. The removal of scapes has no effect on reduction in days to maturity, equatorial diameter of bulb, bulb weight, number of cloves per bulb and cured bulb yield as compared to control. The knotting of leaves 4 and 2 weeks before harvest advanced maturity by 12 and 6 days, respectively, over control. Leaf knotting 4 weeks before harvest significantly decreased equatorial diameter of bulb, bulb weight and cured bulb yield, whereas, leaf knotting 2 weeks before harvest caused non-significant reduction in equatorial diameter of bulb, bulb weight, number of cloves per bulb, 50-clove weight and cured bulb yield as compared to control. It is therefore advisable that the practice of leaf knotting may be omitted to save labour charges, whereas the practice of scape removal in hardneck garlic cultivars should be exercised only after studying the response of that particular cultivar to scape removal.

Root-knot nematode in garlic caused by *Meloidogyne* species : First record from Karnal district of Haryana state. 27 (2): 158-160 (2018)
R C Gupta & S Pandey
Garlic (*Allium sativum* L.) is an important spice crop cultivated all over the country during *Rabi* season except in Ooty hills of Tamil Nadu where it is grown during rainy season. Garlic suffers from various fungal, bacterial as well as viral diseases causing severe yield loss in different cultivated areas in the country. During a survey in garlic fields at village Muradgarh, Tahsil-Indri of Karnal district of Haryana in November, 2016, a number of small, medium and big root galls

mostly formed in root tips were observed in six-week-old garlic plants on local cultivar-Sankar. The infestation of root-knot nematode in garlic was severe and noticed in patches in the field. To the best of our knowledge, this is the first report of root-knot nematode affecting garlic from Karnal district of Haryana.

Morphological and biochemical properties of garlic (*Allium sativum* L.) collections. 30 (1): 81-89 (2021)

P C Tripathi, H M Jadhav, A A Qureshi, V Sankar, V Mahajan & K E Lawande

Garlic (*Allium sativum* L.) is an important constituent of many of traditional medicines. The nutrient composition and biochemical ingredients of garlic vary among varieties and locations. The current experiment was conducted with 35 genotypes of garlic to study variation in morphological and biochemical properties among these genotypes. The weight of bulbs ranged from 6.9 g to 22.6 g. Highest number of clove bulb^{-1} was recorded in collection-286 (44.6) followed by GG-2 (40.6). Clove weight was higher in collection-316 (1.41 g). The dry weight ranged from 28.6 per cent to 38.65 per cent. Highest total soluble solids were found in collection-79 (35.1°Brix). Potassium, iron and zinc content were higher in GG-2 (1.70%, 47 ppm and 19.2 ppm, respectively). Sulphur and copper content were higher in G-41. Manganese content ranged from 6.90 to 23.1 ppm. Highest anthocyanin pigment was found in the peel of cv. Godavari (5.35 mg). There was not much difference in anthocyanin content in pulp of purple and white colour varieties. Pyruvic acid content ranged from 20.9 μ mol ml^{-1} to 24.9 μ mol ml^{-1}. Over all cvs. G-50, G-41, collection-16 were found superior over others.

Studies on character association and path coefficient for quantitative traits to yield and its attributes in garlic. 31 (2): 187-193 (2022)

R K Singh, Mritunjay Rai, Mukul Kumar and S V Dwivedi

Association between characters and path analysis in seventeen genotypes/lines of garlic (*Allium sativum* L.) was studied at the Vegetable Research Farm, BUAT, Banda during 2019 and 2020. The pooled data of correlation studies, revealed that gross yield plot^{-1} had

positive and significant correlation with equatorial bulb diameter, weight of 20 bulbs and weight of 50 cloves at genotypic and phenotypic level respectively. This showed that improving these features could improve the crop's physiological capacity to mobilise and translocate photosynthates to economically valuable organs (the bulb), perhaps increasing bulb yield as seen in the study. Yield was significantly and negatively correlated with bulb shape index, number of cloves bulb^{-1}, and thrips plant^{-1} at genotypic level. The genotypic path coefficient analysis showed that equatorial bulb diameter and plant height had the highest positive direct effect on bulb yield. Weight of 20 bulbs and collar thickness had negative direct effect on bulb yield. Positive direct effect of equatorial bulb diameter and plant height indicated good scope for improvement in bulb yield by selecting genotypes having bigger bulb along with increased plant height.

ONION

Efficacy of sulphur on growth, yield and bulb quality in onion (*Allium cepa* L.). 25 (1): 60-64 (2016)
P Tripathy, B B Sahoo, D Patel & D K Dash

Sulphur has been recognised as an important nutrient for higher yield and quality of onion (*Allium cepa* L.) bulbs. Field experiment was conducted during *rabi*, 2010-11 to 2012-13 to study the efficacy of sulphur nutrition in onion. The treatment combination consisted of two sources of sulphur (gypsum and elemental sulphur) and four levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) in Factorial RBD with three replications. The pooled results over three years revealed significantly higher efficacy of gypsum over elemental sulphur for polar diameter (3.13 cm), bulb weight (48.37 g) and marketable bulb yield (101.39 q ha^{-1}). Similarly, irrespective of sources, sulphur @ 30 kg ha^{-1} recorded significantly higher plant height (55.78 cm), number of leaves plant^{-1} (11.08), bulb weight (67.34 g), bulb yield (marketable, 160.71 q ha^{-1} and total, 224.52 q ha^{-1}) and TSS (12.03%) with higher BC ratio (1.47) as well as better shelf life. Application of sulphur @ 30 kg ha^{-1} as gypsum may be recommended in onion crop for obtaining higher bulb yield with higher BC ratio and better keeping quality.

Marketing channels, dynamics and economic incentives for onion production in Ethiopia : A case study from Oromiya Regional State, Ethiopia. 26 (2): 101-113 (2017)

H Birhanu-Mentafa, G Diriba-Shiferaw & M Temesgen

This research was initiated to assess the market channels and develops value chain map and econometric model outputs for the onion in Ambo and Toke Kutaye districts of West Showa Zone, Oromiya Regional State, Ethiopia. Primary data were collected using interview guided questionnaires from 183 respondents of different actors in onion value chain and four focus group discussions of onion producers. Descriptive and inferential statistics; value chain mapping; marketing margin analysis; and econometrics analysis were used to analyze the data. About four marketing channels were identified in the study areas. The econometric result showed that education level of household, onion farming experience, number of oxen owned, land size used for onion farming, amount of fertilizer used, access to extension services and family size of house hold were variables those significantly influenced the marketable supply of onion at farmers level. Multiple linear regression model indicated that variables like age, farm experience, family size, selling price and improved inputs were significant in affecting onion marketable supply. Thus, to increase the onion productivity and maximize the profits of all value chain actors, it is important to integrate all concerned bodies of the onion value chains along with the supporting sectors.

Effect of drip irrigation on growth and yield of onion (*Allium cepa* L.). 27 (1): 32-37 (2018)

P Bhasker, R K Singh, R C Gupta, H P Sharma & P K Gupta

Drip irrigation is one of the essential, advanced and innovative irrigation methods over surface irrigation. In view of this, an experiment was conducted to study the efficiency of drip irrigation system over surface irrigation in onion during *Rabi* 2013-14 and 2014-15 and *Kharif* 2014 and 2015. The results revealed that drip irrigation system performed superior over surface irrigation system in terms of superior plant morphology, yield and quality of bulb. Drip irrigation recorded maximum plant height (66.37 cm and 61.88), number of leaves (9.23 and 8.00) and neck thickness (1.62 cm and

1.30 cm) in both *Rabi* and *Kharif* seasons. The bulb equatorial and polar diameter, higher gross yield as well as marketable yield obtained in drip irrigation system. In drip, gross yield and marketable yield increased 18.16% and 24.49%, respectively over surface irrigation method and better water use efficiency and also saved 29.36% and 27.12% water during *Rabi* and *Kharif* seasons, respectively.

Variability in yield parameters of onion genotypes in Bundelkhand region of Uttar Pradesh. 30 (2): 175-182 (2021)
R K Singh, Mritunjay Rai, A C Mishra & S V Dwivedi
Of the seventeen onion varieties evaluated for assessment of variability in mean performance, variances, heritability and genetic advance, (L-883 and Bhima Shweta) were most promising genotypes in respect of gross and marketable bulb yield, minimum number of bolters, rotten and multi-centred bulbs, bulb weight, equatorial bulb diameter, total soluble solids, number of leaves per plant and earliness in maturity. High values of genetic and phenotypic for gross and marketable bulb yield, average bulb weight, days to 70% neck fall and plant height indicated more opportunity of selection for these traits. High genetic advance as percentage of mean coupled with high heritability was observed for gross and marketable bulb yield and average bulb weight. Therefore, significant improvement could be expected through selection for these traits.

Effect of different crop management practices for better economic returns from *Kharif* onion. 31 (1): 75-85 (2022)
R L Bhardwaj, D K Parmar, Jaideep Meena & Latika Vyas
The present study was undertaken at the Agricultural Research Substation, Sumerpur-Pali to find out the effect of different fertilizer levels and crop geometry on *Kharif* onion (*Allium cepa* L.) production. The experiment was laid out in split plot design with NPKS levels as main plot and crop geometry as subplot with three replications. Spacious crop geometry with highest dose of fertilizer (15 cm x 15 cm + 140 N: 80 P: 80 K: 40 S kg ha^{-1}) produced maximum plant height (98.20 cm), leaves $plant^{-1}$ (20), bulb polar diameter (79.34 mm), equatorial diameter (85.10 mm), bulb weight (137.44 g) and harvest

index (51.30) with huge quantity of split/multiplier bulbs (6.54 t ha^{-1}). Marketable yield (43.71 t ha^{-1}), gross return (Rs. 5.25 lakhs), net return (Rs. 4.25 lakhs) and B:C ratio (4.25) were higher in the closer crop geometry (10 cm x 10 cm) with highest dose of fertilizer, whereas maximum biological yield (126.75 t ha^{-1}) and total bulb yield (61.60 t ha^{-1}) were reported in the closest spacing with highest dose of fertilizer (7.5 cm x 7.5 cm + 140 N: 80 P: 80 K: 40 S kg ha^{-1}), which also produced the highest quantity (28.69 t ha^{-1}) of unmarketable bulbs. It is concluded that for maximum production of better quality of *Kharif* onion bulb, the seedlings should be planted at 10 cm x 10 cm spacing with the highest level of fertilizer dose (140 N: 80 P: 80 K: 40 S kg ha^{-1}).

SAFFRON

Chromosome stability of callus cultures of *Crocus sativus*. 1 (2): 157-159 (1992)
K S Sarma, G A Ravishanker & L V Venkataraman
Two year-old callus cultures, raised from corm explants of *Crocus sativus*, showed an unusual chromosome number stability when maintained on MS medium supplemented with 2,4-D (2 mg/l) and kinetin (0.5 mg/l). Such studies may give an insight into the possible origin of somaclonal variants.

Temporal variation in saffron (*Crocus sativus* L.). 6 (1): 57 (1997)
S K Lattoo, R Sapru Dhar & A K Dhar
The study indicated that there were appreciable differences in the coefficient of variation for all the floral characters at different locations. However, the available variability is of no use for utilization in breeding because of triploidism. Saffron is basically a clonally propagated crop, hence its population is expected genetically to be similar, if not identical. The variability seems purely due to varied microclimates at different locations since there are not much marked climatic differences prevailing at these locations.

Variability in stigma length and apocarotenoid content in *Crocus sativus* L. selections of Kashmir. 21 (2): 169-173 (2012)
J I Mir, N Ahmed, A H Wafai & Raies A Qadri
Identification of high yielding selections using the existing gene pool of saffron shows promise and potential for improving the productivity of this crop. The present study was conducted at Srinagar (Jammu and Kashmir) with 31 saffron selections. Variations in respect to stigma length was observed. Apocarotenoid content was correlated with stigma length of saffron. Stigma size *vis-a-vis* quality evaluation confirmed that saffron of Kashmir is of intrinsically high quality with respect to colouring, aroma and taste. Variability in stigma characteristics observed in saffron selections can be utilized for saffron crop improvement.

Genetic diversity in saffron (*Crocus sativus* L.). 22 (2): 228-232 (2013)
H Qadri, S P Singh, F A Nehvi & A M Iqbal
Two hundred saffron genotypes collected from saffron growing areas of Kashmir subjected to Mahalanobis D^2 analysis revealed high amount of diversity. Out of 200 genotypes, 171 genotypes were grouped in cluster I, 9 in cluster V and 7 in cluster VI whereas the other 13 clusters were monogenotypic. Maximum intracluster distance (6.50) was recorded for cluster V accommodating SH-21, SH-123, SH-200, SH-51, SH-30, SH-81, SH-69, SH-03, SH-98 genotypes collected from Kushbal, Wuyan, Khrew, Kashbal, Wulan nadh, Kruncho, Dusso, Tang and Darbagh. Maximum intercluster distance (18.14) was recorded between cluster XV and XVI showing maximum genetic divergence among the population for SH-67 collected from Chandhara and SH-89 collected from Khrew area of Kashmir valley. Fresh stamen weight (20.86%) followed by plant height (17.77%), fresh flower weight (15.31%) and pistil length (9.98%) had contributed significantly towards diversity.

Quantitative and qualitative evaluation of saffron (*Crocus sativus* L.) for genetic variability, character association and path analysis. 32 (1): 66-74 (2023)

Mohammad Irfan, Uzma Rashid, Sabeena Naseer, M Ashraf Bhat, Z A Dar, M Altaf Wani, Shahid Rasool, M H Khan & Rayees A Wani

Different accessions of saffron were studied to analyze genetic diversity and heritable component of variation in yield and yield related traits. Dry pistil weight, fresh pistil weight, fresh flower weight corm^{-1} line^{-1}, number of flowers corm^{-1} line^{-1} and big corm index, all had high genotypic coefficient of variation, heritability and genetic advance. The traits included in the selection scheme and correlation among traits (floral and agronomic) are important as varieties must have high yield associated with exemplary quality parameters. At both phenotypic and genotypic levels, the association was found significant among the traits. Stigma length and fresh flower weight had strong direct effect with respect to dry pistil weight followed by number of flowers corm^{-1} line^{-1}, fresh pistil weight and big corm index. Therefore, these parameters can be taken as criteria for selection.

MINT

Effect of drying on flavour quality of Indian spearmint (*Mentha spicata* L.). 3 (2): 142-151 (1994)

B Raghavan, K O Abraham, L Jaganmohan Rao & M L Shankaranarayana

The essential oils obtained from Indian spearmint (*Mentha spicata* L.) subjected to different drying procedures were analysed employing gas chromatography and gas chromatography-mass spectrometry techniques. Forty three flavour components were identified, of which eucarvone, cubenol and α-cadinol are reported for the first time. The essential oil had a higher percentage of limonene (26.82%) compared to Italian and American oils. Carvone to limonene ratios were 2.2:1.0 and 2.3:1.0 in the oil from fresh and shade-dried spearmint, respectively. Blanching leaves prior to drying yielded products which were unattractive with respect to colour and appearance and were also bland and odourless due to loss of

volatile oil during drying. Storing fresh leaves for 12 h after spraying with water increased the volatile oil content by about 6%. Shade drying leaves resulted in a product with a good green colour and minimum loss of volatile oil compared to other drying methods.

Micropropagation and shoot regeneration from leaf and nodal explants of peppermint (*Mentha piperita* L.). 5 (2): 111-119 (1996)

Arun Kumar Kukreja

A two-step procedure for *in vitro* plant regeneration of a commercial cultivar (MP-l) of peppermint *Mentha piperita* is described. Nodal explants cultured on Murashige and Skoog medium supplemented with kinetin (2-3 mg l^{-1}) and indole-3-acetic acid (1 mg^{-1}) or 6-benzyl-aminopurine (2-3 mg^{-1}) and indole-3-acetic acid (0.25 mg l^{-1}) produced multiple axillary and adventitious shoots which rooted on Murashige and Skoog medium containing 0.25 mg^{-1} indole-3-acetic acid. *In vitro* plantlets also served as source for leaf explants. Morphogenetic responses of leaf explants were growth regulator dependent and exhibited a broad maxima over a range of growth regulator levels tested. Optimal regeneration of shoot buds was observed on Murashige and Skoog media supplemented with kinetin (3 mg^{-1}) and indole-3-acetic acid (1 mg^{-1}) or 6-benzylaminopurine (2-3 mg^{-1}) and indole-3-acetic acid (1 mg^{-1}) or a-naphthaleneacetic acid (0.25 mg^{-1}). These plantlets exhibited a high rate (98 per cent) of survival under glass house and field conditions.

Seasonal variation in population of phytonematodes associated with peppermint (*Mentha piperita* L.) and spearmint (*Mentha spicata* L.). 6 (2): 149-151 (1997)

Rakesh Pandey

Seasonal variations in the population of four phytonematodes namely, *Tylenchorhynchus vulgaris*, *Pratylenchus thornei*, *Meloidogyne* sp. and *Longidorus pisi* in the rhizosphere of peppermint (*Mentha piperita*) and spearmint (*M. spicata*) were studied at Lucknow, India. Population of *T. vulgaris* was maximum in March while it was least in May. Population of *P. thornei* was high in February and low

in June. Populations of *Meloidogyne* sp. and *L. pisi* were low throughout the year.

Effect of *Glomus mosseae* (Nicol. and Gerd.) Gerdemann and Trappe on root-knot disease of menthol mint (*Mentha arvensis* sub sp. *haplocalyx* Briquet) caused by *Meloidogyne incognita* (Kofoid and White) Chitwood. 9 (2): 129-132 (2000)
N Ratti, Abdul-Khaliq, P K Shukla, Akhtar Haseeb & K K Janardhanan
Glasshouse experiments conducted to find out the effect of the vesicular-arbuscular mycorrhizal fungus, *Glomus mosseae* on reproduction of root-knot nematode *Meloidogyne incognita* and growth and yield of menthol mint (*Mentha arvensis* sub sp. *haplocalyx*) indicated that *G. mosseae* was effective in reducing populations of *M. incognita* and increasing growth and biomass productivity of menthol mint. Maximum suppression in nematode populations was observed when *G. mosseae* was inoculated 15 days prior to inoculation of nematodes. Shoot length and oil yield of *G. mosseae* inoculated plants was significantly higher than uninoculated plants.

Screening mint (*Mentha* spp.) accessions against root-knot nematode infection. 10 (1): 55-56 (2001)
Rakesh Pandey & Nirmal Kumar Patra
Different mint (*Mentha* spp.) accessions were screened *in vitro* against root-knot nematode (*Meloidogyne incognita*). Root-knot infection was high in Siwalik and Himalaya and two *M. arvensis* cultivars, whereas moderate reaction was found in *M. arvensis* cultivars like SS-11, SS-27, Gomti, Kosi, *M. cardiaca*, and MAH-l. The lowest root-knot infection level was found on SS-4, SS-5, Kalka and SS-20. Moderate to high degree of resistance was recorded in SS-1-4, SS-2-7, SS-15, SS-26, SS-36, *M. pipertia* cv. Kukrail, *M. spicata* cv. Neera, *M. spicata* cv. Arka, *M. citrata* cv. Kiran, *M. gracilis* and *M. viridis*.

Comparative performance of menthol mint (*Mentha arvensis* L. f. *piperascens* Malinvaud ex Holmes) cultivars in semi-arid tropical climate. 11 (1): 67-69 (2002)

Kamla Singh, B R Rajeswara Rao, C P Singh, P N Kaul, Gopal R Mallavarapu & S Ramesh

Biomass yield, quantity and quality of essential oil of three menthol mint (*Mentha arvensis* f. *piperascens*) cultivars namely, Kosi, Shivalik and Himalaya grown in red sandy loam (alfisol) soil in semi-arid tropical climate of South India, were compared. Cultivars Kosi (15.9 tha^{-1}) and Shivalik (15.4 tha^{-1}) recorded similar biomass, which were superior to that of cultivar Himalaya (14.1 tha^{-1}). Cultivar Kosi produced the highest essential oil yield (140.5 $kgha^{-1}$), which was 16.6% and 31.1% higher than the yields of cultivars Shivalik (120.4 $kgha^{-1}$) and Himalaya (107.2 $kgha^{-1}$), respectively. All the three cultivars yielded good quality essential oils having menthol (77.2% in cv. Kosi; 76.3% in cv. Shivalik, 75.5% in cv. Himalaya) as their main constituent. Based on the result, cultivar Kosi is highly promising for commercial cultivation in red soils in the semi-arid tropical climate of South India.

Optimum planting time and row spacing for bergamot mint (*Mentha citrata* Ehrh.) var. 'Kiran' under sub-tropical plains of central Uttar Pradesh. 12 (2): 135-138 (2003)

Man Singh, V P Singh, Saudan Singh & P Saini

A field experiment was conducted at CIMAP farm, Lucknow during 1997-98 to find out the optimum planting time and row spacing for newly developed variety 'Kiran' of bergamot mint (*Mentha citrata* Ehrh.). The crop planted on 15 and 30 December produced higher total herb yield (356 and 349 q ha^{-1}) but maximum oil yield (167 kg ha^{-1}) was obtained from 30 January planting. Planting at a closer row spacing of 45 or 60 cm produced higher herb and oil yield than wider row spacing of 75 cm. Planting of bergamot mint in the end of January at a row spacing of 60 cm is suggested for maximum oil production from crop grown for two harvests. However, for a single harvest, planting in mid-February is suggested to enable the farmers to grow bergamot mint in rotation with winter season crops such as potato,

mustard and vegetables and also rainy season crops after the harvest of bergamot mint.

Effect of zinc and iron on growth, oil yield and quality of Japanese mint (*Mentha arvensis* L.) in sandy loam soil. 13 (1): 58-60 (2004)

K Singh, D V Singh, P P Singh, S U Beg & D Kumar

The results of a field experiment conducted at Lucknow (Uttar Pradesh), to study the effect of different levels of zinc (Zn) (0, 7.5, 15.0 and 22.5 kg ha^{-1}) and iron (Fe) (0, 10.0, 20.0 and 30.0 kg ha^{-1}) on Japanese mint (*Mentha arvensis*) revealed that fresh herbage, essential oil yield and growth parameters (plant height and leaf area index) increased significantly over control with application of Zn @ 7.5 kg ha^{-1} and Fe @ 10.0 kg ha^{-1}. Further increase in their doses did not improve the herbage and oil yield. Essential oil concentration in green herbage and its quality of essential oil with respect to major chemical constituents of oil namely, menthol, menthone and menthyl acetate, did not change with application of Zn and Fe.

A comparative study on direct planted and transplanted menthol mint (*Mentha arvensis* L.) under integrated nutrient management. 13 (2): 102-109 (2004)

Sukhmal Chand, M Anwar, Kambod Singh & D D Patra

An experiment was conducted at Lucknow (Uttar Pradesh) to assess crop productivity and economics of direct planted and transplanted menthol mint (*Mentha arvensis*) in sandy loam soil, under integrated nutrient management. The treatments consisted of five different combinations of farmyard manure (FYM) and inorganic fertilizers (NPK). Herb and essential oil yield was maximum with application of 133:40:40 kg NPK ha^{-1} and 6.7 t FYM ha^{-1} in both the methods of planting. However, the crop established with direct planting of suckers was more profitable than the transplanted crop. Net returns were 269% and 213% higher over control, with combined application of 133:40:40 kg NPK ha^{-1} and 6.7 t FYM ha^{-1} in direct and transplanted crop, respectively, during the first year of experimentation and 305% and 232%, respectively, during the second year. Dry matter production and NPK uptake were also maximum in the same

treatment in both the methods of planting. Maximum N and P uptake was recorded in sole application of inorganic fertilizers (200:60:60 kg NPK ha^{-1}) and maximum K uptake was observed under application of 100:30:30 kg NPK ha^{-1} and 10 t FYM ha^{-1} in direct planted crop during the first year. Postharvest soil characteristics like organic carbon, available NPK, Fe and Zn were higher during the second year, while a reverse trend was observed for soil pH.

Intercropping of menthol mint (*Mentha arvensis* L.) and spearmint (*Mentha spicata* L.) with sugarcane (*Saccharum officinarum* L.). 13 (2): 110-116 (2004)
S K Kothari & U B Singh

Field experiments were conducted at Lucknow (Uttar Pradesh), to study the effect of two sugarcane (*Saccharum officinarum*) cultivars namely, Co-S 767 (early, profuse tillering) and Co-Lk 8001 (late, shy tillering) and two planting geometries namely, 90 cm interval regular rows and 75 cm (row-to-row distance within the pair) x 120 cm (distance between two pairs of rows) paired rows for maximizing productivity, land use efficiency and income benefits through raising of menthol mint (*Mentha arvensis*) or spearmint (*Mentha spicata*) as intercrops in main as well as ratoon crop of sugarcane. As a sole crop, the two sugarcane cultivars were equally productive during the main crop cycle but during the ratoon crop cycle cv. Co-S 767 yielded 15.3% more cane than cv. Co-Lk 8001. Sugarcane cv. Co-S 767 in paired row planting showed no reduction in cane yield by mint intercropping compared to 16.2% to 28.1% reduction in regular row planting during both main and ratoon crop cycles. Sugarcane cv. Co-Lk 8001, however, did not suffer yield reduction by mint intercropping, irrespective of methods of sugarcane planting and crop cycles. However, menthol mint and spearmint suffered yield reduction (52% to 75%) as intercrops compared to their respective sole crop yields. In general, mint oil yield reductions were more during the ratoon crop cycle and when the companion crop was cv. Co-S 767. Mint intercropping with sugarcane cv. Co-Lk 8001 significantly improved land use efficiency (23% to 35%), gross (29% to 46%) and net returns (90% to 137%) and benefit:cost ratio (44% to 63%). Interplanting spearmint with sugarcane cv. Co-Lk 8001 resulted in maximum profits.

Analysis of genetic divergence in menthol mint (*Mentha arvensis* L.). 15 (2): 136-138 (2006)
S P Singh, A K Singh & H P Singh
Sixteen genotypes of menthol mint (*Mentha arvensis*) were evaluated for five quantitative traits namely, plant height, number of internodes, length of internodes, leaf: stem ratio and oil content at Pantnagar (Uttaranchal). These genotypes were grouped into five clusters on the basis of Mahalanobis D^2 analysis. The characters namely, length of internode and number of internodes had maximum contribution towards genetic divergence. The mean performance of the genotypes in each cluster and their D^2 values revealed that genotypes can be selected to obtain superior half-sib progenies.

Intercropping Japanese mint (*Mentha arvensis* L.) with maize, oilseed rape and onion during *rabi* season. 16 (1): 27-30 (2007)
B S Gill, G S Gill & A Salaria
A study was conducted at Ludhiana (Punjab) during *rabi* season to evaluate the performance of Japanese mint (*Mentha arvensis*) as an intercrop with maize (*Zea mays*), oilseed rape (*Brassica napus*) and onion (*Allium cepa*). The fresh herb yield was highest (204.3 q ha^{-1}) in sole Japanese mint treatment which was statistically on par with Japanese mint + one row of onion (192.4 q ha^{-1}). Oil yield was highest in sole Japanese mint (163.1 l ha^{-1}). Japanese mint equivalent oil yield was highest in Japanese mint + one row of onion (273.0 l ha^{-1}) which was on par with Japanese mint + two rows of onion (265.6 l ha^{-1}). The gross returns were also highest in Japanese mint + one row of onion (Rs. 65,520 ha^{-1}).

LEMONGRASS

Genetic variability and character association in lemongrass (*Cymbopogon flexuosus* L. Stapf) 14 (2): 155-157 (2005)
S P Singh, H P Singh, A K Singh & R K Tiwari
The variability and association of genetic parameters of nine genotypes of lemongrass (*Cymbopogon flexuosus*) was studied at Lucknow (Uttar Pradesh). The genetic differences were highly significant for oil, citral, geraniol and geranyl acetate contents and

herb and oil yield. High heritability estimates in broad sense were observed for all the characters. High heritability with low genetic advance recorded for oil and geranyl acetate contents indicated that these characters are under non-additive gene action. Oil yield was positively and significantly associated with herb yield and oil content. Maximum direct effect of herb yield on oil content and oil yield was also observed.

Effect of amount and time of potassium application on herbage yield, oil yield, oil content and quality of lemongrass (*Cymbopogon flexuosus*) under semi-arid tropical conditions. 23 (2): 272-275 (2014)

M Singh, N Guleria & H P Singh

A field experiment on lemongrass (*Cymbopogon flexuosus*) comprising 12 treatments of four levels of K_2O (0, 40, 80 and 120 kg ha^{-1} $year^{-1}$) and three time of applications (full basal at the time of planting, ½ basal + ½ after six months and 1/3rd basal +1/3rd after six months and 1/3rd after first harvest) were tested during 2006-2008. Results showed that application of 40 kg K_2O ha^{-1} $year^{-1}$ in three splits i.e. 1/3rd basal +1/3rd after six months and 1/3rd after first harvest produced maximum herbage and oil yield which was at par with 80 kg K_2O ha^{-1} $year^{-1}$ applied as a basal.

Efficacy of bioinoculants on biomass, nutritional status and yield of lemon grass, *Cymbopogon citratus* (DC.) Stapf. 29 (1): 59-66 (2020)

A Kumar, A Gupta, A Aggarwal & V Bhargav

In the present investigation, different bioinoculants were analysed for their efficacy as bio-fertilizer for lemongrass (*Cymbopogon citratus* (DC.) Stapf.) under controlled conditions. Bioinoculants including dominant arbuscular mycorrhizal fungi (*Glomus mosseae* and *Acaulospora laevis*) and phosphate solubilizing bacteria (*Pseudomonas fluorescens*) were used in the experiment. The effects of these bioinoculants applied alone or in combinations were assessed on one month old saplings of *C. citratus*. The results showed that application of bio-inoculants significantly influenced growth, biomass production, biochemical properties and yield parameters. A consortium of *G.*

mosseae, *A. laevis* and *P. fluorescens* showed best results for plant height, root length and biomass. Mycorrhization status was highest in the consortium treatment. The biochemical and yield (biomass) parameters were also found to be better with the application of consortium.

VETIVER

Effect of sodic water irrigation on yield and cation composition of vetiver (*Vetiveria zizanioides* (L.) Nash.). 8 (1): 89-92 (1999)

Arun Prasad, Dinesh Kumar & D V Singh

The effect of residual sodium carbonate in irrigation water on the yield and cation composition of vetiver (*Vetiveria zizanioides*) was studied in open bottom reinforced concrete cemented cylindrical barrels embedded in the field at Lucknow, India. While shoot and root yields of vetiver were not significantly affected with residual sodium carbonate in irrigation water, oil yield significantly decreased at the residual sodium carbonate concentration of 8 mel^{-1} and above as compared to control (tube well water). The concentration of sodium was about 10 times higher in the root than in shoot tissues. The great ability of vetiver to limit sodium entry in shoot tissues and maintain sufficient potassium and calcium concentration at high residual sodium carbonate concentration indicate that it is a tolerant to sodic stress.

Genetic variability and association analysis for yield and yield components in indigenous and exotic collections of vetiver (*Vetiveria zizanioides* (L.) Nash). 9 (2): 133-136 (2000)

R K Lal

The variability in genetic parameters and their influence on growth and yield of vetiver (*Vetiveria zizanioides*) was studied in 45 indigenous and exotic collections. Considerable variability in morpho-metric traits was recorded in these collections. Strongly positive and significant correlations were found between plant height and root length and oil yield; root length and oil content; fresh root yield and dry root yield and oil yield; dry root yield and

oil yield, and oil content and oil yield. Positive and significant associations were also observed between plant height and root width and fresh root yield; root length and root width. These traits may form a good selection criteria for improvement of essential oil yield in vetiver.

Planting methods, subsurface drip fertigation and bioinoculants on growth and productivity of vetiver [*Vetiveria zizanioides* (L.) Nash]. 23 (2): 276-279 (2014)
G J Shimi & A S Anilkumar
A field experiment was conducted to study the effect of three planting methods, (planting in coconut husk mulched trenches, planting in coconut husk lined trenches and planting on the ridges), two levels of fertigation (subsurface drip fertigation and without fertigation) and two levels of bioinoculants (combined application of bioinoculants and without bioinoculants) on growth and productivity of vetiver. The study revealed that planting vetiver slips in coconut husk lined trenches could considerably increase vegetative growth, root yield, net returns and B:C ratio. Subsurface drip fertigation and combined application of bioinoculants with *Azospirillum*, Fluorescent pseudomonads and AM fungi showed positive effect on growth characters and root yield. However, subsurface drip fertigation was not effective in increasing net income.

PATCHOULI

Effect of varieties and spacings on growth, yield and quality of patchouli (*Pogostemon patchouli* Pellet.). 12 (1): 43-46 (2003)
K M Ramachandra, M Vasundhara, A A Farooqi & K N Srinivasappa
Two varieties of patchouli (*Pogostemon patchouli* Pellet.) were evaluated at different plant densities. The experiment consisted of eight treatments comprising the varieties Johore and Java and four spacings (60 x 60, 60 x 45, 45 x 45 and 45 x 30 cm). The results revealed significant differences in performances of varieties at different spacings. Java variety was more robust and yielded higher dry herbage compared to Johore. However Johore yielded more oil

content (2.7%) and higher patchouli alcohol (44.7%) as compared to Java (1.4% and 34.5%, respectively). Among the different spacings, Java recorded higher cumulative dry herbage (4.21 t ha^{-1}) and oil yield (60.65 l ha^{-1}) under 60 x 45 cm spacing, whereas 45 x 45 cm spacing was found to be the best for Johore, recording more cumulative dry herbage (3.15 t ha^{-1}) and oil yield (86.52 l ha^{-1}).

Influence of nitrogen and nitrogen carrier on herbage, oil yield and nitrogen uptake of patchouli [*Pogostemon cablin* (Blanco) Benth.] in semi-arid tropical condition. 16 (2): 106-110 (2007)
M Singh, R S Ganesha Rao & S Ramesh
A field experiment was conducted at Bangalore (Karnataka) in a semi-arid tropical climate of South India to study the influence of two nitrogen levels (100 and 200 kg N ha^{-1}) and three nitrogen carriers (prilled urea, ammonium sulphate and dicyandiamide (DCD)-coated urea) on herbage, oil yield, nitrogen uptake and oil quality of patchouli [*Pogostemon cablin* (Blanco.) Benth.] grown on red sandy loam soil. Nitrogen @ 200 kg ha^{-1} and DCD-coated urea produced maximum herbage, oil yield, nitrogen uptake and benefit:cost ratio. The oil content varied from 2.48% to 2.60% and was not influenced by nitrogen level and carrier.

Influence of spacing and intercropping on biomass and essential oil yield of patchouli [*Pogostemon cablin* (Blanco) Benth.]. 17 (3): 235-239 (2008)
Munnu Singh
A field experiment was carried out in a semi-arid tropical climate at Bangalore (Karnataka) to investigate the influence of spacing (60 cm x 45 cm and 75 cm x 45 cm) and intercropping systems (patchouli sole crop, patchouli + blackgram, patchouli + soybean, patchouli + French bean and patchouli + lady's finger) on the biomass and essential oil yield and oil quality of patchouli (*Pogostemon cablin* (cv. Johore). The spacing of 60 cm x 45 cm was superior to 75 cm x 45 cm and produced 11.6 t ha^{-1} total biomass yield (total of two harvests; 12.1% higher than that of 75 cm x 45 cm spacing) and 88.9 kg ha^{-1} total essential oil yield (10.9% greater than that of 75 cm x 45 cm). Intercropping with legumes and vegetables did not affect total

biomass yield and total essential oil yield of patchouli and yielded 0.40, 0.35, 5.40 and 4.50 t ha^{-1} over and above that of patchouli sole crop. Quality of oil was not influenced by plant spacing and intercropping systems. Maximum gross return was obtained with patchouli + French bean (Rs. 1,66,470) followed by patchouli + lady's finger (Rs. 1,51,770).

Effect of organic and inorganic fertilizers on growth, yield and nutrient uptake of patchouli [*Pogostemon cablin* (Blanco) Benth.] in a semi-arid tropical climate. 20 (1): 48-51 (2011)
Munnu Singh
A field experiment was conducted for two years at Bangalore, to study the influence of organic (vermicompost) and inorganic fertilizers (NPK) on growth, yield and nutrient uptake of patchouli (*Pogostemon cablin*) in a semi-arid tropical climate. The results revealed that application of vermicompost (5 t ha^{-1}) + 50% NPK (100: 25: 25 kg ha^{-1}) produced significantly higher herbage and oil yield (13.98 t ha^{-1} and 83.4 kg ha^{-1}), respectively, which was on par with recommended dose of NPK (200: 50: 50 kg ha^{-1}). Application of vermicompost (5 t ha^{-1}) + 50% NPK (100: 25: 25 kg ha^{-1}) increased the nitrogen, phosphorus and potassium uptake, respectively, which was at par with recommended dose of NPK (200: 50: 50 kg ha^{-1}). Oil content was not influenced by organic and inorganic fertilizers.

Effect of cultivars and fertilizer levels on growth, yield and quality of patchouli [*Pogostemon cablin* (Blanco) Benth.] under shaded condition. 21 (2): 174-177 (2012)
Munnu Singh & Neha Guleria
A field experiment was conducted at Bengaluru (Karnataka) to study the influence of culivars (Johore and CIM-Shreshtha) and three fertilizer levels [Control (no fertilizers); recommended NPK (200:50:50 kg ha^{-1}) and vermicompost 10 t ha^{-1} + 50% recommended NPK (100:25:25 kg ha^{-1})] on growth, herbage and oil yield of patchouli under shaded condition. Results showed that among the cultivars, CIM-Shreshtha recorded significantly higher plant height and plant spread than Johore. CIM-Shreshtha produced 29.25% and 43.28% higher herbage and oil yield compared to Johore. The application of

recommended NPK (200:50:50 kg ha^{-1}) produced maximum herbage and oil yield compared with control and was at par with vermicompost 10 t ha^{-1} + 50% recommended NPK (100:25:25 kg ha^{-1}). Oil quality was not influenced by cultivar and fertilizer levels.

Effect of potassium on growth and yield of patchouli [*Pogostemon cablin* (Blanco) Benth.]. 23 (1): 76-79 (2014)
M Singh
A field experiment was conducted for two years to study the influence of amount and method of potassium (K) application on growth, herbage yield, oil yield and potassium uptake of patchouli in a semi-arid tropical climate. The results revealed that application of 41.5 kg K ha^{-1} produced significantly higher plant height, plant spread, herbage and oil yield over control (no fertilizer). The increase in herbage yield, oil yield and K uptake was 118.8%, 52.8% and 18.8% higher, respectively over control. Application of potassium in two splits (½ basal + ½ after 60 days) also significantly increased plant height, plant spread, and increased the herbage yield, oil yield and K uptake by 32.2%, 37.9% and 33.2%, respectively over basal application. Oil content was not influenced by amount and method of K application.

Influence of age of rooted cutting, nitrogen and stage of harvest on growth, yield and quality of patchouli [*Pogostemon cablin* (Blanco) Benth.]. 23 (1): 80-85 (2014)
M Singh & K V N S Srinivas
Field experiments were conducted to study the influence of age of rooted cuttings at the time of planting (30, 40, 50, 60, 70, 80 and 90 days), N levels (0, 50 and 100 kg ha^{-1}) and stage of harvest (once in 4, 5 and 6 months) on yield and oil quality of patchouli [*Pogostemon cablin* (Blanco) Benth.] under semi-arid tropical climate. The results indicated that planting 30-day-old rooted cuttings produced higher plant height, plant canopy and oil yield compared with other treatments. Similarly, application of 100 kg N ha^{-1} and stage of harvest after six months of planting produced maximum herbage yield, oil yield and oil content compared to other treatments. The highest net return (Rs. 59,550 ha^{-1}) and B:C ratio (1.168) were recorded with the application of 100 kg N ha^{-1} and stage of harvest once in six months.

Oil quality was not influenced by age of the rooted cuttings and N level.

GALANGAL

Bacterial wilt of *Kaempferia galanga* L. caused by *Pseudomonas solanacearum* (Smith) Smith. 4 (2): 159 (1995)
G N Dake & P S Manoj
Pseudomonas solanacearum is reported for the first time causing bacterial wilt of *Kaempferia* (*Kaempferia galanga*) from Kerala, India.

Micropropagation of *Kaempferia* spp. (*K. galanga* L. and *K. rotunda* L.). 6 (2): 129-135 (1997)
S P Geetha, C Manjula, C Z John, D Minoo, K Nirmal Babu & P N Ravindran
Protocols were standardised for micropropagation of *Kaempferia galanga* and *K. rotunda*. Young sprouting buds of both the species could be established in Murashige and Skoog basal medium supplemented with 0.5 mg l^{-1} kinetin and 1.5% sucrose solidified with 0.7% agar. The buds produced multiple shoots and well developed roots in Murashige and Skoog medium supplemented with 0.5 mg l^{-1} α-naphthaleneacetic acid and 1.0 mg l^{-1} 6-benzylaminopurine. A multiplication ratio of 1:10 and 1:6 with an average of 7 and 5 roots per shoot was obtained in *K. galanga* and *K. rotunda*, respectively. The micropropagated plants were successfully planted out in pots with over 90 per cent survival. The morphological characters and yield of these two species for three crop seasons were also studied.

Influence of planting material, plant population and organic manures on galangal (*Kaempferia galanga* L.) grown as intercrop in coconut (*Cocos nucifera* L.) garden. 8 (1): 35-40 (1999)
H P Maheswarappa, H V Nanjappa & M R Hegde
Field experiments conducted at Kasaragod, India to study the influence of planting material, plant population and organic manures on galangal (*Kaempferia galanga*) grown as intercrop in

coconut (*Cocos nucifera*) garden revealed that when mother rhizome was used as planting material significantly higher rhizome yield was achieved compared to finger rhizome. Plant population did not influence yield. Farm yard manure and major nutrient combinations recorded significantly higher yield compared to farm yard manure, vermicompost, composted coir pith and major nutrients applied alone.

Nutrient content and uptake by galangal (*Kaempferia galanga* L.) as influenced by agronomic practices as intercrop in coconut (*Cocos nucifera* L.) garden. 9 (1): 65-68 (2000)
H P Maheswarappa, H V Nanjappa, M R Hegde & C C Biddappa
Field experiments conducted at Kasaragod, India, to study the influence of agronomic practices on galangal (*Kaempferia galanga*) grown as intercrop in coconut (*Cocos nucifera*) garden revealed that nutrient content did not differ significantly due to different types of planting material or plant population levels. Farm yard manure alone, vermicompost alone and farm yard manure and major nutrient combinations had higher nutrient contents. Nutrient uptake with mother rhizome treatment was significantly higher compared to finger rhizome. Population level of 5,00,000 plants per ha removed more nutrients. Farm yard manure alone, vermicompost application alone and farm yard manure and major nutrient combinations removed higher nutrients. Fresh rhizome yield was significantly higher with mother rhizome and 5,00,000 population level. Farm yard manure in combination with major nutrients recorded significantly higher fresh rhizome yield.

COLEUS

Monitoring of forskolin production from roots and callus by HPTLC in *Coleus forskohlii* Briq. 8 (2): 153-157 (1999)
S Malathy & J S Pai
High Performance Thin Layer Chromatography was a sensitive and accurate method for detection and estimation of forskolin in roots and by tissue culture of *Coleus forskohlii*. Maximum absorption was observed at 315 nm using fluorodensitometric analyis. Forskolin

production was observed in callus cultures from leaf, stem and root origin as well as roots of *in vitro* grown plants.

Response of *Coleus aromaticus* to *Glomus fasciculatum* and other beneficial soil microflora. 10 (2): 141-143 (2001)
N Earanna, R R Mallikarjuniah, D J Bagyaraj & C K Suresh
Stem cuttings of *Coleus aromaticus* were treated with vesicular arbuscular mycorrhiza (*Glomus fasciculatum*) and beneficial microorganisms *viz*., *Bacillus coagulans*, *Pseudomonas fluorescens*, *Azotobacter chroococcum* and *Trichoderma harzianum* either singly or in combination of organisms. The number of leaves and branches; total biomass, nitrogen and phosphorus contents were higher in plants treated with *G. fasciculatum* alone. Synergistic effect was noticed especially in plants treated with *G. fasciculatum* + *P. fluorescens*. Mycorrhizal colonization in roots was also maximum when VAM was applied alone.

ASHWAGANDHA

Optimum stage of harvest for extraction of total withanolides in aswagandh (*Withania somnifera* Dunal). 8 (1): 95-96 (1999)
D Muthumanickam & G Balakrishnamurthy
The various growth stages significantly influenced the total withanolides content in the plant. Six month old plants recorded the highest overall mean of total withanolides content of 0.61%. Among the different plant parts, roots registered the highest amount of withanolides (0.30%) followed by leaves (0.15%) and stems (0.08%). The interaction between growth stages and plant parts was also significant. In the second stage (harvesting the plant 6 months after sowing), the roots possessed the highest amount of withanolides (0.36%) and it was followed by harvesting roots after 7 months. The same trend was also observed with regard to stem and leaf portions of the plants.

Studies on nutritional requirement for aswagandh (*Withania somnifera* Dunal) in Shevroy hills of Tamil Nadu, India. 8 (2): 179-183 (1999)

D Muthumanickam & G Balakrishnamurthy

Nutritional trials were conducted at Yercaud (Tamil Nadu, India) with the objective of increasing root yield and to determine the optimum nutrition level in aswagandh (*Withania somnifera*). The results indicated that a dose of 40, 60, 20 kg N, P_2O_5 and K_2O/ha (entire dose of P_2O_5, K_2O and 50% N basal + 50% N top dressing) recorded the highest dry root yield of 770.37 kg ha^{-1}. There was also improvement in the length of roots, number of root primaries and total withanolides content due to the nutrient application.

Effect of different phosphorus sources and soil amendments on the yield and quality of aswagandh (*Withania somnifera* Dunal) under acid soils. 11 (2): 118-121 (2002)

D Muthumanickam, Murugesan & Sumaiyah

Trials were conducted in acid soil at Yercaud (Tamil Nadu, India) with the objective of identifying the ideal source of phosphorus and soil amendment in aswagandh (*Withania somnifera* Dunal) in acid soils. Application of 60 kg ha^{-1} P_2O_5 as rock phosphate along with dolomite (5.688 t ha^{-1}) for increasing the yield resulted in the highest dry root yield of 814.5 kg ha^{-1} in the present study. There was also an improvement in the total withanolides content due to the application of dolomite and rock phosphate.

Potential and economics of ashwagandha (*Withania somnifera* (Linn.) Dunal) in overlapping cropping system under rainfed conditions of sub-tropical North India. 12 (2): 101-106 (2003)

Saudan Singh, S P S Khanuja, Aparbal Singh, Man Singh & U B Singh

Field experiments were conducted at Central Institute of Medicinal and Aromatic Plants, Lucknow to find out production potential and economic returns of traditional monocropping systems *vis-a-vis* alternative cropping system. The cropping systems evaluated were: pearl millet (*Pennisetum glaucum*)-fallow, maize (*Zea mays*)-fallow and okra (*Ablmoschus esculentus*)-fallow (traditional monocropping

system) and medicinal plant, ashwagandha (*Withania somnifera*), at low (100 x 10^3 plants ha^{-1}) and high (200 x 10^3 plants ha^{-1}) population densities (LPD and BPD, respectively), as mono as well as overlap crop with pearl millet, maize or okra (alternate cropping systems). All the overlapping cropping systems recorded higher productivity in terms of pearl millet grain equivalent yield (PGEY) and economic returns over traditional cropping systems. Pearl millet-ashwagandha (at HPD) overlapping cropping system; recorded 6.8 to 176.7% higher PGRY over remaining traditional as well as alternate cropping systems; the minimum being over maize-aswagandha and maximum over maize-fallow. The corresponding increase in net economic returns was 22.4-278.7%. Ashwagandha at HPD of 200 x 10^3 plant ha^{-1} under monocropping yielded 53.8% and 66.7-73.3% higher roots than it was grown at LOP under monocropping and overlapping cropping systems, respectively. Also, ashwagandha at either of the population densities under monocropping system proved more economical than traditional monocropping systems. Better yield and economic returns make ashwagandha an ideal crop for moisture stress rainfed conditions. Overlapping cropping of ashwagandha is suggested as a way to improve the productivity and economic returns from resource constrained rainfed agriculture in sub-tropical North India.

BASIL

Variations in morphology, phenology and essential oil composition of sweet basil (*Ocimum basilicum* L.) germplasm accessions. 11 (1): 50-57 (2002)

Ajay Pratap Singh, Samresh Dwivedi, Sudhakar Bharati, Maneesha Singh, Vandana Singh, Archana Srivastava, A A Naqvi & Suman Preet Singh Khanuja

Morphology, phenology and essential oil composition variations were analysed in germplasm accessions of sweet basil (*Ocimum basilicum* L.), an important medicinal and aromatic crop. Significant variations were observed for morphological and essential oil traits. All the fourteen accessions studied could be characterised as ten morphotypes ObC-A through ObC-J. Chemotypic indexing resulted in

assigning three chemotypes namely, linalool, methyl chavicol and methyl cinnamate types on the basis of major oil component. Linalool chemotype could also be subgrouped into four subtypes as significant differences were observed in minor components too. Three phenological types were also defined based on genotype performance during different seasons.

Effect of nitrogen and irrigation regimes on the yield and quality of sweet basil (*Ocimum basilicum* L.). 11 (2): 151-154 (2002)
Munnu Singh

Field experiments were conducted at Bangalore, to study the effect of nitrogen and irrigation regimes on growth, herbage, yield and quality of oil of sweet basil (*Ocimum basilicum* L.). Application of nitrogen at 200 kg ha^{-1} significantly increased the plant height, plant spread, herbage and oil yield compared with control (no nitrogen). Irrigation at 0.75 IW:CPE ratio (irrigation water : cumulative pan evaporation) increased the plant spread, herbage and oil yield compared with that of 0.25 IW:CPE ratio. Oil content and quality were not influenced by nitrogen and irrigation regime. Water use efficiency (WUE) was maximum at 0.25 IW:CPE ratio (0.337 kg oil $ha^{-1}mm^{-1}$ water used) compared with 0.75 IW:CPE ratio (0.196 kg oil ha^{-1} mm^{-1} water used). Similarly nitrogen application increased the water use efficiency compared with that of control.

Effect of NPK fertilizers on growth, oil yield and quality of French basil (*Ocimum basilicum* L.). 13 (1): 52-54 (2004)
K Singh, P P Singh, S U Beg, D Kumar & D D Patra

A field trial was conducted at Lucknow (Uttar Pradesh), to study the effect of different levels of NPK on growth, oil yield and quality of methyl chavicol rich cultivar of French basil (*Ocimum basilicum*). Five levels of N, P_2O, and K_2O namely, control (no fertilizer), 37.5, 20.0 and 20.0 kg ha^{-1}, 56.25, 30.00 and 30.00 kg ha^{-1}, 75.0, 40.0 and 40.0 kg ha^{-1} and 93.5, 50.0 and 50.0 kg ha^{-1} were evaluated. The results indicated that application of N, P_2O, and K_2O @ 75.0, 40.0 and 40.0 kg ha^{-1} increased plant height, fresh herbage, dry matter and oil yield significantly over control. The oil content in fresh herbage and its quality were not influenced by fertilizer application.

Intercropping of Indian basil (*Ocimum basilicum* L.) for enhancing resource utilization efficiency of aromatic grasses. 13 (2): 97-101 (2004)

Saudan Singh, Aparbal Singh, U B Singh, D D Patra & S P S Khanuja

Field trials on intercropping of Indian basil (*Ocimum basilicum*) with perennial aromatic grasses such as palmarosa (*Cymbopogon martinii*), lemongrass (*Cymbopogon flexuosus*) and vetiver (*Vetiveria zizanioides*) were conducted at Lucknow (Uttar Pradesh). Indian basil was intercropped with aromatic grasses (spaced at 45 cm) during planting and establishment year of aromatic grasses. Intercropping with Indian basil did not affect the essential oil production of aromatic grasses; however oil yield of Indian basil were reduced by 60% and 24% with palmarosa and lemongrass, respectively, over monocropping. Intercropping however, improved the net economic returns of lemongrass, vetiver and palmarosa by 61% 140% and 65%, respectively, over their respective monocropping. Intercropping led to considerable improvement in land equivalent ratio (1.36-1.91), area time equivalent ratio (1.04-1.19), land use efficiency (120%-151%) and money equivalent ratio (1.37-3.01).

Nitrogen and potassium nutrition of French basil (*Ocimum basilicum* Linn.). 16 (2): 99-105 (2007)

E V S Prakasa Rao, K Puttanna, R S Ganesha Rao & S Ramesh

Studies were undertaken on red sandy loam soil (*Kandiustalf*) in a semi-arid tropical climate at Bangalore (Karnataka) to find out the effect of fertilizer application in influencing oil production, quality and soil fertility in French basil (*Ocimum basilicum*). The study showed that application of nitrogen (up to 100 kg ha^{-1}) increased herb and essential oil yields in the main crop, first ratoon and second crop while potassium application (up to 80 kg ha^{-1}) increased the yields in the second ratoon and second crop suggesting that soil potassium depletion occurred with time. Nitrogen application increased methyl chavicol (by 4.1%) and decreased linalool (by 14.2%) contents in basil oil. Yield increases were accompanied by higher removal of nitrogen, phosphorus and potassium from soil (by 247%, 23% and 94%, respectively) by the crop and lower amounts of exchangeable potassium (by 37.8 %) in soil. Due to the depletion of soil potassium,

interactions between nitrogen and potassium were significant in the second crop of basil. Application of 100 kg nitrogen ha^{-1} and 80 kg potassium ha^{-1} gave optimum yield and quality of oil.

Analysis of genetic divergence in basil (*Ocimum* spp.). 17 (3): 244-246 (2008)
Mayuri Sahu, A K Geda, Anjali Shrivastava & Prabha Nirmod
Analysis of 21 basil (*Ocimum* spp.) genotypes grown at Raipur (Chhattisgarh) revealed that a maximum of five genotypes were accommodated in clusters I and II followed by four genotypes in clusters III and V, and three genotypes in cluster IV. The intra-cluster distance between members of cluster IV was maximum followed by clusters I, II, III and V, suggesting that the genotypes in cluster IV were relatively more diverse.

Influence of organic and inorganic fertilizers on yield and quality of sweet basil (*Ocimum basilicum* L.). 27 (1): 38-44 (2018)
B Al-Mansour, D Kalaivanan, M A Suryanarayana, K Umesha & A K Nair
Field experiments were carried out during *Kharif* season of 2015 and 2016 to study the influence of FYM, inorganic fertilizers and bio-fertilizers on fresh herbage yield, quantity and quality of essential oil of sweet basil (*Ocimum basilicum*). Nine treatments with three replications were adopted in a randomized block design to find out the effect of different levels of N applied through FYM (100, 75 and 50% of the recommended N along with and without bio-fertilizers), recommended dose of NPK (160:80:80 kg ha^{-1}), recommended FYM (10 t ha^{-1}) + NPK (160:80:80 kg ha^{-1}) and control (recommended FYM (10 t ha^{-1}) on fresh herbage and oil yield, oil content and oil quality of sweet basil (*Ocimum basilicum* L.). Pooled results revealed that application of recommended FYM (10 t ha^{-1}) along with recommended NPK (160:80:80 kg ha^{-1}) recorded the highest fresh herbage yield (39.95 and 19.37 t ha^{-1}), essential oil content (0.48 and 0.45%) and essential oil yield (199.7 and 107.58 kg ha^{-1}) in the main crop and ratoon, respectively. With respect to oil quality, bio-fertilizer has a good impact on oil quality, that highest percentage of Methyl chavicol was recorded with application of recommended FYM (10 t

ha^{-1}) + recommended N through FYM along with bio-fertilizers in the main crop of 2016 (63.78%) and in the ratoon (59.39 and 59.67%) of 2015 and 2016, respectively.

MISCELLANEOUS CROPS

Micropropagation of *Clitoria ternatea* L. (Papilionaceae) through callus regeneration and shoot tip multiplication. 2 (1&2): 41-46 (1993)

K Pradip Kumar, E V Soniya, Beena Lawrence & G M Nair

Methods for rapid multiplication of *Clitoria ternatea* through callus regeneration and shoot tip cultures are described. Stem and leaf explants cultured on Gamborg's basal medium supplemented with 0.01-1 mg l^{-1} 2,4-dichlorophenoxy acetic acid in combination with 0.01-2 mg l^{-1} kinetin or 1-3 mg l^{-1} benzyl adenine alone formed callus. These calli on transfer to Gamborg's medium supplemented with 1-2 mg l^{-1} benzyl adenine and 2-3 mg l^{-1} indole-3-acetic acid or 3-4 mg l^{-1} indole-3-acetic acid alone developed shoot buds and the number of regenerated buds was maximum (8-10) with 2 mg l^{-1} benzyl adenine and indole-3-acetic acid containing medium. Callus retained the same morphogenic potential even after repeated subculturing. Multiple shoots were induced from the shoot tips cultured on Gamborg's medium containing 3-5 mg l^{-1} benzyl adenine, 1 mg l^{-1} benzyl adenine with 2 mg l^{-1} gibberellic acid. Shoots, developed from shoot tips, multiplied further by subculturing in the same medium or from callus, were rooted in Gamborg's medium containing 1-3 mg l^{-1} 1-naphthalene acetic acid. The regenerated plants were transferred initially to vermiculite and later grown to maturity in the green house in garden soil and sand (1:3).

***Hyptis suaveolens* (L.) Poit. (Lamiaceae) - A source of edible oil among tribals of Orissa, India. 2 (1&2): 75-76 (1993)**

R D Girach & Aminuddin

The tribal use of *Hyptis suaveolens* (Lamiaceae) as a source for edible oil purpose in cooking medium is reported for the first time from Gandhamardan hill areas of Bolangir district in Orissa, India.

Effect of spacings and nitrogen levels on herb and oil yield, oil concentration and composition in three selections of *Cymbopogon jwarancusa* (Jones) Schultz. 5 (2): 120-126 (1996)
A K Dhar, R Sapru Dhar, K Rekha & S Koul
The performance of three selections of *Cymbopogon jwarancusa* (SL-7822, SL-7869 and SL-7896) was studied under five spacings and two levels of nitrogen. Though herbage and oil yield was higher in 4.0/m^2 stand density (50 x 50 cm spacing), 1l.l/m^2 (30 x 30 cm spacing) stand density was preferred as the projected yield per ha was higher in the latter. Increase in nitrogen from 200 to 300 kg/ha did not result in higher herbage and oil concentration in the leaves. The composition of oil was also not affected by spacings or nitrogen levels.

***In vitro* propagation of liquorice (*Glycyrrhiza glabra* L.) through multiple shoot formation. 7 (1): 13-17 (1998)**
Arun Kumar Kukreja
In vitro plant regeneration of liquorice (*Glycyrrhiza glabra*) through multiple shoot formation from nodal explants is reported. Addition of kinetin (0.05 mg l^{-1}) and indole-3-acetic acid (1.0 mg l^{-1}) to Nitsch medium resulted in rapid elongation of axillary buds. Proliferation of multiple shoots was more effective in Murashige and Skoog medium containing benzylaminopurine (2 mg l^{-1}) and indole-3-acetic acid (1 mg l^{-1}). *In vitro* regenerated shoots were rooted on Murashige and Skoog medium supplemented with 1 mg l^{-1} indole-3-acetic acid and after acclimatization in the glasshouse were transferred to field with 95% survival.

Micropropagation of sweet marjoram (*Majorana hortensis* Moench). 7 (1): 47-49 (1998)
P V Iyer & J S Pai
Multiple shoots were obtained in sweet marjoram (*Majorana hortensis*) when nodal stem explants were cultured on Murashige and Skoog medium containing 2 mg l^{-1} 6-benzylaminopurine. Rooting of shoots was induced with 0.2 mg l^{-1} indolebutyric acid in the same medium.

Effect of nitrogen and weed control on growth and yield of Java citronella (*Cymbopogon winterianus* Jowitt). 7 (2): 95-101 (1998)
K Singh, V P Singh & D V Singh

Field experiments conducted at Lucknow, India on Java citronella (*Cymbopogon winterianus*) to study the effect of manual weeding (weed-free condition) and diuron spray (1.5 kg ai/ha) over weedy check (no weeding) alone and also in association with different levels of nitrogen on growth and yield revealed that fresh herbage yield in weed-free and diuron treated plots were 30 and 15% more over unweeded plots, respectively, Growth and yield parameters in weed-free and weedy plots significantly increased with increase in nitrogen up to 200 kg N/ha and up to 150 kg N/ha in diuron treated plots, The response equation showed that optimum nitrogen doses in first harvest year were 222.22, 168.18 and 126.32 in weed-free, weedy and diuron treated plots, respectively; in second harvest year the respective values were 176.67, 158.33 and 106.45, The net return at optimum level of nitrogen was maximum (Rs. 20,065) in weed-free plots followed by diuron (Rs. 18,120) treated plots in first harvest year, whereas in second harvest year, the respective values were Rs. 26,279 and Rs. 25,088, Weed-free plots produced maximum growth and herbage yield followed by diuron treated plots.

Correlation and path coefficient analysis in tuberose (*Polianthes tuberosa* L.). 7 (2): 149-153 (1998)
P Kannan, G V Rajalingam & K Haripriya

A study carried out at Tamil Nadu, India on the association of metric traits and floral concrete contents of nine ecotypes of tuberose (*Polianthes tuberosa*) revealed that yield components like length of scape, length of spike, diameter of flower, number of scapes per plant and number of flowers per spike exhibited significant positive association with yield. These components were also positively intercorrelated among themselves. Path coefficient analysis indicated that length of scape, length of spike, number of scapes per plant, number of flowers per spike, vase life, longevity and floral concrete recovery had direct positive effect on flower yield, while diameter of flower had negative direct effect. Length of scape and length of spike were the strongest forces influencing yield.

Micropropagation of curry leaf (*Murraya koenigii* L.). 8 (1): 77-79 (1999)

K Mary Mathew, Y S Rao, K Pradip Kumar, Sallykutty Joseph, R Lakshmanan & K J Madhusoodanan

Micropropagation of curry leaf (*Murraya koenigii*) was standardized using nodal segments from mature trees on Murashige and Skoog media supplemented with 6-benzylaminopurine, kinetin, α-naphthaleneacetic acid and indole-3-butyric acid as growth regulators. A multiplication ratio of 1:3 was observed over a 5 week culture period on media with benzylaminopurine (1.0 mg l^{-1}), kinetin (0.5 mg l^{-1}) and naphthaleneacetic acid (0.1 mg l^{-1}). The best response of 1-2 roots per shoot was obtained on medium containing naphthaleneacetic acid and indolebutyric acid (0.1 mg l^{-1} each).

***In vitro* propagation of lemon balm (*Melissa officinalis* L.) through nodal bud culture of adult plant. 8 (2): 171-177 (1999)**

A K Kukreja

A simple and efficient two step procedure for *in vitro* high frequency plant regeneration was developed for clonal propagation of lemon balm (*Melissa officinalis*) using nodal explants. Nitsch and Murashige and Skoog's medium supplemented with α-naphthalene acetic acid (1.0 mg l^{-1}) supported axillary shoot growth and induction of roots in cultured explants. Nitsch medium showed better morphogenetic response than Murashige and Skoog's medium. Murashige and Skoog's medium fortified with 2 mg l^{-1} of either 6-benzyl aminopurine or 6-methyl aminopurine induced rapid proliferation of shoots. Rooting of the differentiated shoots was readily achieved with auxins fortified to Nitsch medium. The plantlets exhibited 80-90% success in establishment under glasshouse conditions.

Pathogenicity of *Meloidogyne incognita* (Kofoid & White) Chitwood on *Matricaria chamomilla* L. 8 (2): 201-203 (1999)

Rakesh Pandey, H N Singh & S Kumar

Experiments conducted to ascertain the pathogenicity of *Meloidogyne incognita* and its effect on growth and flower yield of

Matricaria chamomilla under glasshouse conditions indicated that an increase in the initial inoculum level of *M. incognita* reduced fresh and dry root and shoot weight and flower yield with corresponding decrease in nematode multiplication rate and increase in root-knot indices.

In vitro regeneration of _Majorana hortensis_ Moench from callus and nodal stem segments. 9 (1): 47-50 (2000)
P V Iyer & J S Pai
Rapid multiplication of *Majorana hortensis* was achieved through plant regeneration from nodal stem explants and callus. Nodal stem explants cultured on Murashige and Skoog's medium supplemented with 2 mg/l benzylaminopurine and maltose as source of carbon, yielded up to 40 shoots. The shoots produced roots in the presence of 0.2 mg/l indole-3-butyric acid. Callus was induced in stem explants in medium containing 0.4 mg/l 2, 4-dichlorophenoxy acetic acid. This callus showed organogenesis in Murashige and Skoog's medium containing 3 mg/l benzylaminopurine and 0.2 mg/l indole-3-butyric acid.

Influence of variability and association on essential oil content of German chamomile (_Chamomilla recutita_ (L.) Rauschert). 9 (2): 123-128 (2000)
R K Lal, J R Sharma & S Sharma
The nature and extent of variability, association, co-heritability and path coefficients were studied for 8 economic traits in 48 accessions of German chamomile (*Chamomilla recutita*) assembled from India and abroad. The genotypic correlations were higher than phenotypic correlations for all the traits except dry flower yield, oil content and branches per plant. Fresh flower yield was significantly and positively correlated with branches per plant, dry flower yield, spread area and oil yield at both genotypic and phenotypic levels. Oil content and dry flower yield were also associated with oil yield. All the traits exhibited high heritability, the highest being spread area and lowest for oil content. The genetic advance over mean was the highest for oil yield and lowest for spread area. The highest direct contribution to essential oil yield was by fresh flower yield (0.335)

followed by oil content (0.286), plant height (0.144), dry flower yield (0.050) and spread area (0.013), respectively. Dry flower yield indirectly contributed maximum to essential oil yield. The correlations between plant height and oil content had the maximum co-heritability value (1.306) followed by days to flower (50%) with dry flower yield (1.186) and plant height (1.129). These traits may form a good selection criterion for improvement of essential oil yield in German chamomile.

Variability in ramba (*Pandanus amarylifolius* Roxb.) - A new leaf spice. 9 (2): 177 (2000)
R Richard Kennedy, K Nageswari & G Balakrishnamoorthy
Two accessions of ramba were collected from Devicode, Kanyakumari District (Pa 1) and Shevroys (Pa 2) and evaluated for their performance at Horticultural Research Station, Yercaud (Tamil Nadu, India). The growth attributes of the two accessions exhibited significant differences for plant height, plant spread, number of harvestable leaves, leaf length and leaf breadth. The accession Pa 1 exhibited significantly higher values for all the characters when compared to Pa 2.

Changes in $^{14}CO_2$ assimilate partitioning into primary photosynthetic metabolites in flowering and non-flowering rose (*Rosa damascena* Mill) plants. 10 (1): 25-31 (2001)
N K Srivastava, A Misra & S Sharma
Changes in $^{14}CO_2$ assimilation into primary photosynthetic metabolites in developing leaves of lowering and non-flowering plants of rose have been investigated. Total ^{14}C assimilated increased up to 4.5 h and then declined in flowering plants, while in non-flowering plants maximum assimilation was observed at 1.5 h and thereafter it steadily declined. First and second leaf (from apex) in flowering shoot assimilated maximum photosynthate which continued to increase with time, whereas second leaf of non-flowering plants assimilated maximum CO_2 which decreased with time. Maximum photosynthate translocation to flower occurred at 3 h after feeding. A significant portion of photosynthate remained untranslocated in stems of non-flowering plants. Within leaves, maximum metabolite

labelled was sugars in flowering shoot at 1.5 h, which declined later, whereas amino acids and organic acids level increased upto 4.5 h. Very little metabolite remained untranslocated in stem. In non-flowering plants, level of these metabolites decreased with time, however high level of metabolites remained in stem. Contrasting and reverse pattern of carbon assimilation was observed between flowering and non-flowering shoots. In non-lowering shoot, sugars and amino acids contents were significantly negatively correlated, whereas a significant positive correlation was observed in flowering shoot. The flowering and non-flowering shoots significantly differed in partitioning of primary photosynthetic metabolites between leaf, stem and flower.

Evaluation of safed musli (*Chlorophytum borivilianum* Santapau & Fernandes) germplasm. 10 (2): 147-149 (2001)
S K Kothari & K Singh
Safed musli (*Chlorophytum borivilianum* Santapau & Fernandes), an herbaceous plant belonging to the family liliaceae is mostly collected from wild sources as its tubers are in high demand in indigenous systems of medicine in the preparation of a aphrodesiac drug for curing general debility. Safed musli germplasm were evaluated for their performance. A large variability was observed in terms of morphological and yield attributing characters and tuber yield among the germplasm. CB/MS-6 gave highest number of leaves plant^{-1} (23.8), number of tubers plant^{-1} (10.2), tuber thickness (0.80 cm) and fresh (65.3 g plant^{-1}) and dry (8.5 g plant^{-1}) tuber yield. Further, two distinct plant types (prostrate or spreading and erect) were observed among these accessions. Observations on the crop grown in farmer's field in different locations revealed the feasibility of its cultivation in semi-arid areas of Andhra Pradesh, Madhya Pradesh and Maharashtra.

Effect of spacing and manuring on growth, yield and nutrient content of *Alpinia galanga* (L.) Willd. 11 (1): 22-25 (2002)
P P Joy, J Thomas, Samuel Mathew & Baby P Skaria
Experiment conducted at research farm of the Aromatic and Medicinal Plants Research Station, Odakkali during 1996-1999 to find out the

effect of different spacings and manuring on growth, yield and nitrogen, phosphours and potassium concentration in *Alpinia galanga* revealed that the optimum spacing for maximum rhizome and oil yields was 40 x 30 cm. Application of FYM at 20 t ha^{-1} $year^{-1}$ produced significantly higher rhizome yield, followed by NPK at 100:50:50 kg ha^{-1} $year^{-1}$. Oil recovery was unaffected by these treatments.

Genetic variability for clonal selection in Java citronella (*Cymbopogon winterianus* Jowitt.). 11 (1): 41-44 (2002)
R K Lal

Java citronella (*Cymbopogon winterianus* Jowitt.) grass is one of the important aromatic plants of South Asia. Its oil is used extensively as a source of important perfumery chemicals. The nature and amount of genetic variability and stability factor, among 34 diverse accessions of *Java citronella* assembled from different states of India and Sri Lanka were estimated based on 14 quantitative and qualitative traits. The heritability in broad sense (h^2 BS %) was generally high for all the traits (91.02-98.96%). However, it was medium for leaf length (71.40%) and plant height (71.61 %) and low for citronellal content (10.65%) and oil yield (40.57%). Generally clones were highly unstable for elemol content (SFi = 28.67) followed by herb yield (SFi = 14.67) , oil yield (SFi = 10.50), citronellal content (SFi = 8.18), citronellol content (SFi = 7.2), gerenyl acetate (SFi = 3.77), tillers $plant^{-1}$ (SFi = 3.47) and geraniol content (SPi = 3.07). However, leaf width (SFi = 1.68) and leaf length (SFi = 1.85) were found stable to some extent. The plant height (SFi = 2.31) followed by limonene content (SFi = 2.4), oil content (SFi = 2.6) and citronellyl acetate (SFi = 2.96) were moderately stable. Based on the magnitude of stability factors and different genetic parameters, clone Nos. 10, 20 and 3 for high biomass; 28, 30 and 2 for high oil and 1, 9 and 12 for high oil and citronellol content were identified for commercial exploitation.

Composition of the essential oils of *Origanum majorana* and *O. vulgare* subsp. *hirtum* growing wild in Turkey. 11 (1): 45-49 (2002)

M Özcan & J C Chalchat

The chemical composition of the essential oils isolated by hydrodistillation of the aerial parts of *Origanum majorana* L. and *O. vulgare* L. from Turkey has been examined by GC-MS. A total of 34 and 37 components were identified accounting for 97.80% and 98.61% of the oils of both *O. vulgare* and *O. majorana*, respectively. The oil of *O. majorana* contained carvacrol (43.12%), (E)-β-ocimene (13.03%), *p*-cymene (11.38%), linalool (10.07%) and thymol (4.46%) as main components. Major components of the *O. vulgare* oil were identified as carvacrol (48.38%), *p*-cymene (19.93%), γ-terpinene (16.29%), β-caryophyllene oxyde (1.92%), β-caryophyllene (1.16%), linalool (1.58%) and myrcene (1.32%). It is shown that carvacrol was the dominant constituent of both oils.

Variation in oil and its major constituents due to season and stage of the crop in Java citronella (*Cymbopogon winterianus* Jowitt.). 11 (2): 97-100 (2002)

T C Sarma

Variations in citronella oil and its major constituents due to seasonal changes and stage of the crop were studied for three years under the climatic conditions of Jorhat, Assam. Rainfall, temperature, sunshine and relative humidity have cumulative effect on the oil yield and its major constituents namely, citronellal, citronellol and geraniol. Post monsoon months were seemed to be favourable, contributing higher oil yield. Citronellal content was higher during September (44.3%) and October (45.7%). It was observed that light rainfall (100 to 200 mm), moderate temperature (20-30°C), sunshine hours of 5 to 6 hours and high humidity (90-95%) were the favourable meteorological, parameters for higher oil yield and citronellal content in citronella oil. Growing period or stage of crop growth also had profound effect on the oil yield and citronellal content. Older crop with highly matured leaves found to yield higher oil and less citronellal. Alcohol content in citronella oil was not affected by seasonal variation. However, total

alcohol percentage was found to reduce, while aldehyde percentage increased.

Influence of nitrogen, phosphorus and potassium levels on growth, seed yield and essential oil content in anise (*Pimpinella anisum* L.). 11 (2): 112-117 (2002)
Bhuvaneshwari, A A Farooqi, B S Sreeramu & K N Srinivasappa
A field experiment was conducted to study the influence of three levels, each of nitrogen (0, 40 and 80 kg ha^{-1}), phosphorus and potassium (each at 0, 30 and 60 kg ha^{-1}) on growth, seed yield and essential oil content in anise at Horticultural Research Station, University of Agricultural Sciences, Bangalore. The results of the study revealed significant differences among the treatments with respect to growth, seed yield and essential oil content. The interaction of nitrogen at 80 kg ha^{-1}, phosphorus and potassium each at 60 kg ha^{-1} was found to be significant, recording highest values for growth characters like plant height (62.47 cm), number of leaves (33.33) and total leaf area (653.27 cm^2) per plant and yield parameters such as number of fruits per umbel (595.17), size of the umbel (38.93 cm^2) and also seed yield (698 kg ha^{-1}) compared to control (189 kg ha^{-1}). This treatment also gave the highest essential oil yield of 24.41 kg ha^{-1}.

Genetic variability and associations in shankha pushpi (*Convolvulus microphyllus* Sieb. ex. Spreng). 12 (1): 67-71 (2003)
R K Lal
Nature and amount of genetic variability, co-heritability, path-coefficients and associations were studied on eight economic traits in 52 genetic stocks of Shankha pushpi assembled from different states of India. Genotypic correlation was larger than phenotypic correlation for most of the traits. Days to 50% flowering was significantly and positively correlated with length of main branch and herb yield (g $plot^{-1}$) at both genotypic and phenotypic levels but it was negatively correlated with leaf width at environmental level. Spread area and herb yield (g $plot^{-1}$) were also significant and positively associated at both genotypic and phenotypic levels but it was negatively associated with the main branch length at environmental level. Positive

association was also recorded between main branch length and leaf width at genotypic level only. Negative associations were observed between primary branches and leaf width, leaf length and herb yield (g plot^{-1}). All traits exhibited high heritability h^2 (BS) (96.34-99.24%) except leaf width (37.02%) and days to 50% flowering (71.96%). Genetic advance was high for only spread area and herb yield (g plot^{-1}). Highest direct contribution to herb yield was by days to 50% flowering (0.319) and spread area (0.245) followed by primary branches plant (0.052) and main branch length (0.033). Days to 50% flowering indirectly contributed maximum to herb yield by main branch length. The association between spread area and leaf width showed maximum co-heritability (1.135) followed by that between leaf length and leaf width (1.114) and primary branches plant^{-1} and leaf width (1.072) and hence these traits may form a good selection criteria for improvement of herb yield.

Compatibility of legumes, an aromatic crop and a cereal as intercrops in palmarosa (*Cymbopogon martinii* Stapf.). 12 (2): 190-193 (2003)

Munnu Singh

To utilize the crop growth resources (space, time, water and nutrient) more efficiently during the initial stage, a field experiment was conducted during 1999-2000 in the semi-arid tropical climate of Bangalore, India to explore the feasibility of intercropping (food legumes, aromatic crop and cereal) in palmarosa. The intercropping combination palmarosa + basil resulted in the maximum (17%) increase in land use efficiency followed by palmarosa + blackgram and palmarosa + soybean (16% each) and palmarosa + maize (5%). Palmarosa yield was not influenced by intercropping system. Maximum net return was obtained with palmarosa + basil (Rs. 83,635 ha^{-1}) followed by palmarosa + blackgram (Rs. 83,340 ha^{-1}) and palmarosa + maize was the least remunerative intercropping system (Rs. 68,960 ha^{-1}).

Biochemical changes in agarwood tree (*Aquilaria malaccensis* Lamk.) during pathogenesis. 13 (2): 87-91 (2004)
P Tamuli, P Boruah & R Samanta
Post-infection changes in sugars, ascorbic acid, phenols and protein of agarwood tree (*Aquilaria malaccensis*) were investigated after inoculation with fungi such as *Chaetomium globosum* and *Fusarium oxysporum*. In healthy trees, the biochemical constituents increased, whereas in infected trees they decreased after inoculation with fungi.

New basic chromosome number in *Chlorophytum borivilianum* Santapau and Fernandes. 13 (2): 121-123 (2004)
K A Geetha & Satyabrata Maiti
Cytological studies of *Chlorophytum borivilianum* revealed a new chromosome number, 2n=4x=28 and also the presence of polyploids (tetraploid and octoploid levels) in the population with a basic number of x=7.

Production potential of *Plumbago zeylanica* L. under different harvest schedules and crop geometry. 13 (2): 140-142 (2004)
P B Kanjilal, Jinu Devi, Rumi Kotoky & R S Singh
A field experiment on *Plumbago zeylanica* with three plant densities, namely, 4.9 m^2, 2.7 m^2 and 1.2 m^2 and three harvesting schedules, namely, after first year, second year and third year, was conducted during 1999-2001 at Jorhat (Assam). Plant density significantly influenced number of branches $plant^{-1}$, shoot and root biomass plant and total yield of roots ha^{-1}. Plant height was found to reduce with the age of the plant. The total dry root yield was maximum in the plant density 2.7 m^2 (5.2 t ha^{-1}). The yield attributing characters, namely, number of branches $plant^{-1}$ (25.6), shoot biomass $plant^{-1}$ (408.2 g), root biomass $plant^{-1}$ (607.4 g) and total root yield (7.1 t ha^{-1}) were maximum when harvested at third year. Maximum phenol, carbohydrate and protein contents were recorded in roots (5.06%, 31.70% and 13.04%, respectively) and leaves (3.40%, 10.60% and 7.84%, respectively) of plants harvested during the third year.

Correlation and path analysis in Indian mustard (*Brassica juncea* (L.) Czern & Coss) grown under rainfed condition. 14 (1): 56-60 (2005)

D K Kardam & V V Singh

The nature and magnitude of associations and path coefficients for 10 characters in 200 F_3 and F_4 progenies of Indian mustard (*Brassica juncea*) obtained from six crosses were studied at Jobner (Rajasthan). Phenotypic correlation coefficients were higher in magnitude compared to genotypic correlation coefficients for most of the traits. Seed yield plant^{-1} was significantly and positively correlated with plant height, primary branches plant^{-1}, number of siliquae plant^{-1}, number of seeds siliqua^{-1} and 1000-seed weight. Highest direct contribution to seed yield was by number of siliquae plant^{-1}, followed by primary branches plant^{-1}, 1000-seed weight, number of siliquae on main shoot and number of seeds siliqua^{-1}. Hence, these traits could form a good selection criteria for improvement of seed yield in Indian mustard.

Evaluation of leguminous vegetables as intercrops in pruned fields of jasmine (*Jasminum sambac* Ait.). 14 (1): 61-64 (2005)

M Lakshminarayanan, K Haripriya, K Manivannan & S Kamalakannan

Investigations on intercropping of leguminous vegetables in a pruned field of jasmine (*Jasminum sambac*) carried out in a farmer's field at Keezakundalapadi (Cuddalore District, Tamil Nadu), indicated that intercropping pruned jasmine with double rows of vegetable cowpea (*Vigna unguiculata*) fetched the highest equivalent yield of jasmine (5,393 kg ha^{-1}), land equivalent ratio (1.99), net returns (Rs. 1,44,113 ha^{-1}) and benefit-cost ratio (3:1).

Compatibility of aromatic crops as intercrops in maize (*Zea mays* L.) in semi-arid region of Karnataka, India. 14 (2): 158-161 (2005)

Munnu Singh

An experiment was carried out at Bangalore (Karnataka) to investigate the effect of methods of planting (solid row and paired row) and three cropping systems [maize + palmarosa (*Cymbopogon*

martinii), maize + South American marigold (*Tagetes minuta*) and maize + basil (*Ocimum basilicum*)] on growth and yield of maize (*Zea mays*). Grain yield of maize, harvest index and biomass were not affected by intercrop treatments. Land use efficiency in terms of Land Equivalent Ratio ranged between 1.11 to 1.20, the maximum being with maize paired row + palmarosa and maize paired row + South American marigold (20%). There was no effect of method of planting on yield of maize. Palmarosa, South American marigold and basil did not affect the yield of maize. Maximum net returns (Rs. 20,870 ha^{-1}) and benefit:cost ratio (2.26) was obtained with maize paired row + South American marigold.

Effect of nitrogen and phosphorus on seed yield and uptake of nutrients in musk mallow (*Abelmoschus moschatus* Medic.). 14 (2): 162-164 (2005)

S G Wankhade, P P Khode, M R Kale, S A Agashe & S S Wanjari

A field experiment conducted at Akola (Maharashtra) to study the effect of nitrogen and phosphorus on seed yield and uptake of nutrients in musk mallow (*Abelmoschus moschatus*) indicated that application of 75 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1} recorded significantly higher seed yield and nutrient (NPK) uptake. The maximum uptake of nitrogen was registered at 135 days after sowing and phosphorus and potassium uptake at 180 days after sowing.

Factors influencing technological gaps in adoption of mustard (*Brassica juncea* L.) production technology in arid zone of Rajasthan. 16 (1): 50-54 (2007)

Bhagwan Singh

A study was conducted in four districts of Rajasthan namely, Jodhpur, Pali, Bikaner and Jaisalmer, to identify the technological gaps in adoption of mustard (*Brassica juncea*) production technology and to find out the relationship between the socio-economic characteristics of farmers and technological gaps in adoption of the technology. The study revealed that 68.2% of farmers belonged to medium technological gap category and there was a high technological gap in seed treatment, method of sowing, dose, time and method of application of fertilizers and herbicide, irrigation and plant protection

measures. Out of 16 variables, 9 variables namely, education, caste, irrigation facilities, type of family, extension contact, sources of information and knowledge were negatively and significantly correlated with overall technological gap, whereas, age and farming experiences were positively and significantly correlated with overall technological gap. The 16 independent variables taken together explained 53.7% of the variation in technological gap, and knowledge of farmers was the most important predictor of the technological gap.

Qualitative analysis of essential oil of *Rosmarinus officinalis* L. cultivated in Uttaranchal Hills, India. 16 (1): 55-57 (2007)
Laiq ur Rahman, A K Kukerja, Shishir K Singh, Anand Singh, Anju Yadav & S P S Khanuja
Gas chromatography and gas chromatography and mass spectroscopy analysis of essential oil hydrodistilled from fresh aerial part of rosemary (*Rosmarinus officinalis*) cultivated in Uttaranchal, India, resolved into 33 compounds representing 96.29% of the essential oil according to their chromatographic retention indices and mass spectra. The major compounds of the oil were, camphor (26.40%), 1,8-cineole (23.40%), α-pinene (9.94%), camphene (5.83%), myrcene (4.86%), bornyl acetate (3.97%), verbenone (3.32%), limonene (3.08%), borneol (2.05%) and α-terpineol (2.68%).

Genetic divergence in German chamomile [*Chamomilla recutita* (L.) Rauch.]. 16 (2): 125-128 (2007)
S P Singh, A N Mishra, P K Gupta & V R Singh
Forty genotypes of chamomile (*Chamomilla recutita*) were evaluated for 12 quantitative traits at Nagla (Uttarakhand) and could be grouped into seven clusters depending upon their genetic distance on the basis of Mahalanobis D^2 analysis. Maximum number of genotypes was grouped into cluster I (13) followed by cluster VII (8). Intra-cluster distances ranged from 1.78 (cluster IV) to 2.20 (cluster I). Inter-cluster distance was maximum between cluster II and V (6.91). The results indicated the diversity among the genotypes and sufficient scope for varietal improvement through hybridization. A breeding plan can be adopted from the results of the study to enhance flower

yield, flower diameter, disc floret periphery, disc floret height and number of flowers plant^{-1} through hybrid breeding programme.

Enzyme activities of agarwood (*Aquilaria malaccensis* Lamk.) stem under pathogenesis. 17 (3): 240-243 (2008)
P Tamuli, P Baruah & R Samanta
Cellulase, pectinase, peroxidase and polyphenol oxidase activities were determined in healthy, naturally infected and inoculated agarwood (*Aquilaria malaccensis*) plant parts at various time intervals to study the changes in activities of these enzymes during pathogenesis. Samples infected naturally with *Chaetomium globosum* and *Fusarium oxysporum* exhibited higher activity of all the enzymes compared to healthy samples.

Standardization of planting time for optimum growth and oil production of geranium (*Pelargonium graveolens* L. Her.) under north Indian plains. 17 (3): 247-250 (2008)
Man Singh, Saudan Singh & Mohd Yaseen
The effect of different planting dates on survival, growth, yield and oil characteristics of geranium (*Pelargonium graveolens* L. Her.) was studied at Lucknow (Uttar Pradesh). Fresh terminal stem cuttings were planted on different dates starting from 31 October 2002 to March 2003 at 15 days interval. Cuttings planted in mid-December recorded significantly higher survival (93.5%), fresh biomass (539.7 q ha^{-1}) and essential oil yield (54.9 kg ha^{-1}) than earlier or later planted cuttings.

Influence of row spacing and nitrogen levels on herb and essential oil production and oil quality of *Tagetes minuta* L. 17 (3): 251-254 (2008)
Man Singh, R S Tripathi, S Singh & M Yaseen
The influence of row spacing and levels of nitrogen application on herb and essential oil production and quality of oil of South American marigold (*Tagetes minuta*) was studied at Lucknow (Uttar Pradesh). Plant rows spaced at 30 cm distance produced 26% and 69% more herb and 20% and 47% more oil than 45 cm and 60 cm spacing, respectively. Nitrogen application led to linear increase in herb and

essential oil production. Application of 150 kg N ha^{-1} produced maximum oil (71 kg ha^{-1}) which was 142%, 49% and 23% higher, respectively, over 0, 50 and 100 kg N ha^{-1}. Essential oil biosynthesis was adversely affected in plants that were either spaced closer than 60 cm in rows or received higher quantity of nitrogen. The major chemical component of oil, dihydrotagetone increased with increase in row spacing and sharply decreased with increase in nitrogen level beyond 50 kg ha^{-1}, while a reverse trend was observed for limonene, (Z)-tagetone and (Z)-tagetenone.

Chemical composition of volatile oil of *Thymus vulgaris* L. from Western Ghats of India. 17 (3): 255-258 (2008)
K V Syamasundar, B Srinivasulu, A Stephen, S Ramesh & R R Rao
The aerial parts of *Thymus vulgaris* collected from Western Ghats of India were analysed for essential oil by Gas Chromatography. Forty eight compounds were detected among which 36 compounds, which constituted 98.63% of the oil were identified, with thymol (61.6%), p-cymene (11.2%), ϒ-terpinene (7.4%), methyl thymol (3.9%), methyl carvacrol (3.3%) and β-caryophyllene (2.3%) as major chemical constituents.

Effect of integrated nutrient management through vermicompost and inorganic fertilizers on growth, yield, nutrient uptake and oil quality of geranium (*Pelargonium graveolens* L' Her. ex Ait.) grown on alfisol. 20 (2): 55-59 (2011)
Munnu Singh
The effect of vermicompost and inorganic fertilizers (NPK) on growth, herbage, essential oil yield, oil quality and nutrient uptake pattern of geranium (*Pelargonium graveolens*) was studied at Bengaluru in a semi-arid climate. Among the five treatments compared, the combination of vermicompost @ 5 t ha^{-1} + 50% recommended NPK fertilizer (100:25:25 kg ha^{-1}) gave significantly better growth, high fresh herbage yield and oil yield which was on par with full dose of fertilizer NPK (200:50:50 kg ha^{-1}). A similar pattern was noticed in case of nitrogen, phosphorus and potassium uptake by plants. Oil content and oil quality were not influenced by vermicompost and inorganic fertilizers, alone or in combination.

Organogenesis in anise (*Pimpinella anisum* L.). 21 (1): 59-63 (2012)

Shailendra Nath Saxena, Ishan Ullah Khan & Rohit Saxena

High frequency organogenesis was achieved in anise (*Pimpinella anisum* L.) using hypocotyl explants from *in vitro* germinated seedlings. Both cytokinins, benzylaminopurine and kinetin induced shoot regeneration but the effect of benzylaminopurine was more pronounced. High frequency shoot regeneration (45 shoots explant^{-1}) was obtained on benzylaminopurine 1 mg l^{-1}. Both cytokinins were also tested in combination with auxins (naphthaleneacetic acid/indoleacetic acid). Interaction of benzylaminopurine/kinetin with naphthaleneacetic acid/indoleacetic acid increased the length of regenerated shoots. Different kinds of callus morphology was observed but it had no relationship with regeneration potential. The regenerated plants were normal and healthy.

Effect of agronomic practices on productivity and profitability of anise (*Pimpinella anisum* L.). 21 (2): 102-105 (2012)

S S Meena, R S Mehta, G Lal & M M Anwer

A field experiment was carried out at Ajmer (Rajasthan) to find out the optimum sowing time and crop geometry for realising higher productivity and profitability in anise (*Pimpinella anisum* L.). Fifteen treatment combinations comprising of five dates of sowing *viz*., 15th October, 30th October, 15th November, 30th November and 15th December in main plot and three crop geometry *viz*., 20 cm × 10 cm, 25 cm × 10 cm and 30 cm × 10 cm spacing in sub plot were taken. The results revealed that sowing of anise on 15th October produced significantly higher plant height (7.94 cm, 40.98 cm and 54.88 at 60, 90 DAS and at harvest, respectively), number of branches plant^{-1} (14.70 and 13.92 at 90 DAS and harvest respectively), number of umbels plant^{-1} (40.91), number of umbellates umbel^{-1} (17.4), number of seeds umbellate^{-1} (19.45), test weight (2.60 g), seed yield (892 kg ha^{-1}), gross returns (Rs. 80,280 ha^{-1}), net returns (Rs. 74,280 ha^{-1}) and benefit:cost ratio (12.38). Crop geometry of 20 cm × 10 cm significantly resulted in highest plant height, number of branches plant^{-1} at all stages, number of umbels plant^{-1} (31.57), number of umbellates umbel^{-1} (14.72), number of seeds per umbellate (17.58),

test weight (2.40 g), seed yield (507 kg ha^{-1}), net returns (Rs. 39,630 ha^{-1}) and Benefit:Cost Ratio (6.61). Therefore, sowing of anise on I5th October at 20 cm × 10 cm spacing was optimum for realising higher productivity and profitability of the crop.

Diversity analysis of sesame germplasm using DIVA-GIS. 21 (2): 145-150 (2012)

B Spandana, N Sivaraj, G John Prasanna Rao, G Anuradha, S Sivaramakrishnan & Farzana Jabeen

Sesame (*Sesamum indicum* L.) was studied for its distribution and diversity in India using DIVA-GIS. Grid maps were generated for diversity analysis of the eight quantitative traits *viz*., plant height, inter-node length, leaves per plant, number of flowers per plant, number of capsules per plant, number of seeds per capsule, seed weight and seed yield. The results indicated that diverse accessions for all these traits can be sourced from Maharashtra, Gujarat and Madhya Pradesh (partly covering Chhattisgarh) states and these states are diversity rich pockets for sesame germplasm in India.

Essential oil composition of *Artemisia annua* L. at different growth stages. 22 (2): 181-187 (2013)

V S Rana, K Abirami, M A Blázquez & S Maiti

Chemical composition of the essential oils obtained from the aerial parts of *Artemisia annua* at vegetative, pre-bloom, bloom and post-bloom stages was determined using GC and GC/MS analysis. The yields of essential oil were 0.14%, 0.34%, 0.64% and 0.54% (w/w), respectively at different growth stages. A total of 67 compounds were identified. Oxygenated monoterpenes (39.0%-57.0%) constituted the main fraction of the oils followed by sesquiterpene hydrocarbons (11.8%-26.2%) and monoterpene hydrocarbons (4.2%-15.1%). The main compounds identified in all the analyzed samples were camphor (28.6%-31.7%), 1,8-cineole (2.1%-20.8%), germacrene D (3.8%-12.0%), β-caryophyllene (2.8%-6.9%), *trans*-β-farnesene (0.7%-4.5%), α-pinene (0.5%-2.4%), *p*-cymene (0.8%-2.3%) and terpinen-4-ol, (0.9%-2.1%). The results indicated considerable quantitative variations in both oil yield and chemical composition at different

growth stages and artemisia ketone and artemisia alcohol were found to be absent in the oils.

Evaluation of antibacterial activity of *Lavandula stoechas* L. essential oil. 22 (2): 188-193 (2013)
M C Gayatri, U Sudha, J Shubha & K Kavya
The antibacterial activity of crude and essential oil extract of Lavandula (*Lavandula stoechas*) against the infectious bacteria *viz*., *Escherichia coli*, *Bacillus subtilis*, *Pseudomonas* spp. and *Staphylococcus aureus* were evaluated *in vitro*. It was found that *L. stoechas* oil exhibits high antibacterial activity against *S. aureus*, *Pseudomonas* spp., *B. subtilis* and *E. coli* when compared to crude extract. The *in vitro* Minimum Inhibitory Concentration (MIC) of *L. stoechas* oil was found to be 50 µg mL^{-1} for inhibiting the growth of *B. subtilis* and *S. aureus* whereas, it was found to be 25 µg mL^{-1} for *E. coli* and *Pseudomonas* spp. The statistical analysis for MIC of *L. stoechas* oil was found to be 42.82 µg mL^{-1} for inhibiting the growth of *B. subtilis* and *S. aureus* where it was found to be 22.25 µg mL^{-1} for *E. coli* and *Pseudomonas* spp.

Effect of integrated nutrient management on nutrients availability and uptake by black henbane (*Hyoscyamus niger* L.) in *Tarai* region of Uttarakhand. 23 (1): 86-90 (2014)
A K Gupta, H V Puranik, R K Pal & C S Pandey
Experiments were conducted to quantify the effect of integrated nutrient management on soil health and black henbane (*Hyoscyamus niger* L.). The treatments were, no chemical fertilizer and organic manure (control) [T_1], recommended (rec.) NPK (i.e. 100:50:50 kg ha^{-1}) [T2], 75% rec. NPK +2.5 t vermicompost (VC) [T_3], 50% rec. NPK + 5.0 t VC (T_4), 25% rec. NPK + 7.5 t VC (T_5), VC 10 t (T_6), rec. NPK + Biofertilizers (BF) [T_7], 75% rec. NPK + 2.5 t VC + BF (T_8), 50% rec. NPK + 5.0 t VC + BF (T_9), 25% rec. NPK + 7.5 t VC + BF (T_{10}), 10 t VC + BF (T_{11}) and BF [*Azotobacter* and Phosphorus Solubilizing Bacteria (PSB)]. Highest herbage yield was obtained with application of T_8 during both the years. Integrated application of inorganic fertilizers and organic sources of nutrients increased the N, P, K content and their uptake. Highest available N and K content in soil was observed

with T_2 during 2008-09, while during 2009-10, the maximum available N content in soil was observed with T_8. Highest N uptake was observed with T_6, while highest P and K uptake was recorded with T_8 during both the years.

Antioxidant activity assay of stem and *in vitro* callusing of *Tinospora cordifolia* (Miers.). 23 (1): 91-97 (2014)
K C Verma, S Sapra, A Bagga & M A Baigh

The experiment was conducted to study the antioxidant potential among different hosts of *Tinospora cordifolia*. The results indicated that among the different hosts of *T. cordifolia*, *Ficus religiosa* had highest phenol content (5.25 mg g^{-1}), inhibition activity (52.05%) and reducing capability as compared to others. *F. religiosa* showed the highest antioxidant activity of 41.73 µM Fe (II) g^{-1}. EC_{50} value for lipid peroxidation inhibitory activity was 0.1mg mL^{-1} for all the samples. EC_{50} value for DPPH radical scavenging activity was 0.6 mg mL^{-1} for *F. religiosa*. These results suggested that the active antioxidant compounds were higher in *F. religiosa* as compared to *Roystonea regia*. There was a direct correlation between the total polyphenols extracted and anti-oxidant activity. Among the various explants of *F. religiosa*, leaf explants were found to be superior for *in vitro* callus induction.

Influence of FYM and inorganic fertilizers on growth and yield of isabgol (*Plantago ovata* Forsk). 23 (1): 130-136 (2014)
T Choudhary, S K Sharma & B K Yadav

A field experiment was conducted to assess the effect of inorganic fertilizers and organic manure on plant growth and seed quality of isabgol in a hot arid region. Plant growth parameters *viz*., plant height, number of tillers $plant^{-1}$ and dry matter accumulation was significantly higher with NPK + FYM as compared to other treatments. Yield attributes such as spike length, number of spikes $plant^{-1}$ and number of grains $spike^{-1}$ were also significantly higher with NPK + FYM. Highest grain (13.40 q ha^{-1}) and straw (30.21 q ha^{-1}) yield was obtained with the application of NPK + FYM, which was at par with NPK + Zn. Application of NPK + FYM recorded the highest N, P and K contents. However, highest Zn content was observed with NPK + Zn.

The highest protein content in grain (12.43%) and straw (5.13%) was found with the treatment NPK + FYM, which was at par with NPK + Zn. The results clearly showed that the application of inorganic fertilizers significantly increase isabgol yield, nutrient content and grain quality when applied with organic manure as compared to sole application of inorganic fertilizers.

Evaluating the taxonomic status of *Solanum nigrum* L. using flow cytometry and DNA barcoding technique. 23 (2): 233-242 (2014)
T Nandhini & P Paramaguru

Solanum nigrum L. is a widely distributed species whose taxonomic status remains controversial. The ploidy determination of all the accessions were done based on stomatal, pollen and some morphological characters but morphometry could not provide solution to distinguish these species. In this study, ploidy status of all the accessions were done using flow cytometry and DNA barcoding technique was also applied to identify and distinguish 13 distinct germplasm collections. DNA of all 13 accessions was isolated and sequenced. The sequence was aligned using DNASTAR offline Software. The DNA sequence was subjected to BLAST for identifying at species level. The intra specific variation between the species was calculated using MEGA 5.0. The phylogenetic analysis indicated that among the 13 accessions, six were identified as *S. americanum* Mill, three were identified as *S. nigrum* Linn. and four were identified as *S. villosum* Mill.

Optimizing the date of transplanting to increase seed yield and quality in davana (*Artemisia pallens* Wall.ex.D.C.). 23 (2): 254-257 (2014)
M Jayanthi, A Vijayakumar, K Vanangamudi & K Rajamani

A field experiment was conducted to study the effect of date of transplanting on growth, yield and seed quality attributes of davana. The experiment was laid out with five different dates of transplanting *viz*., October 15th, November 1st, November 15th, December 1st and December 15th with the spacing of 15 cm × 7.5 cm. The results revealed that the seedlings transplanted on 15th November recorded the maximum number of branches plant^{-1} (26), herbage yield plot^{-1}

(1064.39 g), seed yield plant^{-1} (9.01 g), seed yield plot^{-1} (112.66 g), resultant seed germination (64%) and vigour index (168) whereas the seedlings transplanted on December 15th recorded the minimum number of branches plant^{-1} (20), herbage yield plot^{-1} (799.62 g), seed yield plant^{-1} (6.33 g), seed yield plot^{-1} (79.08 g) and the seedlings transplanted on October 15th recorded 61% seed germination and vigour index of 145.

Integrated nutrient management in calendula (*Calendula officinalis* L.) grown in partially reclaimed sodic soil condition. 24 (2): 129-132 (2015)

D Singh, R C Nainwal, L Bahadur & S K Tewari

To study the effect of nutrient management on growth and flower yield of Calendula, field experiments were carried out during 2009 and 2010. Results indicated that significantly higher plant height (40.6 cm), number of leaves (142) at 90 days, total number of flowers plant^{-1} (126), total fresh weight of flowers (87.5 q ha^{-1}) and dry weight of flowers (25 q ha^{-1}) were observed by the application of 10 t farmyard manure (FYM) + ½ NPK + spraying of micronutrients followed by sole application of recommended dose of inorganic fertilizer (i.e. NPK@ 80:30:30 kg ha^{-1}) which was at par with application of half dose of recommended dose of inorganic fertilizer supplemented with half dose of organic fertilizer. Application of 20 t FYM ha^{-1} improved the soil physico-chemical parameters i.e. pH, EC, organic carbon and available NPK in comparison to control.

Socio-economic analysis of lavender crop in Himachal Pradesh. 26 (1): 63-65 (2017)

S Singh & S S Dhillon

The data collected from 20 lavender growers of three blocks of Chamba district by personal interview using multi-stage purpose sampling technique. In lavender farms share of male labour was found to be more than female labour. Working as daily paid labourers followed by farming, service and business was the main occupation of adult family members. BCR (over total variable cost) as well as BCR (over total cost) was worked out as 3.170 and 0.642, respectively for lavender crop. Family labour income and net income measures per

hectare were found to be negative for lavender crop. About 95% and 25% of selected lavender farmers responded positively regarding availability of good quality seed/seedlings and disease problem in seed/seedlings respectively, in the initial stage of sowing of lavender crop. Besides, 90% responded that cost of marketing of produce was high, all the respondents were hiring transport to market the produce. Likewise, 65% responded that there is lack of cheap credit from banks for lavender farming. The lack of profitability indicates the need to strengthen R&D work, extension services, training of farmers, establishment of cold storage facilities, and co-operatives farming societies for enhancing prospects of lavender farming.

Evaluation of stable and non-shattering isabgol cultivar - Gujarat Isabgol 4. 27 (1): 88-90 (2018)
D G Patel, H B Patel, P T Patel, H Patel & A U Amin
Isabgol growing area was surveyed during 2009-10 and selected genotypes were evaluated in preliminary evaluation trial (PET) during 2010-13 and in large scale varietal trial (LSVT) during 2013-15. It was found that JI-09-21 recorded better growth and yield characters and yield over check Gujarat Isabgol 3. The JI-09-21 did not shatter much even after water dripping and recommended for cultivation as Gujarat Isabgol 4.

Volatile metabolites of endophytic Klebsiella aerogenes from *Zingiber zerumbet* rhizome and its antagonistic effect on soft rot causative *Pythium myriotylum*. 29 (2): 122-132 (2020)
K Harsha & R Aswati Nair
Rhizomes of *Zingiber zerumbet* collected from their natural habitat and reported earlier to have high zerumbone content were selected for isolation of endophytes. Biochemical and molecular characterization using 16SrRNA sequencing of the endophytes identified the isolates as belonging to genus *Klebsiella*, *Pantoea* and *Enterobacter*. Isolate designated ZzKSD8 identified as *K. aerogenes* yielded maximal antagonistic activities against *P. myriotylum* determined as 83.5% ± 0.77. Volatile metabolites produced by ZzKSD8 caused absolute impairment of *P. myriotylum* hyphal growth compared to control (23.9 ± 0.37 cm). Volatile metabolites were

extracted from 48 hour grown stationary phase ZzKSD8 cultures using absolute methanol, ethyl acetate and ethanol (60% v/v). GC-MS metabolite profiling detected alkanes and fatty acid methyl esters as the predominant constituents in the solvent extracts. Major constituents included methyl palmitate (31.37%), methyl stearate (18.57%) and cyclopropaneoctanoic acid, 2-hexyl-,methyl ester (17.05%) in methanol extract; alkanes like tetratetracontane (13.18%) and 2-methyloctacosane (12.10%) in ethyl acetate extracts and 4,22-sigmastadiene-3-one as major metabolite (22.51%) and stigmast-5-en-3-ol, (3.beta) (17.40%) in ethanol extract. Identified metabolites reported to modulate defense strategies in plants against phytopathogens makes ZzKSD8 a potential candidate for development of biological alternatives to control soil-borne soft rot disease.

Evaluation of harvesting time and standardization of distillation duration for higher essential oil content and quality in German chamomile (*Chamomilla recutita* L.). 29 (2): 140-147 (2020)
D Kumar, P Suryavanshi, R C Padalia, A Chauhan, K T Venkatesha, A K Tiwari, V R Singh, S Singh & R K Upadhyay

Essential oil yield and composition in aromatic crops might be affected by genetic, agronomical and environmental factors but till date there is no clear information about the harvesting time and distillation for higher essential oil content without affecting quality. The current study was carried out to evaluate harvesting of chamomile flowers without herb and with herb part at three different times (6 A.M., 12 P.M. and 6 P.M.) and four distillation treatments (3 h, 4 h, 5 h & 6 h) for dried chamomile flowers. Results indicated that essential oil content was more in chamomile flowers without herb (0.15-0.18%) as compared to flowers with herb (0.06-0.09%). Essential oil content in chamomile flowers without herb was found statistically at par at harvest time of 12 P.M. (0.18%) and 6 P.M. (0.18%) and significantly higher than harvesting time of 6 A.M. (0.15%). Essential oil of chamomile flowers without herb contained maximum α-bisabolol oxide-B, (Z)-spiroether, and chamazulene at 12 P.M. and 6 P.M. while, α-bisabolone oxide-A and α-bisabolol oxide-A were maximum at 6 A.M. and (E)-β-farnesene was more at 12 P.M. Similarly, in distillation experiment, higher oil content was observed

in chamomile dried flowers which were hydro-distilled for 6 h (1.20%) compared to other hydro-distillation durations. Marker compounds i.e. α-bisabolol oxide-A, α-bisabolone oxide-A, α-bisabolol oxide-B, (E)-β-farnesene and chamazulene were more at 5 h and 6 h distillation duration while (Z)-spiroether was more at 3 h distillation duration. The present study showed that in order to obtain higher essential oil, flowers without herb harvested at 12 P.M or 6 P.M. should be subjected to 5-6 h hydro-distillation.

Impact of paddy straw mulch on germination and growth of celery (*Apium graveolens* L.) seedlings and associated weeds in nursery. 29 (2): 148-152 (2020)

A S Brar, P K Sraw & B S Dhillon

A study was undertaken during three consecutive *rabi* seasons of 2014-15 to 2016-17 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) to determine the effect of paddy straw mulch load and retention time on the germination and growth of celery and associated weeds. The experiment was conducted in randomized complete block design (RCBD) with nine treatments *viz*., paddy straw mulch @ 4 and 6 t ha^{-1} with retention time of 15, 20, 25 days after sowing (DAS), full time retention (60 DAS), and control (without mulch). The results indicated that application of paddy straw mulch @ 4 or 6 t ha^{-1} significantly improved the germination of celery in nursery as compared to no mulch treatment but retention of paddy straw mulch beyond 20 days after sowing suppressed the celery seedlings adversely resulting in lowering seedling population as well as fresh and dry weight of celery seedlings. Application of paddy straw mulch @ 4 or 6 t ha^{-1} resulted in significantly lower density and dry weight of weeds as compared to control. Further, each successive increase in retention time of paddy straw mulch from 15 DAS to full time retention (60 DAS) through 20 and 25 DAS significantly reduced the weed population in celery nursery.

Influence of propagules and growth regulators on the performance of underutilized spice - Spiny coriander (*Eryngium foetidum* L.). 30 (2): 204-209 (2021)
A Samad, B Singh & P R Gajurel
An experiment was conducted to study the effect of propagules of spiny coriander (*Eryngium foetidum* L) as influenced by growth regulators in the Forestry Nursery of North Eastern Regional Institute of Science and Technology during 2018 and 2019. Spiny coriander is an underutilized culinary spice; a medicinal and aromatic plant that belongs to the family Apiaceae. The study consisted of 14 treatments involving two levels of propagules like stem cuttings (S_1) and suckers (S_2) and seven levels of growth regulators namely Indole Butyric Acid (IBA) and Indole-3 Acetic Acid (IAA) [each at 0, 500, 1000 and 1500 ppm]. The results indicated that the treatment T_9 involving sucker (S2 + IBA 500 ppm) was found better in terms of growth and it was comparable with T_{12} (S2 + IAA 500 ppm) during both years. Suckers treated with IBA 500 ppm and IAA 500 ppm showed significantly superior performance over the stem cuttings. It is concluded that suckers (7-10 cm) of *Eryngium foetidum* may be used as propagating material for commercial cultivation, as it is an easy, quick and economical method of propagation.

Floral biology insights into essential oil yield and chemical composition in davana (*Artemisia pallens* Bess), a high-value aromatic plant of India. 32 (1): 75-83 (2023)
R Ravi Kumara, P E Keerthi & N D Yogendra
Floral organs are identified as the major source of essential oil production in some prime aromatic plants. The quality and quantity of the essential oil are also influenced by the floral developmental stages. The present study was undertaken in *Artemisia pallens* Bess (davana) with respect to its floral biology and floral sequence in relation to the essential oil yield and its chemical constituents for industrial extraction. The findings revealed that floral (inflorescence) biomass is the primary source of essential oil yield in davana, with the highest oil yield (0.90 ml/100 g) recovered during the blooming stage, followed by herbage (stems and leaves) biomass. Furthermore, cis-davanone, the major chemical constituent

of davana essential oil, was recorded at a higher percentage in the bud stage (66.36±0.60%) followed by the blooming stage (60.56±0.20%) and the seed setting stage (40.54±0.80%). These findings can be used to optimize harvest timing in order to obtain higher quality and quantity of davana essential oil.

Exploring the therapeutic potential of volatile bioactive compounds from different parts of *Tinospora cordifolia*: A gas chromatography-mass spectrometry (GC-MS) study. 32 (1): 84-93 (2023)

B C Akhilraj, J Suresh, K Rajamani, M Kumar and R Gnanam

Chemicals utilised in the pharmaceutical business can be found in large quantities in medicinal plants. Crude plant herbal extracts are frequently utilised because they combine a variety of secondary metabolites or phytochemical elements with significant therapeutic potential. The main objective of the this research was to identify the medicinally significant phytoconstituents from different economic parts of *Tinospora cordifolia* employing GC-MS. The stem, leaf, and root, respectively, had a total of 93, 74, and 53 peaks, which translates to a sizable number of phytocompounds with therapeutic value. Our results show that oleic acid, columbin, 10E,12Z-octadecadienoic acid, 9- octadecenoic acid (Z), 2, 3-dihydroxypropyl ester, n-hexadecanoic acid, and 9,12,15-octadeca trieno were found in various parts of *T. cordifolia*. The results provide credence to the use of *Tinospora cordifolia* in conventional medical practice for a range of ailments.

Morphological and biochemical characterization of *Alpinia calcarata* rhizomes. 32 (2): 202-213 (2023)

K Shibila, A K Aneesha, A Suma, P Anitha and C R Rashmi

Lesser galangal rhizomes are well known for their anti-inflammatory, anti-microbial and anti-oxidant properties. The aim of the present study was to assess the variability in morphological and biochemical characters of lesser galangal, *Alpinia calcarata* accessions collected from various South Indian states. The results revealed that accession IC 373608 was significantly superior with respect to yield contributing traits including the rhizome length, width, fresh yield and

dry recovery (6.02 cm, 2.40 cm, 14.63 g tiller^{-1} and 33.26%, respectively) among the eighteen accessions studied. The biochemical analysis of rhizomes revealed that the maximum volatile oil and oleoresin content were found in the accession IC 468880 (0.75%) and IC 373608 (34.20%), respectively. The highest values for total phenols, total flavonoids and starch were observed in the accessions IC 373608 (115.25 mg GAE. g^{-1}), IC582825 (55.65 mg QE. g^{-1}) and IC210656 (44.05 mg. g^{-1}), respectively. The accession IC 550112 (7.90%) recorded the lowest crude fibre content, whereas the highest total terpenoid content was noticed in accession IC 210421 (20.25%). The GC MSMS profiling of volatile oil of *A. calcarata* rhizome showed the presence of 28 compounds in it. Considering all economically important characters, accessions IC 373608, IC 582825 and IC 210421 were found to be superior and can be utilized in future crop improvement programmes.

MULTIPLE SPICES AND BIOAGENTS

Crop Improvement and Biotechnology

Isolation of protoplasts from cardamom (*Elettaria cardamomum* Maton.) and ginger (*Zingiber officinale* Rose.). 9 (1): 23-30 (2000)
S P Geetha, K Nirmal Babu, J Rema, P N Ravindran & K V Peter
Protoplasts were isolated from leaf mesophyll tissue, collected from *in vitro* grown plantlets and cell suspension cultures of cardamom (*Elettaria cardamomum*) and ginger (*Zingiber officinale*). In cardamom, a protoplast yield of 3.5 x $l0^5$/ g of leaf tissue was obtained when incubated in an enzyme solution containing 0.5% macerozyme RIO, 2% cellulase Onozuka RIO and 9% mannitol for 18-20 h at 25°C in dark. The yield of protoplasts from cell suspension culture was 1.5 x $l0^5$/ g tissue, when incubated in I % macerozyme RIO and 2% cellulase Onozuka RIO for 24 h at 25°C with gentle shaking at 53 rpm in dark. The viability of leaf mesophyll protoplast was 75% and that of cell suspension was 40% on Evan's blue staining. In ginger, a protoplast yield of 2.5 x $l0^5$/ g of leaf tissue was obtained on digestion in an enzyme solution containing 0.5% macerozyme RIO, 3% hemicellulase and 5% cellulase Onozuka RIO, when incubated for 10 h at 15°C followed by 6 h at 30°C. The protoplast viability was 55%. Protoplast yield from cell suspension culture was 1 x $l0^5$/g of callus when digested with an enzyme solution of I % macerozyme RIO, 3% hemicellulase and 6% cellulase Onozuka RIO and incubated for 10 h at 15°C and later at 30°C for 8 h. Seventy two per cent of the protoplasts were viable. The protoplasts from both the species could be cultured and made to develop up to microcalli stage.

Performance of ginger and turmeric genotypes in Raigarh District of Chhattisgarh. 11 (1): 62-63 (2002)
R K Yadav
A study was conducted at the Regional Agricultural Research Station, Boirdadar, Raigarh, Chhattisgarh, to evaluate eleven turmeric and six ginger genotypes. All entries outperformed the local genotypes used as checks. In ginger, the genotype Varada recorded the highest rhizome yield (175.3 q ha^{-1}), followed by VS-8 (174.0 q ha^{-1}). In

turmeric, PTS-43 yielded the maximum fresh rhizome yield (255.9 q ha^{-1}), followed by JTS-2 (251.2 q ha^{-1}), Acc. 360 (246.9 q ha^{-1}), Raj Sonia (234.9 q ha^{-1}), and JTS-1 (231.6 q ha^{-1}). These genotypes are recommended for cultivation in Raigarh District of Chhattisgarh to enhance ginger and turmeric production.

Crop Production and Postharvest Technology

Turmeric-maize and onion intercropping systems. I. Yield and land use efficiency.
3 (1): 19-27 (1994)
K Sivaraman and S P Palaniappan

Experiments were laid out at Bhavanisagar (Tamil Nadu, India) during 1989-90 and at Coimbatore (Tamil Nadu, India) during 1990-91 to determine land use efficiency, yield and yield attributes of turmeric (*Curcuma longa* L.) and maize (*Zea mays* L.) in various intercropping and sole cropping systems. Turmeric, maize and onion (*Allium cepa* L.) were raised as sole crops adopting recommended package of practices. Maize and onion were intercropped with turmeric in two proportions (50 and 100 per cent of the recommended population levels). Onion was also introduced as additional intercrop with maize with 23 per cent of the population of sole crop. Turmeric yields were reduced from 9 to 25 per cent when intercropped with maize. Turmeric yield reductions due to intercropping were associated with reduction in number of tillers, mother rhizome, primary and secondary rhizomes. Maize yields were higher with intercropping than with sole cropping. Even though yield of turmeric was reduced by intercropping, turmeric-maize and onion intercropping resulted in 17 to 34 per cent greater land use efficiency for the 9 months growing season than in· the sole cropping systems. This is important in developing countries where available per capita arable land is low.

Estimation of phenolic acids in cinnamon, clove, cardamom, nutmeg and mace by high performance liquid chromatography. 4 (2): 129-134 (1995)

Prasad S Variyar & Chiranjib Bandyopadhyay

Phenolic acids of five commercially important spices, namely, cinnamon, clove, cardamom, nutmeg and mace were quantitated by high performance liquid chromatography using external standard method. Protocatechuic acid was the predominant phenolic acid in cinnamon bark, while gallic acid dominated in clove buds. The major phenolic acids in cardamom seeds and nutmeg were caffeic acid + vanillic acid while ferulic acid and synapic acid predominated in mace.

Turmeric-maize and onion intercropping systems II. Leaf area index and dry matter accumulation. 4 (2): 145-155 (1995)

K Sivaraman & S P Palaniappan

Experiments were laid out at Bhavanisagar and Coimbatore (Tamil Nadu, India) to study the influence of intercropping on leaf area index and dry matter accumulation in whole plants of turmeric (*Curcuma longa*), maize (*Zea mays*) and onion (*Allium cepa*) when grown in intercropping and sole cropping systems. Maize was intercropped with turmeric in two proportions (50 and 100 per cent of the recommended population levels). Onion was also introduced as additional intercrop with maize with 23 per cent of the population of sole crop. These crops were also raised as sole crops. Leaf area indices and dry matter accumulation of maize and turmeric at different stages were influenced significantly by intercropping systems, in both locations. Intercropping maize in turmeric significantly reduced the growth of the latter. This effect was quite obvious where maize was raised as intercrop at 100 per cent of the recommended population. Sole cropping of turmeric resulted in higher leaf area indices than turmeric raised as intercrop. Raising onion as additional intercrop did not influence dry matter accumulation of component crops appreciably.

Turmeric-maize and onion intercropping systems. III. Nutrient uptake. 5 (1): 49-57 (1996)
K Sivaraman and S P Palaniappan
Experiments were conducted at Bhavanisagar and Coimbatore (Tamil Nadu, India) to determine uptake of nutrients as influenced by intercropping systems with turmeric (*Curcuma longa*)-maize (*Zea mays*) and onion (*Allium cepa*), and to study nitrogen uptake pattern by various plant parts of turmeric in such situations. The results revealed that nutrient uptake by the intercropping systems was higher than the uptake of either of the sole crops of turmeric, maize and onion. The total uptake of nitrogen by various intercropping systems varied from 61 to 80 per cent more than the uptake of nitrogen by the sole crop of turmeric at Bhavanisagar and 57 to 77 per cent at Coimbatore. Similarly it varied from 82 to 104 per cent more than the sole crop of maize at both the locations. A similar result was obtained in onion also. Similar trends were observed in uptake of phosphorus and potassium in the intercropping systems. The results indicated that for sustainable production of intercropping systems, meeting the combined nutritional requirements of component crops is essential.

Response of clove (*Syzygium aromaticum* (L.) Merr. & Perry) seedlings and black pepper (*Piper nigrum* L.) cuttings to propagating media under nursery conditions. 5 (2): 99-104 (1996)
C K Thankamani, K Sivaraman & K Kandiannan
Various propagating media were evaluated for enhancing growth of clove (*Syzygium aromaticum* L.) seedlings in the nursery and the best was soil and vermicompost mixed in 1:1 proportion. The transplanting time of clove seedlings could also be shortened to 1 year by adopting this media in the nursery. Vermicompost was also evaluated as a propagating media for black pepper (*Piper nigrum* L.) in comparison with potting mixture comprising of soil, sand and farmyard manure. Black pepper cuttings raised in vermicompost were significantly taller and had more number of leaves than in potting mixture.

Turmeric-maize and onion intercropping systems. IV. PAR interception. 5 (2): 139-142 (1996)
K Sivaraman and S P Palaniappan
Experiments conducted at Coimbatore (Tamil Nadu, India) to study the pattern of interception of photosynthetically active radiation in intercropping systems with turmeric (*Curcuma longa*)-maize (*Zea mays*) and onion (*Allium cepa*) indicated that with a high maize population, the mixed canopy could effectively intercept more of available photosynthetically active radiation throughout the growing season, than the sole crop of turmeric, maize or onion.

Coffee-cardamom, black pepper and mandarin mixed cropping system - A case study. 6 (1): 1-7 (1997)
V S Korikanthimath, Ravindra Mulge, Rajendra Hegde & M M Hosmani
Experiments were conducted at Chettalli, a predominantly coffee growing area in Kodagu District (Karnataka, India) to study the yield potential of coffee (*Coffea robusta*), cardamom (*Elettaria cardamomum*), black pepper (*Piper nigrum*) and mandarin (*Citrus reticulata*) in a mixed cropping system. Dry yield of coffee was significantly higher when it was grown as mono crop (2163 kg/ha) compared to mixed crop (1568 kg/ha). Cardamom when introduced as a single hedge by trimming the side branches of alternate rows of coffee, recorded an yield of 204.83 kg/ha. Black pepper vines trained on live standards of shade trees yielded 1222.15 kg/ha. Mandarin was severely infested with greening disease and there was no appreciable yield. The study indicated the feasibility of introduction of high value crops like cardamom and black pepper as mixed crops for increasing the production and productivity of coffee plantations.

Fermented beverages from spices - A new nutraceutical drink. 11 (2): 106-111 (2002)
V Sapna, M Vasundhara & M L Annapurna
An investigation was carried out to develop herbal and spice beverages. Spices *viz*., black pepper, fennel, dill, coriander and cumin were used. The possibility of making spice wines more appropriately

called as "Elixirs" was examined. The nutritive value in terms of chemical components and mineral composition and keeping quality of the product under ambient temperature were worked out. The cost economics was also calculated.

Rates of leaf fall and nutrient recycling of shade trees in coffee (*Coffea arabica* L.), cardamom (*Elettaria cardamomum* Maton) and black pepper (*Piper nigrum* L.) production systems of Mudigere, Karnataka. 15 (2): 108-114 (2006)
M Dinesh Kumar & J Babitha

The rates of leaf fall and nutrient addition by different shade trees in coffee (*Coffea arabica*), cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*) production systems were determined at Mudigere (Karnataka). Most trees shed leaves during September to December. Highest leaf shed (4214.5 g m^{-2} $year^{-1}$) was noticed in *Artocarpus integrifolia* followed by *Ficus tjahela* (3976.2 g m^{-2} $year^{-1}$). Nitrogen concentration of the leaves varied from 0.21% (*Dalbergia latifolia*) to 1.89% (*Albizia lebbeck*); phosphorus concentration from 0.01% (*Holigarna arnottiana*) to 0.11% (*Pongamia pinnata*); and potassium concentration from 0.21% (*H. arnottiana*) to 1.52% (*Lagerstroemia lanceolata*). In coffee production system, *A. integrifolia* recorded highest content of nitrogen (39.19 g m^{-2} $year^{-1}$) while *F. tjahela* recorded higher phosphorus (2.07 g m^{-2} $year^{-1}$) and potassium (34.99 g m^{-2} $year^{-1}$) contents. In cardamom production system, *Erythrina indica* recorded higher contents of nitrogen (25.72 g m^{-2} $year^{-1}$) and phosphorus (1.62 g m^{-2} $year^{-1}$) while *L. lanceolata* contained more potassium (14.11 g m/2 year/1). In black pepper production system, *Michelia champaca* recorded higher contents of nitrogen (31.11 g m^{-2} $year^{-1}$), phosphorus (3.46 g m^{-2} $year^{-1}$) and potassium (29.95 g m^{-2} $year^{-1}$). Species that were rich in nitrogen content had initial lower (< 30) C/N ratio. Lignin content varied from 17.3% to 25.3% and cellulose from 4.4% to 10.1% in various tree species.

Analysis of rainfall of the high rainfall tract of northern agro-climatic zone of Kerala. 17 (1): 16-20 (2008)
K Kandiannan, C K Thankamani & P A Mathew
Analysis of rainfall of the high rainfall tract of northern agro-climatic zone of Kerala was carried out for 26 years (1980-2005) to schedule spice crop management practices precisely. The analysis indicated that the tract received 4461 mm of annual rainfall in 145 rainy days. south west monsoon (June to September) alone contributed 75% of annual rainfall and July was the rainiest month (1117 mm) with 27 rainy days. The length of growing period was identified between 18th standard week to 47th standard week (from 30th April to 25th November) with a mean rainfall of 4284.1 mm. The pre-monsoon period from 2nd April to 6th May (between 14th week to 18th week) with a mean rainfall of 180.6 mm was the right time for land preparation for annual crops like ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) and the period between 30th April to 27th May (18th week to 21st week) with a mean rainfall of 244.4 mm was ideal for planting including first mulching and first schedule of fertilizer application for these crops. The probability of getting 50 mm rainfall per week was more than 60% during the 19th week (7th to 13th May). This is the time for prophylactic plant protection, application of first schedule of fertilizer application and shade regulation for black pepper (*Piper nigrum*) and tree spices. The second schedule of these operations has to be done during the 36th to 39th week (3rd to 30th September) as this period is relatively rainless (September rainfall was 349.6 mm). Though the tract receives high rainfall, there is moisture stress between December and March and adequate moisture conservation (or irrigation wherever possible) is essential particularly for perennial crops in juvenile stage.

Assessment of seed quality in seed spices. 22 (2): 233-237 (2013)
C K Pramila, K P R Prasanna, P Balakrishna, P J Devaraju and Siddaraju
The present study was carried out to assess seed quality of some important seed spices supplied in the local markets of Bengaluru. The results revealed that highest physical purity was recorded in fenugreek seed lots with an overall mean of 98.76% followed by

fennel (97.99%) and coriander (97.68%). The moisture content of all the seed spices ranged from 6.89% to 7.15%. The highest seed germination (89.42%) was recorded in fenugreek followed by fennel (76.82%) and lowest (64.33%) in coriander. The seedling vigour index was highest in fenugreek (range 1116-1819; mean 1532) and lowest in cumin (range 621-832; mean 737). A 12.0% increase in germination and improvement in the vigour index (997-1226) were also noticed in treated seed samples compared to control (900).

Turmeric and cinnamon dominate in antioxidant potential among four major spices. 26 (1): 27-32 (2017)
B Saranya, T Sulfikarali, S Chindhu, A M Muneeb, N K Leela & T J Zachariah
Antioxidant activity of sequential extracts of black pepper, ginger, turmeric and cinnamon was determined by DPPH assay, phosphomolybdate method and ferric reducing power method and compared with that of the synthetic antioxidant BHA. The results revealed that methanol extract of cinnamon has highest antioxidant potential followed by chloroform extract of turmeric. The antioxidant potential was also correlated with total phenol content.

Annual and monthly rainfall trend in plantation and spice farming Western Ghats districts. 27 (1): 45-53 (2018)
K Kandiannan, K S Krishnamurthy, C K Thankamani & S J Ankegowda
Rainfall analysis of important plantation and spices producing districts such as The Nilgiris (Tamil Nadu), Kodagu (Karnataka), Idukki (Kerala) and Wayanad (Kerala) with 100 years data (1901 to 2000) obtained from the India Meteorological Department (IMD), Pune indicated that mean annual rainfall were 1839.7 mm, 2715.7 mm, 2979.4mm and 3381.0 mm with a coefficient of variation (CV) of 16.0%, 17.0%, 25.8% and 19.6%, respectively. The contribution of southwest monsoon (June-September) to the annual rainfall in these districts were 80.3% (Wayanad), 78.9% (Kodagu), 65.2% (Idukki) and 56.3% (The Nilgiris) with corresponding CV of 24.1%, 20.6%, 32.5%, and 24.6%, respectively. The declining trend in mean annual rainfall was noticed for Idukki, Wayanad and The Nilgiris, whereas,

for Kodagu, it was stable. The change was significant in Wayanad and The Nilgiris. Similar trend was also observed for the southwest monsoon rainfall. The maximum decline in annual and southwest monsoon rainfall was noticed in The Nilgiris followed by Wayanad. Pre and post monsoon rainfall receipts were comparatively less with high inter-annual variations. The pre-monsoon (March-May) receipt and its coefficient of variation (CV) was 252.4 mm and 20.6% (Kodagu), 360.9 mm and 36.5% (Idukki), 251.7 mm and 36.6% (The Nilgiris) and 274.2 mm and 54.2% (Wayanad) 252.2 mm. The post-monsoon (October-December) rain was maximum in Idukki 548.1 mm (CV 27.9%) followed by The Nilgiris 503.4 mm (CV 31.3%), Wayanad, 333.1 mm (CV 37.8%) and Kodagu 310.5 mm (CV 32.7%). In all these districts there was a declining trend in the pre-monsoon rain with maximum decline in The Nilgiris. Similar declining trend was also observed in post-monsoon rain except for The Nilgiris, where the trend has been increasing. Overall, the study gives an indication that there was a spatial and temporal variation in rainfall amounts. The maximum decline in annual rainfall and the southwest monsoon was observed in The Nilgiris and Wayanad. July was the rainiest month in all the districts studied. Significant negative trend was associated with The Nilgiris for January, May, June, July and August months. Whereas, in Kodagu, no significant trend was observed for mean monthly rainfall, except for August. In Idukki, significant negative changes were noticed for January, March, October and December rainfall. Monthly rainfall of January, March, April and July monthly rainfall were showed significant negative trend in Wayanad. These negative trends across important plantation and spices producing districts of the Western Ghats would affect not only the agricultural economy of this sector but also water resources.

Effect of modified atmosphere storage on the shelf life and quality of black pepper and turmeric. 28 (1): 20-26 (2019)
T J Zachariah, E Jayashree & K N Shiva

Modified atmosphere packaging and storage of black pepper (var. Panniyur I) and turmeric (var. Prathiba) were studied for a period of 16 months under ambient storage conditions. Whole dry samples of black pepper and turmeric were packaged in three layered metalized

polyester covers (12 μ polyester + 12 μ metalized polyester + 80 μ LDPE) under three modified storage atmospheres *viz*., 100% vacuum, 100% N_2, 90% N_2 + 10% CO_2 and the control samples were stored in small size jute gunny bags. Results indicated that maximum retention of quality in terms of its essential oil and oleoresin contents of black pepper and turmeric was obtained when stored under nitrogen packaging (100% N_2), followed by vacuum packaged (100% vacuum) and modified atmosphere storage of 90% N_2 + 10% CO_2. The essential oil content of stored black pepper reduced from 2.42% to 2.22% (dry weight basis, dwb) in all the three modified atmosphere storage with a loss of 8.26% while control recorded a loss of 16.53% during storage. The oleoresin content decreased from 7.79% to 7.44%, 7.38% and 7.32% in case of black pepper stored in 100% N_2 packaged, 100% vacuum packaged and 90% N_2 + 10% CO_2 packaged storage atmospheres. The quality loss for turmeric in terms of essential oil, oleoresin and curcumin content at the end of storage, when packaged in 100% N_2 atmosphere were 36.60%, 16.12% and 9.48%, respectively while the corresponding reduction in control samples were 40.49%, 20.27% and 19.39%.

Detection of radiation treatment of spices using Electron Spin Resonance Spectroscopy technique. 30 (1): 107-116 (2021)
A A Khan & M K Shahid

Use of ionising radiation for commercial sterilization to increase the hygienic quality of spices is increasing worldwide. Among several detection methods, Electron Spin Resonance (ESR) spectroscopy is one of the reliable techniques for irradiated foods containing some hard and dried parts. Spices are therefore candidates of such a method and radiation treated spices can be detected. The purpose of the present work was to identify the radiation treatment of spices like cinnamon, cardamom, ginger and rosemary using the sensitive technique of ESR spectroscopy. The spice samples were irradiated to 5, 10, 15 and 20 kilogray (kGy) or unirradiated and the samples were dried in vacuum oven and were placed into quartz tubes for ESR measurement. On measurements, the unirradiated samples were found to show the ESR-signal at g-value of 2.004 that is typical in case of plant foods containing cellulose. Whereas, the irradiated samples

showed a formation of a new paramagnetic structure that appeared in the form of a triplet-signal, attributed to radiation-induced cellulose radical. The clear difference between the nature of ESR signals in case of unirradiated and irradiated samples provided the evidence of the radiation treatment of spices samples. It is therefore concluded that radiation treatment of spices can be identified using sensitive ESR spectroscopy during a storage period of three to ten months.

Characterization of Algerian turmeric and ginger based on their physicochemical, functional and biological properties. 31 (2): 143-156 (2022)
Farida Benmeziane-Derradji & Sara Aoun
The purpose of the study was to characterize (physicochemical properties, functional properties, antioxidant contents and biological activities) of two Algerian spices, turmeric and ginger. The results showed the richness of both spices in phytochemicals especially in polyphenols. Compared to ginger, which showed greater affinity for oil, turmeric powder had more affinity for water. In addition, turmeric swelled more (14.17 ml g^{-1}) than ginger powder (8.33 ml g^{-1}). The methanolic extract showed the highest total antioxidant activities of 470.72 ± 3.13 and 228.73 ± 42.19 AAE 100 g^{-1} for turmeric and ginger respectively. The aqueous extracts didn't show anticoagulant activity while, the methanolic and acetonic extracts showed anticoagulant activity in a dose-dependent manner. As the butanolic extracts prevented the blood clot from forming, it could be used for medical application in future. Therefore, turmeric and ginger are a rich source of bioactive molecules and have functional and biological properties to be exploited in the food and pharmaceutical industry.

Crop Protection

New records of insect and mite pests of spice crops in Andaman Islands, India. 3 (2): 164-166 (1994)
K Veenakumari, Prashanth Mohanraj and H R Ranganath
Eighteen species of insects and one species of mite are reported for the first time from seven spice crops *viz*., cinnamon, clove,

black pepper, nutmeg, curry leaf, chillies and turmeric, from Andaman and Nicobar Islands, India.

Yield losses in ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* L.) due to root knot nematode (*Meloidogyne incognita*). 4 (1): 67-69 (1995)
S Ray, K C Mohanty, S N Mohapatra, P R Patnaik & Pratima Ray
Soil application of carbofuran @3 kg ai/ha 3 weeks after planting resulted in avoidable yield losses to the extent of 33.61 per cent in turmeric (*Curcuma longa* L.) and 26.30 per cent in ginger (*Zingiber officinale* Rosc.) due to *Meloidogyne incognita*. Gall index values were correspondingly high in control plots compared to treated ones in both ginger and turmeric.

Seed-borne fungi of seed spices. 4 (1): 78-79 (1995)
M P Jain & S C Jain
Thirty two fungal species were isolated from four seed spice crops and among them, *Alternaria alternata* was the common, dominant species, ecto and endophytic seed-borne in nature in seeds of cumin (*Cuminum cyminum*), fenugreek (*Trigonella foenum-graecum*), fennel (*Foeniculum vulgare*) and coriander (*Coriandrum sativum*).

Detection of organochlorine pesticide residues in black pepper and clove using tolidine paper. 7 (1): 23-26 (1998)
N Gopalakrishnan & C S Narayanan
A simple method was developed for the quick detection of organochlorine pesticide residues in black pepper and clove using tolidine paper, prepared by wetting filter paper strips in 2% orthotolidine in acetone, Colour development when exposed to sunlight, showed the presence of the pesticide residues, The lower limit to which it can be detected was also estimated using gas chromatography fitted with electron capture detector, The tolidine paper detection technique was quick, reproducible and easy to adopt for the detection of organochlorine pesticides like benzene hexachloride, aldrin, endosulfan and dichloro diphenyl trichlro ethane also in black pepper and clove.

Screening of spices for antimicrobial activity. 8 (2): 135-144 (1999)
Minakshi De, Amit Krishna De & Arun Baran Banerjee
Thirty five spices were screened for their antimicrobial activity against *Bacillus subtilis*, *Escherichia coli* and *Saccharomyces cerevisiae*. The results indicated that clove, cinnamon, bishop's weed, chilli, horse raddish, cumin, tamarind, black cumin, pomegranate seeds, nutmeg, garlic, onion, tejpat, celery and cambodge had potent antimicrobial properties.

Evaluation of substrates for mass multiplication of fungal biocontrol agents *Trichoderma harzianum* and *T. virens*. 8 (2): 207-210 (1999)
M G Prakash, K Vinaya Gopal, M Anandaraj & Y R Sarma
Evaluation of four substrates (neem cake, farm yard manure, coffee husk and tea waste) for the mass multiplication of fungal biocontrol agents *Trichoderma harzianum* and *T. virens* indicated that tea waste was the best media. The cultures mass multiplied in tea waste could also be stored for 3 months without much reduction in the population of biocontrol agents.

Growth inhibition in *Rhizoctonia bataticola* and *Xanthomonas axonopodis* pv. *malvacearum* by herbal oils. 12 (1): 83-85 (2003)
A R Thakare, S G Wankhade, R B Somani & B T Raut
Oils extracted from six medicinal plants *viz*., mentha (*Mentha arvensis*), ocimum (*Ocimum sanctum*), lemongrass (*Cympobogan flexuosus*), citronella (*Cympobogan winternus*), turmeric (*Curcuma longa*) and palmarosa (*Cympobogan martini*) were tested under *in vitro* condition for their antifungal and antibacterial properties. Mentha, ocimum, palmarosa and lemongrass oil exhibited 100% inhibition of *Rhizoctonia bataticola* at 1 and 2% concentrations, whereas citronella oil recorded 100% inhibition at 2% concentration. Turmeric oil was found to be less effective against *Rhizoctonia*. Mentha oil showed the highest (17 mm) inhibition zone against *Xanthomonas axonopodis* pv. *malvacearum* followed by ocimum oil (12 mm). The studies showed that mentha oil possessed very high inhibitory effects on fungi and bacteria.

Antibacterial activity of *Piper nigrum*, *Coriandrum sativum*, *Trigonella foenum- graecum* and *Ferula narthex*. 12 (1): 86-88 (2003)

Dhanya Vijayan, K Deepamol, R Manjula, S Mohan & A K Valsa

The antibacterial activity of water and acetone extracts of black pepper, coriander, fenugreek and asafoetida was tested against six clinically important bacteria namely *Escherichia coli*, *Klebsiella* sp., *Staphylococcus aureus*, *Bacillus* sp., *Salmonella typhi* and *Salmonella paratyphi* A, by disc diffusion method, in the lawn culture of the organisms in nutrient agar. *E. coli* was found to be susceptible to all the extracts, except the water extract of black pepper. The growth of *S. typhi* and *S. paratyphi* A was also inhibited by various extracts. Thus our results support the evidence that spices, not only provide flavour to food, but also check the growth of some of the undesirable bacteria.

Antibacterial activity of certain spice extracts. 12 (2): 146-153 (2003)

Q Mandeel, A Hassan & Z Isa

Seventeen raw spice samples were examined for phytochemical constituents and antimicrobial properties. Qualitative phytochemical analysis of crude spice extracts revealed the occurrence of alkaloids, coumarins, flavonoids, saponins, terpenes and tannins. Turmeric, clove and bay leaf showed the highest frequency of occurrence of these plant components among others. Terpenes were present in 94.12% of the samples evaluated. Ethanol extracts of spice samples were *in vitro* evaluated for their antimicrobial properties using well diffusion assay against six Gram positive and Gram negative bacteria. Results showed that all the spice extracts, except black cardamom, possess biological activity on one or more of the test bacteria. Clove extracts displayed the highest antibacterial activity (19.5 mm) against *Escherichia coli*, followed by bay leaf (19 mm) against the same bacteria and cumin (19 mm) against *Pseudomonas aeruginosa*, at 1000 µg/100 µl. Extracts of galangale, turmeric and fennel also exhibited a broad spectrum biological activity. The most susceptible bacteria, based on frequency values, were *E. coli* (76.4%), *P. aeruginosa* and *Bacillus subtilis* (58.82%) and the least susceptible species were

Salmonella arizonae (23.52%) and *Enterobacter aerogenes* (17.64%) at 1000 µg/100 µl. Overall, the presence of biologically active compounds and potent antimicrobial properties elucidate the potential use of spices in small amounts, individually or in combination in human therapy or folk medicine and as food preservative.

Evaluation of fungal bioagents for management of root-knot nematodes in ginger and turmeric fields. 17 (2): 122-127 (2008)
Santhosh J Eapen, B Beena & K V Ramana
Ginger (*Zingiber officinale* Rosc.) and turmeric (*Curcuma longa* L.) are important herbaceous spices widely cultivated in India. As vegetatively propagated crops, they face significant challenges from pests and diseases, including plant-parasitic nematodes. Root-knot nematodes (*Meloidogyne incognita*) in these crops are typically managed using nematicides, cover crops, and organic amendments. Recognizing the potential for biological control, a series of experiments was conducted at the Indian Institute of Spices Research, Calicut, Kerala, to screen and evaluate fungal bioagents for managing root-knot nematodes under field conditions. Ten antagonistic fungi were tested in nematode-infested ginger and turmeric fields across two locations. The most effective isolates included *Aspergillus nidulans* (Is.10), *Fusarium oxysporum* (Is.11), *Paecilomyces lilacinus* (Is.36), *Trichoderma viride* (Is.25), *Verticillium lecanii* (Is.35), and *Pochonia chlamydosporia* (Is.32). Further testing of *F. oxysporum*, *T. viride*, and *P. chlamydosporia* in ginger fields using two delivery methods-soil bed application and seed rhizome dipping-demonstrated that *P. chlamydosporia* effectively suppressed root-knot nematodes and resulted in the highest yields, regardless of the application method.

Enhancing shelf life of *Trichoderma harzianum* by conidial storage in sterile deionized water. 23 (2): 243-249 (2014)
R Suseela Bhai & M Anandaraj
In this study *T. harzianum* conidial suspension was made in different concentrations of cryoprotectants *viz*., glycerol, glucose, DMSO and deionized distilled water and stored at two different temperatures

viz., 25±1°C and 28-32°C for more than 720 days for evaluating the shelf life in order to develop a ready to use liquid carrier formulation. The results showed that submerged conidia formulation in cryoprotectants like glycerol, glucose and DMSO preserved the viability for 75 days only when compared to the formulation in sterile deionized water which at 28-32°C retained the viability for 480 days with a viable count of $\log_e = 6.671$ (3.2×10^6) and for more than 720 days with a viable count of $\log_e = 5.54$ (2×10^5) and in 480 days at 25±1°C with a viable count of $\log_e = 6.3911$ (6.5×10^6) and with a viable count of $\log_e = 5.40$ (2×10^5) for more than 720 days. The viability was tested *in vitro* by recovery in TSM and effectiveness was tested *in vivo* by drenching the suspension on plants and challenge inoculating with *Phytophthora capsici* after seven days. Challenge inoculation of black pepper plants with *P. capsici* after drenching with diluted stored suspension gave a disease reduction of 66.67%. Hence, sterile deionized water can be used as a liquid storage medium for the long term storage of *T. harzianum* culture without losing the viability and effectiveness of the spores.

Mycotoxigenic *Aspergillus flavus* from ginger and turmeric consumed in the Niger Delta Region of Nigeria. 27 (2): 151-157 (2018)

V C Okereke & M I Godwin-Egein

Ginger and turmeric sold in the open markets and retail outlets in southern Nigeria were sampled between April and August, 2017. This period coincided with the first bimodal peak of the rainy season of the 2017 cropping season. Malt extract agar (MEA) and Dichloran 18% glycerol (DG18) media were used to isolate fungi from samples with or without surface sterilization. *Aspergillus* spp. isolated were examined for the production of orange-yellow pigmentation and blue fluorescence on the reverse side of the plate on CAM under UV light. Aflatoxin production by *Aspergillus flavus* on yeast extract sucrose (YES) was verified quantitatively using High Performance Liquid Chromatography (HPLC). Data showed that *Fusarium*, *Penicillium* and *Aspergillus* spp. were the dominant fungal flora. Toxigenic isolates of *A. flavus*; AFg_1, AFg_3, AFt_1, and AFt_3 produced both orange-yellow pigmentation and blue fluorescence on CAM. The production of

AFB_1 and AFB_2 on YES medium was confirmed using HPLC. The occurrence of toxigenic fungi indicates that there is a potential risk of mycotoxin contamination in ginger and turmeric consumed in southern Nigeria and problems can arise from contamination with aflatoxins.

Post-flood outbreak of *Xylosandrus crassiusculus* and *Diuncus corpulentus* (Coleoptera: Curculionidae: Scolytinae: Xyleborini) on tree spices in Kerala. 27 (2): 161-166 (2018)
K D Prathapan & S R Hiremath
Massive outbreak of *Xylosandrus crassiusculus* and *Diuncus corpulentus* (Coleopera: Curculionidae: Scolytinae: Xyleborini) on clove (*Syzygium aromaticum*) and nutmeg (*Myristica fragrans*) is reported from Kerala, India. Infestation results in drying up of branches and death of trees. This is the first report of the ambrosia beetle genera *Xylosandrus* and *Diuncus* on clove and nutmeg.

A modified semi-selective medium for isolation and enumeration of *Pochonia chlamydosporia* (Goddard) Zare & W. Gams. 30 (1): 117-125 (2021)
M K Rincy, R Praveena & S J Eapen
Pochonia chlamydosporia, is one of the most promising biological control agents for managing phytoparasitic nematodes. Isolation and enumeration of viable colonies of *P. chlamydosporia* from soil and other substrates without contamination is a major limitation, when commonly available nutrient media are used. Development of a suitable selective/semi-selective media by incorporating one or more inhibitors of microbial growth can facilitate isolation of the fungus. *In vitro* studies were carried out to test the compatibility of commonly used pesticides, namely, metalaxyl, metalaxyl-mancozeb, carbendazim, copper oxychloride, and chlorpyrifos with *P. chlamydosporia*. The fungus showed relatively high tolerance to higher doses of metalaxyl and carbendazim and was used in the modified medium for better suppression of other soil-borne fungi. In the present study, Kerry's semi-selective medium was modified and evaluated by counting the viable fungal propagules in different substrates (rice, farmyard manure, maize, rice bran, barley, and

sorghum) and soil artificially inoculated with the fungus. The results showed that the modified Kerry's semi-selective medium can effectively be used for isolation and quantification of *P. chlamydosporia* in routine studies.

Social Sciences

Growth and instability in area, production and yield of major spice crops in Rajasthan *vis-à-vis* India. 14 (2): 102-111 (2005)
R C Kumawat & P C Meena

A study on growth and instability in area, production and yield of spice crops such as coriander (*Coriandrum sativum*), cumin (*Cuminum cyminum*), fenugreek (*Trigonella foenum-graecum*), fennel (*Foeniculum vulgare*), garlic (*Allium sativum*) and chilli (*Capsicum annuum*) in Rajasthan *vis-à-vis* India indicated that almost all the spices registered significant growth rates in their production in Rajasthan as well as in India during the entire study period mainly due to significant increases in the same during post-Technology Mission on Oilseeds (TMO) period (1986-87 to 2000-01). The significant increase in production in coriander was mainly due to significant increase in yield whereas in cumin and fennel, it was due to significant increase in area. In fenugreek, the increase in production was the result of increase in both area and yield. In case of chilli and garlic, both area and yield at the national level and only area at the state level played significant role in increasing the production. In majority of the spice crops the instability in production increased during the post-TMO period over the pre-TMO period (1967-68 to 1985-86) in Rajasthan and India as well. However, the magnitudes of coefficients of variations were more pronounced at the state level than at the national level. The instability in area in the state was higher in the post-TMO period than in the pre-TMO period. The same was true of India except that the magnitudes of coefficients of variations were less at the national level. In general, yield instability, on the other hand, decreased during the post-TMO period over the pre-TMO period in both Rajasthan and India. As regards sources of variance of production, area variance played a dominant role in case of coriander, cumin, fennel and garlic. Yield variance predominantly

destabilized the production of chilli in Rajasthan and of fenugreek in India. In majority of spices, area-yield covariance helped stabilize the production in Rajasthan as well as in India.

Economic viability of large-scale production of the biocontrol agent *Trichoderma harzianum* Rifai. 15 (1): 48-51 (2006)
M S Madan, K V Ramana, K A Manoj, M Anandaraj, R Suseela Bhai & I S Meera

The economic viability of large scale production of the biocontrol agent *Trichoderma harzianum* effective against the soil-borne disease Phytophthora foot rot (caused by *P. capsici*) of black pepper (*Piper nigrum*) was studied. The enterprise was highly profitable for the entrepreneur with a benefit:cost ratio of 1.84. The investment returned a net present worth of Rs. 2,42,618 @ 11% interest rate for 10 years period with an internal rate of return of 121%.

Inter-regional variations and future household demand and production of major spices in India. 22 (1): 47-54 (2013)
S K Srivastava, R Kumar, M Hema & R Hasan

India is the largest producer, consumer and exporter of spices in the world with around 52 spices under the purview of Spices Board. The present paper diagnoses the consumption and production pattern of the major spices in India both spatially and temporally and projects their demand and production in future using statistical tools. Spices basket was found to be dominated by dry-chilli and there exists wide regional variations in their consumption across the country. Production of spices follows the same pattern with dry-chilli occupying maximum area under cultivation. Projected figures confirmed domination of dry-chilli in future also. Region specific consumption as well as production of spices necessitates region specific production policies along with the suitable marketing strategies to increase the welfare of both producers as well as consumers.

Spatio-temporal growth of garlic and onion crops in Gujarat. 23 (1): 119-120 (2014)
N J Ardeshna and R L Shiynai
The growth in area, production and yield of onion and garlic in different districts of Gujarat was studied. The secondary data for the period from 1990-91 to 2007-08 was collected and analyzed. The annual area, production and productivity of onion significantly increased at the rate of 6.50%, 9.96% and 0.68%, respectively. In case of garlic, the annual growth was 2.98%, 4.61% and 1.52%, respectively.

Trends of area, production and productivity of spices in the northeastern region. 24 (2): 112-118 (2015)
A Sharma
The present study was undertaken to analyze the trends in area, production and productivity of major spices in the northeastern (NE) region. The study was based on secondary data from 1982-83 to 2011-12. The data was collected from several government publications and web sites. To analyze the trend of area, production and productivity of major spices in NE region, the linear, quadratic and exponential functional forms were used. To fit the trend, exponential functional form was used due to its higher R^2 value as compared to other two forms. Besides these, compound growth rate, coefficient of variation and instability index was also estimated. The effects of area, productivity and their interaction towards increasing production were also estimated. The cultivation of spices was not risky in the NE region as revealed by the lower coefficient of variation. The coefficients of variation (CV) of area, production and productivity of spices were less than 4.16%. The instability indices for area, production and productivity for spices in the NE states were positive, which indicated less variation in growing spices in the region.

REVIEWS

Crop Improvement and Biotechnology

Vegetative propagation of major tree spices - A review. 6 (2): 87-106 (1997)
J Rema, B Krishnamoorthy & P A Mathew
Vegetative propagation of major tree spices grown in India namely, nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum verum*), cassia (*C. aromaticum*), allspice (*Pimenta dioica*), cambogia (*Garcinia gummi-gutta*), kokam (*G. indica*), tamarind (*Tamarindus indica*) and pomegranate (*Punica granatum*) are reviewed. The propagation methods reviewed include cuttings, air layering, budding, grafting and micropropagation.

Molecular markers in improvement of *Capsicum* spp. A review. 15 (1): 1-13 (2006)
Deepu Mathew
Use of various molecular markers in improvement of *Capsicum* spp. including genetic diversity analysis, fingerprinting, mapping the genes of interest with special reference to pungency and stress resistance, seed purity analysis, phylogenetic studies, genomic library construction and linkage analysis has been well demonstrated. This paper reviews the advancement and information available on the use of RAPD, RFLP, AFLP, ISSR, SPAR, CAPS and SCAR markers in crop improvement programmes in *Capsicum* spp.

Nutrition of black pepper (*Piper nigrum* L.) - A Brazilian experience. 18 (2): 73-83 (2009)
Fábio Luiz Partelli
Despite investment risk and price variations, among other difficulties, Brazilian farmers are still investing in black pepper (*Piper nigrum*) cultivation due to relative price increment over the years. Action has already been implemented, on improvement of cultivars and diagnosis, fertilization and irrigation, based on technical information for increasing the productivity of the crop. Adequate nutritional

diagnosis, based on a proper sample method and regional patterns, will result in efficient input recommendation with a consequent improvement in production with higher sustainability. The DRIS (Diagnosis and Recommendation Integrated System) has been extensively used in Brazil, which contributes to efficient nutrition diagnosis and fertilizer recommendation. The use of simple cultural procedures such as use of cover crops and organic fertilization, among others, has a great potential to control weeds, improve soil quality and mineral nutrition in black pepper, contributing to sustainable production. This review includes information on research work being undertaken in Brazil, on black pepper nutrition (nutrient extraction, foliar patterns, nutritional diagnosis and fertilizer recommendations), including fertilization and diagnosis strategies for increasing the productivity of the crop.

Advances in adulteration and authenticity testing of turmeric (*Curcuma longa* L.). 28 (2): 96-105 (2019)
B Sasikumar

Synthetic colorants such as metanil yellow, lead chromate, Acid orange 7, Sudan red; rhizomes of related *Curcuma* sp. besides spent turmeric, starch, chalk and yellow soapstone are the main adulterants in traded turmeric while synthetic curcumin is an adulterant of natural curcumin. Both branded products as well as the produce from the unorganized sector are found adulterated. The adulterants, added either to increase the bulk, improve the colour and appearance or enhance the profit margin, often result in corroding the biological efficacy of the commodity and eroding the public impression besides posing health risks to the consumers. Various physical, chemical and PCR based methods are available to detect the adulterants in traded turmeric. While chemical methods are suited to detect the synthetic adulterants and spent turmeric, DNA based methods are the best options for detecting the biological adulterants (except spent turmeric) in the commodity. Along with adopting a supply chain system and quality linked pricing in turmeric trade, commercial adulteration diagnostic kits, if they can be developed and deployed, will be a very convenient way to ensure the quality of the traded produce.

Nutmeg - Origin, diversity, distribution and history. 30 (2): 131-141 (2021)

B Sasikumar

Nutmeg *(Myristica fragrans* Houtt.) a small holder's crop, with 3500 years of antiquity originated in the Moluccas, Indonesia, is now grown in about 12 countries including some secondary centres of domestication. Centres of domestication overlap the centre of origin in nutmeg. Out of about 175 species in the genus, only five are economically important. Besides species diversity and cultivar diversity, ecosystem diversity is also a component of biodiversity of the genus. The genus is represented by six species including four endemic species and subspecies each in India. A comprehensive work on Indian Myristica is pertinent. The history of the spice is mired in bloody wars, piracies, privateers, clandestine collection trips, wanton felling of the heirloom trees besides inadvertent specimen identity, inaccurate chronology and a treaty of land swap. Though French and British colonial rulers took interest in popularizing nutmeg in their colonies albeit for economic gains, the role of French was pivotal. The package of practices of nutmeg (Colonial Horticulture) in the new French colonies were a complex process of creolizing the expertise borrowed from the native people of the Moluccas with the horticultural knowledge of the colonists, traders, settlers, slaves and other local residents. Though nutmeg, a perennial tree of about 100 years of life span, has only about 300 years of domestication history in the country, the cultivar diversity is amazing as exemplified by the high frequency of farmer's varieties. The nutmeg population of the country also exhibits good phenotypic plasticity as demonstrated by leaky dioecy. While the transnational spread of nutmeg is a legacy of colonial rulers, the settlers mainly Christians, are credited with the intrastate spread of nutmeg in Kerala, the major area of production in India. History of nutmeg is still in an emerging phase and there are gaps in our understanding.

Diversity and distribution of vetiver grass (*Chrysopogan zizanioides* (L) Roberty) and its manifold uses: A review. 32 (1): 1-13 (2023)

Ankit Pandey & S C Tiwari

During the last few decades essential oils derived from different herbs and aromatic plants have received a growing focus of scientific investigation due to their multifunctional uses beyond their traditional roles as food additives and scents. Over 3000 species have been identified as medicinal plants that produce essential oils. Vetiver grass has wide range of diversity throughout the world with diverse genotype variability. It has multifarious uses in various agricultural, medicinal, aromatic, engineering, conservational and in industrial sectors. The *C. zizanioides* is well known in various regions of South Asia, Southeast Asia, and West Africa. Vetiver roots, particularly those from Karnataka, have been utilized to make herbal drinks that are energizing to combat tiredness. The vetiver grass, referred as "vetiver" or "vetiver–vetiver" in India, serves a variety of purposes in aromatic, pharmaceuticals, food, and beverage industries. This paper presents a review of the diversity and distribution of this crop along with its various uses and applications.

Crop Production and Postharvest Technology

Postharvest technology of spices: Pre-treatments, curing, cleaning, grading and packing. 1 (1): 1-29 (1992)

J S Pruthi

The postharvest technology of spices comprises of a whole gamut of operations such as pre-treatments, chemical treatments, curing and similar operations, drying, cleaning, sorting, grading and packing. These aspects are briefly covered in this review. Wherever applicable the problems involved and the relative advantages and disadvantages of the various processes are indicated.

Flavour characteristics of *Piper betle* L. 1 (1): 30-38 (1992)
V R Balasubrahmanyam & A K S Rawat
The betel leaves are aromatic with varied taste ranging from sweet to pungent due to the presence of essential oil. Compounds that contribute to the pungency, flavour and stimulating properties of the leaf are of interest to the flavour industry. The results of investigations carried out so far on the chemical analysis of essential oil of betel leaves have been reviewed. The results of the gas chromatography and mass spectrometry (GCMS) of the oil of all the five recognized varieties of *Piper betle* are discussed. The yield and composition of essential oil of betel leaves have been influenced by age and position of the leaf on the stem, season of harvest, potassium nutrition etc. Promoting the use of this important essential oil in flavour industry and confectioneries so as to utilise the surplus leaves from the assembling and wholesale markets which will otherwise go waste is suggested.

Microbial infestation in black pepper and its control measures. 1 (2): 113-124 (1992)
J S Pruthi
The information available on nature and extent of microbial contamination in black pepper and various processes developed for their elimination are reviewed.

Large cardamom (*Amomum subulatum* Roxb.) - A review. 2 (1): 1-15 (1993)
Y S Rao, Anand Kumar, Sujatha Chatterjee, R Naidu & C K George
Large cardamom (*Amomum subulatum*) is the most important cash crop of Sikkim and also in parts of North Eastern States and West Bengal in India. The information available on various aspects of the crop *viz*., improvement, management, pests and diseases and end products are discussed in the review.

Agronomy of tree spices (clove, nutmeg, cinnamon and allspice) - A review. 3 (2): 105-123 (1994)
C K Thankamani, K Sivaraman, K Kandiannan & K V Peter
Clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans*), cinnamon (*Cinnamomum verum*) and allspice (*Pimenta dioica*) are important tree spices and have economic value as ingredients in food, beverages and medicines. Agronomical aspects like nursery practices, selection of site, spacing, planting, manuring, mulching, weeding, irrigation and harvesting are important packages for higher and sustainable yield. The available information on these aspects are reviewed.

An appraisal of ginger (*Zingiber officinale* Rosc.) production in Sikkim, India. 4 (2): 111-118 (1995)
Patiram, R C Upadhyaya & L N Singh
A general description of Sikkim and various aspects of cultivation and marketing of ginger (*Zingiber officinale*) in the state are discussed. The trend in production and major constraints in productivity are also dealt with.

Agronomy of ginger (*Zingiber officinale* Rosc.) - A review. 5 (1): 1-27 (1996)
K Kandiannan, K Sivaraman, C K Thankamani & K V Peter
Ginger (*Zingiber officinale*) is grown in tropical and sub-tropical regions of the world for it's spice and medicinal values. Successful production of ginger depends on efficient use of available resources by adopting suitable agronomic practices. Such practices like land preparation, seed selection, seed rate, seed treatment, planting season, depth of planting, mulching, nutrient management, use of growth regulators, weed control, irrigation, shade requirement and harvest management are reviewed in detail. The review also covers climatic requirement for cultivation, soil suitability, establishment and growth, pests and diseases, cropping systems, ratooning and economics of cultivation.

Research and development of spices in India. 7 (2): 75-80 (1998)
S Edison (Presidential address)

Agronomy of black pepper (*Piper nigrum* L.) - A review. 8 (1): 1-18 (1999)
K Sivaraman, K Kandiannan, K V Peter & C K Thankamani
Black pepper (*Piper nigrum* L.), a highly valued spice crop, is a perennial vine which originated in the Western Ghats of India and subsequently spread to other countries. Various aspects of crop ecology and agronomical practices such as planting material production, spacing and supports, training and pruning, irrigation, mulching and weeding, nutrition, harvest and cropping systems are reviewed.

Spices research - A crystal gazing. 9 (1): 3-12 (2000)
P N Ravindran
The direction of research on spice crops especially black pepper (*Piper nigrum*) and cardamom (*Elettaria cardamomum*) during the present century has been conceptualized. The revolution that is likely to be created by genetic engineering and biotechnology in the areas of germplasm conservation, crop improvement, crop protection, crop management and postharvest technology, resulting in tremendous increase in productivity of spices has been highlighted.

Agronomic studies in cymbopogons - A review. 9 (1): 13-22 (2000)
K Singh, S K Kothari, D V Singh, V P Singh & P P Singh
Research on agronomic aspects of cymbopogons, Java citronella (*Cymbopogon winterianus*), palmarosa (*C. martinii*) and lemon grass (*C. flexuosus*) with respect to soil and climatic conditions, propagation, manures and fertilizers, irrigation, weed control and harvesting schedules to manipulate their yield potential and quality of produce has been reviewed.

Review of research on kokum, camboge and related spices. 11 (1): 1-12 (2002)

Gilu Lizy George, R Lakshmanan, K Mary Mathew & Y S Rao

Garcinia species are distributed throughout the tropics and have tremendous potential, both as spice and medicinal plants. Though there are more than 200 species in the genus, only 20 are found in India. The two species namely *Garcinia gummi-gutta* (L.) Rob. (camboge) and *G. indica* Choisy (kokum) are widely distributed in the Western Ghats and very popular in the South Indian cuisine. Recently *Garcinia* excited the scientific world for possessing properties that regulate obesity. Though commercially important, these species remained neglected and not much attention was given for their research and development. In this review, an attempt has been made to collect and compile the available information so that areas of interest could easily be identified for further investigation and research.

Processing and quality of black pepper - A review. 12 (1): 1-13 (2003)

P Heartwin Amala Dhas & V S Korikanthimath

Processing of pepper involves different unit operations such as threshing, blanching, drying, cleaning, grading and packaging. these operations are important to ensure clean and quality products. Various mechanical gadgets available for threshing, cleaning, drying, etc. are reviewed. A wide range of threshers with a capacity ranging from 50 to 1200 kg ha^{-1} are available. However, some of the threshers and cleaners need improvisation for commercial acceptability. Cleanliness and quality standards like Agmark, standards prescribed by American Spice Trade Association (ASTA) and European Spice Association (ESA) are reviewed. Different methods for preparation of value added products like dehydrated green pepper, canned green pepper, white pepper, ground pepper, pepper oil, etc. have also been covered in this review.

Pharmacology and chemistry of *Myristica fragrans* Houtt. - A review. 14 (2): 94-101 (2005)
P G Latha, P G Sindhu, S R Suja, B S Geetha, P Pushpangadan & S Rajasekharan
The information available on the pharmacology and chemistry of nutmeg (*Myristica fragrans*) has been reviewed and the areas of interest for further investigation have been suggested.

Health benefits of bioactive molecules from spices and aromatic plants. 21 (2): 87-101 (2012)
M Gunasekar, K Geemon & S J Mariwala
Spices are essentially used to improve the appeal and sensory characteristics of food. The bioactive compounds, which are the key natural flavour and fragrance ingredients of various spices and other aromatic plants play a vital role in healthcare. These are discussed with reference to the recent research carried out in anti-inflammatory, anti-arthritic, neuro-protective, cardiovascular, diabetic support, body weight management, wound healing, antioxidants, antimicrobial as food preservatives, ocular and oral health as well as in aroma-therapy with emphasis on human health and green chemistry.

Garlic nutrient management in Ethiopia - A review. 25 (2): 91-103 (2016)
G Diriba-Shiferaw
The main aim of this review is to provide an overview of the garlic crop productivity and its production management requirements like soil, climate and fertilization in general and specifically in Ethiopia, comparing them with current research trends and to indicate future benefits of soil nutrient management investigations. The application of balanced nutrients under optimum moisture availability in different soil types is an important crop management strategy, which may help maximizing crop yield and quality. Also, lack of optimum nutrients and moisture in the soil has been the major bottlenecks of garlic production and productivity; since the crop has a very shallow root system that requires frequent irrigation and fertilization with different types of fertilizers under various soil types. Low soil fertility

is one of the principal and pervasive constraints to garlic production in Ethiopia; thus, there are differences among soil types in yielding ability under different nutrients and soil characteristics. Most smallholder farmers in Ethiopia appreciate the value of fertilizers, but they seldom apply them at the recommended rates and at the appropriate time according to the soil characteristics. These are because of high cost, lack of credit, delivery delays, and low and variable returns. In addition, the traditional organic inputs, like crop residues and animal manures, it cannot meet crop nutrient demand over large areas because of the limited quantities available, the low nutrient content of the materials, and the high labor demands for processing and application. However, it is possible to increase garlic crop yields through identification/selection of soil type and balanced nutrients application or searching for other nutrients sources beyond urea and diammonium phosphate especially in Ethiopian condition. Therefore, the integrated use of both the organic and inorganic fertilizers was felt as the best option to increase both yield potential and quality of garlic crop.

Instrument-based detection methods for adulteration in spice and spice products - A review. 27 (2): 106-118 (2018)
S K V Bharathi, A Sukitha, J A Moses & C Anandharamakrishnan
Spices play an important role as flavourants, colourants, preservatives and bioactive compounds in medical, food and cosmetic applications. India is the spice bowl of the world and spice production is scattered across the country. Almost every stage of production, including cultivation, harvest, handling, storage, transportation and distribution has impact on spice quality. Adulterants are often intentionally added to fetch better market value through inferior/unacceptable quality products. Adulterants are a concern to quality, market compliancy and food safety. Over the years, several approaches for quantitative and qualitative detection of adulterants have been developed. Though basic and simple testing methods are available to detect the presence of adulterants, instrument-based techniques are often adapted to detect the adulterants quantitatively. The objective of this work is to present a detailed note on these approaches with emphasis on the

various analytical techniques used in the detection and quantification of adulterants in spice and spice products.

Major Indian spices - An introspection on variability in quality. 29 (1): 1-20 (2020)
T J Zachariah
Indian spices like black pepper, cardamom, ginger, turmeric and cinnamon are valued for their culinary and nutraceutical properties. The quality attributes that impart these properties are essential oil, oleoresin and the aroma/pungent principles. Variability in essential oil constituents of black pepper, relevance of bulk density, codex standards and role of phenolics in deciding quality traits possess great relevance in academic and industrial applications. Curing of turmeric and maturity at harvest play a crucial role in drying and curcumin content. Geographical location has great relevance in deciding the curcumin content of turmeric. Coumarin content of cinnamon and cassia has implications in industrial application. This article provides an introspection in to the research programmes on quality attributes of spices carried out at ICAR-Indian Institute of Spices Research for the last three decades in comparison with international scenario.

Spice bioactives in edible packaging. 29 (2): 81-97 (2020)
K Ravi, K Goyal, S Priyadarshi & M M Naidu
Edible packaging received significant attention in recent years. The main advantage of edible packaging over synthetic packaging is that they are environment friendly. The material used in edible packaging (lipids, polysaccharides, proteins) is generally recognized as safe and it acts as a barrier to gases, light and moisture. Spices have been traditionally used for its medicinal value. Spice extract or its essential oil possesses various bioactive compounds which are known for their antioxidant and antimicrobial property. Incorporation of spice extract or its essential oil into edible packaging exerts antimicrobial activity against the food pathogens thus preventing food spoilage and enhances the shelf-life and also increases the nutritional value of the final product. Antioxidant properties of spices retard the lipid oxidation. Dietary allergy and intolerance are also associated with packaging material and spices. Because of the high cost of film-

forming material, scaling-up of edible packaging has remained a problem.

Spices for taming the COVID-19 pandemic : Prospects and perspectives. 30 (1): 1-23 (2021)
S J Eapen
Coronavirus Disease 2019 (COVID-19), first reported in December 2019 from Wuhan in China, had reached the stage of a pandemic. To date (28.06.2021), there are more than 181.9 million confirmed cases of the disease in the world. Even though vaccines have been developed, antiviral drugs are yet to be developed for management and treatment of SARS-CoV-2. Since several medicinal plants are used in traditional medicines, though with controversial efficacy claims, they can be considered as sources of new antiviral drug compounds against emerging viruses. In this context, spices are noteworthy as their anti-oxidant, anti-viral, anti-inflammatory and immunostimulatory properties are well studied and documented. The emerging scientific literature includes a number of papers on the anti-SARS-CoV-2 activity of spice extracts and specific compounds proven through different types of laboratory experiments. Here, the information pertaining to anti-viral properties of spice-based phytochemicals or natural compounds (not crude extracts) is summarized in this review. Spice-based compounds discussed here are an option for testing in COVID-19 patients though we don't have strong data to support their active recommendation. Because of their natural origin, safety, and low cost, they can be a viable option in our fight against viruses and this compilation may be useful for planning and designing more robust experiments in future.

Radioprotection by curcumin : A mini review. 30 (1): 24-33 (2021)
P Sruthi & M M Naidu
Ionizing radiations are detrimental to the biological system. Exposure to ionizing radiations results in many chronic diseases including cancer. It may cause dysfunctions to almost all organs of the body depending on the total dose, duration and site of irradiation. Apart from its bad effect, radiotherapy is now extensively used for the

treatment of several kinds of cancers. Still, the key disadvantage in the procedure is that normal cell, in the surrounding area of the tumour, also receiving radiation doses similar to the tumour, leads to undesirable side effects and risk to patients. Curcumin has been found to protect harmful effects of ionizing radiation. So, it can be beneficial during radiotherapy of cancer. Curcumin helps to kill tumour cells effectively by enhancing the effect of radiation. It also protects normal cells against the harmful effects of radiation. Pre-clinical studies are expected to lead to clinical trials to prove the potential of this age-old golden spice for treating cancer patients. This review summarizes the protective effect of curcumin against harmful radiations.

Spices of the Pacific region with special reference to vanilla and ginger production: Challenges and the way forward. 31 (1): 1-14 (2022)

K Kandiannan, Shalendra Prasad & Amena Banuve

The Pacific region (Oceania) is divided into four sub-regions (i) Australasia (Australia and New Zealand), (ii) Melanesia, (iii) Micronesia, and (iv) Polynesia and the population of this region is around 0.5% of the global population. There are 14 independent countries and 12 dependent overseas territories in Oceania. Most of the countries are smaller in size, less developed (except Australia and New Zealand), remotely placed and vulnerable to natural calamities. Spices are mostly introduced crops to this region. Turmeric was the earliest spice introduced to this region. The Missionaries and Europeans who colonized these regions introduced many other spices. British introduced ginger to Australia during 1788. Fiji is an important South Pacific country, where Fiji-Indians consume considerable amount of spices. Black pepper and vanilla were introduced during 1880's; ginger before 1890 (probably from Australia), cardamom, nutmeg and clove during 1930's to Fiji. The FAO statistics provide data on spices production from ten Oceanica countries with a total production of 618914 tonnes which translates to 0.3% of the global spices production. The spice crops of the region are chillies, onion, garlic, ginger, turmeric, vanilla, nutmeg and coriander. Other spices like tamarind, mango, (tender mango) cinnamon, curry leaf, herbal spices are produced in small scale and

exported within the region. Spice crops like clove, allspice, black pepper, small cardamom are also grown by a few individuals in limited number. There is not much research work on spices except for ginger in Australia and a few on vanilla diseases from the Pacific region. This review provides the status of spices in the Pacific region focusing on ginger and vanilla which helps to understand the status of spices of Oceania. The information complied here may help in designing strategies for enhancing spice production and trade, which can positively influence the economy of the region.

Review on agronomic investigations on cardamom and cardamom-based cropping systems in Karnataka. 31 (2): 111-133 (2022)

V S Korikanthimath & K S Krishnamurthy

Small cardamom (*Elettaria cardamomum* Maton), an eco-friendly high value spice and foreign exchange earner, is a native of Western Ghats of South India. India enjoyed near monopoly in its production till the seventies, but with the emergence of Guatemala as the main competitor, it has been relegated to second position both in production and export. The low production of cardamom up to eighties was due to lack of sound location specific agronomic package of recommendations. Hence, after a detailed survey of entire small cardamom growing areas in India and interaction with cardamom growers and other stake holders, a comprehensive location specific research programme was finalised and carried out for over 25 years. As a consequence of detailed agronomic investigations on cardamom and cardamom-based cropping systems, various agro techniques such as selection of elite lines of cardamom, rapid clonal multiplication technique, nursery techniques, systems and season of planting, irrigation, shade and weed management, apiculture, harvest and post harvest techniques, multistoried cropping system involving cardamom, coffee, arecanut, coconut etc. evolved. These high production technologies were effectively transferred to the cardamom growers based on local specificity which resulted in higher yields (average of 750 kg dry capsules ha^{-1} and a potential yield of 1945 kg dry capsules in demonstrations in farmers' fields in Kodagu,

Karnataka) from an initial benchmark average yield of 120-140 kg dry capsules ha^{-1}.

Crop Protection

Parasitic nematodes and their management in major spices. 4 (1): 1-16 (1995)
K V Ramana & Santhosh J Eapen
Black pepper (*Piper nigrum*), cardamom (*Elettaria cardamomum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and tree spices are the major spices cultivated in India. Several plant parasitic nematodes are reported on these spice crops and among them, root knot nematodes (*Meloidogyne* spp.), burrowing nematodes (*Radopholus similis* and root lesion nematodes (*Pratylenchus* spp.) are the major nematode pests of economic importance. Plant parasitic nematodes are primary incitants of slow decline disease of black pepper. Root knot nematodes are a serious constraint to cardamom cultivation, especially in nurseries. In ginger and turmeric, all three of them cause significant damage. However, not much attention has been given to nematodes of tree spices. The major symptoms of nematode attack, the nature and extent of damage, their interaction with other soil borne microorganisms and various control measures are discussed. Considering the export oriented nature of these crops, emphasis has been given on integrated nematode management with minimum use of chemicals.

Diseases of black pepper (*Piper nigrum* L.) and their management. 4 (1): 17-23 (1995)
M Anandaraj & Y R Sarma
Among the diseases reported on black pepper (*Piper nigrum* L.), blight, root rot and basal wilt in the nursery; foot rot, slow decline and anthracnose in the field are important. Stunted disease, phyllody and leaf spots are also becoming serious. The symptomatology, causal organisms and control measures of major diseases are outlined in this paper and future lines of work suggested.

Fungal and bacterial diseases of cardamom (*Elettaria cardamomum* Maton) and their management. 4 (1): 24-31 (1995)
Joseph Thomas & R Suseela Bhai
Small cardamom (*Elettaria cardamomum*) is susceptible to a number of diseases due to fungi, bacteria and viruses. Twenty six different types of diseases have been reported of which only a few have been considered as major causing severe crop losses. The major diseases of fungal origin are '*Azhukal*' (capsule rot) caused by *Phytophthora meadii*, rhizome rot (clump rot) and seedling rot (damping off) caused by *Pythium vexans*, leaf blight caused by *Phytophthora meadii*, leaf blotch caused by *Phaeodactylium alpiniae* and leaf spots by *Cercospora* sp., and *Sphaceloma cardamomi*, leaf rust by *Phakospora elettariae*, brown spot by *Colletotrichum gloeosporioides* etc. Most of the diseases occur during the South West monsoon period where heavy rain coupled with high relative humidity predisposes the plant to infection. Since the occurrence and spread of diseases are correlated to weather conditions, integrated disease management strategy adopting cultural, chemical and biological control methods are highly suitable to save the crop from heavy losses.

Viral diseases of cardamom (*Elettaria cardamomum* Maton) and their management. 4 (1): 32-39 (1995)
M N Venugopal
Small cardamom (*Elettaria cardamomum* Maton) is affected by many diseases which have been identified as a major production constraint. Among the viral diseases '*katte*' or mosaic is the major viral disease causing severe yield losses to an extent of 68 per cent. In addition, Nilgiri necrosis, infectious variegation virus and '*kokke kandu*' diseases are gaining importance in recent years. The present paper reviews the information available on distribution of viral diseases, symptomatology, crop loss, transmission, etiology, host range and disease management. The future plan of work on aspects such as breeding for disease resistance through genetic engineering, virus characterization and early detection methods are indicated.

Diseases of ginger (*Zingiber officinale* Rosc.) and their management. 4 (1): 40-48. (1995)
G N Dake
Ginger (*Zingiber officinale* Rose.) suffers from 24 diseases of fungal, bacterial, viral and mycoplasmal origin. Of them, soft rot (*Pythium aphanidermatum*), yellows (*Fusarium oxysporum* f. sp. *zingiberi*), bacterial wilt (*Pseudomonas solanacearum*), Phyllosticta leaf spot (*Phyllosticta zingiberi*) and storage rot by many pathogenic, saprophytic fungi and bacteria are of economic importance because of their potential to cause great losses to ginger production. The constraints in disease management and the strategies that have been developed to manage the diseases involving cultural, chemical and biological methods combined with soil solarization are discussed. Future options for the management of ginger diseases by integration of conventional strategies with modern biotechnological means for effective control measures are also discussed.

Diseases of turmeric (*Curcuma longa* L.) and their management. 4 (1): 49-56 (1995)
T G Nageshwar Rao
Turmeric (*Curcuma longa* L.) is severely affected by soil borne as well as foliar diseases. Rhizome rot takes a heavy toll in majority of turmeric areas. Among foliar diseases, leaf blotch and leaf spot are important. Several minor diseases have also been reported on the crop. Future studies on crop loss assessment due to these diseases, their epidemiology under .different cropping systems and the role of biocontrol agents and organic amendments in disease suppression need a thorough investigation to develop appropriate disease management strategies. The present status of turmeric diseases and future strategies for their management are outlined in this paper.

Diseases of cumin (*Cuminum cyminum* L.) and their management. 4 (1): 57-60 (1995)
S R S Dange
Cumin (*Cuminum cyminum* L.) is affected by wilt, blight and powdery mildew diseases which are responsible for heavy yield losses. Witches-broom, probably caused by MLO, has also been

reported from Rajasthan. The symptoms of these diseases and management schedules to be adopted are discussed.

Prevalence of fungal diseases of large cardamom (*Amomum subulatum* Roxb.) in Sikkim, India. 4 (1): 64-66 (1995)
L S Srivastava
The information available on the prevalence of various fungal diseases of large cardamom (*Amomum subulatum* Roxb.) in Sikkim are discussed.

Use of indigenous plant products for management of pests and diseases of spices and condiments : Indian perspective. 20 (1): 1-8 (2011)
R T Gahukar
Plant derived preparations and formulated commercial products have great potential for eco-friendly management of pests and diseases of spice and condiment crops in India. These products act as antifeedant, growth regulator, repellent and a direct mortality factor against pests and as inhibitor of sporulation and development of hyphae of fungal pathogens. However, further research on field application, residual toxicity, synergistic action and hazardous effects on non-target organisms are needed.

Cumin wilt management - A review. 23 (2): 145-155 (2014)
S Lodha & R Mawar
Cumin (*Cuminum cyminum* L.) is one of the oldest seed spice and an important production constraint is wilt caused by *Fusarium oxysporum* f. sp. *cumini* Prasad and Patel (*Foc*) and crop losses could be up to 60%. Maximum population of *Foc* was estimated at 0-5 cm soil depth in the presence of crop, but the population density tended to decline progressively with distance from the surface. Resting structures of the *Foc*, the chlamydospores, survive in the soil for more than 10 years. The inoculum density in the soil increases with each year of cumin cultivation and is directly proportional to disease incidence in the field. In this review, an effort has been made to compile research findings generated during past four decades on symptomatology, ecology and management strategies. In the absence

of resistant sources against *Foc*, to reduce population of pathogen below the economic threshold level, integration of cultural, chemical and biological control measures is the only effective way to manage this disease.

Current status of viral diseases affecting black pepper and cardamom. 27 (1): 1-16 (2018)
A I Bhat, C N Biju, V Srinivasan, S J Ankegowda & K S Krishnamurthy
Black pepper and cardamom are the important spice crops grown in India and other countries. Viruses are one of the major yield limiting factors in both these spice crops. Viral diseases spread at a faster rate in these spices, as they are vegetatively propagated. Lack of sensitive detection methods has led to the widespread distribution of viral diseases in all black pepper and cardamom growing regions. The viruses infecting these two spice crops have now been identified; characterized and sensitive diagnostics developed. Integration of various approaches like use of resistant varieties, virus-free planting materials, vector control and cultural methods are required for the management of viral diseases. Rejuvenation of viral disease affected black pepper plantations through proper soil and plant health management were proved to be successful. The present review deals with characterization, diagnosis and management of viral diseases affecting black pepper and cardamom.

Understanding plant-beneficial microbe interactions for sustainable agriculture. 27 (2): 93-105 (2018)
S Ankati & A R Podile
A better understanding of the specific molecular interactions between plants and microbes is crucial to develop newer strategies for sustainable agriculture. The productivity of wide range of agricultural crops under decreasing land resources and shrinking biological potential of the soil need to be improved. Search for useful microorganisms associated with the plants has been highly productive for sustainable agriculture. We take a close look at the current level of molecular interactions that mostly involve specific molecular patterns of microbes and their cognate receptors in plants and development of

efficient biofertilizers for improving crop yields. This article covers the broader aspects of plant-microbe interactions with more focus on plant growth promoting rhizobacteria (PGPR). Further upcoming strategies to understand the plant-PGPR interactions are discussed.

Plant growth promoting rhizobacteria as a biological tool for augmenting productivity and controlling disease in agriculturally important crops - A review. 28 (2): 77-95 (2019)
B S Dileep Kumar & J Jacob
The ecological role of plant growth promoting bacteria associated with plant root environment is currently gaining increased attention. The tremendous use of chemical fertilizers and pesticides which are environmentally harmful can be replaced with the microbes generally called as Plant Growth Promoting Rhizobacteria (PGPR). These microbes can be developed as biofertilizers because they are eco-friendly, cost effective and are natural living organisms. The advantages of these microorganisms rely on their production of novel bioactive metabolites that inhibit various pathogens in the soil as well as their vast mechanisms in improving growth, productivity and yield in agriculturally important crops. Apart from this, their role in nutrient acquisition, soil fertility improvement and stress tolerance are also inevitable. This review represents the present scenario of beneficial bacteria as plant growth agents and disease control tools. They have been extensively studied for plant disease suppression, plant growth modulation, and interaction with plants. Here, some mechanisms employed by plant growth promoting bacteria from different environments are discussed.

Biorational strategies for the management of insect pests of spice crops. 29 (1): 21-37 (2020)
S Devasahayam, T K Jacob, C M Senthil Kumar & M Balaji Rajkumar
Pest control strategies based on relatively non-toxic procedures that preserve the health of the ecosystem and minimize negative effects on beneficial organisms, and utilize microbial pathogens and their products, plant natural products, semiochemicals, biotechnological strategies and reduced-risk pesticides can be termed as 'biorational

strategies'. This review consolidates the information available on the use of biorational strategies for the management of insect pests of spice crops such as *Piper nigrum* (black pepper), *Elettaria cardamomum* (cardamom), *Zingiber officinale* (ginger), *Curcuma longa* (turmeric), *Coriandrum sativum* (coriander), *Cuminum cyminum* (cumin) and *Foeniculum vulgare* (fennel). The review also identifies the current gaps in knowledge and the opportunities and challenges in using biorational strategies for the production of clean spices, reflecting the global concern over pesticide misuse.

Domestic quarantine : An introspection and future perspectives on biosecurity interventions to contain pathogen spread in vegetatively propagated spices in India. 30 (2): 142-162 (2021)
C N Biju, A Jeevalatha, A I Bhat, M F Peeran, R Praveena, C Sarathambal & S J Eapen Safeguarding biodiversity poses a major challenge that warrants preventive legislative and regulatory frameworks to ensure biosecurity, preserve intrinsic biodiversity and mitigate risks from the invasion of exotic pathogenic microbes thereby sustaining agricultural productivity and food safety. The anthropogenic activities contribute enormously towards transboundary movement of invasive alien pathogens through trade and transport of seeds/propagation materials that need to be regulated by enacting appropriate laws and policy guidelines. Black pepper, cardamom, ginger, turmeric and vanilla are the major vegetatively propagated spices cultivated in India. Since primary spread of the major pathogens in these spices are mediated through planting materials, it is imperative to formulate guidelines for flawless and meticulous implementation of quarantine measures which are otherwise not adopted. This review discusses the significance of domestic quarantine in major vegetatively propagated spices with a comprehensive background on plant biosecurity and invasive plant pathogens which could pose threat to spice cultivation in India. It further illustrates the constraints and possible strategies to annihilate the cryptically disseminated pathogens through vegetative planting materials ultimately to safeguard our self-sustaining agricultural systems.

Social Sciences

Economics of sustained production of cardamom (*Elettaria cardamomum* M.). 4 (2): 119-128 (1995)
V S Korikanthimath
Large scale field trials were conducted by adopting High Production Technology at Chettalli (Coorg District, Karnataka, India) to study labour utilization, input requirement and economics of cultivation of cardamom (*Elettaria cardamomum*). A highest yield of 1625 kg/ha (dry) was recorded during the fourth year after planting. The average of nine crop seasons - 695.66 kg/ha (dry) obtained in the trials was 12 times more than the national average yield of 58 kg/ha. Cultivation of cardamom was highly labour intensive. Out of 747.42 labour days required per ha/year during bearing period, the requirement of women labourers was higher (64.05 per cent); 63 per cent of the labour requirement was for harvesting and processing alone. The annual maintenance cost was Rs. 35,148.00/ha. Partitioning of various inputs indicated that maximum expenditure was incurred towards labour (including supervisory charges) i.e., Rs. 19,574.50/ha (55.69 per cent). A net income of Rs. 1,09,967.11/ha (average of nine crop seasons) was obtained with a production cost of Rs. 57.22/kg (dry).

Competitiveness in spice export trade from India : A review. 28 (1): 1-19 (2019)
L Thomas & P C Sanil
Spices are one of the most traded agricultural commodities across the globe. India, as the world's leading producer and exporter of spices is a significant stakeholder in spices export trade. The paper reviews the studies conducted on the spices export sector with special focus on India and the policy issues applicable to this sector. The review focuses on the history, trade competitiveness and issues related to regional trade agreements, trade barriers and food safety in the export trade of spices. Research gaps on issues like linkages between economic development and spice export are identified. The review concludes with suggestions for promoting growth and development of the spice export sector in India.

BOOK REVIEWS

Spices and condiments. J S Pruthi. 1 (2): 167-168 (1992)
K Sivaraman & K V Peter

The publication 'Spices and Condiments', the first and only handbook available in India presenting a very comprehensive information on various spices in the world assumes importance here. The purpose of this compendium according to the author is 'to compile, col1ate, categorise and condense the available information found scattered in different foreign. and Indian Journals, books, reports and standard reference works which are not easily available to the educated layman'. It is also intended to highlight the economic importance of spices and the tremendous role they play in human health about which the layman may not be fully aware of. To that extent, this book fulfils its objectives exceedingly well in providing authentic, useful and detailed technical information of each spice very comprehensively.

Major spices of India - Crop management and postharvest technology. J S Pruthi. 4 (2): 164 (1995)
K Sivaraman & K V Peter

The book consists of 8 chapters each ending in a select bibliography and with 17 annexures providing supplementary information on various aspects of crop management. The introductory chapter mainly deals with nomenclature and classification of spices, organizations dealing with spices research and development, world trade and future plan for spices development. Chapters 2 to 6 deal with all aspects of black pepper, cardamom (small and large), chillies, ginger and turmeric, respectively. Chapter 7 provides information on quality control and national and international standards of spices. Chapter 8 suggests further avenues of spices research and development. The annexures provide mostly information on crop management aspects.

Medicinal value of Indian spices. Amit Krishna De. 7 (2): 157-158 (1998)
B Chempakam
The book provides a general account of the medicinal values of various Indian spices. The first part of the book is divided into six chapters, each chapter depicting the role of various spices in therapeutics. The second part describes aspects on cultivation, production, processing and quality control in spices. Most of the chapters in the book are papers presented at the National Symposium on Medicinal Values of Indian Spices, held at Calcutta in 1993.

Quality assurance in spices and spice products - Modern methods of analysis. J S Pruthi. 9 (1): 79 (2000)
K V Peter & T John Zachariah
The book is divided into 2 parts comprising of 18 chapters. The first part comprises of 10 chapters on spices (whole, ground, curry powder and other spice blends); the second part covers 8 chapters including 7 on important spice products and the last chapter is on future analytical research needs.

Spices : E V Nybe, N Mini Raj & K V Peter. 17 (1): 36-37 (2008)
B B Vashishtha
The book has been divided into six chapters namely, Introduction, Major Spices, Tree Spices, Seed Spices, Herbal Spices and Other Spices. The book provides exhaustive information in each chapter.