# 8. Crop Management

## PRODUCTION

Substantially faster increase in food production can be achieved by upgrading integrated strategies in cultivation of crop-plants and linking them to other sciences with an impact on the crop production as a whole.

### Cereals

**INFOCROP-Wheat:** This Decision Support System to identify location-specific suitable variety, optimum sowing time and schedule for wheat crop has been developed. Also Decision Support System (DSS) using multi-temporal satellite remote sensing data has been developed for near-real time prototype web-based crop growth monitoring at the district level. The DSS is hosted on the public website http://creams.iari.res.in, and was used to monitor meteorological drought situation in the country during *kharif* season.

**Free Air Temperature Increment (FATI) facility:** This facility has been developed to characterize effects of global warming on the crop-plants. The FATI technology does not involve any enclosure, and the environment is warmed up with the use of infrared heaters in the open field conditions. By using an electronic control circuit, the system tracks the ambient temperature in a reference plot (unheated-control); then in the high temperature-stressed plot, it modulates radiant energy from the heaters to give desired temperature increment in the environment.

**Eco-friendly wastewater treatment facility:** An eco-friendly wastewater treatment facility, involving emergent wetland plants (such as *Typha latifolia*) and native media and microorganisms that mimic natural processes operative in any natural wetland, has been engineered and operationalized.

**P-enriched compost using phytate mineralizing fungi:** A phospho-compost was prepared from high silica paddy straw amended with economical and easily available cattle manure/poultry manure/farmyard manure, each added separately as nitrogen and phosphorus-source. The composting mixture was inoculated with phytate mineralizing fungal consortium, including *Aspergillus* and *Trichoderma*. The inoculation with the fungi improved availability by 20% of bicarbonate P in cattle manure-straw compost and in FYM compost by 15%, compared to their respective controls.

**Wheat-lentil/*toria*:** At Hawalbagh, intercropping wheat (*Triticum aestivum*) + lentil (*Lens culinaris*) in 2:1 and 1:1 row ratio was found superior to sole wheat and wheat + *toria* (*Brassica campestris* var. *toria*) intercropping. Lentil yield was higher in 1 : 1 ratio (4.52 q/ha) than in 2:1 (3.1 q/ha). *Toria* also recorded higher yield in 1:1 (4.1 q/ha) than in 2:1 (3.0 q/ha) ratio. Highest wheat-equivalent yield (52.4 q/ha), net returns (₹ 36,770/ha), benefit : cost ratio (1.81), monetary advantage index (₹ 7,207) and land-equivalent ratio (1.19) were observed with wheat + lentil in 2 : 1 row ratio. Relative crowding coefficient (5.90) and similarly, water-use efficiency (27.6 kg/ha-mm) were highest with wheat + lentil under 2 : 1 ratio.

Wheat-lentil/*toria* intercropping

### Minor millets

In fingermillet, soil application of $ZnSO_4$ at 12.5 kg/ha at the time of sowing enhanced grain yield by 13.3% and grain Zn content by 6.2% (from 3.1 to 3.4 mg/100 g), while foliar spray at 0.5% at the time of flowering and after 20 days, increased grain Zn content by 16.4%.

Among small millets, fingermillet and barnyard millet, followed by foxtail millet were fairly tolerant to salinity, while kodo millet was found sensitive. KMR 204, GPU 28 and Trichy 1 of fingermillet and VL 29 and CO 1 of barnyard millet and Krishnadevaraya and CO 7 of foxtail millet were found suitable for saline areas.

### Forage crops

**Fodder from wastelands:** Hybrid Napier Bajra gave highest fodder yield (300-800 q/ha) in sloping wastelands and under pine-trees. Five to eight cuts can be taken during the growing season from May to mid-November. On the field terrace risers during rainy season, Hybrid Napier Bajra yielded highest green forage (3–4 kg/$m^2$), followed by *Setaria kazungula* (1.7 kg/$m^2$). On the sloping sites of the field terrace risers, green forage yield (0.5–1.0 kg/$m^2$) of pangola grass

Fodder production from wastelands

was highest, followed by kikuyii (0.3–0.6 kg/m$^2$) and star grass.

**Climate-resilient forage production systems:** Tri-specific hybrid of *Pennisetum* (TSH) + *Sesbania* + (sorghum + cowpea–chickpea) performed better, and yielded 750 q TSH green fodder/ha (in four cuts). *Sesbania* yield was 150 q/ha (in four cuts), and sorghum + cowpea (30 +25 q/ha) gave highest green (747 q/ha) and dry fodder yield (177 q/ha).

**Water-use efficiency of fodder system:** Water-use efficiency and evapotranspiration (ET) of Napier Bajra Hybrid + berseem system with organic manure was 17.9, 32.0, 35.2 and 17.8 kg dm/ha-mm and 118.8, 95.0, 86.5 and 147.8 mm for four cuts, respectively, whereas with inorganic fertilizers, water-use efficiency and ET was 13.6, 27.1, 30.6 and 14.5 kg dm/ha-mm and 121.8, 95.3, 86.7 and 154.1 mm, respectively.

**Grassland and silvipasture management:** Four arbuscular mycorrhizal species, *Glomus* spp. (1,408), *Gigaspora* (193.6), *Acaulospora* (70.6) and *Scutellospora* (52.8) with spore density/100g soil (given in parantheses), associated with different grasses, were identified. Four fodder tree species in combination with three grasses and two legumes were tested. Maximum pruned biomass was obtained from *Morus alba* (2.83 kg/plant). Maximum green forage production (290–520 q/ha) was obtained from *Panicum maximum*, followed by *Chrysopogon fulvus* (180–290 q/ha), *Cenchrus ciliaris* (70–120 q/ha), *Clitoria ternatea* (100–210 q/ha) and *Stylosanthes seabrana* (90–140 q/ha).

With different *in-situ* moisture conservation treatments, a*onla*, guava, tamarind and bael hortipasture systems were tested. With contour staggered trenches (moisture content 12.4% and 17.96% at 0–15 and 15–30-cm depth), aonla recorded maximum fruit yield (94 q/ha) with dry fodder yield ranging from 47 to 87 q/ha. Guava variety Lalit produced high fruit yield (63 q/ha) with higher dry matter production (61.2 q/ha). Tamarind variety DTS 2 recorded better growth than cv DTS1.

**Tillage management in fodder-food cropping system:** Under the limited irrigation in sorghum + cowpea–*durum*-wheat cropping system, wheat-grain yield during *rabi* was highest in zero tillage-minimum tillage (ZT-MT; 48.1 q/ha), and was lowest in conventional tillage-conventional tillage (CT-CT; 43 q/ha).

**Microbes for abiotic stress management**

Two mixed inocula (mixture of three compatible abiotic stress tolerant plant growth promoting rhizobacteria) were developed for rainfed crops — CRIDA-MI-I (*Pseudomonas putida* P7 + *Paenibacillus favisporus*-B30 + *Pantoea agglomerans*-G12) for heat stress management and CRIDA-MI-II (*Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17 + *Pantoea agglomerans* G12) for drought stress management. They were tested in maize, sorghum, and sunflower. Under rainfed field conditions, mixed inoculation with 100% chemical fertilizers significantly improved plant growth and physiological status (chlorophyll and relative water content) as compared to uninoculated control and 12–20% increase in grain yield was observed due to mixed inoculation.

Two rhizobacterial strains CRIDA-ZnKPSB-1 (*Burkholderia cepacia*) and CRIDA-ZnKPSB-3 (*Burkholderia cenocepacia*) exhibited efficient *in vitro* solubilization of P, Zn and K in solid as well as liquid medium. The strains also possessed plant growth promoting traits, showed antagonism against *Macrophomina phaseolina* and *Fusarium oxysporum* and were tolerant to heat (45°C), moisture (–9 bars) and salt (8% NaCl) stresses. Under pot studies, inoculation with these strains improved plant growth and nutrient uptake. Partial 16SrDNA sequences of the strains have been submitted to NCBI Genbank database under accession nos JX310700.1 and JX310701.1.

## Oilseeds

**Resource conservation technologies for mustard-based cropping systems:** Five cropping systems, fallow-mustard, green manure-mustard, brown manure-mustard, clusterbean-mustard and pearl millet-mustard were grown under conventional tillage (CT), reduced tillage (RT), zero tillage (ZT) and furrow irrigated raised beds (FIRB). After four years of experimentation, FIRB resulted in significantly higher seed yield (28.2%) than CT. Significant yield enhancement and improvement in the soil physico-chemical and biological properties were also noticed under ZT and RT due to continuous retention of residues leading to build-up of soil organic matter. Clusterbean-mustard system gave highest net returns and B : C ratio, followed by green manure-mustard.

**Use of signature fatty acids to assess live-biomass of AM fungi:** High throughput methods for extraction


Sorghum + cowpea–durum-wheat cropping system: **A.** Minimum tillage; **B.** Zero tillage, **C.** Conventional tillage

of lipids in the soil and in the roots using internal standard 19 : 0 and for extraction of AM fungi biomarker 16 : 1w5 neutral, phospholipids lipids (PLFA/NLFA) and ester linked fatty acids (ELFA) in the soil and in the root samples were optimized. The elution of lipid extracts from either soil or root samples with two times chloroform has been found to be optimum to recover whole NLFA fractions. About 20–35 mg root samples (ground in liquid nitrogen and freeze-dried) were found appropriate to recover neutral lipids. Among all the methods, ELFA was found the best.

**DAPG-producing fluorescent pseudomonads for enhancing groundnut yield:** In groundnut cultivar TG 37A, application of DAPG-producing fluorescent pseudomonads enhanced its growth and also improved pod yield by 11%. The pseudomonads also checked plant mortality due to collar rot from 10% in control to 2–6%.

**Salinity and moisture-deficit stress alleviation in groundnut by endophytic bacteria:** With the inoculation of *Bacillus subtilis* REN51N, groundnut yield enhanced by 26% and 17% (normal and 3 EC-irrigation water) and with *Bacillus firmus* J22N, it increased 17% and 13% (6 and 9 EC-irrigation water), besides modulating stomatal aperture, biochemical parameters and reactive oxygen species (ROS) scavenging enzymes inside the plants, thus alleviating salinity and moisture-deficit stress.

## Pulses

**Pulses in cereal-based cropping systems:** Inclusion of summer greengram in rice–wheat and maize–wheat systems improved soil organic C and soil available nutrients. In upland system, base crop (wheat) productivity was maximum in maize–wheat–greengram (4,639 kg/ha) and lowest in pigeonpea–wheat (3,631 kg/ha) system. Inclusion of summer greengram in rice–wheat system increased rice yield by 10% under the recommended inorganic fertilization.

### e-Kapas network and technology documentation

Using modern advancements in ICT and mobile phone technology, a novel extension mechanism called "e-Kapas network" was executed for effective knowledge transfer among Indian cotton-growers. The programme is designed to cover more than 1 lakh farmers across 11 cotton-growing states involving 18 centres including SAUs working on cotton. The advisories were provided in local languages as voice messages on a regular basis on cotton production, protection technologies, weather and market information in the format of kapas panchang and kapas pedia. So far, total of 728,516 pre-recorded automatic phone calls on a range of topics during the crop season (June-Dec 2013 and 15 June to 31 Aug 2014) were sent to more than 90,000 registered mobile users.

### Innovative jute-retting technology

An improved microbial formulation (*Bacillus pumilus*, bacteria)-based retting technology, popularly branded as 'CRIJAF SONA', suitable for quality fibre production in stagnant water,has been developed. The retting is done by just applying talc-based microbial formulation on the jute-plants while arranging them for retting.

The cheap and simple technology can improve fibre quality at least by 2 grades through improvement in quality parameters. Other advantages of the talc-based retting technology are: retting duration is only 6–7 days, improved yield due to intact fibre strands, besides being user-friendly and safer than traditional retting method.

Quality jute fibre

Formulation packet

An additional income of ₹ 6,000 to 9,000/ha could be earned by jute-growers by spending only ₹ 675 to 900 per hectare of jute/mesta crop over traditional method of retting by following this microbial talc-based technology. A patent application has been filed for the microbial consortium used in this technology.

## Commercial crops

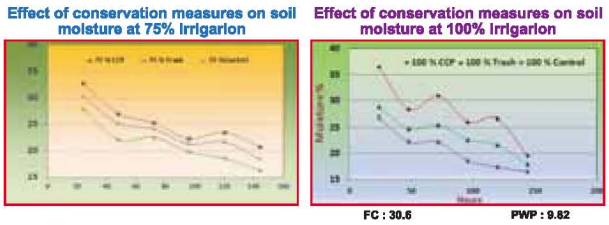
**Conservation of soil moisture in sugarcane:** In total, 30 irrigations were given at 100% level of irrigation and 23 irrigations at 75% level. The results indicated that even under deficit rainfall, a fairly good

### Tray-nursery technique for healthy tobacco seedling production

It is a simple technique and entails sowing tiny tobacco seeds on the coconut coir-pith compost, and transferring young seedlings of about 20–25 days to poly-trays (70/98 cells) for raising them on the growth medium with standard nutrient and watering schedules.

Tray-nursery

The tray-nursery seedlings take about 60–65 days from sowing to transplanting. Such grown seedlings offer unique advantage of ensuring crop uniformity with minimum gap fills and consequently increased cured leaf yield and quality as against seedlings grown under conventional raised soil-bed nursery.

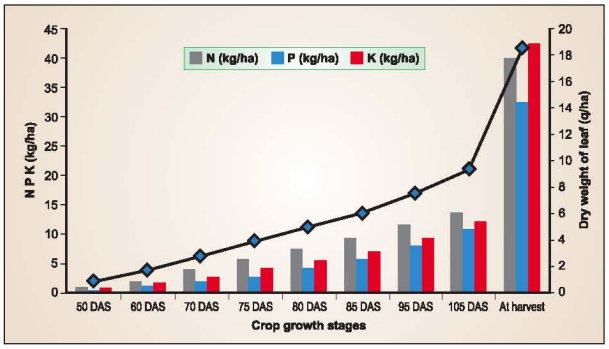



Conservation of moisture in sugarcane

crop of sugarcane (102 tonnes/ha) could be obtained with 23 irrigations by adopting composted coir-pith application.

**Hydroponics to understand nutritional deficiencies in cotton:** Cotton seedlings were grown in Hoagland's solution without the elements of interest (nitrogen, potassium, magnesium and calcium) from germination till harvest. The pots were continuously aerated and were also replenished with nutrient solution regularly. The onset of symptoms, intensity and related physiological and biochemical aspects were studied. The hydroponics system and the deficiency symptoms were digitized for further use so that farmers can overcome specific nutritional disorders in cotton by amelioration strategies.

**Jute leaf fall and its nutrient contribution to cropping system:** In a jute-based cropping system, it was found that yield and nutrient uptake of rice was significantly higher when jute was included in the system. This was due to the nutrients added to the soil




Leaf fall pattern and nutrient contribution at different crop growth stages

through jute leaf fall and their availability to rice crop grown in a sequence. The amount of leaf fall was about 9.3 q/ha up to 105 days after sowing, which contributed to about 13.5 kg N, 10.6 kg P and 11.8 kg K/ha to the soil. The amount of defoliated leaves from jute-plants after harvest was about 18.6 q/ha. It contributed 39 kg N, 32 kg P and 42 kg K/ha to the soil. The jute crop in the existing cropping system can add 27.9 q leaves, contributing to soil in total 52.5 kg N, 42.6 kg P and 53.8 kg K.

## Horticultural crop production

### Fruit crops

Paclobutrazol application on 14-year-old mango trees raised on Vellaikolamban rootstocks recorded reduced canopy vigour, however, the highest fruit yield of 7.8 tonnes/ha was recorded with trees having the above rootstock planted at 5 m × 5 m spacing, without paclobutrazol application. Thus, long-term application of paclobutrazol in mango needs to be further studied.

It was recorded that the corky tissue disorder of sapota cv. Cricket Ball was influenced by seed viability during the initial stage of fruit growth. Ultra dried papaya seeds stored at ambient temperature for 36 months recorded higher germination (88%) compared to untreated seeds (60%).

Micronutrient deficiency maps for mango, tomato and grape were prepared and deficient regions were identified. Combined application of Arka Microbial (AM) Consortium and AM fungi with the recommended dose of fertilizers could increase grape (Bangalore Blue) yield by 23.5%, compared to the application of inorganic fertilizers.

Growth and survival of litchi air-layers in nursery revealed that rhizobacteria (1%) resulted in the highest survival of plants (90%) with maximum root:shoot ratio (0.95), root:plant ratio (0.49) and root colonization (root length/root number,1.91). Foliar spraying of ethrel @ 150 ppm resulted in early colour breaking and fruit maturity by 5 and 4 days, respectively, while spraying with $GA_3$ @ 150 ppm delayed fruit maturity by 7 days.

### Vegetable crops

The production technology for off-season cultivation of English cucumber under naturally-ventilated polyhouse was standardized with an average productivity of 100 tonnes/ha.

Cucumber cultivation under naturally-ventilated polyhouse

Grafting tomato hybrid, Arka Rakshak on brinjal rootstock enhanced survival under excess moisture, while bell pepper hybrid, Indra, raised on chilli rootstock produced significantly higher yield in net house.

Integrated nutrient management (INM) in onion helped reducing the use of inorganic fertilizers by 25%. A combined application of 110 : 40 : 60 : 40 kg NPKS

along with organic manure equivalent to 15 tonnes FYM and *Azospirillum* and Phosphate Solubilising Bacteria (PSB) @ 5 kg each/ha recorded higher marketable bulb yield.

### Spices

A technology for production of healthy black pepper planting material by utilizing coir pith based medium in pro-trays was standardized. Production of single sprouts of ginger in pro-trays was standardized.

### Plantation crops

Application of biofertilizer consortia [*Azospirillum*, *Acetobacter*, PSB and AMF inoculation both near the tree basin at a radius of 45 cm (50 g each/tree) and in the rectangular trenches taken in the middle of four trees (50 g each/tree)] and 100% of recommended dose of nutrients (N: 135 g, $P_2O_5$: 39 g, $K_2O$: 34 g and FYM: 5.6 kg/tree/annum) resulted in increased nut yield for four years to the tune of 53% and 31% in young cashew (5 years old: VRI-3) and mature cashew (12 years old: Bhaskara) plantations, respectively as compared to the control. Foliar application of 3% urea + 0.5% $H_3PO_4$ + 1% $K_2SO_4$ at flushing, flowering and nut development in cashew increased nut yields by 16.1%, while 0.5% $ZnSO_4$ + 0.1% solubor + 0.5% $MgSO_4$ spray recorded 30.5% higher mean yield of nut (four years) in soils deficient in Mg, Zn and B.

The popular varieties of cashew planted at different plant spacing showed the suitability of 5 m × 4 m spacing by recording the maximum cumulative nut yield of 4.6 tonnes/ha in five harvestings. Cashew variety, Ullal-1, recorded the highest yield of 1.3 tonnes/ha, being closely followed by Bhaskara (1.2 tonnes/ha) in the fifth harvesting.

### Mushroom

The time for fruiting body initiation was reduced by 20–25 days through improved cultivation technology for shiitake mushroom. *Volvariella bombycina*, a new paddy straw mushroom species, was successfully cultivated. This mushroom can be stored under refrigerated condition for one week without any deterioration in quality.

### Betelvine

Soil application of zinc sulphate recorded higher production of betel leaves at all levels compared to the control. Application of $ZnSO_4$ @ 30 kg/ha recorded highest marketable leaves per vine (80), number of lateral branches (5.4) and length (180 cm). However, fresh weight of 100 leaves (131 g) was maximum in the control.

### Tuber crops

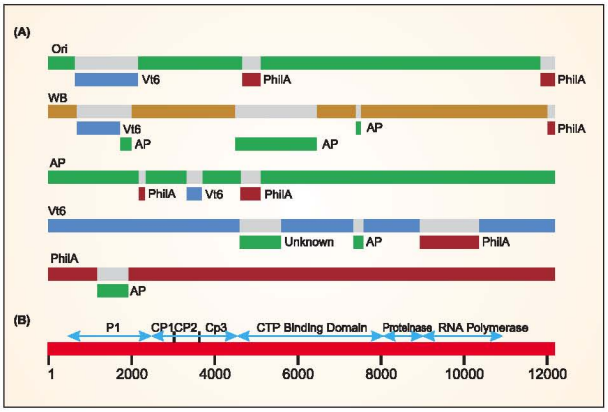
Production systems, viz. conventional, traditional, organic and integrated farming did not record any significant effect on yield of dwarf white yam, Sree Dhanya. Organic farming (14.79 tonnes/ha) recorded on par yield with conventional practice (11.30 tonnes/ha), however, it was 31% higher compared to all other practices. The long-term performance of organic *vs* conventional management in yams and aroids was analyzed through stability index calculated over a five-year period. It was observed that organic farming was equally stable to that of conventional practice.

## CROP HEALTH MANAGEMENT

Pests are major constraints to agricultural production and productivity in agricultural systems. Significant losses occur after harvest because of inappropriate storage methods, which fail to protect harvest from storage pests and pathogens. Reduction in pre- and post-harvest losses would contribute significantly towards more production at lesser cost, and would improve food security and safety and market access.

### Cereals and millets

**RTSV genome:** Among 42 advanced basmati pyramided lines (BPLs), three lines in the background of Taroari Basmati and 10 lines in the background of Basmati 386 showed notable resistance for bacterial blight. Two new germplasm accessions, IC 462402 and IC 577036, have been identified as resistant to gall midge biotype 1. Real-time validation studies confirmed that NBS-LRR for *Gm4* in Abhaya and Proline Rich Protein 3 for *Gm8* in Aganniare, are the candidate genes. Complete genome sequence was deciphered of the RTSV isolate from southern India (Andhra Pradesh) and deposited in the NCBI database (accession number: KC794785).




RTSV genome; 12 recombination events (15 recombination sites) were detected in genome of RTSV. (A) Each RNA segment is indicated by different colour bar, (B) A scale bar showing different parts of the RTSV genome

**Sorghum plant and panicle characters with seed-rot induced by grain mold:** Thirty-six recombinant inbred lines (RILs) along with grain mold resistant (B 58586) and susceptible (296B) parents were evaluated for resistance to *Fusarium* grain mold using artificial inoculation. Seed rot varied from 13 to 93% among RILs. Studies showed that *Fusarium* induced seed rot had strong negative relationship with glume colour and positive relationship with panicle compactness. Seven RILs (RIL 004, RIL 166, RIL 092, RIL 118,

**Microarray chip for detection of plant viruses**

A microarray virus chip, having 17,292 unique probes for all the known plant viruses and viroids for which sequences are available, has been designed.

**Removal of pesticides and heavy metals from water**

Commercially available Bentonite clay was organically modified for pesticide and heavy metal removal from water. Modified clay material was found highly efficient in removal of pesticides like chlorthalonil (~99%), methyl parathion (~98%), butachlor (94%) and heavy metals such as lead (83%), cadmium (15%).

**Diagnostic kits for detection of *Legume Yellow Mosaic Viruses***

Two kits —"LYMVs PCR diagnostic Kit" and "LYMVs Direct PCR Kit"— have been developed for detection of *legume yellow mosaic viruses* (MYMIV, MYMV, HgYMV, DoYMV) infecting greengram, blackgram and cowpea.

A Multiplex-PCR kit for detection of four viruses (MYMIV, MYMV, HgYMV, DoYMV) has also been developed. Using this kit, the PCR will be performed in a single tube for detecting four viruses. Each primer will amplify the target virus, which will be distinguished based on the size of the amplicons.

**Newer insecticide bio-efficacy against pod-borer complex of pigeonpea**

Flubendiamide was quite effective against plume moth larvae, 7 and 14 day after spray, registering 82.5 and 90.7% reduction over control. Podfly damage was also reduced significantly. Flubendiamide at 0.75 ml/litre reduced *Helicoverpa armigera* larval population by 95.6 and 94.3%, respectively at 7 and 14 days after treatment. The treated plots registered estimated yield of 14.7 q/ha as against 7.9 q/ha in control.

RIL 161, RIL 172 and RIL 030) had seed rot resistance at a par with resistant parent, B 58586, but with less coverage of grain with glume and high panicle compactness. Seed rot, glume colour and panicle structure are important characters that play a significant role in precise evaluation of grain mold resistance.

**Bacterial isolates from healthy rice rhizosphere:** Three bacterial isolates were found effective against *Macrophomina phaseolina*, five against *Fusarium oxysporum* f.sp. *ciceri*, causing wilt of chickpea, and eight isolates were effective against *Ustilaginoidea virens* causing false smut of rice.

## Oilseeds

**GeoPest for rapeseed-mustard:** Using GIS interface, a Decision Support System (DSS), integrating weather-based forewarning and management of major insect pests (aphid and painted bug) and diseases (white rust and *Alternaria* blight) of mustard, was developed. The DSS could generate forewarnings one week in advance along with plant-protection advice through GIS maps that could be assessed by farmers/pest managers of rapeseed-mustard-growing villages of the NCR directly through internet.

**Controlled release (CR) thiamethoxam formulations for soybean seed treatment:** CR formulations gave significantly better control (4.0) of major pests, whitefly, *Bemisia tabaci* Gennadius and stem fly, *Melana gromyzasojae* Zehntme, of soybean compared to commercial formulation (5.33) and control (8.0). Similarly, soybean yield was higher with the formulations (1,706 kg/ha) than commercial formulation (1,431 kg/ha). And residue of thiamethoxam in seed and soil at harvest was below the detection limit.

**Monitoring *Spodoptera litura* with sex pheromone traps:** Monitoring *Spodoptera litura* on castor by sex pheromone traps showed two peak catches during 34 to 35th MW and 41 to 43rd MW. Significant positive relation was noticed between egg-masses on castor and trap catches. Response of *S. litura* to light trap was lower than sex pheromone trap. Wheat-bran with sugarcane or palm jaggery attracted more larvae as compared to rice-bran based baits. Wheat-bran + palm jaggery bait mixed with novaluron (10 EC) or chlorpyriphos (20 EC) resulted in more than 90% mortality of *S. litura*.

**Anthracnose and pod blight management in soybean:** Field experiment was conducted in randomized design with three replicates of soybean variety NRC 7 in natural fields. Treatment included seed treatment with fungicides/bio-agents alone and with spraying of

**Plant quarantine**

Imported total samples 119,486, including transgenic and trial material, were processed for quarantine clearance; of the 3,834 samples infested/infected, 2,820 were salvaged. Six Phytosanitary Certificates were issued for export of 1,248 samples. Important interceptions included are: fungi, *Peronospora manshurica* in soybean from Colombia, *Tilletia barclayana* in paddy from China and the USA; insects, *Bruchus ervi* and *B. lentis* in lentil from Syria, *Callosobruchus maculates* in cowpea from Nigeria and Italy; viruses, *Bean common mosaic virus* in soybean from Taiwan, *Bean pod mottle virus, Broad bean stain virus, Broad bean true mosaic virus* and *Red clover vein mosaic virus* in Frenchbean from the USA, *Grapevine fan leaf virus* in soybean from Taiwan, and *Tomato black ring virus* in cowpea from Nigeria; and weeds, *Acetosella vulgaris* in paddy, *Centaurea melitensis* in wheat and *Agropyron cristatum* in pearl millet from the USA, *Avena strigosa* and *Lolium rigidum* in wheat from Australia, *Galium tricornutum* in grass-pea from Syria, and *Ipomoea biflora* and *I. purpurea* in paddy from the USA.

**Stem inoculation technique for testing stem rot tolerance of jute cultivars**

The technique comprised steps of growing inoculum of *Macrophomina phaseolina* on PDA for 3 days at 28±1°C, followed by mixing sterile sand with 3-day-old culture of *M. phaseolina* and gently rubbing stem base of 30–45-day-old jute-plants with the inoculated sand at 10–20 cm above soil. This technique caused 100% infection with typical stem rot symptoms with brown rotting spots of different lengths and intensities encircling stem of Cv. JRO 524, grown in pots. Two different isolates were inoculated. The variation in virulence pattern of the isolates was also evident, as more virulent isolate (from Sorbhog, Asom) produced longer and darker brown stem rot lesions than less virulent strain (from Barrackpore, West Bengal). For mass-scale evaluation of large number of genotypes against jute stem rot, this simple stem inoculaton method can be very useful.

**Resistance mechanism against Bihar hairy caterpillar in wild jute**

On the basis of food preference in terms of larval movement for feeding and extent of leaf area consumption, the wild species of jute, *C. aestuans*, was least preferred by Bihar hairy caterpillar (BHC). *C. aestuans* deterred adults for oviposition with least number of egg mass and eggs/cluster. The adverse biological parameters of BHC on wild species of jute revealed antibiosis effect of *C. tridens* and *C. aestuans*. Maximum antibiosis effect was observed at 5 days after feeding during which the larval weight in wild species was 40-80% less than the cultivated species. The pupation, pupal weight and adult emergence were also adversely affected on wild species due to high antibiosis effect of wild species on larval growth and development. The biochemical components, i.e polyphenol oxidase, total phenol and protein contents in wild and cultivated jute species having variable effect on biology of BHC had certain correlation with the life stages of BHC. The protein had significantly positive correlation with larval survival, on larval weight, pupation and adult emergence of *S. obliqua*. Polyphenol oxidase and total phenol recorded negative effect on survival, growth, pupation and adult emergence.

fungicides at the reproductive stage and 21 days after first spray. Seed treatment (St) alone was less effective than St with different fungicide sprays. St with vitavax powder + fungicide sprays showed better results than seed treatment alone and St with bioagents plus spraying of fungicides. Among seed treatments with vitavax powder coupled with fungicides sprays, the best control was observed with spraying of captan/mixture of kasugamycin+ copperoxychloride/bavistin/benlate/ thiophanate methyl.

**Molecular diagnostics of *Colletotrichum truncatum*:** Species specific primers were designed for accurate detection of *Colletotrichum truncatum*, based on the conserved expressed sequences. Simplex-PCR protocols for detection of *Colletotrichum truncatum* have been standardized. ISSR-based markers were also used for genetic fingerprinting of *Colletotrichum truncatum*. Amplifications of *Colletotrichum truncatum* were observed based on AG, TC and CA repeat sequences. In addition, PCR primers were designed using genes which are specific to *C.truncatum* and also from the internal transcribed spacer (ITS) region of 18S ribosomal gene. PCR conditions are being standardized for genetic fingerprinting and variability studies in *C. truncatum* isolates. In addition to gene specific and ITS primers other approach based on inter-simple sequence repeat is also being used for fingerprinting of the pathogen.

**Bruchid management in groundnut:** Among the four types of storage bags tested for storability and management of bruchid (*Caryedon serratus*), the super-grain bag was found significantly superior over other storage bags, and recorded minimum number of eggs laid (216.1); damage to pods (38%) and kernels (34%) and weight loss in pods (38%) and kernels (34%). The super-grain bags have been recommended for a storage period of four months. Among the four botanical oils (neem, pongamia, castor and eucalyptus) against bruchid (*Caryedon serratus*) in storage, neem (10% v/w) oil treated groundnut pods were found with lowest number of eggs laid (2.3 eggs per 100 g pods), followed by castor (10% v/w) oil (2.5 eggs per 100 g pods). All oils were effective in inhibition of adult emergence as well as no damage to kernels and pods. Pongamia oil (10% v/w) recorded the lowest aflatoxin content of 2.4 parts per billion.

## Pulses

**Viral diseases management in greengram:** Seed treatment with imidaclorpid 17.8SL at 5 g/kg seed and foliar spray of Nurelle D505 at 0.1% at 15 and 45 days after sowing enhanced grain yield by significantly reducing incidence of viral diseases (yellow mosaic and leaf curl/necrosis) in greengram.

**IPM module for chickpea:** Soil treatment with *Trichoderma* + seed treatment with *Trichoderma* at 5 g/kg, imidacloprid and rhizobium + coriander intercropping and 2 foliar sprays, one of NSKE at flowering and the second of chlorantraniliprole at podding stage were found best IPM treatment for chickpea.

## Commercial crops

**Rapid delivery of fungicides to manage sugarcane diseases:** A mechanized sett treatment unit has been developed for rapid delivery of fungicides on sugarcane setts to manage red rot, smut and wilt; the major fungal diseases of sugarcane. The validated results for the efficacy of fungicide delivery revealed that sett treatment with fungicides by the new device effectively reduced red rot and smut from primary sources of fungal inocula. This approach reduced sett treatment time and economized fungicides in terms of quantity and cost. In the long run, this strategy will lead to effective

management of major fungal diseases such as red rot and smut in sugarcane.

**Endophytic *Beauveria bassiana* reduced stem weevil infestation in white jute:** Twelve *B. bassiana* strains, ITCC 6552, 6551, 5409, 4796, 6063, 4668, 5408, 6645, 6869, 4563, 6892 and 6726, were introduced into white jute-plants (cv. JRC 212) in a field experiment through seed treatment with conidial suspensions ($10^8$ cfu/ml) for managing stem weevil. ITCC 6551 and ITCC 4668 strains of endophytic entomopathogen were most effective against stem weevil with lowest infestation of 18.13% and 19.18%, respectively, which could reduce the infestation by 50% compared to control.

**In planta detection of *Macrophomina phaseolina* from jute by a direct PCR method:** *M. phaseolina*, the stem rot pathogen of jute, was detected from field samples by a simple method of direct PCR (dPCR) which obviates steps of DNA extraction. The leaf bits were treated with a lysis buffer at 65°C for 25 min, and stem pieces were initially incubated at 65°C for 5 min, followed by incubation at 60°C for 25 min and the lysate was used as PCR template.

Based on the type of tissues, the composition and concentration of lysis buffer systems were optimized. For leaf samples, the optimized buffer system was composed of 20 mmol tris (hydroxymethyl aminomethane (Tris)-Cl (*p*H 8)/litre, 1.5 mmol ethylene diamine tetra acetate (EDTA) (*p*H 8)/litre, 1.4 mol sodium acetate/litre and 200 µg proteinase K/mL. Further, 3% PVP (w/v) and β-marcaptoethanol (1% w/v) were added into the buffer. In case of stem samples, PVP was not applied but higher concentrations were used for other components. The pathogen could be detected from both leaf and stem samples by *M. phaseolina*-specific ITS primer generating amplicon of 350 bp. It is the first report of detecting *M. phaseolina* by a direct PCR method, without DNA extraction.

**CaneDES for diagnosis of sugarcane disorders**

Timely and accurate diagnosis and control of sugarcane disorders due to biotic and abiotic stresses are required to reduce losses. CaneDES, a web-based expert system, has been developed for diagnosis of disorders. The system is available both in Hindi and English with remote accessibility to sugarcane farmers over the Internet. It consists of 204 textual symptoms and 216 visuals to diagnose disorders caused by 40 insect-pests, diseases and nutrient deficiency factors. Symptoms have been classified into—Symptom Location (Crop Part) and Symptom Attributes, to simplify selection of symptoms by the users. The system is of generic nature and can be used in other crop environments with suitable changes in the knowledge base. The software also gives advisory information about the sugarcane production and protection in the form of crop calendar, integrated pest/disease/nutrient management and state-wise package of practices. Glossary of the system can be used to find out meaning of agricultural terms in English and Hindi. Accessibility of the software is user-id and password-based, for which the user needs to be the member of the system. Necessary online user registration form for membership is available in the software.


Home page of CaneDES

## Biological control

**Predatory bugs for management of insect pests:** The anthocorid predator bug *Amphiareus constrictus* was collected for the first time from sugarcane in Madhya Pradesh and Karnataka. It was amenable to production using UV-irradiated *Corcyra cephalonica* eggs. Another bug *Buchananiella indica* was successfully reared on alternate laboratory host eggs. It could be reared for further studies for more than 10 generations in the laboratory.

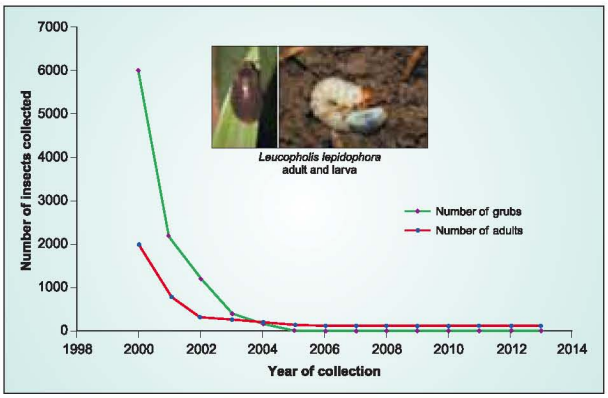
## Rodent control

**Effective rodenticides:** Studies on two new anticoagulant rodenticides, viz. flocumafen (0.005%) and difencoum (0.005%), were carried out for formulation and use as wax blocks. On testing, they demonstrated hundred percent kill of *Rattus rattus* and *Bandicola bengalensis* in a single day exposure. In the case of *Tatera indica* flocumafen cent percent mortality was achieved within two days exposure. The choice tests (with 60–80% kill) indicate that wax block baits of these rodenticides were fairly palatable by the test rodent species. In rice crop, burrow baiting with flocumafen (0.005%) resulted in 60–74% control success, whereas difencoum (0.005%) achieved 58–63% per cent control success in Karnataka. Likewise in coconut, both these rodenticides yielded 80–100% success in Karnataka and Andamans.

**Rodent management technologies:** Laboratory evaluation of cinnamamide against *Rattus rattus* revealed significantly lowest consumption of treated bait. Rats showed no repellency towards treated bait during the first few hours of their exposure, indicating absence of primary or gustatory/olfactory effects toward cinnamamide (0.4%). Polythene trunk banding in coconut resulted in 100% and 94% control of nut damage and rodent infestation, respectively, in Andhra Pradesh and Karnataka. Although economical polythene trunk banding lasts for 2–3 years only in comparison to metallic bands, which may last for 7–8 years. Among local bamboo traps *maat chitap* recorded significantly higher trap index as compared to *Sherman traps*.

## White grub management

Biological control of white grubs was found highly effective for their management. Two local strains of entomopathogenic nematodes, isolated from the third instar grubs of *Holotrichia consanguinea* species, from village Lalsot and RARI Research farm, Durgapura, were found highly promising in control of the grub.




Larval collection by digging and adult collection are the two most plausible and eco-friendly methods for managing arecanut white grub, *Leucopholis lepidophora* Blanchard. The data shown above depicts how the intensity of infestation can be managed using two methods concurrently over time at a village of Karnataka. The inset depicts the adult and the larva of the arecanut white grub


Mass multiplication of the biocontrol strain

The strains were multiplied on wax moth larvae, *Galleria mellonella*, in the laboratory and tested against different instars of *H. consanguinea*. The mortality of grubs was observed in 24–48 hrs. At Ranichauri, a new combination of imidacloprid 200 SL (0.048 kg a.i./ha) with *Metarrhizium anisopliae* spore dust (0.048 kg a.i./ha + $5\times10^{13}$ conidia/ha) or *Beauveria bassiana* spore dust ($5\times10^{13}$ conidia/ha) gave promising control of *H. longipennis* in soybean.

## Pollinators

**Managing Nosema disease of honeybees:** The disease has been diagnosed symptomatologically and microscopically. Its causal organism has been identified a fungus, named *Nosema apis;* earlier thought to be a protozoan of Opisthokonta super group and class Microsporidia. Bacilliform spores of 5.0 µm × 2.0 µm size have been observed in the infected bees and their faecal matter. The spread of infection is managed by replacing infected combs with fresh ones and avoiding confinement of bees in the hives by activating through feeding sugar syrup (50%).

**Pollen inserts for apple orchards:** Commercial production of apple is greatly affected due to inadequate pollination owing to low pollinizer proportion and poor pollinator activity during bloom. To resolve this problem and for ensuring proper pollination, a new technique, i.e. the use of farmer friendly pollen insert, has been found quite effective. Use of pollen insert in apple orchards having low proportion of pollinizers (10–15%) increased fruit-set by 2.5 times.

Pollen insert

### Integrated Pest Management

Integrated pest management (IPM) technology was validated in rice crop cv. Pusa Basmati 1121 in an area of 200 ha in farmers' participatory mode. The strategy employed only one chemical pesticide spray of buprofezin by IPM practitioner-farmer as against 2–4 chemical pesticide sprays in farmers' practice. The post-crop samples showed enhanced levels of organic carbon content (11%), increase in natural enemy count, resulting in reduction of pest population besides increase in yield (IPM: 34.63 q/ha; FP: 27.69 q/ha) as compared to farmers' practice.

Accelerated Pulse Production Programme (A3P) was implemented in pigeonpea, chickpea, lentil, greengram and blackgram covering six major pulse-growing states on 16,443.62 ha in farmers' participatory mode. Significant and varied reduction in infestation of different insect-pests and diseases of the pulse crops, reduction (6 to 0) in foliar sprays of chemical pesticides and up to 100% higher yields in A3P fields were observed as compared to non-A3P fields. Economic impact analysis indicated significant reduction in the number of chemical pesticide sprays to 4.27 in IPM plots from 7.34 in farmers' practice.

Crop Pest Surveillance and Advisory Project (CROPSAP), operated by the State Department of Agriculture, Maharashtra, across 33 districts and 43000 villages of Maharashtra in 39, 38, 15, 11, and 12 lakh ha in soybean, cotton, rice, pigeonpea and chickpea, respectively, was facilitated with the ICT-based pest monitoring.

### Pollinator garden

A "Pollinator Garden" with over 70 species of plants (trees, shrubs, herbs and climbers) belonging to diverse families has been developed at Bengaluru. Several species of pollinators which are attracted to this garden round the year have been studied as potential candidates for pollination of cultivated crops.

**Wax moth traps to protect honeybee combs:** A novel technique for management of wax moth was devised by fixing a piece of *Apis dorsata* comb on a sticky trap and installing the same close to bee-hives.

Trap fitted in a beekeepers farm

Gravid moth catches after release

Observation on moth trap catch showed that *Apis dorsata* comb facilitated significantly higher gravid moth catch (61%) compared to that enticed by *A. cerana* comb (only 1%). The moths attracted to *A. dorsata* comb kept in sticky trap resulted in direct reduction of gravid wax moth female population.

**Quantification of role of specific pollinators:** Bee pollination resulted in enhancement of bittergourd (*Momordica charantia*) fruit-set by 20%, reduction in fruit deformity by 46%, increase in fruit weight by 33%, number of fruits by 12%, seed index by 19% and yield increase by 24%.

## Ornithology

**Eco-friendly bird management:** In Kerala, rice nurseries were hundred per cent protected from weaver birds, munias, blue rock pigeon (*Columba livia*) and pea fowl (*Pavo cristatus*) by the use of stand parallel ropes. Erection of reflective ribbon during sprouting and seed treatment with copper oxy chloride @ 3 g/kg seed (96% and 91% respectively) protected crop from depredatory birds. In Telangana, sunflower plots covered with aluminium coated paper plates yielded 938 kg/ha, followed by those treated by egg solution (583 kg/ha). Wrapping of maize cobs with leaves and erection of reflective ribbon resulted in significantly higher yield (967 kg/ha) compared to control. Erection of coconut ropes at one metre interval and one foot above the ground using pegs in the entire groundnut area conferred 90% protection to the crop during sprouting stage from pea fowl damage. Similarly, erection of coconut rope in three rows one foot apart around the wheat crop during milk stage provided 100% protection from pea fowl.

**Beneficial birds in agricultural landscape:** Barn owls play an important role in managing rat population in agricultural fields. Several methods to attract owls to fields have been validated. In Asom, barn-owl diet consisted mainly (75%) of Grey Musk Shrew (*Suncus munius*) and the remaining 25% was of rodent species; lesser bandicoot rat *Bandicota benghalensis* and house rat *Rattus rattus*. Similarly in Kerala, major component of the diet of barn owl was *Suncus muinus* (81.50%), followed by *Rattus rattus* (18%) and in insignificant quantity was birds and insects remains.

## Wild animals' management

Damage due to wild boar in maize in Hyderabad was checked to a great extent by erection of barbed wire (964 kg/ha), chain link (911 kg/ha), circular blade wire (859 kg/ha) and application of egg solution (807 kg/ha).

## Horticultural Crop Health Management

### Fruits

Pomegranate wilt caused by *Ceratocystis fimbriata* emerged as a major threat causing significant economic loss. Considering the potential of *Streptomyces* species (known for the ability to control soil-borne fungal pathogens besides their plant growth-promoting and nutrient-solubilization abilities), 16 Actinobacterial isolates were characterized. Three isolates, viz. Pan Act-1, Pan Act-2 and Pan Act-3, were selected and identified. All the *Streptomyces* sp. could produce IAA/$GA_3$, siderophores and extracellular enzymes at varying levels and with efficient suppression of growth of *C. fimbriata* resulting in the recovery of pomegranate plants affected by wilt.

Six-month-old pomegranate hybrids and new germplasm accessions were tested for bacterial blight resistance through challenge inoculation. Though none showed resistance, six of them showed tolerance with less than 10% incidence and delay in blight initiation.

Biocontrol agents, viz. *Bacillus subtilis* 1% A.S. ($10^9$ cfu/g) and *Paecilomyces lilacinus* ($10^6$ cfu/g) mixed with FYM and applied @ 2 kg/plant at the time of planting and again at 6 monthly intervals significantly reduced the incidence of nematodes, viz. *Radopholus similis* and *Meloidogyne incognita* on banana roots by 82 and 84%, respectively. The application of these biocontrol agents also suppressed *Fusarium* wilt disease in banana and maximum reduction was recorded in Rasthali variety (disease score 2 in the 1–6 disease scale). All the treated plants sustained up to harvesting, whereas in the control only 35% plants sustained. Application of bioagents also positively influenced the yield-attributing characters.

Apart from honey bee, *Apis florae* and other dipterans like *Chrysomya megacephala* and *Eristalinus arvorum* were identified as important pollinators of mango. Artificial diet and mass multiplication protocols were developed for *C. megacephala* in an attempt to enhance mango polination.

Diversity and abundance of pollinators were recorded in major mango belts of the country. There were significant differences in the species composition among regions. Stingless bee (*Tetragonula iridipennis*) was the dominant forager in areas of low elevation like Kanyakumari, Vengurle and Vijayawada. Indian little bee, *Apis florea* and Calliphorid, *C. megacephala,* were major pollinators in Bengaluru and Chittoor, while Syrphids were predominant in Lucknow. In terms of diversity, Bengaluru (Simpson diversity index 0.78),

Kanyakumari, Vijayawada and Lucknow (more than 0.6) had more diversity index, while Vengurle, Chittoor and Sangareddy had the least diversity (0.2–0.3). The trend in pollinator activity over the last three years was assessed in relation to the existing maximum temperature during peak flowering period on mango at Bengaluru. There were notable shifts in the abundance of pollinator species over the years. While *A. florea* showed significant negative correlation (r = –0.63) with temperature during blossom period, C. *megacephala* and syrphids showed non-significant correlation. The *A. florae* was the dominant forager with 6.36, 7.06, 6.20/panicle/5 minutes in the years 2012, 2013, 2014, respectively followed by C. *megacephala* (2.53, 2.48, 5.07) and syrphids (mainly *E. arvorum*).

Application of fungal formulation of *Metarhizium anisopliae* @ $1 \times 10^7$ spores/ml in combination with 2 ml neem oil were on a par with synthetic insecticides and recorded 80% reduction of thrips, indicating the possibility of a non-insecticidal module for thrips management.

Isolate of *Trichoderma viride* 'NRCL T 01' isolated from rhizosphere of healthy plant was efficient in controlling soil-borne pathogens, particularly *Fusarium solani* under *in vitro* condition and potted litchi plants. It was mass multiplied and a talc-based formulation was developed with minimum count of $2 \times 10^6$ cfu/g.

While assessing the incidence and severity of leaf blight disease on litchi, the typical symptoms starting from tip of leaf with light brown to dark brown necrosis advancing towards both the margins of leaf were recorded. This led to complete necrosis of affected leaves and subsequently drying up of the plants. Pathogenicity test confirmed it as *Alternaria alternata.*

### Vegetable crops

Capsicum seeds, substrate (used for producing nursery seedlings) and seed beds under shade net were treated with *Bacillus subtilis* 1% W.P and 1% A.S., *P. putida* 1% W.P and 1% A.S and *Bacillus pumilis* 1% W.P and 1% A.S. All these bioagent formulations proved to be effective in the management of nematodes, viz. *M. incognita* and *R. reniformis* on Capsicum.

For molecular characterization of begomoviruses infecting chilli, complete nucleotide sequences of DNA-A were determined. Cloning, sequencing and sequence analysis indicated that each sequence contained the same arrangement of ORFs which is typical for whitefly transmitted begomoviruses in general, with 2 ORFs (AV1 and AV2) in virion sense DNA and four (AC1, replicase, AC2, AC3 and AC4) in complimentary sense DNA. The AV1 (coat protein), AV2 (Precoat protein), AC2 and AC3 genes were of the same size in each sequence and only small differences were noted in the AC1 (Rep) and AC4 genes. Comparison of full-length sequences indicated that chilli leaf curl virus (ChLCV), chilli leaf curl multan virus (ChLCMV), chilli leaf curl Pakistan virus (ChLCPV), pepper leaf curl Bangladesh virus (PepLCBV), tomato leaf curl Sri Lanka virus (ToLCSLV) and tomato leaf curl New Delhi virus were associated with chilli leaf curl disease, based on DNA-A sequence nucleotide identity of 90.5–97.7% with the above six viruses.

Integrated module comprising seedling dip with Imidacloprid 1 ml/litre of water, spraying of Buprofezin 1 ml/litre at 25 DAT, Fipronil 0.2 g/litre at 35 DAT, *Verticillium lecanii* 5 g/litre at 45 DAT, Chlorfenapyr 1 ml/litre at 55 DAT, Neem oil 1% at 65 DAT and subsequent rotation of the same was most effective for mite reduction in chilli over the control.

An entomopathogenic fungus, *Isaria farinosa*, causing natural epizootics on whitefly grown under polyhouse was isolated and characterized. The intergenic spacer region (IGS) of the fungus was amplified by using primers 26S311 F/CNS 1. Post- sequencing amplified PCR product was subjected to BLAST (NCBI) analysis and the nucleotide sequence data were deposited in Gen Bank (Acc. No. KJ013353). The incidences of begomoviral diseases are rapidly increasing and are being reported from different parts of India. Two hundred leaf samples were collected from farmers' fields around Varanasi region and were analysed through PCR using begomoviruses specific primers. The study indicated that all samples were associated with new strains of tomato leaf curl Joydebpur virus (ToLCJoV) and Tomato leaf curl Bangladesh betasatellite (ToLCBDB).

A severe outbreak of anthracnose was recorded in Karnataka in which symptoms of anthracnose appeared on leaves, neck and bulbs of onion. Dieback was observed on severely infected leaves, which led to the collapse of plants. Twisting and curling of leaves were associated symptoms of onion anthracnose. Thirty-seven isolates of *Colletotrichum* recovered from diseased leaves and neck were characterized based on morphological characteristics and partial sequences of ACT, TUB2, CHS-1, CAL, CYLH3, GAPDH, GS and ITS genes. The combined multilocus sequence analysis coupled with a critical examination of the phenotypic characters revealed the presence of two species, *C. siamense* (27 isolates) and *C. truncatum* (10 isolates). Pathogenicity of two species were confirmed on onion seedlings cv. Arka Kalyan. This is claimed to be the first report of *C. siamense* and *C. truncatum* causing anthracnose disease in onion.

Pumpkin yellow vein mosaic disease (PYVMD) is caused by three different bipartite begomoviruses, namely Tomato leaf curl New Delhi virus (ToLCNDV), Squash leaf curl china virus (SLCCNV) and Tomato leaf curl Palampur virus (ToLCPaV) in combination with four different beta satellites namely Pepper leaf curl betasatellite (PepLCB), Papaya leaf curl betasatellite (PaLCB), Tomato leaf curl betasatellite (ToLCB) and Ludwigia leaf distortion betasatellite (LuLDB). Molecular studies indicated that all these viruses have typical features of Old-World bipartite begomoviruses with the presence of stem-loop structure within an

intergenic region (IR), and seven open reading frames (ORFs) [AV1 and AV2 in the virion sense and AC1, AC2, AC3, AC4 and AC5 in complementary sense].

Formulations of *Chaetomium* sp. were developed for the biological management of early blight of tomato caused by *Alternaria solani* through induced systemic resistance. Molecular characterization of begamoviruses and tobamoviruses infecting chilli and tomato respectively, was completed.

### Spices

Drenching of carbosulfan (0.1%) was effective for the management of nematodes in nursery for production of healthy rooted black pepper cuttings. In cardamom, spraying of Carbendazim + Mancozeb (0.1%) thrice at 30 days interval resulted in effective management of leaf spot disease in nursery. The natural incidence of leaf blight (*Colletotrichum gloesporioides*) and rhizome rot disease was also recorded in 60 accessions maintained in the field gene bank at Appangala, Kodagu, Karnataka. Thirty- two and 14 accessions of these were resistant to leaf blight and rhizome rot, respectively.

Encapsulation of a plant growth-promoting rhizobacteria (IISR GRB 35-*Bacillus amyloliquefaciens*) in gelatin capsules was effective in delivering PGPR (plant growth promoting rhizobacteria) for growth promotion and rhizome rot disease management in ginger.

### Tuber crops

JHULSACAST, a potato late blight forecasting model for plains of West Bengal and web-based Decision Support System for management of late blight in western Uttar Pradesh were developed. Indo-Blightcast, a web based forecasting model, developed is applicable pan India. Development of triplex lateral flow immune assay (LFIA) was done for simultaneous detection of viruses, PVX, PVA and PVM, duplex RT-PCR for CMV and TMV and multiplex RT-PCR for simultaneous detection of PAMV, PVS, PVM, PLRV and PVX in potato.

### Plantation crops

A new egg parasitoid, *Telenomus cuspis* sp. nov. (Hymenoptera: Platygastridae) on tea mosquito bug (TMB) was reported in cashew which is a new record of the group from India as well from the Oriental region.

Studies on predisposing factors for incidence of root (wilt) disease in arecanut indicated site-specific variations in soil properties in healthy and diseased gardens at the same site. On-farm trials on management of yellow leaf disease (YLD) in arecanut indicated that the Compositional Nutrient Diagnosis (CND) indices for NPK were important discriminators between yellow leaf disease and apparently healthy populations. The results indicated that predisposing factors for YLD might be the nutrient imbalance in soil leading to deficit of major nutrients and accumulation of micronutrients like Mn and Cu in plant.

Two PGPR based bioinoculants, *Kera Probio*, a talc formulation of *Bacillus megaterium* effective for raising robust coconut seedlings and *Cocoa Probio*, containing *Pseudomonas putida* effective for raising healthy cocoa seedlings, were developed.

Addition of biochar from coconut wastes increased the soil organic carbon, total N, available P and K and *p*H, besides improving a number of beneficial microorganisms and their activities. However, vermicomposting earthworm, *Eudrilus* sp., was not affected by addition of biochar to soil. This study indicated that the wastes produced from tender coconut parlours and coir production units can be converted to biochar and used as soil amendment.

Spraying of *Hirsutella thompsonii* @ 20 g/litre/palm ($1.6 \times 10^8$ cfu) in combination with botanicals (neem based) effected 59% reduction in coconut eriophyid mite incidence. Placing a wedge shaped soap fortified with citronella oil and *Clerodendron infortunatum* extracts in leaf axil as a prophylactic measure caused reduction in leaf damage by rhinoceros beetle to the tune of 34%.

Botanical cake in tablet form was developed for effective field delivery and sustained release of active ingredients upon placement on palm leaf axils for subduing rhinoceros beetle incursions in coconut. Perforated sachet containing 3–5 g chlorantraniliprole granules safeguarded juvenile palms up to 5 months. Initial establishment of coconut seedlings was very successful and devoid of rhinoceros beetle damage.

### Flowers and orchids

The occurrence of *Colletotrichum cymbidiicola* and *C. cliviae* in orchids was reported for the first time. The cause of chrysanthemum rust, a serious, emerging disease, was identified and confirmed as *Puccinia horiana*. In addition, an aphelinid wasp, *Coccophagus ceroplastae* (Howard) as a parasitoid of soft scales, *Coccus hesperidum* infested orchids was reported from Sikkim. Further, a new report of *Aphytis* sp. as parasitoid of *Cymbidium* Scale, *Lepidosaphes pinnaeformis* (Bouche) infesting *Cymbidium* Orchids, was made. The activity of the parasitoid was more from April to first week of December and decreased during winter. In addition, a new report of an aphelinid wasp, *Pteroptrix* sp. as a parasitoid of scale insects, was made.

### Mushroom

Two bacterial isolates, B-9 (*Bacillus*) and B-18 (*Alcaligenes*), were promising biocontrol agents for the management of wet bubble disease of button mushroom caused by *Mycogone perniciosa* both under laboratory and mushroom house conditions. Pre-spawning of casing soil 5–20 days prior to pasteurization resulted in reduced incidence of wet bubble disease. Moisture contents of casing soil (less than 60%) at the time of pasteurization favoured the survival of *M. perniciosa.*

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