8. Crop Management

PRODUCTION

Cost-effective farming systems for field crops cultivation for increasing production and productivity in different agroecologies have been developed.

Cereals

High temperature stress at the panicle initiation stage in rice gave 40% seed-set in female-plants, and it was 60% in male-plants. System of rice intensification (SRI) method (12-day-old seedlings, 25 cm × 25 cm spacing, organic source through FYM at 5.0 tonnes/ha and weeding by cono-weeder) was compared with the practices when various nutrient- and weed- management practices were taken separately, keeping unchanged seedling age and spacing of the SRI method. Chemical fertilizers at 120% RFD significantly enhanced yield over organic manure. Herbicide azimsulfuron at 35 g a.i./ha (low dose high efficacy and safe) gave rice yield on a par with cono-weeder.

Rice yield of Sampada variety in the system of rice intensification with application of only organic fertilizers or both organic and inorganic fertilizers was significantly higher (8.16–8.32 tonnes/ha) than that obtained under the best management practices (6.99 tonnes/ha).In rice hybrid KRH 2, application of micronutrient-enriched compost, field-fortified poultry or vermi compost manure resulted in enhanced grain yields.

Nitrogen management plays an important role in aerobic rice production. Leaf colour chart-based N recommendations resulted in higher agronomic N- use efficiency (17–18%) and its recovery efficiency (26–30%) over the recommended doses of fertilizers. In aerobic rice, pre-emergence application of pendimethalin (1.5 kg/ha), followed by post-emergence application of bispyribac sodium (20 g/ha) lowered weed population and increased biomass and grain yield.

Highest production efficiency (REY 14.9 tonnes/ ha) and lowland utilization efficiency were observed in Odisha in rice–potato–sesame cropping system, although rice–maize–cowpea was found the most economical system.

Crop diversification in waterlogged rice fields

Crop diversification in the rice field was possible by using jute-reinforced soil columns of different dimensions. Early season vegetables were grown successfully in rice-vegetable relay system to fetch better market price (₹1.5 to 3 lakh/ha) without affecting rice yield. Raising seedlings of field crops (mustard, *arhar* etc)/vegetables (cucurbits, okra, rajmash) in small jute-bags was found effective to cope with late harvest of rice and timely planting of sequential crops in waterlogged situation.

Rice–fish–horticultural crops–agroforestry-based integrated farming system model developed at Cuttack for deep-water ecology generated a net income of ₹ 1 lakh/ha. Integrated rice–fish farming system, developed for flood-prone areas at Gerua (Odisha), gave gross income of ₹1.63 lakh/ha.

For maximizing wheat production in the North-Western Plains Zone (except Durgapura), two irrigations (30 and 85 DAS) are enough, and so are for the North-Eastern Plains Zone also. For long-term sustainability in the Northern Hills Zone, substitution of 25% of inorganic fertilizers with organic fertilizers (vermi compost) should be adopted in place of the practice of 100% inorganic fertilizers use.

Nitrogen applied just before irrigation gave higher wheat yield compared to its application after irrigation, and three split applications were better than two splits.Urea coated with 1,000 ppm karanj oil/ palmarosa oil/citronella oil/neem oil saved 30 kg N/ha (recommended dose is 150 kg N/ha).Thus, resulting in saving of 20% in fertilizer cost.

For controlling multiple herbicide-resistant *Phalaris minor* populations in wheat-crop, pendimethalin as pre-emergence or pyroxasulfone as post- emergence has been found promising practice.

In malt-barley, row spacing of 18 cm with seed rate of 100 kg/ha should be adopted in timely as well as late sown production conditions of the North-Western Plains Zone to maximize productivity.

In pearl millet–pigeonpea (2 : 1) intercropping system in Karnataka, a medium-duration pigeonpea variety (160–165 days) gave higher pearl millet equivalent yield, net returns and B : C ratio.

Small millets

In Odisha, zinc at 12.5 kg/ha and in Jharkhand and southern Karnataka, boron at 5 kg/ha enhanced productivity of fingermillet in rainfed areas. Fingermillet with pigeonpea (4 : 2) in Jharkhand, fingermillet with pigeonpea (8 : 2) in Odisha and kodo millet with pigeonpea (2 : 1) in Madhya Pradesh were promising systems. In medium-black soils of Andhra Pradesh, foxtail millet (*kharif*)–chickpea (*rabi*) sequence proved remunerative compared to fallow–chickpea system.

Under low fertility rainfed areas, little millet varieties RLM 36 and RLM4 1 in Madhya Pradesh and Sabara in Odisha; fingermillet GPU 66 in Karnataka, PR 202 in Odisha and Jharkhand, GPU 28 in Tamil Nadu and Maharashtra, HR911 in Chhattisgarh and PRM 2 in Uttarakhand improved productivity of the areas.

Oilseed crops

Arbuscular mycorrhizal fungus, *Glomus mosseae*, application resulted 13% increase in groundnut yields. Newly isolated groundnut rhizobia RH 11, RH 17 and RH 20 inoculation enhanced pod yield of groundnut TG 37A; RH 11 was the best.

To achieve higher productivity from the newly released soybean varieties, optimum sowing date is from 20 June to 5 July for the North Plain and Central Zones and 15 June to 30 June for the North-Eastern and Southern Zones. The optimum seed rate recommended is 65 kg/ha in all zones, excepting North-Eastern Zone (its 55 kg/ha). And row spacing is 45 cm for Central, North Plain and North-Eastern Zones and for the Southern Zone, it is 30 cm.

Optimum nutritional levels recommended for soybean in the North Plain and North-Eastern Zones are 125% RDF + FYM at 5 tonnes/ha, and for Central and Southern Zones are 100% RDF + FYM at 5 tonnes/ha. Two irrigations at seedling (15–20 DAS) and pod-filling (20 days after flower initiation) are recommended for the North Plain, Central and Southern Zones.

In Alfisol irrigated areas in Bengaluru, sunflower responded significantly up to 120 kg N and 90 kg P_2O_5/ha.

At Mandor (Rajasthan) in the irrigated areas, 75% RDF + 25% N through FYM + seed treatment with *Azospirillum* + phosphate-solubilizing bacteria mixed with FYM applied in furrows gave maximum castor-seed yield, besides improving soil quality. In light-textured soil and assured irrigated conditions at Sardar Krushi Nagar (Gujarat), castor hybrid GCH 7 fertilized with 150% RDF (180-37.5-0 kg NPK/ha) gave higher seed yield and economic returns.

Pendimethalin or fluchloralin at 1 kg a.i./ha + 1 hand weeding at 40 DAS proved to be the best weed management practice for castor in irrigated areas.

Intercropping of mustard+maize (1 : 1/1 : 2) at Bhubaneshwar and Dholi; wheat + mustard (9 : 1) at Varanasi, Kanke and Nagpur, and mixed cropping of wheat+mustard (9:1) at Chatha proved remunerative than sole crops. However, sole wheat at Kanpur and Morena was comparatively more promising.

For chickpea + linseed (4 : 2) intercropping system, linseed varieties Padmini (Sagar), PKVNL 260 (Nagpur), J 23/Indira Alsi 32 (Raichur), Suyog/RL 914 (Kota), Shekhar/Sweta/Shubhra (Shillongani) and Padmini /JLS 67/JLT 26/JLS 9 (Tikamgarh) were found suitable. At Kota (Rajasthan), Raichur (Karnataka), Palampur (Himachal Pradesh), Shillongani (Asom), soil-moisture conservation through available straw at 10 tonnes/ha as mulch in rainfed linseed gave higher net monetary returns of ₹ 18,926, 6,369, 14,866 and 9,113, respectively

Pulse crops

Maize–wheat–mungbean and pigeonpea–wheat systems resulted in a significant increase of 11 and 10% in organic carbon (respectively) and of 10 and 15% in soil microbial biomass carbon as compared to maize–wheat system. Inclusion of pulses in rice-based system also improved soil organic carbon.

Under moisture stress, *Mesorhizobium ciceri* strain 13 and 30 enhanced yield of chickpea RSG 888 up to 27% and 20%, respectively, over uninoculated control. Bacterial isolates No. 1-13 and 1-14a with ACC deaminase activity have been identified as potential candidates to mitigate moisture stress impact on chickpea root development.

The system productivity in terms of chickpea equivalent yield was highest in rice–wheat–mungbean (5,733 kg/ha), followed by rice–wheat (4,211 kg/ha), and was lowest in rice-chickpea (3,738 kg/ha). PGPR strains, CP 11, PSB 11 and J 7, showed consistent response in increasing chickpea grain yield from 14 to 27% over control in the fields for the last two years, and have been identified for commercial use in chickpea.

Commercial crops

In the northern cotton-growing zone, poor plant-stand, mainly due to seedling mortality under high temperature, is a serious problem. By transplantation of raised seedlings, plant stand up to 92.3% and yield up to 3.18 tonnes/ha were observed, which were significantly higher than the normal sown crop (87.5% plant-stand and yield

Sugarcane bud-chip technology for higher seed multiplication

The technology has been developed and standardized for quick multiplication of quality seed-cane as well as to reduce quantity of seed-cane required per unit area. It ensures seed multiplication rate of 1 : 60 in comparison to 1 : 10 under the conventional method. In bud-chip technology, freshly harvested sugarcane stalks of 10 months' age are used to scoop out bud chips and these bud chips are soaked in specially formulated PGR solution for 2 hr, followed by fungicidal treatment for 20 min. They are then planted upright in plastic-trays/cups filled with soil mixture; 25–30 days old settlings are transplanted in well prepared fields to obtain high tillering and uniform plant population. The quantum of seed material required per hectare could be reduced by about 60–80% by weight. The technology ensures higher number of millable canes per clump, and thereby result in cane yield over 100 tonnes/ha under subtropical conditions.

HDPS for maximizing productivity of cotton

Thirty-four promising cotton lines were identified on the basis of compact plant body and short sympodia. These lines showed determinate growth of lateral branches and reduction in boll numbers (6–8 bolls/plant) and possessed good fibre properties. Among the ten genotypes of *G. hirsutum* evaluated under high density (45 cm × 15 cm) on rainfed Vertic Inceptisols of Nagpur; Suraj, ADB 39 and 28I were promising in terms of yield, morphology, earliness and nutrient-use efficiency. Eight cultivars of *G. arboreum* (AKA 07, CINA 404, JK 5, HD 123, PA 183, JLA 794, JLA 802 , JLA 505), CINA 404, HD123, and JLA 505 performed well under high density planting (HDPS) (222,000 plants/ha). Among ten genotypes (Anjali, C 1412, CCH 724-5, TCH 1608, KC 3, F 2383, NH 615, MCU 7, SVPR 3, PKV 081) under HDPS under irrigated conditions, KC 3 recorded the highest seed- cotton yield (2,655 kg/ha), followed by PKV 081 (2,253 kg/ha), Anjali (2,215 kg/ha) and NH 615 (2,121 kg/ha) compared to 1,596 kg/ha obtained with RCH 2 Bt.

of 2.6 tonnes/ha). The net income of ₹ 4,175 was earned due to extra yield from the transplanted crop.

A talc-based dry formulation of microbial consortium for jute was developed for easy handling and use in farmers' fields, and the formulation could ret jute within 13–15 days with fibre strength of 27.8 to 29.9 g/tex.

A mechanical ramie-planting technique has been developed. This technique helped reduce 60–70 % labour cost, and also saved on planting time.

Gum arabic production using gum-inducer technique

In arid western Rajasthan, *Acacia senegal*, which yields gum arabic, is distributed abundantly on the forest land, farmers' fields and common property resources (CPRs). Gum arabic production potential of the area even though immense, has not been fully tapped. Gum-inducer method with mechanization of boring facilitated rapid treatment of trees. Studies have indicated that gum from *A. senegal* is maximum quantity on sandy terrain and best time of treatment is during late March to April.

HORTICULTURE

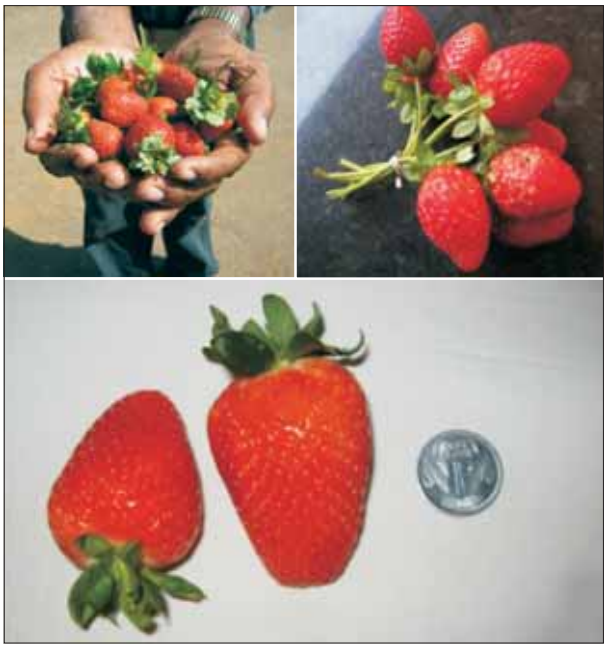
Fruit crops

In banana, planting of 2 suckers/pit at 2.7 m × 3.6 m (2,057 plants/ha) spacing recorded a highest bunch yield (55.13 tonnes/ha), while planting of single plant/pit at 2.4 m × 2.4 m (1,736 plants/ha) (52.43 tonnes/ha), and planting of three suckers/pit at 3.6 m × 3.6 m spacing (2,314 plants/ha) yielded less bunch (49.8 tonnes/ha). In Poovan, soil application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermi compost + 0.9 kg groundnut cake advanced fruit maturity (118.3 days) and recorded highest bunch weight (21.8 kg) with more number of hands (12.7) and fingers (201.2) per bunch. Among banana genotypes, Saba exhibited less salt injury (5.78–9.71%) compared to Nendran and Red Banana which exhibited more than 80% of salt injury with 150 mM NaCl treatment.

Intercropping of cabbage and cauliflower with mango

Among different grape stocks scion combinations, Thompson Seedless grafted on 110 R rootstocks and own rooted vines imparted maximum budburst rate after forward pruning which was attributed to increased peroxidase polyphenol oxidase activity and proline in their buds.

Highest yield per vine was recorded on 110 R rootstock while least was on St. George. Sodium in juice was the highest on vines grafted on Dogridge and own rooted vines, while it was least on 110R rootstock. Further, combination of canopy management practices such as cluster thinning, leaf removal, shoot thinning either alone or in combination improved fruit composition parameters (increased TSS, anthocyanin concentration, phenolic contents and reduced pH, and juice potassium) in Cabernet Sauvignon and Sauvignon Blanc grapes.



Soilless culture of strawberry protects crop from soil-borne diseases

Leaf nutrient norms for commercial citrus cultivars (Malta sweet orange, acid lime and Kinnow mandarin) was developed using DRIS (Diagnosis and Recommendation Integrated System) based analysis. To harness solar energy and other natural resources, different plant architectural systems were tried in apple varieties grafted on M-9 rootstock. The cultivar, Starkrimson, recorded maximum proportion of fruits having more than 90% coloured surface, 'A' grade fruits and maximum number of intense colour fruits from surface, middle and inner canopy region. In vertical axis and espalier training system, Coe-Red Fuji registered highest flowers and fruits/tree, followed by Granny Smith. Similarly in peach, maximum fruit setting, fruit yield/ tree, fruit yield/ha and

fruit quality were recorded in tatura trellis system of training. In pomegranate, application of microbial consortium resulted in higher increase in plant biomass as compared to individual microorganism. Further, inoculation of *Penicillium pinophilum* with *K-feldspar* resulted in increase of available potassium and phosphorus content in soil.

Good growth, yield and quality were better with open-trough compared to either Lay-Flat-Bag system and/or Verti-Gro systems. Earliness in flowering (43 days) and highest TSS (10.61°Brix) were also achieved along with higher marketable fruits (78.33%). However, Verti-Gro system accommodated 48% more plants per unit area.

Vegetable crops

Significantly higher yields of 11.45 and 34.98 tonnes/ha were achieved in cowpea and tomato, respectively with zero tillage on permanent ridges and residue retention, as compared to conventional tillage with flat planting and residue removal. In cowpea-tomato cropping system, net benefit obtained was ₹163,208/ha/year with zero tillage on permanent ridges and residue retention as against ₹111,429/ha/year under conventional tillage with flat planting and residue removal. Organic carbon, labile organic carbon, non-labile organic carbon, carbon pool index and carbon management index were higher by 1.98 g/kg, 0.06 g/kg, 1.80 g/kg, 0.34 and 17.5, respectively, under zero tillage with residue retention compared to conventional tillage with flat planting and residue removal.

Seed pelleting techniques for onion, tomato and carrot were standardized. Pelleted onion, carrot and tomato seeds could be stored for 3 months under ambient conditions without reduction in seed germination and vigour. A carrier-based microbial product which contains N fixing, P and Zn solubilizing and plant growth promoting microbes was developed, evaluated and commercialized. The specialty of this technology is that farmers need not to separately apply N fixing, phosphorous solubilizing and growth promoting bacteria individually. Farmers can apply this product conveniently, either through seed, soil, water or nursery media like coco peat.

Ornamental crops

The protocols for *in-vitro* multiplication of selected orchid cultivars were refined. About 21,000 plantlets of Cymbidium and Cattleya hybrids, were produced for demonstration and setting up of quality orchid farms.

Mushroom

Technology is being standardized for production of iron-rich mushrooms through bio-fortification of the growing substrate. The iron content of mushrooms produced on substrate fortified with 0.05% ferrous sulphate significantly increased iron content (167 ppm) over the control (114 ppm). Indigenous strain of tropical edible mushroom species, viz. *Macrocybe gigantea*, was successfully cultivated on pasteurized and composted wheat straw. Different casing materials, viz. FYM, garden soil, spent mushroom substrate, coir pith and rice husk ash were evaluated and successful fructification was observed with all casing material except rice husk ash. The *M. gigantea* has better shelf and better aroma. It could be recommended in tropical and subtropical regions as an alternative to *Calocybe indica* in summer. Zero energy polytunnel composting process was standardized and it produced higher quantum of quality compost in 16–18 days with only 3–4 turnings. The productivity of this compost is around 20–22 kg mushroom per 100 kg compost which is at par or higher than all other available methods. In addition, a cost-effective, small and farmer-friendly passive aeration structure designed for compost production for button mushroom was also developed. It reduces number of turnings required from 8 to 4 and time requirement from 28 to 20 days compared to normal method of composting.

Palms and nuts

In coconut-based cropping system, elephant-foot yam cv. Gajendra yielded high amount of corm. Guinea grass (var. GGCo 3) produced higher green fodder (89.2 tonnes/ha/year) under husk application. There was lower specific volume of soil and soil porosity (higher soil compaction), and soil dehydrogenase activity (an index of biological activity) as important abiotic pre-disposing factors in incidence of root wilt disease. Growing *Gomphrena globosa* as intercrop in root wilt- affected coconut gardens has been shown to be cost-effective and sustainable. In areca-based mixed farming system, total cash inflows and outflows from arecanut + dairy (3–4 milch cows) amounted to ₹4.41 and ₹5.96 lakh, with a net profit of ₹1.55 lakh. The system productivity of arecanut + cocoa system (3,127 kg/ha) was 30% higher per unit area than arecanut alone (2,405 kg/ha). Integrated nutrient management on four improved arecanut varieties recorded highest chali yield (4.19 kg).

Studies on spore associated bacteria (SAB) in coconut/arecanut based cropping systems under organic management practices revealed an increase in AMF spore load with the number of intercrops. Identification based on BIOLOG revealed the presence of bacteria, viz. *Citrobacter amalonaticus, Staphylococcus arlettae, Bacillus subtilis* and *B. amyloliquefaciens,* in association with spores of *Glomus* spp. The potent phosphate solubilizers isolated from coconut rhizosphere were identified as *Enterobacter cloacae* RNF 267, *Pseudomonas plecoglossicida* KnSF 227 and *P. putida* Biotype B HSF 132 by conventional biochemical tests and confirmed by BIOLOG Microbial Identification System and 16S rRNA gene analysis.

Of the 90 genotypes of walnut, 38 found protogynous and rest were protandrous. Forty-two genotypes showed 7–14 days of male and female bloom overlapping, indicating synchronized flowering while the rest were non-synchronous. The genotype, CITH-W 40, showed maximum synchronizing phase of 14 days, followed by CITH-W 37 and Nugget of 13 days while genotypes CITH-W 10, CITH-W 19, CITH-W 24 and CITH-W 48 showed non-synchronization with respect to male and

female blooming period, indicating need for pollinizer varieties. The most suitable rootstock and scion girth for grafting in walnut was found to be rootstocks with the girth of 25–30 mm and scion of 15–20 mm size, which are fully developed and plumpy.

Foliar sprays on cashew at three different stages, viz. flushing, flowering and nut development, with urea (3%) + H_3PO_4 (0.5%) + K_2SO_4 (1%) and foliar spray of secondary and micronutrients, viz. $ZnSO_4$ (0.5%) + $MgSO_4$ (0.5%) + Solubor (0.1%) recorded highest number of bisexual flowers and nut yield/tree. However, application of paclobutrazol (0.5, 1 and 1.5 g a.i./plant) showed reduction in growth of plants with respect to plant height, canopy spread and internodal length. High-density planting showed significantly higher (3.23 times) nut yield (2,841 kg/ha) as compared to the normal density (880 kg/ha). Intercropping in cashew with Amorphophallus gave highest net returns (₹139,639/ha), followed by tapioca (₹129,992/ha).

Spices

An organic package for production of black pepper, ginger and turmeric by applying farmyard manure, vermicompost, ash, rockphosphate, *Azospirillum* sp. and phosphobacteria and *Trichoderma* sp. and *Pseudomonas* sp. as biocontrol agents for disease control was developed. Further, a foliar spray of 1% solution of complex fertilizer 19 : 19 : 19 (N : P : K) during spike initiation period (April second week, May first week and May fourth week) during lean cropping season under irrigated condition enhanced black pepper (cv. Panniyur I) yield by 20–25%. Soil application of zinc up to 10 kg/ha or foliar spraying of $ZnSO_4$ (0.25%) and Borax (0.2%) twice (60 and 90 days after planting) was recommended for higer yield and quality for turmeric in zinc and boron deficient soil.

Among all the treatments, sprinkler and drip irrigation methods caused early sprouting, early flowering with increased plant height and more number of leaves and flowers/plant as compared to the control (rainfed). Also, stigma fresh weight, dry weight, length and saffron yield were improved in sprinkler and drip irrigation methods over the control. Raised beds resulted in early sprouting, early flowering with increased plant height and more number of leaves and flowers/plant.

In cumin, irrigation with microsprinkler and drip irrigation methods not only enhanced the yield but also improved the water productivity by 47.8 and 14.7 kg/ha cm irrigation water than flood. Among land configuration treatments, sowing of 3 rows of cumin on raised beds (75 cm) enhanced grain yield by 38.4 and 12.3 % and water productivity by 16.6 and 8.9 kg grain/ha cm irrigation water than flat bed and wider raised beds (150 cm). Further, coriander grown in plastic walk in tunnel resulted in higher yield over open condition and gave higher net return of ₹97,700 with a benefit : cost of 1.93. In cumin, low pressure drip irrigation yielded higher by 19.31% (663.28 kg/ha) as compared with flood (555.94 kg/ha), whereas water savings were 30%. In coriander, low pressure drip irrigation produced higher yield (703 kg/ha) as compared with flood (612 kg/ha) with a water saving of 30%.

Tuber crops

Drip irrigation at 100% CPE was found best for obtaining higher tuber yield in cassava. Further, organic farming of cassava produced 9% higher tuber yield (29.4 tonnes/ha) over conventional practice (26.9 tonnes/ha). Decision support systems-Plausible Potato Growing Seasons Estimator (PPGSE) and Yield Estimator were developed for spatial and temporal diversification of potato cultivation. These give the growing seasons and their durations, climatic features of seasons and estimated yield potential for important locations in India. Further, winter potato acreage and production were estimated through remote sensing, GIS and crop modelling. The acreage forecast under winter potato during 2011–12 in Punjab, Uttar Pradesh, Bihar and West Bengal was 90.6, 516, 322.5 and 345 thousand hectares, respectively, while the total production was predicted as 2,071.1, 11,439.7, 5,262.4 and 8,266.2 thousand tonnes, respectively.

CROP HEALTH MANAGEMENT

Crop health management research has brought out tangible and effective methods to suppress various pests in major agro-ecosystems. Indigenous knowledge in this regard has been tested and validated for its suitability.

Cereals

For providing support to wheat-breeding programme, evaluation of disease-/pest-screening nurseries was undertaken under artificially inoculated conditions at various hot-spot locations for identification of resistant genotypes.

Multiple disease-resistant wheat genotypes

MR to leaf blight (LB) + R to Karnal bunt (KB) + Powdery mildew (Pm)	HPW 347, VL 930
MR to LB + R to FS (Flag smut)+ Pm	HPW 317, VL 931, VL 943, VL 944
MR to LB+Pm	HUW 635
MR to LB	GW 1255
MR to LB + KB	HS 525
R to KB + FS	NIAW 1395, PDW 313, AKDW 4021 (d)
R to Pm + FS + KB	HI 8692 (d), HI 8702 (d), HI 8709 (d), MACS 3742 (d)
R to FS + KB + PM + MR to LB	PBW 615, DBW 62, HS 522, HUW 629, KRL 250, TL 2963 (T), MACS 3744 (d), NIDW 577(d), NW 4091, PBW 635, HI 8708 (d), HS 533, UAS 327, UAS 432(d), PDW 315 (d), PDW 317 (d)
R to FS	HPW 289, HD 3002, HD 2982
R to KB	PBW 628, HUW 638, NW 4081
R to Pm	DBW 58, HI 1653, HI 1569
R to Pm + FS	RSP 561, HS 534

MR: Moderately resistant; R: Resistant

The following barley genotypes have been confirmed for resistance against the diseases.

Diseases	Genotypes
Stripe and stem rusts (ACI = 0)	RD 2809
Stripe rust (ACI = 0)	RD 2715, RD 2816, RD 2786, RD 2787, RD 2828
Stem rust (HS = 0)	BH 943, BH 944, DWR 85, HUB 115, NDB1516, PL 863, RD 2552, RD 2668, RD 2794, RD 2811, RD 2813, RD 2815, RD 2819, RD 2829, VLB 124
Leaf blight (HS ≥ 57)	BH 932, BH 942, PL 860
Stem rust and leaf blight	BH 945, BH 946, VLB 123

Oilseed crops

Groundnut genotypes CS 402 and CS 409 showed resistance to stem-rot. For collar-rot, three genotypes (CS 421, CS 426, CS 428) tolerant in summer and nine (CS 422, CS 364, CS 427, CS 386, CS 377, CS 432, CS 433, CS 421, CS 431) tolerant in *kharif* were identified. In summer, application of arbuscular mycorrhizal fungi in seed-furrows brought down stem-rot incidence from 80.5% (untreated plots) to 29.4% (treated plots).

In *kharif* and *rabi* groundnut, seed-treatment with imidacloprid at 5.0 g /kg of seeds lowered jassids and thrips incidence and also gave highest pod yield (2,612 kg/ha). Among seven insecticides evaluated, lowest jassid (3.2/ five-sweeps) and thrip (1.5/five-sweeps) populations were recorded with acetamiprid 20SP.

In rapeseed-mustard, seed treatment with *Azotobacter* + phosphate-solubilizing bacteria each 250g in formulation/ha-seed along with 100% NP resulted in 2 to 14.7% higher seed yield in comparison to 100% NP at Morena, Varanasi, Hisar, Kota, Shillongani, Jobner, Bhubaneshwar, Khudwani, Sardar Krushinagar and Kanke. Soil application of $ZnSO_4$ at 15 kg/ha + borax at 10 kg/ha + sulphur as per recommendation combined with foliar application of carbendazim (0.1%) + mancozeb (0.2%) was most effective in controlling *Alternaria* blight, downy mildew, powdery mildew and sclerotial rot and improving seed yield. Multi-gene cassettes were developed for imparting tolerance against *Botrytis* disease in castor.

For effective management of yellow mosaic virus in soybean, ST with thiamethoxam 70 WS at 3 g/kg of seeds + spray of Imazethapyr 100 g. a.i/ha in plot and bunds at 25 DAS + barrier crop of sorghum/maize + yellow sticky traps 15 DAS + spray of quinalphos at 2 ml/lit at 30-35 DAS have been recommended. For charcoal-rot and *Rhizoctonia* aerial blight management in soybean, deep summer ploughing + ST *Pseudomonas fluorescens* 10 g/kg or *Trichoderma harzianum* at 5 g/kg or carbendazim 2 g/kg + pendimethalin at 1 kg a.i/ha + vermi compost to raise soil organic-carbon up to 0.5% + foliar spray of carbendazim at 0.05% at 30 to 35 DAS have been recommended.

For powdery mildew management in sunflower, two sprays of propiconazole (0.1%) or difeconazole (0.05%) were effective. Spraying dichlorvos 76 WSC 0.15% (2 ml/litre) or methomyl 40 SP 0.04% (1g/litre) twice at 10 days interval was effective in controlling mealy bugs.

For effective and economical management of *Alternaria* leaf spot/blight in safflower in western Maharashtra region, spray formulation of carbendazim 12% + mancozeb 63% (0.2 %) immediately after disease appearance, if needed, followed by the second spray after 15 days.

Pulse crops

Nucleopolyhedrosis virus (NPV) was first time isolated in India in early pigeonpea from spotted pod-borer *Maruca vitrata* under natural epizootic conditions. Application of rynaxypyr 20 EC at 30 g a.i./ha or flubendiamide 20 WG at 60 g a.i./ha or indoxacarb 14.5 SC at 73 g a.i./ha alone or rynaxypyr 20 EC at 30 g a.i./ha in combination with DDVP 76 EC at 200 g a.i./ha or garlic-bulb extract at 1% at 25–30% flowering and podding was found to save crop from *Maruca* infestation.

Eighteen chickpea lines (IPC 2004-3, -8, -52, IPC 2005 -15, -19, -27, -30, -35, -37, -41(A), -41(B), -43, -44, -52, -62, -64, GNG 1861, and CPS 1) screened against 6 races of *Fusarium oxysporum* f. sp. *ciceri* under artificially inoculated sick-tank conditions were found to possess multi-race resistance.

A partial distribution map of *F. oxysporum* f. sp. *ciceri* races identified in different states of India has also been prepared. New molecules such as emamectin benzoate 5 SG at 11 g a.i./ha, flubendiamide 480 SC at 60 g a.i./ha, rynaxypyr at 18 g a.i./ha were found better than currently recommended chemicals for chickpea pod-borer management.

Seven variants of *Fusarium udum* were identified and their distribution maps have been prepared. Uttar Pradesh has all the seven variants, followed by Maharashtra, Karnataka (6 each), Madhya Pradesh, Bihar (5 each), Andhra Pradesh, Rajasthan (4 each), Haryana (3), Tamil Nadu, Jharkhand (2 each); and West Bengal has only one.

Commercial crops

Beauveria bassiana has been introduced as an endophyte in *tossa* jute (*Corchorus olitorius*). And this has been found to reduce stem weevil infestation in white jute (*C. capsularis*). Out of nine strains evaluated, seven *B. bassiana* strains—ITCC 6063, ITCC 4512, ITCC 4563, ITCC 5562, ITCC 4796, ITCC 5408 and ITCC 4705—were established as an endophyte in white jute (*Corchorus capsularis*) through seed treatment.

Suitable constructs were developed by cloning three promoters AtACS4, AtACS5 and AtACS7, sourced from *Arabidopsis*, in pCAMBIA1381z vector, and tobacco transgenic plants were raised and analyzed for the expression pattern of the promoters.

Bio-intensive management of white grub in sugarcane: For management of white-grub beetles, light traps were modified, fabricated and installed for testing against them in sugarcane agrosystems of Uttar

Resistance in jute against Bihar hairy caterpillar

Possible source of resistance in jute against Bihar hairy caterpillar (BHC) was determined on the basis of the antibiosis effect on the pest. Larval growth rate was significantly impaired on the wild jute species, particularly *Corchorus tridens* and *Corchorus aestuans*. The growth of 5-day-old larvae indicates maximum antibiosis effect of *C. aestuans* on BHC. There was no pupation on *C. tridens* and *C. aestuans* because of high larval mortality. The pupation on *C. pseudo-olitorius, C. tricularis and C. fascicularis* was to the extent of 37.5%, 22.5% and 20%, respectively, as compared to 62.5% on the cultivated species, *C. olitorius* (JRO 204). The pupation was significantly less in wild hosts (15–37.5%) compared to 62% in *C. olitorius*. The pupal weight of larvae fed on *C. olitorius* was 95–180 mg more than wild hosts. Among wild species, *C. pseudo-olitorius* only supported adult emergence (27%). Wild jute species as the host manifested adverse effects on larval and pupal growth and survival along with on the pupation clearly indicate antibiosis mechanism of resistance of wild species on Bihar hairy caterpillar.

Pradesh (Saharanpur and Lakhimpur–khiri Districts) and Pravaranagar in Maharashtra. The insect trap (having a combination of light and pheromone) was found very effective in trapping predominant species, *Holotrichia consanguinea*, along with other species of white grubs.

Integrated pest management

An area-wide pest management was implemented in pigeonpea and chickpea for IPM awareness campaigns through conventional and electronic media and through the establishment of the "National Pest Reporting and Alert System" covering more than 35,000 ha in five major pulse-growing states—Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh.

The e-pest surveillance system through dedicated server was validated under the Accelerated Pulse Production Programme (A3P) in different states. A total number of 17,961 SMSs were sent to A3P registered farmers by using centralized server. Maharashtra was enabled for 'crop pest surveillance and advisory programme (CROPSAP)' including horticultural crops also – pomegranate, banana and mango.

Rice: In wet direct- seeded rice, tank-mix application of bensulfuron methyl + pretilachlor (applied as post-emergent 18 DAS at 50 + 450 g a.i./ha) was found effective in controlling predominant weeds (weed control efficiency 91%), and yields (5.67 tonnes/ ha) produced were comparable with hand-weeding twice (5.77 tonnes/ ha).

Profenophos was the best pesticide to manage rice panicle mite *Steneotarsonemus spinki* in the field. Foliar blast disease of rice in the experimental plot was reduced to a minimum of 5% with propiconazole EC spray at 2.5 ml/litre compared to untreated check with 80% disease.

Cartap 4 G at 1 kg a.i./ha treatment recorded lowest percentage of dead heart (3.87%), gundhi bug damage (8.75%), leaf-folder damage (3%) and highest grain yield of 5.25 tonnes/ha. Root-knot nematode was reduced by 84.3% in cartap-treated plot.

Molecular detection of key parasitoid in lac insects

Aprostocetus purpureus is one of the key parasitoids causing economic damage to lac-insect crop. This parasitoid has become a major threat to lac cultivation in recent years. The incidence is severe in summer *baisakhi* crop of rangeeni lac insect. The parasitoid mainly attacks during early stages of lac insect. A sensitive polymerase chain reaction (PCR)-based method requiring small sample of parasitoid was developed, using specific primers for the parasitoid. The PCR reaction yields an *A. purpureus* specific product of ~ 500 bp (base pair) in the lac insects infested with this parasitoid.

Agricultural acarology

In Mashobra (Himachal Pradesh), out of the five horticultural mineral oils tested against winter eggs of European red-mite on apple, Rilso-999 at 1.5% proved very effective (84.7% eggs remained unhatched), followed by Mak All Season and Orchol-13 (77% un-hatched eggs). The lowest mortality of predatory mite *Neoseiulus longispinosus* was recorded with horticultural mineral oil (28.2%), followed by hexythiazox (39.2%), endosulfan (43.8%), fenazaquin (54.7%) and carbosulfan (59.5%), when sprayed at half-bloom stage in apple.

White grubs and soil arthropods

Popillia sp. attacked pigeonpea flowers during October, and has tentatively been identified as a new species and named *P. shivashankari*. A new species of sub-family, Hopliini was recorded for the first time from Karnataka; no other species of the tribe is known from south of Himalayas. *Anomala nandikrishna* has been recognized as a new species collected from Nandi Hills, near Bengaluru.

Clothianidin 50 WDG at 2 g/kg of seeds as seed dresser before sowing is recommended for management of white grubs in groundnut.

As a seed dresser on groundnut, imidacloprid 600 FS at 833.33 and 416.66 ml/80 kg of seeds was found effective against grubs.

Imidacloprid 17.8 SL at 500 ml/acre and fipronil 5 SC at 1 litre/acre are promising insecticides to manage white grubs in arecanut; they gave 75 and 80% mortality of 1st instar grubs of *Leucopholis* sp. These chemicals also performed well against sugarcane white grubs in Karnataka.

Rodent control

Diversity of rodents: Predominance of *Bandicota bengalensis* was noticed in rice–wheat–sugarcane and cotton–sugarcane cropping systems in Punjab over *Millardia meltada*, *Mus booduga* and *Golunda ellioti*. The major rodents in Andaman and Nicobar islands are Miller's long-footed rat, *Rattus stoicus* and Zelebor's Nicobar rat, *Rattus palmarum*; and nocturnal and arboreal species are the major rodent species of Car Nicobar. Nuts

damage due to rodents was significant in coconut plantations between 5.66 and 35.5% in Car Nicobar (A&N Islands) due to lack of food diversity.

Rodent management: Among various botanicals evaluated for efficacy against rodents infesting rice, castor-based repellent ecodon® gave promising results at tillering and panicle initiation stages. Exposure of *Tatera indica* (both sexes) to wax blocks encapsulated with 4 and 6 drops of castor-oil revealed significant (Pd" 0.01) repellent effects of the blocks with 6 drops of the oil. Repellency index was more during 8–12 days, indicating that the oil may have secondary repellent effect, developed from 1 to 7 days period.

Exposure to nifedipine (anti-fertlity compound)-treated bait (at 0.1% and 0.05% concentration) for 12 days in no-choice revealed 33.3% and 50% breeding respectively in *B. bengalensis* as compared to 83.3% breeding in untreated male rats. Feeding triptolide-treated baits at 0.1, 0.2 and 0.3% to male *R. rattus* for 5 days in no-choice resulted in significant reduction in sperm motility (80.65%) and viability (75.14%) at 0.2% treatment, which was 51.67 and 58.33%, respectively, in untreated group.

In field trials at farmers' fields in *rabi* crops in arid zone, rodents control success of 64.28 and 53.85% in cumin and wheat was observed, respectively, on the 4th day after treatment with zinc phosphide (2%). After 2 weeks, control success in zinc phosphide treated fields was reduced to 55.35% (cumin) and 50.76% (wheat). Bromadiolone treatment recorded success of 72 and 68.52% in respective crops within 2 weeks. Integrating acute and chronic rodenticides recorded highest rodent control success of 78.88% (cumin) and 82% (wheat) on the 15th DAT. The seed yield increased by 10.18 and 7.14% due to rodenticidal treatment in wheat and cumin.

Rodent management operations like cultural practices, burrow fumigation in all the crop-growing seasons and bromodiolone baiting at panicle initiation stage were most promising modules showing highest efficacy in suppression of rodent population (86.5%) and damage incidence (83.4%). In sugarcane, treatment with bromodiolone (0.005%) bait significantly reduced rodent population (70.2%) and damage 68.6%. Bromodiolone burrow baiting + burrow fumigation proved effective in reducing nut damage in cocoa and coconut plantations with a control success of 85.2% and 68.7%. In Andaman and Nicobar Islands, crown baiting with bromadiolone reduced damage from 85.7 to 29%. The non-chemical method of polythene trunk banding in coconut recorded 94.5% control success in rodent infestation and 100% control success in nut damage in Andhra Pradesh. Trunk banding of coconut trees with aluminium sheet in Andaman reduced damage from 71.42 to 42.85%.

Rodenticide trials in sugarcane-crop with delayed harvesting in Punjab indicated for three treatments, one during July, second during October–November (each with 2% zinc phosphide, followed by 0.005% bromadiolone after 15 days at 400 g/acre each) and third during January–February with 0.005% bromadiolone at 800 g/acre.

Burrow fumigation with aluminium phosphide (1.5 g tablet per burrow) and baiting with 2% zinc phosphide at germination/growth stage in pea proved effective in managing rodents.

HORTICULTURE

Fruit crops

In mango, there was no interspecific association between two hopper species breeding and feeding in identical niches due to unlimited resources. Area-wide IPM of mango fruit fly and stone weevil demonstrated in 57,000 ha across Karnataka, Tamil Nadu, Andhra Pradesh and Kerala, showed potential of eradicating these pests. Surveys on species composition of mites attacking Nagpur mandarin and bioagents revealed the presence of three species of phytophagous mites, *Eutetranychus orientalis*, *Brevalpus pheonicis* and *Polyphagotarsonemus latus*. A cocinellid predator, *Stethorus* sp. (Coccinellidae) of *E. orientalis* was recorded. Observations on incidence of phytophagous mites in nursery and grown-up Nagpur mandarin orchard showed that incidence of *Polyphagotarsonemus latus* on rough lemon seedlings in nursery was more in spring seasons, whereas incidence of *Eutetranychus orientalis* was more in Nagpur mandarin during winter. Different biorational insecticides/acaricides evaluated against citrus mites revealed that propargite (0.057%) followed by abamectin (0.0007%) and ethion (0.05%) recorded significantly less mite infested fruits than other treatments.

Direct PCR assay without isolating DNA from the sample for molecular diagnosis of *Fusarium oxysporum* f. sp. *psidii* causing wilt disease in guava (*Psidium guajava* L.) was developed and validated. Two sets of species-specific primer were used for accurate and early detection of pathogen for timely management of disease and also for prophylactic treatment/application in potting mixture.

Seventeen *Xanthomonas axonopodis* pv. *punicae* causing pomegranate nodal blight isolates were added from Maharashtra, Karnataka, Andhra Pradesh and IARI,

New Delhi. Eight of the nine isolates from Andhra Pradesh were confirmed to be *X. axonopodis* pv. *punicae*. Variability among *X. axonopodis* pv. *punicae* isolates was observed with respect to lesion size, chlorosis and leaf fall under pot culture. The disease severity was positively and significantly correlated with weekly hour temperatures ranging from 25 to 35°C at RH> 50%. Regression analysis of weekly hour temperatures 25–35°C at RH > 50% and rainfall gave the best fit for predicting disease severity. Further, IDPM (Integrated Disease and Pest Management) spray schedule comprising Streptocycline (500ppm) /Bronopal (500ppm) + copper oxychloride (0.25%) at 15 days interval was found most effective in the management of bacterial blight. Isolations obtained from pomegranate wilt-affected samples revealed presence of *Ceratocystis fimbriata* in 86.36% of the samples. Other pathogens associated were shot hole-borer (*Xyleborus fornicates*, 9.0%), *Fusarium* spp. (9%) and root-knot nematode (*Meloidogyne incognitia*) infestation (9%). Wilt was managed effectively in a wilt-affected orchard (2.16% incidence) in Solapur by soil drenching the plant basin of affected plants and adajacent healthy plants with Carbendazim (0.2%) + Chlorpyriphos (0.2%) at monthly interval, as the treatment revealed no new infection.

Maximum banana stem weevil mortality (76%) was recorded by the strain endo *Metarrhizium anisopliae*–66, while maximum corm weevil mortality (54%) was recorded by the strain endo *Beauveria bassiana*–32. The *Metarhizium anisopliae* strains, viz. NRCB-145 *Ma* (Endo) and 162 *Ma* (Endo), recorded maximum aphid mortality of 80%, while chemical control (Imidacloprid) recorded 100% aphid mortality as against heavy devastation in the untreated control. Native *Trichoderma harzianum* of rhizospheric and endophytic origin colonized root, corm and pseudostem tissues of banana and colonization of root and corm tissues by *Trichoderma harzianum* started only 2 weeks after inoculation and 100% colonization of banana tissues was achieved 5 weeks after inoculation. This information would help in formulating strategies for effective control of Fusarium wilt disease in banana. Lateral flow immune assay (LFIA) based dipstick has been developed for cucumber mosaic virus infecting banana. Using IgG purified from polyclonal antiserum raised against CMV recombinant coat protein, lateral flow strips (dipstick) were prepared and these dipsticks detected the virus in positive samples and not from healthy negative samples.

The *Colletotrichum gloeosporioides* was confirmed by DNA sequence analysis as the dominant pathogen causing grape anthracnose. Increase in mean and minimum temperature during monsoon season could be the possible reason for replacement of *Elsinoe ampelina* by thermophillic *Colletotrichum gloeosporioides* as the anthracnose pathogen. In dual culture, several tested *Trichoderma* isolates could overgrow and parasitize the isolates of *Colletotrichum gloeosporioides* and *C. capsici*, indicating their potential as biocontrol agents.

Persistence and dissipation of picoxystrobin and fosetyl-Al were studied. PHI for single and double dose of picoxystrobin was 3 and 5.5 days respectively, whereas fosetyl-Al residues were below MRL on the date of application itself. Similarly, persistence and dissipation of four growth regulators, viz. Forchlorfenuron, 6-benzyl adenine, Gibberellic acid and homobrassinolide was studied and their half-life and PHI were estimated. A GC-MS/MS based residue analysis method was developed and validated in 5 matrices for targeted screening and quantification of 375 agrochemicals. Further, a LC-MS/MS based method was developed and validated for 250 chemicals.

Two formulations of fungal pathogens, viz. Metarhiziumanisopliae and Beauveriabassiana, were found to be having better efficacy on a par with chemicals like Thiamethoxan and Acephate for effective management of grape thrips. Biopesticide Bt (Halt) @ 2 g/litre gave superior control to bud-borer (76.5 %) and leaf-webber (54.8%) over the control in sapota. Incidence of anthracnose on fruits (*Colletotrichum gleosporioidis*) at harvesting stage was 0–10%. The incidence of leaf spots (in nursery) and twig blight were 31.94–50.3% and up to 61.8%, respectively. The average post-harvest loss (cracking + disease) at transport level in Delhi market was 15.83 %. At the level of retailers the loss varied from 17 to 45%.

Vegetable crops

The PCR-based diagnosis was developed for quick detection and identification of Phytoplasma infecting Cucurbitaceous crops (ash gourd, bitter gourd, bottle gourd and cucumber). *Candidatus phytoplasmaasteries* specific primers based on rDNA conserved region were designed and synthesized. This technique is highly suitable as phytoplasma can be detected before symptom appearance, and even in insect vectors which transmits phytoplasma. In okra, use of petroleum 2T oil @ 2 ml/litre + 5 g surfactant gave superior control of mites (52.8%) and jassids (52.1%) over the control. The lowest bacterial wilt incidence (20%) was reported in tomato grown on cocopith: vermicompost: lime (1 : 1 : 0.01), while it was 56.7% in the control plots.

Invasive mealy bug, *Phenacoccus solenopsis*, is emerging as one of the major sucking pests in vegetable crops. The major biological control agents identified for this invasive pest were nymphal endoparasitoids (*Aenasius bombawalei*) Hayat and *Promuscidea unfasciati* Girault, and their cumulative parasitization was 22.35%. These endoparasitoids attack the second or third instar nymphs of mealy bug and complete their life-cycle during fifth instar of their host. Different insecticide molecules, viz. Imidaclorpid 70 WG @ 0.1 g/litre, 17.8 SL @ 0.5 ml/litre and Chlorpyriphos 20 SC @ 2 ml/litre were highly effective against mealybugs.

A severe incidence of minor and sporadic lepidopteran leaf eating caterpillar *Diaphania indica* on cucumber and bitter gourd was observed from August to October. The infestation was 60–70%. *Cotesia glomerata* was identified as an important larval endoparasitoid of *D. indica*. The microbial pesticides, *Bacillus thuringiensis* var. *kurstaki* @ 2 g/litre and *Metarrhizium anisopliae* @

5 g/litre and insecticide molecules rynaxpyr 18.5 SC @ 0.3 ml/litre, flubendamide 40 SC @ 0.5 ml/litre, emmamectin benzoate 5 SG @ 0.5 g/litre, spinosad 45 SC @ 0.5 ml/litre, fipronil 5 SC @ 0.25 ml/litre and thiacloprid 21.7 SC @ 0.6 ml/litre were found to be most effective against leaf-eating caterpillar (*D. indica*).

The vegetable samples collected from farmers' fields and local markets showed pesticide residues (23%) in which 14% contained residue levels exceeding the prescribed MRL. Cabbage and cauliflower grown in the dry season, accounted for 43% of the samples found to contain residues followed by brinjal and bhendi. Among the organochlorine (OC) compounds, α-endosulfan, β-endosulfan and endosulfan sulfate were detected in 7% of the samples and synthetic pyrethroid (SP) compound residues, such as α-cypermethrin and λ-cyhalothrin were detected in 12% of the samples tested. Organophosphorus (OP) compound residues, such as profenophos, chlorpyriphos, monocrotophos and triazophos were found in 12% of the samples found in brinjal, cauliflower, bhendi, green chilli and French bean.

Ornamental crops

IPM module M 5 (tobacco extract 5%, neem oil 0.03 EC and bifenthrin 10 EC 0.25%) and M 3 (tobacco extract 5%, econeem 3,000 ppm 2 ml/litre and imidacloprid 17.8 SL 0.003%) were effective for controlling mites and aphids, respectively in orchids. Bt (Dipel) 0.012 % and neem oil 0.03% EC 5 ml/litre were found effective for shoot-borer management in *Dendrobium chrysotoxum*.

Palms and nuts

Among the 137 *Phytophthora* isolates collected from bud rot/fruit rot affected coconut gardens in Tamil Nadu, Kerala and Karnataka, four isolates from bud rot affected gardens were identified as *P. nicotianae* and one as *P. capsici*. Since, *P. nicotianae* is found associated with bud rot disease of coconut in three districts representing three states, it is expected that this may emerge as a major pathogen of coconut. Further, placing *Trichoderma* coir pith cake in the innermost leaf axils of coconut palm in disease endemic areas just before the onset of southwest monsoon (May-end) and thereafter at two months interval was found to be very effective in the management of bud rot disease of coconut.

An organic and biodegradable pesticide slow release product, using coir pith was developed, for slow release of Mancozeb to coconut crown and preliminary field trials show that it could effectively replace the polythene sachets. Copper oxychloride (Blitox 0.5%), Metalaxyl + Mancozeb (Ridomil Gold 0.5%) and potassium phosphonate (Akomin 0.5%) were observed to be effective in the management of black pod disease. Isolation and characterization of ABC transporter system in coconut root (wilt) phytoplasma has been accomplished. In phylogenetic tree based on *sec*A gene, the YLD phytoplasma clustered with sugarcane grassy shoot, coconut root wilt and napier grass stunt phytoplasma, all members of 16SrXI group. A novel nanomatrix with ordered pore channels was developed for loading the pheromone and kairomone for controlling red palm weevil. Similarly, a nanomatrix and polymer composite was also developed to load the rhinoceros beetle pheromone (ethyl 4 methyl octonate), which could extend the life-span to 6–8 months.

Surveillance for Eriophyid mite (*Aceria guerreronis* Keifer) infestation was undertaken in five districts of Asom. The highest incidence of mite (35.7%) was recorded in Morigaon, followed by Nagaon (17.67%). The hymenopteran solitary ecto-larval parasitoid recovered from parasitized (*Leucopholis coneophora*) grub was identified as *Campsomeriella collaris collaris* (Fabricius) and the solitary endo-larval parasitoid as *Prosena* sp. nr. *siberita* (Fabricius).

Chemical control of pest complex in cashew increased nut yield from 28.34 to 41.68 % and maximum (41.68%) being with L-Cyhalothrin (0.003%). Similarly, in post-extraction prophylaxis trial for management of cashew-stem- and root-borer (CSRB), with chlorphyriphos (0.2%) treatment, the treated trees without reinfestation varied from 80 to 93.3%. Spiders were observed as one of the most abundant natural enemies of tea mosquito bug (TMB) in cashew agro-ecosystem. A total of 104 species spread over 56 genera and 11 families were identified. The virulence study of entomopathogenic nematodes (EPN), viz. *Heterorhabditis indica, Steinernema abbasi* and *Steinernema bicornutum*, against grubs of cashew stem- and root-borers (CSRB), *Plocaederus* spp. revealed mortality of grubs at a mean duration of 14.1, 12.9 and 12.4 days respectively. *Steinernema bicornutum* induced more than 50% of mean mortality of bait species (wax moth) even after 150 days under simulated conditions.

Spices

A protocol for SYBR green based real-time RT-PCR for detection of Piper yellow mottle virus and Cucumber mosaic virus infecting black pepper and Cardamom mosaic virus (CdMV) and Banana bract mosaic virus (BBrMV) infecting cardamom was developed. A native isolate of *Phytophthora capsici* (Is. No. 98-93) infecting black pepper was completely sequenced using next generation sequencing platform, Illumina-Solexa GA II. The sequence data was assembled by taking Joint Genome Institute's *P. capsici* as reference genome. The treatment of black pepper cuttings with Carbendazim + Mancozeb (0.1%) was effective for the management of anthracnose disease in nursery.

Medicinal crops

Azadiractin (1%) was found effective for the control of Hadda beetle on *Ashwagandha*. Nineteen arthropods were recorded on isabgol. Among them, 13 were phytophagous species belonging to order Lepidopteran (09), Hemipteran (03) and Homopteran and six predatory species belonging to order Coleoptera (03), Neuroptera (01) and Odanata (02). The sequential occurrence of arthropods revealed the presence of aphid (*Aphis gossypii*) from second week of January to fourth week of February, whereas Lepidopteran (*Helicoverpa armigera, Trichoplusia ni,*

Thysanoplusia oricalchae, Spliarictia sp. *Hyposidra successari* and *Olene mendosa* and true bugs (*Graptostethus servus* and *Spilostethus pandurus*) were observed associated during early crop growth stages (i.e. from second week of December). Infestation of aphid was uniformly severe, whereas that of Lepidopterans and true bugs were sporadic and less severe. However, presence of these pest arthropods caused significant reduction in seed yield.

Tuber crops

The new population of *Phytophthora infestans* (mt DNA haplotype Ia), which was introduced in 2002, has almost replaced the old population (Ib haplotype) in all the locations. There is no host-specificity among *P. infestans* isolates of tomato and potato. Further, effect of elevated temperature on efficacy of R genes revealed that resistance of R1 and its combinations may be eroded if *P. infestans* adapts to higher temperature. Validated molecular markers for late blight, potato virus Y and cyst nematode resistance in 165 genotypes and identified 18 genotypes with PVY resistance (*RYadg*), 84 genotypes with late blight resistance genes (*R1* and *R3a*) and 79 genotypes with cyst nematode resistance genes (*HC*, *H1* and *Gro*1-4). Besides, 16 genotypes were identified possessing multiple resistant genes for late blight, PVY and cyst nematodes.

Potato hybrids (LBY 15, LBY 17 and SM/92-338) possessing combined resistance to late blight and potato virus Y, and hybrid, OS/01-497, having combined resistance to late blight and cyst nematode were introduced for multilocational trials. The application of Pencycuron (0.25%) on potato tubers at planting was most economical and effective against black scurf of potato, while that of Thiacloprid (0.4%) alone or in combination with summer oil against sucking pests.

Tuber information café (TIC) in Malayalam, web-based early-warning system for mealy bug incidence in cassava (http://www.ctcri.org/mbug.php), yield prediction model-based on fuzzy logic for elephant-foot yam and a learning system for the same crop using Artificial Neural Networks were developed.

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