



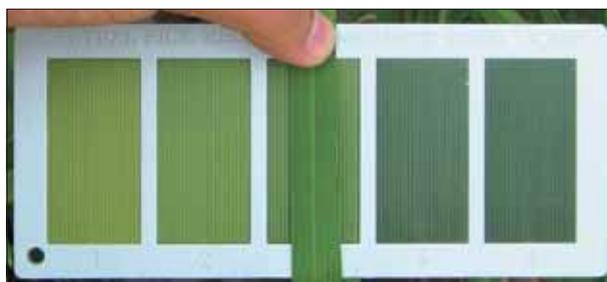
8. Crop Management

PRODUCTION

To maximize yielding ability of improved varieties and hybrids of different field crops, cost-effective and efficient production technologies have been developed for different agro-ecological conditions.

Cereals

A five-panel customized leaf colour chart (CLCC) for nitrogen management in rice for different ecosystems is being utilized. This is an easy-to-use, cost-effective tool. With this, farmers could adjust N application to actual crop demand, and thus obtained higher yields with reduced (10–20 kg/ha) N application.



Leaf colour chart for nitrogen management in rice

Use of mulch coupled with spray of KCl or CaCl₂ at 0.2% resulted in higher grain yield of wheat and also helped mitigate climate change effects on wheat productivity. And under restricted irrigation, hydrogel at 2.5 to 5.0 kg/ha enhanced wheat productivity.

Urea coated with 1,000 ppm karanj- oil/ palmarosa-oil/citronella-oil/neem- oil saved 30 kg N/ha in wheat (recommended dose is 150 kg N/ha); thereby reducing 20% on cost of fertilizers, besides enhancing nitrogen-use efficiency. Split nitrogen application as 1/3rd basal + 1/3rd just before first irrigation (21–25 days) after sowing and 1/3rd just before second irrigation (45–50 days after sowing) improved nitrogen-use efficiency compared to two or four splits.

Oilseeds

A native strain of the plant-growth promoting rhizobacterium was isolated and identified as *Bacillus aryabhatai* MDSR14 (JF 792521). Co-inoculation of this with arbuscular mycorrhizal (AM) fungi in soybean +maize intercropping significantly increased dry-matter accumulation, seed yield and phosphorus-use efficiency of both the crops.

Polythene mulch improved groundnut pod yield by 14.4%, and also resulted in saving of 25% NPK when applied through drip irrigation compared to the recommended dose of fertilizers applied to soil.



Polythene mulch in groundnut

Hydrogel at 1.5 kg/ha significantly improved groundnut pod yield by 9.6 and of haulms by 16.4%. Incorporation of mustard-straw and *Sesbania* green-manure at 2.5 tonnes/ha in the soil enhanced Indian mustard seed yield by 45%.

Pulses

In Inceptisols, inclusion of pulses in cereal-cereal system and integrated nutrient management sequestered more soil organic-carbon and thus improved soil health. In maize-based cropping system, highest system productivity of 3,411 kg/ha in terms of pigeonpea equivalent was recorded in maize-wheat-mungbean system. Under rice-based system, highest system productivity of 5,140 kg/ha in terms of chickpea equivalent was recorded in rice-wheat-mungbean system.

Sowing of chickpea on broad-bed and furrow (BBF) enhanced seed yield by 18.9–33.8% over flat method. Rice-straw mulch maintained 2–3% higher soil moisture during critical crop growth stages of chickpea and lentil in rice-fallow.

In rice-chickpea-mungbean system, yield of summer mungbean was higher with incorporation of residue (13%) and zero tillage (7%) in comparison to no-residue (1,528 kg/ha) and conventional tillage (1,481 kg/ha), respectively. Highest system productivity in terms of chickpea equivalent was obtained in rice-wheat-mungbean (6,546 kg/ha), followed by rice-wheat (4,424 kg/ha) and the lowest was in rice-chickpea (4,291 kg/ha).

Commercial crops

With polymulch technology, cotton cv. Suraj recorded 1.56 tonnes of additional seed-cotton yield /ha than the conventional method in farmers' fields.

In-situ rain-water conservation through seeding in open-furrows or mulching with paddy-straw for jute



Single Cane- Node Technology for higher yields

“Single- node technology of sugarcane planting” was initiated in the cropping season, and was observed in reducing quantity of seed-cane by 50% in sugarcane cultivation, besides rapid germination of cane- buds. Highest germination of 80.9% was recorded in a single-node cane segment as against 42.5 % under 3-bud setts.

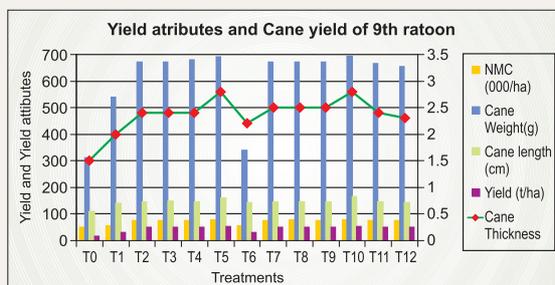
Priming technique for improved germination in cane-node was also perfected using hot water (50°C) + 3% urea solution for 2 hr or cattle-dung, cattle- urine and water in 1:2:5 ratio. Apart from germination, yield and yield attributes were notably higher in a single cane-node technology as compared to the conventional planting of 3-bud and 2-bud setts.



Sprouting enhanced (3-4 days) with priming. Uniform sprouting in single Cane Node technology (*inset*)

Bio-manuring for sugarcane multi-ratooning and for soil health

Effects of different bio-manures on yield and quality of sugarcane under multi-ratooning revealed remunerative yields of sugarcane ratoons up to 9th ratoon (56 tonnes/ha) with continuous application of 10 tonnes of sulphitation pressmud (a sugar industry by-product)/ha + *Gluconacetobacter diazotrophicus*. Bio-manuring improved cation- exchange capacity of roots and also improved composition of root biomass. Soil organic-carbon (SOC) showed increase from initial 0.32 to 0.69% and soil microbial biomass carbon (SMB-C) also recorded an increase.



T₀- Control with *Trichoderma*; T₁-Trash compost @ 10 tonnes/ha; T₂- Vermicompost @ 10 tonnes/ha; T₃-FYM @ 10 tonnes/ha; T₄- Biogas slurry @ 10 tonnes/ha; T₅-Sulphitation pressmud (SPMC) @ 10 tonnes/ha; T₆-T₁+ *Gluconacetobacter diazotrophicus* + *Trichoderma*; T₇-T₂+ *Gluconacetobacter diazotrophicus*; T₈-T₃+ *Gluconacetobacter diazotrophicus*; T₉-T₄+ *Gluconacetobacter diazotrophicus*; T₁₀-T₅+ *Gluconacetobacter diazotrophicus*; T₁₁-*Sesbania* intercrop green manure + *Gluconacetobacter diazotrophicus*; T₁₂-NPK (150:60:60 kg/ha)

cultivation proved beneficial. Under deficit rainfall situation, use of higher seed rate (6-8 kg/ha), elemental sulphur use (30kg/ha), and intercropping of greengram or cowpea with an early-sown jute were found remunerative, and also ensured 30 kg jute fibre (equivalent) yield /ha.

For ramie cultivation, its waste-stalks were established as alternative planting material. With the consortium of alkalophilic pectinolytic bacteria, degumming of ramie fibre could be completed within 2–3 days at 34°C and in 4–5 days at < 31°C. The degumming liquor can be used twice with fresh decorticated ramie fibres without loss in degumming efficiency. Two additional neutral pectinolytic strains with better pectinolytic activity have been isolated.

HORTICULTURE

Fruit crops

In mango, two-year-old polyembryonic Bappakai, Goa, Kuroki, Mylepelian, Moovandan, Nekkare and Vellaikolamban rootstocks were evaluated at different salinity levels. The degree of senescence was less in Nekkare and Kurukkan compared to others. High salinity resulted in decrease in growth rate over the control, which was manifested by defoliation of leaves and stunted growth.

In Kinnow mandarin, analysis of microbial population in soil under semi-arid conditions revealed maximum total microbial population at 0-15 and 15-30 cm depth due to application of recommended dose of N, P, K + FYM and consortium of biofertilizer with maximum fruit yield (60kg/tree), fruit weight and quality (TSS, acidity and juice recovery). A microbial consortia consisting of *Azotobacter chroococcum* (asymbiotic N-form), *Bacillus mycoides* (K-solubilizer), *Pseudomonas fluorescens* (P-solubilizer), *Bacillus polymyxa* (P-solubilizer) and *Trichoderma harzianum* (P-solubilizer) isolated from citrus rhizosphere was prepared. It showed no antagonism among the component microbial species up to 90 days under laboratory incubation. Its application improved soil health besides growth and fruit yield.

In papaya, ultra drying technique of seeds was standardized to maintain original germination, vigour and viability under ambient temperature.

In grapes, increased vigour of Cabernet Sauvignon vines was recorded when grafted on 110R, Gravesac and SO4 rootstocks. Yield ranged from 8.97tonnes/ha (on Fercal) to 11.20tonnes/ha (on SO4 rootstock).

The drip irrigation schedule for grape Cabernet Sauvignon raised on 110R rootstock based upon stage of crop growth and pan evaporation was standardized. The maximum water-use efficiency (103.42kg grape/mm irrigation water applied) was recorded due to minimum application of irrigation water (182.81mm) along with rains received during annual growth cycle.



Covering the vines using shade net resulted in early and more number of sprouted buds (60 buds/vine) compared to un-covered ones (45 buds/vine).

Association of auxins with rachis swelling disorder was confirmed by application of NAA at parrot green stage of cluster. Application of NAA at this stage induced rachis swelling in Tas-A-Ganesh and Manjri Naveen (@ 20ppm), and Sharad Seedless (50ppm) cultivars.

In litchi, relatively early fruit maturity (5-6 days) was recorded with foliar spray of ethrel (100ppm) twice during October and February. Spray of 2.0 % KNO_3 led to early emergence of panicles in cv. China. Maximum flowering in China was recorded due to soil application of paclobutrazol @ 4 g a i/m canopy radius followed by spray of 2.0 % KNO_3 .

In pomegranate, best month for budding *in situ* was January (90% success). For pomegranate cultivation in heavy textured soils, irrigation applied through 6 (2litres/hour) drippers fixed on two laterals and placed on both sides of the plant resulted in better vegetative growth. The soil moisture content in vertical direction in both heavy and light textured soils was sufficient even up to a depth of 90 cm in 2, 3 and 4 dripper system, while it was up to 75 cm depth in ring system and up to 60 cm in two lateral systems of dripper placement.

In aonla, studies on high-density planting systems revealed that different planting systems significantly affected vegetative growth, yield and quality of aonla under rainfed conditions of semi-arid environment. Application of paddy straw mulch recorded the highest bacterial population in basin soil.

In temperate fruits, maximum fruit setting and yield in peach were recorded in tatura trellis training at 2.5m × 2.5m spacing, while open centre training was best under 3m × 3m spacing. Light interception at different canopy height and overall maximum light interception was observed in tatura trellies training system followed by four scaffold system. Fruit colour was best in tatura trellies training followed by four scaffold system.



Y-tatura trellis in peach

Apple planting at 2.5m × 2.5m with tatura trellis training was best for fruit production.

In almond, 75% RDF through fertigation (applied N:K in the ratio of 2/3N : 1/3K from nut setting to development and 1/3N: 2/3K from kernel filling to maturation stage) increased the nut number (2,041 / tree) with maximum yield (5.15 tonnes/ha).

In propagation of temperate fruit crops, chip budding resulted in higher success with 93.6, 91.7 and 91.5% in pear and; 94.2, 93.1 and 90.6% in peach during February-March, June-July and September-October, respectively.

Chip budding in apricot gave 90.4, 86.9 and 85.9% graft/bud success in February-March, July-August and September-October, respectively, with a plant height of 73.4-142.8 cm.

In almond, chip budding during February-March, June-July and September-October gave 89.6, 84.3 and 82.2%. Whereas, chip budding in walnut gave higher success only during February-March with bud take of 83.1 and 77.9% at 8-10 cm and 13-15 cm budding height, respectively. Patch budding in walnut during July-August resulted in only 28.2% success.

Plantation crops

In coconut, two plant growth-promoting bacteria (KiSII and RNF 267) isolated from the rhizosphere of coconut were identified. Co-inoculation of *Bacillus megaterium* TSB16 with *Bacillus coagulans* RSB14 had significantly positive effect on dry weight of coconut seedlings. In addition, dual inoculation of *B. subtilis* VEB4 and *B. licheniformis* KGEB16 on cocoa seedlings had significant enhancement in total dry weight than individual inoculations.

BIOLOG and 16S rDNA sequencing of acid tolerant bacterial isolates from rhizosphere of coconut palms revealed presence of a diverse population of acid-tolerant *Bacillus* spp. For effective bio-waste utilization, *biochar* production from coir pith and tender nut husk was standardized using a simple charring kiln.

In arecanut, productivity (33.16-36.65 kg dry nuts/ha) was *at par* due to either fertigation with 75% NPK or 20% N through vermicompost extract or vermicompost extract (10 and 20% N) + 25% NPK.

In oil palm, duration of phenological phases (spear leaf to 17th leaf) and growing degree days (GDD) ranged from 209 to 244 days and 2760 to 3035 heat units, respectively. Among four oil palm hybrids, Deli × Nigeria recorded higher GDD and phenological duration, while it was lowest in Malaysian hybrid. However, Malaysian hybrids recorded highest phenological duration and GDD from anthesis to maturity. A sudden increase in oil formation was observed from 16-18 weeks and it reached maximum during 20-22 weeks. Malaysian hybrids recorded highest oil to dry mesocarp from anthesis to maturity with very less moisture content, compared to other hybrids.



In cashew, foliar sprays of major nutrients (3% urea + 0.5% H_3PO_4 + 1% K_2SO_4) resulted in 16.1% increase in nut yield and secondary and micronutrients ($ZnSO_4$ + 0.1% solubor + 0.5% $MgSO_4$) spray caused 30.5% improvement in yield over the Mg, Zn and B deficient soils (control).

Vegetable crops

In an attempt on organic production of vegetables, integrated use of poultry manure @ 2.5tonnes/ha + vermicompost @ 3.5tonnes/ha + bio-inoculation with *Rhizobium/Azotobacter* and PSB, recorded significantly higher yield of tomato (335q/ha), cabbage (354.6q/ha) and cowpea (106.2q/ha) as compared with inorganic nutrient management (tomato-268.5q/ha, cabbage-309.5q/ha and cowpea- 80q/ha) grown respectively in *kharif*, *rabi* and *zaid* in a crop rotation sequence.

Performance of four capsicum hybrids/varieties under naturally-ventilated net house (white, 40mesh) was better with respect to growth and yield (386.28- 506q/ha) as compared to open field (98-125q/ha) in *rabi*. The performance of Swarna (yellow) and Indra (red) varieties was better as compared to Cab-1201 and Popti.

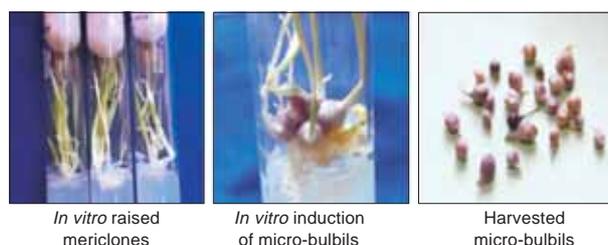
Better yield in pumpkin (5.5kg/plant) and bitter gourd (1.25kg/plant) were realized due to application of neem compost, followed by green manuring with subabul (*Leucaena leucocephala*) and lowest in control.

In onion, N and K uptake was higher at 15-60 days after transplanting (DAT), attaining peak at 25-30 DAT (active vegetative growth) followed by sharp decrease at 60 DAT. Phosphorus and sulphur uptake was higher at 20-60 DAT with peak at 40-50 DAT (late vegetative growth and bulb initiation stages) and it continued up to 110 DAT.

Vernalization significantly enhanced the number of scapes and reduced the days to first scape emergence in onion Bhima Kiran and Bhima Super. On exposure to 10°C for 10 days, the seed yield in Bhima Kiran and Bhima Super was improved by 157 and 123% respectively, compared to untreated control.

Virus-free garlic plantlets were produced through meristem culture from virus indexed explants using 0.1 – 0.3 mm meristems. *In vitro* bulbils were induced from virus-free plantlets on medium containing 6% sucrose. Before planting, cold treatment of bulbils increased germination and reduced the period required for complete germination compared with untreated control.

Soil application of poultry manure at the rate of 10



Virus free garlic seed production through meristem culture

tonnes/ha in onion and garlic produced relatively higher yields compared to other treatments. However, marketable bulb yield recorded in organic farming was 17-48 % lesser than inorganic farming. The status of available nutrients in soil after harvesting showed more available nutrients with application of inorganic fertilizers over organic sources.

Tuber crops

In coleus, growing sunhemp for 45 days and incorporating into soil, application of FYM @ 80 kg/ha, raising nursery with *Trichoderma* (1kg/1000 kg of FYM) enriched FYM and planting 40 days old rooted cuttings at a spacing of 60cm × 40cm in a raised bed recorded a higher dry tuberous root yield (1851 kg/ha) with a benefit : cost ratio of 2.6.

Integrated application of organic manures (FYM @10 tonnes/ha), secondary elements ($MgSO_4$ @25kg/ha) and micronutrients ($ZnSO_4$ @10kg/ha) along with half of the recommended doses of NPK (40:30:40kg/ha) significantly enhanced the cormel yield (13.9 tonnes/ha) in taro as compared to control (without nutrient application – 6.39 tonnes/ha).

Drip irrigation equal to cumulative pan evaporation (CPE) up to stolon formation and thereafter, 1.50 times CPE till early tuber bulking and 1.25 times up to maturity produced significantly higher potato yield (36 tonnes/ha).

In fennel, application of irrigation through drip with low pressure or conventional method proved better for getting higher yield (2137 kg/ha), net return (Rs 70662 /ha), benefit : cost ratio (2.77) and water-use efficiency (6.24 kg /ha/mm) followed by all furrow irrigation. Further, all furrow irrigation proved better over conventional and alternate furrow irrigation. All furrow irrigation yielded 15 and 20 per cent higher grain and straw, respectively over conventional irrigation.

Scaling up water productivity in cumin (543kg/ha) and nigella (1,723.8 kg/ha) by applying irrigation through drip and conservation of moisture by mulching using 20 micron plastic sheet was achieved. Enhanced water productivity in nigella (5.44kg/ha/mm) and cumin (2.66kg/ha/mm) were recorded.

In coriander, 80% RDF in plastic walk-in-tunnel proved significantly better for yield (1582.16kg/ha) and its attributing characters. Plastic walk in tunnel recorded minimum aphid number (20.1) in January as compared to other structures.

Mushroom

Low temperature requiring species of paddy straw, *Volvariella bombycina* (DMRO-481) mushroom was identified and technology for its cultivation developed. Low-cost pasteurization tunnel developed for compost pasteurization of button mushroom also gave good results for oyster and milky mushrooms. Inoculation of *Alcaligenes faecalis* in casing enhanced yield of button mushroom.



Medicinal and aromatic plants

Organic production of kalmegh was standardized by growing sunhemp for 45 days, incorporating into soil, application of FYM @ 80 kg/ha, raising nursery with *Trichoderma* enriched FYM (1kg/1000 kg of FYM) and planting 40 days old seedlings at 30cm × 30 cm in a raised bed with drip irrigation. Harvesting 120 days after planting yielded 1,859 kg dry biomass with a benefit : cost ratio of 1.51.

Intensive agro-techniques for saffron production developed. Two to three irrigations through sprinkler or drip caused early sprouting, early flowering, increased foliage length and number of leaves and flowers as compared to rainfed (control). Pistil fresh and dry weight; length and yield per hectare improved due to sprinkler or drip irrigation as compared to control. Raised beds resulted in early flowering with improved plant growth and more number of leaves and flowers per unit area as compared to ridge and furrow, or flat bed planting. Planting at 10 lakh corms/ha resulted in significant yield improvement (7.51 kg/ha) as compared to 15 lakh corms/ha (7.08 kg/ha) or 5lakh corms/ha (4.64 kg/ha) in raised bed planting with drip irrigation. Maximum propagation coefficient (422%) was recorded due to sprinkler irrigation, followed by drip (410%) at 5 lakh corms/ha in raised bed planting. Propagation coefficient was lesser than 100% in flat bed.

The planting of saffron @ 10 lakh corms/ha on raised beds supplemented with 2–3 sprinklers or drip irrigations resulted in early germination and flowering with improved plant growth, fresh and dry weight of pistil and ultimately significant improvement in yield (7.5 kg/ha).

Maximum propagation coefficient (422%) was recorded in raised bed with sprinkler irrigation and 5 lakh corms/ha planting density, followed by flat bed (410%) with drip irrigation and 5lakh corms/ha planting density.

FLORICULTURE

In gladiolus, Purple Flora, Verona, Snow Princess, Priscilla, Amsterdam, Flavo Souvenir, Jester Gold, Hunting Song, Rosibee Red, Princess Margaret Rose, Yellow Stone, Novalux and Ocilla, varieites were suitable for November planting, while Snow Princess, Beau Jour and Bean Benton performed better for flower production under late planting under north Indian plains.

In orchid, *in vitro* protocol for induction of Protocorm Like Bodies (PLBs) was standardized for seven *Cymbidium* hybrids and *Paphiopedilum* species. The method for *in vitro* flowering in *Cymbidium dayanum* was standardized. The benefit:cost ratio of *Cymbidium* cultivation ranged from 1.43 to 1.6 in Asom and East Sikkim. Spraying of N75 P10 K10 @ 1.0 g/litre improved the survival (75%) and vigor of *ex vitro* grown *Zygopetalum intermedium* plants.

CROP HEALTH MANAGEMENT

To overcome negative impact of different insect-pests, diseases and weeds in major agro-ecosystems, crop- health management research has led to the development of improved practices and gadgets, in addition to innovative practices for management of pests.

Cereals

In rice, Flucetosulfuron, a new post-emergence sulfonyl urea herbicide, when applied 7 days after sowing at 25 g a.i./ha showed 90% efficiency in controlling predominant grassy weeds, sedges and annual broad-leaf weeds. Application of Metsulfuron+ Carfentrazone (Ready mix) at 25 g a.i./ha in wheat was found effective in controlling broad-leaf weeds, and resulted in maximum grain yield in the North Western Plains Zone, North Eastern Plains Zone and Central Zone. And application of ready mixture (Vesta and Total) provided effective broad spectrum weed control and higher wheat productivity in the North Hills Zone, North Western Plains Zone, North Eastern Plains Zone and Central Zone.

Oilseeds

Pre-emergence application of Pendimethalin at 1kg/ha + one intercultivation at 40 days after sowing (DAS) resulted in better weed- control efficiency to realize higher castor- seed yields and net returns. Isoproturon 75WP at 0.10 kg a.i./ha or 0.15 kg a.i./ha in 250 litres of water at 30 DAS; Oxyfluorfen 23.5EC pre-emergence (PE) or 0.75 kg/ha Trifluralin 48EC pre-plant incorporation (PPI); 0.06 kg a.i./ha Clodinafop 15WP (25-30 DAS) and 0.09 kg a.i./ha Oxadiargyl 80WP (PE) were effective against castor weeds and reduced yield losses significantly.

Soil application of ZnSO₄ at 15 kg /ha + S (location specific), followed by 2 foliar sprays of Carbendazim + Mancozeb at 0.2% at 45 and 60 DAS were most economical and effective in reducing major foliar diseases of mustard. Spray of Dimethoate at 1 ml/litre, followed by release of *Coccinella septempunctata* at 5,000 beetles/ha was recommended for eco-friendly integrated pest management of mustard aphid.

For management of safflower aphids, foliar sprays of Clothianidin at 50g/ha or Chlorpyrifos (50%) + Cypermethrin (5%) 55 EC at 1,000 ml/ha were effective with a field efficacy of 94.4% and 84.0%, respectively, and IBC ratio of 10.7 and 12.2.

Pulses

Pendimethalin 30 EC+ Imazethapyr 2 EC (Ready mixture Vellore 32) at 1.0 kg a.i./ha (3.125 litre/ha) for heavy clay soils and at 0.75 g a.i. (2.5 litres/ha) for light soils managed weeds effectively in mungbean, urdbean, lentil and fieldpea. In pigeonpea, pre-emergence herbicide, Pendimethalin at 0.75 kg a.i./ha



Trichoderma -based bioformulation (Pusa 5SD)

Pusa 5SD, a seed-dressing formulation of *Trichoderma harzianum*, was validated against wilt and root-rot of chickpea at different locations in Madhya Pradesh, Maharashtra, Rajasthan, Gujarat, Jammu and Kashmir and Delhi. At 4g/kg of seeds, formulation reduced disease incidence by 8.3- 63.8% and enhanced grain yield by 14.7-39.6%. In combination with Vitavax (1g/kg), the formulation further reduced disease incidence by 51.1-100% and enhanced grain yield by 19.9-62.5%.

Accelerated Pulse Production Programme (A3P)

The programme was implemented on 114,000 ha in 11 states, covering 106 blocks, 576 villages and 23,594 farmers across the crops— pigeonpea, chickpea, lentil, mungbean and urdbean. A3P farmers' fields registered significant reduction in pest incidence and used less pesticides compared to non-A3P farmers. Besides there was an increase in yield of pulses by 15-18%, as the result of the implementation of the programme. "e-National pest reporting and alert system", aided A3P registered farmers to adopt appropriate measures for minimizing pest infestation on pulses through critical IPM inputs.

and post-emergence application of Imazethapyr at 100 g a.i./ha at 10–15 days after sowing (DAS) at 2-3- leaf stage of weed+one hand -weeding at 50 DAS effectively managed weeds. Two sprays of post-emergence herbicides, Imazethapyr + Imazamox in combination at 40 g/ha effectively managed weeds of guar and cowpea. Significant reduction of wilt disease in pigeonpea was observed with *Trichoderma* strains, IPT 31 and IPT 11 (9.5–10.8% against 23.7% in control). All treatments excepting *Trichoderma* strain from Bengaluru gave 198–255 kg/ha higher yield over the control.

Biological control

Production protocol for anthocorid predators:

A protocol has been standardized to rear *Montandoniella indica*, predator of pepper gall- thrip, *Liothrips karnyi*, using UV irradiated *Corcyra cephalonica* eggs as prey and bean pods as an ovipositional substrate. Both nymphs and adults of *Blaptostethus pallescens* released over *Frankliniella schultzei* pupae in soil gave, respectively, 74.0 and 89.3% mortality compared to 41.3% mortality in the control.

Fruits and plantation crops pests: A multiple insecticide-resistant strain of *Trichogramma chilonis* was released to control fruit- and- shoot borer (*Leucinodes orbonalis*) on brinjal and bollworm (*Helicoverpa armigera*) on tomato in Tamil Nadu and Punjab. In Tamil Nadu, inundated release resulted in reduction of insecticides application by 80 and 50% on brinjal and tomato, respectively, with a concomitant increase in yield by 15–20%; resulting in an overall benefit of ` 15–20 thousand per acre to farmers. In Punjab, mean fruit damage and crop infestation in

Endosymbionts of insect-pests

Culturable endosymbionts of yeast and bacterial species were isolated from *Aphis gossypii*, *Aphis craccivora* and *Myzus persicae* from Karnataka. They possess potential to detoxify pesticides used to govern parasitism of the pests. Yeast *Wickerhamomyces anomalus* tolerated and grew in insecticide amended medium up to 96 hours of inoculation. Endosymbiotic yeasts, *Metschnikowia reukaufii*, *Pichia ohmeri*, *Wickerhamomyces anomalus* and *Candida apicola* increased fitness attributes like parasitism, sex-ratio and fecundity in *Trichogramma japonicum*. *Enterobacter* sp. isolated from *Chrysoperla zastrowi sillemi* larvae degraded Acephate and Indoxacarb. *Cotesia plutellae* fed with *Wolbachia* recorded higher parasitism (74.8–91.2%) and adult emergence (64.1–82.2%) than *Wolbachia*- cured populations (68.2–82.3 and 60.4–72.2%, respectively). These endosymbionts can serve as important candidates for biocontrol of pests.

tomato were lesser by 85.8% and 89.0% with biocontrol measures as compared to farmer's practice. The intervention resulted in an increase in farm income by Rs 14,600 per acre.

Papaya mealy bug control: Parasitoid, *Acerophagus papayae*, provided a sustainable control of papaya mealy bug, *Paracoccus marginatus*, at all tested locations. It significantly protected papaya, tapioca and mulberry from this menacing pest, and saved on ` 700 crore during 2012-13.

Coconut leaf caterpillar, *Opisina arenosella*: Systematic monitoring and release of larval parasitoids, *Goniozus nephantidis* and *Bracon brevicornis*, reduced damage by 42% due to *Opisina arenosella*; the pest population was reduced by 93% in different regions of Kerala within a period of seven months.

Botanicals and bio-agents for control of soybean insects: Aqueous extract of seeds of *Acacia arabica* and *Datura stramonium* and of leaves and seeds of *Annona squamosa* proved as effective as *Bacillus thuringiensis* in management of semiloopers and *Spodoptera litura* on soybean-crop. Native isolates of *Beauveria bassiana* were effective against *Helicoverpa armigera*- infesting soybean.

Nematode control

Seed treatment with Carbosulfan at 1% was better than seed dressing with *neem*, *mahua* and jatropha kernel extract at 10% for controlling *Meloidogyne javanica*, while seed treatment with neem seed kernel extract at 10% was better than Carbosulfan at 0.5% and extracts of *mahua* and jatropha at 10% for controlling *Meloidogyne incognita*. Cropping sequence of non-host crops, wheat-*bajra*-wheat reduced root -knot nematode population by 45%, and of wheat-mungbean-wheat reduced nematode population by 35%.

Integrated pest management

In farmers' participatory mode, an IPM module was implemented in 120 ha with rice cultivar Pusa Basmati



Pest management in rice fields through light trap

Newly invented insect light trap was validated in farmer's participatory mode in rice fields (cv. Pusa Basmati 1121) at NCR Delhi during *khari*f and in chickpea fields during *rab*i at Aakasara, Distt Bikaner, Rajasthan. The "light trap for managing insects" has qualified the standards of the International Bureau of the World Intellectual Property Organization.

1121 at Bambawad village in Uttar Pradesh with only 20 g a.i. Carbendazim /ha during the entire season compared to 2,250 g a.i. /ha normally used in farmer's practice (FP). Incidence of *Bakanae* disease caused by *Fusarium moniliformae* was reduced to 3.3% in IPM plots as against 14.7% in farmer's practice (FP). Besides, IPM practice increased spider population (7.7 per hill in the IPM as against 5.9 in the FP) as well as paddy yield (4 tonnes in the IPM as against 3.3 tonnes/ha in the FP).

Pesticide residues

Residue analysis of fungicide, Tebuconazole 60 FS on wheat; neonicotinoid insecticide, Thiacloprid 240 SC, on brinjal, and synthetic pyrethroid, Deltamethrin 10 EC, on tea was done through multilocation field trials in different agroclimatic conditions of the country. On the basis of the persistence and dissipation study, Food Safety Standard Authority of India, Ministry of Health and Family Welfare has fixed the maximum residue limit (MRL) as 0.07 ppm for Tebuconazole 60 FS; 0.3 ppm for Thiacloprid 240 SC and 2.0 ppm for Deltamethrin 10 EC on respective crops. Based on the data, the Central Insecticide Board and Registration Committee, Ministry of Agriculture, has approved label claim for the above pesticides for their commercial use in the country.

DNA bar-coding of rice insect-pests

To facilitate identification of major insect-pests of rice, DNA barcodes were generated using cox 1 primers for eight pests. These include brown planthopper (*Nilaparvata lugens*), striped stem borer (*Chilo suppressalis*), green leaf hopper (*Nephotettix virescens*), yellow stem borer (*Scirpophaga incertulas*), white stem borer (*Scirpophaga innotata*), pink stem borer (*Sesamia*

Improved diagnostics

PCR based diagnostics were developed for wheat stripe rust (*Puccinia striiformis* f.sp. *tritici*) and chickpea wilt (*Fusarium oxysporum* f. sp. *ciceris*) pathogens based on ITS and β tubulin, respectively. Polyclonal antibodies based on recombinant coat protein were developed for detection of *Grapevine roll associated virus 3* (GLRaV-3) in grapes, *Garlic common latent virus* (Gar CLV) in garlic, *Large cardamom chirke virus* (LCCV) in large cardamom and *Potato virus S* (PVS) in potato. Cocktail polyclonal antibodies were generated against multiple viruses for detecting mixed infections of *Potato virus Y* (PVY) and *Potato virus X* (PVX) in potato.

Simulation model for rice gall- midge

A simulation model for rice gall-midge, *Orseolia oryzae*, an important pest of rice in eastern India, was developed using thermal constants, development thresholds and abiotic and biotic mortality factors for different developmental stages of the pest. The model has projected that gall-midge incidence on rice may increase by 2020 but would decline by 2050 compared to 2000 under Cuttack and other similar environments.

inferens), angoumois grain moth (*Sitotroga cerealella*) and red flour beetle (*Tribolium castaneum*). Barcodes of these have been submitted to BOLD (biodiversity of life database) system, and gene bank accessions have been obtained.

Identification of markers for development of DNA barcodes of plant pathogens

Suitable markers were identified to develop DNA barcodes for fungal and nematode pathogens. Multiloci sequence typing (MLST) revealed β tubulin as a suitable marker for interspecific differentiation of *Trichoderma* spp.; NADH dehydrogenase subunit 6 (ND6) as a suitable marker for *Fusarium* spp. and cox1 as a suitable marker for entomopathogenic nematodes.

Acarology

Biological control of mite pests: Spidermites have become an economic pest of vegetables and fruits and also of other crops. Two-spotted spidermite, *Tetranychus urticae*, infestation reduced yield by 21.1% of the marketable brinjal-fruits.

Pole-bean supported mass multiplication of obligatory predatory phytoseiid mite, *Neoseiulus longispinosus*. Pilot study with the predator against infestation of *T. urticae* on grapevine in Bengaluru in 1:50 (predator: prey) resulted in significant reduction in prey mite population (23 mites/leaf to <1/leaf) in 5 weeks. Acaro-pathogenic fungus, *Acremonium zeylanicum*, caused epizootics of *T. urticae* infesting brinjal- plants under polyhouse conditions in Thrissur.



Neoseiulus longispinosus, a potential phytoseiid predator of spidermites

Wild boar management

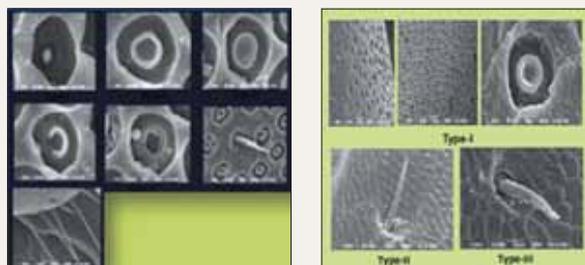
Damage to crops due to wild boar (*Sus scrofa*) in four districts of Telangana region was estimated to the extent of 22–35% in paddy, 30–48% in maize, 28–42% in groundnut, 28–57% in sugarcane and 14–21% in vegetables. Since wild boar is protected



Characterization of white- grub (*Lepidiota mansueta*) pheromone to develop traps

White-grub (*Lepidiota mansueta*) has appeared as a severe key pest of many field crops in Majuli in Jorhat district of Assam; the largest mid-river deltaic island of the world. Potato, sugarcane, *Colocasia* and mungbean are most severely affected with annual damage ranging from 42 to 48, 15 to 20, 35 to 40 and 30 to 35 %, respectively.

Lepidiota mansueta is a biennial species and its adults



Sensillae found in antennal lobes of female (left) and male (right)

exhibit sexual dimorphism; females have seven types of chemoreceptors and males have only three types.

Third instar grub of *L. mansueta* was reared in the white-grub laboratory to obtain virgin adults, known to respond well to pheromones. Pheromone glands for sex pheromone

extracted from male and female adults indicated that males have aggregation pheromone, signaling congregation of females at one place, while females have sex pheromone (s) to attract males. These results strongly reveal possible involvement of pheromones in mating behaviour of *L. mansueta*. Identification and synthesis of pheromonal compounds are in progress.



Mating white grub (*L. mansueta*) adults



Border rows of castor around maize control losses due to wild boar

by Wildlife Protection Act 1972, their management needs to be logical, strategic and economical. Planting four wide border rows of castor around maize in the farmer's field showed higher yield (5,524 kg/ha) as compared to control (133 kg/ha). Castor plantation around maize prevented 95% wild-boar damage, besides additional income from castor (1,244 kg/ha). Similarly, groundnut surrounded with 4 border rows of safflower was protected from the animal and resulted in higher yields (1,560 kg/ha) compared to unprotected crop (457 kg/ha); and an additional income was generated from safflower (458 kg/ha).

Novel agrochemicals

Amphiphilic nano-polymer was synthesized and used to develop controlled release formulation of Thiamethoxam for controlling white-fly and stem-fly incidence in soybean. Significant reduction in whitefly incidence was achieved with polymer-coated Thiamethoxam formulation compared to commercial formulation. No residue of Thiamethoxam was detected in seed and soil at harvest.

New rodenticides

Two new anticoagulant rodenticides, Difencoum (0.005%) and Focoumafen (0.005%), wax blocks showed fairly good acceptability and palatability by *Bandicota bengalensis* and *Rattus rattus* causing complete mortality in no-choice and 80% mortality in free choice trials in laboratory. Both the rodent poisons registered 70-100% control success in controlling the pest under field conditions in rice and coconut crops in Andhra Pradesh, Karnataka and Andaman and Nicobar Islands.

Ornithology

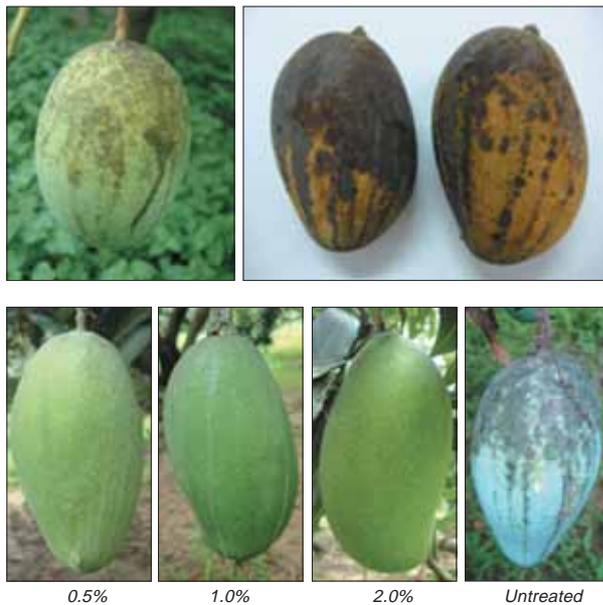
The depredatory birds are dispersed from agricultural fields, especially sunflower and sorghum using bioacoustics. The technology chiefly uses alarm, distress and predator bird calls in sequences, interspersed with silences of various durations.

Call sequence-1 and 2 were tested in sorghum research plots and in farmer's fields in Andhra Pradesh. Interquartile Range analysis showed 43% and 59% dispersal using call sequence-1 and 2, respectively. The yield of sorghum and sunflower increased by 40-50% in bird-damage prone areas compared to traditional control methods employed. Acclimatization to call sequences was delayed by adjusting silence periods in the broadcasting equipment.

HORTICULTURE

Fruit crops

In mango, area-wide IPM validation for fruit fly management was implemented by deploying 70,000 fruit fly traps, covering 11,650 acres mango orchard in Andhra Pradesh, Karnataka and Tamil Nadu, which resulted in a saving of 25-30% fruit yield. The fruit fly infestation in Banganapalli cultivar was nil due to



Management of shoulder browning and tear staining through tree oil formulation spray

adoption of pre-harvest IPM module for its management consisting of methyl eugenol traps; sanitation and bait sprays as against 23% in the control.

An artificial diet for rearing of the calliphorid pollinator of mango, *Chrysomya megacephala*, was standardized.

One new isolate of entomopathogenic nematode, *Steinernema abbasi*, was identified and validated using ITS region of ribosomal DNA tandem repeat unit. The DNA sequence (1-960bp) of *Steinernema abbasi* was deposited in the DNA Gene Bank (No. KF573496). Spraying of tree oil formulation @ 2.0% at the end of June (before onset of monsoon) was most effective for management of shoulder browning and tear staining diseases of mango.

In grapes, spraying of *Bacillus subtilis* (Milastin-K) followed by Chitosan (90% de-acylation grade) 10% solution @ 1.0 ml and 5 ml/ litre, respectively after fruit pruning showed good control of powdery mildew in Tas-A-Ganesh vineyard.

Pre-harvest spraying of Chitosan 10% solution (70 or 90% de-acylation grade) @ 2.0 ml/litre showed least rotting index and increased shelf-life in Sharad Seedless grape. Such a treatment could be useful for distant marketing of table grapes. Extensive survey and laboratory analysis of leaf samples revealed absence of Grapevine Fan Leaf Virus (GFLV) and *Botrytis cinerea* in vineyards in Maharashtra.

Isolates of *Colletotrichum* from hot arid regions were more virulent on grape leaves than the isolates from other regions. Leaf wetness, minimum temperature and RH contributed significantly for anthracnose severity.

Biochemical analysis of grape accessions with combined or variable resistance or susceptibility to anthracnose and downy mildew indicated the role of peroxidase in imparting resistance to anthracnose. SCAR markers were developed for the identification of

Carbendazim resistant isolates of *Colletotrichum*. Isolates of *Bacillus* and *Pseudomonas* antagonistic to Carbendazim resistant *C. gloeosporioides* isolates were identified.

Sixteen *Trichoderma* isolates with potential for bio-control of grape diseases were further characterized for their sensitivity to fungicides and compatibility with other isolates. Most of the isolates were compatible to each other and may be used in singly or in consortia mode. Four *Bacillus* strains isolated from grapevines or grape rhizosphere enhanced the degradation of insecticide profenofos *in vitro*, in soil and on grape berries.

Of all the three species of thrips recorded infesting grapes in Nasik, Sangli, Pune and Solapur, *Scirtothrips dorsalis* was most common. Spinosad 45 SC and cyantraniliprole 10 OD were compatible with GA₃ and CPPU and most effective in reducing thrips damage when applied along with two application of GA₃ (40 ppm)+ CPPU (2ppm) through bunch dipping.

In addition to red spider mite, *Tetranychus* spp.; two new species of mites, viz. *Panonychus* spp. and *Oligonychus* spp. were observed infesting grapevines. Application of Hexythiazox 5.45 % EC @ 25 g a i/ ha was effective in managing mites.

Pesticide residue in grapes: Export purpose 350 grape samples, assessed for multi-residues of agro-chemicals, were in compliance to the MRL of European Union. In addition, 80 wine samples collected from different wineries of the country and 92 raisin samples had residues of agro-chemical, heavy metals and allergens (sulphur, albumin and casein) mostly either within the safety limits or below the MRLs.

In citrus, effects of Dimethoate, Endosulfan, Acephate, Thiamethoxam and Imidacloprid on Asian Citrus Psyllid (*Diaphorina citri*) populations from Nagpur and Amravati showed low to moderate resistance both in adult and nymphs, whereas adult thrips, *Scirtothrips dorsalis*, from Nagpur showed high resistance to Acephate (RR=25) and moderate resistance to Dimethoate (RR=9.3).

In pomegranate, all the isolates of *Xanthomonas axonopodis* pv. *punicae* produced typical yellow mucoid raised colonies on nutrient glucose agar after 8 days of incubation at 30°C. Colony growth was visible after 72 hours and Fuscan production was seen after 20 days. The isolates did not grow above 5.0 and 7.5 pH or more than two per cent NaCl. Comparative genomics of isolates from diverse geographical location (Karnataka, Andhra Pradesh and Maharashtra) indicated that the strain causing bacterial blight could have a single virulent lineage. The bacterial blight severity varied from 5.5% in September and increased (27.7%) in November.

Wilt affected 81.8% pomegranate samples had association of fungi *Ceratocystis fimbriata*, one per cent samples had shot hole borer (*Xyleborus fornicatus*) and *Fusarium* sp., whereas two per cent had root-knot nematode (*Meloidogyne incognita*).

Incidence of fruit-borer (*Deudorix isocrates*) was



lesser than 10% but severity of thrips (*Scirothrips dorsalis*) was ~ 10.0% in Solapur.

In banana, wild and fungicide resistant mutants of *Trichoderma harzianum*, *Penicillium pinophilum*, *Pseudomonas putida* and *Bacillus* sp. applied five times at monthly intervals (50g/plant) either singly or in combination with talc based formulation from first month after planting in Mortaman recorded 50% reduction in vascular discolouration index of *Fusarium* wilt disease and increased the yield by 101%.

An entomopathogenic fungi collected from Asom was identified as *Beauveria bassiana* and its pathogenicity confirmed on banana weevils. *In vitro* evaluation of six endophytic *M. anisopliae* isolates indicated 100% stem weevil mortality in 14 days.

Full genome of a new BSV species infecting Hill Banana was cloned using rolling circle amplification (RCA) technique. All the isolates except the two Indian ones (TN 14 and TN 16) of banana bract mosaic virus (BBrMV) clustered together in genetic diversity analysis. Five recombination events were detected in CP gene of BBrMV.

In guava, there was heavy infestation of root-knot nematodes in guava orchards of Badaun and Lakhimpur Kheri districts of Uttar Pradesh which were manifesting with *Fusarium* wilt symptoms. Infested plants showed reduced vigour, pale yellow leaves and unthrifty vegetative growth typically associated with nematode infestation. Both apparently healthy (<1-2mm) and sick (>2-5cm) roots had nematode galls.

In sapota, physiological disorder or internal breakdown (corky tissue) in sapota ranged from 20 to 70%, especially in summer. It was identified as one of the major constraints in the cultivation of Cricket Ball variety. The reduction or complete loss of seed viability during the early stage of fruit development was identified as primary cause for the development of this disorder.

In apple, survey of farmers' orchards at Lolab, Handwara, Khansahib, Charar-i-sharif, Uri, Tangmarg, Bandipora and Sopore in Kashmir valley revealed and ELISA detection of symptomatic leaves confirmed the presence of Apple Mosaic Virus (2.08-16.20%), Apple Chlorotic Leaf Spot Virus (2.83-19.64 %), Apple Stem Grooving Virus (up to 7.84 %) and Apple Stem Pitting Virus (0.69 -11.16 %).

Plantation crops

Coconut, arecanut and cocoa: Cultural, morphological, pathogenic and molecular characterization of *Phytophthora* isolates infecting coconut and cocoa revealed distinct inter and intra-specific variability, especially in *P. palmivora*. The rate of spread of infection (lesion size) by six *Phytophthora* isolates revealed Laccadive Orange Dwarf to be highly susceptible to *Phytophthora* infection, while a high level of resistance was observed in Malayan Green Dwarf.

A preliminary study conducted to assess the susceptibility of cocoa varieties to *Phytophthora* species

showed variability among the seven varieties, and only NC × 45/53 to be susceptible to infection by all six isolates, with distinct differences in lesion size. Among the eight isolates of *P. meadii*, P8 was found highly virulent. Among fungicides, Melody Duo and Mixol (125ppm), curzate (500ppm) and Companion (1000ppm) showed 100% inhibition of mycelial growth of *Phytophthora*.

Among biocontrol agents, *Trichoderma virens* exhibited maximum inhibition of mycelial growth of *Phytophthora* (up to 62.5%) in simultaneous inoculation and was also found compatible with all tested fungicides except Companion. A simple low-cost technology for production of *Trichoderma* enriched coir pith formulation with a shelf-life of 12 months along with a simple activation process was developed for environment-friendly management of coconut stem bleeding and cocoa stem canker diseases.

Loop mediated isothermal amplification primers were synthesized and positive amplification obtained for quick detection of root wilt of coconut. Besides, chromosome preparation from actively growing root tips of coconut for fluorescent *in situ* hybridization with coconut specific probe was standardized.

Integrated pest management in plantation crops: Placing of banana food baits with pheromone lure had synergistic effect in trapping red palm weevils and when yeast was added to fermenting banana, there was increase in release of volatile compounds. In field trials, behavioural assay revealed that a blend of major and minor compounds released from the fermenting food baits caused increased orientation of weevils to pheromone which effectively trapped more weevils.

Integrated management of rhinoceros beetle (*Oryctes rhinoceros*) was demonstrated in a large area of 100 ha in Alappuzha district. After one year, there was 43-47% reduction in leaf damage and 60-80% reduction in site occupancy by the pest. A botanical cake with hexane and methanolic extracts of *Clerodendron infortunatum* and *Eupatorium* sp. was developed for prophylactic leaf axil filling against black beetle infestation in coconut. Laboratory evaluation of Cartap hydrochloride (Boregan 4% G) and Fipronil (Sargent 0.3% G @ 0.01g/grub) on red palm weevil grubs revealed 65 and 95% mortality, respectively in 24 hours.

Brontispa longissima was not located in any of the surveyed areas in the mainland, Lakshadweep and Andaman Islands. Coconut inflorescence moth (*Batrachedra arenosella*) was recorded from Minicoy Island, Bay Island and Kasaragod. Leaf mealy bug (*Pseudococcus cryptus*) and spadix mealy bug (*Dysmicoccus finitimus*) were observed infesting coconut in Kerala and Tamil Nadu.

Entomopathogenic nematode (*Steinernema carpocapsae*) caused 97.77% mortality of grubs when applied @ 20 lakh infective juveniles in 91.20 m² of area of vermicompost harbouring grubs of Royce's rhinoceros. Inundative release of EPN on organic substrate were not pathogenic to juveniles and adult



earthworms. The castings collected after two- and-a-half months showed presence of virulent (*Steinernema carpocapsae*) infective juveniles suggesting safe exclusion from the gut with no adverse effect on reproduction of earthworms.

In oil palm, a molecular diagnostic kit was developed for rapid detection of *Ganoderma*, causing basal stem rot disease in oil palm. Its specificity was confirmed through specific primers, *gan-1* and *gan-2*. Basal stem tissue recorded highest colony forming units of *Ganoderma lucidum* and the results were supported by *Ganoderma* specific primers.

In cashew, a total of 17 reduviid species were recorded and the biology of *Rihirbus trochantericus*, useful for biocontrol of tea mosquito bug (*Helopeltis antonii*) was worked out.



Reduviid *Rihirbus trochantericus* feeding on tea mosquito bug

The entomopathogenic nematodes (EPN), of the genus *Heterorhabditis* and *Steinernema* were found pathogenic on grubs of cashew stem-and root-borers, *Plocaederus* spp. An indigenous strain of EPN, *Steinernema felitiae* was isolated from soil samples of cashew ecosystem.

Vegetable crops

Molecular characterization of begomoviruses in French bean

Characterization of a new strain of tobacco curly shoot virus (TbCSV) infecting common bean revealed it to be a recombinant between tobacco curly shoot virus, mungbean yellow mosaic virus, tomato leaf curl Jodhpur virus, tobacco leaf curl Yunnan virus and *Ageratum* enation virus like ancestors, transmitted both by whitefly and inoculation of infected sap. An analysis of whole genome of this begomovirus revealed close association with TbCSV (89.1-94.5% sequence similarity) infecting Solanaceous and other weed crops. Absence of DNA-B and association virus isolate with betasatellite confirmed this as monopartite begomovirus. The identified betasatellite shared a highest sequence

identity (53.9-93.9%) with tomato leaf curl betasatellite.

Summer squash showing severe yellow mosaic disease symptoms was confirmed as infected by begomovirus through ELISA, dot blot, IC-PCR and PCR amplification. The comparison of coat protein gene sequence revealed that virus isolate shared highest nucleotide identity of 99% with squash leaf curl china virus (SLCCNV) infecting pumpkin. The minimum acquisition access period (AAP) and inoculation access period (IAP) required by *Bemisia tabaci* transmitting SLCCNV were 15 and 10 minutes, respectively with females being more efficient than males in transmitting the virus.

In cucurbits, the incidence of Phytoplasma in bitter gourd, bottle gourd, cucumber, ridge gourd and watermelon ranged from 0.5 to 13.7%. SEM of infected samples revealed the presence of pleomorphic bodies in the cell which are Phytoplasma. For further diagnosis, PCR based diagnostics were developed using Phytoplasma-specific 16SrRNA primers. In addition, amplified 1.8kb and 0.7kb PCR fragment from infected plants was identified using phytoplasma specific 16SrRNA and ISR primers.

Promising bioagents identified

A promising parasitoid (*Apanteles paludicole*) with 45% parasitization during August-September was recorded from plume moth (*Sphenerches caffer*) infesting bottle gourd. Similarly, nymphal parasitoids *Aenasius bombawalei* and *Promuscidea unfasciati* were identified from mealybug (*Phenacoccus solenopsis*) infesting brinjal, tomato, okra, pointed gourd and chilli with maximum cumulative parasitization in tomato (36%). Another parasitoid (*Diaeretiella rapae*) showed differential response for parasitization to different aphid species, maximum being on *Myzus persicae* (59%).

The RT-PCR based detection protocol was standardized for detection of GCLV by using primers flanking its coat protein gene. Similarly, N gene of IYSV was characterized for recombinant antigen production for the preparation of indigenous ELISA kits in onion.

Tuber crops

Serological and nucleic acid based diagnostic techniques were standardized for sweet potato leaf curl virus (SPLCV) and dasheen mosaic virus (DsMV) in *Amorphophallus* and yam mild mosaic virus (YMMV) infecting *Dioscorea* sp. Early and accurate detection technique for *Phytophthora colocasiae* was developed through PCR using species specific-primers.

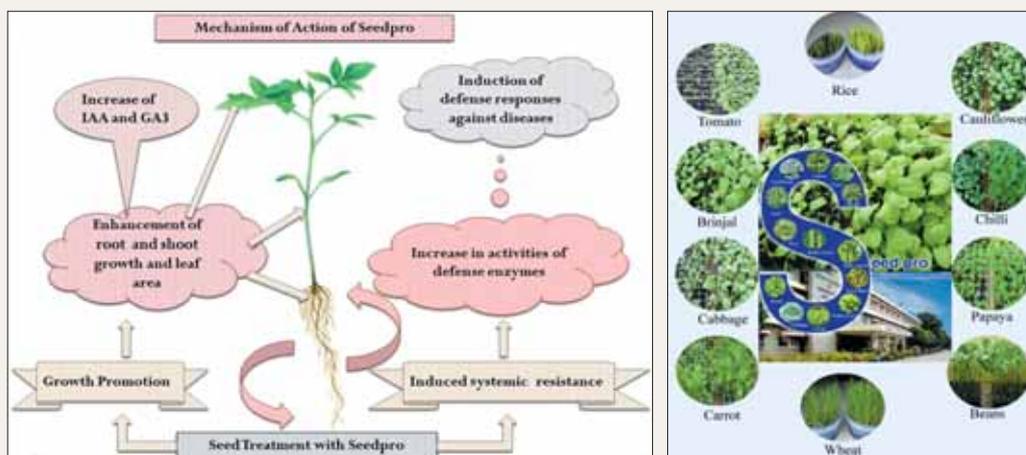
Potato

Late blight forecasting model, JHULSACAST, was developed for *tarai* region of Uttarakhand. Protocols for detection of PLRV and PVY in aphids (RT-PCR), ToLCNDV-potato in whiteflies (PC-PCR), duplex RT-PCR for PVA and PVS, PVY and PVS, and real time PCR for PVX and phylotype detection in *Ralstonia solanacearum* were standardized.



Microbial growth promoter *Seedpro*

Seedpro, a microbial plant growth promoter and fungal disease suppressor has been developed as a seed coating formulation. It is an immobilized product of *Bacillus subtilis* OTPB1 and *Trichoderma harzianum* OTPB3. It induces systemic resistance against blights caused by *Alternaria solani* and *Phytophthora infestans* and is highly effective in promoting seedling growth, vigour and yield in major cereal/vegetable/fruit crops.



Spices

A quick detection assay based on loop mediated isothermal amplification (LAMP) was developed for detection of Piper Yellow Mottle Virus (PYMoV) and reverse transcriptase (RT) for detection of Cucumber Mosaic virus (CMV) infecting black pepper.

The transcriptome from infected and healthy tissues of susceptible ginger and resistant mango ginger (*Curcuma amada*) to *Ralstonia solanacearum* causing bacterial wilt were sequenced. Large-scale expression profiling showed that many of the disease resistance related genes were expressed more in *C. amada*. Comparative analysis also identified genes belonging

to different pathways of plant defense against biotic stresses that were differentially expressed in either ginger or mango ginger. The identification of differentially expressed defense related genes provided an insight to the resistance mechanism in *Curcuma amada* and *Ralstonia solanacearum* pathosystem.

The bacterial endo-symbiont *Wolbachia* was identified from cardamom thrips (*Sciothrips cardamomi*) collected from major cardamom-growing areas in Kerala, Karnataka and Tamil Nadu. Entire thrips population was infected with sub-group 'Con' belonging to super-group B; both male and females being infected with the same sub-group.

□