2. Salient Achievements

Crop Improvement and Management

PLANT GENETIC RESOURCES

Germplasm Collection, Introduction and Supply

A collection of 11,889 accessions could be added through 186 explorations, which include cereals and pseudocereals (2,080), oilseeds (855), vegetables (1,867), horticultural crops (881), medicinal and aromatic plants (1,894), spices (779) and other crops (792). Besides, 33,092 accessions of diverse crops from various countries (including 25 samples of transgenic crops) and 59,000 samples of different international trials have been introduced; and 12,041 accessions have been exported and 11,659 samples of crops have been supplied to different research stations in India.

Plant Quarantine

Accessions, numbering 45,093 received under germplasm exchange, have been processed for quarantine clearance. A mandatory hot-water treatment was given mainly to paddy (18,597 accessions), prophylactic fumigation was given to trial materials introduced (59,000 accessions), and 10% tri-sodium orthophosphate treatment was given to chilies, tobacco and tomato (87 accessions). Important

- Accessions totalling to 33,092 of diverse crops from various countries and 59,000 samples of different international trials have been introduced in the country.
- Under germplasm exchange, 45,093 accessions have been processed for quarantine clearance.
- Added accessions 20,453 of orthodox seed species including cereals, millets, forages, oilseeds etc to the National Seed Genebank for long-term conservation at –20°C and 11,517 to medium-term storage at 5°C.
- Maintained *in-vitro* cultures of 1,366 accessions.
- Characterized, evaluated and maintained 7,588 accessions of different crops.
- Identified promising accessions of *Brassica juncea, B. campestris* var. *toria*, *B. campestris* var. yellow sarson and *B. napus* with oil percentage >47%, of urdbean with protein >26% and of pea with protein >30% and of *Mucuna pruriens* with L-DOPA ranging from 2.46 to 5.64%.
- Fingerprinted more than 600 varieties and elite germplasm lines of 15 crops using a variety of molecular profiling techniques.
- Sorghum material with high genetic variability found.
- AFLP profile of exotic cotton and Indian cotton *Gossypium hirsutum* varieties revealed their common gene pool.
- Studies on banana confirm the hypothesis that India is a part of the centre of diversity of banana.
- Marker ACC oxidase isoform I (ACO 1) identified in tomato that determines rate of tomato ripening.
- Accomplished cloning of fruit specific promoters *Le Exp 1* and *ACS 4*.

(a) *Oryza sativa* (Jacanica trait), a tall landrace from Nagaland
(b) *Oryza rufipogon* collected from the Western Ghats
(c) *Oryza meyeriana* var. *granulata* from the Western Ghats
(d) Primitive maize (*Zea mays*) variety collected from Sikkim Himalayas

(a) Komal dhan. A soft-rice, collected from Majuli island of Assam, (b) Landraces of cowpea, collected from Kerala, (c) Variability in citrus species, collected from Arunachal Pradesh

NATP for PGR

Plant biodiversity. Accessions, totalling, 74,754, comprising crop landraces, local cultivars, trait specific materials, wild relatives of crops, lesser known species and wild economic plants have been collected.

Seed-health testing for pest-free conservation. Important interceptions include *insects-Callosobruchus analis* in *Vigna radiata, C. phaseoli* in *Lablab purpureus, Conicobruchus albopubens* in *Cyamopsis tetragonoloba, Specularius* sp. in *V. unguiculata, Spermophagus pygopubens* in *Abelmoschus, Systole* sp. in *Coriandrum sativum;* and pathogens-*Drechslera oryzae, D. sorghicola* and *Ustilaginoidea virens* in *Oryza sativa, Fusarium solani* in *Pisum sativum* and *F. solani, F. semitectum* and *Rhizoctonia solani* in *Phaseolus vulgaris*.

Integrated approach to control stem necrosis disease of groundnut. Fifty accessions of advanced groundnut breeding lines have been tested by sap inoculation of tobacco streak virus (TSV). None were found resistant. Three isolates of TSV from groundnut, sunflower and marigold have been sap inoculated on to a set of differential hosts. Groundnut isolates have showed differences in host-reaction severity.

Genetic evaluation and improvement of Sesbania *and* Crotalaria *for green manuring*. Evaluation of 86 accessions of *Sesbania* and 17 of *Crotalaria* at 8 locations for various traits has resulted in identification in *Sesbania* Ses-H 9, Ses-Pant 10 and *Crotalaria* Crota-ND 3, Crota-NBPGR 1. Based on the three years' performance for green-manuring traits, *Sesbania* Pant Dhaincha 1, DH 1 and *Crotalaria* Narendra Sanai 1 have been identified by the Variety Identification Committee for release at the national level.

PGR management and related policy issues

- Critical technical inputs were provided on the Biological Diversity Act 2002.
- Technical inputs were prepared for draft for the International Standards for Phytosanitary Measures (ISPM-11).
- Proforma have been developed for documentation of farmers' varieties and extant varieties.

interceptions are: *insects-Araecerus* sp. in *Zea mays* and *Bruchidius* sp. in *Trifolium alexandrium*; *fungi-Peronospora manschurica* (a fungus not yet reported from India) in *Glycine max*, *Colletotrichum capsici* in chili; *viruses*-7 in *Phaseolus vulgaris*; and *nematodes-Meloidogyne* sp. and *Pratylenchus* sp. in *Malus*, *Prunus* and *Pyrus* from the USA. Two hundred and four phytosanitary certificates have been issued for export materials.

Germplasm Conservation

Accessions, totalling to 20,453 of orthodox seed species, including cereals (8,466), millets (2,709), forages (838), pseudocereals (658), grain-legumes (2,395), oilseeds (2,200), fibre crops (649), vegetables (2,015), fruits (42), medicinal and aromatic plants (184), narcotics (4), spices (2), released varieties (174) and genetic stocks (117), are added to the National Seed Genebank for long-term conservation at –20°C; and 11,517 accessions have been added to medium-term storage at 5°C as reference samples. Cryostored 410 accessions comprise fruits and nuts (148), agroforestry species (90), legumes (55), vegetables (37), medicinal and aromatic plants (10) and others (70); and pollens of mango (30). Accessions 1,366 in number of the 47 genera belonging to 121 species, mainly *Allium sativum* (10), *Curcuma* (24), *Fragaria* (10), *Ipomoea batatas* (20), *Morus* (32) and *Musa* (20) have been maintained as *in vitro* cultures, and 179 new accessions of various vegetatively propagated species have been added to *in-vitro* genebank.

Germplasm Characterization, Evaluation and Maintenance

In *rabi* 2002-03, 7,588 accessions of different crops

(a) High-yielding sorghum developed through selection from a landrace in Maharashtra, (b) Early-maturing guar (*Cyamopsis tetragonoloba*) accession grown at the NBPGR Regional Station, Jodhpur, (c) Characterization of lentil germplasm at the NBPGR Regional Station, Bhowali

IPR-related activities

IPR Cell at the ICAR has filed 101 patent applications. And during 2003-04, 24 applications have been filed. This includes also for securing patent rights in foreign countries under the Patent Cooperation Treaty. Steps have also been accelerated for commercialization of ICAR technologies. So far, 31 technologies have been assigned by the ICAR to the National Research Development Corporation (NRDC) for commercialization.

have been characterized, evaluated and maintained.

Maize, pearl millet, cowpea, urdbean, brinjal, bottle-gourd, ridge-gourd, sponge-gourd, aloe, mucuna, vetiver, sesbania and sunnhemp 4,187 accessions have been sown/ planted at the NBPGR Headquarters and 20,276 at various regional stations for seed increase, characterization, preliminary evaluation and maintenance in *kharif* 2003.

Rapeseed-mustard (708), safflower (501), wheat (76), pea (185), walnut (10), urdbean (300) and cowpea (95), totalling to 1,875 accessions, have been analyzed for respective quality traits like total oil, and protein and fatty acid profiles. Promising accessions of *Brassica juncea*, *B. campestris* var. *toria*, *B. campestris* var. yellow sarson and *B. napus* with oil percentage >47%; of urdbean with >26% protein and of pea with >30% protein; and of *Mucuna pruriens* (6 samples) with L-DOPA ranging from 2.46 to 5.64% have been identified.

DNA Fingerprinting

More than 600 varieties and elite germplasm lines of 15 crops have been fingerprinted using a variety of molecular profiling techniques.

Cereals and millets. Fingerprinting 38 varieties/ parental lines of sorghum using sequence tagged microsatellite sites (STMS) markers has revealed on an average 5.8 alleles per locus for 8 selected STMS loci and

Molecular markers reveal wide genetic diversity in banana

Recent reports in the international press had raised alarm about the possible extinction of edible banana due to its susceptibility to black sigatoka and Panama diseases. The National Research Centre on DNA Fingerprinting, New Delhi, has analysed molecular diversity of 220 traditional varieties of banana, grown in different regions of India. The study has revealed that varieties comprise 5 different genomic groups, *viz.* AA, AB, ABB, AAB and AAA; and in each group, high amount of genetic diversity exists. These results confirm hypothesis that India is the part of the centre of diversity of banana, and the country harbours extensive genetic variations in this crop. The wide genetic diversity existing in farmers' fields ensures that there is no immediate threat of extinction of banana in India.

Electronic database of plant genetic resources

A software has been developed, and the data of about 2.5 lakh accessions are being maintained in the genebank converted into database format by adopting standard codes for facilitating smooth retrieval of information on the genetic resources. About 50,000 entries of the newly collected germplasm have also been entered in the database.

a diversity index of 0.226-0.800. This indicates high genetic diversity in the material. In 54 selected barley varieties, 10 STMS primers have revealed diversity index of 0.037-0.614.

Pulses and oilseeds. Pigeonpea (31) profiled with 15 amplified fragment length polymorphism (AFLP) primers has revealed 82% polymorphism and chickpea has showed 93% polymorphism. Among safflower, soybean, sesame and niger, AFLP diversity in safflower has been found very low, and in sesame, it is higher, which may be attributed to liberal use of indigenous landraces in its breeding programmes.

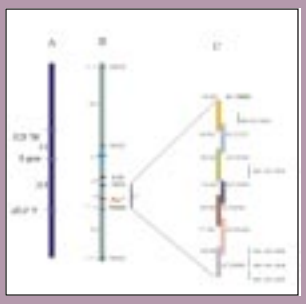
Fibre crops. AFLP profile of cotton (30) has revealed that exotic and Indian *Gossypium hirsutum* varieties are from common gene-pool.

Plant Biotechnology

Selections BIO 169-2000, BIO 64-2001 and BIO 54-2001 of mustard have showed significant yield superiority with 18.8, 17.1 and 15.1% yield advantage over the best check, Pusa Jai Kisan. CMS of (*Diplotaxis catholica*) *Brassica juncea* derived through somatic hybridization has indicated duplicated *coxI* gene in this system. RNA blots

Magnaporthe grisea resistance helped mapping *Pi k^h* gene on rice chromosome 11

The *indica* rice line Tetep possesses durable resistance to *Magnaporthe grisea* population of the north-western Himalayan



Integrated linkage map of gene Pikh derived from RAPD, AFLP (A) and CAPS, RAPD and STMS (B) Markers and putative physical location (C) of R-gene on rice chromosome

region of India. It has been used in mapping *Pi k^h* gene with AFLP and RAPD markers. This gene has now been mapped within 2.1 cM on the rice chromosome 11.

Summary status of Genebank Genes predicted in the rice genome sequences at the IARI

Total rice genome sequences submitted in the Genebank	6734077 bp
Total number of genes predicted	984
Genes showing 100% match with existing genes	154
Putative genes	39
Unknown genes	78
Hypothetical genes	411

Effects of protease inhibitors on *Helicoverpa armigera* larvae growth

Helicoverpa armigera larvae, when reared on the artificial diet supplemented with protease inhibitors of different crops, *viz*. Pigeonpea Protease Inhibitor (PPI), Mungbean Protease Inhibitor (MPI) and Chickpea Protease Inhibitor (ChPI); have showed reduced growth rate in terms of body weight and number of days required for pupation. Cloning cDNA and genes of these inhibitors is continuing. The plasmid DNA from these clones has been isolated, and presence of an insert DNA of 4-5kb in mungbean and cowpea and of 2 kb in chickpea has been observed.

Marker for tomato ripening identified

To determine rate of ripening in tomato, a marker has been identified as ACC oxidase isoform 1 (ACO1), which has showed a direct relationship with ripening in 3 tomato cultivars.

prepared from leaf and flower-bud tissues of male sterile, fertile and euplasmic lines of *B. juncea* have been probed with mitochondrial *coxI* gene probe. In leaf tissues of all the 3 lines, a transcript of 2kb hybridized to probe, and their flower buds have showed variable *coxI* transcript size.

*LeExp*1 cDNA has also been cloned from tomato for developing its transgenics with delayed ripening. Cloning of fruit-specific promoters *LeExp*1 and ACS4 has been accomplished.

FOOD CROPS

Rice

Crop improvement: In rice, 19 varieties and one hybrid have been released.

Crop production. Rice variety Nidhi has been found most suitable for direct seeding under puddle conditions using sprouted seeds at 125 kg of seeds/ha along with Butachlor at 1.5 kg a.i./ha and one spot weeding.

Planting one or two seedlings of rice hybrids/hill at 20

Hybrid rice technology

In advanced variety trials, 4 hybrids, MPH 5401, PRH 122, HRI 126 and PAC 89001 have showed promise. Two CMS lines, DRR 2A and DRR 3A, have been registered with the NBPGR, New Delhi.

It is estimated that around 2 lakh hectares were planted with hybrid rice in the country during 2002, mainly in the eastern Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Haryana, Punjab and Maharashtra.

- Registered 2 CMS rice lines DRR 2A and DRR 3A with the NBPGR.
- Planted 0.2 million hectares with hybrid rice in the country, mainly in the eastern Uttar Pradesh, Bihar, Chhattisgarh, Jharkhand, Haryana, Punjab and Maharashtra.
- Identified SSR markers RM 316, RM 219 and RM 444, located on the short-arm of chromosome 9, as more tightly linked markers with the gall-midge resistance gene *Gm I*.
- In rice released Dhanrasi, RH 204 as Central releases and GR 8, Dandi, Shah Sarang, Lam Puch as State releases.
- Rice Nidhi found most suitable for direct seeding under puddle conditions.
- White-ear damage by yellow stem-borer significantly lowered on main crop rice RP 4-14, wherein trap crop Pusa Basmati I was planted with it in 9:1 ratio in east-west direction as compared to plots with the sole main crop.
- For sheath-rot management fluorescent *Pseudomonas* S-cag-6 found most effective when seeds and seedlings were treated with it, followed by a foliar spray of 0.1% Carbendazim.

Developed database on rice for linked SSR markers for gall-midge

Three SSR markers RM316, RM219 and RM444, located on the short arm of the chromosome 9, have been identified as more tightly linked markers with gall-midge resistance gene *Gm1* with a linkage distance of 8 cM, 4.9 cM and 6.0 cM. The linkage distances and orientation of these markers with respect to *Gm1* have been validated in $BC_1F_{2:3}$ population of cross Swarna/W1263//Swarna. A database of marker allele sizes in base pair (bp) has been developed for the linked SSR markers in a set of gall-midge resistant and susceptible genotypes of rice.

Fluorescent *Pseudomonas* isolates for controlling sheath-rot in rice

Three isolates of fluorescent *Pseudomonas* C-1, S-cag-2 and S-cag-6 have been evaluated in the field for management of sheath-rot disease. The antagonistic bacterium S-cag-6 has been found the most effective one when seed and seedlings were treated with it, followed by one foliar spray coupled with one spray of 0.1% Carbendazim.

Rice varieties released

Variety/Designation/ IET No.	Days to 50% flowering	Grain type	Ecosystem	Yield range (tonnes/ha)	Reaction to pests/diseases	Recommended state/region
			Central Releases			
Dhanrasi IET 15358	115-120	SB	Shallow lowland	5.5-6.5	R-BL; MR-BLB, RTV, ShR	Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu
RH 204 IET 16442 (Hybrid)	90-95	LS	Irrigated	6.0-6.5	R-Lbl	Andhra Pradesh, Karnataka, Tamil Nadu, Haryana, Rajasthan
			State Releases			
GR 8	75-80	-	Rainfed upland	-	-	Gujarat
Dandi IET 14906	-	-	Irrigated, salt tolerant	-	R-BLB, BL; MR- WBPH	Gujarat
Shah Sarang 1 IET 14620	115	SB	Rainfed/ irrigated lowland	-	MR-BL	Meghalaya
Lam Puch 1 IET 15057	113	SB	Rainfed/ irrigated lowland	-	MR-BL	Meghalaya
Bha Lum 1 IET 16486	94	LB	Rainfed upland	-	R-BL	Meghalaya
Bha Lum 2 IET 16487	95	LB	Rainfed upland	-	R-BL	Meghalaya
Gouri IET 15923 KAUM 38-4-1 (MR 1)	85-90	SB	Irrigated	5.0	R-ShR, Stack-burn, BS; MR-ShBl	Peat soils of Kuttanad district of Kerala
IET 15376 R 636-405	90-100	MSl	Irrigated	4.0	R-GM1	Chhattisgarh, Madhya Pradesh
IET 14400 CN 846-30-3-1	140-150	LS	Shallow water	4.5	-	West Bengal
Bhudeb IET 14496 (CN 1035-61)	120-125	LS	Semi-deep water	4.5-5.0	R-BPH, Bl, BLB; MR-ShBl, ShR	West Bengal
Sweta IET 14735 rpp 7-23-1-2-3	100-105	SB	Irrigated	5.0	MR-WBPH, BL, BS, ShBl, ShR; MS- BLB, RTV	Irrigated areas of Kerala
IET 16075 SYE 14-9-8	100-105	SB	Irrigated	4.5-5.0	MR-WBPH, BPH, BL, BLB	Vidarbha areas of Maharashtra
Varsha IET 16709	85-90	SB	Irrigated/ lowland	4.5-5.0	-	Kerala
Chingam	70-75	MB	Irrigated upland	3.5-4.0	-	Kerala
Dhanu	120-130	SB	Irrigated boro	4.5-5.0	-	Kerala
Kunjukunju-Varna	75-80	LB	Irrigated lowland	6.0-6.5	-	Kerala
Kunjukunju-Priya	75-80	LB	Irrigated lowland	6.0-6.5	-	Kerala
Pant Dhan 15 IET 14132	110-115	LS	Basmati area	3-4	MR-NBl, Lbl	Uttaranchal

BL-Blast; BLB-Bacterial Blight; BPH-Brown Planthopper; BS-Brown Spot; GM-Gall Midge; Lbl-Leaf Blight; LB-Long Bold; LS-Long Slender; MB-Medium Bold; MR-Moderately Resistant; MS-Moderately Susceptible; MSl-Medium Slender; NBl-Neck Blast; R-Resistant; RTV-Rice Tungro Virus; SB-Short Bold; ShBl- Sheath Blight; ShR- Sheath Rot; WBPH- White Backed Planthopper.

× 10cm or 20 × 20cm has recorded comparable grain yields. And for seed production of hybrid DRRH 1, planting 'A' line at 15 × 15cm and 'R' line at 15 × 15cm or at 30 × 10cm has recorded higher seed yields.

Rice cultures IET 15392, IET 12067, IET 15353 and IET 14336 have recorded higher P-use efficiency and grain yields under low to moderate (10–30 kg P_2O_5/ha) as well as at higher P-levels (40-60 kg P_2O_5/ha).

A ten-year study has showed that grain yield of *kharif* rice (variety, Krishnahamsa) increased significantly (6.0-6.2 tonnes/ha) as against control (4.98 tonnes/ha) by growing green manure during pre-*kharif* and incorporating crop in the soil prior to land preparation for *kharif*. Even *rabi* crops grown subsequently in these plots performed significantly compared to control.

Crop protection: In field experiements Pusa Basmati 1 rice variety, known to attract yellow stem-borer (YSB) moths, has been used as the trap crop and variety RP 4-14 as the main crop, grown during *rabi* and *kharif* 2002 in different row ratios and planted in east-west or north-south directions. White-ear damage by YSB was significantly lower in the main crop in plots wherein trap crop was planted in 9:1 ratio with it and planted in east-west direction as compared to plots with sole main crop; besides the higher yield of the main crop.

Recent monitoring of stem-borer species at 15 locations in the country has revealed that in north-western parts, yellow stem-borer (YSB) populations were higher, followed by white stem-borer (WSB) and pink stem-borer (PSB). At Pantnagar, striped stem-borer (SSB) was also observed. In southern parts, YSB was the only species present in Andhra Pradesh, and besides this PSB was observed in Tamil Nadu. In eastern parts, dark-headed borer (DHB) was observed in addition to other three species. In hills, WSB was higher than PSB and YSB. Thus, stem-borer species composition is probably influenced by the suitability of the local rice varieties and other crops grown in the area.

Weather-based forewarning studies have indicated significance of maximum temperature, crop age and morning humidity for leaf blast severity and crop age and maximum/minimum temperatures for neck blast.

Wheat and Barley

Crop improvement: Seven wheat and one barley varieties have been released for commercial cultivation.

Ten wheat and two barley varieties have been identified for release.

Diversification/intensification of rice-wheat system: Replacing rice with soybean/pigeonpea and wheat with mustard, followed by mungbean, can diversify rice-wheat system and can improve soil health.

Vegetable pea (as green pod), mustard and mungbean have recorded up to 34.0, 20.4 and 11.8% higher yields as compared to flat planting; indicating utility of bed planting for diversification/intensification of rice-wheat

- Released wheat VL 829, HS 420, HS 375, DBW 14, NW 2036, MP 4010 and HI 1500
- Improved soil health, with replacement of rice with soybean/pigeonpea and wheat with mustard, followed by mungbean.
- For wheat rotary tillage proved better than zero tillage, followed by FIRBS, followed by conventional practice.
- Attack of various rusts on PBW 343 signals that effective life of the variety may not be very long from now onwards.
- One of the major diseases of wheat, powdery mildew, caused by *Erysiphe graminis,* found favour under the FIRBS, due to the change in microclimate.
- Achieved effective control of Karnal bunt through 2 foliar sprays of *Trichoderma viride,* before ear-head emergence and at its emergence.
- Prepared an atlas for various quality parameters for wheat.

Wheat and barley varieties for commercial cultivation

Varieties	Production conditions	Area of adaptability
Wheat		
VL 829	Rainfed, early sown	Hills of Jammu and Kashmir, Himachal Pradesh, Uttaranchal and Sikkim
HS 420	Irrigated, late sown	Hills of Jammu and Kashmir, Himachal Pradesh, Uttaranchal and Sikkim
HS 375	Rainfed, summer sown	Snow-bound areas of north-western hills
DBW 14	Irrigated, late sown	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam
NW 2036	Irrigated, late sown	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam
MP 4010	Irrigated, late sown	Gujarat, Madhya Pradesh, Chhattisgarh, Kota and Udaipur (Rajasthan), and Bundelkhand region (Uttar Pradesh)
HI 1500	Rainfed, timely sown	Gujarat, Madhya Pradesh, Chhattisgarh, Kota and Udaipur (Rajasthan) and Bundelkhand region (Uttar Pradesh)
Barley		
BHS 352	Rainfed, timely sown	Hills of Jammu and Kashmir, Himachal Pradesh, Uttaranchal and Sikkim

Hybrid wheat

Among 23 entries in pilot trial (19 hybrids + two 'checks' i.e. PBW 343 and HD 2687 at two seed rates 50 kg/ha and 100 kg/ha each), only one hybrid HM 01150 has exhibited 15.06% standard heterosis

DBW 14 wheat. It has been released for commercial cultivation for irrigated, late sown areas of eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam.

PBW 502 wheat. This has been identified for release for irrigated, timely sown areas of Punjab, Haryana, western Uttar Pradesh, Delhi and parts of Rajasthan.

system with better returns. Nodule formation and root dry matter in mungbean under bed-planting system have been found higher as compared to flat-planting system.

HD 2687, PBW 343, BW 1485, DL 1266 and CBW 23 wheat under zero, rotary, FIRBS and conventional tillage options have indicated varietal differences in yield. HD

Wheat and barley varieties identified for release

Varieties	Production conditions	Area of adaptability	Developed by
Wheat			
VL 832	Rainfed, timely sown, high altitude	Hills of Jammu and Kashmir, Himachal Pradesh, Uttranchal and Sikkim	VPKAS, Almora
HPW 155	Rainfed, timely sown, high altitude	Hills of Jammu and Kashmir, Himachal Pradesh, Uttranchal and Sikkim	HPKV, Palampur
PBW 502	Irrigated, timely sown	Punjab, Haryana, western Uttar Pradesh, Delhi and parts of Rajasthan	PAU, Ludhiana
HD 2824	Irrigated, timely sown	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam	IARI, New Delhi
MACS 6145	Rainfed, timely sown	Eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam	ARI, Pune
Raj 4037	Irrigated, timely sown	Madhya Pradesh, Chhattisgarh and Gujarat	RAU, Durgapura
GW 1189 (Durum)	Irrigated, timely sown	Maharashtra, Karnataka, and parts of Andhra Pradesh and Tamil Nadu	GAU, Vijapur
NIDW 295 (Durum)	Irrigated, timely sown	Maharashtra, Karnataka, and parts of Andhra Pradesh and Tamil Nadu	MPKV, Niphad
UP 2565	Irrigated, late sown	Maharashtra, Karnataka, and parts of Andhra Pradesh and Tamil Nadu	GBPAU&T, Pantnagar
HD 2833	Irrigated, late sown	Maharashtra, Karnataka, and parts of Andhra Pradesh and Tamil Nadu	IARI, New Delhi
Barley			
RD 2624	Timely sown, rainfed	Punjab, Haryana, western Uttar Pradesh, Delhi and Rajasthan	RAU, Durgapura
NDB 1173	Saline/alkaline soils	Salt-affected regions in India	NDUAT, Faizabad

Sound IPM strategy for wheat

This year, the IPM module was validated in 5 acres of land in two villages, namely Darar and Taraori in Karnal. The seed treatment with a combination of reduced dosage of Vitavax 75WP (at 1.25g/kg of seed) plus *Trichoderma viride* at 4g/kg of seed (commercial product), followed by broadcast in insecticide (Endosulfan)-treated soil at 15 days after sowing and one spray of Confidor 200 SL on border rows were the only management activities in the IPM plots. The wheat yield gain was in the range of 12.40 to 14.56% in the experimental fields and 8.7 to 14.58% at the farmers' fields. Pest incidence data have indicated that target pest, termite, was lower in the IPM plots compared to non-IPM plots. Also, incidences of foliar aphids and loose smut were lower in the IPM plots.

2687, PBW 343 and BW 1485 were at a par in yield in zero tillage and conventional tillage, and were significantly superior to others. In rotary tillage, HD 2687 and PBW 343 were at a par and significantly superior to others. In FIRBS, DL 1266 produced the highest yield and was significantly better than others, exceptilng HD 2687, which showed higher grains/ear-head. In general, rotary tillage has been better among all tillage systems, followed by conventional practice.

Crop protection: No serious outbreak or epidemic of any pest has been reported during the season. Brown rust has been recorded on the dominant PBW 343 in various locations in Punjab; the disease had developed late in the season. Hence, losses are expected to be negligible. This year, yellow rust has been recorded in the SAARC disease-trap nursery, planted in Pakistan at Islamabad, and in traces at Humle in Nepal. This is the signal that effective life of PBW 343 may not be very long from now onwards.

HD 2824 wheat. This has been identified for release in irrigated, timely sown areas of eastern Uttar Pradesh, Bihar, Jharkhand, West Bengal, Orissa and Assam. It has given an average yield of 4.6 tonnes/ha with a potential of 6.5 tonnes/ha. It has excelled over popular variety PBW 343 by a margin of 5–14%.

HD 2833 wheat. It is found suitable for irrigated, late-sown areas of Maharashtra, Karnataka, parts of Andhra Pradesh and Tamil Nadu. This variety has exhibited high degree of resistance to black and brown rusts in older plants.

Pest problems in rice – wheat cropping system in a system's perspective

The continuous rotation of rice and wheat, year after year, has influenced pest situation with the introduction of several new tillage techniques in the recent years.

Powdery mildew, caused by *Erysiphe graminis*, is one of the major diseases of wheat, and is influenced by tillage practices due to the change in the microclimate. This disease has been found to be favoured under the FIRBS. The Per Cent Disease Index (PDI) under the FIRBS, zero tillage (ZT) and conventional (CT) has been calculated to be 58.22, 42.44 and 12.44 in 2002-03.

Termite is a very important pest of wheat in loose soils in the North-Western Plains Zone. The damage due to termites is highly influenced by tillage system. During 2002-03 crop season, the termite damage under the FIRBS, CT and ZT has been 1.63, 1.01 and 0.24 tillers/m^2.

Multiple disease/pest resistants wheat genotypes

Resistant to three rusts + Moderately resistant (MR) to Leaf Blight (LB) + Flag Smut (FS): HPW 185

MR to LB + Karnal Bunt (KB) + FS: HW 3082, DWR 1006 (d), PDW 215 (d) and TL 2877 (T)

Resistant (R) to KB + FS: HI 8591 (d), Raj 6557 (d), MACS 3127 (d) and DWR 247

MR to LB + KB + FS + Powdery Mildew (PM): TL 2908 (T), TL 2910 (T), TL 2788 (T), TL 2908 (T) and COLOTANA

R to KB + PM + FS: HI 8550 (d)

Resistant to stem and leaf rust +
R to KB: PBW 486 and LOK 42
R to KB + FS: GW 1172

Resistant to leaf and stripe rust + R to KB + PM + FS: WH 896 and HD 4687

Resistant to three rusts + Loose smut (LS) + FS + KB: HD 4672 (D) and HI 8498 (d)

Resistant to Root Aphids + Brown Wheat Mite + Shoot Fly + Powdery Mildew: SONORA Pm 3

Resistant to Root Aphids + Brown Wheat Mite + Three Rusts+ Karnal Bunt: HI 8498 (d)

Resistant to Brown Wheat Mite + Shoot Fly +Three Rusts+ KB + LB + PM + FS: TL 2877 (T) and TL 2908 (T)

Genetic variations for yield and its components in fixed breeding populations of wheat

To find out variability generated for various yield component lines, the fixed generation breeding materials were distributed in 6 distinct groups through Metroglyph analysis for various traits. These materials have been shared with other wheat-breeding centres in the country, and are being utilized in the hybridization programme.

Genetic background	Yield/plot (kg)	Tillers (metres)	Grains (spike)	Thousand grains (weight)	Spikelets (spike)	Spike (length)	Harvest index	Biological yield
Synthetics								
Range	1.788-2.356	116-158	42.6-73.4	35.7-56.9	16.8-23.4	9-13.7	0.29-0.39	5.2-6.4
Mean	2.011	133	55.7	41.9	21.2	11.5	0.34	5.7
Buitre								
Range	1.528-3.426	49-135	59-97	31.6-46.7	19.8-25	10.8-15.2	0.27-0.46	4.5-7.4
Mean	2.005	88.7	75.1	38.8	21.9	13.0	0.35	5.7
PBW 343	2.385	145	61.4	41.0	18.8	9.7	0.38	6.25
SE (±)	58	5	2.0	0.6	0.3	0.2	0.007	0.10

Epidemiological studies to manage Karnal bunt (KB): An effective control of KB (0.33% incidence) could be achieved through 2 foliar sprays of *Trichoderma viride* at different crop growth stages; one spray before ear-head emergence and the second at the ear-head emergence. And foliar sprays of Tilt 25 EC at 0.1% at these growth stages gave cent-per-cent control. This is in comparison to 0.13% disease incidence with Tilt 25 EC at 0.1% spray at the later stage, which is the present-day recommendation for disease control. Hence, by adopting epidemiological approach, an effective management of the Karnal bunt disease could be achieved through *T.viride*. Spraying has to be done at different growth stages, by coinciding sprays with movement of *Tilletia indica* from soil to target part i.e., ear-head.

Wheat genotypes rich in nutritional quality

Attribute	Value	Genotypes
Triticum aestivum		
Protein	≥14.5%	Lok 45 (C), PBW 525, PBW 530, CBW 25, NW 2083, UAS 269
ß-carotene	≥4.2ppm	HS 240 (C), VL 849, VL 864, VL 865, UP 2625, HD 2859, HW 5023
Iron	≥75ppm	NW 1014 (C), HUW 533 (C), NIAW 34 (C), HW 1085 (C), HW 2044 (C), PBW 521
Zinc	≥50ppm	PBW 373 (C), NW 2036 (C), K 8027 (C), GW 322 (C), PBW 522
T.durum		
Protein	≥14.0%	MACS 2846 (C), UAS 1023, MPO 1152
ß-carotene	≥6.0ppm	PDW 233 (C), WH 896 (C), HI 8627, GW 1189, NIDW 295
Iron	≥75ppm	HD 4701, UAS 1023
Zinc	≥45ppm	HD 4701, NIDW 309, UAS 2024,

Wheat genotypes for end-products

Products	Released varieties	Final year entries
Chapati	PBW 175, C 306, K 9107, NW 1014, C 306, GW 322, Lok 1, HW 2004, HI 1500	PBW 509, Raj 4037, HD 2833
Bread	VL 738, K 9107, Lok 1, HI 977	HS 431, HUW 549
Biscuit	Sonalika, VL 829, UP 2425, PBW 498, PBW 175	HS 436
Pasta	PBW 34, PDW 233, WH 896, Raj 1555,	GW 1189

Quality: Attempts have been made to classify and grade Indian wheats on the basis of the quality analysis of the harvested produce that reaches different '*mandis*'. Out of 2002 wheat-grain samples collected from 108 places, covering eleven wheat-growing states, 32% samples belong to internationally accepted overall

grade 1. An atlas has been prepared for various quality parameters, and following classes have been proposed: (i) Indian medium hard wheat (IMHW) for chapati and other related products, (ii) Indian hard wheat (IHW) for bread, (iii) Indian soft wheat (ISW) for biscuit, (iv) Indian durum wheat (IDUW) for pasta and traditional products, and (v) Indian dicoccum wheat (IDIW) for traditional and pasta products.

For improving wheat quality for chapati and bread, systematic crosses were made using a large number of Indian germplasm lines, 16 Australian, 5 Argentinean and 3 Canadian lines. Some of the superior crosses for bread quality are K 9107/PBW 435, K 68/WH 542, WH 542/Terra (F_6 generation); WH 147/K 9107, UP 2338/WR 849, HUW 524/GW 273, GW 273/WH 157, WH 542/HI977, HUW 524/HI 1123 (F_4 generation), VL 796/K 9107 and K 9107/PBW 435//WH 542/Terra (F_2 generation). Similarly, for chapati, some of the superior crosses are: Raj 1482/WH 542, HI 1077/PBW 343, Hyb 633/UP 2338, NP 4/WH 291, C 306/K 9107, PBW 343/WH 147 (F_6 generation); C 306/GW 273, UP 2338/C 306, BW 11/HD 2687 (F_4 generation) and NP4/HD 2687 and CBW 09/GW 273 (F_2 generation).

Maize

Crop improvement: Eleven maize cultivars have been released for various agroclimatic regions.

Two single cross hybrids i.e. CML 175 × CML 176 and CML 142 × CML 150 and one three-way hybrid (CML 142 × CML 150) × CML 186 have given extremely good performance in *kharif* as well as in *rabi*. Considering increasing popularity of baby-corn in the country, maize cultivars, VL 42, Pusa Hybrid -1, -2, -3 and Parkash have been identified for production of baby-corn.

- Released 11 maize cultivars–Pratap Composite Makka 4, Pusa Early Hybrid 5, Pragati, Deccan Hyb. 115
- Two single-cross maize hybrids and 1 three-way hybrid gave extremely good performance in *kharif* as well as in *rabi*.
- Identified maize VL 42, Pusa Hybrid 1, Pusa Hybrid 2 and Pusa Hybrid 3 and Parkash for production of baby-corn; which is becoming popular in the country.

Maize varieties/hybrids released

Variety/Hybrid	Maturity	Grain colour	Area adaptation
Pratap Composite Makka 4 (EC 1108)	Early (80 –85 days)	White semi-flint	Jammu and Kashmir, Himachal Pradesh, Hills of Uttaranchal, Hills of West Bengal, North-east Region
Pusa Early Hybrid 5 (AH 421) (Single-cross hybrid)	Early (80 –85 days)	Yellow orange semi-flint	Delhi, Haryana, Punjab and Uttar Pradesh
Pragati (D 994) (Composite)	Early (80 –85 days)	Orange semi-flint	Eastern Uttar Pradesh, Bihar, Assam, Orissa, West Bengal and Jharkhand
Deccan Hyb. 115 (BH 2187) (Single-cross hybrid)	Early (80 –85 days)	Orange flint	Eastern Uttar Pradesh, Bihar, Assam, Orissa, West Bengal, Jharkhand, Jammu and Kashmir, Himachal Pradesh, Hills of Uttaranchal, Hills of West Bengal, North-east Region, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra for *kharif*
PRO 345 (4644) (Hybrid)	Medium (90 days)	Orange semi-flint	Eastern Uttar Pradesh, Bihar, Assam, Orissa, West Bengal and Jharkhand
JKMH 68-2 (Hybrid)	Full season (100-110 days)	Orange-yellow flint	Jammu and Kashmir, Himachal Pradesh, Hills of Uttaranchal, Hills of West Bengal, North-east Region, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra for *kharif*
BIO 9682 (Hybrid)	Medium season	Orange-yellow flint	Delhi, Haryana, Punjab and Uttar Pradesh
Pratap Maize Hybrid 1	Early	White semi-flint	Rajasthan
Vivek Comp. Maize 11	Early	Orange flint	Uttaranchal
Comp. Girija	Medium	Orange flint	Himachal Pradesh
Comp. Sharadhamani	Medium	Orange flint	Uttar Pradesh

Maize resistant germplasm against insect-pest *Chilo partellus*

Full-season maturity		Medium maturity		Early maturity		Extra early maturity		Quality protein maize	
R	M	R	M	R	M	R	M	R	M
BH 1015 BH 1620	17	-	17	BISCO 2032	11	-	4	HQPM-3 JHQPM 24 JHQPM 84 XP 0103 CML 142 × CML 150	27

R-Resistant line, M-no. of moderately resistant lines

PEEHM 5 (AH421) maize. This is an early variety released for Delhi, Haryana, Punjab and Uttar Pradesh. It is yellow-orange semi-flint type. This has an average yield of 5 tonnes/ha and it has potential of 6 tonnes/ha.

Crop production: Irrespective of cultivars for *kharif* maize, N dose of 120 kg for full and medium maturity groups and 80-100 kg N for early and extra-early material have been found optimum.

Crop protection: Many maize genotypes have been found resistant to biotic stresses

Sorghum

Crop improvement: DSH 4 (SB 401A × SPV 570), a *rabi* season sorghum hybrid, has been released and recommended for cultivation in northern Karnataka. Its

Maize genotypes resistant to biotic stresses

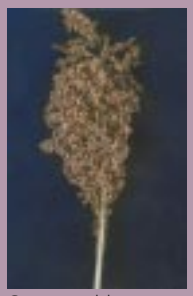
Diseases	Genotypes
A. Full-season maturity group	
MLB, TLB, BSDM, PFSR, CR	BH 2528, PRO 359, F 1562, BIO 92327, NECH 110, BISCO 851, PAC 7005
B. Medium maturity group	
MLB, TLB, BSDM, ESR, CR	BISCO 1102, X 1280 A, HKH 1191, PRO 349, PRO 345, NECH 113, X 2003, JKMH 1080, PAC 70009, AH 1121, BIO 92218, X 46172
C. Early maturity group	
MLB, TLB, PFSR, BSDM	X 2185, X 2002, AH 10411, BISCO 2434, JH 3851, PAC 70001, Seed Tech 1202, BIO 92136
D. Extra early	
MLB	BISCO 2051, AH 421

MLB- Maydis leaf blight; TLB- Turcicum leaf blight; BSDM- Brown stripe downy mildew, PFSR- Post-flowering stalk rot; CR- Common rust; ESR- Eriwinia stalk rot

DSH 4 sorghum is a *rabi* season hybrid between SB 401A and SPV 570. This has been released for cultivation in northern Karnataka. Its duration is 115-120 days with an yield potential of 3.0-3.5 tonnes of grains/ha and 6.0 tonnes of fodder/ha.

Occurrence and increased severity of biotic stresses in sorghum

A new sub-race of Sorghum



Grain-mold resistant sorghum germplasm

It is the first report on the occurrence of *Sorghum bicolor* ssp. *bicolor* race *guinea* sub-race *conspicuum* from the explorations made in the Ganga Basin and Bundelkhand regions of Uttar Pradesh. This sub-race possesses unique characteristic of gaping glumes, which may prove beneficial in resistance breeding programmes to grain-mold infection during *kharif*.

Cost of production (per litre) of ethanol from sugarcane and sweet-sorghum

Particulars	Sweet-sorghum (Rs/litres)	Sugarcane molasses (Rs/litres)
Manpower	0.50	0.25
Steam	1.00	1.00
Electricity	1.00	1.00
Yeast	0.10	0.10
Management/ Administration	0.10	0.25
Pollution control measures	Nil	0.25
Raw material	10.41	6.40[1]-9.70[2]
Total	13.11	9.25 – 12.55

1-Imputed cost in case of industries' own production. 2- Cost in case of market purchase of molasses

- To avoid the complexity in analysis, the investments were not considered.
- For raw material cost, molasses at Rs 1,600/tonne and sweet-sorghum stalks at Rs 500/tonne, that existed during the survey period, has been considered.
- While considering the output of alcohol, in case of sweet-sorghum, the quantity obtained in the laboratory analysis of 48 litres/tonne has been considered as against the actual yield of 18 litres/tonne in the pilot run (they could not run to full capacity and time).

duration is 115-120 days with a yield potential of 3.0-3.5 tonnes of grains/ha and 6.0 tonnes of fodder/ha.

Another hybrid, SPH 837 (AKMS 14A × SU 556), has been recommended for *kharif* in sandy-silt loam (light soils), and moderate to low rainfall (<550 mm) areas of Rajasthan. Its duration is 85-90 days that makes it escape terminal drought.

Crop production: Sweet-sorghum has the ability to rapidly accumulate sugars during and after crop maturity,

Economical alcohol production from sweet-sorghum

Pilot study was conducted in collaboration with Renuka Sugar Factory, near Belgaum, for alcohol production from sweet-sorghum variety SSV 84. The juice of 47,000 litres with 18% brix was extracted from 100 tonnes of stalks. This was diluted to 60,000 litres with 12% brix, and mixed with yeast, *Saccharomyces cerevisiae* in fermentor for ethanol production (95% alcohol), and was distilled to obtain rectified spirit. The bagasse contains 46.5% and 2.6% of moisture and sugar, which could be successfully used for cogeneration of electricity (approx. 2,086ca energy from green cane/tonne). Ash produced due to combustion of bagasse, fermentation sludge, and water-treatment compost was mixed together and sold at Rs 250 per tonne. The leftover fermentation contains sugars that contribute to 6.4% brix; since fermentation was for a limited period of 30 hr. The recovery can still be higher, if fermentation is allowed for more time, and a more efficient yeast strain is used. With further refinement, cost of ethanol production can be reduced. It is worthwhile to note that, in addition to sweet-talk, more than 1.0 tonne of grains/ha is also available.

and this is very much comparable with sugarcane due to its short duration (120 days). It can produce a green-cane yield of 40-50 tonnes/ha, of 15-23% brix and 40-50% juice extractability. With sweet-sorghum, it is possible to extend crushing season, so that the same machinery can be used for a longer period.

Crop protection: Increased severity and widespread occurrence of corn planthopper (*Peregrinus maydis* Ashm.) in parts of Karnataka and western Maharashtra and significant infection of long smut (*Tolysporium ehrenbergii*) in Gujarat have been recorded. Similarly, there has been an increase in infection of maize mosaic and maize stripe viruses transmitted by *Peregrinus maydis;* to an extent of 10-15% in Karnataka.

Pearl Millet

Crop improvement: Five hybrids of pearl millet have been identified for release at the national level, and three pollinated varieties and a hybrid have been released at the state level.

Crop production: The crop sequence of pearl millet after legumes has resulted in higher pearl millet equivalent yield (PMEY) as compared to pearl millet after fallow, pearl millet after sesame and pearl millet after pearl millet.

- Pearl millet hybrid MH 946 responded as the best hybrid to terminal drought during *kharif* and summer.
- Pearl millet hybrids MH 1001, MH 1109, MH 1169 and MH 1179 exhibited multiple resistance against downy mildew and smut.

Pearl millet varieties released

Hybrids/ Varieties	Area of recommendation	Mean grain yield (tonnes/ha)	Salient features
	Central Releases		
GHB 577	Rajasthan, Haryana, Gujarat, Uttar Pradesh, Madhya Pradesh, Punjab and Delhi	3.10	Medium maturity, downy-mildew resistant
RHB 127	Rajasthan, Haryana, Gujarat, Uttar Pradesh, Madhya Pradesh, Punjab and Delhi	2.91	Early maturing, downy-mildew resistant, bristled hybrid
SAMH 166	Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka	3.00	Late maturing, high-grain yield, downy-mildew resistant
Hybrids for summer cultivation			
PB 180	Gujarat, Maharashtra, Tamil Nadu and parts of Rajasthan	4.00	Late maturing, high grain and fodder yields
	State Releases		
HC 10	Haryana	2.24	Medium maturity, high grain yield, resistant to diseases
PPC 6	Maharashtra	2.67	Late maturing, moderately resistant to downy mildew
PCB 164	Punjab	2.15	High yield, dual purpose
HHB 117	Haryana	–	High grain and fodder yields, remains green till maturity

Application of 50-75% of the recommended N through inorganic source and 25-50% through vermi-compost has recorded considerably higher PMEY over 100% recommended N through urea in succeeding wheat, sunflower and soybean crops.

Crop protection: Pearl millet hybrid MH 946 has responded as the best hybrid to terminal drought during *kharif* and summer. Hybrid MH 1021 (GHB 577) has showed complete resistance to downy-mildew disease. And MH 1001, MH 1109, MH 1169 and MH 1179 hybrids have exhibited multiple résistance against downy mildew and smut.

SMALL MILLETS

Crop improvement: Foxtail millet variety SR 51 (Pratap Kangni 1), maturing in 65-70 days and yielding about 1.8-2.0 tonnes/ha, has been notified for cultivation in Rajasthan. Proso-millet variety GPU 21, maturing in

- Fingermillet+field-pea intercropped in 8:1 ratio found suitable and profitable in Karnataka and Tamil Nadu.
- Fungicide 'Saaf' at 0.2% showed its effectiveness in controlling blast in fingermillet.
- *Cercospora* leaf spot incidence lowered in fingermillet plots receiving farmyard manure instead of inorganic fertilizers alone.

GPU 21 proso-millet. This variety maturing in 65-70 days has been identified for Karnataka and Tamil Nadu.

Fingermillet + field-pea in 8:1 ratio has been widely accepted profitable intercropping system for augmenting legume production.

65-70 days, has been identified for Karnataka and Tamil Nadu.

Crop production: Fingermillet + field-bean (8:1) intercropping system has been found suitable and profitable in Karnataka and Tamil Nadu. Kodo millet and pigeonpea intercropping in 4:2 has been found more profitable than farmers' intercropping practice of kodo millet and urdbean in Madhya Pradesh.

Crop protection: The fungicide 'Saaf' (Carbendazim + Mancozeb) at 0.2 % has showed its effectiveness in controlling blast in fingermillet.

Incidence of *Cercospora* leaf-spot had significantly lowered in fingermillet plots receiving farmyard manure compared to plots receiving inorganic fertilizers alone.

UNDERUTILIZED CROPS

Crop improvement: One variety in grain-amaranth and 3 varieties in ricebean have been identified.

- Identified one variety of grain-amaranth and 3 of ricebean.
- Most appropriate cropping system in Tamil Nadu is grain-amaranth and pigeonpea. It gives a cost : benefit ratio of 1:89.

Quality: Highest protein contents have been observed in amaranth Akola local (14.6%), faba bean HB 123 (19.9%), ricebean RBL 33 6 (20.5%), kalingada GK 1 (52.5%), winged-bean EC 38955 (35.8%) and jatropha Hansraj (47.9%). Maximum oil percentages have been seen observed in amaranth SKNA 20 (10.8%), kalingada SKNK 2 (49.3%), winged-bean IC 26945 (20.7%), jatropha Hansraj (48.9%) and *Simarouba* Mettupalayam Selection (61.1%).

Germplasm collection of underutilized crops

Plant	Collection
'kankoda' (Spine-gourd)	*64*
Amaranth	*47*
Buckwheat	*10*
Chenopods	*3*
Job's tear	*1*
Ricebean	*19*
Adzuki bean	*6*
Perilla	*10*
Jatropha	*2*
Citrullus colocynthis	*1*

Crop production and protection: Grain-amaranth-pigeonpea is the most appropriate cropping system in Tamil Nadu. It gives a cost:benefit ratio of 1: 89, and pre-emergent application of Alachlor at 1.5 kg a.i./ha has been effective for controlling weeds in buckwheat.

Underutilized crop varieties identified

Crop	Seed yield (tonnes/ha)	Salient features	Area of adoption
Grain-amaranth PRA 9401	1.99	High-yielding, medium maturity	North-western hills
Ricebean BRS 1	1.62	Medium maturity, dark-green seeds	North-western Hills
RBL 35	1.09	Early maturing	All plains zone
RBL 50	1.23	Green seeded	All plains zone

FORAGE CROPS

Crop improvement: Five varieties, one each in cowpea, tall fescue grass, *Setaria* grass, pearl millet and berseem have been released for cultivation at the central/state level.

- Released five varieties of forage crops, one each in cowpea, tall fescue grass, setaria grass, pearl millet and berseem, for cultivation.

OILSEEDS

Groundnut

Crop improvement: TG 37 A is an early-maturing (104 days), Spanish-bunch groundnut variety having wider adaptability. This has been identified for *kharif* in Uttar Pradesh, Rajasthan, Punjab and Haryana. During *kharif*,

- Identified TG 37 A, an early-maturing, Spanish-bunch groundnut variety for *kharif* with wider adaptability.
- CS 19 groundnut, a stem-rot-resistant genotype of interspecific origin, developed for the first time.
- In rainfed areas, groundnut + sesame gave the highest water-use efficiency of 5.41 kg/ha/mm, followed by groundnut + castor and groundnut + pearl millet.
- For screening high temperature tolerance in groundnut, specific leaf area is one parameter; genotypes with low SLA have high temperature stress tolerance.
- Groundnut genotypes CS 19 and PBS 12032 showed multiple disease resistance.

Forage crops varieties released

Forage crops	Variety	Adaptation region/ Agro-ecology	Green forage (tonnes/ha)	Duration	Salient features
		Central Release			
Cowpea	UPC 607	Subtropical to tropical plains of North-west Zone comprising Uttaranchal, northern Uttar Pradesh, *tarai* belt, Punjab, Haryana and Rajasthan	35-40	Medium late (140-150 days) (seed to seed)	Better dry matter digestibility than recent releases, UPC 5286 and UPC 287; resistant to anthracnose, mosaic virus, collar/ root rot, bacterial blight, aphids, defoliators and semi-loopers; better seed yield; a dual-purpose material with white testa
		State Releases			
Tall fescue grass (*Festuca arundinacea*)	Hima 4	Temperate grasslands and orchards in Himachal Pradesh	30-40 (in 2-3 cuts)	Early (230-250 days)	Resistant to cold, frost and lodging, disease-free
Setaria grass (*Setaria anceps*)	Setaria 92	Subtropical grasslands and pastures between 300 and 1,400m above sea level in Himachal Pradesh	25-30 (in 3-4 cuts)	Late	Very thin tillers, tolerant to drought, cold and frost,disease-free
Pearl millet	FBC 16	Plains of Punjab	70-80	–	Multicut, resistant to major diseases, high voluntary dry matter intake and low concentration of oxalates
Berseem	BL 42	Plains of Punjab	85	–	Superior nutritional quality and seed yield (0.4 tonne/ha)

pod and kernel yields realized were 1,993 and 1,272 kg/ha. The variety has also been identified for *rabi*/summer cultivation in Orissa, West Bengal and North-eastern Hill region. GPBD 4 is an early-maturing (104 days), foliar diseases (late leaf spot, rust) resistant variety identified for late-sown areas of Tamil Nadu, Andhra Pradesh, Karnataka, Kerala and southern Maharashtra during *kharif*. Its pod and kernel yields realized were 1,983 and 1,336 kg/ha.

For the first time, a stem-rot-resistant groundnut genotype (CS 19) of interspecific origin has been developed.

Crop production: Pod yield of groundnut (1,889 kg/ha) has been found maximum in sequential cropping of groundnut-wheat-mungbean. Inter Row Water Harvesting (IRWH) could increase pod yield by 15% over traditional method of planting, without moisture conservation (1,192 kg/ha). The highest water-use efficiency (WUE) of 4.16 kg/ha/mm has been recorded in the IRWH and the lowest of 3.96 kg/ha/mm in control (without moisture conservation treatment).

In groundnut-based intercropping system in rainfed areas, groundnut+sesame intercropping gave the highest WUE of 5.41 kg/ha/mm, followed by groundnut+castor (4.42 kg/ha/mm). And groundnut+pearl millet recorded the lowest WUE (3.47 kg/ha/mm).

Groundnut genotypes NRCG 7085-1, 6820, 6919, MOR 161 and ICGHNG 88448 have been found as Ca-efficient and NRCG 7085-1, 1308, 6155, PBS 13, PBS 18057, 20016, MOR 204, PBS 11037, 20016, 20057 and MOR 139 have been found as P-efficient.

At Hanumangarh, high temperature stress tolerance genotype screening has indicated that genotypes with low specific leaf area (SLA) gave higher yield; SLA can be used as a parameter for high temperature tolerance screening.

Crop protection: Two groundnut genotypes CS 19 and PBS 12032 have showed multiple disease resistance (early leaf spot, late leaf spot, rust) in fields.

Seed treatment with *Trichoderma harzianum* at 4g/kg of seed and soil application of castor-cake have given fairly good control of aflaroot, collar rot and stem rot diseases, and have also resulted in highest pod yield of 1,457 kg/ha.

For control of stem rot, seed treatment with Captan (2g/kg), followed by soil solarization + seed treatment with *Trichoderma harzianum* at 4g/kg of seeds has been found effective.

Rapeseed-mustard

Crop improvement: Two varieties have been identified for release.

- In rapeseed-mustard CS 614-4-1-4 and JD 6 have been identified.
- Developed a new CMS (*canarianse*) promising system in mustard.
- Plant extracts of *Parthenium, Datura, Eucalyptus, Azadirachta* and *Calotropis* when used as spray on rapeseed have been effective in reducing severity of *Alternaria* blight.

CMS (*mori*) and its restorer are being transferred into 500 of F_1–BC_6 and 37 of BC_1–BC_4 genotypes through backcrossing in Indian mustard. CMS (*mori*) -based experimental hybrids, 94 in number, have been developed and evaluated to study the level of restoration and yield. A promising new CMS system (*canarianse*) has been developed in mustard. In yellow sarson, hybrid-seed production technology for GMS-based YSMS 8163 hybrid has been standardized.

Rapeseed-mustard varieties identified

Variety	Areas of adoption	Developed by
CS 614-4-1-4	Salt-affected soils of Indo-Gangetic plains and waterlogged saline soils of semi-arid regions	CSSRI, Karnal
JD 6	An early-maturing genotype, suited for rainfed agro eco-system, ZoneV (Orissa, West Bengal, Bihar, Jharkhand, Chhattisgarh and Assam)	IARI, New Delhi

Promising strains possessing low erucic acid and high oleic acid (up to 55 %) in Indian mustard (*Brassica juncea*) and having oleic acid up to 72% in *B. campestris* var. *toria* have been identified. Two double low strains of Indian mustard, Heera and NUDH-YJ 5, received from the NDDB, have been registered at the NBPGR, New Delhi.

Crop production: For pearl millet–mustard crop sequence, application of 80 kg N + 30 kg P_2O_5/ha along with 10 tonnes of FYM + 40kg S + 25kg $ZnSO_4$ per hectare to mustard has been recommended for southern parts of Haryana.

Thiourea (0.1%) spray at flower initiation along with basal application of 40 kg S/ha through gypsum has been found remunerative in north-western parts of Rajasthan. For north Gujarat, 40kg S/ha through gypsum has been recommended for increasing mustard productivity.

Crop protection: Plant extracts of *Parthenium, Datura, Eucalyptus, Azadirachta* and *Calotropis* when used as spray have been found effective in reducing severity of *Alternaria* blight disease. Aqueous solution (2%) of garlic (*Allium sativum*) when applied at 45 and 75 days after sowing has also been found to reduce infestation of *Alternaria* blight in mustard.

And seed treatment and foliar spray (2%) of garlic (*Allium sativum*) bulb extract at 45 and 75 days after sowing has been effective in reducing *Sclerotinia* rot also.

Sesame

Crop improvement: Four new varieties have been identified for release.

- Identified Gujarat Til 10, Prachi, Chandana and Thilarani sesame for release
- Entry KMR 44 of sesame found free from leaf roller/capsule borer and Shekhar moderately resistant to *Macrophomina* stem/root rot.

Gujarat Til 10. A black-seeded, high-yielding variety, developed by the GAU, Amreli, has been released in Gujarat for cultivation in *kharif*. It matures in 105 days, contains 47.5% oil and gives an average yield of 750 kg/ha.

Prachi (ORM 17). This a deep-black-seeded, high-yielding variety with high degree of tolerance to major diseases and pests has been recommended for Orissa.

Chandana (JCS 94). A high-yielding variety with sandalwood-coloured seed, tolerance to major pests and diseases and suitable for all seasons has been released for Andhra Pradesh.

Thilarani. A high-yielding variety, characterized by dark-brown-coloured seed with high oil content (51%), early maturity (80 days), yield ability of 680 kg/ha and suitability for cultivation in *rabi* has been released for Kerala.

Crop production: Highest sesame equivalent yield (1,524 kg/ha) has been recorded in sesame+cotton (3:1) intercropping system at Amreli with 100:50% recommended fertilizer dose to main: intercrop as per the area occupied by the crops.

Highest seed yield and net returns could be recorded with 50% N through urea+50% N through castor-cake at Jalgaon; 50% N through urea+50% N through 'Thumba' cake+P at Mandore; 50% N through urea+50% N through FYM+P at Nagpur and 50% N through urea+*Azospirillum*+*Azotobacter*+PSB+half P at Tikamgarh.

Sulphur at 45 kg/ha, through gypsum at Nagpur, Vridhachalam and Tikamgarh and through single super phosphate at Jabalpur recorded highest sesame seed yields and highest net returns.

Sesame+mungbean (2:2) at Jabalpur and

sesame+soybean (2:2) at Powerkheda, sesame + groundnut at Mandore and sesame+cotton (3:1) at Amreli have been remunerative sesame intercropping systems.

Two hand weedings at 15 and 30 days after sowings produced maximum seed yields at Amreli, Jalgaon, Powerkheda, Vridhachalam and Kayankulam.

Highest seed yields at a par with recommended chemical fertilizers could be recorded with FYM at 2.5 tonnes/ha+neem-cake at 250 kg/ha at Amreli and with FYM 3.75 tonnes/ha+neem-cake at 900 kg/ha + wood-ash 75 kg/ha+bone-meal 75kg/ha+ELS 20 kg/ha+PSB 5 kg/ha + *Azotobacter* 5 kg/ha+*Trichoderma viride* (0.04%) seed treatment+neem oil (2.0%) spray thrice at 15, 30 and 45 days after sowing or/Azadriachtin (0.03%) at 30 DAS) at Jabalpur, Vridhachalam and Jalgaon.

Crop protection: On sesame, leaf roller/capsule borer (*Antigastra catalaunalis*) and gall-fly (*Asphondylia sesami*) are the major insect pests and *Macrophomina* stem/root rot, *Phytophthora* blight, phyllody and powdery mildew are the main diseases. Entry KMR 44 has been found free from leaf roller/capsule borer and sesame Shekhar moderately resistant to *Macrophomina* stem/root rot disease.

Seed treatment with Carbendazim 50 WP (0.1%) + Thiram (0.4%) or *Trichoderma viride* (0.4%) or *T. harzianum* (0.4%) or cowdung ash (0.04%) reduced incidence of *Macrophomina* stem/root rot.

Seed treatment with Thiram (0.2%)+Carbendazim 50 WP (0.1%) + spray of Macozeb (0.25%) + Endosulfan (0.07%) at 30-40 and 45-55 days after sowing minimized incidence of leaf-roller/capsule borer, powdery mildew. *Alternaria* leaft spot and phyllody and *Macrophomina* stem/root rot disease at Nagpur and Vridhachalam.

Niger

Crop improvement: NRS-96-1 a high-yielding, early-maturing (94 days) variety developed at Varanasi has been released for Gujarat. This has recorded 37% higher seed yield in Rajasthan, Gujarat and Maharashtra over IGP 76, the national check.

- Developed at Varanasi NRS 96-1, an early-maturing niger, released for Gujarat.

JNS 14, BNS 8 and NJS 17 are found high yielding in advanced stage of testing. Two hundred twenty-nine new collections have been made in three explorations in Jharkhand, Madhya Pradesh and Karnataka under the NATP.

Over 1.5 tonnes of breeder seed of 7 varieties have been produced against the indent of 0.73 tonnes.

Crop production: Niger+Frenchbean (4:2) at 20 cm spacing gave highest niger equivalent yield of 945 kg/ha at Semiliguda.

Sulphur at 30kg/ha recorded highest seed yields when supplemented through gypsum/single super phosphate.

Maximum seed yields were recorded with N 40 kg/ha+P 20 kg/ha (SSP)+ P 20 kg/ha + PSB at Igatpuri and Kanke, and with N 40+ P 20 (DAP) + P 20 + PSB at Semiliguda. However, highest seed yield of 631 kg/ha could be obtained with N 20+P 20 (DAP) + PSB at Chhindwara.

At Igatpuri, maximum yield was recorded with natural inputs FYM at 2.5 tonnes/ha +neem-cake at 400 kg/ha+wood-ash at 50kg/ha+bone-meal at 50kg/ha+PSB at 5 kg/ha+*Azotobacter* at 5 kg/ha+15 kg S/ha (ELS)+ *Trichoderma viride* seed treatment (0.04%).

Soybean

Crop improvement: Soybean MAUS 81, developed by the Marathwada Agricultural University, Parbhani, has been identified for the Central Zone, comprising Madhya Pradesh, Gujarat, Rajasthan and parts of Maharashtra. It is early maturing (93 days variety), tolerates moisture stress and shows resistance to bacterial pustule, yellow mosaic virus and *Rhizoctonia* aerial blight; and also to insect-pests like stem-fly, girdle beetle and green semilooper.

- Soybean MAUS 81 identified for Central Zone is an early-maturing variety.
- Soybean LSb1, MACS 58, MACS 330 and Shilajeet showed higher level of oleic acid; a monosaturated fatty acid.
- Inclusion of maize in soybean-based intercropping system has showed beneficial effect on the system's efficiency in terms of productivity, energy and cost.
- In soybean, phosphorus as single superphosphate gave 16.2% higher yield than phosphocompost.
- Soybean breeding lines D_3P_8 and D_5P_{11} are identified as promising for resistance against *Spodoptera litura*.

LSb 1, MACS 58, MACS 330 and Shilajeet soybean have showed comparatively higher level of oleic acid; a monounsaturated fatty acid.

PK 1029, PK 1024, Co 2, Hardee, HIMSO 1563, MACS 124, Bragg and JS 335 were screened with RAPD markers that generated 295 bands. Out of these bands, 202 are found polymorphic.

Crop production: Inclusion of maize either in soybean-wheat crop rotation or in soybean-based intercropping system has showed beneficial effect on the system's efficiency in terms of productivity, energy and cost.

Integration of nutrients, using inorganic (50% recommended dose of fertilizer-RDF) and organic carriers, i.e. poultry manure and FYM, have produced comparable soybean equivalent yield, and has been found equally remunerative to 100% RDF alone.

At flowering stage of soybean, additional 20 kg N/ha increased seed yield to 10.7% over basal application of 20

SUCCESS STORY

Participatory soybean seed production – under TAR-IVLP Project

The NRC on Soybean adopted Bhagora village under the IVLP programme and had 6 interventions on production of quality seeds of improved soybean varieties. As a first step, the TAR-IVLP team assessed seed requirement of the soybean-farmers in the village. About 0.42 tonne/ha of MAUS 47, 0.8 tonne of NRC 12 and 0.16 tonne of NRC 37, 0.48 tonne of NRC 2 were provided to select farmers in 2001 and 2002. Since it was a participatory programme, farmers met cost of other critical inputs.

The core team of TAR-IVLP trained farmers in intercropping system and seed-production techniques along with other aspects of production technology.

In spite of the uneven distribution and deficit rainfall (around 70%) during 2001 (786.4 mm in 21 days) and 2002 (675.6 mm in 19 days), farmers could realize average seed yield of 1.16-3.11 tonnes/ha depending on the variety. The farmers were motivated to exchange quality seed with fellow-farmers. During subsequent year (2002), the seeds of newly released varieties produced by them were made available to other farmers of the adopted village on the cost basis. Some farmers sold soybean-seed at Rs 50/kg (against about Rs 18/kg for certified seed) to neighbouring farming community. The efforts made have not only saturated adopted village with quality seed of improved varieties but seeds could be supplied to nearby villages also. Farmers have been able to raise their income by selling soybean as seed. Thus, seed production of soybean by adopting farmers' participatory approach on the seed-village concept became a successful effort to spread the use of good quality seeds.

kg N/ha. Maximum seed yield was noted in JS 335 with $N_{20}+S_{40}$ kg/ha.

Phosphorus through single superphosphate gave 16.2% higher yield than phosphocompost. Among varieties, JS 335 outyielded PK 416, PK 1029 and Ahilya 4.

Crop protection. Breeding lines D_3P_8 and D_5P_{11} for resistance against *Spodoptera litura* have been identified as promising on the basis of the leaf consumption in laboratory (no-choice test).

Bacillus thuriengiensis and Monocrotophos, an fungicide, gave good protection against defoliators, stem-borers and foliar diseases and also resulted in higher yields.

Chlorpyriphos 20 EC at 1.5 litres/ha, Ethofenprox 5 EC, Methomyl 40 SP at 1.0 kg/ha and Quinalphos 25 EC at 1.5 litres/ha gave good insect control; Chlorpyriphos was most cost-effective.

Studies have indicated that self-sown and *rabi*/summer-sown soybean acted as the primary source of rust inoculum for *kharif*-sown crop. There may be little or no role of collateral host, if any, in initiation of the rust in India.

Sunflower

Crop improvement: DRSF 108 has been identified and recommended for cultivation in rainfed areas for *kharif* in sunflower-growing areas of the country. The variety has high seed yield potential of 1.0-1.2 tonnes/ha with high oil content of 40-45%.

- Sunflower DRSF 108 identified and recommended for cultivation in rainfed areas in *kharif*.
- Sorghum as a border crop around sunflower and seed treatment with Imidochoprid at 5 g/kg of seed + Confidor 200 SL 0.01% spray at 15, 30, 45 days after sowing reduced significantly sunflower necrosis disease incidence.

Four inbreds have been developed through inter- and intra-specific hybridization that are diverse with respect to duration (74-88 days), seed yield (14-35 g/plant), autogamy (67-84%) and oil content (26.6–39%), besides possessing resistance to *Alternaria* blight and necrosis diseases.

Among new populations, PKVSF 27, TS 82-8-1/3 and TS 22-7-2/5 at Akola; GAUSUF 31, GAUSUF 48 and GAUSUF 52 at Amreli; TNHAP 89, TNHAP 19 and TNHAP 3 at Coimbatore; NDSV 4 and NDSV 6 at Nandyal; and SP 3 at Raichur have showed promise.

Crop production: In Marathwada region, in soybean-sunflower cropping system on Vertisols, it is possible and profitable to substitute 50% P for sunflower by seed treatment with phosphorus-solubilizing bacteria and application of 5 tonnes of FYM/ha, when preceding soybean is supplied with the recommended P.

Sunflower yields were highest when both sorghum and sunflower in sequence were fertilized with 150% RDF, followed by NPK + FYM-NPK and NPK-NPK+B. FYM along with NPK resulted in build-up of soil N and P in the system. Similar response was recorded for the sunflower productivity as in the Vertisols in mungbean-sunflower sequence.

Crop protection: Sorghum as a border crop around sunflower and seed treatment with Imidochoprid at 5g/kg of seed + Confidor 200 SL 0.01% spray at 15, 30, 45 days after sowing significantly reduced sunflower necrosis disease incidence and increased sunflower seed yield.

Sunflower necrosis virus (tobacco streak virus) for the first time has also been found infecting safflower.

Safflower

Crop improvement: Phule Kusum (JLSF 414) has been identified and recommended for release for both rainfed and irrigated safflower-growing areas of the country.

Mitochondrial diversity study in the safflower and its wild species was made using a PCR technique, based on the repetitive elements developed, and perfected at the DOR, Hyderabad, which had higher throughput than the RAPD analysis.

- Safflower Phule Kusum (JLSF 414) identified and recommended for release for both rainfed and irrigated safflower-growing areas of the country.
- Safflower seeds treated with *Trichoderma harzianum* and/or *T. viride* showed lesser wilt incidence on the crop.

The high-yielding, wilt-resistant advanced breeding lines of safflower 96-520 and 96-519-2 have been found tolerant to aphids in late-sown areas.

Wilt resistant hybrids DSH 172 and DSH 173 developed at the DOR, Hyderabad, have yielded 65 and 27% higher seed yield and 84 and 38 % higher oil content than the check hybrid DSH 129. The wilt-resistant hybrid DSH 174 has been found on a par with DSH 129 in yield, but gave 20% higher oil yield.

Carthamus oxycantha has been identified as the donor of sterile cytoplasm in the progenies of *C. oxycantha* × *C. tinctorius*.

Crop production/protection: Integrated nutrient management in the mungbean-safflower at Annigeri in rainfed areas has indicated the need for applying100% NP to both the crops. Part substitution with seed treatment with *Azotobacter/Azospirillum* and phosphorus-solubilizing bacteria was not found possible. Similar results are indicated in soybean-safflower sequence at Indore and Phaltan in irrigated areas and chickpea-safflower at Sholapur in rainfed areas. However, at Parbhani, in soybean-safflower sequence in irrigated areas, 50% NP in safflower was substituted by *Azotobactor/Azospirillum* and phosphorus-solubilizing bacteria.

Safflower seeds when treated with *Trichoderma harzianum* and/or *T. viride* have showed lesser wilt incidence in safflower.

Castor

Crop improvement: Castor RG 109 and RG 724 have been found resistant to *Fusarium* wilt and *Macrophomina* root rot; RG 2752 to wilt and grey rot; RG 1468 and RG 1624 to wilt and nematode; RG 1608, RG 1624 and RG 2719 to wilt complex; and castor RG 111, RG 224, RG 2727, RG 2730 and RG 2732 have showed resistance to wilt and tolerance to moisture stress.

- Castor RG 109 and RG 724 found resistant to *Fusarium* wilt and *Macrophomina* root rot; RG 2752 to wilt and grey rot; RG 1468 and RG 1624 to wilt and nematode; RG 1608, RG 1624 and RG 2719 to wilt complex; RG 111, RG 224, RG 2727, RG 2730 and RG 2732 to wilt and tolerant to moisture stress.
- Castor DPC 16 identified and stabilized as a new pistillate line.
- Standardized a simplified growth-room screening technique for studying *Botrytis* grey-rot in detached spikes of castor.

Developed insect-resistant castor transgenics

Transformation of castor with constructs harbouring insect-resistance gene (s) *Cry 1E* (c) and *Cry 1Aa* has been done through particle-gun bombardment and *Agrobacterium*-mediated methods. Molecular analysis using gene-specific primers for *Gus, Hpt* and *Cry 1Aa* have confirmed presence of genes. Insect bioassays of 15 primary transgenics have showed mortality of castor semilooper larvae within 1 day in 1 plant, within 2 days in 3 plants and in 4 days in 1 plant.

DPC 16 has been identified and stabilized as the new pistillate line.

Crop production: For higher returns of castor, precede *rabi* castor in north Gujarat by mungbean, fodder sorghum or sunnhemp for green manuring, besides applying 80 kg N/ha to *rabi* crops.

Crop protection: Farmyard manure and neem-cake applications and seed treatment with *Trichoderma viride* have recorded lowest wilt incidence in castor.

A simplified growth-room screening technique has been standardized for studying *Botrytis* grey-rot in detached spikes of castor.

Among 77 isolates of *Bacillus thuringiensis*, 54 strains had both *Cry1* and *Cry2* genes, 3 strains had only *Cry1* gene, 10 strains had only *Cry2* and 10 strains had none. Specific primers have been designed to characterize *Cry 1* genes in DOR-1 local isolate.

Mass multiplication of improved strains of *Trichoderma* has indicated that formulation prepared from biomass obtained through shaker-culture method has been found to retain shelf-life (up to 9 months) of *T.viride* (TV-N); stored in refrigerator. Seed treatment with Carbendazim + *Trichoderma* at 10 g/kg of seed+ soil application of *Trichoderma* has been found most effective in managing castor wilt.

Linseed

Crop improvement: KL 224 linseed has been identified for Haryana, Punjab, Himachal Pradesh and Jammu and Kashmir.

A catalogue of 2,053 accessions documented for 22 descriptors has been published.

Promising resistant/tolerant cultures of linseed against wilt are GS 362 and H 22; and against *Alternaria* blight are EC384154, H 8, H 10, H 15, H 34, H 43 and JRF 1.

- Linseed KL 224, yielding 511 kg/ha, identified for Haryana, Punjab, Himachal Pradesh and Jammu and Kashmir. It has showed moderate resistance to *Alternaria* blight and powdery mildew.
- At Raipur and Sagar rainfed areas, soybean-linseed crop sequence with 100% recommended dose of fertilizers to linseed has been adjudged very remunerative.

SUCCESS STORY

Water-harvesting technique for soybean cultivation

Mr Bhagat Singh has 9 hectares of land along with tractor and other agricultural resources for cultivation. His five family members are involved in the agricultural activity with him. He was producing soybean, potato, garlic, onion and chickpea in the limited area only due to severe water crisis during *rabi* till the year 2001. The technical support provided by the IVLP members has helped him not only in increasing cultivable area but also gross income from Rs 315,720/ha/yr to Rs 645, 700/ha/yr.

To limit run-off from canal, which is running along with the boundary of his farmland, he staked gunny-bags filled with sand/soil/pebbles at specified locations (*bori* bandh). The water collected in the canal was drained in open-wells through underground pipeline. In addition, all four bore-wells in farmland were interlinked and in turn linked with the collected water. In case of excess collection, he pumped water to bore-wells facilitated with percolation arrangement around them. For facilitating percolation in each bore-well, he had dug up to 5-metre in depth with 3-metre in diameter. First 2 metres were filled with 40-mm size boulders, followed by 20-mm size in another 2-metre. The top one metre space was filled with coarse-sand. A casing pipe of 4-metre length having small holes and wrapped using coconut rope was inserted into bore-well to filter rain-water. The water levels in the bore-wells got recharged quickly with these efforts and water availability in the bore-wells could extend from February to May. The total expenditure was Rs 70,000 for this facility.

Mr Bhagat Singh was having soybean cultivation in about 4.5 hectares and groundnut in 2 hectares during *kharif* and potato (2ha), garlic (0.5ha) and chickpea (6ha) during *rabi*. After establishment of this system, the area under potato has been increased from 2 hectares to 7 hactares and, accordingly, farm income has increased. An account of benefit accrued is as follows.

Benefits accrued from water-harvesting system

	Before the project initiation				After the project initiation			
Season	Crop	Area (ha)	Yield (tonnes/ha)	Gross income (Rs/ha)	Crop	Area (ha)	Yield (tonnes/ha)	Gross income (Rs/ha)
Kharif	Soybean	4.5	1.6	26,045	Soybean	4.5	2.6	52,000
	Groundnut	2.0	5.0	45,000	Groundnut	2.0	5.5	55,000
Rabi	Potato	2.0	14.5	126,875	Potato	7.0	23.4	245,700
	Garlic	0.5	6.8	108,800	Garlic	0.5	12.6	189,000
	Chickpea	6.0	0.6	9,000	Onion	0.5	26.0	104,000
	Total			315,720				645,700

In the process of water harvesting by Shri Bhagat Singh, the bore-wells numbering 20 of adjacent farmers also got recharged. Other farmers in Bhagora village were fascinated by this innovative approach and vowed to adopt in the next season.

Linseed variety identified

Variety	Average seed yield (kg/ha)	Days to maturity	Salient features
KL 224	511 (*Utera*)	171-203	Erect, purplish-blue flowers, brown seeds, has resistance to rust and powdery mildew and moderate susceptibility to wilt, moderate resistance to *Alternaria* blight and powdery mildew and moderate susceptibility to wilt. It has oil content of 39.70%

Crop production: Soybean-linseed crop sequence with 100% recommended dose of fertilizers (RDF) to linseed has been adjudged remunerative at Raipur and Sagar in rainfed areas. At Kanke, urdbean–linseed/Paddy–linseed cropping sequence with 100% RDF to linseed has been the best.

At Nagpur, in rainfed areas, linseed+chickpea (9:2) with 100% RDF to main crop and no fertilizer to intercrop has been the best.

Crop protection: For managing linseed wilt, seed treatment with *Trichoderma harzianum* at 4g/kg of seed has been most effective.

Two fortnightly applications of Imidacloprid 200 SL at 100 ml/ha have been found effective and economical for bud-fly management in irrigated as well as rainfed areas. Linseed germplasm lines CI 1956, EC 1392, EC 1424, EC 41636, ES 1474, ES 1476, GS 4, GS 192, RL 99-19, LMS 1-23 and LMS 49-2 K have showed promise against bud-fly.

PULSES

Chickpea

Crop improvement: Haryana Channa 3 (HK 98-155), a kabuli chickpea variety, has been developed from a single cross ICCV 2 × Surutato 77, and has been identified for Haryana, Punjab, Delhi, parts of Rajasthan and western Uttar Pradesh. It is characterized by plants of spreading, medium-tall nature with white flowers and dark-green broad leaves. It matures in 145 days and its average yield is 18-19 tonnes/ha. Its seeds are white-beige and seed weight is 25g/100 seeds.

- Developed Haryana Channa 3, a kabuli chickpea variety, from a single cross. It has been identified for Haryana, Punjab, Delhi, parts of Rajasthan and western Uttar Pradesh.
- Rice-chickpea system proved economical, giving higher returns of Rs 10,260/ha over rice-wheat system, and is gaining popularity.

And variety Anvita (RSG 931) has also been developed from a single cross RSG 44 × RSG 524. It is identified for rainfed areas of Haryana, Punjab, Delhi, parts of Rajasthan and western Uttar Pradesh. It has semi-erect nature with profuse branching and matures in 130-140 days with an average yield of 1.6-1.7 tonnes/ha, and has 100 seeds weight of 14.5g with moderate resistance to dry root-rot.

Crop production: Rice-chickpea (kabuli) system is gaining popularity. It is economical and has produced higher returns of Rs 10,260/ha over rice-wheat system. Rice-chickpea (*desi*) cropping system has been found almost equal in returns to rice-wheat system.

Crop protection: Entries FG 11, FG 712, H 99-117 and BCP 15 have been found resistant or moderately resistant against wilt.

Wilt incidence could be reduced significantly by seed treatment with *Trichoderma viride* + vitavax in chickpea sown in mixed and intercropped with linseed.

Under advanced stage screening, promising cultivar, BG 1053, has received minimum pod-borer damage.

Pigeonpea

Crop improvement: Three varieties have been released for commercial cultivation.

- Released pigeonpea Pusa 992, MA 6 and GAUT 00IE for commercial cultivation.
- Ridge planting of pigeonpea under recommended fertility increased its yield up to 32% over flat planting in the North-Eastern Plains Zone.
- Pigeonpea early genotype Pusa 2001 and medium-duration genotype KM 163 showed multiple tolerance to pod-fly and pod-borer.

Pigeonpea varieties released

Variety	Adoption region	Yield (kg/ha)	Duration (days)	Other salient features
Pusa 992	North-Western Plains Zone	2,400	119-162	Medium-bold seeds, six days earlier than UPAS 120
MA 6	North-Western Plains Zone	2,281	248-267	Resistant to pod-fly and pod-borer
GAUT 001E	Central Zone	2,610	140-150	Yield advantage (44%) over best check UPAS 120

Twenty-nine promising pigeonpea lines with a minimum of 5% yield advantage have been identified from different co-ordinated varietal trials and have been advanced to next stage.

Crop production: Intercropping of pigeonpea with mungbean/urdbean/soybean has proved superior to sorghum or pearl millet across the zones, and spray of 2% urea at 15 and 45 days after harvest of intercrop increased pigeonpea yield.

Application of 15 kg zinc sulphate/ha along with the recommended dose of fertilizers (20-18-27-20 NPKS) increased pigeonpea productivity up to 28%. *Rhizobium*, new strains, *viz*. A 5 A 7, RAU 10, BPR 9804 and 9806 have showed promising results. *Rhizobium*, PSB and compost (2.5 tonnes/ha) application reduced 50% on the cost of fertilizers.

Ridge planting of pigeonpea under the recommended fertility increased yield up to 32% over flat planting in the North-Eastern Plains Zone.

Crop protection: Early genotype Pusa 2001 and medium-duration genotype KM 163 have showed multiple tolerance to pod-fly and pod-borer. Pigeonpea MAL 13, RA 6, JKM 1, JKM 169, KPL 143 and KPL 44 have been identified as resistant to *Fusarium* wilt.

KPL 43, PP 16 K, PP 17 K, PPKL 6 and PSMR 2006 K have been identified as exhibiting multiple resistance to wilt and sterility mosaic and tolerance to *Phytophthora* blight. Sowing pigeonpea on ridges reduced *Phytophthora* blight incidence by 50% as compared to flat sowing. Blight incidence on ridges was only 44% compared to 82% in the flat sowing.

MAL 9 has been found resistant to pigeonpea cyst nematode (*Heterodera cajani*) and Pusa (B) 35 has exhibited tolerance to both cyst and root-knot nematodes. Wilt resistant lines KPL 43 and GPS 33 have also showed resistance to root-knot nematode.

Soil application of Carbofuran (3) at 2kg a.i./ha and seed treatment with Monocrotophos at 0.1% for 6 hours increased pigeonpea yield by 38.9 and 18.6% over control in root-knot nematode-infested fields.

MULLARP (Mungbean, Urdbean, Lentil, Lathyrus and Rajmash)

Crop improvement: Four new varieties have been identified for release.

Urdbean NDU 99-2. Developed from a cross of T 9 × PDU 102, this has showed consistent superiority in yield performance (12%) and in resistance to yellow mosaic virus (YMV); it is identified for Hill Zone for *kharif*.

- Identified urdbean NDU 99-2, KU 96-3, fieldpea IPF 99-25 and lentil KLS 218 for release.
- Recommended row ratio of 4:4, 4:3, 4:2 for urdbean+ragi intercropping in rainfed areas.
- Lentil *Rhizobium* strain LR 31-97 proved promising with superior yield over check strain LB 4.
- Mungbean MH 98-1 showed resistance to YMV across locations, BPMR 145 against powdery mildew in multilocations and PDM 96-262 against yellow mosaic virus and *Colletotrichum* leaf spot.

Urdbean KU 96-3. Developed from a cross of PU 19 × NP 21 with an advantage of 19% over the best check TPU 4 in the Central Zone, it has showed resistance to YMV; it is identified for the Central Zone (*kharif*).

Fieldpea IPF 99-25. This tall-type fieldpea has been developed through pedigree selection from a cross PDPD 8 × Pant P 5. It has yield superiority of 23.5% over the check variety in the Central Zone and has also high level of resistance to powdery mildew; it has been released and notified for the Central Zone.

Lentil KLS 218. This small-seeded variety has a yield advantage of 27% over the best check in the North-Eastern Plains Zone and is fairly tolerant to rust; it is identified for the North-Eastern Plains Zone.

Crop production: Early pigeonpea + mungbean (1:2) with 1.42 land-equivalent ratio have performed well in South Zone with mungbean contributing to the most.

Soil mulch and 2% KCl spray have been recommended for mid-season drought management in urdbean. Intercropping urdbean + ragi with increased urdbean row (4:3, 4:4 or 4:2) has been recommended in the rainfed areas.

Sprouted seeds of lentil sown 15 days before harvest of rice increased lentil yield by 30% in the North-Eastern Plains Zone (NEPZ). A plant population of 0.66 million per hectare (15 × 10 cm) was needed for best yields (1,867 kg/ha) in the extra early fieldpea in the NEPZ.

Lentil *Rhizobium* strain LR 31-97 has been promising with superior yield over check strain LB 4. Fonoxa propethyl at 56 g/ha (post-emergence) applied 28 days after sowing increased yield by 24.9% in urdbean.

Crop protection: Mungbean MH 98-1 has showed resistance to YMV across locations, BPMR 145 has showed multilocation resistance against powdery mildew, and PDM 96-262 has been found promising against yellow mosaic virus (YMV) and *Colletotrichum* leaf spot (CLS).

Lamda Cyhalothrin (Karate 0.04%) alone and in combination with NSKE (5%) and Thiodicarb (0.04%) has proved effective against sucking pests and pod-borer in mungbean and urdbean.

Urdbean genotype KU 96-3 has showed broad-based resistance to YMV; KU 99 and TU 99-51 against CLS. Lentil genotypes IPL 406, IPL 405, L 4650, L 4618, IPL 306, L 184-8, LH 2K-27, L 4649 and L 4619 have showed resistance against rust.

And fieldpea KPMR 641, KPMR 615 and KPMR 640 has showed broad-based resistance to powdery mildew.

Seed treatment with *Trichoderma viride* has reduced wilt incidence in fieldpea by 50%. Mungbean genotype TM 2000-2 has showed broad-based resistance against powdery mildew.

Arid Legumes

Crop improvement: Following varieties of arid legumes have been identified for pre-release.

Guar strain RGM 112. Three years' multilocation testing has established its average grain yield potential of 1,508 kg/ha, being 22.0% higher over the better check RGC 1002 (1,234 kg/ha). This strain put forths flowers in 35 days and matures in 92 days.

- Identified *Guar* RGM 112 and Mothbean CZM 45 for pre-release.
- In rainfed monocrop situation, guar–guar at Hisar (Rs 21,960/ha) and *bajra*–urdbean at Gwalior (Rs 18,606/ha) proved remunerative cropping systems.

Mothbean strain CZM 45. Across three years' multilocation testing, it has yielded up to 571.5 kg/ha, being 27.7% higher over the check CAZRI Moth 1 (447.5 kg/ha). Having tendency to escape YMV infection, it tends to flower in 34-35 and matures in 68-70 days. It has high grain-protein (25.0%) and appears suitable for both short and long range rainfall situations.

Guar strain HGS 870. It is characterized with maximum gum content (31.78%), endosperm (39.50%) and appreciably good viscosity (5166 cP) profile.

Cowpea strain GC 9040 has maintained higher crude protein (25.24%) and minimum tannin content (0.18 mg/g), and cowpea V 240 required minimum cooking time (13.8 min.). Horsegram strain AK 42 possesses maximum crude protein (31.6%).

Crop production: In rainfed monocrop situation, guar–guar at Hisar (Rs 21,960/ha) and *bajra*–urdbean at Gwalior (Rs 18,606/ha) have proved most remunerative cropping systems.

At Hisar, Bawal, Durgapura and Gwalior, one spray in guar with 0.5% $ZnSO_4$ at 25 or 45 DAS gave 8.98 kg of grains/ha compared to 6.92 kg/ha in control, particularly in Zn-deficient soils.

Trials at Sardar Krushinagar, Pattambi and Durgapura have showed that maximum grain yield (619 kg/ha) of cowpea could be obtained with 2 sprays of 0.5% $FeSO_4$ at 25 and 45 DAS; 26% higher with Rs 1,952 kg/ha additional returns over control (491 kg/ha).

Crop protection: Guar RGC 1074 and HGS 891 have showed less than 3.0% infection against bacterial leaf blight (BLB), and cowpea TC 99-1, DCP 5, DCP 6 and KBC 3 have showed less than 3.0% infection against cowpea yellow mosaic virus; hence may be rated as tolerant.

Seed treatment (1 g/kg) with streptocycline along with 3 sprays (150 ppm) at an interval of 15 days was most effective in reducing BLB intensity and increasing yield of guar considerably. Cowpea seed treatment with Carbendazim at 2 g/kg of seed was found effective in reducing seedling mortality percentage due to root rot besides increasing grain yield.

COMMERCIAL CROPS

Cotton

Crop improvement: Six varieties/hybrids have been released/notified for commercial cultivation.

Long staple diploids for better fibre properties for North Zone (having tolerance to leaf curl virus) and for dryland areas have been developed at Dharwad and Parbhani for multilocation testing.

- Cotton NH 545, LD 694, RBDV 7, PA 255, PKVHy 5 and PKVDH 1 released/notified for commercial cultivation.
- Registered *Gossypium hirsutum* genotype CNH 123, resistant to cotton leaf curl virus, and *G. arboreum* genotype 30838, resistant to grey mildew, with the NBPGR, New Delhi.
- In cotton–wheat sequential cropping, incorporation of wheat straw and cotton-crop residue after harvest improved productivity of both.

Gossypium hirsutum genotype CNH 123 (INGR No. 02021) resistant to cotton leaf curl virus has been registered with the NBPGR, New Delhi.

One *Gossypium hirsutum* genotype CNH 123 (INGR No. 02021) resistant to cotton leaf curl virus and one *G. arboreum* genotype 30838 (INGR No. 02020) resistant to grey mildew have been registered with the NBPGR, New Delhi. Also GMS line with LRA 5166 background has been registered (INGR No. 02012) with the NBPGR, New Delhi.

Crop production: In irrigated areas in the North Zone, significant increase in seed yield and quality parameters could be observed in varieties when crop was sown at 120 cm × 90 cm and sprayed with DAP 2% at 45 DAS, $MgSO_4$ 1% at 50 DAS, boron 0.1% at 60 DAS and $ZnSO_4$ 2% at 75 DAS.

In cotton-wheat sequential cropping system, incorporation of wheat straw and cotton-crop residue (stalks and leaves) after harvest has improved productivity of wheat and cotton both.

In summer cotton at Coimbatore, seed yield increase due to drip in cv. Surabhi ranged from 28.9 to 61.5%. The water-use efficiency (WUE) ranged from 8.8 to 15.8 kg/ha/cm in drip irrigation, and it was only 4 kg/ha/cm under flood irrigation.

Crop protection: The IPM modules have recorded less pest incidence and significant higher seed-cotton yield than the conventional pest management. Important packages of IPM modules are: seed treatment with

Cotton varieties/hybrids released/notified

Variety/hybrid	Developed by	Kind	Area of notification/cultivation
NH 545	MAU, Nanded	*G.hirsutum*	Marathwada
LD 694	PAU, Ludhiana	*G.arboreum*	Punjab
RBDV 7 (*Pratap Kapi-1*)	ARS, MPUAT, Banswara	*G. herbaceum*	South Rajasthan
PA255 (*Turrab*)	MAU, Parbhani	*G.arboreum*	Marathwada
PKVHy 5	PDKV, Akola	CMS based intra-*hirsutum* hybrid	Vidharba
PKVDH 1 (AKDH 7)	PDKV, Akola	intra-*hirsutum* hybrid	Vidharba

SUCCESS STORY

Yield improvement of cotton through moisture-management practices in rainfed areas

Ten farmers each on upper, middle, lower and bottom toposequences were selected at Thugaon micro-watershed in Amaravati (Maharashtra) for managing and conserving rainwater in different toposequences for yield maximization of rainfed cotton.

Improvement in crop/seed production

Ridge-and-furrow system enabled increase in sorghum and seed-cotton yield by 1.0 and 0.3 tonne/ha over flat bed, and 1.5 and 0.5 tonnes/ha over farmers' practice in upper toposequence. Sowing of cotton on contours has been beneficial, compared to moisture conservation in flat-bed method.

Intercropping mungbean resulted in increased seed-cotton yield by 0.2 tonne over sole cotton, besides increasing moisture conservation when cotton was also grown on contours.

Recycling rainwater harvested in farm-pond or recharged well or 'Nallah' was effective in increasing seed-cotton yield by 0.5 tonne/ha in upper and 0.8 tonne/ha over farmers' practice in lower to bottom toposequences. Stored water in water-harvesting pond increased seed-cotton yield as high as 2.25 tonnes/ha in the bottom toposequence.

Excess moisture management in cotton

Ridge-and-furrow and broad bed and sunken-bed system in bottom toposequence helped to drain-out excess rainwater and improved seed-cotton yield by 0.4-0.6 tonne/ha.

Ridge-and-furrow system in rainfed cotton

Improvement in quality parameters in cotton

Soil-moisture management practices results showed that ginning percentage was higher in middle and lower toposequences, and lower in upper and valley bottom.

Gross monetary returns (Rs/ha)

Intercropping sorghum with cotton is not advisable to avoid problems in cross-intercultural operations after knee-height stage. However, strip cropping of sorghum with cotton is profitable than cotton alone on upper toposequences. Soil-moisture conservation through ridge-and-furrow system and one protective irrigation increased gross yield and gross returns with additional income of Rs 13,000 in upper plains, Rs 7,000 in the middle plains and Rs 25,000 in the lower plains over farmers' practice.

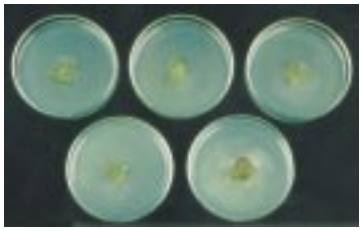
Technological impact

Ridge-and-furrow system is considered best among all moisture-conservation practices.

Intercropping mungbean, soybean and sorghum as a strip crop in cotton is being adopted by farmers to reduce run-off and improve soil moisture, and has facilitated increase in area under double-cropping system.

Imidachloprid or Thiamethoxam, raising castor or okra or marigold as trap-crop, release of egg parasitoid *Trichogramma chilonis*, spraying neem principles or its formulations, erecting bird perches, monitoring moth activities through pheromone traps, detopping terminal shoots when the crop is 100 days old and mechanical collection and destruction of egg masses and visible larvae of pests.

Location-specific IPM/IRM modules for eco-friendly and sustainable cotton production in 33 farmers' fields have helped reduce mean number of insecticidal sprays from 5.12 to 2.16 and plant protection cost from Rs 5,120 to Rs 2,160/ha over 'Control' village. In irrigated areas in the North Zone, neem-seed kernel extract (5%) along with insecticides reduced insect-pests and cost without significantly affecting yield. Though yield has been more in farmers' spray practice, its C:B ratio at 1:1.49 is lesser than IPM module (1:1.70) in the station trials.



New synthetic medium has been developed and a new technique of inoculation for healthy leaf tissues of cotton has been identified for obtaining sporulating pathogenic culture of grey-mildew pathogen *Ramularia*.

The IPM participatory farmers obtained average cotton-seed yield of 1.78 tonnes/ha compared to 1.62 tonnes/ha by non-IPM farmers under large-scale (50 acre plots) demonstration of IPM technologies in Pannihari village in Sirsa district. The C:B ratio in IPM farmers (1:3.15) was more than non-IPM farmers (1:2.62).

New synthetic medium has been developed and a new technique of inoculation for healthy leaf tissues has been identified for obtaining sporulating pathogenic culture of grey-mildew pathogen *Ramularia areola* Atk.

Sugarcane

Crop improvement: Five sugarcane varieties have been identified for commercial cultivation.

Thirty-one promising clones of sugarcane have been identified, of which 16 belong to early group and 15 belong to mid-late; 14 clones have showed high sucrose of more than 20% at harvest. Another 14 clones have showed cane yield of more than 100 tonnes/ha. In Co 0303, Co 0114, Co 0313, Co 0315, Co 0322 and Co 0323 clones

A photoperiodic facility at the SBI is being utilized to artificially induce flowering in non-flowering parents, delaying flowering in early-flowering parents and advancing flowering in late-flowering parents.

combined high yield of above 100 tonnes/ha and sucrose of above 20% have been noticed.

Nine accessions of *Saccharum spontaneum*, *Erianthus arundinaceus* and other related grasses have been collected during Andaman-Nicobar islands explorations that represent new variability.

Five cytotypes of *Saccharum spontaneum* (2n= 48 to 66) have been identified based on the cytological studies of 37 new accessions from Tamil Nadu, Andhra Pradesh, Arunachal Pradesh and Orissa.

A photoperiodic facility is being utilized to artificially induce flowering in non-flowering parents, delaying flowering in early-flowering parents and advancing flowering in late-flowering parents. Thus, several crosses between non-flowering and non-synchronous flowering parents have been made possible. This would help in development of improved sugarcane varieties.

- Identified sugarcane Co 94008, Cos 95255, Co Pant 93227, Co Se 96234 and Co Se 96436 for commercial cultivation.
- Identified 5 cytotypes of *Saccharum spontaneum* (2n=48 to 66) based on the cytological studies of 37 new accessions.
- Developed in the sugarcane institute a photoperiodic facility to induce artificially flowering in non-flowering parents and to cross early-flowering and late-flowering parents by delaying and advancing flowering.
- Designed an innovative overlapping cropping system for wheat-sugarcane sequential system to enhance sugarcane productivity.
- Autumn-sugarcane intercropped with 2 rows of maize and *rajmash* produced cane equivalent yield of 134.7 and 108.6 tonnes respectively and proved highly remunerative.
- In sugarcane, a dual-row planting system through mechanized cultivation has been developed to improve cane yield.
- Developed a laboratory-rearing technique for mass multiplication of sugarcane black-bug, *Dimorphopterus gibbus*.

Crop production: For multiple ratooning, integration of stubble shaving, gap filling, trash mulching and cultivation in alternate rows with use of Phorate (15 kg/ha) may be adopted to sustain higher cane ratoon yields. Keeping ratoon beyond third year does not appear to be economical.

Erianthus arundinaceus. This has been collected during Andaman-Nicobar islands explorations, and represents new variability.

Sugarcane varieties identified

Variety	Adaptation zone	Maturity group	Cane yield (tonnes/ha)	Sucrose (%)	Reaction to red rot
Co 94008 (*Shyama*)	Peninsular	Early	119.76	18.31	Moderately resistant
CoS 95255 (*Rachna*)	North West	Early	70.49	17.49	Moderately resistant
CoPant 93227	North West	Mid-late	75.38	17.30	Resistant
CoSe 96234 (*Rashmi*)	North Central	Early	64.11	17.94	Moderately resistant
CoSe 96436 (*Jalpari*)	North Central	Mid-late	67.12	17.73	Moderately resistant

In sugarcane keeping ratoon beyond third year is not economical. But fourth ratoon could be sustained with trash mulching and gap filling.

To enhance productivity of sugarcane in wheat-sugarcane sequential system, an innovative overlapping cropping system has been designed. This accommodates 3 rows of wheat in November on raised beds and sugarcane in 80-cm apart furrows in February (optimum time of sugarcane planting in subtropical India) in the Furrow Irrigated Raised Beds (FIRB) system. Sugarcane registered 30% higher cane yield as compared to wheat–sugarcane sequential system without reduction in wheat yield. In this system, irrigation is applied only in furrows, requiring less volume of water, which works out to be a 20% water-saving.

Autumn-sugarcane intercropped with 2 rows of maize and *rajmash* (Frenchbean) produced cane equivalent yield of 134.7 and 108.6 tonnes/ha and these proved highly remunerative sugarcane-based intercropping system.

To further improve cane yield under wide rows, 'dual-row planting', through mechanized cultivation, has been developed. In this, broad furrows are formed at the spacing of 150 cm, and in the middle of the furrows, sugarcane setts are planted in two rows with a spacing of 30-cm. The dual-row system gave a cane yield of 136.3 tonnes/ha compared to 126.7 tonnes/ha recorded in the single-row system.

An Integrated Nutrient Supply System (INSS) for sugarcane consisting of organics to supply 25% of the

Raised beds are formed for wheat in wheat-sugarcane sequential system. On this, an innovative overlapping cropping system has been designed to enhance productivity of sugarcane. In raised beds 3 rows of wheat are accommodated in November and sugarcane is grown in furrows 80-cm apart in February. Sugarcane stand remains after wheat harvest (*bottom*).

Sugarcane intercroppings
Sugarcane + rajmash; Sugarcane + potato

recommended dose of N, chemical fertilizers to supply 50% of the recommended dose of NPK, *Azospirillum* and phosphobacteria each at 10 kg/ha in 2 equal split doses at 30 and 60 DAP and *dhaincha* as an intercrop on the top of the ridges and its *in-situ* incorporation at 45 DAP has been developed. This system recorded a cane yield of 141.0 tonnes/ha; which is 16.0% higher compared to recommended practice.

Dual-row planting in sugarcane through mechanized cultivation has been developed.

Sugarcane transgenics developed

Transgenics of Co 86032 and CoC 92061 with gene encoding for 'aprotinin' have showed varying levels of resistance to top-borer, and are now being multiplied for further evaluation against pests. CoC 671 calli have been transformed with genes encoding for Chitinase, ß-Glucanase and DM-Amp1 in an attempt for gene pyramiding.

Crop protection: For effective mass multiplication of *Trichogramma chilonis* parasitoid (sugarcane strain), response of the tricocards of different colours (white, orange, yellow, red and green) were studied in laboratory, as phytophagous insects are known to perceive intensity, hue and saturation of colours. The study indicates that white or green colour is most favourable for mass multiplication of the parasitoid.

Raising *dhaincha* as an intercrop as the component of the integrated nutrient supply system in sugarcane.

A laboratory rearing technique for mass multiplication of sugarcane black-bug, *Dimorphopterus gibbus*

Sustainable sugarcane production

For organic sugarcane production, 5-year cropping sequence was sugarcane (plant) – sugarcane (ratoon) – fingermillet – cotton – sugarcane (plant) – sugarcane (ratoon). In the initial 3 years, applied 100% recommended N through organics plus biofertilizers produced comparable yields of crops with the recommended dose of nutrients only through the inorganic fertilizers. In subsequent years, application of 100% of recommended N through organics plus biofertilizers was better than continuous application of inorganic fertilizers only. On the completion of the 5-year sequence, bulk density, organic-carbon and microbial status of the soil improved favourably under the organic system. Results indicate feasibility of obtaining sustainable sugarcane production through organics.

SUCCESS STORY

National Sugarcane Varietal Improvement Programme

At the SBI, varietal improvement work is carried out in two modes (i) sharing of "Co" varieties to all research stations (ii) through supply of hybrid seed from crosses made at the SBI for raising seedlings at the location concerned for selection and release of location-specific varieties.

The varieties evolved at the SBI in collaboration with the State Agricultural Universities through Fluff Supply programme occupy almost entire area under sugarcane cultivation in the country. A total of 279 sugarcane varieties were developed with the support of this programme and recommended for commercial cultivation in different states. Due to the impact of the superior varieties evolved, the country is today, one of the largest producers of sugar in the world, currently producing 18.5 million tonnes of sugar from 800 million tonnes of cane harvested from 4.28 million hectares of land. The estimated contribution to National GDP per year is around Rs 22,500 crore at an average cost of Rs 750 per tonne of cane. Presently, sugar on hand is 12.5 million tonnes, which is equivalent to 8 months of consumption in the country. If today India has produced 18.5 million tonnes of sugar, a major share in this successful venture goes for varietal improvement programmes catalyzed by the Institute.

The varieties evolved from this Institute have not only been accepted for cultivation in the country but are also valued in foreign countries. Varieties bred at Coimbatore are now being used in 28 other countries either for commercial cultivation or as parents.

Resistant sugarcane varieties

Varieties	Resistance against
Co 97014 and Co 97015	Red rot, smut
CoJ 99192, CoPant 99214, CoS 96275 and CoS 97264	Moderately resistant against red rot
Co 97014, Co 97016, Co 96017, CoPant 99214, CoS 96269, CoS 96275 and CoS 97264	Resistant against smut

(Fabricius), has been developed. This is based on the natural substrate. There are two main components of insect-rearing (i) egg-laying bags (ii) paper-cone for nymphal development. With this technology, insect population in the laboratory can be maintained indefinitely without any deterioration in insect vigour, fertility and sex ratio. Thus technique can be further employed for mass multiplication of its egg parasitoid, *Eumicrosoma* sp., and for evaluation of insecticides against black bug and release of bug or parasitoid in field.

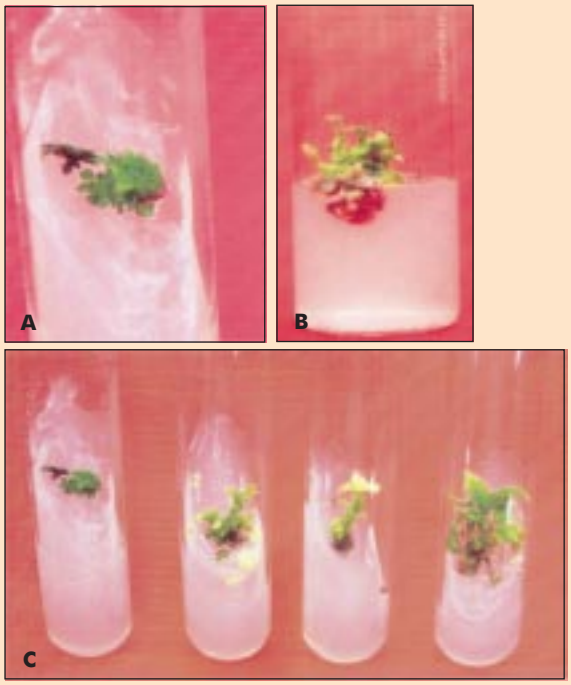
Jute and Allied Fibres

Crop improvement: Accessions of wild species of *Corchorus* collected from East Africa and other parts of the globe have been evaluated for resistance to different biotic stresses in the field. Accessions of different species, *C. aestuans*, *C. fascicularis*, *C. pseudo-olitorius* and *C. trilocularis*, have showed resistance for yellow mite, stem weevil and stem rot.

Crop production: Soil-test-based fertilizer application has led to attaining fibre yield of 2.0 and 2.5 tonnes/ha in Katihar (Bihar), Bahraich (Uttar Pradesh) and Nagaon (Assam).

In-vitro raised jute-plants transferred to field

Shoot-tip explants raised *in vitro* from jute (*Corchorus capsularis* L. cv JRC 212) have been used to produce multiple shoots. Modified MS medium containing BAP (1 mg/litre) and NAA (0.1 mg/litre) has been found best for induction of multiple shoots within 3 weeks of repeated subculturing in the same medium. The regenerated plantlets have been transferred to the field after hardening.



A. Induction and growth of shoot-buds from shoot-tip callus of Jute JRC 212

B. Regenerated shoots on modified MS medium with 1 mg/litre BAP and 0.1 mg/litre NAA.

C. Elongation of shoots after repeated subculturing in the same medium

Bast fibre portable extractor machine developed

Bast-fibre portable extractor machine has been developed, and demonstrated successfully to farmers and govt officials. It takes much less time (4-5 days compared to 21 days in conventional method) and is much less labour(1-2)-consuming. And the extraction produces quality fibres.

Crop protection: Natural products (seeds and organic matter from jute leaf) have been found suitable as the base material for making biocide with *Trichoderma viride*. The mature culture of *T. viride* was finally mixed with kaolin in seeds at 15g/100g of seed and packed with labelling for controlling major diseases of crops.

IPM practices *versus* farmers' practices in farmers' fields at Coochbehar (West Bengal) gave 2.63 tonnes/ha of fibre yield with IPM practices against 1.51 tonnes/ha with farmers' practices in *olitorius* jute.

Tobacco

Crop improvement: A *Jati*-tobacco variety Manasi with a yield potential of 1,600-1,700 kg/ha has been recommended for release for cultivation in the *Jati*-tobacco (*Chama* type)-growing areas of North Bengal.

- Recommended a jati-tobacco variety Manasi with a yield potential of 1,600-1,700 kg/ha for cultivation in jati-tobacco-growing areas of North Bengal.
- Generated molecular markers for 20 *Nicotiana* spp. and 78 released tobacco varieties.
- Thirty-eight derivatives of crosses involving *Beinhart 1000-1* and *L. 1128* (SR), found promising as resistant donors in tobacco against brown-spot disease.
- Maize+soybean (*kharif*), followed by chickpea (*rabi*) found remunerative against monocrop of FCV tobacco in the Northern black soils.
- In tobacco, production of seedlings in plastic trays is promising as eco-friendly, non-chemical approach; this has potentiality to replace conventional nursery management and can create revolution in seedlings production.
- In FCV tobacco and *rustica* tobacco, tagetes (single whorl), tagetes (multi whorl), chickpea and zinnia showed promise as trap crops for bud-worms.
- Phyton T found effective against black-shank disease in tobacco nursery.

Molecular (RAPD and AFLP) markers have been generated for 20 *Nicotiana* species and for 78 released tobacco varieties.

Advanced breeding lines JS 73, JS 78, JS 115, JS 119, JS 125 and JS 126 have recorded low tar values (around 20 mg/cigarette) in the Northern light soils (NLS) of Andhra Pradesh.

Among 7 natu selections evaluated in the Central black soils of Andhra Pradesh, selections II-1872 and II-1876 outyielded check varieties and exhibited resistance against *Spodoptera litura* under natural conditions.

Thirty-eight derivatives of crosses involving *Beinhart 1000-1* and *L.1128* (SR) have been found promising as resistant donors against brown-spot disease.

Two country-cheroot tobacco selections HV.97-7 and HV.97-10 tested in growers' fields in the cheroot tract of Tamil Nadu have showed promise, recording higher yields. HV.97-10 recorded maximum quality score of 33 out of 40, followed by HV.97-7 with 31 compared to 27 of the check pure-line variety.

Crop production: Maize + soybean (*kharif*), followed by chickpea (*rabi*) recorded highest net income of Rs 25,860 /ha with a C:B ratio of 1: 2.06 as against mono-crop of FCV tobacco in the Northern black soils with Rs 16,070/ha net income and 1:1.49 C:B ratio.

In soybean–FCV tobacco sequence, dual inoculation of soybean with *Rhizobium* + phosphorus solubilizing bacteria improved succeeding tobacco leaf yields by 16.3%, 27.07 % and 12.91% in cured, bright and grade out-turn in the Northern black soils of Andhra Pradesh.

In Tamil Nadu, chewing tobacco + beetroot recorded a higher net return of Rs 74,245 /ha, with a C:B ratio of 1: 3.09, followed by the sole crop of chewing tobacco. Also, ragi in *kharif* and chewing tobacco in *rabi* recorded higher net return of Rs 67,747/ha.

Highest net return of Rs 49,901 could be achieved when *Motihari* tobacco was intercropped with one row of garlic in every alternate row of tobacco under recommended dose of fertilizer for tobacco + 50% N for intercrops. The same treatment schedule with two rows in every alternate row of tobacco has also fetched higher net return of Rs 49,776.

A new eco-friendly, non-chemical approach viz. production of seedlings in plastic trays is found very promising method with potential to replace conventional nursery management and may create revolution in the seedlings production.

Crop protection: Application of glyphosate at 1.5 kg a.i/ha along with ammonium sulphate at 10 g/ litre of spray solution, 3 weeks prior to tobacco sowing on foliage of weeds, effectively controlled all weeds, including nutsedge in tobacco nursery. In combination with 'APSA', an adjuvant, glyphosate at 1.25 kg a.i / ha was equally effective in weed suppression. These two treatments recorded better weed-control efficiency than soil solarization.

IPM module with cultural, biological and need-based application of insecticides as components gave C.B ratios of 1: 1.52 to 1:1.60 in IPM plots as against 1:1.46 to 1: 1.56 in farmer's method.

In FCV tobacco and *rustica* tobacco, tagetes (single whorl), tagetes (multiwhorl), chickpea and zinnia were promising trap crops for bud-worms in terms of trapping ability, reduction of infestation and natural enemy activity.

Fumigation of tobacco stacks with magnesium phosphide plates (Degesch plates) at a dose of 1g/m^3 with 5 days exposure is sufficient to cause cent per cent mortality of all stages (including eggs) of cigarette beetle, *Lasioderma serricorne*, and it was superior to aluminum phosphide as is evidenced by quick release of phosphine. Aeration of fumigated stacks for 72 hr resulted in safe level of phosphine i.e. <1ppm.

Kocide (Copper hydroxide) at 0.2% applied at the time

of planting along with water and followed up with drench around plant at 30 and 45 DAT is found a better fungicide than Carbendazim (Bavistin) and Thiophanate Methyl (Topsin M) for effective control of *Fusarium* wilt in FCV tobacco field-crop. The disease was controlled to the extent of 88.3 to 93.8%.

Phyton T, a plant nutrient containing inorganic salt of phosphorus (40% phosphoric acid + 36% potassium phosphonate), has showed 100% inhibition of growth of *Phytophthora parasitica* var. *nicotianae* in *in vitro* and has been found effective against black-shank disease in nursery.

Contaf (Hexaconazole) and companion (Carbendazim + Mancozeb) controlled both phases (leaf and stem infection) of anthracnose in nursery effectively besides controlling frog-eye disease.

SEED PRODUCTION AND TECHNOLOGY

Breeder Seed Production

During 2002-03, a total of 3,067.10 tonnes of breeder seeds have been produced; major quantities belong to oilseeds (1,243.07 tonnes) and cereals (1,112.59 tonnes), followed by pulses (657.33 tonnes), forages (40.27 tonnes) and fibre crops (13.84 tonnes). Besides, additional breeder seeds were also produced against the indent of state level varieties.

- Produced a total of 3,067.10 tonnes of breeder seeds.
- Closer spacing of 45 cm between rows with 120kg N + 60 P_2O_5 kg/ha gave highest seed yield in male and female parental lines of maize hybrid.
- Variety characterization of wheat, paddy maize, sorghum, pigeonpea, chickpea etc. harmonized with the National Test Guidelines for DUS of these crops; which is to be done under the Protection of Plant Varieties and Farmers' Rights Act 2001.

Sieve sizes recommended for grading screen

Crop	Sieve size
Sunflower TCSH 1 and KBSH 44	2.5mm
CO 3	4.5mm
Delinted cotton (MCU 5)	4.5mm
Pearl millet (H 77/83-2)	1.8mm (oblong)
Berseem (Mescavi)	1.1mm (oblong)

Seed Technology

Hybrid seed technology: Flowering in sorghum hybrids CSH 16 and CSH 17 during *rabi* has showed that parents of these achieve better synchrony in Rahuri area, which is thus suited for hybrid-seed production.

Closer spacing of 45 cm between rows combined with application of 120 kgN + 60 kg $P_2 0_5$/ha gave highest seed yield in male and female parental lines of maize hybrid.

Spray of growth regulator T1BA at 25.5ppm at the button stage on 'A' line of sunflower significantly enhanced seed yield. Sunflower pollen could be stored up to 36 hours in ambient conditions in the earthen pots filled with water. Commercial seed production of sunflower hybrid around Bangalore and Jamnagar has been found profitable (C: B ratio at Bangalore is 1:1.86; and at Jamnagar it is 1:1.88).

Diagnostic characterization: Variety characterization of 14 major field crops (wheat, paddy, maize, sorghum, pearl millet, chickpea, pigeonpea, mungbean, urdbean, soybean, groundnut, sunflower, castor and cotton) has now been harmonized with the National Test Guidelines for the DUS of these crops, which is to be done under the 'Protection of Plant Varieties and Farmers' Rights Act 2001'. The data is being compiled for digitalization and publication.

Seed storage. Validity period for groundnut-seed certification for 9 months has been found appropriate if stored in the favourable environment. However, conditions of high relative humidity with high temperature prevailing at Bhubaneshwar limits its validity to 6 months only.

Studies on the large-scale seed storage have confirmed that HDPE interwoven, non-laminated bags may be used for bulk-seed storage as the substitute to jute-canvas bag, provided seeds are dried properly (moisture content not exceeding 10% at the time of packing). Packing less than the capacity of bag helps in proper stacking of bags.

Information collected from the State Seed Testing Laboratories (STLs) of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu for 3 consecutive years has clearly revealed that germination status of cotton-hybrid seed is fairly high (more than 70% in majority of the samples). Germination of cotton-hybrid seeds from private seed industry has been still higher (above 90%). Therefore, it is strongly recommended that Minimum Seed Certification Standards for germination of cotton-hybrid seed should be upgraded from 65 to 70%. This will not affect availability of hybrid cotton-seed but will help in providing better quality seeds to farmers.

Seed health: Loose smut of wheat caused by *Ustilago segatum* var. *tritici* can be managed by seed treatment with *Glyocladium virens* at 4 plates/kg + 0.125 g/kg Vitavax in place of the recommended dose of Vitavax only at 0.250 g/kg to reduce chemical pollution.

Seed Processing: Delinted cotton seed (MCU 12, Surabahi and AKA 5), paddy (IR 20, ASD 18, ADT 36, Pusa 44 and PNR 381), chickpea (HC 1), fieldpea (HFP 4), soybean (Soya Harit), maize (Early composite), safflower (Bhima) and sunflower (TCSH 1, KBSH 44) must be processed by multi-stage seed processing by at least two machines comprising seed-cleaner-cum-grader and

specific-gravity separator. However, in large-seed processing plants, pre-cleaner must invariably be installed.

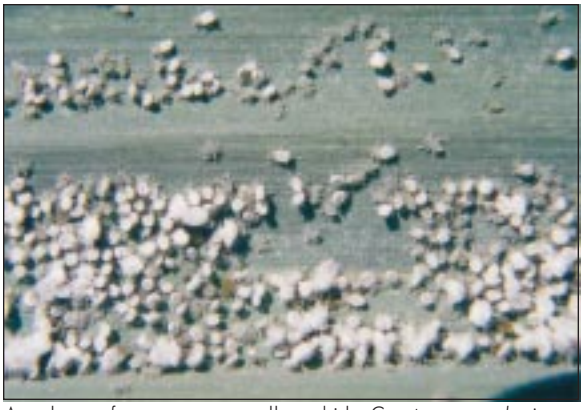
Specific gravity separator to meet certification standards can upgrade marginal seed-lots of mungbean (Kopargaon and TAP 7) to around 65% germination lots. Shade drying or mechanical drying at 45°C air temperature is suitable for maintaining seed quality in groundnut pods and mungbean seeds.

PLANT PROTECTION

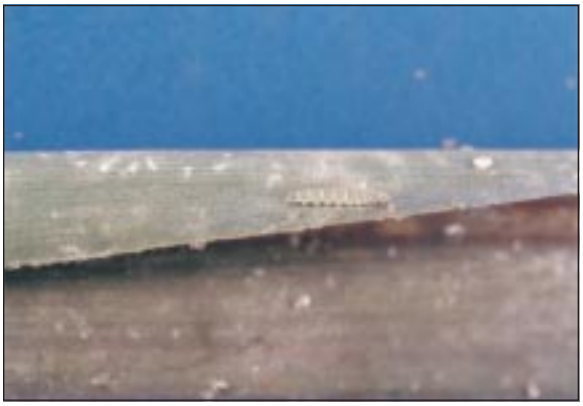
Biological Control

Natural enemies of sugarcane woolly aphid: Surveys in northern districts of Karnataka and western Maharashtra for natural enemies of the sugarcane woolly aphid, *Ceratovacuna lanigera*, have revealed *Dipha aphidivora* (Pyralidae), *Dideopsis aegrota* (Syrphidae), *Cheilomenes sexmaculata*, *Anisolemnia dilatata* and *Synonycha grandis* (Coccinellidae) being predating on aphid. *Dipha aphidivora* has been observed in large numbers in Kolhapur. Mass production technologies are being standardized for their adoption by farmers in the area.

Rearing/culturing techniques and studies on natural enemies: A rearing protocol to produce predatory mite *Amblyseius longispinosus* in large numbers has been standardized. First instar nymphs of the spiralling whitefly *Aleurodicus dispersus* have been found most suitable for parasitization by aphelinid parasitoid, *Encarsia guadeloupae*. A pest: parasitoid ratio of 1:5 of *Spodoptera litura* larvae to *Campoletis chlorideae* adults could produce 80.57% parasitism, and 1:15 ratio 81.95% parasitism. The pest population was reduced by 79.64 and 81.10%.



A colony of sugarcane woolly aphids *Ceratovacuna lanigera*



Dipha aphidivora Meyrick—a promising predator of *Ceratovacuna lanigera*

- Mass production technologies for natural enemies of sugarcane woolly aphid are being standardized for farmers' adoption
- Standardized a protocol to produce predatory mite *Amblyseius longispinosus*.
- Isolated nucleopolyhedrosis viruses of *Trichoplusia ni, Spodoptera exigua, Crocidolomia binotalis, opisina arenosella, Chilo infuscatellus, Chrysoperla carnea* and *Cadra cautella* and of a neogregarine protozoan pathogen *Mattesia dispar* from *Cadra cautella*.
- Developed a rapid and cheap production method using vermiculite for *Steinernema carpocapsae* and *Heterorhabditis indica*.

Behavioural studies on natural enemies: Parasitization of *Helicoverpa armigera* eggs by *Trichogramma chilonis* was more on Arka Alok and Pusa Ruby tomato varieties.

Artificial diet for host-insects and natural enemies: The parasitoids *Goniozus nephantidis*, *Brachymeria nephantidis* and *B. nosatoi* could complete their development successfully on diet-reared hosts.

Improved strains of natural enemies: Field trials conducted in Tamil Nadu (cotton) and Haryana (sugarcane) with high temperature tolerant strains of *Trichogramma chilonis* have recorded higher parasitism by these strains on pest eggs besides reduction in pest incidence compared to locally reared laboratory strain. Field trials conducted in Gujarat, Tamil Nadu and Karnataka to evaluate efficacy of multiple insecticide tolerant strain against cotton bollworms in comparison with normal laboratory strain of *T. chilonis* have revealed higher parasitism of bollworm eggs, lesser boll damage and higher yield in all trials than the normal strain.

Studies on entomopathogenic viruses and fungi: Nucleopolyhedrosis viruses of *Trichoplusia ni*, *Spodoptera exigua*, *Crocidolomia binotalis*, *Opisina arenosella*, *Chilo infuscatellus*, *Chrysoperla carnea* and *Cadra cautella* and of a neogregarine protozoan pathogen, *Mattesia dispar* from *Cadra cautella* have been isolated. Conidial spore production of *Nomuraea rileyi* has been cheap; it was maximum with 5% yeast granules as yeast source. The best liquid medium for conidial production of *N. rileyi* has been rice extract (5%) + yeast granules (5%). The need to add UV protectants (Congo Red, Ranipal) in the new wettable dust powder formulation of *Bacillus thuringiensis* has been established; as increased mortality of *Helicoverpa armigera* has been observed despite exposure of formulation to UV.

Fungal and bacterial antagonists: Seed biopriming

with a suspension of *Trichoderma* powder (10g TH + 10g FYM powder + 5g gum arabica in 50 ml water for 1 kg of seed) has resulted in rapid and uniform seedling emergence and better seedling growth and protection against seed-and-soil borne diseases in rice, wheat, chickpea, lentil, pigeonpea, tomato, brinjal, capsicum, cabbage, cauliflower and chilli especially in 'Usar' soil in Uttaranchal. Farmers have adopted production of *T. harzianum* in their fields, by colonizing antagonists in the FYM.

Entomopathogenic nematodes: A rapid and cheap mass production method using vermiculite has been developed for *Steinernema carpocapsae* and *Heterorhabditis indica*. *Heterorhabditis* isolates are more effective than *Steinernema* isolates against whitegrub, *Holotrichia lepidophora*.

Biological control of plant parasitic nematodes. Pochonia chlamydosporium produced in corn meal agar (CMA) medium has been better than water agar medium in inhibiting hatching of nematode eggs and also in its parasitizing ability. Microplot experiments carried out in root-knot nematode infested farmers' fields of tomato to evaluate combinations of talc formulation of *Paecilomyces lilacinus* and organic amendments have revealed that egg mass parasitization and reduction in nematode population was maximum with vermicompost, followed by neem-cake, farm compost and pelletized organic manure.

Biological suppression of crop pests: Commercial crops. Demonstrations for biocontrol of sugarcane borers have been conducted at Pravaranagar, Maharashtra, by releasing *T. chilonis* at 50,000/ha at 10 days' interval. These showed reduced incidence of early shoot borer.

Evaluating performance of bio-intensive integrated pest management practices in the management of cotton pests in Andhra Pradesh, Maharshtra, Tamil Nadu and Gujarat have resulted in decrease in jassids and whiteflies population, increase in natural enemies like coccinellids, spiders and lacewing; and higher 'kapas' yield than in farmers' practice and untreated control. *N. rileyi* formulation in aqueous suspension and oil in water emulsion at $5x10^{11}$ spores/ha has been as effective as Endosulfan (0.07%) in reducing incidence of *H. armigera* in cotton.

Pulse crops. Bio-intensive pest management trials in pigeonpea with special reference to pod-borer complex in Andhra Pradesh have showed that alternate sprays of *Ha*NPV and NSKE (*Ha*NPV-NSKE-*Ha*NPV-NSKE) have fared better in suppressing *Helicoverpa armigera* as well as pod-wasp and pod-fly with least pod damage. Similar trials in Tamil Nadu, but with *Bt*-*Ha*NPV alteration have showed lesser *H. armigera* larval population besides damage to pods by pod-wasp and other pod-borers was the lowest.

Vegetable crops. In cabbage, neem-seed powder and *Bt* in combination with *Trichogrammatoidea bactrae* have recorded lesser population of *Plutella xylostella* than *T. bactrae* alone on crop in Bangalore. Three sprays of *Bt* at 2kg/ha at weekly intervals starting from initiation of flowering have been effective against brinjal fruit borer (*Leucinodes orbonalis*), recording minimum fruit infestation (4.49%) and maximum marketable fruit yield (14.99 tonnes) in Pune.

Release of *Copidosoma koehleri* at 1 mummy/4kg tubers and *Chelonus blackburni* at 2 adults/kg tubers at 15 days' interval has been the most effective method of releasing parasitoids in local storage devices to control potato tuber-moth.

Honey Bee Research

Bee management: Double bee strength colonies with 1 or 2 queen bees of *Apis mellifera* have yielded more than even cumulative honey production from combination of 2 single strength colonies each with single queen.

For dearth period feeding of *A. mellifera* L. colonies, the diets based on brewer's yeast and parched chickpea (brewer's yeast 42% + parched chickpea 4% + skimmed milk powder 4% + sugar 25% + water 25%) with or without pollen were consumed most and could result in better growth of colonies.

In Orissa to ensure optimum bee strength before honey flow season (February-May), supply of pollen substitutes to bee colonies during December-January is felt imperative.

- Double bee strength colonies with 1 or 2 queen bees of *Apis mellifera* yielded honey more than even cumulative honey production from combination of 2 single strength colonies each with a single queen.
- For optimum pollination in litchi with *Apis mellifera,* 20-25 bee colonies per hectare are required.
- Combs treatment with Delfin, a Bt formulation, at 7% (0.7 g/hive) gave 93-97% control of wax moth, *Galleria mellonella*.
- Semen of yellow or black drones stored at room temperature for 60 days can be used for instrumental insemination of honeybee queens.

Hive products

For royal jelly production in *Apis mellifera*, cell acceptance was highest in 20 bee-frame strength colonies and lowest in 10 bee-frame strength colonies. The positions (top, middle or bottom) of cell bars did not result in any significant difference. Both these variables did not affect royal jelly production on per cell basis.

In an experiment on the production of propolis from *Apis mellifera* colonies by different methods, plastic screen alone, screen + sticks (to increase penetration of light) and scrapping, it has been found that propolis collection was maximum by scrapping, followed by screen + sticks, and lowest in use of screen alone.

Drone rearing for instrumental insemination of queen bees

Data on the number of spermatozoa in semen of yellow (3.49 × 10^6 sperms per drone) and black drones (3.09 × 10^6 sperms per drone) of *Apis mellifera* have revealed non-significant differences in their sperm count. Semen of drones stored at room temperature for 60 days can be used for instrumental insemination of honeybee queens.

Bee pollination: Apis mellifera and syrphid fly were the predominant visitors on radish. Intensity of visit of the insect on the crop was higher in forenoon and that of *A. mellifera* was in noon. Rate of foraging was higher for pollen foragers (*A. mellifera*) than nectar foragers. Three visits of *A. mellifera* bee resulted in significantly highest number of seeds per pod.

A. mellifera constituted the major proportion of total bee species visiting the flowers of sesame (51.9%) and sunflower (56.2%). Crop yield enhancement due to overall bee pollination was also noticed to the tune of 79.0, 55.0, 10.5 and 33.0% in sunflower, sesame, mustard and niger. While finding colony requirement for proper pollination with *A. mellifera* in litchi, it has been observed 20-25 colonies per hectare are optimum.

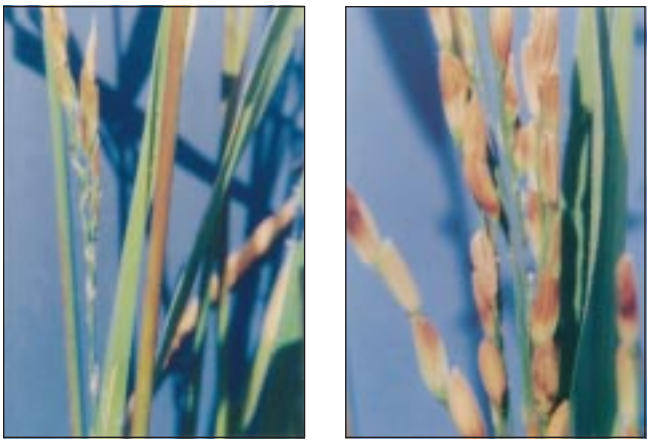
Diseases and enemies: A. mellifera apiaries in Punjab have revealed very low (1.65%) incidence of European foulbrood (EFB) – a bacterial disease caused by *Melissococcus plutonius*. This bacterial pathogen has been isolated and cultured. Out of 5 bacterial isolates, 3 have been identified as *M. plutonius*, *Lactobacillus eurydice* and *Paenibacillus alvei*. Significantly positive association has been found between migration of honey bee colonies and incidence of EFB. Shook swarm coupled with brood alone or brood + pollen combs have resulted in disappearance of EFB.

Treatment of combs with Delfin, a Bt formulation, at 7% (0.7 g/hive) gave 93-97% control of wax moth (*Galleria mellonella* L.).

Agricultural Acarology

Mite Infestation: Rice. Rice sheath mite *Steneotarsonemus spinki* Smiley (Tarsonemidae) has caused significant damage to rice crop in many districts of Karnataka and South Gujarat, both during *kharif* and summer. As many as 10-48 mites on leaf sheath and 0.5 to 1.5 mites (per 5 grains) on developing grains have been recorded in Karnataka. During *kharif* 2002, extensive damage by spidermite *Oligonychus oryzae* (Tetranychidae) on the crop was observed in Raichur and Bellary in Karnataka, in Navasari inGujarat.

- Weed plants *Chenopodium album, Amaranthus viridis, Trianthema monogyna, Euphorbia hirta* in the vicinity of cucurbitaccous plants supported multiplication as well as spread of *Tetranychus urticae*.
- Reported for the first time, eriophyid mite (*Cisaberoptus kenyae*) on Dussehri mango in Punjab and *Schizotetranychus baltazari* on citrus in Arsikere, Karnataka.
- Insecticides Monocrotophos, Cypermethrin Fenvalerate, Deltamethrin caused resurgence of yellow mite on chilli in Navasari (Gujarat).



Damage of *Steneotarsonemus spinki* on rice leaf sheath (*left*) Discolouration of glumes due to damage by *Steneotarsonemus spinki (right)*

Wheat. Rainfed wheat (PBW 175, PBW 299) and late-sown, irrigated wheat (PBW 373) in Ropar, Anandpur Sahib, Ballowal Saunkhri and Hoshiarpur have been found moderately infested (30-35 mites/plant) by brown wheat mite, *Petrobia latens*, during March. In Gujarat, sorghum mite, *Oligonychus indicus*, which appeared during second fortnight of August, gradually attained peak of attack by the first fortnight of November and then declined. Both predatory insects and mites were also active during this period.

Cucurbitaceous and other field crops. *Tetranychus urticae* infestation on cucurbitaceous crops, particularly on summer squash, ash gourd, bottle gourd and muskmelon, has been severe in parts of Ludhiana, of which muskmelon had high mite infestation of 325 mites/leaf. Survival of this mite on a number of weed plants *Chenopodium album*, *Amaranthus viridis*, *Trianthema monogyna*, *Euphorbia hirta* and *Polypogon monspeliensis*, in the vicinity of the crops showed that these weeds supported multiplication as well as spread of *T. urticae* on to cultivated crops.

Sugarcane. Ratoon sugarcane (COJ 83) has been found severely infested by *Oligonychus* sp. (33-475 mites/leaf) in Laddowal in Punjab, and profuse webbing and reddening of infested leaves was seen during June-July. Occurrence of this mite has also been noticed on regular sugarcane crop in Mandya (Karnataka) due to extended dry weather.

Horticultural crops. Eriophyid mite (*Cisaberoptus kenyae*) has been reported for the first time on 'Dussehri' variety of mango in Punjab, so also *Schizotetranychus baltazari* on citrus in Arsikere, Karnataka.

Chilli. In Kalyani, damage by yellow mite, *Polyphagotarsonemus latus* accounted for a yield loss of 28.6% or Rs 3,261/ha during 2002.

Resurgence of yellow mite in chilli

Monocrotophos, Cypermethrin, Fenvalerate and Deltamethrin caused resurgence of yellow mite *Polyphagotarsonemus latus* on chilli in Navasari, Gujarat. Evaluation of certain newer molecules against this mite in Karnataka has showed moderate efficacy of Bifenthrin, Fenpropathrin and Milbemectin only up to 7 days after application, compared to effectiveness of Dicofol up to 10-14 days. In Coimbatore, application of Diafenthiuron 50 WP (0.09%) caused 74- 93% reduction in chilli mite population in 15 days; followed by Fenpyroximate (0.006%) and Buprofezin (0.03%); these treatments helped realizing higher fruit yields. In Varanasi, Abamectin (0.028%) and Dicofol (0.05%) effectively controlled spidermite infestation on brinjal, and Fenpyroximate 5 SC (0.006%) was superior on okra mite in Coimbatore, recording maximum fruit yield, followed by Diafenthiuron 50 SC (0.09%).

Coconut. Coconut mite *Aceria guerreronis* has been observed to infest nuts of palmyra, *Borassus flabellifer*, and mite feeding caused reddish-brown patches on the inner side of the bracts. Unlike coconut, no significant feeding marks have been seen either on the outer surface of the nuts or on the developing tissues underneath the perianth.

Survival of coconut mite: Eriophyid mite vector, *Aceria cajani*, has been observed surviving on voluntary or stray pigeonpea plants, sterility mosaic infested stubbles or ratoons in Navasari, Gujarat, and also on the weed, *Atylosia scarabaeides*, in Bangalore.

Activity of predatory mites: Significant activity of predatory mites *Amblyseius longispinosus*, *A. alstoniae* and *Phytoseius roseus* on various crops has been observed in different parts of Punjab. *A. longispinosus* suppressed the population of spidermite *T. urticae* on roses in a polyhouse near Bangalore.

Host resistance: Cotton varieties GK 151 and LD 327 have been relatively more infested by spidermites (3.4-4.1 mites/leaf), and LD 327 was least preferred (0.2 mites/ leaf). Brinjal varieties, Punjab Neelam (16.8 mites/leaf) and Punjab Barsat (18.8 mites/leaf) are found more susceptible to *T. urticae* damage, and BH 1 with 3.2 mites/leaf has been fairly tolerant. Among okra varieties, Pusa A 4 and VR0 6 have been found heavily infested (76-97 mites/2 cm^2 leaf area), and Varsha Upahar (12 mites/2 cm^2 leaf area) was least infested. In Karnataka, coconut like West Coast Tall × Choughat Dwarf Orange, West Coast Tall × Gangabondam, West Coast Tall × Malaysian Dwarf Yellow, Gangabondam × Fiji, Gangabondam × Philippine Ordinary and Gangabondam × Lakshadweep Ordinary have consistently showed low mite damage.

Pesticide Residues Management

A safe waiting period of 30 days has been found adequate for Imidacloprid (200 SL) on apple when applied at 20 and 40 ml/4 litres. Residues of Imidacloprid (600 FS) in cottonseed, lint and soil are found below detectable limit at harvest when applied 9, 12, 18 and 24 ml/kg of seed dressing. And Spinosad (45 SC) were below detectable limit in cottonseed, lint and oil 50, 75 and 150 g a.i./ha. Similarly, no residues of b-Cypermethrin (5 EC) have been detected in any portion of cotton crop when applied at 15, 20 and 40 g a.i./ha. Residues of Chlorpyriphos (20 EC) on paddy were from below detectable limit to 1.70 ppm in grain, husk and straw at the application rate of 375g a.i./ha 30 days before crop harvest.

- A safe waiting period of 30 days found adequate for Imidacloprid (200 SL) on apple when applied at 20 and 40 ml/4 litres.
- Detected the commonly used pesticides in 64% of the vegetable samples (592) and 46% of the fruit samples (359). Only 9% vegetable samples contained residues above maximum residue limit (MRL), and none of the fruit samples contained above the MRL.

Residues of different commonly used pesticides were detected in 64% of vegetable samples (592) and 46% of fruits samples (359). And only 9% vegetable samples contained residues above maximum residue limit (MRL) values, compared to 12% reported in 2001. It was satisfying to note that none of the fruit samples contained pesticide residues above prescribed MRL value. Out of 214 butter samples collected all over the country, residues of DDT and HCH were detected in 66 % samples. The average level of these organo-chlorine pesticides has been found lower than the level detected in 2001. HCH residues were detected in 56 and 62% of vegetarian and non-vegetarian diet samples DDT contamination was detected only in 27% of vegetarian diet samples and 20% non-vegetarian diet samples. In animal feed and fodder samples (400) also, residues of OC pesticides were detected in 34% samples. Repeated observation have indicated without any doubt that pesticide residues from vegetables can be easily removed up to 50-100% by simple decontamination processes like washing, pealing and cooking before consumption.

Whitegrub Management

Whitegrub (*Holotrichia consanguinea*) management through beetle control by spraying insecticides (Chlorpyriphos 20 EC, 0.05% a.i. or Quinalphos 25 EC, 0.05% a.i. or Carbaryl, 0.2% a.i.) on host trees, followed by pheromone chemical (methoxy benzene) at 15 ml/3 pieces of sponge (each 5cm × 5cm) per tree for 3 successive days has been found very effective. Technology

- Chlorpyriphos 20 EC at 400 g ai/ha alone or in combination with Nicast (organic manure) 500 kg/ha at the time of second earthing in June found effective in protecting potato-crop from whitegrub at Palampur (Himachal Pradesh).

has been further improved to economize on pheromone. Pheromone chemical dose has been reduced to 1.5 ml/3 pieces of sponge (each 5cm × 5cm) per tree.

Field performance of M. anisopliae *against whitegrub: M. anisopliae* formulation at 1×10^{14} conidia/ha at 4 soil depths (10, 15, 20 cm and normal sowing depth has reduced plant mortality (56.5–61.2% protection) along with 40-44% higher mean pod yield in groundnut as compared to plots-sown without bioagent formulation. Enhanced crop protection and pod yield were obtained in 10 and 15 cm depths as compared to normal sowing depth.

Post-sown treatment in potato against whitegrub

Chlorpyriphos 20 EC at 400 g a.i./ha alone or in combination with Nicast (organic manure) 500 kg/ha at the time of second earthing up in June has been very effective for protecting potato-crop from whitegrub (*Holotrichia coriacae*) at Palampur (Himachal Pradesh).

Nematode Management

White-tip and root-knot nematodes: Rice. Paddy seed soaking in Carbosulfan 25 EC at 0.1% for 12 hours has been effective on farmers' fields in reducing root-knot nematode infestation and increasing grain yield by 78 and

- Paddy seed soaking in Carbosulfan 25 EC at 0.1% for 12 hours effectively reduced root-knot infestation; 78% in Karnataka, 13% in Assam and 64% in Orissa in farmers' fields.
- Root-knot nematode disease in groundnut reduced up to 40% by applying castor-cake at 1,000 kg/ha + neem oil at 5 litres/ha + Carbofuran.

26% in Karnataka, 13 and 18% in Assam, and 64 and 30% in Orissa.

Pulses. Seed soaking with Carbosulfan 25 EC at 0.1% for 6 hours or seed-dressing treatment with Carbosulfan 25 ST at 3% w/w in chickpea, cowpea, mungbean, pigeonpea and urdbean managed plant parasitic nematodes *Meloidogyne incognita*, *Heterodera cajani*, *Rotylenchulus reniformis* and *Pratylenchus thornei* infecting these crops and increased their yield by 15.7–38% over control.

Oilseeds and fibre crops. Root-knot nematode disease in groundnut could be reduced up to 40% by applying castor-cake at 1,000 kg/ha + neem oil at 5 litre/ha + Carbofuran at 1 kg a.i./ha and this increased yield by 46.7% over control with a cost benefit ratio of 1:1.47.

Root-knot nematode (*Meloidogyne incognita*) and reniform nematode (*Rotylenchulus reniformis*) infection could be controlled on cotton by soaking seeds in Carbosulfan at 500 ppm for 6 hours + soil application of Carbofuran at 1kg a.i./ha. This resulted in 19.6% increase in yield over control.

Vegetable and fruit crops. Root-knot nematode infection in brinjal, tomato and chilli could be reduced by deep summer ploughing and solarization of main field transplanted with seedlings raised on nursery-beds treated with Carbofuran at 0.3 a.i. w/w. Integration with neem cake at 200 kg/ha at places where solarization is not possible further improved efficacy.

Meloidogyne incognita, *M. javanica*, *Radopholus similis*, *Pratylenchus* spp. and *Helicotylenchus* spp. on banana were managed with highest cost:benefit ratio of 1:2.24 by paring of suckers + hot water treatment at 55°C for 20 minutes + Carbofuran (3G) at 16.6 g/pit + neem-cake at 1 kg/pit.

Agricultural Ornithology

For the first time, ashy wren warbler (*Prinia socialis*) has been observed resting in cotton-crop and feeding nestlings with available larvae in the cropped area. Due to erratic rainfall and delayed agricultural operations, breeding performance of rose-ringed parakeet has been affected, and it registered low (68.5%) reproductive success.

- For the first time ashy wren warbler (*Prinia socialis*) observed resting in cotton-crop and feeding nestlings with available larvae in the cropped area.
- Occurrence of house-sparrows reduced significantly in South Zone and Krishna Godavari Zone with a flock range of 4-11 birds.
- Observed for the first time Ruff (*Philomachus pugnax*) in Jamnagar, a coastal district of Gujarat, feeding on harvested earheads of pearl millet.

In Gujarat, within 5-km radius of a roost of rose-ringed parakeet of about 4,000 individuals, together with rock pigeon and ring dove, 22% damage to groundnut was observed during sowing to sprouting stage.

Migratory short-toed lark (*Calandrella cinerea*) and calendar larks (*Melanocorypha calandra*) caused heavy damage to wheat during sowing; to the extent that some farmers were compelled to re-sow their fields in Gujarat.

Ruff (*Philomachus pugnax*) has been observed in Jamnagar, a coastal district of Gujarat, for the first time feeding on harvested earheads of pearl millet, which were kept in field for drying. Sindh Jungle sprarrow (*Passer*

Status of house-sparrows

A survey was undertaken for house-sparrows in five different agroclimatic zones. Out of 184 villages, sporadic populations of house-sparrows, were found in 60 villages. The occurrence of house-sparrows, has significantly reduced in South Zone and Krishna Godavari Zone with a flock range of 4-11 birds. Occurrence is mainly restricted to village habitats. The main reason for decline of these species is attributed to loss of preferred habitat and other changes in the socio-economic conditions in rural areas.

pyrrhonotus) has been recorded feeding on the berry of *Salvadora* spp. for the first time from central Gujarat.

Rodent Control

Rodent surveys: Except for extreme arid tracts, *Bandicota bengalensis* has been predominant in all agroclimatic regions of the country. Its population during the year was generally higher in fodder, sugarcane, rice and wheat crops near sugarcane fields; rice crops near vegetable fields. Other major rodent species associated with *B. bengalensis* are *Tatera indica* and *Millardia meltada* (Gujarat and Karnataka); *Mus booduga* (Andhra Pradesh, Assam and Himachal Pradesh), *T. indica* and *Mus* sp. (Punjab), and in arid regions, major rodent species complex comprised *Meriones hurrianae – Tatera indica* and *Millardia meltada*.

- Except for extreme arid tracts, *Bandicota bengalensis* predominates all agroclimatic regions of the country
- Indigenous traps *Butta* and *Tanjore* Kitty traps evaluated in Godavari delta recorded a trap index of 0.028-0.04 and 0.013-0.015 for *Bandicota bengalensis* and *Mus booduga* in rice fields.
- Jojoba seed-cake powder with pearl millet flour at 10 and 20% concentration(w/w) recorded repellency index of 84.2 and 93.4% in *Tatera indica*.
- Rodent population was higher in zero-tilled fields as compared to conventionally tilled wheat field in Punjab.

Behavioural ecology: A significant increase in pre-copulatory behaviour was noticed in male and female partners during all stages of oestrous and met-oestrous stage of *Bandicota bengalensis*. Urinary pheromones were involved in such intra-specific communications. Addition of fresh burrow sand at 25% in plain baits significantly enhanced food consumption by *B. bengalensis*. Two breeding peaks of lesser bandicoots at October-November and March-April were noticed in West Godawari Delta in Andhra Pradesh. Population growth estimates have revealed that bandicoots breed 2.6-2.3 times/season, with an annual productivity of 65 and 61/females in *kharif* and *rabi*. Rodent population was higher in zero-tilled fields as compared to conventionally tilled wheat field in Punjab.

Management strategies: Mechanical control. Indigenous traps, *Butta* and *Tanjore* kitty traps, evaluated in Godavari delta have recorded a trap index of 0.028-0.04 and 0.013-0.015 for *B. bengalensis* and *M. booduga* from rice fields.

Botanicals. Jojoba seed-cake powder mixed with pearl millet flour at 10 and 20% concentration (w/w) has recorded a repellency index of 84.2 and 93.4% in *Tatera indica*. Similarly, aqueous leaf, kernel and pulp extracts of *Melia azedarach* and *Datura stramonium* have been found effective in reducing food consumption by rodents from 2.6-45%.

Chemosterilants. Administration of 50-100 mg/kg of body weight of epi-chlorohydrin resulted in reduction of weights of reproductive organs and accessory sex glands in *Rattus rattus*.

Control of poison shy rodents. Difethialone (0.002%) in pearl millet baits resulted cent-per-cent mortality of zinc-phosphide-induced bait-shy population of *Tatera indica* and *Rattus rattus*.

Field evaluation of rodenticides. Single application of second generation anticoagulants *viz.* bromadiolone (0.005%), brodifacoum (0.005%) and difethialone (0.0025%) have resulted in over 70% rodent control from a pest complex of *M. hurrianae-T. indica-R. meltada* up to 120 days in wheat-cumin-mustard cropping system in western Rajasthan. Similarly, single baiting with Coumatetralyl (0.0375%) placed in tyre-bait station yielded 75-89% and 67-84% rodent control in rice and wheat,. Difethialone (0.0025%), Bromadiolone (0.005%) and Coumatetralyl (0.0375%) baiting recorded over 80% control in groundnut, wheat, cotton and sugarcane in Gujarat.

Social engineering activity on rodent control. In Punjab and Rajasthan, adoption of rodent management technology has been higher in *rabi* than in *kharif* crops. As a result, a yield loss of 49.4 kg/ha and 89.8 kg/ha could be saved in *kharif* and *rabi*. Similarly, in Gujarat, adopted villages recorded lowest crop damage in groundnut (1.7-3.3%) and wheat (0.73-1.1%) with over 75% reduction in rodent pest infestation. In Karnataka

Rodent problem in NEH regions with special reference to bamboo flowering

In Manipur, four districts have been identified for abundant bamboo flowering; where about 27,000 hectares are likely to suffer due to rodent menace; coinciding with bamboo flowering. The predominant rodent species in bamboo-growing areas of Manipur are *Rattus rattus bullocki, R. manipulus, R.r. brunnusculus* and *Bandicota bengalensis*. In Assam's Karbi Anglong district, 570 hectares under jhoom rice were damaged by rodents in Khonbamon and Singhason areas. All 641 farm-families of the region were badly affected by rodent menace during the year. Sudden proliferation of rodent population has been assessed as the attribute of bamboo flowering.

also, rodent damage could be prevented to the tune of 58-78% in different crops in adopted villages.

Integrated Pest Management

IPM technology has been validated on farmers' fields for mungbean–safflower cropping system in 3 watershed villages around Parbhani, Maharashtra. The package comprised timely sowing undertaken during first week of October, seed treatment with Carbendazim at 2g/kg of seed, and border spraying with Dimethoate at 0.05% on 4 rows on each side under 180-cm across the plot on both sides. First application of NSKE at 5% and second with Dimethoate at 0.05% for aphids, and installing bird perches and pheromone traps for *Helicoverpa* proved effective and remunerative as compared to farmers' practice. The cost:benefit ratio in IPM and FP has been 1:7.1 and 1:5.1.

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