8. Crop Management

Crop management techniques have been recommended to farmers, after participatory on-farm validation of them to reap good genetic potential of crop varieties. They enable better farm economy by elevating utilization of land, water and nutrients with improved efficiency. Wholesome packages could be developed due to location-specific validation of crop management technologies by the national agricultural research system. Crop health management as a component of crop management is essential to secure harvested yield.

PRODUCTION

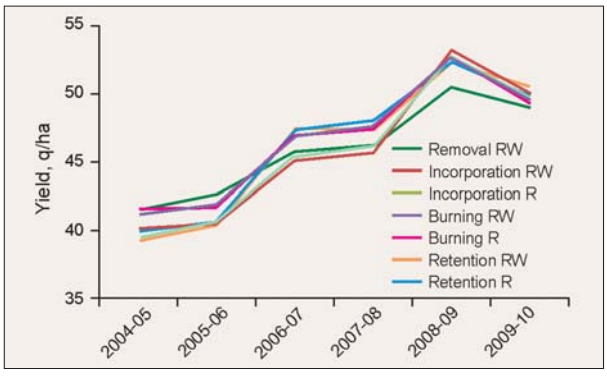
Cereals

In rainfed upland ecosystem, **rice** + sunnhemp intercropping with nutrient schedule of 60:40:40:500 or 60:60:40:500 N:P:K:lime kg/ha and foliar spray of 0.5% $ZnSO_4$ was found promising for enhancing grain yield as well as soil health. In aerobic rice intercropped with *dhaincha* at 1:1, application of nitrogen at 100-125% of the recommended dose + pre-emergence herbicide application + hand-weeding at 60 days after sowing or 2,4 D-Na application at 25-30 days after sowing proved effective.

For increasing rice productivity in sodic soils of *p*H 10.6, gypsum application up to 100% and supplementation with zinc at 50 kg $ZnSO_4$/ha or combined application of zinc and iron (30 kg Fe-EDTA/ha) with or without organic manures were found effective along with the enhancement in utilization efficiency of N, P and Fe nutrients. Growing of alkali-tolerant varieties CSR 13 and CSR 23 recorded higher and stable yields.

During terminal heat-stress situations, photosynthesis and water relations and spikelet fertility and pollen fertility were relatively superior in rice IET 20924, IET 20935, IET 20734, IET 20893, IET 20907 and IET 20905.

Rice-wheat system : In rice-wheat system, tillage did not affect wheat yield. But, zero tillage transplanted rice gave significantly lower yields as compared to puddle transplanting. There was no significant effect of residue management (retention, burning, removal, incorporation) on the wheat yield. The surface retention of the crop residue was advantageous in the situations with limited irrigation water, as it acts as a mulch and helps in conservation of soil moisture.



Oilseed crops

In Alfisols at Bengaluru, **sunflower**-seed treatment with *Azotobacter* along with the 50% recommended N resulted in seed yields comparable to 100% N; indicating possibility of saving N up to 50%.

At Mandor in Rajasthan, integrated application of 75% recommended fertilizer dose + 25% N through farmyard manure + seed treatment with *Azospirillum* + phosphate solubilizing bacteria mixed with farmyard manure (FYM) applied in furrows gave maximum **castor**-seed yield, besides improving soil quality in terms of organic carbon, available P and K. And integrated application of either Pendimethalin or Fluchloralin at 1 kg a.i./ha + 1 hand weeding at 40 days after sowing was found best for weed management.

In western Maharashtra, in **soybean-safflower** system, 100% recommended P could be subsituted by seed treatment with phosphate solubilizing bacteria and application of 5 tonnes of FYM/ha without any adverse effects on the safflower productivity. It is necessary to apply $FeSO_4$ (10 kg/ha) or $ZnSO_4$ (20 kg/ha) or recommended fertilizer dose + 5 tonnes of FYM/ha to safflower in scarcity zone of Maharashtra in addition to recommended dose of NPK fertilizers for higher yields.

In **groundnut**-wheat-greengram cropping system, groundnut fertilized with FYM (5 tonnes/ha) + 50% recommended doses of fertilizers, wheat with FYM (5 tonnes/ha) + 50% RDF along with green-manuring with greengram recorded highest total system productivity (2,451 kg/ha) and net returns (₹ 33,541/ha). Application of 2 kg citric acid + 2 tonnes of FYM/ha significantly improved groundnut pod yield (2,605 kg/ha). Maximum pod yield of groundnut varieties TG 37A and GG 2 was obtained with 50 kg N, 80 kg P_2O_5, 100 kg K_2O, 150 kg Ca, 40 kg S, 50 kg Mg, 4 kg Zn and 1.5 kg B/ha. And highest pod and haulm yields were obtained from GG 7 and GG 20 with 60 kg N, 100 kg P_2O_5, 125 kg K_2O, 200 kg Ca, 50 kg S, 60 kg Mg, 5 kg Zn and 2 kg B/ha.

Line sowing of **rapeseed-mustard** after land preparation in rice field with 80 kg N/ha fertilizer is recommended under *utera* cropping system in Himachal Pradesh and Kashmir valley and Bihar, Chhattisgarh, Odisha, Jharkhand, West Bengal, Asom, and other north-eastern states.

Castor-seed production by Andhra farmers: Seed programme of two castor hybrids DCH 177 and DCH 519 was organized in farmers' fields at 3 villages, Cherkur, Peddapur and Veldanda of Mahabubnagar district (Andhra Pradesh) in participatory mode. The farmers were trained on cultural practices along with the seed-crop management. Hybrid seeds of 8.1 tonnes of DCH 177 and 35 tonnes of DCH 519 were procured from farmers. The farmers also sold bulk seeds of male-parent of these hybrids. Farmers were able to get on an average of ₹ 45,000/ha as profit by growing hybrid seed-crop for 6–7 months.

DCH 177 castor-seed production training to farmers

Maize-mustard (short duration)-greengram system was found more remunerative than traditional maize-wheat system for Pantnagar and Kangra conditions.

Commercial crops

On rainfed Vertisols, **cotton** genotype PKV 081 was found most suitable for high density planting system (HDPS) (166,006 plants/ha) based on the yield (1,921 kg/ha), morphological features, earliness, tolerance to sucking pests and boll weight. On yield basis, *Gossypium arboreum* CINA 404 (2,174 kg/ha) performed the best under the HDPS (222,000 plants/ha).

High density planting of *Bt* Anjali cotton gives better returns than RCH 2 *Bt* cotton

Across the genotypes, spacing of 45 cm × 13.5 cm (166,000 plants/ha) was optimum for short, compact types, and spacing of 45 cm × 10 cm (222,000 plants/ha) was optimum for short compact *G. arboreum* plant types.

In non-*Bt* genotypes Anjali, CCH 7245 and C 1412, spacing of 45 cm × 15 cm, with 148,148 plant/ha resulted an edge of 0.3 to 0.8 tonne/ha over seed-cotton yield of RCH 2 *Bt* (planted at spacing of 90 cm × 60 cm). High density planting of Anjali gave 22.5 and 24.5% higher gross returns (₹ 119,538/ha) and net returns (₹ 78,286/ha) in comparison to RCH 2 *Bt*.

Leaf reddening in cotton: Leaf reddening was lesser under irrigated conditions. Among the treatments, nutrient consortia showed distinct difference in maintaining greenness of leaves up to the harvest, followed by *Panchakavya* and DAP (1%) + KCl (0.5%). In control, 70–75% leaf reddening was recorded and with nutrient consortia spray, symptoms were to the extent of 30–35%.

Sugarcane plant and ratoon crops can be fertilized with 75% of the recommended NPK through inorganics + 25% of the recommended N through organics (FYM) along with furrow application of *Azotobacter* + phosphate solubilizing bacterial biofertilizer each at 2.5 kg/ha, and biopesticide (*Trichoderma* sp.) was inoculated at 1.0 kg/ha mixed with 100 kg of FYM; apart from trash mulching and green-manuring (*Sesbania*) in alternate rows in ratoon-crop.

Cane-node technology for sustaining sugarcane yield: A primed node technology for sustaining high population shoot density has been developed. In this technology, cane-nodes having buds along with the root band after priming in an organic slurry are kept under decomposed farmyard manure with 60% moisture for 4-5 days. Sprouted buds are then planted in the field. The technology has the potential to break yield

CaneInfo website

CaneInfo is a registered member of the CIARD-RING [Coherence in Information for Agricultural Research for Development -Route map to Information Nodes and Gateways], an initiative by the GFAR (Global Forum on Agricultural Research) to facilitate discovery of sources of agriculture-related information across the world. As per the available NIC (National Informatics Centre) records, CaneInfo site has had more than 5.5 lakh hits up to 31 March 2011 from the date of its launch (07 July 2010).

Mapping of 'within' field variability in sugarcane

In a sugarcane farm in Ooradithottam near Sathiyamangalam, Erode district of Tamil Nadu, soil samples were collected from the field in grids and were characterized. Soil parameters were krigged to one meter block in the IDRISI software, and variability map was prepared. The results revealed that the field was low in available N and K (74.26% and 85.6%); *p*H of 42% of the field was alkaline and 27.2% had ESP of more than 15. The variability of various parameters within the field ranged from 2.4% in *p*H to 58.0% of available P. Uniform management parcels were demarcated.

Efficient water-use for improving productivity of sugarcane

Use of water-saving sugarcane technologies—skip-furrow method of irrigation, ring-pit planting method, irrigation at critical growth stages and trash mulching—at the fields of cane-growers in the participatory mode in the Central Uttar Pradesh in sugar mill zones of Biswan, Sitapur, Rauzagaon and Haidergarh and Barabanki was demonstrated. The maximum increase in cane yield was recorded in ring-pit method of planting (109.70%) over conventional method, followed by skip-furrow method of irrigation (49.12%), irrigation at critical growth stages (18.44%) and trash mulching (17.63%). Increase in irrigation water-use efficiency (IWUE) was recorded highest in ring-pit method of planting (151.61%) over the conventional method, followed by skip-furrow method of irrigation (149.78%), irrigation at critical growth stages (90.58%) and trash mulching (41.17%).

Ring-pit method of sugarcane planting

barriers by doubling cane yield. This technology will help reducing germination time from 45 days to about 15-20 days, besides increasing population density.

Cane-node technology

To reduce area under **tobacco**, particularly of non-exportable types, from 0.45 ha to 0.20 million ha by the end of the XII Plan with a targeted production of 250 million kg of the exportable types of tobacco, FCV, Burley and Oriental, identification, demonstration and popularization of alternative crops/cropping systems to *bidi* and chewing tobaccos in different agro-ecological sub-regions assume greater significance. Following alternative crop(s)/cropping system(s) to tobacco have been identified in different Agro-Ecological Sub-Regions (AESRs) of the country.

Tobacco type	Alternative crop(s)/ cropping system(s)
Bidi tobacco (Gujarat-AESR: 5.2)	Mustard, Groundnut, Chilli, Maize, Cotton, Cotton-Groundnut or Castor-Groundnut (summer)
Bidi tobacco (Karnataka-AESR: 6.4)	Sugarcane, Soybean-Sorghum and Groundnut-Sorghum
Bidi and Natu tobacco (Andhra Pradesh-AESR: 7.1)	Pigeonpea, Maize-Sunflower and Maize-Chickpea
Chewing tobacco (Tamil Nadu-AESR: 8.1)	Chilli + Annual Moringa, Aggregatum onion + Annual Moringa and Maize-Sunflower
Chewing tobacco (West Bengal-AESR: 15.3)	Maize, Potato, Wheat, Sugarcane, Mustard Maize-Potato

The national productivity of **jute** and **mesta** was around 2.2-2.3 tonnes/ha and 1.1-1.2 tonnes/ha in rainfed areas. Following agronomic management practices have been found to realize fibre productivity from 3.2 to 3.7 tonnes/ha in jute and 2.3 to 3.3 tonnes/ha in mesta under deficit rainfall/limited water supply.

- Bunding all-around the jute field for *in-situ* rain-water conservation, and one post sowing irrigation for germination with high seed rate (6.25 kg/ha) produced 3.3 tonnes of fibres/ha at the recommended fertilizer dose (N:P:K::60:30:30).
- Bunding all-around the field and sowing of jute seed in open-furrows (developed by nine tine cultivator) with high seed rate (8 kg/ha) produced 3.2 tonnes of fibres/ha at 120 days after sowing at the RDF (60:30:30) under deficit rainfall.
- Elemental sulphur at 30 kg/ha with high seed rate (8 kg/ha), one post-sowing irrigation and bunding all-around the field yielded 3.7 tonnes of fibres/ha at the RDF(60:30:30).
- Mulching at 2–3 tonnes/ha (rice/wheat straw) on seeded rows with the RDF (60:30:30), high seed rate (6.25 kg/ha) and bunding all-around the field produced jute fibres up to 3.3 tonnes/ha under deficit rainfall.

Under deficit rainfall condition, quality jute and mesta fibre was extracted in polyethylene-lined micro-tank (1:1; V/V) in 12-15 days time.

Fruit crops

In a canopy architecture studies in **mango**, highest fruit yield of 7.91 tonnes/ha was realized during off-

year at 3 m × 3 m spacing with Olour rootstock and low rate of Paclobutrazol. The highest photosynthetic rate was recorded in Kurukkan rootstock (11.79 µmol CO_2/μ^2/sec.). The seeds extracted from fruits harvested at three-fourths ripe stages and onwards resulted in better seed quality with more than 88% germination, whereas seeds extracted from early stages of fruit maturity recorded 78% germination.

In **litchi**, application of ethrel (150 ppm, 100 ppm), NAA (40 ppm) and MH (15 ppm) during October showed early shoot maturation and initiation of flowering. Spraying of NAA (40 ppm) advanced fruit setting by one week in cultivar Shahi, however two sprays of Bavistin (0.2%) and Ca $(NO)_3$ at 10 days interval during fruit development stage improved fruit retention. Covering litchi plants with 30 and 50% green agro shade net at the time of colour turning extended the harvesting period by 10-12 days, while pre-harvest spraying of $KMnO_4$ (2.0%) delayed colour break stage in litchi.

The drip irrigation at 0.75 cumulative pan evaporation (CPE) and micro-sprinkler at 1.00 CPE gave best growth in **kinnow**. Similarly, maximum water-use efficiency (WUE) and fertilizer-use efficiency (FUE) were recorded with 0.75 CPE and 1.00 CPE, respectively, in **ber**. The maximum moisture was extracted at 30-60 cm vertical depth and 30-60 cm horizontal distance from the main stem in kinnow.

In **pomegranate**, application of Rexoline (micronutrient mixture) @ 1.5 g/litre + boom flower (nitrobenzene 20%) resulted in 82.76% fruit setting, followed by ammonium nitrate @ 0.05% (71.01% fruit setting) and IAA @ 20 ppm (67.62% fruit setting).

In a pilot study on influence of Dogridge and 110R rootstocks on fruit attributes of Fantasy Seedless and Manjri Naveen **grapes** revealed that more berry diameter, berry weight and berry length were obtained from vines grafted on Dogridge, however more TSS was obtained in 110R. Among different modifications in Y trellis training systems, vines of Tas-A-Ganesh grapes trained to four cordon had highest number of bunches and yield per vine, however, higher single bunch weight was obtained from single cordon.

Under bower system of training also, vines trained to four cordon yielded higher number of bunches, although average bunch weight was higher in two cordon. The difference for berry diameter and TSS were non-significant. Regarding stem retension, double stem gave higher yield than single stem. An application of K_2O @ 100 kg/ha resulted in significant increase in bunch number per vine and average yield in Cabernet Sauvignon.

In **banana**, highest bunch weight (18.5 kg) was recorded in foliar spraying of 0.5% ferrous sulphate and zinc sulphate and soil application of 5 g borax/plant along with sulphur application, followed by soil application of 5 g ferrous sulphate, zinc sulphate and borax/plant without sulphur application (17 kg), while control recorded the lowest bunch weight (10 kg). Under fertilizer tailoring experiment with Grand Naine banana, lowest total dry matter of 5.92 kg/plant was recorded at 0 g N, 50 g P_2O_5, 0 g K_2O/plant without organic manure, while highest total dry matter of 12.54 kg/plant was recorded at 200 g N, 50 g P_2O_5 and 400 g K_2O with organic manure. The mean total dry matter production increased significantly with increasing rates of NPK levels. The leaf N concentration ranged from 1.95 to 3.61%.

In **temperate fruits**, medium- and high-planting density orcharding tried in **apple** for increasing vertical productivity involving different varieties on clonal (M 9, MM 106) and seedling rootstocks. On M 9, five varieties were tried at 3 spacings, i.e. 1.5 m × 3.0 m (2,222 plants/ha); 2 m × 3 m (1,666 plants/ha) and 2.5 m × 3.0 m (1,333 plants/ha). Among different plant densities, highest fruit yield (tonnes/ha) was obtained under 1.5 m × 3.0 m spacing followed by 2 m × 3 m spacing. Among varieties, Mollies Delicious (35.46 tonnes/ha), followed by Gala Mast (20.62 tonnes/ha) under 1.5 m × 3.0 m spacing; Vista Bella (42.5 tonnes/ha) followed by Gala Mast (38.58 tonnes/ha) under 2 m × 3 m spacing and Mollies Delicious (14.92 tonnes/ha) under 2.5 m × 3 m recorded highest yield on M 9, while Starkrimson (31.59 tonnes/ha), Mollies Delicious (31.0 tonnes/ha) and Silver Spur (29.45 tonnes/ha) on 2.5 m × 2.5 m spacing; Starkrimson (23.16 tonnes/ha), Royal Delicious (34.27 tonnes/ha), Vista Bella (20.59 tonnes/ha) and Red Chief (19.65 tonnes/ha) on 2.5 m × 3.5 m spacing and Starkrimson (12.50 tonnes/ha) and Mollies Delicious (12.65 tonnes/ha) under 3.5 m × 3.0 m spacing recorded the highest yield. However on seedling rootstock, cultivars Red Delicious (39.65 tonnes/ha), Oregon Spur (32.4 tonnes/ha), Red Chief (29.50 tonnes/ha), Royal Delicious (25.8 tonnes/ha) and Red Fuji (16.3 tonnes/ha) were found best at 4 m × 4 m medium density.

To harness solar energy, different training systems were tried using different varieties grafted on M 9 rootstock. Among training systems, Espalier resulted in highest yield as compared to Single Axis. Coe Red Fuji and Granny Smith recorded highest yield, 58.31 and 48.07 tonnes/ha and 24.47 and 17.12 tonnes/ha, respectively, in both the training systems. In Spindle Bush, Head and Spread and Modified Leader systems, cultivars, Mollies Delicious (39-49.7 tonnes/ha) and Starkrimson (46.96-37.3 tonnes/ha) resulted in highest yield in all the training systems. In **peach**, under high-planting density orcharding on seedling rootstock planted at spacing 2.5 m × 2.5 m, accommodating 1,600 trees/ha, maximum size in terms of fruit weight (99.97 g) and tree yield (34.56 kg/tree) were recorded in cultivar Gloheaven.

Plantation crops

In cropping of Gajendra variety of elephant-foot yam in **coconut** plantation under coastal littoral sandy soil, yielded high corm yield (17.6 tonnes/ha) when grown with soil moisture conservation measures like husk and coir pith application. Guinea grass (var. GGCo 3) gave higher green fodder yield under husk

application (ranging from 8.0 to 8.5 tonnes/cutting with a total yield of 82.2 tonnes/ha/year). Thevam variety of **black pepper** recorded significantly higher dry berry yield (1.71 kg/vine) when grown as a mixed crop in coconut garden. Recycling of biomass along with application of organic manures (cowdung, cow urine, biogas slurry) in cropping system is found to be self-sustainable in terms of nutritional requirement of coconut and other component crops in a mixed farming system for root (wilt)-affected coconut gardens.

The maximum annual nut yield (6.23 kg/tree) of **cashew** was recorded in moderate dose (0:250:125 g NPK/tree). The increase in yield under high-planting density (600 plants/ha) was 36.90% higher as compared to normal density (200 plants/ha). In high-density cashew plantations, number of nuts/m^2 was highest (24.70) in 200 plants/ha at 75:25:25 NPK (kg/ha) at Jhargram. Under intercropping trials, highest net returns were obtained with intercropping *Amorphophallus* (₹ 139,639/ha), followed by tapioca (₹ 129,992).

Results of a study on stress responses of the selected PGPR (22 coconut and 21 cocoa isolates) indicated that *Bacillus cereus* (ESB 15), *Bacillus* sp. (RSB 14), *Serratia marcescens* (KiSII) isolated from the rhizosphere of coconut and 5 *Bacillus subtilis* isolates (CSB 8, KGEB 10, PEB 2, PEB 4 and VEB 17) from cocoa rhizosphere could tolerate a maximum temperature of 60°C and were also able to grow on TSA medium amended with 12% NaCl.

Vegetable crops

For enhancing productivity and input-use efficiency in tomato, seedlings were raised in bed + foliar spraying of water-soluble fertilizers (WSF 0.5%) + seedlings treated with biofertilizers (*Azospirillum* and phosphorus-solubilizing bacteria (PSB) @ 2 kg/ha + foliar application of micronutrient mixture (0.1%) + plastic mulching of beds resulted in maximum fruit yield of tomato (520 q/ha) and nitrogen-use efficiency of 1.989 q/kg N. The minimum fruit yield (281.3 q/ha) was recorded under the farmers' practices. Under IPNM module for *kharif* **cowpea**, cultivar Kashi Kanchan registered maximum yield (142.5 q/ha) with the application of FYM @ 10 tonnes/ha + NPK (30:30:30 kg/ha) + biofertilizer (PSB) @ 2 kg/ha (seed treatment). The minimum yield of 120.7 q/ha was recorded in control, i.e. with 60:60:60 NPK kg/ha. Similarly, application of vermicompost @ 2.5 tonnes/ha + NPK (60:30:30 kg/ ha) + biofertilizers (*Azospirillum*) @ 2 kg/ha (seedling root treatment) recorded maximum head weight (1.37 kg) and marketable yield (389.7q/ ha) in variety Pusa Snow Ball K 1 as against 1.12 kg head weight and 352.5 q/ha yield in the control (NPK 120:60:60 kg/ha).

Alternate furrow irrigation and polythene mulch in **tomato** cv. Kashi Vishesh revealed that maximum yield (43.52 tonnes/ha) was obtained in well-watered plots combined with black polythene mulch; however maximum water-use efficiency of 9.42 q/ ha-cm was achieved when irrigation was given in alternate furrows and mulched with black polythene. With use of black and transparent polythene, 34 and 20% water was saved respectively, whereas about 40% water saving was noticed under alternate furrow irrigation over normal flood irrigation. In studies on off-season production of muskmelon, cv. Kanchan sown in October-end gave highest yield of 56 tonnes/ha. Precision farming studies in *Capsicum* involving raised bed method of cultivation, mulching, drip irrigation, fertigation and foliar nutrition of micronutrients resulted in highest yield of 46.5 tonnes/ha, compared to 27.5 tonnes/ha in furrow irrigated, non-mulched, and non-fertigated plot.

The integrated nutrient management (INM) for sustainable **onion** production revealed that combined application of 75% recommended dose of fertilizer (RDF) + 7.5 tonnes farmyard manure + 3.75 tonnes poultry manure/ha recorded significantly higher marketable yield (46.9 tonnes/ha) over inorganic fertilizer applied treatments (44.6 tonnes/ha). Application of 100% RDF along with 20 tonnes/ha of FYM registered 45.5 tonnes/ha marketable bulb yields. The highest pyruvic acid content (5.50 µmoles/g fresh weight) was recorded in inorganic fertilizers applied treatment. Bulbs harvested from INM treatments recorded lower pyruvic acid level (less than 4 micromoles/g fresh weight) than inorganic fertilizer alone applied treatment. Storage losses were significantly less in only inorganic fertilizers and biofertilizers (15.60%) applied treatments followed by 75% RDF and 15 tonnes/ha FYM (16.46%) over other treatments.

Among various organic manures applied, farmyard manure package recorded relatively higher yield (21.5 tonnes/ha in onion and 3.33 tonnes/ha in garlic) than other organic manures evaluated. However, almost 21-40% lesser marketable yield was recorded in organic system in comparison to inorganic production system in both the crops. The influence of organic sources of nutrients on soil biological properties revealed that soil bacteria, fungi and actinomycetes population was higher in soil nourished with organic manures than inorganic fertilizers applied plots. The drip irrigation at 100% PE daily recorded the highest onion seed yield with higher cost : benefit ratio of 1:3.81. There was 48-60% saving of water in drip irrigation over surface irrigation. For weed control during *rabi* season, soil application of oxyflurofen 23.5% EC @1.5 ml/ litre before planting and one hand-weeding 55 days after transplanting recorded higher marketable bulb yield of 43.5 tonnes/ha.

Spices

For multiplication of **nutmeg**, green chip budding with orthotropic buds on its own rootstock gave 90-100% success. The ideal time for budding was August-November. In **turmeric**, organic and integrated systems recorded comparable yields (30.2 and 30.6 tonnes/ ha). The variety Alleppey Supreme recorded higher yield (17%) under organic system compared to inorganic system. Soil organic C,N,P,K,Ca, Mg and Zn contents

were higher under the integrated system.

In **ginger**, highest yield was obtained under organic system (20 tonnes/ha) and varieties Mahima and Varada performed better (up to 19% increased yields). Soil N, K and Ca contents were higher under the integrated system, and Mg content was higher under organic system. The field study on different irrigation methods comprising conventional, furrow and drip irrigation in **fennel** was conducted in which low pressure drip irrigation using 42% lesser water resulted in 37% higher yield over conventional method, thus resulting in higher water-use efficiency.

In **saffron**, natural corm multiplication is very slow which takes about four years from small cormlets to produce flower bearing corms of 10-12 g size. The highest corm yield (20.55 tonnes/ha) was obtained with treatment of NAA 1,500 ppm with highest corm weight of 4.8 g, followed by GA_3 300 ppm (14.78 tonnes/ha) with corm weight of 4.95 g, but BA 40 ppm resulted in highest number of corms/plant (18.1) with corm weight of 2.3 g. Highest flower bearing corms (65.6%) were obtained in NAA 1,500 ppm, followed by GA_3 300 ppm (64.95%).

Potato and tuber crops

For mass multiplication of mini-tubers of **potato**, an aeroponic system with locally-available materials has been developed. On an average of about 60 mini tubers per plant were produced under the areoponic system. The germination of aeroponically produced mini-tubers varied from 92.3 to 100% and the yield from their progeny ranged from 93.4 to 173.2 g/plant.

The protocol for estimation of potato acreage and production through remote sensing, GIS and crop modeling in Punjab, Uttar Pradesh, Bihar and West Bengal has been standardized. Water-use efficiency of potato has been worked out as 177, 170 and 93 kg tubers per ha-mm water with drip, sprinkler and furrow irrigation methods respectively.

A nutrient decision support system website, cassava site-specific nutrient management (CASSNUM) containing all details about SSNM of cassava including N, P and K management enabling the farmers/extension officials to determine the amount of fertilizers to be applied for individual field for a particular yield level, considering the yield potential of locality, native soil fertility and cultivar used, has been developed. Application of 20 and 30 kg/ha of $ZnSO_4$ and $MgSO_4$, respectively, along with recommended doses of NPK and FYM was found essential to produce higher and sustainable crop yields of sweet potato. In **yams** and **taro**, organic farming was on a par with conventional practice.

Floriculture

In **chrysanthemum**, cocopeat, soil + sand + vermicompost (2:1:1 v/v), cocopeat + sand + FYM + vermicopost (2:1:0.5:0.5 v/v) and soil + sand + FYM were standardized as potting mixture for flower production. In **orchid**, *Cattleya*, cocochips + tree bark + cocopeat + brick pieces (4:2:2:2) was identified as best potting mixtures. Similarly in ***Cymbidium*** hybrid leaf mould + coconut chips + brick pieces (4: 2: 1) found as best potting mixtures.

In integrated nutrient management of **gerbera** cultivars Debor (Hessarghatta), Rosaline (Pune), Red Monarch (Kahikuchi) and Elegant (Kalyani); the recommended doses of fertilizers (75%) + FYM (1 kg/m^2) + vermicopost (300 g/m^2) + *Azospirillum* (2 g/plant/year)+ phosphate-solubilizing bacteria (PSB) (2 g/plant/year) were found to be the best. Application of NPK (20:10:10) (0.2%) along with *Azospirillum* and PSB improved growth and flower production in ***Dendrobium*** cv. Sonia. About 75% of RDF (200 N, 100 P_2O_5 and 150 K_2O kg/ha) along with FYM @ 1 kg/m^2/year + vermicompost (300 g/m^2) + *Azospirillum* @ 2 g/m^2 + PSB (2 g/plant) was recommended for increasing production of flower stalks and suckers in gerbera cultivar Red Monarch.

Pendimethalin (1.0 kg a.i./ha) in **gladiolus** at Pantnagar, Srinagar and Ranchi; Metribuzin (0.5 kg/ha) at Ludhiana; Atrazine 1.5 kg a.i./ha at Kahikuchi; Pendimethalin (1.0 kg a.i./ha) or Atrazine (1.5 kg a.i./ha) or Metribuzin (0.25 kg a.i./ha) at Pusa, Bihar; Metribuzin (0.25 kg a.i./ha), followed by the same chemical at higher dose of 0.50 kg a.i./ha at Hyderabad were applied. Mulching with black polythene sheet (200 micron) also proved superior for checking weed population in **rose** plantation at Ludhiana, Pune, Ranchi and Pantnagar.

Mushroom

The cultivation trials of paddy straw mushroom (*Volvariella volvacea*) using composted substrate prepared from cotton gining mill waste and paddy straw has revealed BBSR-007, BBSR-002 and BBH-01 as high-yielding strains. Besides, coconut industry waste mainly rachis and inflorescence can also be used for cultivation of *Pleurotus djamor* var. *roseus*.

PLANT HEALTH MANAGEMENT

Phytosanitation: A total of 97,700 imported samples including transgenics and trial materials were processed for quarantine clearance; 5,038 samples were found infested/infected with different pests, and 5,024 samples were salvaged. Sixteen Phytosanitary Certificates were issued for export of 5,835 samples. Important interceptions included **insects**–*Acanthoscelides obtectus* on common bean from Mexico, Peru, and the USA, *Bruchus dentipes* on *Vigna narbonensis* from Afghanistan and *Quadrastichodella eucalypti* on *Eucalyptus* from Australia; **fungi**–*Peronospora manshurica* on soybean from Brazil, Canada, Taiwan, Thailand and the USA, *Rhizoctonia solani* on maize from Mexico and Thailand, on soybean from Canada, and on chilli and brinjal from Taiwan; **viruses**–Broad bean stain virus on faba-bean from the ICARDA, Syria, Cherry leaf roll virus on soybean from the AVRDC, Taiwan, Sri Lanka, Thailand and the USA, and on

common bean from the CIAT, Colombia, and Raspberry ring spot virus and Tomato ring spot virus on soybean from the AVRDC, Taiwan, Sri Lanka, Thailand and the USA; and **weeds–***Lamium amplexicaule* on *Medicago lupulina* from Switzerland, and *Conyza canadensison* on rice from the USA.

Cereals

Promising breeding lines and germplasm accessions of **rice** have been identified—four rice germplasm accessions 316311, 346884, 352833 and 334179 were against bacterial blight, and 12 accessions of *O. rufipogan* and one of *O. longistaminata* were against blast and rice tungro virus. Field experiments showed that application of four entomopathogenic nematode (EPN) isolates (*Steinernema asiaticum, S. glaseri, Heterorhabditis indica* and *Oscheius* sp.) at 1×10^5 infective juveniles/m^2 at the booting stage significantly lowered incidence of white-ears.

Weed management in wheat: Both grassy and broad-leaved weeds infest wheat-crop. A ready-mix combination of Sulfosulfuron + Carfentrazone 45 (25+20) WDG was found effective in controlling complex weed flora in wheat. For its better efficacy surfactant is required; a dose of 625 ml/ha with surfactant is sufficient of the mixture as compared to 1,250 ml/ha. Where this combination is used in wheat; succeeding crop of sorghum and maize should not be grown. A new herbicide Pyroxsulam also found promising in controlling most of the grassy and broad-leaved weeds, viz. *Phalaris minor*, *Avena ludoviciana*, *Malva parviflora*, *Lathyrus aphaca* and *Medicago denticulata*. As far as herbicide resistance in *P. minor* is concerned, Pyroxsulam effectively controls susceptible as well as its populations that are resistant to Clodinafop and/or Isoproturon but it could not control Sulfosulfuron-resistant populations.

Weed management in wheat

Pulse crops

Two hundred and five lines of **chickpea** were found moderately resistant to wilt (< 10% wilt). Eight lines were resistant to representative isolates of all six races-1, 2, 3, 4, 5 and 6. In **lentil**, out of 51 genotypes screened against wilt pathogen (*Fusarium oxysporum* f. sp. *lentis*), five genotypes (PL 4147, PL 02, GP 3278, GP 4076 and JL 3) showed less than 30% mortality.

Ug99 race of stem-rust

The surveys conducted revealed that wheat stem-rust race Ug99 was not recorded anywhere from India. Indian wheat material is being evaluated at Kenya and Ethiopia for resistance against Ug99; as a part of the strategy to meet the challenge in case this race enters into India. Wheat breeding materials WH 896, HI 8498 and MACS 3742 have shown resistance during three-crop seasons.

From the amplified products of ten samples, five of **mungbean** and five of **urdbean**, DNA fragments of ~900 bp and ~800 bp were obtained corresponding to *NSm* genes and *NP* genes of groundnut bud necrosis virus; healthy samples gave negative results. This confirms that leaf curl disease of mungbean and urdbean at Kanpur is caused by groundnut bud necrosis virus.

At Kanpur, yellow mosaic in wild species/sub-species of *Vigna* has been confirmed caused by mungbean yellow mosaic India virus (MYMIV). This is the first report of nucleic acid-based identification of the MYMIV as the causal agent of the yellow mosaic disease in *V. hainiana*, *V. trilobata* and *V. radiata* var. *radiata*. Similarly, yellow mosaic disease of the cultivated mungbean and urdbean at Kanpur, Ludhiana, Navsari and Dholi is also caused by MYMIV, and at Vamban and Coimbatore, it is caused by mungbean yellow mosaic virus (MYMV).

Reactions of **chickpea** accessions for botrytis grey-mould disease severity were rated on a 0–9 scale. Accession IPC 2010199 was disease-free. Thirty accessions recorded disease at rating scale 1, 11 accessions at 1.5, 25 accessions at 2-4, 10 accessions at 4.5-7, while remaining 39 accessions were at 7.5–9 scale.

Field infestation of bruchids on different cultivars of mungbean ranged from 0.8% (Samrat) to 5.0% (NDM 1) with an average of 2.7% on the pod basis. Grain infestation of bruchids on different cultivars of mungbean ranged from 0.1% (Samrat) to 0.8% (NDM 1). Among urdbean cultivars, bruchids infestation ranged from 2.2% (Type 9) to 3.2% (Shekhar 1) with an average of 2.8% on the pod basis and 0.6% (Uttara) to 0.9% (Shekhar 1) with an average of 0.7% on the grain basis.

IPRT 2, 3, 6, 7, 13, 17 and 26 were the best *Trichoderma* isolates, which reduced growth of *Cercospora canescens*, increased plant stand, promoted growth and vigour in mungbean. Inhibitory effect of salicylic acid at 10 ppm was evident on all the 14 isolates of *C. canescens*.

Commercial crops

Cotton leaf roll dwarf virus (CLRDV) identified: Total RNA was isolated from probable infected samples using Sigma Spectrum RNA isolation kit. RT-PCR was performed using virus-coat protein specific primers of different viruses. Only in case of Jai, NBt amplicon was obtained using CLRDV coat-protein gene specific

Infected plant showing symptom of CLRDV

primer. The presence of virus was tested from infected samples. The cDNA thus obtained was sent for sequencing, and sequenced product was matched using NCBI blast; and it was observed that the virus belong to Luteovirideae family.

Fruit crops

The IPM practices of stone weevil in mango with bark cleaning + trunk spray of Endosulfan followed by Imidacloprid, gave an excellent control of 97.65% in cv. Alphonso. In IPM of fruit fly in **guava**, sanitation + methyl eugenol traps showed significant reduction in fruit damage. A single step multiplex PCR-based rapid and sensitive assay for detection of *Colletotrichum gloeosporioides*, the causal agent of mango anthracnose pathogen, using four sets of primers, viz. two sets of gene specific primer, one species-specific and one of ITS primer, have been developed and validated.

A new challenge of 'twig blight' in **litchi** has been noticed. The symptoms are drying of leaves on new shoots and a foliar blight and tip dieback which is difficult to separate. The leaf blight appeared as tan spots on leaves. The affected leaves look as if they were scorched from the sun. The severity of twig blight was as high as 100% in some plants. The twig blight along with infestation of foliage feeding pest complex particularly, new weevil pest *Apoderus blandus*, leaf miner, leaf cutting weevil and shoot-borer severely hampered growth of young plants and reduced the potential fruit-bearing flushes in grown-up orchards.

Fruit piercing moths, *Eudocima materna*, *E. phalonia* and *E. homaena*, were recorded feeding on matured Nagpur mandarin fruits. Larvae of *E.materna* and *E. homaena* were collected and reared up to adult on *giloe* (*Tinospora cordifolia*). Ectoparasitoid, *Euplectrus* sp. was collected from second instar caterpillar of *E. materna* during August 2011. Foliar application of Mak All Season Horticultural Mineral Oil @ 1.5% against leaf miner and @ 2.0% against mites was effective.

In **banana**, significant reduction in nematode population (>85%) was recorded in plants treated with Nemacinus (*P. linacinus*) + neem cake @ 250 g/plant; Nemacens (*P. fluorescens*) + neem cake @ 250 g/plant; marigold intercrop + *P. linacinus* + *P. fluorescens* + neem cake/plant; marigold intercrop with VAM (*Glomus fasciculatum* + *G. mosseae*) compared to the control and other treatments. Lateral flow strips (dipstick) were prepared using the IgG purified from polyclonal antiserum raised against CMV recombinant coat protein and this dipsticks could detect virus in positive samples but not from healthy negative samples. In banana, banana streak virus (BSV) and banana bract mosaic virus (BBMV) infected Poovan banana, application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake recorded the highest bunch weight (18.6 kg) with 12.3 hands and 192.5 fingers/bunch.

Three new bactericides, namely Piperaciline (500 ppm), Dichloropene (500 ppm) and Triclosan (0.5%), were found effective in managing bacterial blight of **pomegranate** under field conditions. A 6-year-old severely wilt-affected orchard of pomegranate cv. Bhagawa was adopted for wilt management. Soil drenching around the plant basin with Carbendazim (0.2%) + Chlorpyriphos (0.2%) at monthly intervals and one soil application of Phorate @ 20 g/plant resulted in reduction of wilt incidence with no new infections.

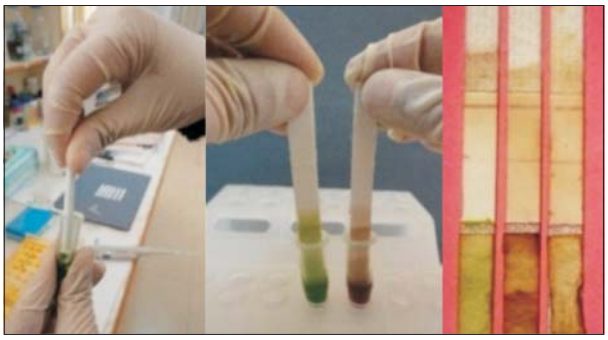
Spices

The black pepper accession, 1114 (Kumbhachola), was tolerant to *P. capsici*. The accession was earlier found resistant to pollu beetle and drought. A new bacterial wilt disease on small cardamom was recorded in Wayanad, Kerala. The phenotypic and genetic characterization revealed that causative organism is *Ralstonia solanacearum* (Biovar 3 phylotype 1) and was 100% similar to ginger strain of *R. solanacearum*. *Bacillus amyloliquefaciens* (GRB 35) and *Serratia marcescens* (GRB 68) were promising for enhancing sprouting of rhizomes, growth promotion and reducing the incidence of soft rot and bacterial wilt diseases in ginger in the field.

Bioagents *Trichoderma viride* and *Aspergillus versicolor* applied as seed treatment (10 g/kg seed) and soil application (2.5 kg/ha) and soil amendment mustard residue (2.5 tonnes/ha) + mustard cake (0.5 tonne/ha) + neem cake (0.5 tonne/ha) are effective eco-friendly approaches for the management of cumin wilt caused by *Fusarium oxysporum* f.sp. *cumini*. Seed wasp, an important pest of coriander, can be successfully controlled by application of botanicals neem oil (2%) and insecticides like Thiomethoxam (0.025%) and Imidachlorprid (0.005%). Application of neem oil (2%), *Metarrhizium anisopliae* and *Verticillium lacanii* at 10^8 spores/ml gives good control of cumin and fennel aphids.

Potato and tuber crops

A PCR-based protocol was validated to detect latent infection of *Phytophthora infestans* in seed **potato** tubers. This could detect the infection up to 20 mm away from the disease lesion. The PCR and RT-PCR protocols for PALCV, PVX, PLRV, PVY, PVS and PSTVd and real time PCR protocols for PALCV, PLRV and PVY have been standardized.



Dipstick for detection of potato viruses

Soil solarization together with incorporation of stable bleaching powder @ 3 q/ha was found effective for control of russet scab disease of potato. Application of Thiacloprid (0.3 and 0.4%) along with summer oil (0.06%) gave longer protection against aphids, while application of Thiacloprid alone was effective against whitefly. Monocropping of potato hybrid OS/93 D 204 in potato cyst nematode infested plots in Nilgiris resulted in the lowest PCN population, followed by the recommended practice of growing potato + French-bean intercropping in the autumn season.

Floriculture

In **gerbera**, for controlling rot/root rot disese at Pune, neem cake colonized by the disease biocontrol agent, *Trichoderma harzianum* (500 g/m^2), followed by drenching and foliar spraying either with Captan (0.3%) or Metalaxyl MZ 72 WP @ (0.3%) or copper oxychloride (0.3%) and for checking leaf spot/blight intensity, Azoxystrobin (0.1%), Iprodine + Carbendazim (0.2%) and Difenoconazole (0.05%) were found effective. For the management of *Fusarium* wilt in **gladiolus**, pre-storage treatment of corms with hot water (50°C for 30 minutes) followed by bulb dipping in Captan and Carbendazim @ 0.2% and pre-planting bulb dip treatment in *Trichoderma harzianum* @ 10 g/litre for 30 minutes was found effective with least disease incidence. Whereas, pre-storage treatment of gladiolus corms in hot water combined with Captan (0.2%) and Carbendazim (0.2%) at 50°C for 30 minutes was recommended in reducing *Fusarium* wilt. It also improved the number of spikes and corms, as well as number and weight of cormels.

Nematode-infested *Cymbidium* plant

For the first time, an ecto-parasite nematode responsible for poor growth on ***Cymbidium*** hybrids has been isolated from different orchid growers in Sikkim. The roots of infected plants were showing severe necrosis, swelling and fluffiness. The leaves of affected plants were also showing bending, twisting and abnormal growth.

Foliar sprays for the control of marigold bud blight (Iprodine + Carnebdazim @ 0.2% each) at Pune and alternaria blight (Mancozeb-Dithane M-45), Iprodione+Carbendazim and Difenconazole, @ 0.2, 0.2 and 0.1%, respectively, were found effective at Ludhiana. In **tuberose**, incidence of leaf blight was significantly less with foliar spraying of Azoxystrobin @ 0.1%, whereas final population of *Meloidogyne* and root galling index in cv. Single Local, was significantly less in case of treatment with neem seed power, Carbofuran, *Trichoderma harzianum* and *Paecilomyces lilacinus* + *T.harzianum* treated soils at Ludhiana.

Shoot-borer, *Peridaedala* sp. on *Epidendrum orchids* has been managed efficiently by using *Bt* (Dipel) 0.012% and neem oil 0.03% EC 5 ml/litre. The IPM modules of tobacco extract (5%), neem oil (0.03%) EC 5 ml/litre and Bifenthrin 10 EC (0.25%) was most effective against mite on *Cymbidium*. Aphid on *Cymbidium* flowers has been managed efficiently by using Econeem (3,000 ppm) @ 2 ml/litre and neem oil (0.03%) EC 5 ml/litre.

Safer chemical insecticides for broodlac treatment: Eight insecticides were evaluated on two lac insect parasites, *Tachardiaephagus tachardiae* and *Eupelmus tachardiae* and two lepidopteran predators *Eublemma amabilis* and *Pseudohypatopa pulverea* by dipping of broodlac in insecticidal formulation. Indoxacarb (0.007 and 0.014%), Fipronil (0.05%), Spinosad (0.05%), Ethofenprox (0.05%), and Endosulfan (0.05%) resulted in significant reduction in the population compared to control, without adverse effect on lac insect survival, when dipped for 10–15 min. These insecticides at the recommended concentrations may be utilized for checking the population of parasites and predators in the broodlac prior to inoculation on new trees, to minimize carry-over.

New fungicides for control of sooty mould affecting lac production: New suitable fungicides were identified for control of sooty mould on lac insects. Lac crop yield could be increased by spraying of 2.5 g/litre Kavach (chlorothalonil) (88.5%), 2.5 ml/litre Cantaf (hexaconazole) (74.3%) and 3 g/litre Ridomil MZ (ridomil + Mancozeb) (65.5%) over control.

Integrated pest management

Rice: The IPM validation trials in Basmati rice were conducted at Bambawad (Uttar Pradesh), Sibouli (Haryana) and Doodhali (Uttarakhand) and at Bolena and Patara villages of Jalandhar district (Punjab).The IPM module included planting of *dhaincha*, seed treatment with Carbendazim, seedling root-dipping in

e-Pest Surveillance

Visualizing emergent need to increase pigeonpea and chickpea production in a sustainable manner, major initiative was taken to use "e-Pest Surveillance system" to facilitate availability of IPM components. The programme was implemented on 36,000 hectares based on the Area-wide Integrated Pest Management System in collaboration with the state governments and state agricultural universities in 5 states of India. Major objective was to develop "Nuclear Model Villages" in 10 selected districts for demonstrating IPM modules in farmers' participatory mode.

A centralized "National Pest Reporting and Alert System" has been established through networking of pulse-growers in addition to strengthening of pest diagnostic laboratory. The system has three-tier architecture with facilities of online data entry, reporting, and advisory to farmers through short messaging system (SMS).

Pseudomonas (5 ml/litre of water), planting of 2–3 seedlings/hill, optimum dose of fertilizers (60 N:50 P:40 K kg per ha) and $ZnSO_4$ at 25 kg/ha, installation of pheromone traps for yellow stem borer monitoring, systematic monitoring for insect pests, diseases and natural enemies, need-based application of Tricyclazole for blast, Streptocycline for bacterial leaf blight, Buprofezin for brown planthopper and *Trichogramma japonicum*, manual weed management and installation of straw bundles (20/ha).

Pigeonpea: An IPM for pigeonpea sole-crop sown on ridges recorded lowest incidence of *Fusarium* wilt (33.3%) and *Helicoverpa armigera* (1.6% pod damage) as compared to damage of 37.5% and 38.8% due to *Fusarium* wilt, 2.4% and 2.2% pod damage due to *H.armigera* in the IPM module for pigeonpea and urdbean as intercrop and IPM module for pigeonpea and sorghum as intercrop.

Biological control

In-vitro screening of two entomopathogenic nematode (EPN) isolates of *Heterorhabditis* from Maharashtra and one of *Heterorhabditis* and *Steinernema* from Srinagar against second and third instars of whitegrub (*Anomala bengalensis*) on arecanut revealed that all the four isolates were effective causing 100% mortality of whitegrub. *Heterorhabditis indica* and *S. carpocapsae* obtained from *G. mellonella*, *C. cephalonica* and root grub exhibited better infectivity (90% mortality in 18-20 hr) in shorter duration against *G. mellonella* and white grub compared to the progeny

Healthy arecanut whitegrub Whitegrub killed by EPN

obtained from *H. armigera*, *S. litura* and *P. xylostella*. Wettable powder formulations of *Heterorhabditis indica* and *H. bacteriophora* were developed with a shelf-life of 8-10 months. Wettable powder formulations of *Heterorhabditis indica* and *S. abbasi* were effective against root grubs (*Leucopholis lepidophora*, *Anomala bengalensis* and *L. burmestrii*) in arecanut.

Eucalyptus gall wasp, *Leptocybe invasa* (Eulophidae: Hymenoptera) was accidentally introduced into India, and has become a serious pest on eucalyptus, threatening Indian paper industry. Parasitoids, *Quadrastichus mendeli* and *Selitrichodes kryceri* (Eulophidae: Hymenoptera) were imported from Israel for its biocontrol. *Q. mendeli* could be established in all released areas of eucalyptus plantations in Karnataka, Andhra Pradesh, Odisha, Gujarat, Haryana and Punjab.

Eucalyptus galled shoot (*inset : Quadrastichus mendeli*)

Agricultural acarology

Aerobically cultivated rice in Karnataka showed higher infestation (50%) by sheath mite *Steneotarsonemus spinki* as compared to conventional puddle system (33%), as former harboured more number of sheath mites. In Kadapa (Andhra Pradesh) and Bengaluru (Karnataka) rural districts, sweet orange suffered heavily due to rust mite *Phyllocoptura oleivora*, especially during summer months (February–March), which significantly reduced fruit yield.

In Kalyani, tenuipalpid mite *Brevipalpus phoenicis* appeared in serious proportion on betelvine and pointed- gourd. *Oligonychus oryzae*, serious pest on rice during July–August damaged banana-crop severely in the Gangatic belt of West Bengal. In Kerala, severity of mite pests especially during summer months,

February–March on vegetable crops like amaranth, ash-gourd, cowpea, tapioca; ornamentals like coleus, duranta, orchids; flower crops like Chinese balsam was observed. Also Jyothi variety of rice was severely damaged by leaf mite *Oligonychus oryzae* in Palakkad district during June–July, which was attributed to the dry spell during this period. Strawberry-crop in Mashobra region of Himachal Pradesh was damaged severely by spotted spidermite *Tetranychus urticae* from April onwards. Higher incidence of yellow mite *Polyphagotarsonemus latus* on *Bt* cotton was observed in Coimbatore (Tamil Nadu) and Dharwad (Karnataka) in the early crop growth stage. *Tuckerella kumaoensis* infested sapota- crop throughout the year in Navsari of Gujarat.

In Coimbatore, rice leaf mite incidence in rice reduced significantly by 70-78% with the application of Fenazaquin or Fenpyroximate or Spiromesifen.

Horticultural crops: In Andhra Pradesh, application of 0.005% Fenpyroximate resulted in reduction of citrus rust mite population as well as damage in sweet-orange, on a par with 0.001% Abamectin and 0.057% Propargite. In Ludhiana, against okra mite *Tetranychus urticae*, Spiromesifen and Fenazaquin application was found promising.

Application of horticultural mineral oil (HMO) against *T. urticae* on strawberry offered good control for only 7 days compared to synthetics like Propargite and Fenazaquin (for 14 days); Hexythiazox was more promising between 7 and 14 days.HMO was relatively less toxic to phytoseiid predators (< 30% mortality in 7 days) compared to Carbosulfan, Endosulfan, Fenazaquin and Hexythiazox (for 15 days). *P. ulmi* on apple was also effectively controlled by HMO at 1-1.5%, which could adversely affect hatching of mite eggs (70-84%) up to 3 weeks. In Ludhiana, high level of resistance to Dicofol (100–200 folds) and moderate resistance (40-50 folds) to propargite and Fenazaquin was observed in *T. urticae* infesting brinjal-crop.

Phytoseiid predator *Neoseiulus longispinosus* released against spidermite-infested polyhouse betelvine at 1:50 or 1:100 (predator : prey) eliminated spidermites completely in 4 weeks, and at 1:20 and 1: 40 required 6–7 weeks.

Plant parasitic nematodes

Application of *Pseudomonas fluorescens* at 20 g/m^2 as nursery-bed treatment in paddy was found effective against *Meloidogyne graminicola* and resulted in 17.18% increase in crop yield. In mungbean, seed treatment with *Pseudomonas fluorescens* and *Trichoderma viride* each at 5 g/kg of seed against root-knot nematode (*Meloidogyne incognita* race-2) proved effective in reducing root-knot nematode population. In cotton, use of rhizotrophic rhizobacteria (*Gluconacetobacter diazotrphicus*) at 100 g/5 kg of seed has been found effective in reducing reniform-nematode (*Rotylenchulus reniformis*) population by 47.64%.

Nematode control in glasshouses

Among various nematodes recorded, *Meloidogyne incognita* has been identified as one of the limiting factors in successful cultivation of ornamentals, and nurseries of vegetables, ornamentals and fruit crops in greenhouses.

Metham sodium has been found promising for management of this nematode. This chemical was evaluated as soil sterilant (at 30 ml/m^2) alone before transplantation of seedlings and was also evaluated in combination with neem-cake at 200 g/m^2, enriched with either *Paecilomyces lilacinus* at 50 g/m^2 (cfu 2 ×10^6) or *Pseudomonas flurescens* at 50 g/m^2 (cfu 2 × 10^9) mixed 15 days prior to sowing.

Root system of plant grown in metham sodium-treated soil at 30 ml/m^2

Rodent control

Rodent species diversity: High altitude zone of Andhra Pradesh recorded 6 rodent species—*Bandicota bengalensis* (58.8%), *Rattus rattus* (12.9%), *Mus booduga* (16.8%), *Millardia meltada* (5.7%) and *Tatera indica* (5.7%) and *Mus musculus*.

Tatera indica, followed by *B. bengalensis* was the predominant species in the eastern dry zones of Karnataka. However in coastal region of the state, where cashewnut, cardamom and coconut are major plantation crops, *Funambulas palmarum* was a major threat, followed by *R. rattus* and *B. bengalensis*. In the southern transitional zone, maize and *jowar* fields were mainly infested with *B. bengalensis*, *T. indica* and *M. booduga*.

Bandicota bengalensis, *Rattus rattus*, *Mus musculus*, *Mus cookii nagaram* (Cooks mouse) and an arboreal species, parti-coloured flying squirrel *Hylopetes alboniger alboniger* were recorded from Arunachal Pradesh. In storage godowns, *M. musculus* (55%), *R. rattus* (30%) and *B. bengalensis* (15%) were major rodent pests in Arunachal Pradesh.

Rodent damage: An extensive survey in 39 locations of Andaman district revealed 2.5 to 74.5% rodent infestation in coconut-orchards. The extent of nut damage ranged between 4.2 and 6.3%. Highest trap index was reported during July–August and least during April.

In costal Karnataka, 8.5 to 21.5% coconut-trees were affected by rodents. The maximum damage period was from January to April. In cardamom-orchards,

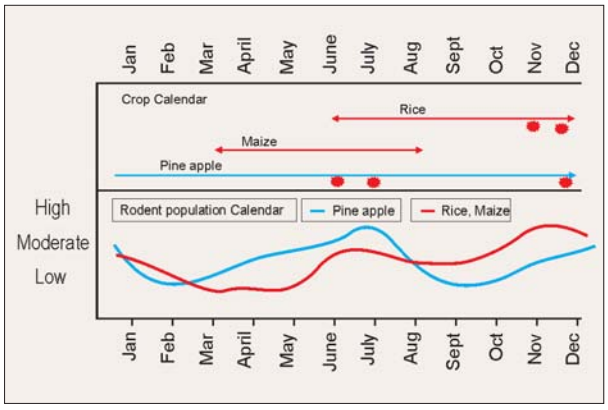
Funambulas palmarum and *Rattus rattus*, followed by *B. bengalensis* were active throughout the year.

In Asom, rodent infestation pattern in rice revealed least rodent incidence (8.2 burrows/ha) with only 2.4% tiller damage, which increased to 33.3 burrows/ha with 14.6% tiller damage at the ripening stage. In Andhra Pradesh and Karnataka, rice suffered 7.9-9.5% and 2.3-7.5% tiller damage, respectively, during the year.

In rice-vegetable cropping systems in Asom, *rabi* vegetables recorded maximum rodent damage in peas (16.8%), closely followed by potato (15.9%) and pumpkin (11.8%). Tomato and cabbage recorded ~6% rodent damage.

In East Siang District of Arunachal Pradesh, wetland rice fields registered 15.3 live-rodent burrows/ha during June that reached to 28–30 by October–December. Among horticultural crops in the NEH region, pineapple and tapioca suffered severe damage, ranging from 12.6 to 6.87%.

Crop-rodent seasonal calendar in Arunachal Pradesh: During transplantation stage in rice (June-July), rodent population was moderate, and followed increasing trends from PI stage, attaining peak at maturity/harvesting (Nov-Dec), leading to severe damage. Similarly, maize sown in March–April registered low rodent activity which increased at cob formation. The pineapple crop which is grown throughout the year suffered maximum rodent damage at fruit-bearing stage twice a year, in June–July and December–January.



Crop-rodent seasonal calender

Rodent management research: *Botanicals:* Under laboratory, exposure to bait containing 1, 3, 5% castor oil for 5 days to *R. rattus* in bi-choice feeding test revealed significant antifeeding effects; no such effects were found in no-choice condition. The repellency index was highest (63%) at 5% and was least (55%) at 1%. Repellency index of neem bark-treated baits (5%) and *Calotropis* latex-treated baits (3%) was 76.66% and 41.95% in *R. rattus*. Citronella oil-treated bait at 3% recorded repellency index of 24% in *B. bengalensis*.

Gliricidia (*Gliricidia sepium*) leaves and bark cooked with bait and exposed to *B. bengalensis* for 10 days, registered ~ 30 % mortality of bandicoots, followed by seed extract of *Argemone maxicana* in baits (13–20% mortality) and leaf and bark extracts of *Thevetia peruviana* (8–10% mortality).

Anti-fertlity compounds: Exposure to baits containing 0.1, 0.05 and 0.025% triptolide to male-house rats *R. rattus* for 7 and 14 days in no-choice feeding tests revealed sterilant effects in terms of reduction in sperm motility, viability and density and separation of sperm head-tails up to 55.99% . Antifertility effects of triptolide were found to be irreversible up to two months in rats treated for 14 days in no-choice tests. Papaya-seed powder treated baits at 2% concentration showed anti-fertility effects on *R. rattus* in terms of reduced sperm motility and sperm counts.

Rodenticides: Brodifacoum wax block formulation (0.005% a.i) yielded cent per cent kill of *B. bengalensis*, *R. rattus* and *M. musculus* in no-choice tests, and it was 60–80% in choice tests. At Jodhpur, death period ranged from 3 to 10 days in *B. bengalensis* and 4–13 days in *R. rattus* with an a.i. intake of 2.39–2.62 mg/kg in no-choice and 1.5–1.8 mg/kg in choice tests.

Exposure to Bromadiolone (0.005%) as loose bait and ready-to-use wax cake to *R. rattus* and *B. bengalensis* in no-choice, higher consumption was observed of freshly prepared loose bait. And mortality in *B. bengalensis* was less and somewhat delayed compared to *R. rattus*.

Rodent management in storage: Treatment of rural grain-stores with 0.005% Bromadiolone, followed by second treatment after 15 days with 10% peppermint oil or 5% castor oil showed higher (61.59%) reduction in rodent activity with castor oil compared to peppermint oil (29.63%), as the second treatment.

Agricultural ornithology

Bird damage: In rainfed areas of different agroclimatic zones, larger roosts with more than 50,000 birds were predominantly found due to availability of diversified cropping patterns. Distribution of the land cover revealed that 59% of the agricultural area was predominantly used by birds, followed by agricultural fallow lands (16%), wastelands (8%) and others (17%).

At coastal districts of Andhra Pradesh, 23 species of birds were identified causing damage to fish/prawn fingerlings to the tune of 3–11%.

Eco-friendly bird-management practices: In Andhra Pradesh, main crop of maize was fully protected from bird damage by using thick fodder maize (1,848 kg/ha) and fodder sorghum (1,558 kg/ha) as border/ screen crop, as compared to control (1,168 kg/ha).

In sunflower for managing birds egg solution at 20 ml/litre showed higher yield (1,409 kg/ha), followed by ribbon (1,316 kg/ha) and Ecodon (1,146 kg/ha) as compared to control (959 kg/ha) in Andhra Pradesh.

At Arunachal Pradesh, no parakeet infestation was recorded in the ribbon + wrapping of maize-cobs (100% reduction in parakeet infestation), and it was on a par with the installation of ribbon alone with 0.50% infestation. Wrapping of cob with leaves in four boundary lines showed 23.50% infestation and 57.47% reduction over control.

Beneficial birds in agricultural landscape: At ARS, Tandur (Andhra Pradesh) during *rabi* in chickpea, NPV and bird perches plots showed higher yield (2,053 kg/ha) as compared to control (1,421 kg/ha). In Kerala, 21 species of birds reduced 20–33% of *Helicoverpa armigera* in tomato and chickpea. A total of 15 organic and 17 conventional farms were surveyed in south Telengana Zone and south zone of Andhra Pradesh, and the bird incidence showed higher occurrence of species in organic farms (25 spp.); 4 grainivorous species very common (66.5%) were – rose ringed parakeet, myna, munias and crows; 10 insectivorous species were 26%; including shrike, great tit, robin, drongo, blue jay, dove, oriole, cattle egret and stone chat. Factors such as crops, field size, height and age of trees and presence of hedges played important role in occurrence of these birds.