



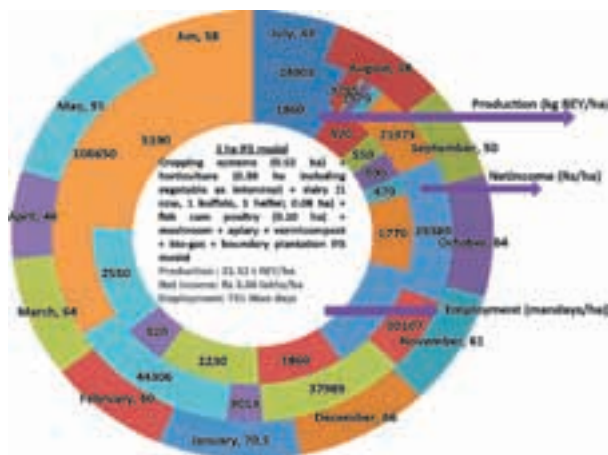
7. Crop Management

PRODUCTION

Food production can be increased substantially by upgradation of integrated strategies for cultivation of crop-plants and linking them to other disciplines.

Cereals

Integrated farming system model for round-the-year production: One ha integrated farming system (IFS) model comprising cropping systems (rice-wheat-mungbean, rice-potato-urdbean, rice-mustard-mungbean and berseem+oat-maize + sorghum with hybrid napier on bund) in 0.52 ha + horticulture (guava as main crop, lemon and mango (Amarpali) as boundary crop and



Integrated farming system model for round-the-year production (kg REY/ha), profit (₹/ha) and employment (man-days/ha) for the farm-family at Jammu (Jammu and Kashmir)

broccoli, knolkhol, cabbage, cauliflower, radish, okra as intercrops) in 0.30 ha + dairy (1 cow, 1 buffalo, 1 heifer) including biogas and vermicompost unit in 0.08 ha + fish-cum-poultry in 0.1 ha + mushroom (dhingri and button) developed for the mid to high altitude plain zone (JK-1) in Western Himalayas provides round-the-year production (21.52 tonnes REY/year), profit (₹3.06 lakh/year) and employment (731 man-days/year). The maximum production and profit was realized in June while employment was generated in May month, suggesting opportunity of the work even during the lean period. The model also meets around 85% of the inputs required for different enterprises within the farm besides providing all the commodities (cereals, pulses, oilseeds, vegetables, fruits, mushroom, milk, egg, and fish) required for the farm-family.

IPM in rice: Adoption of IPM practice in over 100 acres of land in Mahanga block of Cuttack in farmers' participatory seed programme over a period of 3 years resulted in successful production of high-quality seed.

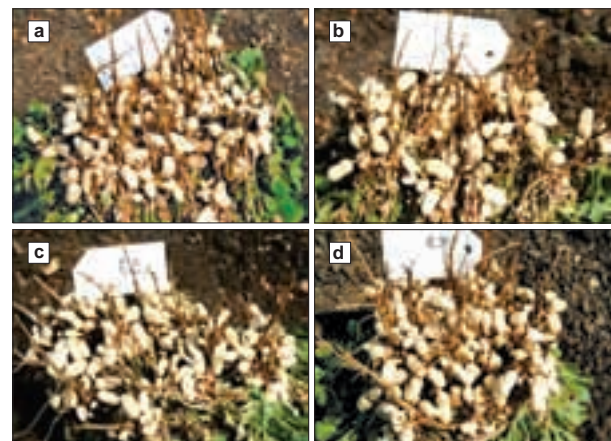
ITK-based botanicals for IPM in rice

ITKs of tribal farmers for the use of botanicals were validated scientifically for effectiveness against different insect-pests of rice. Neem (*Azadirachta indica*), karanja (*Pongamia pinnata*), water pepper (*Polygonum hydropiper*), parasi (*Cleistanthus collinus*), wild sugarcane (*Saccharum spontaneum*) and kochila (*Strychnos nux-vomica*) were employed through bio-intensive IPM in tribal area of Nilgiri block of Balasore district, Odisha. The ITKs were refined further before their implementation in farmers' fields for pest management in *kharif*.

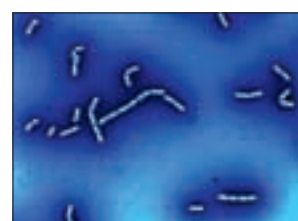
Seed treatment of Pooja and Gayatri varieties with 2% Carbendazim before sowing and need-based application of 0.5% neem oil + 2% detergent liquid or 0.05% Imidacloprid or 2% Chlorpyrifos as foliar spray for swarming caterpillar/case-worm/BPH/YSB kept the rice-crop pest- and disease-free. Monitoring of pests prevalence and their management at the initial stage of crop infestation/infection was the key factor for successful seed production.

Oilseeds

Moisture-deficit stress alleviation in groundnut: Endophytes *Bacillus subtilis* REN51N and *B. firmus*



Effect of application of endophytes on the pod yield of groundnut (cultivar TG 37A); cultivated without supplementary irrigations after sowing during summer 2015. (a) Control; (b) E2= *Pseudoxanthomonas mexicana* REN 47; (c) E3= *Pseudomonas pseudoalcaligenes* SEN 29; (d) E9= *Bacillus firmus* J22N.



Bacillus subtilis REN 51N, a root endophyte of groundnut





J22N isolated from seed, root and stem of groundnut were found effective in mitigating drought stress and enhancing growth and yield of the crop. Yield enhancement up to 40% in cultivar TG 37A was recorded over uninoculated control under extreme moisture deficit (soil moisture at 0-10-cm zone below 5%)

Conservation agriculture for groundnut-wheat system: Minimum tillage increased pod yield and net returns as compared to the conventional tillage. Wheat stubble retention + *Cassia tora* mulch increased pod yield and net returns compared to no residue application.

Plant-growth promoting rhizobacteria in soybean-maize: *Bacillus aryabhattai* MDSR 14 (JF 792521) and arbuscular mycorrhizal fungi co-inoculation significantly increased dry-matter accumulation, seed yield and phosphorus-use efficiency in soybean and maize intercropping. There was depletion of native organic-P and acid extractable-P and increase in inorganic-P in rhizosphere soil with co-inoculation; this indicates role of co-inoculation in mobilizing native unavailable organic-P and inorganic insoluble-P pool of soil to available-P.

Commercial crops

Cane yield enhancement through growth regulators: Application of ethrel, gibberelic acid (GA₃) and cytokinin at critical growth stages of sugarcane (90, 120 and 150 days after planting) in autumn-planted crop enhanced plant population to 11.6 lakh plants/ha against 3.83 lakh plants/ha in the control at 180 days after planting. Tiller survival of 61.8%, number of millable canes (NMC) 4.43 lakh/ha and cane yield of 330 tonnes/ha were recorded against tiller survival of 60.8%, NMC of 1.52 lakh/ha and cane yield of 129 tonnes/ha in control.



Enhancement of cane yield through growth regulators—(a) Control; (b) Ethrel+GA₃+cytokinin

Horticulture

Fruit crops

Variable response of different shoots on tree to the same environmental stimuli appears to be one of the major reasons leading to staggered flowering in old Alphonso mango trees. Observations on leaf net P_N revealed that more than 70% of the older leaves (> 6-8 months) on trees were photosynthetically inefficient (-7.7 to 1.5 μ moles/m²/s) as compared to relatively

younger leaves (3-11.5 μ moles/m²/s) irrespective of the month in a year. Complete defoliation of trees resulted in highly synchronized vegetative shoot formation with the primordia getting activated within 5-7 days in Alphonso mango.

Application of paclobutrazol from fourth year at 0.125 or 0.250 g/tree/year of age to Alphonso mango on olour rootstock under high density (1,111 trees/ha) planting was stabilized by the tenth year. The orchards gave more than five-fold increase in fruit yield during the initial 15 years (93.95 and 94.99 t/ha, respectively) over the conventional planting at 100 trees/ha (17.48 t/ha).

In mango, application of 50% recommended dose of fertilizers + 50 kg FYM + 5 kg vermicompost recorded higher yield (59.6 kg/tree) than the control (25.52 kg/tree) at Sangareddy in variety Banganapalli.

The sodium chloride induced salinity (3.83 ds m⁻¹) in papaya resulted in increased number of days to flower, higher percentage of male plants, and decline in pollen viability in cv. Red Lady as compared to cv. CO-4. The ultradried seeds of Arka Prabhat with 4.1% moisture, stored at ambient temperature and at 15 °C showed higher germination percentage (83 and 86) compared to those dried at 8% moisture content.

Application of black polythene mulch on sloping surface in interspaces of guava followed by 10 cm thick coir waste mulch in basin retained 41-50% more moisture than the control after 75 days of rainfall cessation. Application of 50% recommended dose of fertilizers + 25 kg FYM + 250 g *Azotobacter* recorded higher yield of guava at Sangareddy (36.26 kg/tree) and Udaipur (29.26 kg/tree).

Doubling planting density (500-1,000 plants/ha) in fig from increased yields in cv. Poona from 1.3 to 3 t/ha and in cv. Deanna from 2.5 to 4.8 t/ha.

In macropropagation of banana, application of sawdust + BAP (4 ml) + *Bacillus substillis* (30 g) produced more number (18.5) of plantlets in Grand Naine (24.3), Tellachakkarakeli (31.38) and Karpura Chekkarakeli (20.0).

Application of farmyard manure (FYM) @ 10 kg + neem cake @ 1.25 kg + vermicompost @ 5 kg and wood ash @ 1.75 kg/plant + triple Green manuring with sunhemp (one time) and cowpea (two times) along with biofertilizers, viz. AM (25g/plant), *Azospirillum* (50 g/plant), PSB (50 g/plant) and *Trichoderma harzianum* (50 g/plant) registered higher yield in Grand Naine (46.8 t/ha - 70.84 t/ha) and Nendran (24.44 t/ha) banana.

Mulching with black polyethylene paper in pomegranate resulted in improved fruits weight (273.91 g) and fruit yield (23.08 kg/tree) with low incidence of wilt (die-back) and fruit spots.

Application of 50% recommended dose of fertilizers + 50 kg FYM + 5 kg vermicompost recorded higher yield in Rose Scented (53%), Bombay Green (46%), Shahi (49%) and Mandraji (34%) varieties of litchi over the control. Foliar spray of K₂HPO₄ (1%) + KNO₃ (1%) in litchi resulted in early flowering by 6 days and increased fruit weight (23.27g), TSS (21.57°B), fruit yield (82.33 kg/plant) and reduced fruit acidity (0.341%).



Vegetable crops

In onion cv. Arka Kalyan and Arka Nikethan, both ultradried seeds (H²O 3% moisture) and seeds with 5.2% moisture maintained > 90% germination and vigour even after 50 months irrespective of storage temperatures (ambient and at 15 °C). Spray of 5000 ppm ethrel 45 and 60 days after planting resulted in reduced (55%) scape length in onion.

Mushroom

The technology for production of iron-fortified mushrooms was standardized. The iron content of fortified oyster mushrooms (*Hypsizygus ulmarius*) was increased by 143% over the control. By using short duration cultivation technology for shiitake mushroom the first harvest could be taken in 45 days as compared to 75-80 days in previous technology.

Spices

Based on soil test values, fertilizer recommendations for Appangala 1 and Green Gold varieties of cardamom were developed for fixed target yield. In both the varieties, the recorded yield were higher in target specific application (690–1140 kg/ha) as compared to general recommendations (470–690 kg/ha). Application of irrigation (9 litres/clump/day) with 100% RDF through drip in small cardamom recorded highest capsule yield (207.41 kg/ha), followed by 9 litres/clump/day with 75% RDF (201.23 kg/ha).

In turmeric, under integrated nutrient management system (50% organic + 50% chemical + micronutrient), variety Sudarsana recorded highest fresh yield (31.3 t/ha). The protrait technology of rapid multiplication of turmeric through single bud rhizome was successfully demonstrated to farmers in Tamil Nadu and Andhra Pradesh.

Maximum saffron yield (5.43 kg/ha) and B:C ratio (4.63) was obtained by planting 10 lakh corms/ha on raised bed system with sprinkler/drip irrigation, while maximum propagation co-efficient (515.6%) was recorded in fifth year on raised beds with sprinkler irrigation and 5 lakh corms/ha plant population.

Medicinal and aromatic plants

In *Coleus forskohlii* variety, K 8, planted in September produced maximum dry tuberous root yield (18.5 q/ha) with improved forskolin content (0.7%), leading to 12.95 kg/ha forskolin yield, 180 days after planting. In ashwagandha (*Withania somnifera*) variety, JA 20, maximum root yield (272.46 kg/ha) and seed yield (227 kg/ha) were obtained with July planting. Under organic cultivation, kalmegh (*Andrographis paniculata*) planted in June produced maximum dry biomass (3848 kg/ha) with two cuttings (at 60 days interval) with a B: C ratio of 1.55.

Tuber crops

The low input management strategy comprising NUE genotype (Ac. No. 906) with low-cost soil fertility management involving soil test based application of fertilizers (NPK @ 106:0:83 kg/ha), green manuring *in*

situ with cowpea as organic source and use of nutrient mobilizing biofertilizers resulted in a significantly higher tuber yield of 36.46 t/ha with a saving of 10-20% in cost of cultivation.

The green manuring *in situ* with cowpea in elephant-foot yam (EFY) yielded higher (31.9 t/ha) over application of FYM @ 12.5 t/ha (24.9 t/ha). Fertigation (RDF) (40 splits) at 4 days interval produced maximum corm yield (38.3 t/ha) in EFY. Flood irrigation over 1-24 weeks and drip irrigation at 100% CPE (cumulative pan evaporation) during 13-24 weeks yielded at par (41.9 t/ha).

Plantation crops

A soil-based AMF bioinoculant, *KerAM*, was released. The bio-inoculant contains *Claroideoglossum etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem with high potential to increase the growth of coconut seedlings.

Application of borax @ 120-180 g/palm with husk burial resulted in amelioration of boron deficiency symptom in 65% palms.

In laterite soils, spraying of 0.1-0.3% ZnSO₄, or soil application of 10 g ZnSO₄/palm and skipping of nitrogen/phosphorus application in arecanut reduced disorder like crown choking, bending and cross nodes, with normal growth of emerging leaves in young palms of less than 10 years age.

A procedure for culturing oil palm (*E. guineensis* and *E. oleifera*) embryo in MS medium by excising fresh embryos to silica gel for 8-10 hours and storing in liquid nitrogen after desiccation to prevent contamination was standardized.

Floriculture

In China aster cv. Arka Kamini, seeds with normal moisture (5.9%) and stored in ambient conditions showed no germination, whereas seeds at 15 °C maintained original germination irrespective of seed moisture content. Ultra dried seeds gave higher germination (74%) and vigour even under ambient conditions but showed signs of decline compared to the controlled temperature storage (germination 79%) after 43 months .

Potting mixtures were standardized for commercial cultivation of *Cymbidium*, *Dendrobium*, *Vanda*, *Oncidium Phalaenopsis* and *Cattleya*. The standardized mixtures are: for *Cymbidium* = coco-chips + cocopeat + brick pieces (3: 1: 1v/v) + slow release fertilizer @ 5g/pot; for *Dendrobium* = cocopeat + brick pieces + tree bark (1: 1: 1); for *Vanda* = coco-chips + brick pieces + leaf fern (1:1:1); for *Oncidium* = coco-chips + brick pieces + leaf moulds (1:1:1) ; for *Phalaenopsis* = coco-chips + brick pieces + leaf moulds + green moss (1:1:1:1) and for *Cattleya* = coco-chips + brick piece + leaf mould/ leaf fern (1:1:1)

CROP HEALTH MANAGEMENT

Crops are influenced by an array of biotic stresses, which need to be managed to sustain productivity. The year





witnessed a number of crop -pests like armyworm, whitefly, white grubs, pink bollworm etc. on cereals, vegetables, cotton and pulses. The invasive insect, *Tuta absoluta*, the South American pin-worm, affected many states after its first introduction into the country during the last year. All around prevailing threat of climate change is further adding to crop losses owing to pests and diseases. Incorporation of biofertilizers, particularly microbial, beneficial algae and bacteria in agricultural practices is now realized to have a vital role in promotion of soil- health. Biological control based IPM through deployment of parasitoids, predators and microbes has already gained visibility and can bring in holistic management of insect-pests and diseases.

Plant quarantine

A total of 136,257 imported samples including transgenic and trial materials were processed for quarantine clearance. Of 14,374 samples infested/infected with different pests, 14,187 samples have been salvaged. Important interceptions include- **fungi-** *Rhizoctonia solani* and *Periconia hispidula* in paddy from the Philippines; *Stenocarpella zae* and *S. maydis* in maize from Indonesia, Mexico, Columbia, Nigeria, the Philippines and Zimbabwe; *Lasioidiplodia maydis* in maize from Indonesia, the Philippines, Thailand and USA; *Colletotrichum graminicola* in sorghum from Argentina and Mali; *Drechslera setariae* on sorghum from Argentina; *Pseudoperonospora cubensis* in bottlegourd from the USA; *Peronospora manshurica* in soybean from Costa Rica and the USA; *Lasioidiplodia* spp. and *Rhizoctonia bataticola* in cotton from the USA; *Tilletia barclayana* on paddy from China and maize from the Philippines and Thailand; **insects-** *Bruchus ervi* on lentil from Lebanon; *Sitophilus oryzae* and *S. zeamais* in paddy from the Philippines; *Corcyra cephalonica* in maize from Nigeria; and *Trogoderma granarium* from the USA; *Cryptolestes ferrugineus* in sorghum from Mali; **viruses-** *Arabidopsis mosaic virus* in soybean and lima-bean; *Tomato ring spot virus*, *Peanut stunt virus* and *Tomato black ring virus* in soybean and cowpea; *Grapevine fan leaf virus* in soybean from Canada, Costa Rica, Nigeria, USA;

Plant quarantine and biosecurity alert

A consignment of six metric tonnes of seeds of basil (*Ocimum basilicum*) imported from Germany was thoroughly examined for invasive as well as any other pests/diseases of quarantine significance. Based on thorough experimental procedure of testing of seeds and risk assessment, imported consignment was found contaminated with four species of weed seeds.

Taxonomic characterization led to identification as *Asphodelus fistulosus* and *Atriplex patula*, which were not known to occur in India and hence were of high quarantine risk. Based on the information, inactivation of the seeds through irradiation or heat treatment was advised. DPPQ&S, MOA and FW was advised to inactivate the seeds in the consignments through irradiation or heat treatment.

Pre-harvest crop-health monitoring

Wheat-crop health was rigorously monitored during normal as well as off-season in high hills of Himachal Pradesh (Lahaul, Spiti, Kullu), Nilgiri hills (Tamil Nadu) and Jammu and Kashmir (Ladakh). Though the yellow rust was observed in early January 2015; however, due to resistance in cultivated varieties as well as proactive steps taken for the management, this could be managed well. In Karnataka, leaf rust was observed in Lokur area of Dharwad in January 2015 in Local bread wheat variety (parrot green colour ear-head).

In Maharashtra, leaf rust was observed in January 2015 in village Kenjal (Satara), on var. Lok1. Except for the yellow rust in NHZ and NWPZ, the overall crop health status was satisfactory in the country.

ICT-based pest surveillance and advisories

e-pest monitoring was implemented across 33 districts, 348 talukas and 43,000 villages under Crop Pest Surveillance and Advisory Project at Maharashtra on five crops— soybean, cotton, rice, pigeonpea and chickpea. Dissemination of pest management advisories using short message services numbering 9310, 14171, 15193, 8097 and 10594 were made for the crops, respectively, based on the economic threshold levels of different pests. A total of 36 forecast models were developed for predicting population levels of thrips and white flies on cotton for the North Western India.

nematodes- *Aphelenchoides besseyi* in paddy from China, the Philippines, Brazil, USA; *Tylenchorhynchus* spp. in blackberry from the USA; and **weeds-** *Bifora testiculata*, *Galium aparine* and *G. tricornutum* on barley from Lebanon ; *Echinochloa colona* and *E. crus-galli* on paddy from Brazil.

Cereals

Pathotype distribution of wheat rusts

Yellow rust of wheat (*Puccinia striiformis*): Prevalent races of yellow rust of wheat was avirulent to rust resistance genes: *Yr5*, *Yr10*, *Yr13*, *Yr14*, *Yr15*, *Yr26*, *YrSp* and *YrSk*. Pathotype 46S119, virulent against *Yr9* and *YrA*, was observed in more than 72% of the analyzed samples. Four new pathotypes with more virulence than the existing pathotypes were documented during the season. They appeared to have originated as a result of mutation in the existing pathotypes on Suwon × Omar and Riebesel 47/51. These new pathotypes were designated as 110S119, 238S119, 46S117 and 110S84.

Black rust of wheat (*P. graminis tritici*): Virulence on *Sr31* (Ug99 type pathotype) was not documented anywhere in India. Population of black rust of wheat was avirulent against a number of host genes including *Sr26*, *Sr27*, *Sr31*, *Sr32*, *Sr35*, *Sr39*, *Sr40*, *Sr43*, *SrTt3* and *SrTnp*. Among the eight pathotypes of black rust, pathotype 11 was observed in more than 50% of the samples, followed by 40A and 21-1.

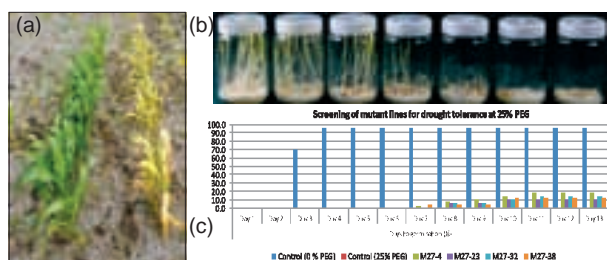
Brown rust of wheat (*P. tritricina*): There was a shift in virulence pattern with pathotype 77-9; becoming more frequent in occurrence in Tamil Nadu, Karnataka,





Maharashtra, Madhya Pradesh and Punjab. Three predominant pathotypes, i.e. 77-9 (38%), 77-5(32%) and 104-2 (14%) constituted 85% of the flora. Population of brown rust of wheat in the region was avirulent to leaf rust resistant genes *Lr24*, *Lr25*, *Lr29*, *Lr32*, *Lr39*, *Lr42* and *Lr45*. Two new pathotypes designated as 107-2 and 20-1 were documented. They were, however, less virulent than the existing pathotypes and do not appear to have any epidemiological significance.

Induced mutations in sorghum for herbicide tolerance: Induced mutant progenies of M35-1 (Maldandi) were screened for resistance to glyphosate herbicide (round-up) from M₂ onwards. Four mutant lines showed tolerance to glyphosate in M₂ and M₃ generations, when screened against 0.4% herbicide.



(a) M 35-1 mutant line showed resistance to 0.4% glyphosate compared to control; (b) Polyethyleneglycol (PEG); (c) PEC 17 derived mutant lines showed germination in 25% PEG compared to control

Identification of QTLs conferring resistance to diseases in wheat

Karnal bunt: A set of 75 wheat recombinant inbred lines (RILs) developed from a cross between Karnal bunt susceptible (WH 542) and resistant (ALDAN) genotypes were screened for two years with the pathogen populations prevalent in the north India. Parental genotypes were screened with 330 SSR markers; out of which 16% showed polymorphism. Analysis of variance revealed significant differences in disease severity among RILs (G), years (E) and G × E interactions over two years (2012-13 and 2013-14). A QTL (Qkb.dwr-5BL.1)-mapped between the marker *Xwmc235* and *Xbarc140* on chromosome 5B accounted for 16.9-18.0% of phenotypic variation.

Spot blotch: In 209 lines of a mapped population, derived from the cross involving Sonalika and BH 1146, two stable QTLs for spot-blotch resistance were identified on chromosome 7BS (Qsb.iwbr-7B) and 7DS (Qsb.iwbr-7B) at LOD score above 2.4, which explained phenotypic variation (R²) of 11.4% and 9.5%, respectively. These two QTLs were detected in three environments and for three years consecutively.

Oilseeds

Managing insect-pests of groundnut: Intercropping *bajra* with groundnut (3:1) supported lowest population of thrips, hoppers and aphids as compared to other intercrop combinations. Among three bio-pesticides tested for efficacy on sucking pests, Ponneem (an organic preparation containing 45% neem oil, 45% pungam oil and 10% soap solution) @ 6ml/L and azadirachtin 1.5%

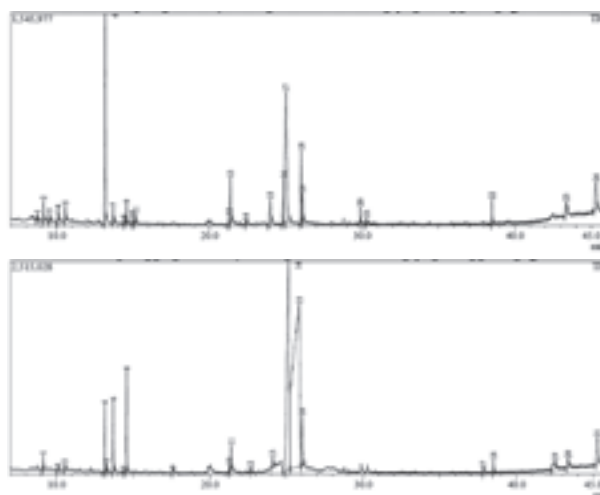
Success story

Integrated pest management in rice

Integrated pest management (IPM) technology in rice-crop was demonstrated successfully in farmers' participatory mode in cluster of villages around Gautam Budh Nagar, Uttar Pradesh. Need-based single application of Buprofezin by IPM practising farmers in selected plots as against 2-4 sprays of one or more chemical pesticides (Carbofuran, Phorate, Cartap Hydrochloride, Monocrotophos, Malathion, Imidacloprid, Fenobucarb, Dichlorvos and Hexaconazole) in farmers' practice (FP) was compared. The post-crop analysis showed enhanced levels of organic carbon content (11%), increased natural enemy count (spider population 1.36/hill in IPM against 1.05/hill in FP), and reduction in yellow stem borer (*Scirpophaga incertulas*) and leaf folder (*Cnaphalocrocis medinalis*) infestations. No infestation of brown plant hopper (*Nilaparvata lugens*) and incidence of Bakanae foot-rot (*Fusarium moniliforme*) were documented in IPM plots.

@ 7.5 ml/L were found effective in reducing leafhopper population significantly. Azadirachtin 1.5% @ 7.5 ml/L and standard check of Monocrotophos 36 SL @ 1.2ml/L were effective for checking thrips.

Stem-rot resistance basis in groundnut: Stem-rot (*Sclerotium rolfsii*) tolerant genotype of groundnut (CS 19) showed higher constitutive level of pyrocatechol, which is a substrate for polyphenol oxidase enzyme, 2-furancarboxaldehyde 5-(hydroxymethyl) and l-(+)-Ascorbic acid 2,6-dihexadecanoate as compared to susceptible genotype TG 37A. Besides constitutive level, the genotype also retained higher level of characterized metabolite post infection along with linoleic acid, which is a substrate of lipoxygenase enzyme.



A. Metabolites of stem-rot tolerant genotypes of groundnut at 30 DAS (non-infected) Line no. 4: Pyrocatechol, 6: 2-Furancarboxaldehyde 5-(hydroxymethyl), 18: l-(+)-Ascorbic acid 2, 6-dihexadecanoate. **B.** Metabolites profile of stem-rot susceptible genotype of groundnut TG 37A at 30 DAS (non-infected) Line no. 2: Pyrocatechol, 4: 2-Furancarboxaldehyde 5-(hydroxymethyl), 16: l-(+)-Ascorbic acid 2, 6-dihexadecanoate. Peak area of these metabolites is higher in CS19 than that of TG37A. Metabolites were analyzed by GCMS.





Damage caused in tomato field by *Tuta absoluta* (top), Efficacy of NBAIR NML lure (bottom left), commercial lure (bottom right) on *T. absoluta*

Biological control

Ecofriendly management of *Tuta absoluta*:

Destruction of infested tomato-plants and fruits; preservation of potential natural enemies like *Nesidiocoris tenuis*, *Necremnus* sp., *Orius* sp. and *Trichogramma* spp.; mass trapping of male moths both in nursery and main field (40 traps/ha) using nanomatrix lure trap; use of biopesticides (*Bacillus thuringiensis*, *Beauveria bassiana*) and entomopathogenic nematodes showed a great promise in management of this pest.

Predators documented: A new invasive mealybug, *Phenacoccus madeirensis* Green, known to occur in South American region, was recorded in severe form in Chamrajnagara (Karnataka) on cotton; infesting 80% plants. Some of the commonly affected host-plants are cotton, hibiscus, tomato, potato, brinjal, Acalypha, etc.

A potential gnat predator,



Predator of *Phenacoccus madeirensis*

Detailed leaf assay screening for castor against grey mold

A detached leaf technique was standardized to screen castor genotypes against grey mold caused by *Botryotinia ricini*. Abaxial surface of the detached castor leaf was inoculated with agar disc (5 mm) cut out from margin of a 7-day-old culture. The inoculated leaf was incubated at 25° C and 90% RH with periodic wetting. in a petri-dish lined with moist blotting paper. The petiole of the infected leaf was covered with moist cotton-swab to maintain turgidity. The disease severity was recorded, starting from 3 days after inoculation. This technique can be used for rapid screening of castor genotypes.

Tuta absoluta: A New Invasive Pest

During October 2014, a new invasive pest was reported in Western and Southern regions of the country. *Tuta absoluta* also called South American pin-worm was observed initially in Pune on tomato-plants grown in polyhouses and fields. Subsequently, it was found infesting tomato in Karnataka in mild to moderate levels.

Survey carried out in five states and 15 places recorded up to 52.4% infestation of fruits and stems of tomato. The management of the pest was taken up with pheromone compound 3E, 8Z, 11Z -3, 8, 11-tetradecatrien-1-yl acetate on a nanomatrix for delivery. Field trials conducted at farmers' fields in Hosur (Tamil Nadu) and in and around Bengaluru (Karnataka) revealed that pheromone nanomatrix lure (NML) trapped 20% more moths than available commercial lure. The lure had a lower load of pheromone, making it highly cost-effective compared to conventional technology.

Diadiplosis hirticornis, was documented infesting invasive mealy bug *Phenacoccus madeirensis*. Unique association was observed between predator gnat and mealybug, wherein predator lays eggs (5-22) on mealy bug females resulting in maggots crawling into the ovisacs to feed on pest eggs. Predation of eggs was recorded in more than 60% of the ovisacs, and 12-16 gnats emerged from each ovisac. Gnat lives for 5-6 days, with a developmental period of 12-16 days. The predator can be mass produced easily in laboratory on pink mealybug, and can be utilized as a potential biocontrol agent.

Biological control of pomegranate root-knot nematode

Successful biological control of pomegranate root-knot nematode, *Meloidogyne incognita*, was done in more than 100 acres of land where heavy infestation (480-760 J₂/200 cc of soil) of nematode had been causing losses since 2010. Field application of two bioagents, viz. *Trichoderma viride* and *Pseudomonas fluorescens*@ 20 kg/ha resulted in reduction of nematode population by 42.1 and 37.5% with concomitant increase in yield by 53.45 and 38.45%, respectively. Farmers were also demonstrated integrated nematode management strategies through the use of healthy seedlings, clean cultivation, application of organic amendments (FYM/compost and neem-cake), intercrops (marigold) and need-based application of nematicides (Carbofuran 3 G and Phorate 10 G).

White grub management

Lepidiota mansueta a biennial species of white grub is a severe endemic pest of multiple field crops in Majuli river island of Assam. Mass-emergence of beetles occurs following pre-monsoon showers during April-May. Beetles were trapped by operating light traps in endemic pockets (during pre-mating hours from 6.30-7.00 pm) as well by hand collection of beetle pairs in copula from 7.00-8.30 pm. Bio-ecological and behavioural research led to the concept of Social





Whitefly infestation in cotton in North India

Whitefly, *Bemisia tabaci* (Gennadius), one of the common sucking pests infesting cotton, also feeds on about 600 plant species. The adults and the nymphs suck cell sap resulting in leaf yellowing, wilting and thus there is an overall decline in seed-cotton yield. It further damages cotton directly, as it acts as a vector for leaf geminivirus on cotton.

During *kharif* 2015, unprecedentedly heavy infestation of whitefly on cotton was documented in Punjab and Haryana. Significant damage to cotton-crop occurred in Punjab where more than 75% of the cotton-crop was delayed in sowing owing to late harvest of wheat. In Haryana, relatively lesser damage was noticed where nearly 50% cotton area could be timely sown. Deficient rainfall coupled with hot, humid and cloudy weather during June–July led to severe whitefly outbreak. The heavy infestation was also influenced by a number of other factors, including lack of field sanitation including weed control, cultivation of susceptible Bt cotton-hybrids, using high doses of nitrogenous fertilizers, indiscriminate and injudicious use of tank mixes of unregistered pesticides, faulty spray application technology, and failure of active flow and field-translation of advisories issued by the ICAR and other agencies.

A comprehensive strategy to prevent reoccurrence of the pest during the next season has been planned.

Engineering/Farmers Participatory Approach as community action programme for management of adult *L. mansueta*. This mass campaigning explored group approach of extension, involving 400 farmers from 40 endemic villages, mostly from flood and erosion prone areas. The endeavour led to massive collection and killing of about 307,450 number of beetles in Majuli during 2010-2015. These efforts would have the potential of cutting down on to losses due to white grubs by 40-50% during subsequent years.

Cooked/fried adults of *L. mansueta* are relished by tribal people in the Majuli area. The beetles serve as the source of protein-rich food, having nutritional and nutraceutical value. Food-value analysis revealed that beetles contain carbohydrate (10.93%), fat (4.10%), protein (76.83%), fibre (5.16%), ash (2.98%) and seven dietary elements.

Processing, refinement and value-addition of beetles resulted in two dishes viz., Beetle fry and Roasted beetles, which have become popular among ethnic tribes and other communities of Majuli. The efforts have potential to improve both livelihood and nutritional security of the affected farmers.

Management of mites

Mite-tolerant rice: Mite infestation is becoming widely significant across crop commodities including field and horticultural crops. Rice varieties, BR 2655, Thanu and IR 64, were found relatively tolerant to sheath-mite damage in Mandya region of Karnataka. Similarly, okra varieties Aruna and Susthira and chilli variety K2 were found reasonably tolerant compared to the popular ones.

Bio-acoustics for managing higher vertebrates

Bio-acoustic gadgets equipped with alarm and distress calls of different animals when installed effectively warded off birds and wild animals from feeding on crops. The device protected sorghum and groundnut from wild boars. The calls from a single device effectively scared monkeys from damaging crops in 6 acres of land.

Suction trap for whitefly management

The device was designed and evaluated for its efficacy in trapping adult whiteflies. The shoulder mounted, portable trap helps in sucking whiteflies present on the underside of the cotton-leaves with minimal harm to natural enemy fauna and to cotton-crop. The adhesive



aluminium/fibre board fixed on the upper side of the trap acts as a sticky trap for trapping whiteflies, which are dislodged from the plant canopy with fan fitted with the device. Under heavy adult whitefly pressure, the trap could reduce whitefly adult population by 40-52%.

Management of depredatory birds

Bird management through bioacoustics: The call sequences involving alarm and distress calls were worked out to formulate an effective strategy for bird management in sunflower and sorghum. A total of 4 call

Ecofriendly protocol for trapping melon-fly

Fruit-flies (*Bactrocera* spp.) are one of the biggest limitations to profitable cultivation and trade of fresh fruits and vegetables. An efficient protocol to trap melon-fly was developed. The formulation neither required alcohol for impregnation nor any insecticide (like DDVP) to kill trapped insects. The trap used cue lure {4[4-(acetoxy) phenyl]-butanone} to attract fruit flies. Field studies with this formulation resulted in trapping 2.5 times more fruitflies compared to those caught by conventional trap





sequences were constructed by recording and analysing alarm and distress calls of 25 birds under field conditions. Call sequence 1 (CS-I) with 43 minutes of duration resulted in 42% efficacy involving 7 species of predatory/depredatory birds, while call sequence 2 (CS-II) of 15 minutes duration involving 12 species proved promising resulting into 59% efficacy. On the other hand call sequence 3 (CS-III) of 14.4 minutes resulted into 66.3% efficacy involving 17 species, while call sequence 4 (CS-IV) of 17.36 minutes duration gave maximum efficacy of 80-89% involving 17 species of birds. Call sequences constructed and tested at several locations were documented to provide protection to crop from the birds up to 25 days. CS-IV was found most effective in *rabi* with 89% efficacy and in monsoon with 70% efficacy.

Pea-fowl management through physical barrier (jute rope) in maize, groundnut and soybean: Fixing jute rope at 1 feet height around the sprouting crop with the help of pegs arranged at 1 metre distance and also making a checkered pattern forming 1m × 1m



squares above the crop with the same jute rope was found promising in containing entry of pea-fowl into crop fields. The pea-fowl damage was reduced up to 98% in maize, groundnut and soybean. The economics of this technique worked out to be ₹ 600 per acre (₹ 300 for jute rope and ₹ 300 for labour) thereby proving it to be cost-effective for practical application.

Fruit crops

The incidence of banana skipper, an invasive butterfly pest (*Erionota torus*) was recorded across Kerala in monsoon. For the management of *Fusarium* wilt on banana, dipping of suckers in Carbendazim (0.2%) for 30 min + drenching Carbendazim (0.2%) + 2% Carbendazim injection (3ml) at third, fifth and seventh MAP recorded least incidence of *Fusarium* wilt at Coimbatore (18.5% PDI, with 76.9% reduction in disease over the control) and Jorhat (29.6% PDI, with 53.5% reduction in disease over the control).

Complete genomes of three Banana Streak Virus (BSV) species were amplified and cloned. Complete genomes of Banana Streak Mysore Virus (BSMYV) and Banana Bunchy Top Virus (BBTV) were obtained. Transgenic banana plants resistant to BBTV were generated using BBTV replicase gene construct and the resultant 52 plants tested negative to BBTV. Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines. The *Trichoderma asperellum* was effective in extending shelf-life of banana fruits by 28 days at 23°C and 55 days at 13°C. A protocol for the detection of *Trizteza* virus in citrus aphids (*Aphids citricola*) was validated.

Isolates of three *Pseudomonas* species (*P. geniculata*, *P. plecoglossicidia* and *P. fluorescens*) reduced pomegranate bacterial blight incidence by 58-66% and severity by 22-33% over the control. Silicon, salicylic acid and chitosan based formulations reduced pomegranate bacterial blight incidence by 75.5%, 74.5% and 71.5%, respectively, over the control.

The PCR amplification of Bhagawa, Nana, Daru and Ganesh pomegranate using the *in silico* revealed the presence of the *Xanthomonas* interacting gene homologous sequence in six out of eight genic primers.

Arid crops

Spinosad 2.5 SC @ 1 ml/litre and Indoxacarb 14.5 EC @ 1 ml/litre were effective in controlling ber stone weevil (8.8–9% damage) at Rahuri, Anapapur, Bawal and Jobner. Fruit rot on date palm was effectively controlled using *Trichoderma viride* + Azadirachtin (0.3%) + date leaf cover.

A real-time PCR protocol was developed at CPCRI, Kasaragod, for specific detection of *Phytophthora meadii*, causing fruit rot of arecanut. Self-grown *Colocasia* in arecanut garden was identified as an alternate host for *P. meadii* for initial establishment of inoculum in arecanut garden. A real-time LAMP (RT-LAMP) assay using the Genei II LAMP system, Optigene, was developed for detection of phytoplasma associated with root wilt disease of coconut and yellow lead disease of arecanut using the phytoplasma 16Sr DNA as target for amplification.

A tablet shaped botanical cake (each weighing 1.9 g) for the prophylactic leaf axil filling for management of adult rhinoceros beetles of coconut was developed. Y-tube response of rhinoceros beetle towards essential oils, viz. basil oil, ginger oil, citriodora oil, thymol oil and ajowan



oil showed 70–75% repellency. Area-wide bio-suppression of rhinoceros beetle indicated significant reduction in leaf damage by rhinoceros beetle (65.2–85.5%). A pest-weather regression model (PWRM) between log values of monthly rhinoceros beetle (RB) infestation and weather variables during 2010-2014 was established.

A prototype of red palm weevil detector based on acoustic system, which could be linked to mobile phones, was developed in association with Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram. Evaluation of the entomopathogenic fungi on red palm weevil revealed that placement of three filter paper sachets containing 12–15 *Heterorhabditis indica*-infected *G. mellonella* cadavers on the leaf axils after application of 0.002% Imidacloprid could recover 60% of infested palms. Studies on effect of EPN on root grub population in coastal sandy soils showed that root zone drenching of EPN liquid formulation of *S. carpocapsae* (100-200ml solution) containing 0.5×10^6 infective juveniles per palm during June-July and September - October resulted in 61% reduction of root grub population.

The leaf webworm on oil palm was identified as *Acria meyricki* (Depressariidae: Lepidoptera) which is a new species infesting on oil palm in India. The Mitochondrial Cytochrome Oxidase based DNA barcode was also generated.

Spices

Two strains (GRs-SIK and GRs-MEP) of *Ralstonia solanacearum* infecting ginger were sequenced using Illumina Next-Generation Sequencing Platform and the raw data was assembled using 'A5-miseq'; both the strains were also annotated using the software tool 'Prokka'. Reference based alignment with GMI1000 showed that 83% of reads properly paired with the reference genome. SNP calling indicated that there were 4,368 and 4,648 SNPs in GRs-MEP and in GRs-SIK, respectively. A total of 74 Type 3 effectors were present in IISR strains compared to those of 11 other strains of *R. solanacearum*.

Vegetables

Explorative surveys carried out in Bengaluru (Rural

and Urban), Kolar, Chikkaballapur, Ramanagara and Tumkur districts in Karnataka indicated the presence of south merical tomato leaf minor in all the areas surveyed. The species identification was confirmed by both morphometric and molecular methods. The infestation of *T. absoluta* ranged from low to high in different tomato fields surveyed (up to 15 mines/plant). In some of the fields up to 87% of the tomato plants were infested.

Detection of seed borne tobamoviruses in vegetable crops

Seeds collected from infected plants (cucumber, capsicum and tomato) were tested for different tobamoviruses by ELISA and RT-PCR. There was externally seed borne infection of CGMMV (8%), PMMV (12%) and ToMV(14%) and none of the viruses were detected in embryo and cotyledon indicating absence of internal seed transmission of CGMMV, PMMV and ToMV in cucumber, capsicum and tomato.

Sequences of S-RNA and M-RNA of Indian isolate of Iris Yellow Spot Virus (IYSV), a tospovirus affecting seed onion crop were determined that showed > 95% identity with other known isolates and occurrence of intra- and inter- species recombination at intergenic region.

Orchids

An encyrtid wasp, *Anagyrus* sp. (Howard) as a parasitoid of long tailed mealy bug, *Pseudococcus longispinus* and mealy bug, *Pseudococcus* sp. infesting orchids was reported for the first time.

RNAi or gene silencing technology

The RNAi constructs were made for actin gene and also for vATPase gene isolated from tea mosquito bug *Helopeltis antonii*, a pest of cashew. Delivery of cognate dsRNA through sponge mimicking the cashew stem elicited feeding by the adults. The effect of RNAi was validated using RT-qPCR, which showed a 50% down regulation of these target genes. Silencing of OBP2 resulted in delayed host recognition based on the electro antennogram readings. Similarly, silencing of both vATPase and JHBP genes resulted in 80% mortality of treated aphids at 12.5 µg.

