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Crop Management

PRODUCTION

Rice: System of Rice Intensification and Integrated Crop Management resulted in increase of grain yield over standard transplanting. Penoxsulam 24 SC at 0.250 kg a.i./ha as pre-emergence or post-emergence effectively controlled broad spectrum of weeds.

Under the irrigated ecology, rice-potato-sesame gave the highest rice equivalent yield of 18.23 tonnes/ha; which was 42 % higher than that obtained with conventional rice-rice-rice sequence cropping. The benefit of mulching with rice-straw in terms of rice equivalent yield was significantly higher for sesame (3.82 tonnes/ha), followed by horsegram (3.01 tonnes/ha) and greengram (2.70 tonnes/ha).

Population densities of culturable iron reducer soil microorganisms ranged from 10^3 to 10^6 per gram, and the Polymerase Chain Reaction Denaturing Gradient Gel Electrophoresis (PCR-DGGE) analysis of the total microbial community DNA from the soils showed that eubacterial microorganisms during peak iron reduction process varied in these soils.

Wheat: Long-term effects of conventional tillage, zero tillage, rotary tillage, strip tillage and bed planting in wheat were evaluated in a fixed plot trial. Eight years' mean yields were 3.04% higher in rotary tillage, and were 7.55% and 12.81% lower in strip tillage and bed planting compared to conventional field preparation. Yields under zero tillage and conventional tillage were similar.

Improving soil-organic C through residue management. Increase in soil-organic C was about 0.1% after two years and about 0.2% after four years with full residue retention or incorporation of rice and/or wheat crops.

Pearl millet: In pearl millet, nitrogen at 60 kg and 40 kg per hectare increased 24.58 and 14.35% grain yield and 18.93 and 12.09% fodder yield over 20 kg N in states having <400 mm rainfall such as north-west Rajasthan, Gujarat, parts of Haryana and Madhya Pradesh.

In summer, grain and fodder yields of pearl millet advance hybrids increased significantly at 120 and 90 kg N/ha over 60 kg N/ha. GHB 558 and MSH 185 responded more to higher doses of nitrogen.

Optimum management of the crop produced 18.94% more grains and 13.24% more fodder compared to low management practices in Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.

Small millets: Sowing fingermillet and transplanting 40-45 days old pigeonpea seedlings in 8:2 row proportion as intercrop gave 250-270% higher pigeonpea yield over recommended practice of simultaneous sowing of fingermillet and pigeonpea. In terms of fingermillet grain equivalent yield, transplanting of pigeonpea gave yield advantage of 38 and 86% over drilling pigeonpea in intercropping system and farmers' practice of *Akadi*.

Forage crops: In *ex-situ* conservation in rainfed areas, grasses, herbaceous legumes, shrubs and

Culturing fishes in rainfed lowland rice

Breeding and culture of ornamental fishes, introduced first time in the rainfed lowland rice ecology, produced 500 egg-layer species (Blue gourami, Red gourami and Pearl gourami) and 15,000 livebearer species (Guppies and Red sword-tail guppies).

In dry season, 1.03 tonnes of sunflower (KBSH 1), 1.1 tonnes of groundnut (AK12-24), 0.4 tonne of mungbean (PDM 139), 12.5 tonnes of watermelon (Sugar Baby), 8.1 tonnes of pumpkin (Guamal), 5.8 tonnes of cucumber (Chaitali) and 3 tonnes of okra (Hybrid F_1) per hectare were produced.

trees, suited for rangeland/wastelands were evaluated. Mean above ground biomass of *Albizia procera* (12-years old) varied from 27.17 to 42.13 kg/plant. The proportion of the small timber, firewood and fodder was 47, 40 and 13% of the total above-ground biomass.

Groundnut: Groundnut-wheat-greengram cropping system recorded maximum productivity and improved soil-nitrogen and organic-carbon over groundnut-groundnut, groundnut + pigeonpea, groundnut + pearl millet and groundnut-wheat cropping systems.

VG 9902 at Virddhachalam, K 4 at Kadiri, JL 501 at Jalgaon and GG 5 at Junagadh were promising genotypes for late sowing in *kharif* .

Nitrogen 100% to groundnut as basal and 50% nitrogen in 3 splits to intercropped cereal-crop was best fertilizer scheduling for groundnut + cereal intercropping systems at Jalgaon, Junagadh, Chintamani. This saved 50% N to cereal crops.

Polythene mulching on paired-row bed furrows in groundnut with irrigation either at 0.8 or 0.6 IW/CPE ratio and 100 % recommended dose of fertilizers and seed treatment with *Rhizobium* and phosphate-solubilizing bacteria were ideal for water and nutrient management.

For groundnut under rice fallow system, *Rhizobium* strain NRCG 9 or IGR 6 was found suitable at Vriddhachalam and Jagtial.

Sunflower: *Rabi* sorghum succeeding sunflower was adversely affected compared to fallow, in terms of emergence, growth and yield compared to other *rabi* crops, chickpea, coriander and safflower, in scarce rainfall zone of Andhra Pradesh at Nandyal in rainfed areas.

Rapeseed-mustard: Growing sesbania as a green-manure crop preceding mustard recorded significantly higher mustard seed yield in north-eastern Rajasthan and Haryana.

Castor: Sulphur at 20 kg/ha through gypsum to castor in irrigated areas in Rajasthan, wherever the available soil S status is low to medium, gave higher seed yield and economic returns.

Safflower: In Vidarbha region (Akola) of Maharashtra, sulphur at 30 kg/ha through single superphosphate recorded increased seed yield and returns in rainfed areas.

In scarcity zone (Solapur) of Maharashtra, it is possible to substitute 50% N and P needs of chickpea-safflower rotation by seed treatment with phosphate-solubilizing bacteria (PSB) to chickpea and to safflower by *Azotobacter/Azospirillum* and PSB without any adverse effects on the productivity.

Soybean: Arbuscular mycorrhizal fungi found in soybean rhizosphere are *Glomus intraradices*, *Glomus* sp. 1 and *Glomus* sp.2. These dominant isolates can be mass produced and used for improving soybean productivity.

Pseudomonas isolates SP4, SP8, DP5, UP1, UP4 and UP8, identified from soybean rhizosphere, showed *in-vitro* potential for solubilizing zinc phosphate, zinc oxide and zinc carbonate.

Integration of 100% recommended dose of fertilizers + oil cake (250 kg/ha) + *Azospirillum* (5 kg/ha) + phosphate-solubilizing bacteria (5 kg/ha) + *Trichoderma viride* (2.5 kg/ha) + *Pseudomonas fluorescens* (2.5 kg/ha) in soybean resulted in higher yields, net monetary returns and benefit:cost ratio.

Pulses: Raised-bed planting of chickpea gave higher yield as compared to flat-bed planting, besides increasing water-use efficiency.

Intercropping pigeonpea + sorghum in 2:1 row ratio on raised-bed planting gave higher yield than flat-bed planting.

Raised-bed resulted in higher grain yield in lentil and fieldpea over flat-bed sowing. In lentil, grain yield also increased with increase in phosphorus from 25 kg/ha to 50 kg/ha and sulphur from 20 to 40 kg/ha.

In rice-chickpea sequential cropping, incorporation of chopped rice straw +20 kg N + irrigation resulted in significantly higher yields. Chickpea residue incorporation also proved beneficial over removal of straw. Foliar spray of 2% urea in chickpea at 75 days after sowing increased grain yield significantly over 200 kg per hectare.

Residue incorporation of the component crop significantly increased total productivity of rice-lentil system.

Short-duration pigeonpea variety Pusa 992 was found compatible for intercropping with urdbean and mungbean in the North Western Plains Zone, and medium duration GT 101, JKM 189, JKM 7 and BSMR 853 was compatible with groundnut, maize and soybean in the Central Zone.

In mungbean-ragi sequence, phosphate-solubilizing bacteria + 40 kg P_2O_5/ha to mungbean saved 30 kg P_2O_5/ha in the succeeding ragi. Mixed spray of 2% potassium chloride + 0.1 ppm boron and 2% of urea spray maximized yield of urdbean under drought.

Sugarcane: IISR-microbial formulation inoculated into farmyard manure/press-mud cake at 20 kg/hectare was recommended for application in furrows above seed-cane setts at the time of planting. This practice managed sugarcane diseases and improved sugarcane productivity.

In areas with limited irrigation, cane-setts required for one hectare should be soaked in saturated lime water (80 kg lime/1,000 litres of water) for two hours a day before planting to improve germination and cane yield.

In sugarcane-based sequential cropping systems,

Sugarcane ratoon management device

Ratoon management device performs off-baring, deep tilling and fertilizer placement in the ratoon crop simultaneously in one pass of the tractor. This device saved 8-10 tractor-hours, 200-250 man-hours in a hectare, thus economizing Rs 5,000-6,000 per hectare.

pre-planting weed control with Glyphosate, followed by in crop weed control with 'pre-emergence Atrazine' and 'post emergence Ethoxysulfuron' or 'directed post emergence Paraquat' or 'directed post emergence Glyphosate' managed weeds, including cynodon and nutgrass, which are persistent in nature in plant and ratoon sugarcanes.

Drip irrigation saved about 40% of water as compared to the conventional furrow irrigation. Cane yield data revealed that paired-row planting of sugarcane with fertigation helped save 25% of chemical fertilizers.

Cotton: *Bt hybrids*. At Nagpur and Coimbatore, irrigation through drip at 0.8 Etc or through furrows at 0.6 IW/CPE improved seed-cotton yield and water-use efficiency. In rainfed areas, cotton+greengram provided the highest cotton equivalent yield and water-use efficiency. Highest seed-cotton equivalent yield and net returns were obtained with multitier cropping of cotton with radish, beet-root and coriander.

Tobacco: Seedling growth under micro-sprinklers was vigorous; transplantable seedlings were more and ready for transplanting in 45 days as compared to 60 days from traditional method of watering seedbeds. Application of water to tobacco seedbeds through micro-sprinklers reduced labour cost by Rs 145,000/ha.

Mango: An optimum irrigation of 40% of evaporation losses under drip irrigation with an application of 65% of recommended dose of fertilizers through fertigation was optimum for getting higher yield. Pre-harvest application of radioactive tritiated water to developing fruits of Alphonso mango showed higher mobilization of water into seed in the affected fruits compared to seeds in healthy fruits.

Maximum fruit yield was recorded in the trees pruned on alternate limbs after harvesting with the application of Paclobutrazol @ 10g a.i./tree. For rejuvenation of overcrowded orchards, maximum fruit yield was recorded in heading back of crowded branches and centre opening with application of Paclobutrazol @ 10g a.i./tree during rest period. Modified central leader system of training gave maximum yield at Pantnagar and Pusa.

Banana: In banana, planting three suckers/pit at 1.8 m × 3.6 m spacing recorded higher leaf-area index and facilitated the plants to have lower light transmission ratio (39.5) for Poovan at Coimbatore. At Kannara, plant spacing of 2 m × 3 m with three plants/pit (5,001 plants/ha) with 100% RDF for Nendran recorded highest yield (39.05 tonnes/ha). Inclusion of VAM, PSB, *Azospirillum* at 250, 50, 50 g/plant, respectively, with 100% recommended dose of fertilizer was superior. Application of 25% CAN + 25% urea + 50% ammonium sulphate constituting 200g N, in addition to 50g P_2O_5 and 200g K_2O favoured higher bunch weight (13.5kg) for Ney Poovan banana at Coimbatore. Application of 250:90:250g $N:P_2O_5:K_2O$ plant/crop with bunch spray of 2,4-D (10 ppm) recorded higher yield and benefit:cost ratio for Grand Naine (AAA) at Gandevi and Barjahaji (AAA) at Jorhat. The application of 80% N and 20% K_2O of the RDF in the first five months after planting resulted in higher B:C ratio at Kannara.

Banana Ney Poovan and Karpuravalli showed better nitrogen assimilation capacity under salt affected field (EC 1:2.5 = 3.34) than Nendran and Rasthali. Saba, Karpuravalli and Ney Poovan showed normal finger development and fruit filling under salt-affected field (EC 1:2.5 = 3.34) and Nendran and Robusta recorded small and ill-filled fingers. Imbogo(AA) was found tolerant to soil moisture-deficit stress and Saba, Karpuravalli and Poovan showed drought-tolerant traits, viz. higher relative water content (43- 55%) and epicuticular wax.

Litchi: In litchi, maximum fruit yield was obtained with the use of biofertilizer, *Trichoderma* and *Pseudomonas*, along with half the recommended dose of N P K and 50kg FYM in Shahi. Irrigation and sprinkling of water had significant impact on reducing fruit cracking in Shahi at RAU, Pusa.

Papaya: In papaya, inclusion of VAM, PSB, *Azospirillum* at 50, 25, 25 g/plant, respectively in papaya with 100% recommended dose of fertilizer was observed superior for yield. At Coimbatore, in papaya, application of 30:30:30 g of $N:P_2O_5:K_2O$ (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 in papaya.

Citrus: Best site-specific treatment N800 – P400 – K600 – M1 (250 g/tree each of $FeSO_4$, $MnSO_4$ and $ZnSO_4$/tree) showed its clear cut superiority (yield 52.8 kg/tree) over recommended doses of fertilizers (yield 42.0 kg/tree) and farmers practices (yield 38.3 kg/tree) with reference to yield and quality in addition to higher tree efficiency.

Inclusion of VAM, PSB, *Azospirillum* and

Trichoderma harzianum (500, 100, 100 and 100 g/plant respectively) to 100% of recommended dose of fertilizer recorded higher growth in mandarin and better growth and yield characters for acid lime at Akola. Application of RDF through fertigation resulted in saving of RDF to 25% in Kinnow mandarin at Ludhiana. At Rahuri, intercropping of greengram (*kharif*) followed by gram (*rabi*) in sweet orange was superior in Maharashtra.

Grape: Highest raisin recovery was found in Thompson Seedless grafted on 110 r and dogridge. Tas-a-Ganesh grafted on dogridge recorded more shoots positioned vertically to cordon more fruitful than the horizontal. The bunch weight was more in single cordon placed horizontally than double and four cordon system. Cumulative total uptake of sodium in cane, lamina and petiole was significantly more in Tas-a-Ganesh grafted on dogridge 110r. Dogridge rootstock could not exclude sodium under saline irrigation. The total accumulation of chloride among different tissues was found highest in lamina followed by cane and petiole both in grafted and ungrafted vines. However, potassium concentration was low in all three vine parts in case of own rooted vines compared to grafted vines.

Walnut: In walnut, maximum grafting success was recorded in wedge grafting performed during 10-31 March. It gave maximum success of 68.31% under ordinary polyhouse conditions.

Almond: Medium high and high-density orcharding in almond has been standardized with early, mid and mid to late season varieties, Makhdoom, Shalimar and Waris respectively for Karewa conditions of Kashmir valley. The orchard has been established at three different spacing of 3.5 m × 3.5 m, 3.0 m × 3.0 m and 2.5 m × 2.5 m, accommodating 816,1111 and 1,600 trees/ha, respectively, against 278 trees/ha under conventional planting. Maximum yield (2.01 tonnes/ha) was recorded in almond Shalimar under high-density planting of 2.5 m × 2.5 m spacing, providing irrigation through drip at critical stages of kernel filling and development, maintaining optimum canopy under central modified leader system with more fruiting wood through regular pruning.

High-density plantation in almond

Apple: Five apple varieties on clonal rootstock, MM 106 were found very promising under high-density plantation of 2.5 m × 2.5 m spacing. In seventh year, with about 50% canopy cover Oregon Spur recorded maximum yield of 17.79 tonnes/ha, followed by Red Chief (16.64 tonnes/ha), Vance Delicious (16.16 tonnes/ha), Red Fuji (13.47 tonnes/ha) and Silver Spur (12.98 tonnes/ha). These cultivars were significantly superior to traditional cultivar Red Delicious (11.20 tonnes/ha). However, under Mukteshwar (Uttarakhand) conditions Red Chief, Well Spur, Starkrimson, Spur type Red Delicious and Skyline Supreme performed better.

High-density plantation in apple

Underutilized fruits: Soft wood grafting has been recommended for khirni *(Manilkara hexandra)* during March-June and July-August and for *Chiraunji (Buchanania lanzan)* plants in June and August.

Aonla-based multistorey cropping system ground storey crops did not exert any competition on the growth and development of aonla up to four years of intercropping. Moth bean-cumin and moth bean-gram was observed to be profitable crop combinations in arid region.

Vegetables: Intercropping of gram, lentil, and vegetable peas with potato increased net returns at Jalandhar. Highest system productivity was obtained in maize–potato–onion (45.7 tonnes/ha), followed by paddy–potato–wheat (43.2 tonnes/ha). Traditional method of potato storage in heaps and pits was improved with single spray application of the CIPC. CIPC residues in peels of treated potatoes was only 0.11-3.22 ppm after 100 days of storage.

Peas: Technology for growing double crop of peas has been standardized with FC 1 and Arkel. First main season crop can be successfully grown during October-May and second off-season crop from July to October. Rotation involving pea-chilli crops also resulted in lower incidence of wilt and higher chilli yield.

Coconut: Higher coconut yield was recorded under coconut + vegetable intercropping system

(130 nuts/ palm/year) compared to monocropping of coconut (118 nuts/palm/year). Growing vanilla as mixed crop in coconut garden with cowdung slurry application recorded more number of infloresences (21), beans (208) and fresh bean yield (2.0 kg) per vine, followed by vermiwash application and vermicompost + biofertilizer application treatments. Integrated nutrient management with NPK and organic manure application resulted in improvement in health of root (wilt) disease affected palms and higher yield. The coconut-based farming system involving coconut with integration of grass, pepper if trailed on coconut, banana (on border of garden), dairy and poultry resulted in the net returns of Rs l29,070/ ha. Coconut, milk and broilers sale accounted for 91% of the revenue generated from the system.

Arecanut: In arecanut garden, mixed cropping with pepper, banana, citrus found to economically advantageous in North East Region. In *tarai* region, flower crops like aster, marigold and gladiolus gave higher yield in arecanut garden. 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 treatment (66.3 nuts/palm/year) and differed significantly compared to other treatments.

Cashew: In high-density plantation (416 and 500 trees/ha) in cashew, yields was significantly higher (1,093 and 1,078 kg/ha respectively) than in normal tree density plantation (511 kg/ha). In intercropping trial, total net returns from intercrops as well as main crop (cashew) at Bhubaneshwar was maximum in colocasia (Rs 44,908) followed by brinjal (Rs 37,666), okra (Rs 36,650) and cowpea (Rs 36,398). The highest net return (Rs 48,766) was recorded by tapioca followed by colocasia (Rs 43,290).

Turmeric: The highest curcumin content of 3.5% was recorded in accession CL 57. Oleoresin content varied from 8.5 to 12.5%. The highest oleoresin content (12.5%) was found in CL 219. The essential oil content varied from 2.0 to 4.5%. The highest essential oil content (4.5%) was found in CL 20. Integrated treatment recorded highest rhizome yield (24.8 tonnes/ha) followed by inorganic (22.9 tonnes/ha), whereas organic treatment recorded 21.2 tonnes/ha in the trial on organic farming in turmeric at Jagatial. Soil application of FYM @ 30 tonnes/ha + 20 q/ha vermicompost + 8 q/ha neem oil cake produced maximum plant height (126.67 m), tillers/plant (5.40), leaves/tiller (14.60) and yield/plot (15.20 kg/3m^2) or yield (50.67 tonnes/ha), followed by soil application of FYM at 30 tonnes/ha + 15 q/ ha vermincompost + 8 q/ha neem oil cake at Dholi.

Fennel: In fennal, application of inorganic nitrogen (100%) + FYM 5 tonnes/ha + *Azospirillum*, inorganic nitrogen (75%) + *Azospirillum* + FYM 5 tonnes/ha and inorganic nitrogen (50%)+ *Azospirillum* + FYM-5 tonnes/ ha and inorganic nitrogen (50%) + *Azospirillum* + FYM 5 tonnes/ha were found significantly superior to the control for umbels/plant, umbellet/ umbel, grains/umbellet and grain yield/ha.

Mushroom

At Solan, the 1:1 combination of cotton ginning mill waste+paddy straw gave more than 25% yield in paddy straw mushroom, which was highest till date in first flush. The addition of laccase activator tannic acid and p-anisidine stimulated 3-fold higher dyes decolourization with *P.sajor-caju*. The pellet form of mushroom mycelia and agitated growth conditions enhanced days decolourization by oyster mushroom. The mushroom grown on cotton waste compost were found to contain higher protein content, followed by those grown on cotton waste + paddy straw and paddy straw.

Fenugreek: In fenugreek, JF 270 recorded higher yield of 573 kg/ha which was at par with Rmt 303 (543.33 kg/ha) at Coimbatore. FGK-14 was identified promising at Dholi. HM 348 and HM 355 were identified as promising in IET at Hisar. The J.Fg. 244 and NS 2006-3 were identified as drought tolerant at Jobner. Spraying of Tricontanol 1.0ml /litre at 40 days after sowing resulted in highest grain yield of 595 kg/ha.

Tuber crops: In taro, use of whole mother corm as planting material was recommended. The application of vermicompost @200 kg/ha with RDF with 80: 50: 100 or FYM (10 tonnes/ha) + neem cake (1 tonne/ha) or FYM (10 tonnes/ha) + mustard cake (1 tonne/ha) was recommended for Jharkhand and Chhattisgarh. The application of 50% N through vermicompost and remaining NPK through chemical fertilizers was recommended for Uttar Pradesh. Application of 125: 60: 100 kg NPK/ha along with 50 kg N through vermicompost was recommended for bunda crop in Uttar Pradesh. In greater yam, application of paddy straw @ 1 kg/pit and 75% recommended dose of NPK (80:60:80 kg/ha) was recommended for Chhattisgarh. In elephant-foot yam, application of FYM @10 tonnes/ha and mustard cake @0.5 kg/pit was recommended for West Bengal. In elephant-foot yam, application of vermicompost @200 kg/ha and 50% recommended dose of NPK (80:60:80) applied at the time of planting was recommended for Bihar.

PROTECTION

Rice: INRC 4598 is the new source of resistance identified against gall midge. Identity of the new gene in MR 1523, a donor for gall-midge resistance, is established by RM 17, RM 235, RM 28706,

RM 28784, lying on chromosome 12, which showed co-segregation.

IET 19913 (CR 662-2211-1-1) showed resistance to leaf blast, neck blast and tungro, IET 20441 (JKRH 1206) to leaf blast, neck blast and brown spot, IET 20448 (DRRH 57) to neck blast, tungro and sheath blight and IET 20453 (CRHR 25) to neck blast, sheath blight, sheath rot and brown spot.

Trifloxystrobin 25% + Febuconazole 50% (Native 75 WG) were found effective in checking severity of blast, sheath blight and glume discolouration and Fenoxanil 5% + Isoprothiolane 30% checked blast severity and increased grain yield.

Wheat: Seed treatment with Imidacloprid at 0.6 g a.i./kg of seeds was found promising in checking aphid build-up 70-85 days after sowing and also gave yields at a par or better than Imidacloprid at 100 ml/ha (check). Likewise foliar spray of Oxydemeton Methyl reduced aphid population and increased yield significantly.

Phalaris minor, wheat weed: Phalaris minor, a serious weed on wheat, has evolved for multiple herbicides resistance to three modes of action (photosynthesis at photosystem II site A, ACCase and ALS inhibitor). Some resistant populations had GR_{50} (50% growth reduction) values for Clodinafop; >11.7 times than those of the most susceptible populations. The populations resistant to these three modes of actions were found sensitive to Trizine (Metribuzin and Terbutryn), Dinitroaniline (Pendimethalin) herbicides as well as to Glyphosate and Paraquat.

Barley: Seed treatment with Vitavax powder at 3 g/kg and Imidacloprid 70 WS (Gaucho) at 0.6 g a.i./kg + foliar spray of Propiconazole (Tilt 25 EC) at 0.1% and Imidacloprid (Confidor) at 20 g a.i./ha reduced incidences of stripe and stem rusts, covered rusts, covered smut and foliar blight as well as aphids.

Maize: Five pink stem-borer *Sesamia inferens* resistant lines WNZ PBTL2, WNZ PBTL3, WNZ PBTL6, WNZ PBTL8 and WNZ PBTL9 with desirable agronomic traits have been developed for their use in developing pink stem-borer resistant hybrids/varieties.

Pearl millet: Hybrids/varieties MH 1248, MH 1291, MH 1294, MH 1299, MH 1328, MH 1397, MH 1363, GHB 538, GHB 558, PB 106, Pusa 266, Raj 171, ICMV 221 and JBV 2 have exhibited resistance against downy mildew, smut and rust.

Forage crops: *Verticillium* wilt of lucerne, caused by *Verticillium albo-atram* Reinke & Berthold, was first reported in Jhansi in 2007.

Application of 2% asafeotida suspension significantly reduced root-knot nematodes (p=0.0001 at 95%) in cowpea. Three sprays of *Ipomoea carnea* leaf extract (8% water extract), at 15 days interval, resulted in 65-70% reduction in major insect pests damage over control.

Groundnut: Genotypes NRCG CS 144, 156, 158, 159, 160, 168, 196, 222 and PBS 25001 are found to possess multiple disease resistance. These will now be tested at the hot-spot locations.

Soil application of castor-cake enriched *Trichoderma* (isolate T-170) at 50kg/ha (*Trichoderma* multiplied on sorghum grains and mixed with 50 kg castor-cake) + intercropping with maize (3:1 ratio) + gypsum at 500kg/ha at flowering + foliar application of Chlorothalonil effectively controlled collar rot, stem rot, early leaf spot and late leaf spot.

Azadirachta indica and *Annona squamosa* fresh leaves dried in shade and applied at 500g/10 kg of pods reduced post-harvest *Aspergillus flavus* infection and aflatoxin contamination.

Trichoderma isolates NRCG T 07, 11, 14 and 29, identified to be thermo-tolerant, could grow well at 35-37 ºC. *Trichoderma* isolate NRCG T12 enriched with neem-cake or castor-cake effectively controlled collar and stem rots, *A. flavus* infection and aflatoxin contamination. Soil drenching with talc-based *Trichoderma viride* at 2.5kg/ha applied at 30 days after sowing effectively reduced stem-rot disease.

Seed treatment with 0.0035% Imidacloprid + 2 sprays of 0.008% Imidacloprid at 30 and 45 days after sowing were quite effective against jassids and thrips.

Groundnut promising resistant germplasm accessions

Centre	Hot spot for	Disease/insect pressure	Promising germplasm accessions
Kadiri	Peanut Stem Necrosis Disease (PSND)	0.12-23.14%	NCAc 515 (0.2%)
Raichur	Peanut Bud Necrosis Disease (PBND)	4.0-72.0%	NRCG 6696 (5.2%) NRCG 13129 (7.1%) NRCG 13078 (7.7%) NRCG 9238 (8.8%) NRCG 13177 (9.8%)
Junagadh	Collar rot	0.0-35.0%	NRCGs 4206, 9740, 1079, 11604, 13011, 13010, 4236, 11611, 13024, 13076, 13051

Groundnut + castor and groundnut + *Bt* cotton intercropping systems reduced jassid population. Groundnut + castor and groundnut + hybrid cotton reduced thrips population. Intercropping with pigeonpea gave highest cost:benefit ratio (1: 3.99), followed by castor (1: 3.46) compared to sole groundnut and other intercrops.

The life-table of *Caryodon serratus* (pod borer) on groundnut pods was studied at 25, 30 and 35°C. The net reproductive rate was highest at 25°C (R_0 = 170.04), and on an average, a female insect could produce 170 female offsprings during its life-span; indicating that insect can assume a status of serious pest at this temperature.

Safflower: For effective and efficient control of safflower aphid, two sprayings either of 0.005%, Thiamethoxam 25 WG or 0.004% Acetamiprid 20 SP or one spray of each alternatively first at ETL (40-45 DAS) and second spray at 55-60 DAS were recommended in the scarcity water zone of Maharashtra (Solapur).

For effective and efficient management of safflower aphid, 2 need-based sprays of either 0.005% Thiamethoxam 25 WG or 0.0045% Imidacloprid (17.8%) were recommended particularly in the northern parts of Karnataka (Annigeri).

Rapeseed-mustard: Imidacloprid 70 WS at 7 g/kg of seeds was found effective in controlling painted bug incidence in Indian mustard. Oxy-demeton Methyl 25 EC spray at 1 ml/litre of water, followed by neem-seed kernel aqueous extract (5%) and neem oil (2%) proved best for controlling mustard aphid

Castor: *Trichoderma* sp. N 13 formulation was found to reduce *Botrytis ricinii* grey-rot disease significantly under detached spike technique.

Soybean: Seed treatment 50 days prior to sowing with Carboxim (37.5%) + Thiram (37.5%) at 0.2% besides giving best management of seed and seedling diseases of soybean also resulted in higher monetary returns and energy output.

Seed treatment with either Carboxim at 3g/kg or *Trichoderma* at 10g/kg and soil application of zinc at 2.5kg/ha with B at 0.5kg/ha reduced chaffy pods as well as disease incidence of charcoal rot due to *Macrophomina phaseolina* to the tune of 75- 85% as compared to control.

Seed treatment with *Trichoderma* and irrigation at the time of moisture stress especially at the time of pod formation reduced charcoal rot incidence by 50%.

Pigeonpea: Resistant sources for *Fusarium* wilt (ICP 14722, 89046, 89048, 89049, Banda palera, PI 397430, BWR 377), pod fly (ICP 4542, JBP 120A), *Heterodera cajani* (Pusa 2007, JKM 213, JSA 28, PA 296) and *Meloidogyne javanica* (JSA 81) have been identified.

Mass multiplication of *Trichoderma*

Eight locally available agrowaste substrates viz. wheat straw, soybean refuge, spent maize cob, safflower, mustard waste, chickpea, lentil wastes and grass straw individually and in consortium were tried for mass multiplication of *Trichoderma* species. *Trichoderma* multiplied in all the substrates. One and two years old substrates were better as compared to the fresh substrates for mass multiplication of *Trichoderma.*

Chickpea: Resistant sources for *Fusarium* wilt (GJG 0505, H 04-31, WCG 2000-12,H 04-87, Phule G 9621-8, GNG 1778, GJG 0506, IPC 2005-64,IPC 2006-13, H 82-2, BCP 91,JSC 35, MPJG 2001-04, GJG 02-05, GJG 03-12, JG 2000-14 and JG 2003-14-16), dry root rot (GJG 0419, GJG 0505, H 04-31, GJG 0107, GJG 0315), collar rot (IPC 2005-66, IPC 2005-61 GNG 1763, NDG 7-701 and Phule G 9621-8), *Ascochyta* blight (H 03-45, CSJ 479, NDG 7-602, GNG 1778, GNG1488 and GG 1362) and *Botrytis* grey mould (IPC 2005-64 and IC 269380) have been identified.

Mungbean: Resistant sources for *Cercospora* leaf spot (Co4, Co5, COGG 7, UPM 98, TM 98-50, BM 4, BM 7 and ML 515), mungbean yellow mosaic virus (MYCV) (KM 2241, COGG 923 and ML 1299) and root-knot nematodes (RMG 976 and ML 1299) have been identified.

Urdbean: Resistant sources for powdery mildew (DU 1) and leaf crinkle disease (PLU 662, UH 82-2, JU 4, IPU 99-218, IPU 99-229, IPU 99-259, Aligarh 1, U 15 and JU 2) have been identified. KUG 216 showed multiple resistance to mungbean yellow mosaic virus, stem necrosis, *Cercospora* leaf spot and anthracnose.

SUCCESS STORY

Pulse growers of Uttar Pradesh selected chickpea varieties

In Fatehpur district of Uttar Pradesh, farmers mostly follow paddy/*bajra*-wheat cropping sequence under irrigated conditions. Survey revealed that chickpea vanished from the cropping sequence mainly due to the continuous decline in the yield due to *Fusarium* wilt and non-availability of quality seeds in Fatehpur. In view of this, farmers participatory varietal selection programme was taken up at 20 sites across six villages in two years (2006-08). Six improved varieties of chickpea, DCP 92-3, JG 16, KWR 108, PG 186, KGD 1168 and JGK 1 and two local large- and small-seeded varieties were assessed. Varieties JG 16 (2,850 kg/ha) and DCP 92-3 (2,550 kg/ha) proved most promising in the region. Farmers preferred JG 16 for mid-October planting and DCP 92-3 for planting during the first week of November. They produced 28 tonnes of seeds of DCP 92-3 and 15 tonnes of JG 16.

Lentil: Resistant sources for wilt (RG/L 2, RG/L 17, ILL 9981, ILL 9976, RGC/L 14, ILL 8114, IPL 86, IPL PP 12), rust (L 4688, L 4691, L 4147, L 4583, VL 133, RLG 73, IPL 315 and HUL 57) and root-knot nematodes (LL 1020, PL 406, VL 516, L 4695) have been identified.

Fieldpea: Pant P 108, Pant P 74, Pant P 25, Pant P 86, TRCP 8, RFP 29 and Pant P 107 showed resistance against rust and powdery mildew.

Phenolic acids–chlorogenic, caffeic, coumaric and ferulic acids–imparted resistance against wilt in chickpea. Chlorogenic acid was most predominant phenolic acid for wilt resistance.

Dust formulation (30×10^5 IJS/ha) of EPN species *Steinernema masoodi* and *S. seemae*, worked better for the management of lepidopteran-borer complex. A dose of 6×10^5 IJS/ha of *S. masoodi*/plot was sufficient to kill physiologically matured larvae.

Seed soaking in 0.1% Imidacloprid or 0.1% Carbosulfan reduced nematode population and assured plant health.

Sugarcane: *Trichoderma viride* and *T. harzianum* were effective for management of red rot, wilt and smut.

Dipping of smut-affected setts before planting in *T. viride* (Tv-6) spore suspension (10^6 spores/ml) reduced smut incidence and enhanced number of millable canes and yield in plant-crop. In ratoon, smut incidence was comparatively low that resulted in more millable canes and yield.

Two split doses of urea at 75 kg N/ha at planting and at the appearance of 1st moth of third brood of top-borer (15-25th June) with three weekly releases of *Trichogramma japonicum* at 50,000 adults/ha combined with neem-based insecticide formulation spray at 3 litres/ha at the time of egg-laying reduced infestation and increased cane yield.

Jute: In stale seed-bed method, Glyphosate at 2.46 kg + 2,4-D at 2kg a.i./ha and Glyphosate 2.46 kg + Pyrozosulfuron Ethyl (PSE) at 60g/ha, followed by one hand-weeding was found promising for broad-range weed control at the early stage in jute field. It reduced *Cyperus rotundus* population by more than 80% over control after two years' cycle and yielded significant jute fibres/ha.

Glyphosate at 2.46 kg SL + Paraquat 0.72 kg SL per hectare at 15 DAE using herbicide-brush controlled wide range of weeds in jute and mesta fields.

Tobacco: Crude sugar ester fractions from *Nicotiana glutinosa* at 2% concentration brought about 92% mortality of the aphids.

Application of *Paecilomyces lilacinus* at 10g/m^2 in FCV tobacco nursery caused 32.1% increase in number of root-knot-free-healthy transplants compared to the check. It also reduced root-knot index to 2.05 compared to 3.75 in check, and was on a par with *P. lilacinus* + neem cake (1.87) and *P. lilacinus* + vermicompost (1.82).

Mango: Pongamia and neem oils at 0.2 % were highly synergistic with Imidacloprid (0.3 ml/litre) against chilli thrips, *Scirtothrips dorsalis* (73 – 76 % mortality). Acephate @ 1 g/litre along with pongamia oil 0.1 % resulted in 67 % mortality of thrips.

Wooden block methyl eugenol trap was found highly efficient in trapping fruit flies (1,584 flies/trap), followed by agriland, sun agro and bottle trap. Hot water treatment of fruits at 48±1°C for 1 hour controlled all stages of fruit fly, *Bactrocera zonata* in Dashehari, Langra, Chausa, Amrapali and Mallika without affecting ripening of fruits. Thiamethoxam (0.005%) was found highly effective in controlling mango thrips.

Guava: Sixteen Fusarium isolates (F6, F9, F10, F26, F27, F30, F31, F36, F39, F41, F43, F45, F46, F47, F49, F50) exhibited typical guava wilt symptoms. In field evaluation of bioagents for the management of guava wilt, *Aspergillus niger*-AN 17 showed plant growth-promoting activity. Isolates AN 9, AN 10 and AN 11 were also effective. Soil application of *Trichoderma viride* along with FYM applied in the root zone was found most effective in reducing the incidence of guava wilt at BCKV, Mohanpur.

Citrus: At Tirupati, coat protein gene of acid lime isolate of CTV was cloned in P drive vector and sequenced. The clone can be used for recombinant technology based diagnosis of CTV. At Rahuri, two sprays of acephate (0.1125%) or Imidacloprid (0.005%) or Thiamethoxam (0.0025%) were effective to control citrus leaf folder. Spraying of Acephate (0.1125%) at Periyakulam, Imidacloprid 200 SL (0.005%) at Tirupati and Imidachloropid 200 SL, Acephate (0.1125%) and single application of Ithiodicarb 75 WP (75%) at Tinsukia were effective against citrus leaf miner. Among natural products, NSKE (5%) was also effective at Periyakulam and Tirupati. At Periyakulam, NSKE (5%) and fish oil resin soap (0.3%) were effective against citrus butterfly.

The *Bacillus thuringiensis* (BT) @ 0.1% was effective for lemon butterfly and leaf miner management at Tirupati. Spraying of streptomycine sulphate (100 ppm) with copper oxychloride (0.3%) was best at Periyakulam, while NSKE (2%) was effective at Pusa. Biopesticides abamectin @ 0.32 ml/litre followed by spinosad @ 0.34 ml/litre and novaluron @ 0.87 ml/litre were found effective for 15 days against citrus leaf-miner. Application of petroleum spray oil @ 3.72 ml/litre and *Bacillus thuringiensis* @ 1.9 g/litre water were found

effective for 11 days. However, treatments of neem oil, azadirachtin, neem soap, and pongamia soap were found effective for one week. A chrysopid predator, *Mallada boninensis* and a eulophid parasitoid *Tamarixia radiata* released @ 30 larvae/tree and 40 adults/tree, respectively, alone and in combination in six Nagpur mandarin orchards with marigold as border crop covering Nagpur district resulted in 31-35, 46-49 and 26-32% reduction of blackfly, psylla and leaf miner population respectively. PCR technique for rapid detection of citrus greening bacterium was developed. A rapid and sensitive diagnostic assay based on PCR was developed.

Banana: For the management of rhizome rot disease of banana, suckers from diseased plot followed by dipping in copper oxychloride (0.4%) and streptocycline (0.03%) for 45 minutes was effective at Arabhavi, Coimbatore and Gandevi. Planting disease-free suckers from disease-free fields followed by dipping in Carbendazim (0.2%) for 45 minutes followed by drenching with Carbendazim (0.2%) at 5th, 7th and 9th month was highly effective against Panama wilt at Jorhat and Kannara. For the management of Sigatoka leaf spot disease in Robusta, spraying of propiconazole (0.1%) + *Pseudomonas fluorescens* (0.5%) was found to be effective (PDI-11.2) compared to the control (PDI-23.2) at Coimbatore. At Coimbatore, *Pseudomonas fluorescens* as both sucker treatment and soil application [10g as sucker application - *Pseudomonas fluorescens* (2.5 kg + 50 kg FYM mixture) and 20 g/sucker as soil application] was effective in suppressing nematode population, root and corm index and gave an increased yield (56% over control).

About 100% mortality in burrowing nematode was observed in two isolates at 100% concentration when exposed to 48 hour, whereas eight out of 12 bacterial isolates exhibited 100% mortality at 100% concentration when exposed to 72 hour. Promising biocontrol agents, viz. *Paecilomyces lilacinus, Trichoderma viride* and *T. harzianum* were mass multiplied by using banana wastes such as banana leaves, pseudostem and petiole. The genotypes, Karthobiumtham and Calcutta 4 showed tolerant/ resistant reaction to *P. coffeae*.

Grape: The rootstocks differed significantly in leaf damage caused by leaf blackening. The symptoms were more severe in Salt Creek followed by Dogridge and own rooted vines. However, symptoms were not observed in vines grafted on 110R rootstock. The 110R rootstock showed tolerance against saline water. A procedure of sampling grapes from vineyards was standardized for pesticide residue analysis. As per this procedure sampling by collecting 5 kg grapes comprising small bunchlets will be laboratory sample from 1 ha for residue analysis with homogenous results.

Plant Protection measures in bitter gourd

In bitter gourd, repellent spray of neem formulation enhanced the field performance of Male Annihilation Technique (MAT) and Bait Application Technique (BAT). The bait (molasses 10% + carbaryl 0.1%), repellent spray (neem formulation 0.3%) and installation of cue-lure baited traps @25 /ha) initiated from the flowering was most effective in reducing the fruit damage caused by fruit fly. Application of neem as a repellent increased the catch in para-pheromone traps and enhanced the luring ability of para-pheromone by 52%.

Sapota: Application of 5 kg vermicompost with 200g N, 40 g P_2O_5 and 150g K_2O/plant/year in sapota at Arabhavi and Periyakulam continue to record significantly higher growth and yield.

In sapota, Carbendazim (0.1%) effectively reduced leaf spot disease (after I spray) at Arabhavi. At Gandevi, a trap named "NAUROH-STONEHOUSE FRUIT FLY TRAP was designed and produced commercially to make available to the orchardists.

Pomegranate: Pomegranate bacterial blight (*Xanthomonas axonopodis* pv.*punicae*) was managed effectively avoiding rainy season crop (*Mrig bahar*) and regulating winter season (*Hastha bahar*) crop during October- April, orchard sanitation, pruning of diseased branches and application of Bordeaux paste to cut ends of stems, dusting orchard soil with copper dust 4% @ 20 kg/ha or drenching with bleaching powder @ 2.0% and regular sprays of Streptocycline (500 ppm) along with Carbendazim (0.15%)/mancozeb (0.2%)/ copper oxychloride (0.25%) at 15 days interval.The adoption of integrated schedule resulted in 82.2% bacterial blight control and managed fungal leaf and fruit spots caused by *Cercospora punicae, Colletotrichum gloeosporioides, Alternaria* spp. and *Phytophthora* sp. The defoliator *(Achaea janata)* was manged by spraying of Chlorpyriphos (0.1%) and fruit-borer *(Deudorix isocrates)*, mealy bug *(Ferussia virgata)* and ahids *(Aphis punicae)* were controlled effectively by spraying of Monocrotophos (0.15%).

Chilli: Seed and seedling treatment against wilt with Carbendazim (0.05%) and transplanting in second week of April on raised beds followed by drenching with Carbendazim (0.05%) using black polythene mulch in between rows reduced wilt incidence and increased yield of green and dry red chilli.

Black pepper: The plots treated with potassium phosphonate @ 0.3% and *Trichoderma harzianum* @ 50 g/vine was found effective in managing foot rot in black pepper, followed by Bordeaux

mixture 1% spray and COC 0.2 % drenched plots. Among the biorationals evaluated, neem gold (0.5%) was found effective in suppression of mussel scale *(Lepidosaphes piperis)* population and the least scale population was recorded on vines treated with Dimethoate (0.05%).

Cardamom: In cardamom, application of inorganic P alone or with P-solubilizer was significantly superior to other treatments. Panicle and clump infections due to capsule and rhizome rot disease were minimum in plots treated with *T. harzianum* and consortium of bacteria @ 50 g/ plant. The efficacy of Phorate (2.34), Imidacloprid (1.77), Thiamethaxam (1.90) and neem cake (2.33) were found superior in recording lowest number of dead hearts per clump compared to other chemicals. Significant reduction of cardamom root grub was observed in plots treated with combined application of Imidacloprid (0.006%) and *H. indica* (100IJ/grub).

Integrated pest management

IPM validation in rice. In rice, IPM validation in Dehraduni Basmati (Type 3) was carried out at village Tilwari, Dehra Dun, in 25 hectares with main interventions like seed treatment, pheromone traps for yellow stem borer (YSB) monitoring, release of parasitoid *Trichogramma japonicum* for YSB and leaf folder and spray of Carbendazim for rice blast disease, which suppressed the incidence of all major pests. Net returns were Rs 42,840/ha in IPM as compared to Rs 34,465/ha in farmers' practice. IPM validation programme was also initiated in Pusa Sugandh 4 (1121). *Bakane* disease was observed as the main problem of this cultivar, which was effectively managed by seed treatment and *Pseudomonas.* IPM provided higher cost : benefit ratio (1:6.76) as compared to farmers' practice (1:5.76).

IPM in brinjal. IPM and INM technologies in brinjal were advanced to organic trial and validated, which yielded clean and better quality produce as it did not contain any chemicals though the yields were lower compared to farmers' practice. It also resulted in increased biodiversity (natural enemies and soil flora and fauna) and non-pollution of underground water.

Pink bollworm management in cotton

Pink bollworm (PBW) in later stages of crop growth in cotton was managed successfully by mating-disruption technique. PBW moth catches in pheromone traps in control block ranged from 3.0 to 9.4 with a mean of 7.25 moths/week/trap against 0.8-2.8 with a mean of 0.65 moth/week/trap in an experimental block where PB Rope L was used. Green boll damage due to PBW (%), due to PBW larvae, open-boll damage and locule damage/20 bolls ranged from 0.4-2.0 (mean 1.43), 0.25-1.4 (mean 0.75), 9.8-12.2 (mean 11.04) and 3.2-4.4 (mean 3.64) in experimental block against 1.0-7.6 (mean 5.21), 0.6-6.2 (mean 3.64), 20.4-27.4 (mean 23.44) and 7.0-9.8 (mean 8.36) in control block. Seed-cotton yield at harvest remained higher in experimental block as compared to control block.

A hand-held device developed for e-pest surveillance

This is a portable, hand-held device, a type of protected Personal Digital Assistant (PDA), for capturing number of pests and beneficial insects, and the collected data can be sent to NCIPM database through Internet. A software for entering population dynamics of insect-pests in cotton and weather data was developed. The data from 23 centres of the AICCIP were collected for 2006-07. And the data were entered in this programme, which generates reports either in tabular or in chart form. Interaction studies using three years (2003-04 to 2005-06) data on mealy bug colonies with weather suggested that significantly higher rainfall associated with cooler winter provided congenial environment for outbreak of grape mealy bugs.

Biological control

Exotic egg parasitoid for managing diamond-back moth. Imported egg parasitoid *Trichogramma brassicae* release at 1 lakh/ha in Jorhat, Jammu, Pune and Coimbatore revealed its better efficacy than *T. chilonis* in controlling diamondback moth *Plutella xylostella* in cabbage at Jorhat and Jammu. In Pune and Coimbatore, *T. brassicae* was as effective as *T. chilonis* on cauliflower.

SUCCESS STORY

Biological control of rice pests

Rice-sucking pests, leaf folder and stem borer as well as sheath blight were controlled using *Trichogramma japonicum,* pheromone, neem oil and *Pseudomonas fluorescens* over 1,250 hectares of *Kole* lands of Adat Panchayat in Thrissur district. The perceived effect of the people's movement in this village was enhanced biodiversity of the rice-farms, in terms of increase in birds, predatory insects and reduction in pests in terms of insects and diseases in rice-crop as well as enhanced human and livestock health, as reported by villagers. The average yield level of 6.5 tonnes/ha as against the state average of 2.5 tonnes fetched premium price since the farmers' cooperative bank marketed it as non-chemical rice with premium price. Collateral co-ordination of input supply and marketing of paddy by the village panchayat brought economic advantage to farmers.

Development of fungal formulations with enhanced shelf-life: Formulations of *Trichoderma harzianum* with 12 months shelf-life have been developed, and the bioefficacy study confirmed potency of the organism. A simple and economical solid-state fermentation technique has been developed and commercialized.

Antagonistic organisms for control of mango fruit rot: *Trichoderma harzianum* and *Pseudomonas fluorescens*, isolated from mango orchards, as mixed pre-harvest sprays, followed by post-harvest dip of fruits in a suspension of *P. fluorescens* was found effective in suppressing post-harvest fruit rot in Dasheri mango at Pantnagar.

Natural enemies control cotton mealybug: Cotton mealybug *Phenacoccus solenopsis* notable natural enemies are predators, *Spalgis epius* caterpillars *Mallada desjardensis*, *Cryptolaemus montrouzieri* and a parasitoid *Promuscidea unfascialiventris*. Hymenopteran parasitoid, *Aenasius* sp. has been reported from Punjab. These natural enemies could be conserved by avoiding chemical pesticides and relying on natural suppression of mealy bugs.

Catterpillars of *S. epius* feeding on mealy bugs (*inset: Spalgis epius* adult)

Rodent management

In Punjab, rodent damage to rice and wheat was very low (up to 2% only) but damage to pea, groundnut and sugarcane was in the range of 2.0-11.5, 9.1 and 13.8%. In western Rajasthan, 36-65 live burrows of *Mus hurrianae* and *Tatera indica* were observed in *bajra*-mungbean-*guar* fields. Among pulses, pigeonpea, cowpea and soybean suffered 3-3.33, 6.6-7.7 and 7.0-7.5% pre-harvest rodent damage. Groundnut in Bangalore and Bidar districts recorded 9.0 and 6.0% damage by rodents. Similarly damage to sesame was 5 to 6.8% in Ramanagar rural district of Karnataka. In tuberose (a flower crop) at Bidar, a maximum (47 live burrows count/ha) rodent population was observed during flowering with a mean of 11% damage. In Assam, rice (*sali* and *bao*) recorded 10-15.9% tiller damage. Pea, mustard and pumpkin and potato crops suffered 11.54,2.36, 9.4 and 13.7% damage by field rodents.

Botanicals: Feeding of wheat-sugar-oil (WSO) mix supplemented with 1, 3, 5, 7 and 10% *Calotropis procera* latex to *Rattus rattus* resulted in antifeeding index from 1.03 to 41.95%; with its maximum value (41.95%) at 3% latex concentration. With daily consumption (g/100gbw) of bait having *C. procera* root powder mixed in WSO at 2, 4 and 6% results were comparable to plain WSO food, but the intake of treated bait prolonged the cyclicity of the treated rats. Male house rats fed on WSO containing 0.1, 0.2 and 0.3% beiao (antifertility agent extracted from

Indigenous storage structures in NEH region and rodent-proofing

Rodent species composition in grain storage in Assam (indoor and outdoor granaries) comprised *Rattus rattus, Bandicota bengalensis, M. musculus castaneus, R. norvegicus* and *Dremomys lokriah macmillani*.

There are two kinds of indigenous storage structures, one for indoors for small to medium period of storage, and the other one for longer duration of bulk storage outdoors. Both types of storage systems mainly utilize bamboo and mud plaster. Different types of indoor storage structures include (i) *Duli,* (ii)*Mer,* (iii) *Tum,* (iv) *Bakharu,* (v) *Hak*. Similarly for bulk storage outdoors, two kinds of structures *Guchi bharal* and *Guti bharal* are quite common. They are erected on bamboo poles supported by timber/ brick-cement pillars or large wooden blocks. *Guchi bharal* is mainly used for bulk storage of paddy and *Guti Bharal* is used for storing threshed paddy. Indoor structures are vulnerable to rodent attack therefore rodent-proofing can be done by fixing rat-guards made of GI or aluminum sheets on pillars supporting platforms at 60 cm above ground and keeping grains stored in bags in *duli, mer, tum* at a 50 cm distance from the walls. *Bharals* can also be made rodent-proof by fixing similar types of rat-guards on the pillars.

One of the indigenous storage structures in NEH region (*Mer*)

Tripterygium wilfordii) revealed no significant difference in the consumption of beiao treated and plain WSO by rats excepting at 0.3% concentration, indicating its good acceptability.

Rodenticides: *Cholecalciferol (Vitamin D_3):* Cholecalciferol (vitamin D_3) feeding at different doses to house rats resulted in higher values of calcium and phosphorus levels in the serum of treated rats as compared to the control rats. Toxic levels of calcium and phosphorus led to death of treated rats due to mineralization of soft tissues like heart, liver, lungs, kidneys and stomach.

Brodifacoum: Efficacy of brodifacoum in wax-cake formulation containing a.i. of 0.005% was evaluated against commensal rodents at Jodhpur, Bangalore and Jorhat. In no-choice trials, cent per cent mortality was observed in *B. bengalensis* and *R. rattus* within 4-10 days in the laboratory. In choice tests, the mortality was reduced to 80% in 5-10 days (*B. bengalensis)* and 70% in 4-10 days (*R. rattus)*. The bioefficacy and palatability of brodifacoum baits were comparable with that of bromadiolone.

Aluminium phosphide: Fumigation of live burrows of *Tatera indica* with an experimental formulation of aluminium phosphide (6% a.i) yielded a control success of 68.43% (horticulture), 66.66 %(silvipasture) and 65.39% (grasslands), which was closely comparable with the check treatment of celphos pellets (54% a.i.). The experimental fumigant may have an edge over celphos due to reduced a.i. of poison in formulation under similar bioefficacy.

Whitegrubs and other soil arthropods

Whitegrubs: In groundnut, seed treatment with Thiomethoxam 25 WG and Thiomethoxam 70 WS both at 1 g a.i./kg of seeds and Imidacloprid 200 SL at 0.6 g a.i./kg of seeds, and to suppress whitegrubs in standing crop, Thiomethoxam 25 WG at 150 g a.i./ha, Imidacloprid 0.75 G at 90 g a.i./ha and Thiomethoxam 70 WS at 150 g a.i./ha, were effective for managing *Holotrichia consanguinea*.

In the pot experiments, 1,200 IJs/grub gave 50% mortality on day 4 and dose of 1,500 IJs/grub gave 90% mortality on day 7. Entomopathogenic nematode strain *Heterorhabditis indica* provided 46-51% protection to groundnut against whitegrub *Holotrichia consanguinea* at 2 to 3 million IJs/10 m^2 doses.

In potato, soil application of Imidacloprid 200 SL at 48 g a.i./ha and Imidacloprid 0.75 G at 90 g a.i./ha were promising against whitegrubs, *Holotrichia longipennis* and *Apogonia* sp., as well as in arecanut against *Leucopholis lepidophora*.

Cutworms: In capsicum, spray of Imidacloprid at 0.04% and Lambda Cyhalothrin at 0.04% one week after transplanting were promising for managing cutworms in Kullu valley.

Plant-parasitic nematodes

Nematode distribution atlas of economically important plant-parasitic nematodes of major crops has been compiled and digitized.

Rodents in NEH region

Sporadic to mass flowering of bamboo *Dendrocalamus hamiltonii* and *Melocanna bacifera* was observed during October-November, and fruiting was from January-April in Mizoram, Meghalaya and Tripura. The rodent activities started increasing from April to September with an average number of active burrows ranging from 36 to 60.49 and 38.89 to 58 in Meghalaya and in Mizoram, respectively. Rodent activities in fields were maximum in July-October and were least in January-February. Highest activities of rodents were observed in upland cultivated areas.

A total of eight rodent species from Meghalaya and twelve from Mizoram were collected and identified. In overall collection, *Bandicota bengalensis* was the predominant species, followed by *Rattus* sp. In bamboo-flowering areas, *Rattus* sp. was predominant. Trap index was calculated, which varied from 0.0135 to 0.239 for local traps in Mizoram in different sites.

Rice crop was most affected by rodents. In Mizoram, damage to almost all crops increased significantly after shedding of bamboo fruits. Upland rice, lowland rice, *jhum* paddy and maize suffered losses between 14.67 and 32.54%, 18.52 and 30.05%, 32.70 and 36.90% and 18.60 and 40.12%, respectively. The bait preference studies with *Rattus* spp. indicated higher preference for bamboo fruit, followed by rice > maize > soybean. Among the local traps, *Vaithang* proved most effective with 70-90% catches in different locations, followed by *Chepthang* (50-80 %), which was fairly high in comparison to Sherman's traps (10-20%) and Snap traps (10-30 %). Among rodenticidal trials, zinc phosphide was most effective, followed by racumin and bromadiolone.Bait stations made up of bamboo proved effective in comparison of other methods.

Chepthang – a local rodent trap in Mizoram

SUCCESS STORY

Cyst nematode management in pigeonpea in Tamil Nadu

The crop is widely attacked by the nematodes in the state. To minimize losses caused by pigeonpea cyst nematode (*Heterodera cajani*), combined treatment of *Pseudomonas flourescens* + *Trichoderma viride* at 5 + 5 g/kg of seeds led to 32.5% decrease in *Heterodera cajani* population in soil and 37.1% increase in grain yield. The cost : benefit ratio was 1:2.29. This recommendation is widely accepted by Tamil Nadu farmers.

Hot-spot areas in paddy against *Aphelenchoides besseyi* in West Bengal and Himachal Pradesh and *Meloidogyne graminicola* in Tamil Nadu, Karnataka and Himachal Pradesh were identified. Polyhouses having carnation, capsicum in the districts of Bilaspur, Hamirpur and Kangra in Himachal Pradesh were badly infested with root-knot nematodes.

Management of *Meloidogyne graminicola* infesting paddy was achieved through soil solarization of nursery + Carbofuran at 1kg a.i./ha 45 days after transplanting or application of neem-cake at 100 g/m^2 in the nursery + Carbofuran in the main field.

The combined application of neem-cake at 100 g/m^2 + *Trichoderma viride* at 2.5 kg/ha as soil application at the sowing time was effective for root-knot nematode management in mungbean.

Agricultural acarology

In Gujarat, Propargite (0.05%) was statistically better than Diocofol (0.05%), wettable sulphur (0.125%), Ethion (0.1%) in reducing rice sheath mite damage.

At Bangalore, chilli PBC 61, Udaipur 2, BVC 47 and BVC 53 were free from yellow mite infestation.

In Gujarat, *Tetranychus urticae* was observed to have resistance to Dicofol 1.5 fold at Navasari, 1.6 at Wada, 1.9 at Dungri and 2.7 fold at Sandhier.

To sustain predatory mite populations of *Neoseilus longispinosus*, Frenchbean plants provided optimum food for spidermites up to 50 days, and hence spidermites (prey) can be mass produced on Frenchbean plants up to 50 days.

At Ludhiana, Propargite (Indofil) 57 EC at 850 g a.i./ha reduced significantly yellow mite population on chillies. Propargite was found comparatively safe to predatory mites and was not phytotoxic on chilli plants.

Spiromesifen (96 g a.i./ha), Diafenthiuron (450 g a.i./ha), Milbemectin (4 g a.i./ha), Chlorfenapyr (75 g a.i./ha) and Fenazaquin (125 g a.i./ha) were significantly effective in reducing yellow mite population in chillies up to 14 days after each application at Bangalore. At Ludhiana, Diafenthiuron (Polo) 50 SC at 300 g a.i./ha proved effective in reducing *Polyphagotarsonemus latus* up to 10 days after spray, followed by Propargite 57 EC at 750 ml/ha, and Dicofol provided good control up to 7 days after spray during July-August. Propargite 57 EC at 750 and 1,000 ml/ha and Spiromesifen 240 SC at 400 ml/ha were effective in reducing *Tetranychus urticae* on brinjal up to 14 days after spray during May-June.

Pesticide residues

Spirotetramat on chilli was studied at four locations – Jaipur, Kalyani, Vellayani and Hyderabad – at 60 and 120 g a.i./ha, first at fruiting and second 10 days after first spray. Red chilli at harvest and soil samples at 20 days after second spray did not show any residue of Spirotetramat and Enol metabolite.

At Hyderabad and Kalyani, new generation insecticide Spiromesifen was used as foliar spray at 120 and 240 g a.i./ha twice at interval of 10 days. Residues in fruit samples were below the limit of observed quantity (LOQ) level of 0.01 ppm after 3 days at the recommended dose with post-harvest interval of 3.12 days. At Kalyani, Solan and Vellayani, two foliar applications of Spiromesifen were given on tea-crop in 7 days interval at 400 and 800 ml/ha. The residues reached below LOQ level of 0.05 mg/kg in green tea leaves after 7-10 days at 400 ml/ha. No pesticide was detected in processed tea and tea liquor after 14 days of application.

At Kalyani, Vellayani, Rahuri and Ludhiana, Bifenthrin 10 EC was sprayed in sugarcane in basal furrow at 100 and 200 g a.i./ha. Residues in juice and soil samples at harvest after 290 days were below the limit of determination of 0.025 ppm.

A recently introduced ß-Cyfluthrin 9% + Imidacloprid 21% were tested in supervised field trial on brinjal, tomato and okra. Three sprays were given at an interval of 7 days at (18+42) and (36+84) g a.i./ha. The proposed waiting period after the spray is 7 days.

Combi-formulation of (Trifloxytrobin 25% + Tebuconazole 50%) WG at Hyderabad, Kalyani and Rahuri on chilli was applied first at fruiting stage and the second 10 days after first spray at two doses (62.5+125) and (125+250) g a.i./ha. Half-life of Tebuconazole on chilli was found 2 days and of Trifloxystrobin was 0.38 days. The proposed waiting period for this formulation is 15 days.

Flubendiamide 24% + Thiaclorid 24% 480 SC on tomato at Bangalore and Rahuri was applied twice at 10 days interval at (48+48) and (96+96) a.i./ha. The half life of Flubendiamide was found

1.59 days. Thiacloprid residues deposit on tomato was 0.37 and 0.63 mg/kg, which dissipated with a half-life of 1.29 days. Flubendiamide and Thiacloprid were below the detectable level in soil at harvest following dosages.

Agricultural ornithology

Birds damage in different crops: In rice, the Indian peafowl *Pavo cristatus*, teals and common moorhen *Gallinula cloropus* damaged the crop to the tune of 10.0, 5.0 and 12.0%. And in wheat field in Gujarat, migratory short-toed lark *Calandrella cinerea* and calendar lark *Melanocorpha calandra* damaged sown seed to the extent of 90%. In maize, rose-ringed parakeet *Psittacula krameri* in Andhra Pradesh caused 40% damage, and in sorghum damage was between 5 and 25%, mostly by rose-ringed parakeet *Psittacula krameri*, common myna *Acridotheres tristis* and munias *Ploceus* species.

Eco-friendly birds management practice: In IBPM in cultivators' fields, different management modules during *kharif* consisting of net (1,471 kg/ha), reflective ribbon (1,361 kg/ha) and botanical spray (1,305 kg/ha) proved effective in controlling bird damage in sorghum over control (912 kg/ha).

For the first time, birds like small green barbet *Megalaima viridis*, white cheeked bulbul *Pycnotus jocosus* and tree pie *Dendrocitta vagabunda* played a vital role in propagation of *Momordica dioica*, a cucurbitaceous climber. And the seeds found in the excreta of these birds readily germinated (100%), unlike seeds harvested manually.

Role of beneficial birds: In Kerala, insectivorous birds (14) controlled rice insect pests and recorded higher yield in experimental plot (3,215 kg/ha) than control (1,895 kg/ha). T-shaped perches with nucleopolyhedrosis virus proved effective in controlling medium and large-sized larva *Helicoverpa armigera* in pigeonpea in Gujarat. In castor, 22 birds species controlled 48% of *Spodoptera litura*, and in Kerala, crow pheasant *Centropus sinenis* in cardamom devoured 5% of stem-borer larvae, and termites were voraciously fed on by common crow *Corvus splendens*. In tomato-crop, 11 species of insectivorous birds reduced 25% of *Helicoverpa armigera* larvae while in chickpea 8 birds species reduced 20-23% of *H. armigera*. Nest boxes designs were standardized for cavity-nesting birds. In Kerala, feeding behaviour of barn owl *Tyto alba*, Fish-eating owl *Bubo flavipes* and spotted owlet *Athene brama* was studied that showed dietary rodent remnants (82%) in barn owl diet, crab remnants (65%) in fish-owl and insecta remnants (60%) in spotted owlet throughout the season.