8. Crop Management

PRODUCTION

Cereals

During the first fortnight of January, spot-seeding (dibble-seeding) with **rice** cv. Naveen at 15 cm × 15 cm spacing under saturated puddle condition (by putting 2-3 pre-germinated seeds/ hill) produced comparable yields (5.87 tonnes/ha) to transplanting (5.98 tonnes/ ha). The highest benefit : cost ratio of 2.75 was recorded in the plots where the crop was established by seeding with plastic drum-seeder at rows 15 cm apart. All the direct-sown plots showed higher benefit : cost ratio (2.57-2.75) than the transplanted plots (2.49).

Bensulfuron methyl + Pretilachlor (50 + 450 g a.i./ha) when applied to rice as post-emergence herbicide mixture after 18 days of sowing was found effective with 89% efficiency for controlling predominant weeds.

Among the different rice-based cropping systems, total productivity and gross returns were higher in rice–maize, followed by rice–pulse, rice–wheat, rice–rice and rice–oilseed system. One-month-old rice genotypes when subjected to elevated CO_2 up to flowering stage resulted in 25% reduction in photosynthesis and 38% in leaf conductance.

In the sodic soils of Kanpur with *p*H 10.6, integrated use of green manure (10 tonnes/ha), critical nutrients like zinc (200% initially and later at the normal dose) along with 50% of gypsum requirement and growing of alkali-tolerant varieties, CSR 13, CSR 23 recorded higher and stable yields with significant improvement in soil properties. Rice–wheat–mungbean system recorded 15.4% higher productivity over rice–wheat system, and the highest rice grain yield was obtained when crop residues of all the three crops were incorporated.

In coastal Andhra Pradesh, especially among the farmers in Guntur and adjoining Krishna and Prakasam districts, growing of **sorghum** in rice fallows has gained popularity. In the fallows, sorghum hybrids performed better than varieties. Hybrids CSH 16, Kaveri 6363, Mahalaxmi 296, Sudama 333, MJ 4334, MRS 4094, and SBSH 151 gave yields ranging from 7.37 to 8.44 tonnes/ha.

Zero-tillage sorghum is grown presently in more than 4,000 ha with an average productivity of 5.7 tonnes/ha—the highest in the country (average sorghum yield is < 1.0 tonne/ha).

Treatment of **ragi** seeds of varieties resistant to neck and finger blasts with Carbendezim at 2 g/kg or *Pseudomonas flourescens* at 4 g/kg of seeds controlled leaf blast effectively and resulted in higher grain yield. Among different crops, **fingermillet** and **niger** are found promising for late-sowing areas of Jharkhand.

Hand-held NDVI optical sensor device could monitor nitrogen levels in the standing crop and resulted in saving of more than 15% applied nitrogen in wheat and more than 20% in rice.

Oilseed crops

Soybean *Rhizobium* isolate 5a showed thermo-tolerance at 35–36°C, and has been found capable of enhancing nodulation, proline content and also trehalase activity. In Marathwada region, fertilizer P application to soybean could be replaced by treating seeds with phosphate-solubilizing bacteria + farmyard manure 5 tonnes/ha without adversely affecting system productivity when 100% recommended P was applied to safflower.

In Bihar, application of 40 kg S through ammonium sulphate or single superphosphate along with the recommended doses of NPK resulted in 15–20% higher seeds and oil yield in spring **sunflower**. In north Gujarat, simultaneous sowing of **castor** + mungbean in 1 : 1 intercropping under assured irrigation was found to give benefits in the range of 20 to 30%.

Application of 20 kg S/ha through gypsum or single superphosphate increased castor yield to the extent 15 to 20%.

Pulse crops

Raised bed of 75 cm, improved **urdbean** productivity by 32%, followed by raised bed of 67.5-cm (27.5%) over flat-bed system. Significant improvement in **chickpea** yield was recorded when sowing was done on 75 cm raised bed as compared to flat-bed sowing. In the ridge-and-furrow planting, two rows planting of **fieldpea** at 60 cm on ridges yielded the highest. Pre-sowing irrigation and one irrigation at the podding recorded highest chickpea yields . Among the various genotypes, KWR 108 recorded highest yield, and RSG 143-1 was the most efficient genotype with 19.5 kg grains/ha-mm water-use.

Pigeonpea sowing on the raised beds ensured optimum plant population and16–17% yield advantage on an average. Medium-duration pigeonpea genotypes, TTB 7, LRG 41 and JKM 189, are found compatible for intercropping with groundnut and TJT 501 with mungbean and BSMR 853, BDN 708 and BSMR 736 with soybean.

Commercial crops

In low-productive **jute** areas in farmers' fields spread over different Gram Panchayats of Balurghat and Kumarganj Blocks of DakshinDinajpur district of West Bengal, line sowing and nutrient management gave a better reflection in yield attributes over farmers' practice.

Varieties JRO 128 and JRO 8432 performed better than the traditional JRO 524 used by farmers. By adopting improved practices, yield up to 2.19 tonnes/ha could be achieved which was 8.9% higher than the existing yield.

In the field trials on the flue-cured Viriginia **tobacco** with drip irrigation in the northern light soil, 50% saving in irrigation water and 25% improvement in yield were observed in comparison to conventional furrow irrigation. Fertigation with 100% recommended fertilizer doses increased tobacco yield by 45% and fertigation with 80% recommended fertilizer doses increased yield by 36%. In the low-cost drip system for **cotton**, the existing drip system was modified by replacing the LLDPE laterals by 150 micron thick polytubes for water delivery. Cost of laterals constituted nearly 80% of the cost of the system. Initial investment for this low-cost drip system (₹ 31,252/ha) was 58% lesser than the existing drip system (₹ 74,400/ha); without changing in water-saving effectiveness.

Fruit crops

The high-density orcharding in **mango** involving different planting densities of Alphonso on Vellaikulamban and Olour rootstocks, with or without the application of paclobutrazol, showed highest fruit yield of 6.74 tonnes/ha during tenth year with a 3 m × 3 m spacing using Olour rootstock and lower rate of paclobutrazol compared to the control at 10 m × 10 m spacing.

In **litchi**, foliar application of GA_3 @75 and 50 ppm, and MH @ 25 ppm during October showed early initiation of flowering panicles and conversion of vegetative flushes into mixed flowering panicles. The sprays of $KMnO_4$ (2 and 4%) and $CaNO_3$ (1%) delayed the colour break stage by four days and increased fruit retention by 18 and 26%, respectively. In **pomegranate**, height and spread of single-stem trained plants were poor as compared to double and triple stem system. Soil solarization in April for four weeks recorded lowest weed population. Application of different bioinoculants, namely *Pseudomonas flurorescens*, *Azospirillium* and PPFM, improved plant height, number of branches, roots/plant, total biomass and water-use efficiency significantly in cv. Bhagwa. The *P. fluorescens* + *Azospirillium* enhanced more number of roots/plant as compared to other treatments.

In **citrus**, *C. macrophylla* was found as a superior rootstock compared to Jambiri. A microbial consortium developed was found effective both in nursery as well as in orchard. Drip irrigation recorded higher yield and 55% saving in water in Nagpur Mandarin. Growth stage was most critical in Nagpur Mandarin for water requirement. Scheduling of irrigation at 20% depletion in mandarin and 30% in acid lime was found optimum. Spraying of 10 ppm 2,4-D or GA_3 along with 20% urea was the best to reduce fruit drop.

In **banana** cv. Udhayam, maximum bunch weight (35.7 kg) was recorded at a wider spacing (2.1 m × 2.4 m) with 300 g N and 400 g K/ plant. Soil application of 5 g $FeSO_4$ and 5 g $ZnSO_4$ and 0.5% foliar spray of Borax in combination with soil application of bentonite sulphur (20 g/plant) enhanced fruit yield by 109% compared to the control with a net profit of ₹ 85,100/ha in Nendran banana. Drought-tolerant cultivars recorded higher chlorophyll pigment content, membrane stability index and vegetative growth under water stress conditions. *Musa balbisiana*, Saba and Monthan cultivars were identified as drought tolerant. Mean temperature and relative humidity were positively correlated with leaf emergence pattern in Grand Naine cultivar. The rate of leaf emergence was more than one per week at mean temperature of 25–27ºC coupled with 90% RH. Decrease in mean temperature below 25–27°C reduced the rate of leaf emergence below one per week. The potassium ion concentration ranged from 6.31 to 8.12% at flowering and harvesting in leaf midrib of Karpuravalli and Saba. Higher K^+/Na^+ ratio (> 200) was recorded in leaf midribs of Karpuravalli and Saba at flowering and harvesting. The potassium ion concentration and K^+/Na^+ ratio found to be indicators for salt tolerance.

In **grapes**, the application of Zn @ 5 g/vine resulted in early bud sprouts with improved success in establishing plants on Dogridge rootstock. Similarly, use of VAM and humic acid in propagating media improved plant establishment under nursery condition. Thompson Seedless grafted on different rootstocks was evaluated for yield and quality parameters. The number of bunches, bunch weight and yield were maximum in vines grafted on 110R rootstock. The vines raised on double stem and trained to double cordons with horizontal direction performed better in growth and yield. The covering of bunches with papers resulted in reduced incidence of pink berry in Thompson Seedless. The berry crispness, berry length and TSS also improved in covered bunches.

In arid regions, drip irrigation at 0.75 CPE and micro-sprinkler at 1.00 CPE gave best growth in **kinnow** and **ber**. Phylogenetic relationship in datepalm cultivars could be identified using a specific flavonoid spot or combination of spots. In **aonla**, bud intake was maximum (93.58%) when budding was done on 15 July and minimum on 30 September at Faizabad, while highest success was observed through propagation of aonla by soft wood grafting during December and January (88%) at Rahuri. In fig cv. Poona Fig, light to medium pruning with 500 ppm Ethrel spray immediately after pruning gave higher yields than un-pruned plants.

The seedling populations of **almond** variety Waris, having poor yield and quality were rejuvenated applying different pruning intensities, fertilizer doses, water harvesting structures and grafts of commercial varieties. The highest grafting success was noted in pruning of second order branches with fertilizer application at 50 kg FYM + NPK (500 g + 250 g + 700 g) and cup-plate water harvesting structures. However, highest nuts per rejuvenated tree was noted in pruning of second order branches with fertilizer application at

50 kg FYM + NPK (500 g + 250 g + 700 g) and full moon type water harvesting structures.

In **walnut**, scion wood taken from middle portion recorded highest grafting success (90%) in wedge graft under polyhouse done during middle of March. The 15th March was the best date for maximum graft success. The low-cost polyhouse or polytrench were found ideal environmental condition for maximum success due to better humidity and ideal temperature than open field. The organically produced peaches were superior in quality attributes than the control (inorganically produced) in high-density planting systems. Maximum yield of 5.38 kg/plant was obtained with treatment of vermicompost + mycorrhiza.

Plantation crops

In **coconut**, intercropping of ash gourd, pumpkin or amaranth in orchard gave higher yield of coconut (124 nuts/palm/year). Perennial *Stylosanthes* was found to be a suitable fodder legume under coconut in root (wilt)-affected areas for higher fodder production. Similarly, yield of cocoa in oilpalm plantations ranged from 0.25 to 1.5 kg/plant/year, whereas cocoa yield under coconut gardens varied from 0.5 to 2.7 kg.

In **oilpalm**, sap flux in 9th and 17th fronds was close to 0 in morning and reached peak fluxes of 45 cm/hour during noon. The peak sap flux in 25th frond was lesser than that of 17th frond. While in the trunk, peak sap flux was only 8 cm/hour. Thus, sap flux is more in younger fronds of palm, indicating its importance in maintaining growing parts. The amount of carbon sequestered by oilpalm hybrids ranged from 17.98 to 38.10 tonnes carbon/ha with Papua New Guinea and Ivory Coast hybrids sequestering the highest and lowest carbon contents, respectively. Direct embryogenesis without callus phase was obtained from cotyledonary nodes of germinated immature zygotic embroys. The globular embryos with clear suspensor region appeared directly on the explants and multiplied. Other stages such as topedo and heart shaped embryo were seen on sub-culturing. On transfer to light in Y 3 media, they matured into complete plants.

The **cashewnut** yield was found to be 63% more at a spacing of 5 m × 4 m and 45% more at 6 m × 4 m compared to normal spacing, i.e. 10 m × 5 m. On top-worked trees, nut production was higher in trees receiving paclobutrazol compared to trees receiving just pruning treatments and no further pruning after limb pruning. The highest cumulative nut yield (75.97 kg) was recorded in cashew in the treatment 500 : 125 : 125 g NPK/tree, followed by 500 : 250 : 125 g NPK/tree (70.96 kg).

Vegetable crops

Organic production system by use of crop rotation, crop residues, organic manures and biofertilizer improved the organic carbon in soil and soil microflora, beside quality of vegetables. Raised bed planting coupled with paddy straw mulching improved yield and water-use efficiency in **tomato**. In **cucumber**, single-stem training in greenhouse cultivation irrespective of varieties recorded highest yield (628.87 q/ha), followed by double stem. In Capsicum, three levels of pruning recorded highest number of fruits/plant (7.22) and fruit yield (660.56 q/ha), followed by double stem. The elevated CO_2 (550 ppm) influenced overall growth, water-use efficiency and total biomass in onion Arka Kalyan. The total biomass was maximum at 90 DAP (18.6 g/plant) compared to the control (13.4 g/plant). Its increment at elevated CO_2 levels varied from 52 to 81% at different growth stages. Two cultivars of **okra**, viz. Arka Anamika and US 7109, were grown in naturally-ventilated polyhouse during winter to overcome seasonal barrier in productivity. Okra fruit yield was significantly higher (28.1 tonnes/ha) in mid-October planted crop compared to mid-November planted crop (21.5 tonnes/ha). Out of 172 plant growth-promoting rhizobacterial isolates, *Azospirillum* (AzosH10), *Azotobacter* (Azotbel2), Phosphobacteria (Psbel 6) and *Pseudomonas* (Mpf2) were found to be superior in rhizosphere competence, growth promotion and plant nutrient uptake as compared to others.

The pre-emergence application of Oxyflurophen @ 0.15 kg a.i./ha, 10 days after transplanting recorded the highest marketable yield combined with higher cost : benefit ratio of 2.23 and maximum weed control efficiency in onion. The seed pelleting with DAP 30 g + $ZnSO_4$ 0.10 g + Bavistin 3 g/kg of seeds recorded significantly higher yield combined with higher cost : benefit ratio of 4.3 and 4 on raised and flat beds, respectively. Application of Pendimethalin 30 EC, a pre-emergence herbicide @ 2 ml/litre at the time of sowing effectively controlled weed population in onion nursery compared to other herbicides.

Spices

Intercropping *Vetiveria zizanioides* in juvenile black pepper garden recorded maximum net returns of ₹ 46,225, followed by *Alpinia calcarata* (₹ 44,600) with a benefit : cost ratio of 2.3 and 2.2, respectively. Alternate year of black pepper bearing was studied and found that carbohydrate to cytokinin ratio was more during the bearing year compared to non-bearing year. Three genotypes of cardamom, IC 349591, IC 349537 and IC 349550, were found relatively tolerant to moisture stress. The mean yield of turmeric was recorded higher (8.1 kg/ 3 m^2 bed) under organic system, which was at par to other management systems (7.4–7.7 kg/3 m^2 bed). Organic farming significantly increased biomass-C, P, soil respiration, dehydrogenase, acid phosphatase and beta glucosidase activities.

In saffron, maximum size (2.5 g) of micro-corms were obtained on Linsmaier and Skoog (LS) medium supplemented with 21.6 µM NAA and 22.2 µM BA, followed by 2.2 g on Murashige and Skoog (MS) medium supplemented with 21.6 µM NAA and 22.2 µM B.A. Shoots were generated from ovaries, small corms and eye buds. Shoots when cultured on half strength MS medium containing BAP and NAA

developed 2 cormlets/shoot with an average fresh mass of 2.3 g. A total of eight months was taken to harvest a cormlets from eye bud which otherwise takes 22 months under field conditions.

Potato and tuber crops

Thematic maps were prepared for the areas climatically suitable for growing *kharif* potato in India and growing seed crop in the north-eastern states. **Potato** acreage and production were estimated through remote sensing GIS and crop modeling in Punjab, Uttar Pradesh, Bihar and West Bengal. In long-term manurial/ fertilizer experiment, productivity of potato was higher in maize-potato-onion (54.5 tonnes/ha), followed by rice-potato-wheat. New prototype of aeroponics for faster multiplication of potato mini tuber production was designed, developed and tested successfully. A decision support system (DSS) for precise application of nutrients (N) was developed for facilitating location-specific nutrient management. A database of potential productivity of popular potato cultivars in different agroclimatic zones was created. For monitoring health of seeds and plants a dipstick kit was developed which can be used by even farmers to check the presence of virus.

The site-specific fertilizer recommendations were developed for **cassava** using the yield-uptake relationships. A website on site-specific nutrient management and online fertilizer calculation software was developed for uploading in CTCRI website. The demonstration and popularization of INM practices involving secondary and micronutrients in cassava, soil test-based application of Zn, NPK and FYM was observed to be the most economical (benefit : cost ratio 1.75), followed by application of Mg, NPK and FYM (benefit : cost ratio 1.62) compared to farmers' practice (benefit : cost ratio1.09). Organic farming technology for elephant-foot yam validated under on-farm trials proved significantly superior with higher corm yield (34.60 tonnes/ha) and additional returns (₹ 43,651/ha) over conventional practices.

Floriculture

Integrated nutrient management using FYM, vermicompost and Azospirillium and PSB found superior in rose, carnation, gerbera and orchids. Potting media of cocopeat, sand, FYM, vermicompost (2 : 1 : 05 : 0.5) recorded higher flower yield and duration of flowering. Micronutrient application of $FeSO_4$ raised early flowering and increased yield. Anthurium had higher yield and luster of flowers with application of borax.

Medicinal and aromatic plants

Phenological stage of bloom was observed to be the best time of harvesting in Artemisia to obtain higher essential oil content (0.76%) and yield (33.96 kg/ha).

Mushroom

Cultivation of pleurotous on pasteurized wheat straw recorded highest yield. Shiitake mushroom *Lentinula edores* recorded highest yield on wheat straw supplemented with 20% wheat bran, sawdust + 5% wheat straw and wheat straw + 10% wheat bran.

PLANT HEALTH MANAGEMENT

Cereals

Two distinct mechanisms confer resistance to gall midge in **rice**—one involves hypersensitive reaction (HR) in variety Suraksha and the other without HR in variety Kavya.

Nine *Lr* genes(*Lr*1, 3, 10, 13, 14a, 23, 24, 26 , 34) of **wheat** in 145 lines ,10 *Sr* genes (*Sr*2, 5, 7b, 8a, 9b, 9e 11,13, 24, 31) in 157 lines and five *Yr* genes in 74 entries either alone or in combination were characterized. National repository of 125 pathotypes of different rusts is being maintained.

Oilseed crops

Foliar application of *Trichoderma* isolate T-170 culture-filtrate effectively reduced collar-rot disease in **groundnut**; and stem-rot incidence was lowered with its spore suspension foliar spray at 1.5×10^6 colony-forming units (cfu)/ml.

Alternaria leaf spot could be effectively managed in **sunflower** with seed treatment with Iprodine at 0.2% and its two sprays at 0.2% at 30 and 45 days after sowing (DAS). For management of sunflower necrosis disease, seed treatment with Thiamethoxam at 4 g/kg of seeds and its sprays at 0.05% at 30 and 45 DAS were found effective.

Trichoderma harzianum Th4d, and *T. viride* Tv2 at15 g/kg of seeds were effective in reducing **safflower** root-rot incidence by more than 80%. For management of safflower aphids in Malwa Plateau of Madhya Pradesh, spray of Thiamethoxam 25 WG 0.005% or Imidacloprid 17.8 SL at 0.0045%, twice at 15 days interval was observed to be effective and economical.

Spraying Spinosad 0.018% or Indoxacarb 0.015% was found effective in controlling **castor** defoliators and capsule-borers.

Since last three years, **linseed** PoIf 5, Polf 19, Polf 22, H 15 and H 43 have shown consistent resistance reaction against *Alternaria* blight.

Pulse crops

Mungbean genotype Pusa 9531 and **urdbean** Pant U 35 showed moderate resistant reaction to powdery mildew. *Maruca vitrata* occurrence in early **pigeonpea** varied from 0.8 to 18.2 larvae/plant. Lowest pod damage (4.8%) owing to this pest was recorded with Indoxacarb 14.5 SC and Spinosad 45 SC treated plots as against 15.4% in the untreated control. Multiple disease resistance against wilt and sterility mosaic was observed in pigeonpea genotypes IPA 8F, IPA 16F, IPA 204 and BSMR 736. These lines are being used in the breeding programme. **Lentil** genotypes PL 01 and PL 02 showed multiple disease resistance for wilt and rust over the years, and are being used in resistance breeding

programme. Similarly, in **fieldpea** HUDP 28, Pant P 25 and HUDP 33 genotypes showed resistance against rust disease and are being utilized in breeding programme.

Commercial crops

Several infected buds of **sugarcane** CoLk 7701 (HS variety) were found free from *Colletotrichum falcatum* after treatment with *Trichoderma harzianum* and moist hot-air treatment (MHAT) at 54°C for 2½ hr at 90% relative humidity, either alone or in combination. With *Trichoderma* mixed culture (TMC), MHAT and TMC + MHAT treatments, the pathogen could not be traced from 53, 68 and 73% of buds. It was also apparent that *T. harzianum* was effective in eradicating sett-borne infection of the pathogen.

Parasitism rate of *Aenasius bambawalei* on the **cotton** mealybugs varied from 17. 2 to 48.8% with an average of 25.7%— minimum parasitism was during the early crop growth and it increased in subsequent weeks, reaching a peak of 30.4% during September third week.

Cotton jassids showed resistance of 110 fold, 57 fold, 2,500 fold and 5,450 fold to Acephate, Monocrotophos, Thiomethoxam and Imidaclorprid, respectively. Variability in susceptibility in *Helicoverpa armigera* to *cry1Ac* was 4.71 fold across north India, 152 fold across Maharashtra, 62.8 fold across Gujarat and 1.91 fold in south India.

Pest management systems

Based upon the online weekly data collected under the **National Information System for Pest Management (NISPM)** from 12 districts, spread over 9 major *Bt* cotton-growing states, jassid, thrips and whitefly populations showed increasing trend and crossed economic threshold level (ETL) across 109, 71 and 68 locations, respectively. In the case of mealybug, only 13 hot spots were noted. Mirid bug emerged as the serious pest in Perambalur (Tamil Nadu) and Belgaum (Karnataka) districts. Hot spot incidence of various pests of cotton could be identified from the accrued database. The improved surveillance system, i.e. **Crop Pest Surveillance and Advisory Project (CROPSAP)** was also developed. Research on e-surveillance of pests and diseases could be undertaken as two models—one for soybean and cotton in Maharashtra and another for rice in Odisha.

E-pest surveillance has so far indicated pest situations across all districts of Maharashtra instantly so as to advocate timely pest management advisories during *kharif* 2010. *Spodoptera* incidence above ETL was noticed only at some talukas of Latur, Gadchiroli and Ahmadnagar. Girdle beetle sporadically occurred at six districts, viz. Buldhana, Nandurbar, Nagpur, Dhule, Bhandara and Wardha.

In *kharif* 2009, upland rice in 1.65 lakh ha was affected by swarming caterpillar (*Spodoptera mauritia*) during August-September and by brown planthopper (*Nilaparvata lugens*) during October–November. Pest surveillance and management programme in 13 districts of Odisha was ICAR-enabled computer-based data assembly along with the interpretation.

Pest and natural enemy alerts in crops

Mirid bug*Campylomma livida* Reuter was noticed for the first time in the cotton fields on both Bt hybrids and varieties of *Gossypium hirsutum* and *G. arboreum* in Haryana (Sirsa and surrounding areas). Blackened anthers in flowers and black warts with beaked tips in developing bolls were observed. Suitable control strategies using systemic pesticides are being evaluated.

Papaya mealybug *Paracoccus marginatus* caused serious economic losses to crops in Tamil Nadu, Kerala, Karnataka and Andhra Pradesh. Many of the backyard grown ornamentals such as *Hibiscus, Acalypha* and weeds like *Parthenium* and *Euphorbia* in barren land and roadside aid in spatial spread of this pest. Recently *Acerophagus papayae*, an encyrtid parasitoid, has been detected in papaya mealybug colonies of Maharashtra and Tamil Nadu and this is expected to suppress the pest in many crops under conserved agro-ecologies.

Incorporation of three co-evolved parasitoid species *Anagyrus loecki*, *Acerophagus papayae* and *Pseudleptomastix mexicana* from Peurto Rico is also at the advance stage for classical biological control of this aggressive papaya mealybug species.

Integrated pest management

An IPM validation programme in bell pepper in Daha village, Karnal (Haryana), was launched in about 10 ha. It comprised raising healthy nursery on raised bed, soil solarization, mixing of *Trichoderma* enriched farmyard manure in the soil, seedling root dip in *Pseudomonas* sp. solution, neem (aphids) and Spinosad (thrips) spray, pheromone-based monitoring for fruit-borer, release of egg parasitoid *Trichogramma chilonis*, and spray of *Ha*NPV and emamectin benzoate in the main crop. Adoption of this resulted significant reduction in the number of pesticide sprays from 15 to 5–6 along with substantial increase in yield and in natural enemy population.

In a large-scale demonstration covering 1,000 ha of Taraori basmati **rice**, application of mixed formulation of *Trichoderma harzianum* and *Pseudomonas fluorescens* through FYM, seed treatment and foliar spray, effectively suppressed both bacterial late blight and stem borer incidences in the organically cultivated Pusa 1121, Taraori basmati and Pusa 1 rice.

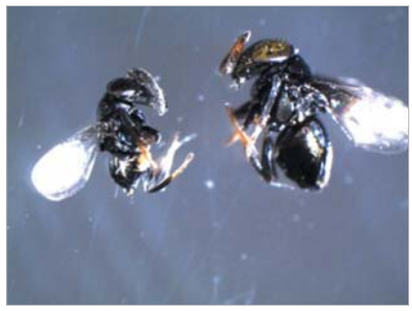
Biological control

Native natural enemies of the papaya mealybug recorded were *Menochilus sexmaculatus*, *Nephus regularis*, *Curinus coeruleus* and *Apertochrysa* sp. nr. *crassinervis*. *Spalgis epius* was also often found feeding on *Paracoccus marginatus* in the field.

Aenasius bambawalei, Metaphycus sp. (Encrytidae: Hymenoptera) and *Promuscidea unifaciventris* (Aphelinidae: Hymenopetra) were observed to parasitize *Phenacoccus solenopsis* mealy bug up to 30% in the pest affected states.

Cumulative 106 host-plants of *Phenacoccus solenopsis* in cotton + pigeonpea cropped area were

Mealybug *Phenacoccus solenopsis* infested by *Aenasius bambawalei*



Aenasius bambawalei, male (*left*), female (*right*)

Lab multiplication of parasitized *Aenasius bambawalei*

recorded spreading across 27 plant families— the major families were Asteraceae, Malvaceae, Leguminaceae, Solanaceae, Fabaceae, Amaranthaceae, Euphorbiaceae, Poaceae, Labiateae and Apiaceae.

Pest control in soybean: Application of *Heterorhabditis indica* (NBAII isolate) aqueous formulation at 2 billion infective juveniles/ ha recorded significantly lowest population of the larvae of *Chrysodeixis acuta* and *Spodoptera litura,* and registered highest grain yield of soybean.

Anticipatory research for the quarantine of *Brontispa longissima*

Coconut leaf beetle*Brontispa longissima* has invaded many of the south-east Asian countries and South Pacific islands, and there is a likely threat of this pest entering our country either through Myanmar or Maldives. DNA bar codes of this pest have been developed, which will facilitate rapid identification of the pest in the event of its invasion. *Acecodeshis pinarum* and *Tetrastichus brontispae* are potential parasitoids for the classical biological control of *B. longissima*

Sugarcane woolly aphids management: Intensity of aphids in Pune and Satara districts of western Maharashtra, Tamil Nadu and Karnataka lowered owing to occurrence of its predators *Dipha aphidivora* (1–3 larvae/leaf), *Micromus igorotus* (3–7 grubs/leaf) and syrphids (1–2 larvae/leaf) and also parasitism by *Encarsia flavoscutellum*.

Control of root-knot nematode in carnation: Root-knot nematodes infection in carnation grown in commercial polyhouses was controlled effectively by application of talc preparations of *Paecilomyces lilacinus* or *P. chlamydosporia* at 100 g (10^7 spores/g) with farmyard manure at planting of cutting, followed by a light irrigation.

Plant parasitic nematode management: In pigeonpea (var. Vipula) in *kharif* 2009, combined application of *Trichoderma harzianum* at 5 kg/ha and *P. chlamydosporia* at 20 kg/ha was most effective in reducing reniform nematodes' female population (38.5%) and increasing crop yield.

In pomegranate (var.Sindhuri), combined application of *Paecilomyces chlamydosporia* (100g/plant) and mustard cake (2 tonnes/ha) resulted in maximum reduction of 57.83% in nematode counts, followed by *Paecilomyces lilacinus* (100 g/plant) + mustard cake.

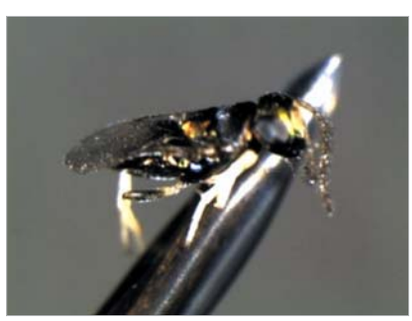
Control of mango leaf hoppers: Leaf hoppers could be effectively managed by spraying *Metarrhizium anisopliae* at 1×10^9 spores/ml with oil and sticker. Three sprays of *M. anisopliae* at 1×10^7 conidia/litre on tree trunk during off-season and three during flowering were effective in suppression of mango hoppers in Pune.

Pest control in temperate fruits: Two sequential releases of *Trichogramma embryophagum* significantly reduced fruit damage by codling moth, and reduction in fruit damage over control ranged from 23.6 to 36.1% at Mangmore, Shanigund and Hardas.

White grub control in potato: Soil application of *M. anisopliae*-enriched FYM (2×10^{10} conidia/kg) at 20 kg/plot at the time of planting of tubers was found effective in reducing white grub (*Holotrichia consanguinea*) population with higher mycosis.

Soil application of *B. bassiana, M. anisopliae, H. indica* and *Steinernema carpocapsae* resulted in low potato tuber damage by white grubs (28.4–37.4%) as compared to control (55.7%).

Metaphycus sp.



Promuscidea unifasciativentris

Gitonides perspicax

Baryconus sp.

Odontacholus sp.

Scelio sp.

Agriculturally important insects

Chrysoperla (*carnea* group) collected on cotton were characterized as *Chrysoperla zastrow arabica* Henry *et al*. based on the acoustic analysis of the mating signals.

A total of 14 genera belonging to three subfamilies—Scelioninae, Telenominae and Teleasinae—of Scelionidae were recorded; these include *Baryconus, Odontacholus* and *Scelio*.

Plant parasitic nematodes

Plant parasitic nematodes (920 nematodes/200 cm^3 of soil) population was maximum in the sorghum-wheat cropping system in the semi-arid ecosystem of Maharashtra at the time of termination of wheat crop wherein 100% N, P and K was applied through inorganic fertilizers. In Anand (Gujarat), hot spots were identified for root-knot nematode (*Meloidogyne* spp.) and reniform nematode (*Rotylenchulus reniformis*) infecting papaya.

Trichoderma harzianum at 10 g/m^2 along with Carbosulfan at 1.5% a.i. (w/w) as seed treatment was effective against root-knot nematodes infecting urdbean. Highest yield of lentil was recorded with combined application of neem cake at 100 g/m^2 and *Trichoderma viride* at 2.5 kg/ha at Jorhat, in *Meloidogyne incognita* infested field. In Rajasthan, in castor crop, reniform nematode *Rotylenchulus reniformis* population reduced when *Paecilomyces lilacinus* at 2.5 kg/ha was applied in the soil , followed by *Trichoderma viride* at 2.5 kg/ha. Soil application of *Pseudomonas fluorescens* at 2.5 kg/ha was found effective in reducing reniform nematodes on cotton and castor in Tamil Nadu. In bottlegourd, neem-cake at 30 g/plant was effective in reducing root-knot nematode populations.

Barcoding of lac insects using *Cytochrome oxidase I* gene

Cytochrome oxidase I (COI) gene was sequenced in lac insects for barcoding. *COI* gene is universally used for barcoding of life, for identification of species and also to understand their relationships based on the variation in the DNA sequence. Universal primers recommended for amplification of *COI* gene are not satisfactory due to mutations in the primer binding region. A new set of primers were designed for amplification of about 650 bp region of *COI*, which was required for barcoding. The sequences have been submitted to GenBank. Analysis of sequence data of the amplified region of 53 lines of *Kerria lacca,* and two of *K. chinensis* and one of *K. sharda* was carried out. The analysis confirmed the sub-specific status of *kusmi* and *rangeeni* forms; *K. sharda* did not show sufficient divergence required for a species as assessed by disparity index. This method will be used for barcoding the lac insect collections of the National Lac Insect Germplasm Centre.

Agricultural acarology

In Gujarat, IPM package for coconut eriophyid mite including farmyard manure (50 kg/palm), neem cake (5 kg/palm), magnesium sulphate (500 g/palm), borax (50 g/palm), recommended NPK and 3 applications of neem formulation (crown spray) in the fourth consecutive year was found promising.

In Bengaluru, *Neoseiulus longispinosus* released on carnation in the polyhouse at 1 : 25 eliminated *T. urticae* within 5 to 6 weeks. Predatory potential of *Stethorus pauperculus* against *Oligonychus oryzae* and *O. indicus* in Tamil Nadu revealed that females were more voracious (108.14 eggs, 49.14 nymphs, 46.85 adults/individual/day) than males, which consumed 71.28 eggs, 43.85 nymphs, 33.14 adults/individual/day, fourth instar larvae consumed more preys than other stages. Predatory potential of *Oligota* sp. on *T. urticae* showed that grubs preferred to feed more on eggs (81.25 nos.), followed by nymphs (45.71 nos.) and adults (15.54 nos.). In spidermite infested pointed-gourd in Kalyani, predatory mite *Neoseiulus longispinosus* (Evans) was found effective when released at the interval of 7 days at the rate of 2/m^2, starting from first week of February.

Whitegrubs and soil arthropods

Application of cadaver preparations of entomopathogenic nematodes (EPN) (*Heterorhabditis indica* and *Steinernema carpocapsae*) successfully controlled *Leucopholis lepidophora, Anomala bengalensis* and *L. burmestrii* in 6 to 8 days in arecanut fields at Sulya (Karnataka).

In groundnut, a new chemical clothianidin (Dantotsu) 50 WDG at 2 g/kg of seeds was found effective against **whitegrub** *Holotrichia consanguinea*. Among granular insecticides, fipronil 0.3 G at 33.33 kg/ha proved most

effective, providing 85.97% protection to groundnut crops from *H. consanguinea*. Fipronil 0.3 G at 100 g a.i./ha was also found effective against whitegrub in potato at Jorhat. Another formulation of Fipronil—Fipronil 5 SC at 800 g a.i /ha was found effective against whitegrub species at Durgapura and Jorhat. At Palampur, soil drenching of Quinalphos at 800 g a.i /ha effectively protected potato from whitegrub *Brahmina coriacea.*

Among the entomopathogenic fungi, *Metarrhizium anisopliae* gave maximum control of whitegrubs at Palampur.

At Ranichauri, Imidaclorprid 70 WG at 0.20 kg a.i./ha found effective against **cutworm**. For **termite** management in groundnut, Imidacloprid 17.8 SL at 3 ml/kg of seeds was found effective, providing 89.12% protection over untreated control. Clothianidin 50 WDG at 2 g/kg of seeds provided 85.77% protection to groundnut.

New whitegrub from Asom: New record of whitegrub *Lepediota mansueta* damaging potato, colacasia, sugarcane and greengram in the river island of Brahamputra in Jorhat (Asom) has a biennial life cycle. Unlike other whitegrubs pests, its adults as active swimmers have degenerated mouthparts and they do not feed.

Agricultural ornithology

Eco-friendly bird management practices: In maize fields (2 ha) at farmers' fields of Nalgonda and Mahaboobnagar districts of Andhra Pradesh, bird management methods showed that fodder maize as screen around the main crop (maize) gave higher yields (2,025 kg/ha), followed by wrapping method (1,983 kg/ha) as compared to control (1,543 kg/ha).

In paddy (1.5 ha) at Chagantipadu village of Krishna district, ribbon along with Biobird repellent (BBR^{+}) recorded yield of 229 kg/acre, and the extent of damage recorded was to the tune of 3% only. While in Kerala, at the seed production plots, demonstration of reflective ribbon showed 40% increase in yield as compared to control plots.

In maize, integrated bird management modules during *kharif* consisting of wrapping along with reflective ribbon showed higher yield (1,790 kg/ha) than control (1,320 kg/ha).

During *kharif,* seed treatment with copper oxychloride at 3 g/kg of seeds reduced percentage abundance of birds drastically from 30 to 10%; especially rose-ringed parakeet reduced significantly after treatments.

Andrographis paniculata and *Ipomaea carnea* at 10 ml/litre showed 71% repellency in captive birds.

Role of beneficial birds in agricultural landscape: In Andhra Pradesh, IPM module consisting of HDP net, T-shaped perches and NPV were used to control *Spodoptera litura* larva; T- perches with NPV proved effective in controlling medium and large size larvae to the extent of 68% in castor at farmer's field.

In pigeonpea, large-scale demonstration in farmers fields (5 ha) at Ranga Reddy district of Andhra Pradesh, NPV+ Bird perches (at 20/acre) reduced incidence of *Helicoverpa armigera* and showed higher yield (1,694 kg/ha), as compared to control (1,156 kg/ha). In Kerala, 18 species of birds reduced 20–33% of *Helicoverpa armigera* in tomato and chickpea.

Artificial nest boxes of different sizes for cavity nesting birds showed successful breeding of 12 bird species. Barn owl breeding was successfully completed in the specially developed artificial nest boxes at Kerala.

New Rodents from Andamans

Three rodent species *Mus booduga* and *Rattus tanezumiandamanensis* (in old huts and orchards), *Cremnomys cutchicus* (in rocky areas) were reported for the first time from Andaman and Nicobar Islands. The first two species are common in the main lands of the country also but the last is the native of Andamans only. The monthly trapping from October 2009 to July 2010 in coconut orchards of Andamans indicated a trap index of 4.2–8.3 (Mean: 5.81).

Rodent control

Effect of temperature on bait shyness behaviour: Zinc phosphide induced bait shyness in house rats *Rattus rattus* persisted for 40 days at a temperature range of 18 to 25°C and at higher temperature range (28 to 35°C), it lasted for longer period (60 days). Studies were conducted on the mitigation of bait shyness in *Tatera indica* and *F. pennanti* at two temperature regimes. Exposure of coconut oil (2%)-treated baits to bait shy *T. indica* for 3 days at a lower temperature regime reduced persistency of bait shyness from 50 to 25 days, and at higher temperature similar intervention reduced the bait shyness period from 75 to 30 days.

Rodent damage: Sugarcane, buckwheat and summer rice in lower Brahmaputra valley zone of Asom experienced 14, 12.6 and 12% rodent damage mainly by *Bandicota bengalensis*. Similarly, vegetables recorded 2.5–6.7% damage by rodents in the state. In Andaman and Nicobar Islands, solanaceous vegetables like brinjal and tomato recorded 5.8 to 46.6, and 8.3 to 33.9% fruit damage.

In north-eastern hills region, Jhum rice registered higher rodent depredations (16–24%) as compared to wetland rice (4–12%) in Arunachal Pradesh. Similarly, sugarcane fields with 20–26 burrows/ha also registered 2–3% cane damage, however tapioca and maize suffered 8–12% rodent damage. In coastal Andhra Pradesh, 24% coconut trees suffered rodent attack recording 2.54% damage to the tender nuts/tree. Cocoa intercropped in coconut orchards also experienced 42% pod damage by rats and squirrels.

Rodent management: Laboratory feeding trials on baits mixed with four botanicals—leaf powder of neem, *Vitex niguindi*, *Polygonum* and neem kernel powder—against *Rattus rattus* at Jorhat revealed antifeedent properties in leaf powders at 3.66 and 4.98g/100g; field evaluation of botanicals for repellent effects against

Bandicota bengalensis in rice in Andhra Pradesh revealed that castor-based Ecodon gave the maximum control (55.3%), followed by pongamia oil 10% (41%) and castor oil 10% (39.7%). Further, Ecodon offered relatively better protection for a longer period over the others; laboratory evaluation of 'Bio' a botanical formulation consisting of glucosides of *Trypterigium wilfordii* against male *R. rattus* exposed for 30 days revealed anti-fertility effects; at Ludhiana, *Tatera indica* exposed to castor-oil treated baits for 5 days showed significant antifeeding effects (44.89-61.39%).

Fruit crops

In **litchi**, combination of Tricho card and *Kamdhenu Keet Niyantrak* or Nimbicidine gave good control of fruit-borer. Pruning of infested twigs in June, September and February, followed by spraying of Dicofol @ 0.05% or Dimethoate @ 0.05% or Profenofos @ 0.05% managed the mite infestation completely. Deltamethrin treatment was found to be significantly superior over Dimethoate, *Bt*, neem soap and pongamia soap even after fourth harvest to control sapota seed-borer (*T. margarias*).

In field trials, two antibiotics (Rifampicin and Amoxycillin), one each of chemical (copper hydroxy carbonate) and botanical (neem seed whole) were found useful in reducing bacterial blight in pomegranate. The vascular wilt of pomegranate was found to be caused by *Ceratocys fimbriata*, however, some wilt infections revealed association of *Fusarium* spp, *Macrophomina phaseolina, Rhizoctonia bataticola* and *Pythium* spp. *In-vitro* evaluation of chemicals against wilt pathogen *C. fimbriata* revealed effectiveness of chemicals like copper sulphate (0.2%), nickle chloride (0.2%), salicylic acid (0.1%), sulphur (0.1%) and Propiconazole (0.1%) as these chemicals provided complete inhibition of pathogen's growth. Bioformulation like Kalisena (*Aspergillus niger*-based formulation) and Josh (VAM base formulation) were also found effective in managing wilt infections in pot experiments. In field, drenching of soil with Carbendazim (0.2%)/ Propiconazole (0.2%) managed wilt in diseased orchards.

Fruit spots and rots of pomegranate were effectively managed by spraying of Carbendazim (0.1%)/ Thiophanate-methyl (0.1%)/Mancozeb (0.2%)/copper oxychloride (0.2%)/copper hydroxide (0.2%) at regular intervals depending on disease severity. A new black thrips (*Phlaeothripidae*), solenopsis mealy bug (*P. solenopsis*) and two Lymantrid hairy caterpillars were found to have economic importance.

In **grapes**, three isolates of *Aspergillus niger* were able to solubilize P under saline condition. In anthracnose-affected grape samples, 361 isolates were obtained. Majority of them belonged to *Colletotrichum gloeosporoides* and to *C. capsici.* Based on colony morphology, 17 groups were formed among *C. gloeosporoides*. Protocol was standardized for Reverse Transcriptive (RT-PCR)-based detection of GLRaV-3 virus. Symptomless carrier plants were detected as positive by PCR as well as ELISA tests. Information on eight important grapevine diseases and nine post-harvest grape diseases was compiled and displayed by creating web pages. The increase in thrips population coincided with flowering period and absence of rains.

Mite population build-up was attributed to increase in temperature, decrease in humidity and absence of rain. Similarly, mealy bug population increased with increase in temperature and as the fruit approaches maturity in terms of level of sugar. Two different species of thrips, viz. *Scirtothrips dorsalis* and *Retithrips syriacus* were present in vineyards. The major species of jassids affecting grape was identified as *Amrasca biggutula biggutula*. Parasitoids of mealy bugs were collected. These parasitoids develop internally in mealy bug and mummify mealy bugs.

Soap nut-based formulations 'mealy quit' and 'mealy kill' @ 8 and 10 ml/litre, respectively were found effective against mealy bug. Among new generation insecticide, HGW80 was found effective. A multi-residue analysis method was optimized and validated based on GC-TOFMS for 135 pesticides and 25 organic contaminants in grape and wine. An improved method was developed for sensitive and selective determination of residues of meptyldinocap in grape, mango and pomegranate by LC-MS/MS. Of the 500 export grape samples assessed for compliance to the EU-MRL, residues were found to be below their maximum residue limits (MRLs). In 50 domestic samples, residues were found to be below the MRL. Samples of red and white wines obtained from the Indian wineries were found free from pesticide residues.

In **banana**, significant reduction (92%) in root-lesion (*Pratylenchus cofeae*), and root-knot nematode (*Melodogyne incognita*) population with 30% increased yield was recorded in Ney Poovan plants treated with VAM (*Glomus fasiculatum* and *G. mosseae*) along with two biocontrol agents (*Paecilomyces lilacinus* and *Trichoderma viride*) under field conditions. Diversity of banana Sigatoka leaf spot was analyzed using the spores collected from 18 samples utilizing r-DNA-ITS sequencing indicated that all the isolates belong to *Myycospharella eumusae*. The *Fusarium* wilt was managed by endophytic *Trichoderma* strain Bc2 + rhizospheric *T. koningii*, Dsr1 + *T. koningii* and prr2 + *T. harzianum* isolates @ 30 g/plant even after 6 months of transplanting when wilt was prevalent. The BBrMV and BBTV coat proteins isolates from hill banana were expressed in bacterial expression sytem which will be useful in production of polyclonal antiserum.

Spraying of Bayleton (0.1%) and Sulfex (0.2%) was found effective in controlling powery mildew of *ber*. A spray schedule comprising three sprays at 30 days interval starting from fruit setting with Fenvalerate (0.01%), Deltamethrin (0.02%), Carbaryl 50 WP (0.2%) and Quinalphos (0.05%) were found to be most appropriate to control ber fruit-borer at Rahuri. For integrated management of fruit fly, two sprays of Azadirachtin (0.3%) at 15 days interval in April,

followed by two sprays of Chlorothalonil (0.2%) during August is recommended to control aonla rust, whereas for managing leaf gall midge in **aonla**, two sprays of Azadirachtin (0.3%) at 15 days interval during April followed by two sprays of Endosulfan (0.07%) in August at 20 days interval is recommended at Jobner.

Plantation crops

In **coconut**, control of bud rot disease was obtained by pouring Mancozeb 5 g in 300 ml water coupled with placing of two perforated sachets containing 5 g Mancozeb to innermost leaf axils at bimonthly intervals. Assessment of trap density using the refined PVC traps of 1.5 m height and size of windows of 10 cm × 15 cm indicated maximum catch of beetles in traps placed @ 1 trap/ha area. Laboratory screening of new molecules against red palm weevil revealed 100% mortality of grubs with Imidacloprid (confidor 200% SL).

In **cashew**, stem- and root-borer (CSRB) grubs, reared entirely on semi-synthetic diet (SSD) from nascent stage (immediately after hatching), could successfully complete their life-cycle leading to adult emergence for the first time. The incidence of flower drying disease was lower in Mancozeb (8.9%)-treated trees, followed by copper oxychloride (11.9%) and Propiconazole (14.6%). The damage rating in untreated control was 22.8%. For control of tea mosquito bug (TMB) and other insect pests, Lambda-cyhalothrin (0.85%) was the best compared to the control (2.48%). Under curative control trial for management of CSRB, Chlorpyriphos 0.2% resulted in 83.33% trees without re-infestation at Bapatla and 90% at Bhubaneswar.

Vegetable crops

In **onion**, re-infestation of thrips is mainly through external migration of adult thrips and eggs that were laid inside the leaves. A predatory thrip, *Aeolothrips mongolicus* was found effectively feeding on thrips in onion plants. Fipronil @60 g a.i./ha was identified as an effective insecticide against thrips. To control thrips in onion during *rabi* season, three sprays of Fipronil @1.5 ml/litre at 15 days interval from 30 days after transplanting were effective.

Soil application of neem cake, followed by spraying of neem soap and neem seed powder were effective for control of leafhopper in okra during *kharif*, but only moderately effective during summer when the pest incidence was very high. Sprinkler irrigation was found to significantly reduce the number of chilli thrips without insecticide spray, while weekly spraying of *M. anisoplaie* @ 1×10^9 spores/ml with sunflower oil @ 0.01%, followed by weekly release of *Blaptostethus pallescens* @ 1/plant recorded significant reduction in thrips population in chilli and *Capsicum*. The CP gene primer was designed for leaf curl disease of chilli. This gene was cloned and sequenced and submitted to National Centre for Biotechnology Information Database. Similarly, planting of maize and sunhemp in four rows as barrier crop was effective in reducing yellow vein mosaic virus (YVMV) incidence in okra.

Potato and tuber crops

In **potato**, dipstick assay was standardized for detection of five viruses, viz. PVX, PVA, PVS, PVM and PVY. Kufri Badshah and Kufri Pukhraj were transformed with replicase gene of potato apical leaf curl virus. Kufri Pushkar was found highly resistant to russet scab and pitted type common scab. Soil application of stable bleaching powder @ 3 q/ha was most effective in managing russet scab. Thiacloprid 240 SC was found effective for managing *Myzus persicae*, *Aphis gossipii* and white flies. Spraying of neem and *ratna jayot* extracts in cow urine @ 10% caused 88 and 83% mortality of glasshouse whitefly. Integrated package of practices for managing late blight and bacterial wilt diseases were recommended specifically for the Hassan area of Karnataka.

Spices

The efficacy of endophytic bacteria (BP-35,25,17 and TC 10) and rhizobacteria (IISR 853 and IISR 6) against *Phytophthora capsici*, *Radopholus similis* and *Meloidogyne incognita* infecting **black pepper** was evaluated in field conditions. Application of TC 10 + Metalaxyl-mancozeb and IISR 853 + Metalaxyl-mancozeb were found effective for growth and canopy. A model for estimating risk of downy mildew to support the decision on spraying in vineyards was prepared. The model considers daily data on temperature and relative humidity. The model was tested using last two years' data on weather parameters and disease incidence and was found reasonably accurate in estimating the risk. Enzyme linked immunosorbent assay (ELISA) and reverse transcription–polymerase chain reaction (RT-PCR)-based methods were standardized for detection of cardamom mosaic virus.

A virtual screening of phytochemicals from Dr Duke's phytochemical and Ethnobotanical database, literature search, PASS prediction and ADME/Tox screening has identified 56 promising lead compounds with potential nematicidal activity. Flexible docking studies revealed that six of these phytochemicals, ie curcumin, brucine-n-oxide, colubrine, brucine, vanillin, genostrychnine and strychnine, had good binding score (MolDock score) and favourable hydrogen bond interaction with glutathione-S-transferase (GST) of *Brugia malayi*. A new database, GST Lead Base (www.spicebioinfo.res.in/gstleadbase) was developed and hosted. The database includes chemical properties and other details of potential nematicidal compounds that inhibit glutathione-S-transferase in nematodes. *SpiceStat*, the database on vital statistics of spice cultivation, production and export was relaunched with additional features. A new accounts module was developed and integrated in ARISoft, the existing office automation software. An interactive CD on ginger and turmeric package of practices was developed.

Floriculture

In **orchids** ciprofloxacin hydrochloride and tetracycline hydrochloride were found sensitive against soft rot bacterium. Among insecticides and bio-pesticides tested against two spotted red spider mite, Imidacloprid 17.8 SL @ 0.3 ml/litre was found best (98.67%) for the control of mite population. The maximum reduction in scale's crawler population (98.72%) was reported in neem oil 0.03% EC (5 ml/litre). The minimum shoot-borer infestation (4.37%) was recorded on plants treated with Bt (Dipel) @ 0.012%. The corm dip treatment of gladiolus cv. Rose Supreme in Emisan-6 (0.2%) coupled with soil application of *Trichoderma viride* was found to be the best for management of *Fusarium* wilt.

Mushroom

The compost prepared by combination of INRA and Anglo Dutch methods produced on an average yield of 11.14 kg mushrooms/q compost in 40 days of cropping. Among various substrates/ composts tried for paddy straw mushroom, compost prepared with cotton ginning mill waste + paddy straw proved better substrate as it gave the same yield in two weeks as obtained in 4 weeks from spinning mill waste + paddy straw compost. Srains, OE-274, SSI and OE-55-08 gave higher mushroom yield with superior quality fruiting bodies. Physiological studies conducted on various strains of *L. edodes* revealed that 20–25°C

Crop of strain, OE 274 of *V. volvacea*

temperature is optimum for vegetative growth of all the strains. Strain, OE-38, showed wide adaptability to *p*H and could grow even at *p*H 4.0, whereas *p*H 6.5–7.0 was optimum for growth of all strains. Corn cob was best medium for the growth of most of the *L. edodes* strains. Sawdust and wheat straw (50 : 50 w/w) gave 114% biological efficiency (BE) in six months cropping period. Shock treatment of cultivation substrate for 6 hr proved to be the best as it resulted in the maximum production of shiitake mushroom.

Planting material

Disease-free nucleus quality planting material (41,41,261) and breeder seeds (33956.69 q) of different horticultural crops were produced.

Details of seed and planting material of horticultural crops

Crop category	Planting material/seed produced
Fruit crops	15,94,501 (number)
Plantation crops	8,50,690 (number)
Spices	2,24,300 (number) 150 (q seed)
Potato	33,466 (q. seed) 4,10,573 (mini-tubers) 5,10,242 (min-tubers from tissue culture)
Tuber crops	50,000 (number) 240 (q seed)
Medicinal plant	2,65,505 (number)
Ornamental plants	65,450 (number)
Vegetables	1,70,000 (number hybrid seedlings) 61.6 (q seed)
Mushroom	39.09 (q spawn)

Medicinal and aromatic plants

In isabgol, aphid infestation was positively influenced by N doses. Hence, irrespective of irrigation schedules, maximum aphid infestation (33.78) was highest at N/60 kg/ha. Downy mildew disease severity was also significantly influenced by fertilizer doses but not due to irrigation schedules. Maximum disease was recorded at 60 kg N/ha (14.23 PDI) which was at par with 45 kg N/ha (13.29 PDI). Both sowing time and seed rate had significant effects on *Alternaria* leaf blight disease development in Asalio (*Lepidium satibum*). Delay in sowing increased the disease severity till 10 November and it reduced thereafter. Increasing seed rate resulted in increase in blight severity. Hence, 6–8 kg/ha seed sown on 10 October had minimum (10.8–13.2 PDI) disease severity, while maximum (38.9 PDI) was recorded at 10 November sowing with highest seed rate. At Faizabad, *Alternaria* leaf blight could be best managed with foliar application of Mancozeb thrice (40, 55 and 70 DAS) which resulted in maximum diseases suppression and consequently increased seed yield (1,880 kg/ha). Systemic fungicide (Propaconazole) was less effective. ❑