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Crop Management

PRODUCTION

Wheat: The long-term effect of five tillage options, *i.e.* conventional tillage, zero tillage, rotary tillage, strip tillage and bed planting were evaluated. The mean yield was 3.04% higher in rotary tillage, whereas 7.55 and 12.81% lower, respectively in strip tillage and bed planting, options compared to conventional field preparation. However, yield under zero and conventional tillage was similar. In six out of eight years and on mean basis, the yield recorded was highest in rotary tillage. Cost savings in zero tillage varied from Rs 2,500 to 3,000/ha and Rs 2,000 to 2,500/ha in rotary tillage.

Millets: Intercropping of 40 – 45 day old pigeonpea seedlings with finger millet (2 : 8) was found to be promising and remunerative in light red soils of southern Karnataka.Application of composted poultry manure @ 1.5 tonnes/ha in Uttarakhand and 2.0 tonnes/ha in red soils of Karnataka is a better option for organic cultivation of finger millet.Finger millet variety, Indaf-7, is a better choice for planting in *rabi* (second fortnight of October) for sustaining higher yield in southern dry zone of Karnataka (Mandya region).Sequence cropping of foxtail millet as an early *kharif* crop followed by pigeonpea or sunflower in *rabi* is a more remunerative cropping sequence for Rayalseema regions of Andhra Pradesh. Intercropping of kodo millet + soybean (4 : 1) is a better choice and remunerative practice for Bastar region of Chhattisgarh. Transplanting paired row of pigeonpea with finger millet is a boon to enhance productivity of pigeonpea (2,070 kg/ha) as well as finger millet grain yield (8,382 kg/ha) than drill sown pigeanpea (638 kg/ha and 6,250 kg FMGEY/ha) under rainfed conditions. The system provides an additional return of Rs 4,080/ha.

Groundnut: Bt cotton + groundnut intercropping at a row ratio of 1:3 was found to give high groundnut equivalent yield at Dharwad (Karnataka) and Junagadh (Gujarat) and at a row ratio of 1:1 at Jalgaon (Maharashtra).Groundnut varieties, TKG 19A, GG 7, GG 20, ICGS 76, CSMG 84-1, ICGV 86590 and M 13, were relatively tolerant to soil acidity, aluminium-toxicity, and Al-induced P-and Ca-deficiencies with a yield potential of 1,500-4,000 kg/ha and have been recommended for cultivation in NEH region.

Rapeseed-Mustard : Sesbania green manuring along with soil incorporation of mustard waste @ 2.5tonnes/ha in *kharif* season has shown beneficial effect on soil health as well as mustard yield. The beneficial effect of Sesbania + mustard straw incorporation was further enhanced when recommended dose of fertilizer (80 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha) was applied to mustard crop. Mustard hybrids produced more yield at a 45 cm × 15 cm spacing. The wider spacing opens avenues to reduce the recommended seed rates of hybrid mustard by 33%, augmenting hybrid seed availability for more acreage.

Soybean: Soybean-wheat-maize-wheat rotation system was proved to be the best for productivity, profitability and energy efficiency. Ridge tillage and broad bed furrow significantly increased soil microbial biomass, soil enzyme activities and seed yield as compared to minimum tillage and flat bed planting under soybean-wheat and soybean-chickpea system.

Thirteen thermo-tolerant rhizobia surviving at 45°C have been identified.

Bacillus isolates, KHBD-6, KHBAR-1, BDSD-2-2C, KDMR-1-1, KHTH-4-1and KHBD-2-1A, were found promising for solubilization of zinc salts.

Sunflower: The highest seed yield of *kharif* sorghum was obtained with 150% RDF application, while *rabi* sunflower yield was highest with RDF application with preceding sorghum receiving RDF

+ sunflower residue incorporation. Sunflower equivalent yield was highest with 150% RDF to both crops, followed by NPK+CR-NPK to sorghum-sunflower cropping system.

Safflower: It is possible to substitute 50% N and P needs of chickpea-safflower rotation by seed treatment with PSB to chickpea and seed treatment in safflower by *Azotobacter/Azospirillum* and PSB without any adverse effect on productivity in Maharashtra.

Castor: Simultaneous sowing of castor and greengram in castor + greengram (1:1) intercropping system was found promising in north Gujarat under assured irrigation. Integrated use of organic sources and biofertilizers can help to reduce the fertilizer needs of castor. Integrated use of 75% RDF + 25% N (FYM) + *Azospirillum* (ST) + PSB was found beneficial and more remunerative for castor as compared to application of 100% RDF.

Sesame: Integration of RDF + two foliar spraying of urea (2%) at flowering + capsule formation stage resulted in maximum seed yield, net monetary returns and benefit: cost ratio. The highest sesame yield was obtained with 100% RDF + 2.5 tonnes/FYM + 20 kg $ZnSO_4$ + 25 kg $FeSO_4$/ha.

Niger: Integration of foliar spraying of urea (2%) at flowering and seed development gave higher yield and net monitory return. Pre-emergence application of Pendimethalin + sieving of seeds was found to control *Cuscuta* in niger most effectively with higher seed yield.

Linseed: JLS -9, JLT-26 and Kartika were observed to be the best for cultivation after soybean with recommended package of cultural practices even in late sowing at last week of November.

Pulses: The maize -wheat- greengram system recorded highest productivity (pigeonpea equivalent yield2, 953 kg/ha) as compared to other systems. Inorganic fertilizer application resulted in highest pigeonpea equivalent yield followed by organic treatment.

The bulk density, porosity and water-holding capacity improved considerably after the inclusion of pulses after completion of fifth cycle. The soil organic carbon content, microbial population and microbial biomass carbon also increased with incorporation of crop residues in pulse-based cropping system as compared to maize-wheat system.

Zero tillage led to highest consumptive use of water (108.5 mm) in chickpea. The highest consumptive use of water (102.4 mm) was recorded in no mulch against the lowest in cultural mulch. The chickpea genotype, KWR 108, was more efficient in water use (water-use efficiency, 19.28 kg/ha-mm) under rainfed conditions. Under irrigated conditions, RSG 888 RSG 143-1 was the most efficient in water use.

In maize-chickpea cropping sequence, application of FYM at 5 tonnes/ha to maize gave 14.2% higher grain yield of chickpea and 13.6 % chickpea equivalent yield over no FYM. Agronomic efficiency of phosphorus (kg grain / kg P_2O_5 applied) increased from 3.8 to 9.2 and 6.5 to 7.6 due to application of FYM and PSB, respectively.

Sowing pigeonpea on raised beds with 75% RDF through band placement gave higher pigeonpea yield than flat sowing and broadcasting.

Inclusion of green manure crop and pulses in rice-based cropping systems increased the productivity by 11.2% in rice-wheat- *dhaincha*, 8.2% in rice -fieldpea -greengram and 7% in rice - wheat - greengram cropping system as compared to rice -wheat. The highest net return was recorded in rice-fieldpea-greengram cropping system which was at par with rice-wheat-greengram, followed by pigeonpea-wheat. The highest benefit:cost ratio was recorded in maize-chickpea system (3.94), followed by pigeonpea-wheat (3.77).

Soil organic carbon content increased from initial level of 0.24 to 0.42% and 0.35% under organic and integrated production systems, respectively when chickpea, greengram and mustad were cultivated.

Arid Legumes: The application of 50% N through organic source (FYM)+50% through inorganic source (urea) recorded highest seed yield. Among the nutrient management treatments applied in the preceding crop clusterbean, application of 100% N through organic source (FYM) gave highest seed yield of cumin. The highest cumin equivalent seed yield of cropping system was recorded due to the application of 25% N through iorganic source of urea+75%N through FYM.

Sugarcane: In the first ratoon crop, paired row planting with fertigation at 100 and 75% of the recommended dose of fertilizer performed well with cane yield of 108.0 and 111.7tonnes/ha, respectively and was on a par with surface irrigated crop (111.3tonnes/ha). There was not much difference in Brix and sucrose content between drip irrigated and surface irrigated crop. There is a possibility of reducing 25% of N and K fertilizers and water saving of 42-51% through drip fertigation.

Bud chip technology: The conventional system of sugarcane planting requires about 6-8 tonness /ha seed cane. In order to reduce the quantity and improve the quality of seed cane, one alternative is to plant excised axillary buds of cane stalk, popularly known as bud chips. The bud chip technology could be one of the most viable and economical alternatives in reducing the cost of sugarcane production, besides other advantages.

This technique could be of immense uses to farmers.

Tobacco: Sunnhemp raised as a green manure crop and ploughed *in situ* at 45 days + *Azospirillum* @ 10 kg/ha + Phosphate Solublizing Bacteria @ 10 kg/ha along with 100% recommended dose of fertilizer (75 kg N+100 kg P_2O_5+50 kg K_2O/ha) to chewing tobacco at Vedasandur was an effective strategy to get high productity and net return.

*Efficiency of tobacco curing:*Integrated barn comprising Ventury furnace and modified flue pipe system reduced wood consumption for tobacco curing. Coffee husk was found to be a beneficial/ effective alternative fuel for curing tobacco at Shimoga. Coffee husk requirement for tobacco curing was estimated at 5.11 kg/ kg cured leaf.

Mango: The application of paclobutrazol @ 2.5 g a.i/plant during second week of July increased fruit yield and advanced harvesting time of Totapuri by 26 days. The rootstock, Nekkare, recorded maximum cumulative yield (216.55 kg/ tree) with scion Banganpalli. In planting system-cum high-density planting of mango, double hedge row system of planting gave highest yield at most of the centres. Heading back of branchlets at 50cm level on entire tree, during rest period before emergence of new growth along with application of paclobutrazol @ 10g a.i./ tree gave highest yield of Alphonso at RFRS, Vengurle, with and Neelam at Periyakulam

The formation of jelly seed, one of the most serious problems in mango Dashehari, particularly in northern belt, was characterized by loosening of pulp, jelly formation, off-flavoured and dull colour around stone, resulting reduction in shelf-life of fruits. The affected fruits appear normal from the outside but after slicing give an unpleasant appearance and become unfit for consumption.

An integrated management approach involving application of black plastic mulch (100-µ thick) in tree basin during October-November and foliar spray of dihydrated calcium chloride (2.0%), potassium sulphate (1.0%) one month before harvesting of fruits along with application of 150 g borax per tree in soil during November, has been found quite effective.

In mango Dashehari, branch angle and its relationship with bearing was studied and most productive branch angle was identified as $30\text{-}60^0$ from vertical axis as there were maximum fruits (49.33 %) on these branches with higher fruit weight. Least fruiting (6.88 %) was recorded from narrow angled branches of less than 30^0.

Guava: In planting system-cum high-density planting experiment, maximum cumulative yield was recorded in double hedge row system of planting at most of the centres.

Litchi: Maximum cumulative yield was obtained in double hedge row system of planting both at GBPUA&T, Pantnagar and BCKV, Mohanpur. The maximum cumulative yield was recorded when fruits were harvested with 50cm long branches at BCKV, Mohanpur.

Citrus: Leaf analysis and fruit yield data bank generated through exploration of 7 states across northeast India were analyzed through diagnosis and recommendation integrated system (DRIS) to determine leaf nutrient optima and geographical information system (GIS) to develop spatial variogram of nutrient constraints to delineate major production zones. The DRIS interpretation revealed leaf nutrient optima as : 19.7-25.6 N, 0.9-1.0, P, 9.9-19.3 K, 19.7-24.9 Ca, 2.4-4.8 Mg as macronutrients (g/kg), 85-249 Fe, 43-88 Mn, 3-14 Cu and 17-27 Zn as micronutrients (mg/kg) vis-à-vis productivity of 33-56 kg/tree. Maps for spatial distribution of nutrient constraints were superimposed, which delineated three most important citrus productivity zones.

Kinnow: The drip irrigation at 0.75 CPE and micro-sprinkler at 1.00 CPE gave best growth in kinnow. Similarly, maximum WUE and FUE were recorded with 0.75 CPE and 1.00 CPE, respectively.

Banana: At Arabhavi centre, 75% RDF / plant and 2 suckers/ hill gave higher yield while at Kannara, a plant spacing of 2m × 3m with three plants / pit (5,001 plants/ha) with 100% RDF recorded highest yield under high-density planting.

Sapota: Application of 100% RDF at three stages of growth, viz. 25% N + 100% P_2O_5 + 25% K_2O in June, 50% N + 50% K_2O in August and 25% N + 25% K_2O in October was observed to produce better results than the control.

Papaya: At Coimbatore centre, application of 30:30:30 g of NPK (60% RDF) applied @ 100:25:25% during transplanting to flower emergence, @ 0:50:50% from flowering to first harvesting and @ 0:25:25% from first harvesting to end of first cropping period recorded better fruit characters. Application of 100% RDF at three stages of growth, viz. 25% N + 100% P_2O_5 + 25% K_2O in June, 50% N + 50% K_2O in August and 25% N + 25% K in October gave better results than the control.

Aonla: Evaluation of aonla-based diversified cropping model at CIAH, Bikaner, demonstrated that ground storey crops performed well without affecting the yield of main crop. These crops played a vital role in supplementing N, P and K through residue incorporated in soil. The system gave a net return of Rs 53,050.00 with a benefit : cost ratio of 2.54 from aonla + bottle gourd purely under rainfed conditions of semi-arid ecosystem.

Under various planting systems, viz. square, hedgerow, double hedgerow, cluster and paired demonstrated that double hedgerow planting system

can be adapted by aonla growers for getting 123.79 % more yield over traditional square planting system under rainfed conditions.

Pomegranate: At CIAH, Bikaner, in 5-years-old tress pomegranate Ganesh, two sprays were applied during vegetative growth and at initial fruit development. Highest number of fruits (102.33) and maximum yield/plant (24.5 kg) were obtained in treatment of boric acid and zinc sulphate @ 0.25%. The fruit cracking was reduced to 9.96% by application of boron with zinc each at @ 0.25% compared to 22.33 % in the control.

Application of leaf litter of subabool (5 kg / plant) gave higher fruit yield (27.72 kg / plant) in six year trees of Ganesh. Application of leaf litter also increased soil organic carbon.

The application of different bioagents, *viz. Azosprillium*, *Azosprillium* + *Pseudomonas striata, P. fluorescens, Trichoderma viride* resulted in high dry- matter (total biomass), longer roots and more number of roots/ plant. Use of *Azospirillium* + *P. striata* improved photosynthetic and transpiration rate as compared to the control.

The maximum graft success (85.00%) was recorded with wedge grafting done on 30 January. The grafted plants during this period had perfect graft union, indicating high scion and rootstock compatibility. Four pomegranate rootstocks (Bhagawa, Mridula, Phule Arakta and Ganesh) were tested taking Bhagawa and Ganesh as scion varieties. Maximum graft success of 84%, was recorded with Mridula (rootstock) and Ganesh (scion) graft combination.

Grape: The double stem performed better than single stem. Similarly, maximum bunch weight, berry weight and berry diameter were obtained with vines trained as double cordon horizontal. However, overall yield was higher in four cordon system.

Different rootstocks varied in their response to IBA for successful rooting and their growth. Removal of leaves 6-8 days before grafting resulted in improved graft success and performance. Thompson Seedless grafted on nine different rootstocks was evaluated for different parameters. Higher bunch weight and yield recorded on vines grafted on 110R and Dogridge. Under salinity stress, Thompson Seedless grafted on B2-56 rootstock performed better than those grafted on Dogridge and Salt Creek and resulted in higher biomass and yield. B2-56 was more efficient in P and K uptake under saline irrigation.

Banana: Requirement of N, P_2O_5 and K_2O for producing one tonne of Poovan first ratoon banana was worked out as 11.52, 1.57 and 22.96 kg, respectively. Out of which, 51.2, 37.8 and 58.3 % of N, P_2O_5 and K_2O respectively were contributed by soil, and applied fertilizers contributed 58.2, 42.6 and 58.7 % of N, P_2O_5 and K_2O respectively.

Apple: In medium density plantation**,** 11 varieties of apple were planted on seedling root-stocks with pollinizer variety Golden Delicious at a spacing of 4m × 4m, accommodating 625 trees/ ha against 278 trees/ha in conventional system. During seventh year, with 55-60 % canopy cover, the yield was recorded maximum in Royal Delicious (12.35 tonnes/ha), followed by Red Chief (12.05 tonnes/ha), Oregan Spur (11.40 tonnes/ha) and Red Fuji (10.20 tonnes/ha).

In-situ moisture conservation in almond: Half moon system (left) and full moon system (right)

Almond: The maximum nut yield (2.22tonnes/ ha) and soil moisture content were recorded with full moon structure + plastic mulch followed by half moon + plastic mulch.

Walnut: Wedge grafting recorded highest success of 75% under polytrench followed by polyhouse (70%), while it was only 19.16% under open field conditions with an overall average of 54.66% when grafting was done during mid-March as against only 45.18% in tongue grafting.

Walnut propagation under polyhouse

Strawberry: Under polyhouse or in polytunnels, strawberry Chandler, Gorella, Camarosa, Oso Grandy and Addie, produced higher yield with better size of fruits compared to open field.

Coconut: Intercropping banana, hybrid Napier grass CO-3 and ash gourd in coconut garden under littoral sandy soil with husk and coir pith application resulted in higher yield. Higher coconut yield was recorded under coconut + vegetable intercropping system (130 nuts/palm/year) compared to monocropping of coconut (118 nuts/ palm/year).

Intercropping systems

- Ginger, tapioca, coleus, Amorphophallus and hybrid napier were found suitable for intercropping in black pepper garden (more than 15 years old).
- Sweet potato + red gram intercropping system (1.8 m strips each accommodating 3 rows) recorded significantly higher tuber equivalent yield (13.01 tonnes/ha) compared to other cropping system, followed by sweet potato as a sole crop (12.96 tonnes/ha). Maximum net return and benefit: cost ratio were recorded with sweet potato + red gram intercropping system.
- Elephant-foot yam intercropped in orchards gave higher net returns with sapota/mango orchard with recommended dose of NPK at Coimbatore, Dholi and Ranchi.
- For Dharwad and adjoining areas of Karnataka, *kharif* potato-*rabi* sorghum crop sequence was recommended for higher productivity and profitability with 20 tonnes/ha FYM and 100% of recommended doses of NPK to potato crop.
- For Kalyani and adjoining areas (West Bengal) in potato-okra-paddy cropping sequence, application of FYM @ 20 tonnes/ha and 100% recommended doses of NPK to potato and 50% of recommended doses of NPK to okra and 75% recommended dose of NPK to paddy was recommended for higher productivity and net return.
- Potato + garlic intercropping system in a 1:1 ratio with 100% recommended doses of NPK fertilizers to both the crops was recommended for Chhindwara and adjoining areas of Madhya Pradesh.
- For Kota and adjoining areas of Rajashtan, potato + *methi* (every fourth row of potato replaced by two rows of *methi* at 30 cm spacing) was recommended for higher productivity and net return.
- At Faizabad, intercropping of potato with garlic in a 3:1 ratio with recommended doses of NPK for both the crops was recommended.
- In Nilgiris, potato-Frenchbean combination has been found to reduce the build-up of potato cyst nematodes, enhancing soil organic carbon content due to nitrogen-fixing capacity of beans.

Economics of coconut based farming system involving coconut with integration of grass, pepper (trailed on coconut), banana (on border of garden), dairy and poultry resulted in the net return of Rs l,29,070 /ha. Sale of coconut, milk and broiler was found to give 91% of the revenue generated from the system.

Cowdung slurry application on vanilla grown as mixed crop in coconut garden was found to increase the number of infloresences (21), number of beans (208) and fresh bean yield (2.0 kg/vine), followed by vermiwash application and vermicompost + biofertiliser application.

Allelopathic studies in coconut-based cropping system indicated that the microorganisms are capable to catabolise the allelochemicals in leachates and nullify their plant suppressive properties.

The coconut yield was higher with the treatment, organic + inorganic manuring + tillage practice (158 nuts/palm/year) under rainfed situation. Application of 50 % VC +50% NPK recorded significantly higher nut yield (68.8 nuts/ palm/ year) and was on a par with application of 25% VC + 75% NPK (T2) treatment (66.3 nuts per palm per year.

Arecanut: In arecanut garden, mixed cropping with pepper, banana and citrus was found to be economically advantageous in North-East Region. In Sub-Himalayan Terai Region, aster, marigold and gladiolus performed better under arecanut garden.

Cashew: The yield in high-density plots (416 and 500 trees/ha) was significantly higher (1.13 and 1.12 tonnes/ha, respectively) than in normal planting system (200 trees/ha) (0.72 tonnes/ha) 7 years after planting. Cashew yield was appreciably higher in coconut husk burial (2.04 tonnes/ha) and modified crescent bund treatments (2.03 tonnes/ ha) than in reverse terrace (1.94 tonnes/ha), catch pit (1.39 tonnes/ha) and the control (1.48 tonnes/ ha) treatments**.**

Potato: At Deesa, 75% recommended dose of NPK (full dose of P and K and half of N as basal and remaining half of N applied 30, 37, 44 and 51 days after planting) through drip fertigation is recommended as it saved 25% NPK fertilizers, increasing potato productivity. The drip system should be operated for 45 minutes during November - January and 65 minutes during February - March at alternate days with the discharge rate of 4 litres/ hour. Irrigation at 25-30 mm CPE and mulching with paddy straw or any other locally available organic mulch material @ 5 tonnes/ha is recommended for higher yield of potato.

Mushroom: An average yield of 14.07 kg of button mushroom per quintal compost prepared by using combination of INRA and Anglo Dutch methods, was obtained from the trial in 40 days of cropping. The tenth and eleventh organic crops of button mushroom were raised successfully with an average yield of 10.13 kg and 7.43 kg mushroom/quintal, respectively. While evaluating different strains of paddy straw mushroom, highest mushroom yield was recorded in strain, OE-274, followed by BBH-1. *Lentinula edodes* was cultivated successfully on wheat straw where spawn run was completed in 48 days.

Black pepper: Irrigating of pepper vines once in a fortnight from March to May @ 50 litres/

vine enhanced pepper yield substantially. The mean dry yield obtained was 6.8 kg/vine in irrigation treatment as against 3.25/kg vine under rainfed condition.

Ginger: The experimental results at Kumarganj indicated that foliar spray of 0.05% zinc sulphate (60 and 90 DAP), 0.2% of borax (60 and 90 DAP) and 1.0% of ferrous sulphate (60 and 90 DAP) increased the yield (55.53 q/ha) and quality.

Tuber crops: Organic manure sources, *viz*. vermicompost @ 3.91 tonnes/ha (tuber yield 31.42 tonnes/ha) and coir pith compost @ 4.6 tonnes/ha (27.04 tonnes/ha) were equally efficient as a substitute to FYM 12.5 tonnes/ha (30.97 tonnes/ha) in cassava. The INM was worked out for sweet potato at Kalyani, Rajendranagar, Udaipur and Dharwad. The INM has been developed for taro cultivation. Significantly highest tuber yield of sweet potato (10.72 tonnes/ha) was recorded with the application of lime + FYM + NPK + $ZnSO_4$ with a yield response of 15 % over that of FYM + NPK, closely followed by lime + FYM + NPK + $MgSO_4$ (10.65 tonnes/ha). Application of 50, 100 and 150 % of NPK showed an increase of 63, 138 and 136 % tuber yield of sweet potato over the control.

Orchid: Good quality flowers were obtained from 100% leaf mould in terms of highest survival rate (100%), plant height (36.2 cm), number of leaves (12.3), width of leaves (1.6) and girth of bulbs (1.9cm) compared to other growing media within six months. *Cymbidium* hybrid 'H. C. Aurora' under 30% shade with 50% water regime showed maximum vegetative growth and backbulbs formation. Total chlorophyll content was maximum in 0% shade with 25% water regime. Nutrient analysis showed that fully opened flowers contain higher amounts of N (0.95%) and potassium (0.54%) as compared to bud stage. In *Cymbidium* hybrid 'Spring King', the pH of leachate of growing media decreased with the progress of crop growth irrespective of treatments.

Elephant-foot yam: Organic farming continued its superiority for the fifth consecutive year, producing significantly higher corm yield (34.81 tonnes/ha). The crude protein content of organic corms was significantly higher. The INM schedule including biofertilizers gave higher corm yield in different centres.

Caradmom: Biofertilizers, *Azospirillum* and P-solubilizers, were found to increase growth and yield of cardamom. Application of 100% inorganic nitrogen + 50 g *Azospirillum* + 5 kg FYM or 100% inorganic phosphorus + 50 g *phosphobacteria* + 5 kg FYM was found very effective in increasing yield.

Honeybees and pollinators

Apple blooms were visited by *A. mellifera, A. cerana*, Syrphieds, butterflies and coleopterans but honey bees contribute significantly in apple pollination. In apple orchards, fruit setting was 26.2% when four colonies of *A. mellifera* in a hectare were introduced with fruit setting of 16.7% in orchards without introduction of honey bee colonies.

Seed production of radish: For seed crop of radish variety Pusa Chetki, siliqua, setting, seed setting, seed weight and seed yield were higher in open-pollination as compared to plants caged with colonies of *A. mellifera* having two entrances. For an efficient pollination, 5 colonies of *A. mellifera* each at 10 frames bee strength per hectare are required.

*Cucumber:*In cucumber, fruit setting of 74.9% was obtained through honey bee pollination, while it was 12.2% in open-pollination. The augmentation of 6 colonies of *A. mellifera* produced 21.80 fruits/plant, yielding 10.84 tonnes/ha as compared to open-pollination (8 tonnes/ha).

*Litchi:*The fruit setting was recorded 38.4% in open panicles where honey bees were main pollinators as compared to 0.4% in panicles which were caged to exclude insects pollinators.

*Champaka (*Eugenia jambos*):* The fruit setting in *A. cerana* augmented plants was 43.50% with average fruit weight of 60.61 g and fruit setting in cage plants was only 29.54% with average fruit weight of 46.83 g, whereas pollination by stingless bees produced 59.62% fruit setting with an average fruit weight of 113.5 g.

Winged bean: In *A. cerana* introduced plots fruit setting was 63.96%, whereas in stingless bees fruit setting was 83.16% as compared to plot which were not introduced by bee colonies (22.22% fruit setting).

*Mustard:*There was a significant increase in mean number of pods (114-128 pods/plant) as compared to self-pollinated (103 pods/plant) and seed weight and seed yield/plant due to augmentation of *Apis mellifera* colonies.

PROTECTION

Sugarcane: Post-emergence herbicide Glyphosate was found useful to manage weeds including *Cynodon* and nutgrass which are persistent in nature, in both plant and ratoon sugarcane.

Management of red rot: Thiophanate methyl, a systemic fungicide at 0.25% alone or 0.1% concentration along with *Pseudomonas fluorescens* as sett treatment effectively controlled debris borne inoculum of red rot pathogen. The treated plots recorded significantly higher cane population than the untreated plots.

Treatment of setts with salicylic acid (0.05%)

in combination with culture filtrates of *Trichoderma harzianum* or application of *Trichoderma harzianum* (2 kg nucleus culture multiplied on 20 kg sterilized sulphitation press mud for a week; mixed with 200 kg fresh press mud before application to cater one ha) in furrows at the time of planting gave higher protection (79-87%) to cane crop in challenge inoculation with red rot pathogen (*Colletotrichum falcatum).*

Tobacco: Application of Fluchloralin @ 1 litre/ha along with irrigation just before the emergence of Orobanche in December decreased the Orobanche infestation, increasing the cured leaf yield of *bidi* tobacco at Anand.Application of neem cake to FCV tobacco @ 40 g/plant was effective against root grub in light soils of Karnataka.

IPM module having castor and marigold as trap crops and one spray of NSKS 2% was affective against *S. litura* incidence in bidi tobacco at Anand.

Fibre crops: Non-selective herbicides namely Glyphosate @0.8-1.2 kg/ha +2% urea or Glyphosate @0.8-1.2 kg/ha + Paraquat 0.48 kg/ha or Glyphosate @0.8-1.2 kg/ha + 2% ammonium sulphate effectively controlled the composite weed flora in between jute, mesta and roselle seed crops having 30-45 cm row-row spacing. Application of herbicides like Glyphosate and Paraquat through herbicide applicator was equivalent to conventional manual weeding twice (45.8 q/ha). Six row nail weeder was found suitable for killing wide range of weeds at early stage (4 and 15 DAE).Butachlor @ 3 kg a.i./ha with irrigation effectively controlled wide range of weed in jute crop when applied 10 days before sowing of jute.

Mango: At CISH, Lucknow, 48 pathogenic isolates of *Colletotrichum gloeosporioides*, the causal agent of anthracnose disease of mango were collected and characterized on the basis of cultural and morphological characters. The hopper population was positively correlated with temperature and negatively with relative humidity. Methyl eugenol trap @ 4/ acre were found effective in monitoring the fruit fly population. Three sprays, i.e. first spray with Imidacloprid (0.005%), second with NSKE (5%) after 21 days of first spray and the need-based third spray with Endosulphan (0.07%), when fruits were at pea-sized stage, was found most effective for hopper control at most of the centres.

For control of mango anthracnose, combi product (Carbendazim 0.1%+ Mancozeb 0.2%), Chlorothalonil (0.2%) and Propineb (0.2%) reduced anthracnose significantly at different centres. The minimum temperature of 13-15ºC and maximum of 28-32ºC and low RH 54-65% were congenial for the appearance and development of diseases in inflorescence.

Litchi: At NRC for Litchi, Muzaffarpur, the IPM strategy for minimizing fruit drop at early stage and fruit damage at harvesting has been standardized with cleanliness of orchard, setting of pheromone trap (*Conopomorpha cremenella*) and application of Trico cards @50,000 eggs/ha at panicle emergence stage and spraying of *Kamdhenu Keet Niyantrak*/Nimbicidine/Endosulfan at peanut and colour-break stage of fruits.

Pruning of infested twigs/leaves during June, just after fruit harvesting, followed by spraying of Dicofol @0.05% twice at flush emergence during September-October at 7 days interval effectively controlled litchi mite.

Guava: Soil application of *Trichoderma viride* along with FYM applied in root zone was found effective in reducing the incidence of wilt at BCKV, Mohanpur.

Citrus: The population of citrus psylla, bark-eating caterpillar, leaf miner and mites become more serious causing heavy damages. Leaf miner in citrus was effectively controlled by spraying of Imidacloprid (0.005%) followed by NSKE (5%) / *Bacillus thuringiensis* (Bt) at 0.1 %. Acetamiprid (0.005%), Fenvalerate (0.005%), Imidacloprid (0.005%) and Triazophos (0.05%) were found to be consistently effective in the management of citrus psylla (*Diaphorina citri*) and aphids (*Toxoptera citricida*) at Chethalli and Ludhiana in different seasons. In citrus, *Phytophthora* induced gummosis, foot rot, root rot and bacterial canker have been reported as major diseases at most of the centres. Citrus yellow mosaic disease has been re-recorded in newer areas like different locations in Maharashtra. Application of *Pseudomonas fluorescens* (0.5%) along with FYM (25 kg / plant) and neem cake (2 kg / plant) was found better in reduction of dry root rot of citrus.

Spraying Streptomycin sulpahte (100 ppm) and COC (0.3%) was found better against citrus canker at Periyakulam and Tirupati, while at Pusa NSKE (2%) was found effective. The release of biocontrol agents, viz. *Mallada boninensis* Okamols and *Tamarixia radiata* (Waterston) in citrus orchards resulted in 31-33, 47-49 and 26-30% reduction of blackfly, psylla and leaf miner population, respectively. Among several bio-intensive pest management modules against citrus blackfly and psylla, the module with clean cultivation + *Mallada boninensis* released @ 30 larvae/tree + foliar spray of sweet flag (3%) + *Verticilliuim lecanii* @ 5g/litre of water + trap crop, *Murraya koenigii* on border laies was found to be more promising. Field evaluation of biopesticides against citrus leaf miner under nursery conditions revealed that Abamectin @ 0.32 ml/litre of water followed by Spinosad @ 0.34 ml/litre of water and Novaluron @ 0.87 ml/litre of water were found effective for the period of 15 days.

Banana: The volatile components were identified from corms of Nendran (12) and Poovan (13). The NRCB-Ma/24 recorded 100 % stem weevil mortality in banana stem traps smeared with the entomopathogen. For management of banana scarring beetle tilling and clean cultivation with spraying of Acephate (0.1125%), followed by bunch covering successfully controlled the pest at Mohanpur. At Coimbatore, *Pseudomonas fluorescens* as both sucker treatment and soil application (10g as sucker application + *Pseudomonas fluorescens* (2.5 kg + 50 kg FYM mixture) @ 20 g/sucker as soil application) was effective in suppressing nematode population, root and corm index with increased yield of 56% over the control. Both tissue culture/ sucker grown plants were affected with viruses. The BBrMV, BSV, *Fusarium* wilt, Sigatoka leaf spot and Erwinia head rot remain as major diseases, occurring in different parts of the country. Planting disease-free suckers + dipping suckers in Carbendazim (0.2%) for 45 minutes followed by Carbendazim drenching (0.2%) or injecting the same @3 ml of 2% solution (5^{th}, 7^{th}, 9^{th} month) proved to be best in controlling *Fusarium* wilt disease.

Six endophyte isolates, viz. 73YMD, 83PCC 50YR, 51KMD, 56GCTR and 77CAMD, recorded 91.3 - 98.1% inhibition of spore germination as compared to the control. An epiphyte isolate 60pbe recorded 90.8% inhibition of spore germination. The rDNA-ITS sequencing of 18 isolates of Sigatoka leaf spot pathogens confirmed the presence of *Mycospharella eumusae* isolate.

Grape: At NRC on Grapes, Pune, weather-based disease forecasting for major grape-growing regions of country and advisory for disease management are placed on Institute website and updated weekly. The advisory has received overwhelming response from grape growers. An electronic database is being developed for grapevine diseases and insect pests.

Pomegranate: Survey of bacterial blight (55% orchard affected) and pomegranate wilt (45% orchards affected) was conducted. Out of 63 germplasm accessions screened for bacterial blight resistance under field conditions, 6 were found partially resistant (Patna 5, Nana, 1C-1182, IC-1197, IC-1198 and IC-1205). In net house conditions**,** screening of germpalsm under net house conditions revealed 3 accessions /hybrids (K x R, N X R and Nana) to be totally free from bacterial blight. For management of wilt, *in vitro* studies revealed complete inhibition of *C. fimbriata* by antibiotic cycloheximide (100 and 200 ppm) and boric acid (0.1 and 0.2%), whereas bioformulation of *Trichoderma viride* (0.1 and 0.2%) was found significantly superior over the control.

At IIHR, Bangalore, 85 F_2 hybrids of pomegranate were screened under epiphytic conditions for reaction to bacterial blight. Under greenhouse conditions, 230 hybrids were artificially inoculated with *Xanthomonas axonopodis* pv. *punicae*. About 25 plants were resistant to moderately resistant and 15 were free of symptoms.

Ber: Application of Fenvalerate (0.005%), or Endosulfan (0.07%) along with Bayleton (0.1%) significantly reduced the incidence of fruit fly and fruit-borer in ber Gola and Umran. Bayleton (0.1%) and Sulfex (0.2%) were found effective in controlling powdery mildew on ber.

Coconut: Fourty fluoresent pseudomonad isolates were obtained from coconut leaf vermicompost, of which 34 produced IAA in varying quantities. Nine endophytic bacilli from coconut roots and 12 coconut rhizospheric bacilli were found to inhibit both *Thielaviopsis paradoxa* and *Ganoderma* sp.

The Nonnegative Constrained Least Square (NCLS) algorithm, sub pixel classifcation of root (wilt) affected palm in IRS P-6 satellite data map showed that, among 7 southern districts of Kerala, nearly 30% of the coconut land cover is affected by coconut root (wilt) disease.

Combined application of *Bacillus subtilis* + *Pseudomonas fluorescens* was found effective in the management treatment of leaf rot disease in coconut. Placement of Mancozeb sachets in leaf axils around spindle leaf has been found to be an effective prophylactic measure for bud rot on coconut. For managing stem bleeding disease of coconut, soil application of *Trichoderma harzianum* + *T. virens* and root feeding of Tridemorph were effective.

By releasing parasitoids, infestation on coconut leaf by leaf-eating caterpillar could be controlled effectively. Evaluation of talc-based formulation of two virulent strains of *Hirsutella thompsonii*, viz. CPCRI-19 and CPCRI-51(II) resulted in 74-82% mortality of coconut mite in treated buttons.

The release of egg/larvae predator, *Cardiastethus exiguus*, in the crown of 10 % of coconut palms in garden, @ 50 bugs / palm at 5 days interval for six times consecutively at egg-early larval stages of coconut black headed caterpillar (*Opisina arenosella)* gave effective control of the pest in Tamil Nadu and Andhra Pradesh.

Cashew: The *Tribolium castaneum* and *Ephestia cautella* were found to be the common storage insect pests noticed in cashew processing units surveyed in Tamil nadu, Goa and Kerala. At Bapatla, Triazophos (0.1%) was significantly superior against inflorescence thrips followed by Profenofos (0.05%) which recorded a damage score of 0.46 and 0.64, respectively. Profenophos could effectively check the damage by leaf caterpillar,

leaf miner and thrips at Jagdalpur. The ë-cyhalothrin was effective in managing tea mosquito bug, thrips and apple and nut-borer at Vengurla and Vridhachalam. Chloropyriphos (0.2%) was the best treatment resulting in 100% of the treated trees without reinfestation by cashew stem and root-borer (CSRB) at Vengurle and Jhargram and 86% at Bhubaneswar, 78.38% at Chintamani and 72.73% at Jagdalpur.

Pest on TPS: A *Tribolium castaneum* Herb. has been identified as a new pest of untreated one-year-old true potato seed (TPS) stored in cloth bag. The infected TPS could not germinate in the field, resulting in severe loss in seedling establishment in nursery beds. Adult female lays about 400-500 clear white sticky eggs scattering them in the flour or foodstuffs. The eggs hatch in about 4-12 days into small brownish-white grubs, which are fully grown in 27-90 days under favourable condition and then pupate. The pupae are white in colour and pupal period ranges from 1 to 2 weeks. The pupae hatch into adults, which normally live for about six weeks.

Cardamom: Fifty-eight cardamom accessions were screened for leaf blight, rhizome rot and leaf blotch resistance under natural field conditions. The IC- 349646 was found to be resistant with an average leaf blight incidence of 20%. Twenty-three accessions exhibited highly resistant reaction to rhizome rot disease.

Turmeric: Maximum disease reduction of rhizome rot was observed with Metalaxyl-Mancozeb (44.5%) followed by copper oxychloride (36.5 %) compared to the control. *Apanteles taragamme*, an un-identified hymenopterous parasitoid and earwigs, were documented as natural enemies of shoot-borer (*Conogethes punctiferalis*) infesting turmeric. Four strains of entomopathogenic nematodes were isolated from 71 soil samples collected from rhizosphere of ginger and turmeric. Of these, one strain each was tentatively identified as *Heterorhabditis* sp. and *Steinernema* sp.

Ginger: Soft rot of ginger could be controlled by bio-fumigation using cabbage and mustard plant refuses. The bio-fumigation using cabbage increased germination and yield (8.5 kg/plot) by decreasing soft rot (2.25%) and bacterial wilt incidence.

Cumin: Spraying of Mancozeb @ 0.25% at 40, 50, 60 and 70 DAS was found to be effective in controlling blight. Soil solarization + soil application of *Trichoderma harzianum* + spraying of Mancozeb @ 0.25% at 60 DAS and application of vermicompost + soil application of *T. harzianum* + spraying of Mancozeb @ 0.25% at 60 DAS were also effective for controlling the disease.

Orchid: Anthracnose disease caused by *Colletotrichum gloeosporioides* was found to infect seriously in *Phalaenopsis* and *Cattleya* hybrids. Application of Mancozeb (200 – 500 ppm) + Carbendazim (200 – 500 ppm) reduced the infection of anthracnose. The black spot disease caused by *Aternaria alternata* was observed on leaves of *Coelogyne* and *Thunia* .

Tuber crops: Marigold and yam bean were found to be effective barrier crops for sweet potato weevil. Bio-intensive management of taro leaf blight was found to be effective in suppression of disease, increasing cormel yield at Dapoli, Dholi, Kalyani, Raipur and Rajendranagar. IDM package for elephant-foot yam was found to be effective in suppressing the diseases and enhancing corm yield. Yam bean seed extract was found to be effective as a biopesticide against aphids and leaf-eating caterpillars. Sweet potato weevil was found in all sweet-potato growing areas. Sweet potato viruses were also noticed in certain areas. Cassava mosaic occurring in serious proportions in Tamil Nadu, Kerala and Andhra Pradesh, was also observed in Faizabad. Taro leaf blight and elephant-foot yam diseases were found common in all taro-growing areas.

Mushroom:Various plant extracts, certain oils and two commercial formulations of neem were evaluated against *Mycogone perniciosa*. The *Tegets erecta* extract caused 27.34% inhibition of mycelial growth, whereas oils of *Allium cepa*, *Trachysepermum ammi*, *Nigella sativa* and *Coriandrum sativum* caused 100% inhibition of mycelial growth of *M.perniciosa*.

The studies of Carbendazim in processed and marketable mushrooms reduced to 28.6% from 81.9% in different mushrooms by simple washing. The nucleotide sequence comparisons of 5.8S rRNA identified 15 *Cladobotryum* isolates, into three taxa, viz. *C.dendroides*, *C.mycophilum* and *C.asterophorum*.

Integrated Pest Management

Parasitoids on Mealy Bug: Two new parasitoids, *Promuscidea unfasciativentris* Girault (Chalcidoidea: Aphelinidae) and *Aenasius bambawalei* (Chalcidoidea: Encyrtidae), were recorded, parasitizing *Phenacoccus solenopsis* on cotton and *Parthenium* in Maharashtra and Delhi, respectively. The parasitization on cotton as well as on weeds ranged from 20 to 70%. Hymenopterous parasitoid on mealy bug were found in Gujarat and Maharashtra. Entomo-pathogen, *Fusarium pallidoroseum*, was also isolated from mealy bug (*P. solenopsis*) cadavers collected from Haryana and Maharashtra. This pathogen was a key mortality factor of mealy bug in Punjab.

Weekly data on mealy bug was electronically

collected from 320 villages of eight districts in Punjab and was processed and put on the institute website for use by policy-makers as well as State Agriculture Department personnel for identifying hot spots and issuing advisories.

Database and information system on IPM: The NCIPM has initiated development of Plant Protection Personnel Information System (P3IS) and web-based crop-pest database and redesigning institute website under NAIP AGROWEB-ADDSIAR project. P3IS is a database of profiles of plant protection personnel of different disciplines provide information about human resources of plant protection. Online information module of system has been developed and loaded on the institute's website **(URL: www.ncipm.org.in/p3is/startpage.aspx)**. Development of web-based crop-pest database, information on key pests of 65 crops on different parameters have been collected and fed into the MS access database. The web-based user interface for accessing the pest information of different crops is in progress.

IPM / IRM strategies: The on-farm trials were conducted in Burj Bhangu village of Sirsa, Haryana, with hybrid RCH 134 Bt in one acre area and included sowing with two border rows of pigeonpea, pheromone traps for all bollworms, yellow sticky traps for whitefly and application of neem oil and Imidacloprid for sucking pests and Profenophos for mealy bugs. Recommended package of practices (RPP) included three applications of noital Thiomethoxam, Acephate and Imidacloprid for sap sucking pests and three Profenophos for mealy bugs. The results indicated that mean seed cotton yield was 2.73 tonnes/ha in IPM/IRM against 2.36 tonnes/ha in RPP field. The cost: benefit ratio in IPM field was 1:4.43 as against 1:3.65 in RPP field.

IPM technologies in vegetables: The IPM technology was developed and validated in bell pepper in village Daha, Karnal district, Haryana, in 10 acres, which resulted in reduction of number of sprays to 5-6 from 13-14, increasing yield up to 14.1 tonnes/ha from 12.2 tonnes/ha with farmers' practices, respectively with higher cost:benefit ratio of 1:2.99 in IPM compared to 1:2.48 with farmers' practice respectively.

The curd yield of cauliflower and head yield of cabbage were higher in IPM fields as compared with farmers' practices by 13-15%. Net returns for cauliflower in *kharif* season were Rs 1,22,958-1,68,111/ha in IPM fields and Rs 90,143-1,18,740/ha with farmers' practices. In late *rabi* season, net returns were Rs 88,820/ha in IPM as compared to Rs 70,620/ha with farmers' practices.

Agriculturally Important Insects

Potential predator: A neuropteran predator (*Micromus timidus)* with potential for biocontrol of sugarcane woolly aphid and *Aphis craccivora* has been identified and being exploited through conservation ecology of sugarcane agro-ecosystem.

Biocontrol potential of natural enemies: Two species of symbiotic yeasts namely *Pichia anomala* and *Candida apicola* capable of increasing the fecundity of *Trichogramma japonicum* have been identified and utilised in the diet of parasitoids in rearing protocol.

Strain of *Cryptolaemous montrouzieri* tolerant to Acephate has been identified. Populations of *Goniozus nephantidis* and *Cotesia flavipes* with higher biological parameters like higher adult emergence and sex ratio in favour of females have been studied.

Endophytic bacteria for disease management: Four endophytic bacteria were isolated from healthy pigeonpea plants. Of them, 3 were gram positive and one gram negative. Two isolates showed 40-48% inhibition of *Sclerotium rolfsii* under *in vitro* conditions.

Entomopathogenic and plant parasitic nematodes: Integrated use of talc formulations of antagonistic fungi with crop-soil sterilization (formaldehyde) in capsicum and tomato in polyhouses at Denkinkotai, Hosur, reduced the incidence of nematode-root wilt disease complex by 64% in treated beds compared to untreated ones.

Biological control of nematodes: The antagonistic fungi against reniform nematode (*Rotylenchulus reniformis)* in red gram (var. Vipula) in *kharif* 2008 at Rahuri revealed that combined application of *Trichoderma harzianum* @ 5 kg/ha and *Pochonia chlamydosporia* @ 20 kg/ha was most effective in reducing reniform nematode female population (15.6), increasing the yield of pigeonpea (1,750 kg/ha). The cost: benefit ratio was 1: 1.92.

Biological suppression of sugarcane pests: Large scale demonstration of effectiveness of *Trichogramma chilonis* against Plassey-borer was carried out at farmers' fields on Co BLN 9605 variety in 10 ha. Nine releases of *T. chilonis* @ 50,000/ha/release at 10 days interval from second week of July to first week of October, 2008 resulted in significant reduction of infested cane and higher cane yield (84,450 kg/ha) than at farmers' fields.

Biological control of rice pests: In Punjab, two field demonstrations on use of biological IPM package on organic rice revealed a higher net return of Rs 1,12,798/ha compared to farmers' fields (Rs 98,188).

Biological control of mango hoppers: Off-season spraying of *Metarhizium anisopliae* @ 1 x 10^7 spores/ml on trunk during November and one spray during flowering period reduced mango hopper (*Idioscopus nitidulus)* incidence on mango.

SUCCESS STORY

Root-knot nematode management

Rice root-knot nematode, a pest on rice-wheat cropping system, has spread in south-west Haryana. In Badesara village (Bhiwani), farmers could only harvest paddy @ 7 q/ha during 2005-06; and increased paddy yield up to 21.5 q/ha. Poor management in nursery as well as in the main field, application of imbalanced fertilizer doses were recognised as predisposing nematode attack in paddy. In another farmer's field, Carbofuran was applied @ 1.5 kg a.i./ha during 2006-07 for management of rice root-knot nematode which increased paddy yield up to 55 q/ha.

In Tamil Nadu, application of *Verticillium lecanii* @ 1 x 10^9 spores/ml on tree trunk during off-season and one spray on shoots reduced the hoppers significantly.

Plant Parasitic Nematodes

Yield losses of 18% due to *Meloidogyne graminicola* in paddy, 27% due to *Meloidogyne* spp. in vegetable crops; 16% due to *Radopholus similis* in banana and 10% due to *Meloidgoyne incognita* in pomegranate in hot spot areas were estimated in Karnataka.

Inclusion of crop rotation with onion, garlic, potato and cauliflower in suitable cropping sequences led to reduction in population of root-knot nematode in vegetable-based cropping systems. While in summer, crop rotation of okra-potato-clusterbean led to maximum reduction in root-knot nematode population followed by okra, cauliflower and clusterbean.

Hot water treatment at 5^0 C for 30 minutes followed by foliar spraying of Carbosulfan @ 0.1% 40 days after transplanting reduced white tip nematode by 34%, increasing rice yield by 87% over untreated control.

Lesion nematode (*Pratylenchus thornei)* on chickpea was managed by seed treatment with neem seed kernel powder + *Trichoderma viride* both @ 5 g/kg seed, decreasing nematode population by 67% and enhancing the yield by 53.5% over untreated control. The same treatment against pigeonpea cyst nematode, *Heterodera cajani*, on pigeonpea was effective, resulting in significant reduction in nematode population and enhancing of yield and nodulation.

Intercropping of greengram with sesamum was effective in reducing root-knot nematode, enhancing the yield by 19.18%.

Reniform nematode (*Rotylenchulus reniformis)* on cowpea was managed by seed dressing with neem-seed kernel powder @ 10 g/kg seed, increasing the yield by 19% over untreated control.

Reniform nematode infecting blackgram was managed with the soil application of *Trichoderma harzianum* @ 2.5 kg/ha + *Pochonia chlmydosporia* @10 kg/ha, increasing the yield by 13.5% over untreated control in Rajasthan.

Root-knot nematode along with *Sclerotium rolfsii* complex on groundnut was managed with the seed treatment of *Pseudomonas fluorescens* @ 20 g/kg of seed and furrow application of *Pseudomonas fluorescnes* @ 2.5 kg/ha, increasing pod yield, with reduced stem rot and root-knot nematode disease.

Citrus nematode, *Tylenchulus semipenetrans*, on citrus was successfully managed by using Carbofuran @ 1 kg a.i./ha, reducting nematode population by 38.4% and enhancing the yield by 32%. Further, *Pochonia chlmydosporia* @ 20 kg/ha was also effective in reducing nematode by 26.7%, enhancing yield by 27.5% over untreated control at Hisar.

Treatment combination of paring and hot water at 55^0C for 20 minutes to banana rhizomes against root-knot nematode followed by field application of Carbofuran @ 0.3 g a.i./ha + neem cake @ 1 kg/plant significantly reduced the root-knot nematode by 40.6%, increasing banana fruit yield by 43.4% over untreated control at Anand. This treatment was also effective against burrowing nematode, lesion nematode and *Helicotylenchus multicinctus* nematode complex on banana in Kerala and Karnataka.

Pesticide residues: There were no residues of Imidacloprid 200 SL on chilli when applied thrice at 10 days interval at 50 and 100 g a.i/ha at Jaipur, Rahuri, Kalyani and Vellayani in red chillies at harvesting (36 days after last spray) and soil 20 days after application. Half life of Imidacloprid in chilli fruits were estimated as 1.027 days. Dissipation / persistence of combi-formulation Trifloxystrobin (25 %) and Tebuconazole (50 %)-75 WG on apple were studied at four locations. None of the residues was detectable in apple fruits and soil at harvesting after two foliar applications of formulation given @ (100+200) and (200+400) g a.i./ha, 40 days before harvesting. When four applications of the same formulation was applied on grape @ 175 and 350 g/ha, residues of Trifloxystrobin (25 %), its metabolite or Tebuconazole (50 %)-75 WG were found to dissipate below detectable level of 0.01 mg/kg in 15 days at recommended dosage.

Foliar sprays of Quizalofop-ethyl (5 % EC) on blackgram given at 50 and 100 g/ha at Anand, Ludhiana and Kalyani did not show presence of any residues at harvesting, i.e. after 94 days of spray. On onion crop, Quizalofop-ethyl 5 % EC residues in onion bulbs were not detectable on

5th day of sampling when applied at 50 and 100 g/ha . Harvest time resideus of combi-formulation of Flusilazole (12.5 %) and Carbendazim (25%)-37.5% SE on paddy crop were below detectable limit when the formulation was applied at 960 and 1920 ml/ha.

For the fixation of maximum residue limit (MRL) of deemed registered pesticides supervised field trials have been conducted for Carbaryl on grape and sesame; Phorate on cotton and cowpea; Quinalphos on Bengal gram, brinjal, cabbage, cauliflower, cotton, onion, groundnut, paddy and potato; Zineb on turmeric; methyl-parathion on blackgram and cotton; mancozeb on ginger, cauliflower and potato.

The modified Quick, Easy, Cheap, Effective, Rugged, Simple (QuEChERS) method for pesticide residue analysis in fruits, vegetables, cereals, pulses, tea, etc. was developed and validated.

White grubs and soil arthropods

Lepidiota mansueta has also appeared as a severe key pest of potato, sugarcane, blackgram and Colocasia affecting almost ten villages in Majuli of Jorhat district of Assam. The *Lepidiota stigma* was observed to damage maize in Himachal Pradesh; due to its biennial life-cycle heavy crop damage has been observed in alternate years. In Rajasthan, *Holotrichia consanguinea* was found to be predominant species, infesting almost all *kharif* crops. In some parts of Western Rajasthan (Bikaner Division), *Maladera insanabilis* was observed to cause damage to groundnut crop.

Seven new species of scarab beetles, *viz. Anomala perplexa, Lepidiota mansueta, Maladera insanabilis, Schizonycha ruficollis, Adoretus versutus, Brahmina coriacea, Adoretus bomblinota*, were identified from Asom. Among 35 species of whitegrub recorded in Uttarakhand hill, *Holotrichia longipennis* Blanch. was recorded as predominating species, followed by *Anomala lineatopennis, Anomala demideata* and *Brahmina coriaceae.* Sugarcane producing blocks of Haridwar districts were infested with *Lepidiota mansueta* Burmeister. The bio-ecology study of this white grub sp. revealed that life-cycle is completed in two years.

Brahmina crinicollis was found to cause extensive damage in pear orchards. Adult beetles feed on flowers and reduced fruit setting. On a single inflorescence, 10-15 beetles congregated, flowers were completely destroyed. Maximum emergence of beetles occurred in March.

The *H. serrata* is being reported as a pest of sugarcane in several parts of Kanataka after nearly 35 years of a mass campaign carried out to control this pest in Belgaum dstrict. Unusual emergence of *H. reynaudi* was recorded 15 years after its successful management in Tumkur district.

Healthy and milky white diseases affected *Leucopholis lepidophora* larvae collected from field

SUCCESS STORY

Management of white grubs

Success with *in vitro* production has been achieved with *Paenibacillus popilliae* Dutky that is a spore forming bacterium to cause milky white disease in white grubs. *P. popillae* is not easily amenable for *in vitro* culturing. As many as 16 local isolates have been collected from the field infected grubs in Karnataka. The bacterium could be successfully cultured on an artificial medium with proline, charcoal and an antifoaming agent such as pig fat as the important components. An average of 2.9 to 4.2 × 10^7 sporangia per ml could be produced on this medium. The sporangia produced by *in vitro* method when tested for their infectivity against the III instar larvae of *Holotrichia serrata* and *Leucopholis lepidophora*, could cause milky white disease in both these species. Further work should provide a technology based on this bacterium to manage arecanut and sugarcane white grubs.

White grub management campaign: The beetles of white grub start emerging and aggregate on host plants, especially on neem from mid-May after some pre-monsoon rains; emergence continues in June-July. Collaborative programme on management of white grubs in western Uttar Pradesh on a community basis with a sugar mill is in place. All the neem trees in all the 40 villages were provided with aggregating pheromone and sprayed with Chlorpyriphos/ Imidacloprid. The large-scale campaign in the target area resulted in huge beetle collection and in a sharp decline in the grub population, reducing the infestation to negligible extent in sugarcane.

Agricultural acarology

The rice panicle mite, *Steneotarsonemus spinki*, has been observed as one of the major mite pests in West Bengal, reducing 25-30% yield in lET-4094 and lET-4786. Low mite population was observed on rice variety, Masuri. Maximum reduction in rice panicle mite population was observed in Dicofol treated plots, followed by

Propargite, Fenazaquin and Carbofuran treated plots. The application of Propargite (0.05%) was better than Dicofol (0.05%), wettable sulphur (0.125%) and ethion (0.1%) in reducing mite damage.

Out of 25 varieties investigated for reaction to panicle mite, *Steneotarsonemus spinki*, at Mandya in Karnataka, no variety was completely free from tarsonemid mite damage on flag leaf sheath. Mean sheath mite population recorded on different varieties ranged from 0 to 134.3 per flag leaf sheath. Varieties like CTH 1, BPT 5204, KHRS 26, lET 7191, KHP 2 and Shakthi recorded <10 cm length of leaf sheath discolouration with lower mite damage (<2%).

The extent of loss of dry chilli due to yellow mite infestation was 11.39% in Guntur variety and 18.56% in *Byadgi Kaddi* in Karnataka. Byadgi Kaddi variety recorded more number of mites as well as more mite damage compared to Guntur. Screening of chilli lines for reaction against yellow mite, *Polyphagotarsonemus latus*, revealed that PBC-61, Udaipur-2, BVC-47 and BVC-53 were free from yellow mite infestation.

Pesticide resistance in *Tetranychus urticae* was monitored in Kolar and Bangalore districts. Resistance to Dicofol was high, compared to wettable sulphur, Fenazaquin, Propargite and Diafenthiuron. The level of resistance to all pesticides showed a gradual increase in a cropping season as evidenced by bioassays carried out at monthly or bimonthly intervals. Monitoring of resistance level in mites to acaricides has shown that *Tetranychus urticae* has developed 1.5 fold, resistance to Dicofol at Navsari, 1.6 fold at Wada, 1.9 fold at Dungri, and 2.7 fold at Sandhier in Gujarat.

Investigations on biological control of spider mite, *T. urticae*, using Phytoseiid predator, *Neoseilus longispinosus* clearly indicated that Frenchbean plants provided optimum food for spider mites up to 50 days and hence the prey mites can be mass produced on Frenchbean plants up to 50 days. When 20 days old Frenchbean plants were infested with 5 spider mites per leaflet and with prey : predator ratio of 100:1, maximum number of predators (up to 125 per leaflet) could be harvested when Frenchbean plants were 65 days old.

Propargite 57 EC at 850 g ai/ha significantly reduced yellow mite on chilli after three rounds of spraying with increased yield of 24.01 tonnes of green chilli fruits/ha. Spiromesifen 96 g ai/ha, Diafenthiuron 450 g ai/ha, Milbemectin, 4 g ai/ha, Chlorfenapyr 75g ai/ha and Fenazaquin (125g ai/ha) were significantly more effective in reducing yellow mite population in chilli up to 14 days after each application. Effectiveness of mineral oil at 1 % was more evident with second application when the yellow mite population became low and it was next to synthetic insecticides in effectiveness.

Chilli lines tolerant to mite in Karnataka were: PBC 631, Udaipur-2, BVC-47, CA-14, 7A, 8A X CA14, CMS 2B, PJ X 8O, CMS 7A, CMS8A, CMS6B, CMS 6A and CMS7B. Chilli lines Suryamukhi 4, Canning Suryamukhi 6 and 7, Suryamukhi Bullet 5 and 6, Canning Bullet 3, BC-CH-SL-4, Black Cluster, CH-1, K-1, CO-3 and CO-4 showed moderate resistance to *Polyphagatarsonemus latus* lower yellow mite infestation in CA-71, CH3, CO3, CH1, Punjab Surkh and BC-CH-SL-4 lines of chilli

Okra varieties, AOL-04-U2 and JOL-05-07, were found tolerant or less susceptible to spider mite, *T. macfarlanei* due to low leaf hair density in Gujarat.

The efficacy of horticultural mineral oil at 0.75-1%, was modest with 62% reduction in spider mite population on okra. The effectiveness of mineral oil (causing 80% reduction) on chilli against yellow mite was comparable to that of newer chemical acaricides.

At Kalyani, *T. urticae* tolerant varieties have been identified in pointed gourd (BCPG-5), cowpea (Shwetha and Lola) and okra (P-7 and DSU-1), recording less number of mites on leaves.

Application of Fenazaquin (@125 g ai/ha), Propargite (@570 g ai/ha) and Diafenthiuron (@400 g ai/ha) offered significant control of spider mite on brinjal at Ludhiana for two weeks.

Rice sheath mite (*Steneotarsonemus spinki*) infestation, much noticed in the east-cost states, was more significantly checked with application of Propargite (0.05%).

The application of mustard cake and glyricidia leaf compost were found more promising over newer acaricides against *Steneotarsonemus spinki* on rice in West Bengal.

Holistic nutrient management in coconut gardens with FYM, recommended NPK fertilizers and micronutrients like boron, zinc, calcium and sulphur, neem cake and root feeding of azadirachtin, reduced mite infestation, improving nut yield in Karnataka, Tamil Nadu and Gujarat. Abamectin/ Milbemectin @4-5g ai/ha, Diafenthiuron @450g ai/ha, Chlorfenpyr @75g ai/ha, Propargite @570g ai/ha, Fenpyroximate @30g ai/ha and Fenazaquin @125g ai/ha were used against insecticide-resistant *T. urticae* on tomato crop.

The *Bt* cotton accessions were found severely infested by yellow mite while some *Bt* brinjal entries in Ludhiana recorded severe infestation of spider mite (*T. urticae*).

Successful and economic mass production of both prey mite (*T. urticae*) and its potential obligate phytoseiid predator (*Neoseiulus longispinosus*)

using Frenchbean plants has been demonstrated. When *Neoseiulus longispinosus* was released at 1:50 and 1:100 (predator: prey) ratios caused complete elimination of spider mite on polyhouse roses in 2-3 weeks.

In IPM experiments, application of Abamectin was detrimental to *Neoseiulus longispinosus* predator at least for one week. Potentiality of insect predators like *Stethorus pauperculus, Scolothrips* sp. and of *Chrysoperla carnea* was good at Coimbatore .

Check list of phytoseiid mite fauna prepared for four agroclimatic regions in southern Karnataka comprises 51 species under 14 genera. Predatory phytoseiid genera, *Amblyseius* and *Typhlodromus*, were found abundant in Himachal Pradesh and Punjab on pear, peach, plum, kinnow, litchi, pomegranate, mango and apricot apart from field and vegetable crops.

Agricultural Ornithology

Bird damage: In rice, Indian Peafowl (*Pavo cristatus*), Teals and Common Moorhen (*Gallinula cloropus*) caused damage 10.0, 5.0 and 12.0 respectively. While in wheat fields during sowing stage, migratory Shot-toed lark (*Calandrella cinerea*) and Calendar Lark (*Melanocorypha calandra*) caused damage to the sown seed up to 90%, compelling some farmers to re-sow their fields in Gujarat. In maize, hose-ringed parakeet caused damage up to 40% in Andhra Pradesh, while in sorghum bird damage ranged from 5 to 25% mostly by Rose-ringed Parakeet, Common Myna and unias (*Ploceus* species). After harvesting of groundnut, about 100kg/ha grains remained in fields as spillage. Several species of birds, viz. Demoiselle Crane Anthropoides Virgo, Black Ibis, Blue Rock Pigeon, Indian Ring Dove and Rosy Pastor fed on these grains.

Eco-friendly bird management: In Punjab, combined effect of reflective ribbon, manual drumming and scare crows was found effective (>95%) from bird attack for 18 sunny days at milky stage. The IPM at farmers' fields, different management modules during *kharif* consisting of net (1,471kg/ha) reflective ribbon (1,361kg/ha) and botanical spray (1,305kg/ha) proved effective in controlling bird damage in sorghum over the control (912kg/ha).

Birds like, Small Green Barbet (*Megalaima viridis*), White Cheeked Bulbul (*Pycnotus jocosus*) and Tree pie (*Dendrocitta vagabunda*) helped in the propogation of the recently surging *Momordica dioica*, a cucurbitaceous climber weed in agriculturre. The seed found in excreta of these birds readily germinated unlike the seeds harvested manually.

Role of beneficial birds in IPM: Fourteen species of insectivorous birds controlled rice insect pest, recording higher yield in experimental plot (3,215 kg/ha) than the control (1,895kg/ha). The IPM module consisting of HDP net, T-shaped perches and NPV were used to control *Helicoverpa armigera* larvae, from which T-shaped perches with NPV proved effective in controlling medium and large-sized larvae in pigeonpea in Gujarat. In castor, 22 species of birds controlled 48% of *Spodaptera litura*, while in Kerala Crow Pheasant (C*entropus sinenis*) devoured 5% of stem-borer larvae in cardamon and termites were voraciously fed by common crow (C*orvus splendens*). In tomato, 11 species of insectivorous birds reduced 25% of *Helicovepa armigera* larvae, while in chickpea 8 species of birds reduced 20-23% of *H. armigera*.

In muskmelon, watermelon and bitter gourd crops, artificial perches attracted 6-13 species of birds. Standardized nest boxes design for cavity nesting birds and succeeded in breeding success of 14 species of birds. The comparative studies on feeding behaviour of 3 species of owls Barn owl, *Tyto alba*, Fish eating owl, *Bubo flavipes* and spotted owlet *Athene brama* revealed that rodent remnants (82%) in Barn owl diet, crab remnant(65%) in Fish owl and insecta (60%) in Spotted Owlet were found throughout the season.

Insect biosystematics: Exploration of insect and mite biodiversity led to surveys in 19 states and 86 districts of India, covering all the important *kharif* agro-ecosystems. These have led to collection of 72,343 specimens of major insect and mite groups. Majority of these have been processed for biosystematic studies. These collections have

SUCCESS STORY

Rodent control campaign

Based on knowledge, attitude and practice (KAP) analysis, farmers' awareness through trainings, field demonstrations rodent control campaigns was organized on community basis in 80.0 ha cropped area in Penumachili village of Achata Mandal, West Godavari district. On the basis of mean live burrow counts, the bait requirement for the block was arrived. Bromodiolone (0.005%) poison bait was prepared by involving the farmwomen at temple centre of the village and the bait was made into packets of 10g each and applied @ one packet / burrow, covering field bunds, canal bunds and farmhouses. Rodent control success of 84.81 % in *kharif* and 90.58% in *rabi* was achieved in the village. As a result, farmers harvested an additional yield of 240.5 kg/ha in *kharif* and 202 kg/ha in *rabi.* Farmers were benefited with Rs 50 in *kharif* and Rs 54 in *rabi* for every one rupee spent towards rodent

taken the accessions of agriculturally important insect and mite biodiversity to more than half a million. More than 90 % of these had been taxonomically characterized and subjected to morphological studies.

The biosystematic studies have led to morphological characterization of 280 species under 50 genera of insects and mites of agricultural importance. These comprise more than 802 illustrations and photographs on taxonomic characters and field diagnostics. The highlight of these studies includes description of 53 new species of insects and mites of agricultural importance and a large number of parasitoids of biological control significance. These include description of two new species of mites, namely *Acalitus delhiensis* and *Cosetacus sharadi* published in a high impact factor international journal Zootaxa; diagnostics of lepidopterous pests of vegetables, in particular, the Pieridae; ecological observations on the outbreak of migratory locust *Locusta migratoria migratorioides* in the cold desert agro-ecosystems of Leh, Ladakh; revisionary studies on three genera of Coccinellidae and Chalcidoidea; updating and digitizing of computerized databases of identified insect collections at National Bureau of Agriculturally Important Insects and the National Pusa Collection at IARI; and preparation of illustrated diagnostic keys for the families of major insect and mite groups occurring in different agro-ecosystems of India.

Rodent damage vis-à-vis commensalization of field rodents

Indian gerbil, *Tatera indica*, essentially a field rodent species established its population in residential and grain storage areas. The gerbil species had shown predominance round the year with 57-85% share (mean 66%), followed by *Rattus rattus* (mean 34%). In Punjab, trappings carried out during August-September revealed the presence of *B. bengalensis* along with *R. rattus* in human inhabitations indicating commensalization of *B. bengalensis*. Its commensalization was also seen in residential premises including grain storage in both rural and urban areas (26.19%) of Assam, potentially threatening food security.

Rodent damage and behaviour

Bait shyness in *T. indica* and *F. pennanti:* Zinc phosphide induced bait shyness in *T. indica* persisted for 73-75 days at mean temperature of 31° C, which was reduced to 50 days at 21° C. The younger gerbils (<100g-body weight) recovered the shyness behaviour earlier to older ones. Similarly, in case of *F. pennanti* shyness behaviour lasted for 20-25 days.

Rodent abundance vis-à-vis mulching: The mulched fields encouraged higher rodent population in Assam. Maximum rodent abundance (4.67 burrows/20 m^2) and damage (11.65%) were recorded in water hyacinth mulched and intercropping with pumpkin as compared to 0.33 burrows/20 m^2, in the control.

Rodent damage: Rats and squirrels inflicted about 54.2% pod damage to cocoa, intercropped in coconut orchards. In South Andaman, rodent damage was observed preferably to young and tender coconuts in both dwarf and tall varieties. The damage of 8.57-26.67% was observed in all coconut-growing areas of South Andamans. In Asom, rice grown as *Bao* suffered maximum rodent damage (13.75%), followed by sugarcane (11.33%), pea (9.43%), rice grown as *Sali* (9.02%) and potato (8.98%). *Rabi* vegetables also suffered up to 9.89 % in pumpkin and 6.59 % in bottle gourd.

Rodent management strategies

Leaf powders of *Vitex nigundi* and *Polygonum* treated food recorded least preference by *Rattus rattus* in laboratory, indicating anti-rodent properties. Field trials with castor-based herbal repellent showed higher repellency against rice rodents, followed by castor oil *10%* and pongamia oil *10%* in Godawari delta region. Five days exposure of bait containing 0.1% eucalyptus oil to *B. bengalensis* revealed repellent effect of eucalyptus oil. Oral intubations @ 40 and 80 mg/kg dosage of pure gossypol and 100 and 200 mg/kg of seed extracted gossypol did not cause any toxic and antifertility effects in *B. bengalensis*.

Feeding trials with a plant origin compound, 'Bio' containig glucosides of *Tripterygium wilfordii* in noodle formulation (0.25%) is being done.

Single oral administration of three doses of triptolide to male *R. rattus* revealed no mortality at 50 mg/kg dose. However, at 100 and 150 mg/kg, it resulted in 16.67 and 33.33% mortality within 1-3 days. Sperm mortility, viability and morphology were found affected.

Application of zinc phosphide through plastic cover at tillering and maturity stage, removal of bushes and weeds, trimming and cleaning of bunds at monthly interval resulted 62.68 and 70.96% reduction in crop damage and rodent population, respectively. In Assam, trapping with cage trap@40/ha at maximum tillering stage followed by one application of 2% zinc phosphide baiting at panicle initiation stage could effectively control *Bandicota bengalensis* in irrigated *Boro* paddy. Per cent control success was more where bait was kept in paper bags.

Recommendation on modification in critical

timings of rodent pest management in groundnut crop has been included in package of practices for *kharif* crops of PAU, Ludhiana. Encapsulation of zinc phosphide in bait form has been successfully attempted.

Bamboo flowering and rodent problem in NEH Region: Gregarious flowering of *Melocanna bacifera* was reported in all the three Garo Hill districts and West Khasi Hills of Meghalaya and Assam. There was no sign of upsurge of rodent population in Meghalaya as rodent damage to almost all crops in bamboo flowering areas was normal except certain locations, where slight increase in damage was reported in paddy and maize. Feeding of bamboo fruits did not show any effect on reproductive parameters of rats under laboratory condition.

Under arid farming systems, double baiting by integrating acute and chronic rodenticides fetched highest rodent control success in pearlmillet and in moth on 15th DAT. Double baiting seemed to have an edge due to quicker and sustained management of rodent pests.

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