6. Crop Improvement

Crop-improvement programme focuses on development of new crop varieties and hybrids with wider adaptability and higher yield along with tolerance/ resistance to various insect-pests and diseases and for overcoming adverse impact of abiotic stresses. To realize envisioned goal, greater emphasis is laid on the development of genomic resources for targeted traits and crops, besides pre-breeding for identification of desirable genes in related and wild species to broaden genetic-base by transferring desirable alleles from alien sources. Suitable biotechnological tools such as marker-assisted selections, transgenic crop variety development and many such novel tools and techniques have also been deployed for faster and accurate identification of promising crop genotypes.

Cereals

Rice: Two varieties and a hybrid of rice have been released by the Central Sub-Committee of Crop Standards, Notification and Release of Varieties, and

Rice varieties released

Central/State	Variety	Grain type	Ecosystem	Reaction to pests/diseases
		Central Releases		
	CO 4 (Hybrid)	MS	Irrigated	MR- BL, BS
	NDGR 201	SB	Semi- deep waters	MR- BS, SBr
	CR SugandhDhan 907	MS	Eastern India	MR-LBl, NBl, BS, ShR
		State Releases		
Andhra Pradesh	Sheetal	LS	Irrigated	MR- BPH
	Siddhi	MS	Rainfed, shallow lands	MR- GM
	Krishna	SS	Irrigated	R- BL
	Sujana	MS	Irrigated	T-BLB; R-GM
	Prathyumna	MS	Rainfed, upland	T-BL;MR-GM
	Pranahitha	LS	Irrigated	T-BL, BLB; MR-GM
	Nellore Sona	MS	Irrigated	T- BL
	Swetha	MS	Irrigated	T- Heat , BL
Asom	Kanaka Lata	MS	Boro areas	MR- BLB, ShBl, BS
Bihar	Sabour Surbhit	LS	Irrigated	MR- BL, BLB, BS, SBr BPH
Gujarat	GNR 2	MS	Coastal salinity	R-BLB
Maharashtra	Karjat 8	SS	Rainfed, shallow lands	MR- BL, GM
	Phule RDN 6	LS	Irrigated	R- BLB, GLH, BPH, WBPH; MR- BL, SBr
Odisha	Luna Sankhi	MS	Coastal salinity	MR- LBl, ShBl
	Luna Barial	SB	Coastal salinity	MR- ShBl, BS, LF
Uttar Pradesh	CSR 43	SB	Irrigated, salinity/ alkalinity	MR- BS
Uttarakhand	Pant Sugandh Dhan 21	LS	irrigated	MR- BL, SBr
Manipur	Mangalphou	LS	Irrigated	R-RTV
	Eenotphou	-	Shallow, deep waters	MR-GM
	RC Mani-phou 12	LB	Irrigated	R-GM

SB: Short Bold; MS: Medium Slender; LB: Long Bold; LS: Long Slender; SS: Short Slender; R: Resistant; MR: Moderately Resistant; T:Tolerant; BL: Blast; BLB: Bacterial Leaf Blight; BPH: Brown Planthopper; BS: Brown Spot; GLH: Green Leaf Hopper; GM: Gall midge; LBl: Leaf Blight; LF: Leaf Folder; NBl: Neck Blight; RTV: Rice Tungro Virus; ShR: Sheath Rot; ShBl: Sheath Blight; SBr: Stem Borer; WBPH: White-Backed Planthopper.

State Variety Release Committees have recommended 20 rice varieties for different ecosystems of the country.

The first early-maturing rice basmati variety Pusa Punjab Basmati 1509 released in Punjab gave average yield of 3.94 tonnes/ha; at a par with Pusa Basmati 1121. It was found resistant to leaf blast and brown spot.

Wheat: Nine varieties have been released for different production conditions in wheat-growing areas of the country.

Wheat HD 3059 released for late sowing after cotton or late-maturing rice in Punjab and Haryana is an early- maturing (121 days), semi-dwarf (93 cm) variety with an average yield of 4.25 tonnes /ha, and a genetic potential of 5.94 tonnes/ha under late sown, irrigated areas.

Wheat HD 3059 is resistant to all three rusts, including stem rust race Ug99 and its variants. It showed high protein content (13.6%), high sedimentation value (52 ml) and best Glu-1 Score (10/10), and meets all criteria for superior bread and *chapati*-making qualities.

Barley: Four barley varieties have been released for commercial cultivation for different production conditions in the wheat-growing areas of the country.

Wheat varieties released

Variety	Production conditions	Area of adoption
TL 2969 (triticale)	Rainfed, timely sown	North Hills Zone: Hilly area of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Arunachal Pradesh and Sikkim Odisha, Asom and plains of north-eastern states
HD 3059	Irrigated, late sown	North Western Plains Zone : Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), western Uttar Pradesh (except Jhansi division), Jammu and Kathua districts of Jammu and Kashmir, Paonta Valley and Una district of Himachal Pradesh, and *tarai* region of Uttarakhand
HPW 349	Rainfed and irrigated, timely sown	North Hills Zone: Hilly area of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Arunachal Pradesh and Sikkim
WH 1105	Irrigated, timely sown	North Western Plains Zone: Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), western Uttar Pradesh (except Jhansi division), Jammu and Kathua districts of Jammu and Kashmir, Paonta Valley and Una district of Himachal Pradesh, and *tarai* region of Uttarakhand
HI 8713 (Pusa Mangal) (d)	Irrigated, timely sown	Central Zone: Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh
HW 5216 (Pusa Thenmalai)	Restricted irrigation, timely sown	South Hills Zone:Nilgiri and Palani hills of Tamil Nadu and Kerala
DBW 71	Irrigated, late sown	North Western Plain Zone: Punjab, Haryana, Delhi, Rajasthan (except Kota and Udaipur divisions), western Uttar Pradesh (except Jhansi division), Jammu and Kathua districts of Jammu and Kashmir, Paonta Valley and Una district of Himachal Pradesh, and *tarai* region of Uttarakhand
UAS 304	Irrigated, timely sown	Peninsular Zone: Maharashtra, Karnataka, Andhra Pradesh, Goa and plains of Tamil Nadu
MP 3336	Irrigated, late sown	Central Zone: Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan and Jhansi division of Uttar Pradesh

Barley varieties released

Variety	Salient characteristics	Production conditions	Area of adoption
DWRB 91	Two-row malt barley, resistant to yellow and brown rusts	Late sown, irrigated	North Western Plains Zone
VLB 118	Six-row feed barley	Timely sown, rainfed	North Hills Zone
RD 2786	Six-row feed barley, resistant to rusts	Timely sown, Irrigated	Central Zone
RD 2794	Six-row feed barley	Timely sown, Irrigated	Salinity conditions of North East/North Western Plains Zones

Malt-barley cultivation in late- sown conditions of northern plains

To widen the scope of malt-barley cultivation in the late-sown conditions of the northern plains in rotation with cotton, pearl millet, sorghum, maize and sugarcane, a new variety, DWRB 91 has been released for commercial cultivation. This variety gave good grain yield with acceptable malting quality under late sowing up to mid- December.

Maize: Five hybrids and one open-pollinated variety (OPV) have been released for different agro-ecological conditions.

Maize hybrids / open-pollinated varieties released

Hybrid/ OPV	Area of adoption
Late-maturing hybrids (> 95 days)	
CMH 08-282	Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh
Early-maturing hybrids/OPVs (75 -85 days)	
Shalimar Maize Composite 3 (OPV)	Jammu and Kashmir
KDM 438	Jammu and Kashmir
Pant Shankar Makka 1	Uttarakhand
Extra-early maturing hybrid (< 75 days)	
Vivek Maize Hybrid 45 (FH 3483)	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, Jharkhand, Odisha, Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu
Quality Protein Maize	
Pratap QPM Hybrid 1 (EHQ 16)	Rajasthan, Gujarat, Madhya Pradesh and Chhattisgarh

Small millets

In ragi, a partial genetic male sterile line (PS 1) identified in GPU 28 background having resistance to neck and finger blast, is extensively used in hybridization. In PS 1 line, partial seed set was observed to an extent of 11.8% under selfing, and progeny grown from these seeds was sterile, uniform and homogeneous. An increase in seed- set (20.54%) was observed under open pollination. Unlike conventional genetic male sterility, PS 1 could be easily maintained and propagated by selfing or multiplication in isolation.

Pearl millet

Three hybrids and one variety have been released for various agro-ecologies of the country.

Pearl millet hybrids / varieties released

Hybrid/ OPV	Area of adoption
Pratap Hybrid (MH 1642)	Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu
PKV-Raj Hybrid (BBH 3)	Maharashtra
ABPC 4-3 (MP 484)	Maharashtra
Hybrid CO 9	Tamil Nadu

Forages

Sorghum variety SPV 2057(CSV 30 F) has been identified for cultivation in a single-cut forage- growing areas. This showed 7.2% higher green fodder yield (44.34 tonnes/ha) and 11.4% higher dry fodder yield (13.96 tonnes/ha) over the national variety CSV 21F. It also possessed superior fodder quality (50.2% *in-vitro* dry matter digestibility) and lower HCN content (56.5 ppm). Bundel Guinea 4 guinea- grass has been found resistant to lodging and responsive to fertilizer application, and remains green throughout the year in irrigated areas. Bundel Lobia 4 cowpea, a high- biomass yielding variety (average of green fodder yield 35 tonnes/ha), tolerant to flea beetle has been recommended for rainfed areas in the North- Eastern Hills.

Sorghum variety SPV 2057(CSV 30 F)

Oilseeds

Total 26 varieties/hybrids of oilseeds, including 10 of Indian mustard, four of soybean, three each of groundnut, sunflower and safflower and one each in castor, linseed and sesame have been released for different agro-ecological regions.

Oilseed varieties / hybrids released

Crop/ Variety/Hybrid	Recommended state/region	Salient features
Indian Mustard		
RGN 229	Delhi, Haryana, Punjab, Jammu and parts of Rajasthan	Tolerant to high temperature and salinity during seedling stage; seed yield (2,162-2,568 kg/ha)
RGN 236	Delhi, Haryana, Punjab, Jammu and parts of Rajasthan	Tolerant to high temperature and salinity during seedling stage
DRMRIJ 31	Delhi, Haryana, Jammu, Punjab and northern Rajasthan	Large seed , seed yield (2,246-2,757 kg/ha)
RH 0406	Delhi, Haryana, Jammu and Kashmir, Punjab and parts of Rajasthan	Lodging resistant; large seed, seed yield (2,200-2,300 kg/ha)
Raj Vijay Mustard 2	Delhi, Haryana, Jammu and Kashmir, Punjab and parts of Rajasthan	Moderately resistant to white rust; seed yield (1,276-1,874 kg/ha)
RH 0749	Delhi, Haryana, Jammu and Kashmir, Punjab and parts of Rajasthan	Timely sown irrigated condition; large seed, long siliqua; dominance of primary branches; seed yield (2,400-2,800 kg/ha)
Pusa Mustard 29	Delhi, Haryana, Jammu and Kashmir, Punjab and Rajasthan	Low erucic acid; timely sown irrigated condition
Pusa Mustard 30	Uttar Pradesh, Uttarakhand, Madhya Pradesh,Rajasthan	Low erucic acid; timely sown irrigated condition
RRN 573	Rajasthan	Irrigated, normal sown condition
Pant Rai 20	Plains of Uttarakhand	High temperature tolerant; large seed, seed yield (1,701-2,539 kg/ha)
Soybean		
Pusa 12 (DS 12-13)	North Plains Zone	Determinate growth habit; yellow seed and black hilum; matures in 124-131 days; resistant to YMV, *Rhizoctonia* aerial blight and bacterial pustules; oil content 19.6%; protein content 37.8%, seed yield 2,290 kg/ha
Pant Soybean 1368 (PS 1368)	Uttarakhand	Tall and sturdy plant; matures in 117-125 days; resistant to YMV, bacterial pustule and *Rhizoctonia* aerial blight; seed yield 2,120 kg/ha.
MACS 1188	Southern Zone	Determinate growth habit, yellow seed and black hilum; matures in 101 days; resistant to bacterial pustules, *Rhizoctonia* aerial blight and charcoal-rot diseases and defoliator, pod-borer, leaf-folder and leaf-miner pests; oil content 19.1%; protein content 41%; yield potential 2,500-3,950 kg/ha
Pratap Soya 45 (RKS 45)	Rajasthan	Determinate growth habit; creamy yellow seed and brown hilum; matures in 95-98 days; responsive to high fertility under irrigated condition and suitable for water-stress condition; moderately resistant to bacterial pustules, charcoal rot and YMV; oil content 21%; protein 40-41%; seed yield 3,000-3,500 kg/ha
Groundnut		
GJG 22 (JSSP 36)	Gujarat	Tolerant to collar-rot, seed yield (1,770 kg/ha)
GJG 17 (JSP 48)	Gujarat	Tolerant to stem-rot, seed yield (1,798 kg/ha)
Dharani	Andhra Pradesh	Drought tolerant; tolerant to dry root-rot and stem-rot; seed yield (1,100 kg/ha (rainfed) 2,600/kg/ha (irrigated)

Crop/ Variety/Hybrid	Recommended state/region	Salient features
Sunflower		
RSFV 901 (Kanthi)	Karnataka	Seed yield 1,200-1,400 kg/ha, oil content 39%; matures in 95-100 days; tolerant to necrosis disease
RSFH 130 (Bhadra)	Karnataka	Seed yield 1,200-1,500 kg/ha; oil content 40%; matures in 95-100 days; tolerant to necrosis disease
CO 2	Tamil Nadu	Seed yield 1,900-2,200 kg/ha, oil content 39%; matures in 85-90 days; moderately resistant to *Alternaria* leaf spot, rust and tolerant to thrips and leafhopper
Safflower		
SSF 708	Western Maharashtra	Seed yield 1,300-2,200 kg/ha, oil content 29%; matures in 115-120 days; tolerant to aphid
PKV Pink (AKS-311)	Maharashtra (Vidarbha region)	Seed yield 2,500 kg/ha, oil content 29%; matures in 115-120 days
NARI-H 23	Maharashtra, Karnataka, Madhya Pradesh, Chhattisgarh, Rajasthan, West Bengal	Seed yield 1,711 kg/ha, oil content 31%; matures in 114-156 days; tolerant to safflower aphid; suitable for irrigated conditions
Castor		
GC 3	Gujarat	Seed yield 2,340 kg/ha, oil content 49%; resistant to wilt, tolerant to *Macrophomina* root-rot; suitable for irrigated conditions
Sesame		
HT 9713 (HT-2)	Haryana, Punjab, Himachal Pradesh and Jammu and Kashmir	White seeded; tolerant to phyllody and leaf curl virus; seed yield 600-800 kg/ha, oil content 48-50%
Linseed		
Pratap Alsi 2	Rajasthan	Matures in 129-135 days; average yield 1,957 kg/ha, oil content 41.8%; suitable to irrigated condition; moderately resistant to *Alternaria* blight, powdery mildew and wilt

Pulses

Total 19 varieties of different pulses, including five each of chickpea and pigeonpea, three each of mungbean and urdbean, two of fieldpea and one of lentil have been released for different agro-ecological regions.

Varieties of pulses released

Crop/Variety	Maturity (days)	Recommended states	Salient features
Chickpea			
GNG 1958	146	North- western Rajasthan, Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Delhi	Large-seeded (25.4 g/100 seeds), seed yield 2,600 kg/ha; moderately resistant to wilt and tolerant to root- rot, stunt and collar-rot
GNG 1969	146	North- western Rajasthan, Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Delhi	Profuse branching, semi-erect and large seeded (26.2 g/100 seeds), tolerant to wilt and root- rot; seed yield 2,200 kg/ha
L 555	146	North- western Rajasthan, Punjab, Haryana, western Uttar Pradesh, Uttarakhand and Delhi	Large- seeded *kabuli* variety (27.8g/100 seed); semi erect, tall, light-green foliage; tolerant to wilt; seed yield 2,300 kg/ha
CSJK 6	188	Jammu and Kashmir, Uttarakhand and North-Eastern Hills region	Large- seeded *kabuli* variety (32.8g/100 seeds), seed yield 1,106 kg/ha; moderately resistant to root- rot and tolerant to wilt
NBeG 3	100	Andhra Pradesh	Large- seeded *desi* variety (24.0g/100 seeds), seed yield 2,300 kg/ha; tolerant to drought with good rooting quality, tolerant to wilt

Crop/Variety	Maturity (days)	Recommended states	Salient features
Pigeonpea			
Rajeshwari (Phule Toor 12)	135	Gujarat, Maharashtra, Madhya Pradesh., Rajasthan and Chhattisgarh	Semi-spreading, indeterminate; moderately resistant to *Fusarium* wilt, SMD and tolerant to pod-borer and pod-fly
RGT 1	150	Andhra Pradesh and Karnataka	Semi-spreading, indeterminate, resistant to wilt; white-seeded
Rudreshwar (WRG 65)	165	Andhra Pradesh	Semi-spreading, indeterminate; resistant to wilt, moderately tolerant to *Helicoverpa*
PKV Tara	165	Vidarbha region of Maharashtra	Semi-spreading, indeterminate; moderately resistant to sterility mosaic and wilt; medium seed sized
Prakash (IPA 203)	250	Eastern parts of Uttar Pradesh, Bihar, West Bengal, Asom, Jharkhand	Semi-spreading, indeterminate; resistant to sterility mosaic and wilt and tolerant to *Phytophthora* stem blight
Mungbean			
MH 421	60-65	Punjab, Haryana, New Delhi, western Uttar Pradesh	Suitable for summer cultivation; resistant to MYMV; seed yield 1,100-1,200 kg/ha
KM 2195	65-70	Uttar Pradesh	Suitable for *kharif* cultivation; resistant to MYMV, seed yield 1,000-1,200 kg/ha
BM 2003-2	65-70	Maharashtra	Green, shining bold grains, seed yield 800-1,100 kg/ha
Urdbean			
NUL 7	65-70	Madhya Pradesh, Maharashtra, Gujarat, Chhattisgarh, Bundelkhand region of Uttar Pradesh	Early type, suitable for *kharif* cultivation, seed yield 1,000-1,200 kg/ha
VBN 6	65-75	Tamil Nadu	Suitable for all seasons, resistant to MYMV, seed yield 800-900 kg/ha
UH 1	70-75	Haryana	Resistant to MYMV, medium-bold, attractive seeds, seed yield 1,100-1,300 kg/ha
Fieldpea			
IPFD 6-3	110-115	Uttar Pradesh	Dwarf type; resistant to powdery mildew; and tolerant to rust disease, seed yield 1,500-1,800 kg/ha
HFP 529	125-135	Punjab, Haryana, New Delhi, Western Uttar Pradesh	Dwarf type; resistant to powdery mildew; seed yield 2,200-2,500 kg/ha
Lentil			
IPL 316	120-125	Madhya pradesh, Bundelkhand region of Uttar Pradesh, Chhattisgarh and Rajasthan	Large-seeded; tolerant to wilt; seed yield 1,500 1,800 kg/ha

Commercial crops

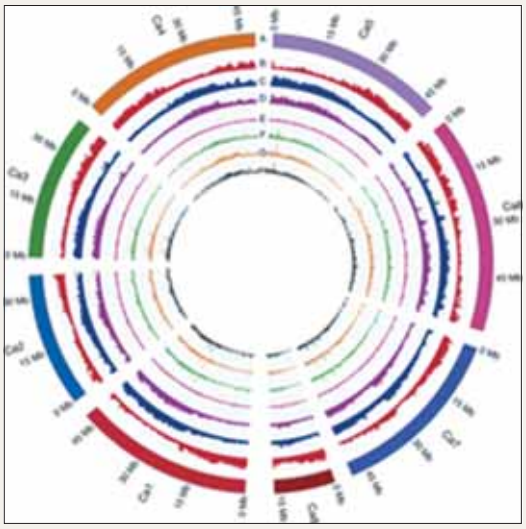
Jute: JROM 1 (Pradip) *tossa* jute variety has been recommended for release in all *tossa* jute-growing states. Its average fibre yield potential is 3.7 tonnes /ha, with yield advantage of 8.75% and 20.73% over the existing checks JRO 8432 and JRO 524, respectively. It is found resistant to major pests and diseases (stem-rot, root-rot and semilooper, Bihar hairy caterpillar and yellow mite), and produced fibre of grade TD_3 with lesser defects, and also yielded 6.2 tonnes of sticks /ha as a by-product.

White jute JRCM 2 (Partho) variety with yield potential of 2.8 tonnes/ha and resistance to major pests and diseases has been released for all white jute-growing states.

Mesta: Kenaf variety JBM 81 (Shakti) has been recommended for release in all mesta-growing states.

Draft whole genome sequence of chickpea

The draft whole genome sequence (~738 mb) of a *kabuli* chickpea variety CDC frontier was reported. A total of 28,269 protein coding genes in the chickpea genome were identified, in which 187 genes were found linked to disease resistance. The genome sequence shall be used to identify large number of markers which will be useful for marker-assisted breeding in chickpea. Knowledge of location of genes in the genome will help faster discovery of genes associated with agronomic traits such as yield, drought and heat tolerance, disease and insect resistance. The sequencing data of chickpea will provide not only access to agronomically important traits but would also speed up breeding work to develop high-yielding chickpea varieties that can tolerate better biotic and abiotic stresses and also to address climate change issues. This genome sequence of chickpea is the culmination of years of genome analysis by the International Chickpea Genome Sequencing Consortium, led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India. The consortium includes 49 scientists from 23 organizations in 10 countries including Indian Council of Agricultural Research (ICAR), India.



The average fibre yield potential of the variety is 2.5 tonnes/ha, and is found tolerant of stem and- root rot disease. The fibre tenacity of the variety was 22.25 g/tex.

Sunnhemp: SUIN 037 (Ankur) variety is found suitable for Uttar Pradesh, Tamil Nadu and Maharashtra. Its yield potential is 1.0-1.2 tonnes/ha, and showed fibre tenacity of 21.0 g/tex.

Sugarcane: Co 06027 with a mean cane yield of 110 tonnes/ha has been released for Tamil Nadu, Karnataka, Andhra Pradesh, Kerala, Maharashtra, Gujarat and Madhya Pradesh. This variety gave 14.80 tonnes/ha sugar yield and 19.32 % of sucrose in 360 days. It was found resistant to red-rot and showed tolerance to drought and salinity.

Sugarcane varieties : (A) Co 06027; (B) Co 06030; and (C) Co 05009

Co 06030, a mid-late variety for Odisha, coastal Andhra Pradesh, Tamil Nadu and Puducherry, gave an average cane yield of 103 tonnes/ha, mean sucrose content of 16.60%, and was found resistant to red-rot.

Co 05009 (Karan 10), an early-maturing sugarcane variety, with a yield potential of 76 tonnes/ha and mean sugar yield of 9.2 tonnes/ha has been released for Punjab, Haryana, Rajasthan, western and central Uttar Pradesh and Uttarakhand. It showed resistance to red- rot disease along with non-lodging and non-flowering attributes.

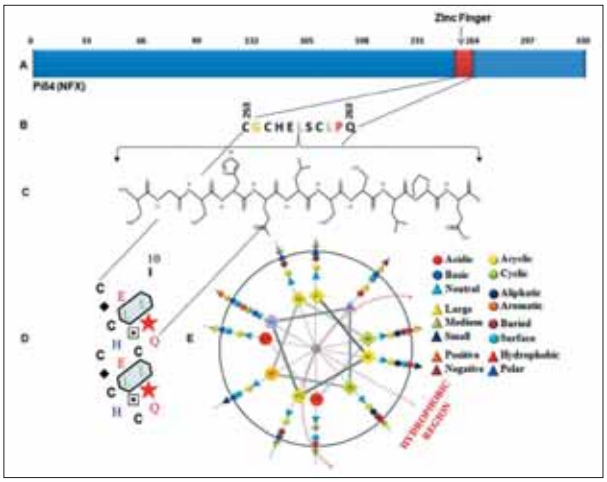
CoLk 9709, an early-maturing sugarcane variety, with yield potential of 72 tonnes/ha and moderate resistance to red- rot has been released for Uttar Pradesh.

Cotton: A genetic, male-sterility-based cotton hybrid CSHG 1862 has been released for cultivation in Punjab, Haryana and Rajasthan due to its superiority in lint yield, ginning out-turn and fibre quality with spinnability of 50s counts, and has been found moderately resistant to cotton leaf curl virus.

Tobacco: Two chewing tobacco varieties Abirami CR (HV.2000-6) and Kamatchi (VDH 3) have been released for Tamil Nadu. *Fusarium* wilt tolerant flue-cured tobacco (FCV) variety FCH 222 has been released for cultivation in Karnataka.

Biotechnology

Comparative analysis of Pi54 rice- blast resistant protein: For the first time, it has been reported that Pi54 (Pi-k^h-Tetep) has a small zinc finger domain of NFX type. Compositional analysis depicted by the helical wheel diagram revealed presence of a hydrophobic region within this domain, which may enable exposing LRR region for a possible *R-Avr* interaction. This domain is unique among all other cloned plant disease-resistant genes, and may play an important role in broad-spectrum nature of the rice-blast resistance gene, *Pi54*.



Structure of *Pi54* zinc finger domain. (A) Positional analysis of the domain showed that this domain is C-terminal in nature. The type of this zinc finger domain is NFX. (B) The amino acids, numbers and their positions in this domain. (C) Chemical structure of individual amino acids. (D) Secondary structure of zinc finger domain. (E) Helical wheel diagram of *Pi54* zinc finger domain. The helical wheel is a plot of the amino acid residues around a potentially helical segment. The graphical representation showed clustering of polar and/or non polar residues toward one face of helix.

Use of candidate gene-specific markers for rice lines: The validation of the selected material using candidate gene-specific markers in eighteen lines of rice in the background of Taraori Basmati and Basmati 386 introgressed with three bacterial blight(BLB) genes (*Xa21, xa13, xa5*) exhibited high level of resistance against BLB.

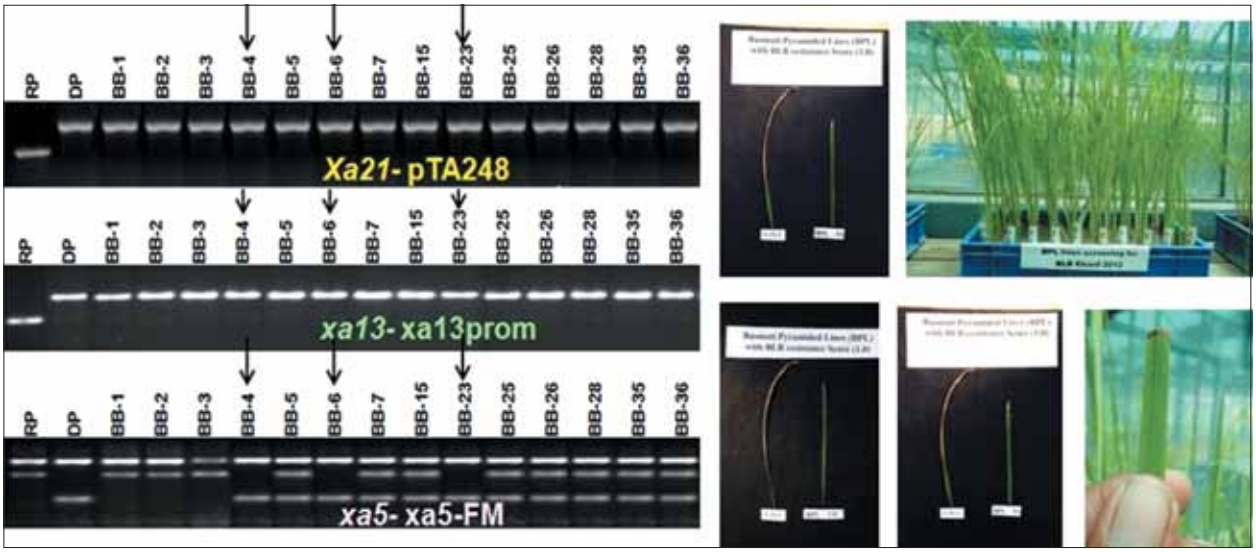
Functional marker for distinguishing *Glu-B3b* allele in common wheat: Full length sequence of *Glu-B3b* was cloned and sequenced from two wheat cultivars to develop functional marker for the allele. The marker was amplified in all genotypes carrying both *Glu-B3b* and *Glu-B3g* alleles. The marker in combination with the marker for *Glu-B3g* could distinguish *Glu-B3b* allele in diverse set of 182 Indian wheat cultivars. This removed discrepancy in identification of *Glu-B3b* allele using PCR-based markers.

Lipoxygenase- free soybeans for soy-food industry

Lipxygenase-2 is the major enzyme responsible for generating off-flavour in soy- products. NRC 109 and NRC 110, the first-ever two Indian lipoxygenase-2- free soybean genotypes developed, can contribute immensely in boosting soy-food industry. Crossing programme was carried out between Samrat and PI 086023 and advanced to F_7 generation. Validation of null lipoxygenase-2 plants in the advanced generations was performed using null allele-specific marker from the sequence analysis of *lox2* gene.

NRC 109 NRC 110

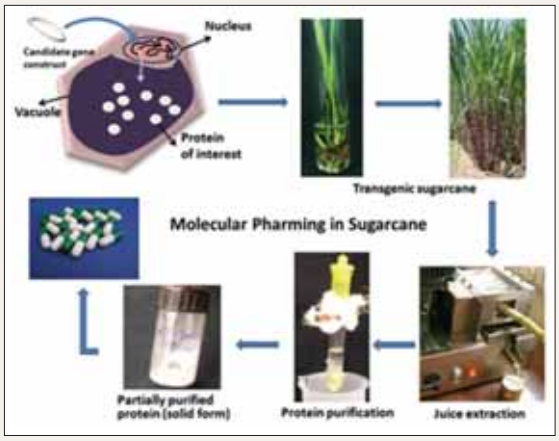
Amplicons generated using gene-specific marker for null allele of lipoxygenase-2 (*lox2*). Lanes 1, 2 NRC 109; 3, 4 Samrat; 5, 6 PI 086023 (donor of *lox2*) and 7, 8 NRC 110



Screening for *Xa21*, *xa13* and *xa5* using candidate gene-specific markers and validation by phenotyping

Molecular farming using sugarcane as a candidate crop

With the use of an in-house developed promoter for higher expression in sugarcane culm (stem) and a vacuole- localizing signal, transgenics were developed that express either Green fluorescent protein (GFP) or Beta-glucuronidase (GUS). GUS with his-tag could be isolated and partially purified from sugarcane- juice without any loss of enzymatic activity, and in some selected events, protein yield (70 % purity) was as high as 1 mg per ml of juice. Easy extraction and low protein content from sugarcane in juice made downstream processing easier. By using GUS and GFP as model proteins, possibility of sugarcane as a platform for molecular farming is being established. This technology will be useful for production of high- value protein molecules — pharmaceutical proteins like vaccines, therapeutic proteins, oral vaccines, or any other intermediate proteins of industrial value. With a definite advantage over other crops, sugarcane holds promise as a new candidate crop for molecular farming.



Marker assisted selection for kunitz-trypsin inhibitor-free soybean: Seventy-five BC_1F_2 homozygous recessive kunitz-trypsin inhibitor-free plants (*titi*) were identified from a population of JS97-52 × PI542044 and 9 from NRC7 ×PI542044 using SSR marker Satt228. One hundred and eighteen BC_2F_1 plants of JS97-52 ×I542044 were genotyped for hybridity using Satt 228 (tightly linked to *Ti* locus) and gene-specific marker. Twenty- four BC_2F_1 plants confirmed for trueness to hybridity.

Transgenic sunflower for conferring resistance to necrosis disease: Sunflower necrosis disease (SND) resistant transgenics have been developed through deployment of coat protein gene of tobacco streak virus in sense direction *via Agrobacterium*-mediated transformation. Stable integration of the introduced gene was confirmed through PCR, RT-PCR, Southern analysis; while expression analysis was done through Northern blotting and Real-time PCR analysis. Virus challenging homozygous plants in T_4 generation, followed by ELISA and RT-PCR confirmed resistance to sunflower necrosis disease. Five promising events have been multiplied for utilization in backcross breeding programmes.

Transgenic *Botrytis*-tolerant castor-plants: Two multi-gene cassettes, each carrying three genes previously reported to impart partial resistance, have been developed for imparting tolerance in castor against *Botrytis*. These vectors are being validated using tobacco as a model system and simultaneously efforts are on to use them for transforming castor with triple as well as double gene constructs using meristem- based as well as *in- planta* transformation methods. T_1 progeny plants were obtained from *in- planta* transformation procedure.

Detection of viruses infecting *Vigna* species

Species-specific primers were designed for accurate detection of viruses infecting *Vigna* species. Simplex-PCR protocols for detection of four viruses, Mungbean Yellow Mosaic India Virus (MYMIV), Mungbean Yellow Mosaic Virus (MYMV), Horsegram Yellow Mosaic Virus (HgYMV) and Groundnut Bud Necrosis Virus (GBNV), have been standardized.

Genetic transformation of chickpea and pigeonpea

Genetic transformation of chickpea (cv. DCP 92-3) with *AtDREB1A* gene was done, and 1,167 explants were co-cultivated. Three resistant shoots identified against kanamycin monosulphate were established. To discriminate transgenics from non-transgenics, 48 T_1 progenies (from 3 T_0 plants) were screened with new set of oligos for the presence of the gene.

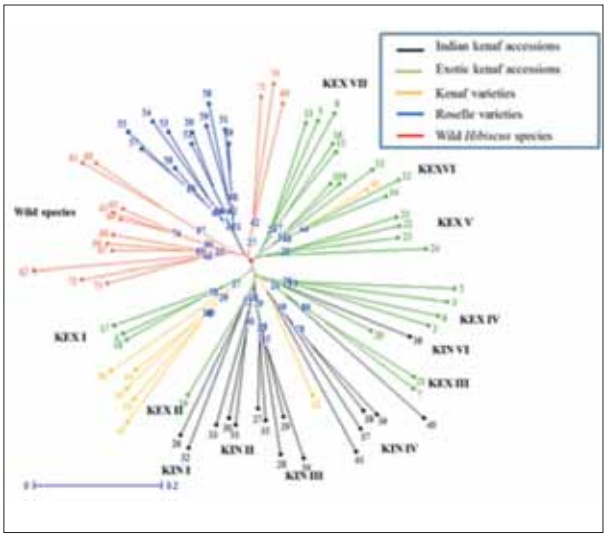
Genetic transformation (*Agrobacterium*-mediated and micro-projectile) in chickpea and in pigeonpea using *Bt* gene (*cry1Ac)* was done with 73,309 and 31,187 explants, respectively. This resulted in establishment of 32 and 211 independent primary transgenics of chickpea and pigeonpea, respectively. Further, pigeonpea variety Asha and chickpea variety DCP 92-3 were transformed using *Agrobacterium tumefaciens* harbouring a synthetic *Bt* gene (*cry1Aabc*).

Validation of gene cassettes using tobacco as model system for *Botrytis* grey mould disease of castor: Transgenic tobacco-plants carrying three single gene cassettes (ACS4-BIK1, ACS5-ERF1 and ACS7-AtEBP1) independently were crossed to stack gene cassettes. At least 24 progeny plants of each cross (ERF × BIK1, BIK1 × At EBP and AtEBP × ERF1) were confirmed using PCRs and RT-PCRs, and plants for the presence of the gene cassettes were identified. Plants that expressed two genes (e.g. *AtEBP, ERF1*) were crossed with tobacco-plants carrying corresponding third gene cassette (e.g. BIK1) to stack all three gene cassettes. Thus, three cross combinations were made to have plants carrying all the cassettes. The results indicated Mendelian segregation of three gene cassettes in one of the progenies analyzed.

Mapping *Fusarium* wilt resistance genes in chickpea and pigeonpea: Two mapping populations (JG 62 × WR 315 and K 850 × IPC 2004-52) of chickpea were advanced to F_4 generation. F_2 mapping population derived from cross JG 62 × WR 315,

representing 178 individuals was phenotyped for *Foc* race 1 in pots and genotyped with 84 polymorphic markers. In Marker Assisted Back Crossing (MABC), 12 F_1 plants confirmed true hybrid on the basis of molecular marker were backcrossed and 57 BC_1F_1 seeds were obtained. Similarly, 7 true BC_1F_1 plants derived from KWR 108 × ICC4 958 crosses were backcrossed and 35 BC_2F_1 seeds were harvested. In pigeonpea, mapping population comprising 191 F_5 lines (Asha × UPAS 120) for wilt resistance was advanced and 24 SSR markers were identified polymorphic between parents.

Genetic association of kenaf (*Hibiscus cannabinus*), roselle (*H. sabdariffa*) and wild *Hibiscus:* Evolutionary relationship between kenaf, roselle and their wild relatives have been elucidated using SSR (12 No.) and ISSR (13 No.) markers. Kenaf accession and varieties with similar genetic background and geographical origin formed closely related groups.



Genetic association of kenaf, roselle and wild *Hibiscus*

Hibiscus surattensis was found to have more genetic similarity with kenaf compared to other species. Other wild species were genetically more distinct from the cultivated species. At sub-genus level, members of sections like Trichospermum (*H. calyphyllus*), Ketmia (*H. caesius*) or Pterocarpus (*H. vitifolius*) formed separate groups and exhibited higher genetic distance from members of section Fucaria (*H. cannabinus, H. sabdariffa, H. surattensis, H. acetosella and H. radiatus*).

Identification of candidate genes for cotton fibre strength improvement: Expression profile of genes during secondary wall formation of cotton fibre such as *GhcesA1, GhcesA 2, and GhcesA 7, GhFLA3,* and *GhCobl4* were studied. The qRT-PCR analysis showed that all genes maintained relatively higher expression at the secondary wall synthesis phase in high fibre strength genotypes than those with low fibre strength. *GhcesA2* and *GhcesA7* showed relatively higher level of expression during secondary wall synthesis in *G. hirsutum* genotypes, especially at 27, 33 and 36 days post anthesis.

DNA fingerprinting

Microsatellite- based markers have been used for genetic diversity analysis and cultivar identification in pearl millet (27), fingermillet (35), maize (143), flax (94), pomegranate (45), *Luffa* (37) and others (46). Molecular profiling was done in core collections of cucumber (120), melon (155), mothbean (250), *Lathyrus* (225), sesame (450), and minicore in finger-millet (110), wheat (186) and aromatic and non-aromatic rices (104) using simple sequence repeat (SSR) markers. Trait-specific markers were generated for tomato leaf curl virus in sponge-gourd, for flowering characteristics in gynoecious bitter-gourd, high erucic acid in *Crambe*, for oxidative stress management and zinc transporter genes in cowpea and maize, and for biotic (UG99) and abiotic (drought, salt and heat) stresses in wheat. Curated transcripts were identified through transcriptome profiling for moisture- stress tolerance and allele mining from tolerant and susceptible genotypes, respectively, in *Cucumis* (12,859 and 13,448), mothbean (5,047 and 5,016) and *Lathyrus* (20,992 and 19,553). Qualitative and quantitative event-specific PCR/real-time PCR assays were developed for detection of *Bt* brinjal event EE1, and GM maize events TC1507, NK603, *Bt*176 and MON810; and multiplex PCR assays for GM maize events TC1507 and MON89034 × NK603 ×TC1507. Imports of cotton, maize, rice and sorghum (1186 accessions) were tested for the presence/integration of transgene. Loop-mediated isothermal amplification assays were developed for visual detection of screening elements (*P-35S, P-FMV, nptII* and *aadA*) in genetically modified crops.

Seed technology

Seed priming for micronutrient bio-fortification in forage crops: Generally requirements of Ca, P, Cu and Zn of lactating and mature cows are not met from the feed and forages given to them. Specially, availability of Cu and Zn were reported below the required level. Seed priming with 0.05% solution of $ZnSO_4$ + $CuSO_4$ + $MnSO_4$ for 12 hr + VAM + 50% RDM (Zn:Cu:Mn :: 10:2.5:5 kg/ha) resulted in significantly higher green forage yield of oat (517 q/ha) and sorghum (252 q/ha) in comparison to common practice (486 and 201 q/ha, respectively). The adoption of integrated nutrient management (INM) in sorghum and oat was effective in improving productivity and quality of forage.

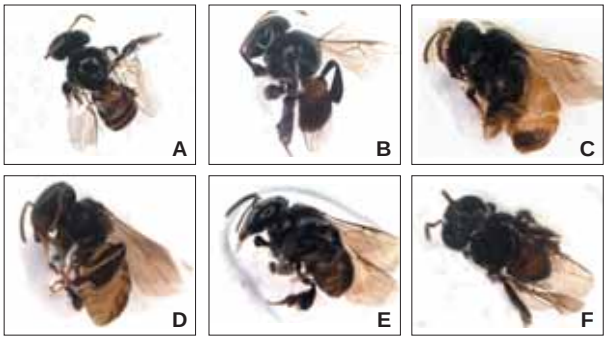
Quality seed production

Under the quality seed-production programme, 11,835 tonnes of breeder seeds, 14,984 tonnes of foundation seeds, 22,281 tonnes of certified seeds and 14,939 tonnes of truthfully labeled seeds were produced. Besides, 5,237 tonnes of planting material plus 3.7 lakh tissue-cultured plantlets of sugarcane and 182.44 lakh rooted cuttings of the forage grasses were also distributed.

Pollinators

Improved seed- setting in onion through honey bees. Pollination through honey- bee *Apis mellifera* resulted in enhancement of onion-seed yield by more than 10 times compared to open-pollination of inflorescence. Installation of two *Apis mellifera* colonies per hectare was required for optimum pollination in onion.

Stingless pollinators. Six stingless bee species, *Tetragonula canifrons, T. irridipennis, T. atripes, T. laeviceps, T. ventralis* and *T. ruficornis* were identified from the North -East India. For sustenance of these stingless pollinators, number of foraging plants have been identified and categorized according to the blooming period and floral rewards (nectar, pollen or both nectar and pollen sources). Stingless bee-colonies showed better growth and development in wooden boxes (25cm×15cm ×13cm) compared to earthen-pots or bamboo pieces.



Bee species: (A) *Tetragonula irridipennis,* (B) *T. canifrons,* (C) *T. atripes,* (D) *T. laeviceps,* (E) *T. ventralis* and (F) *T. ruficornis*

Horticulture

Fruit crops

An extra early-maturing (15 March to 15 April) mango variety, Arka Neelachal Kesari, with attractive fruit colour and shape was identified for cultivation in eastern coastal regions of India. It escapes fruit fly damage and yields 70-110 kg fruits /tree.

Progeny R_1P_2 of Amrapali × Arka Anmol hybrid had medium-sized fruits (224 g) with a TSS of 24° Brix, deep yellow pulp and 68.8% pulp recovery. Another hybrid progeny, H81 (Amrapali × Eldon), was selected for medium-sized fruits having attractive peel, pulp and high TSS (21°Brix).

Arka Neelachal Kesari mango

Of the 60 mutant lines generated in grapes, 6 (Mutant No. 320, 348, 375, 388, 391 and 528) were promising for fruit colour, weight and TSS.

Crossing of pomegranate Baghawa and Ganesh cultivars with wild, Himalayan land race of *Punica granatum* was successful. Four-year-old progenies of crosses between Bhagawa (commercial) and blight tolerant *Daru* and *Nana* were taller to female parent. Six hybrid progenies with more than 3% acidity (NRCP H-1, 3, 4, 11, 12 and 15) were identified for *anardana* preparation. Evaluation of 500 pomegranate seedlings of sub-Himalayan origin to challenged inoculation with *Xanthomonas axonopodis* pv. *punicae* (Xap) under glasshouse showed 45-100% disease index. Out of 321 M_0 population of Bhagawa, a potential mutant plant (M_0) with ≥ 400g fruit weight, red glossy and thin rind, dark red/dark pink juicy arils (> 60%), bold arils (> 550 mg), high TSS (> 18º Brix), less acidic (< 0.4 %) and very soft seeds was identified for further evaluation.

NRCP Hybrid-12 suitable for preparation of *anardana*

In papaya Coorg Honey Dew**,** F_6 generation with stable hermaphrodite and female plants were sib-mated and a few lines with no male plants, 50 % homozygosity for plant height, first flowering, fruiting height, fruit setting and fruit shape were identified for further evaluation. Five inter-generic progenies, viz. R_1P_{16}, R_1P_{17}, R_2P_{17}, R_1P_{20} and R_1P_{24} with 552.5g to 1.34kg fruit weight and 3.44 cm pulp thickness were selected, sib-mated and advanced to F_5 generation.

In guava, five hybrid progenies, two from Apple Colour × Purple Local and one each from Purple Local × Apple colour, Purple Local × Sardar and Thailand × Purple local crosses with 88.6 - 180.1 g fruit weight, TSS (11.0 - 13.5°Brix) and seed hardiness (8.0 - 13.5 kg/cm^2) were observed promising for further evaluation.

In litchi, a large number of crosses involving Shahi, China and Bedana were made in all possible combinations and 1,310 seedlings and 26 open pollinated progenies raised for identification of superior types.

In passion fruit, 43 promising hybrids from Kaveri × Yellow types were selected for further evaluation. One of them, hybrid IIHR-18/42 produced purple coloured,

Passion fruit hybrid suitable for direct consumption

high flavoured fruits with high juice recovery (35-38%), and is suitable for processing. Hybrid, IIHR 1/31, yielded fruits with low acidity (0.4 - 0.6%), more sweetness (TSS: 21-22 °Brix) and can be used for direct consumption.

Two rambutan cultivars, Arka Coorg Arun (red), weighing 40-45g, yielding 750 - 1000 fruits/tree and Arka Coorg Peetabh (yellow), with yellow fruits, weighing 25-30 g, white juicy and sweet aril were released.

Rambutan — Arka Coorg Peetabh

In almond, two new high-yielding genotypes, CITH-A-23 (4.69 tonnes/ha) and CITH-A-22 (4.53 tonnes/ha) and another accession, CITH-A-8, with maximum kernel recovery (56.14%) were identified for further evaluation.

In strawberry, a hybrid (Festival × Howard 17) with large fruits and good quality (TSS>10.0°Brix) was selected for further screening.

Plantation crops

In coconut, hybrid Kalpa Samrudhi (Malayan Yellow Dwarf × West Coast Tall) had excellent yield (100 nuts/palm), whereas another hybrid Malayan Yellow Dwarf × Niu Leka Dwarf (MYD × NLGD), had robust growth and recorded 400ml tender nut water.

In arecanut, three hybrids, Shriwardhan x Sumangala, Shriwardhan × Mangala and Mohitnagar x Sumangala, were identified for high nut yield. Two varieties, Madhura Mangala (VTL62) and Nalbari (VTL-75), were submitted for release and notification by Central Variety Release Committee.

In cocoa, two high-yielding varieties, VTLC-119 and VTLC-115, were developed.

In cashew, hybrid H-68 performed better (3.54 kg/plant at third harvesting). This hybrid is mid-season with bold nut (>10 g). Another hybrid H-73 recorded maximum cumulative yield (80.70 kg nuts/ tree) over a period of 15 years, whereas HC-6 showed dwarfism.

In olive, of the 25 varieties, Corotina was found high-yielding with optimum fruit maturity index and oil content when harvested between 10-30 October in Kashmir valley.

In noni, four varieties, CARI Samridhi, CARI Sanjivini, CARI Sampada and CARI Rakshak, were identified for cultivation in Andaman and Nicobar Islands.

Vegetable crops

In tomato (determinate), Kashi Aman, showed high level of resistance to both monopartite and bipartite viruses both under artificial and open field screenings. It yielded 50-60 tonnes/ha and was recommended for cultivation in Punjab, Uttar Pradesh, Bihar and Jharkhand. Six F_1 hybrids pyramided with ToLCV resistant genes (Ty1+Ty2+Ty3) were evaluated for triple disease resistance to ToLCV+BW+EB. H-329 (56tonnes/ha), H-367 (53tonnes/ha) and H-363 (48tonnes /ha) were high-yielding with triple disease resistance.

In brinjal, for the first time, bacterial wilt resistant lines of were selected and advanced to F_3 and F_4 generations. Progenies of two cross combinations, IIHR-3 × IIHR-108-37-36-4-1 and IIHR-3 × IIHR-108-37-36-1-3, were promising for yield. Fertility of sterile F_1 interspecific hybrid in a reciprocal cross of *Solanum macrocarpon* × *Solanum melongena* was restored by backcrossing with *Solanum macrocarpon*.

In okra, four lines (IIHR-296-22-10-11-598, IIHR-291-14-11-585, IIHR-294-1-10-1-595 and IIHR-285-6-10-11-138) resistant to Yellow Vein Mosaic Virus were identified under naturally hot spot condition at Attur, Tamil Nadu. Among inter-specific crosses, 100 % fruit setting was observed in *A. tuberculatus* × *A. esculentus* followed by *A. tetraphyllus* × *A. esculentus* (97.3 %).

In carrot, of the ten male sterile lines evaluated, MS 32-3-3, MS 32-2-2, MS 50-7 and MS 40-2, were 100% sterile and stable with good root yield and quality characters. Two maintainer lines, MF 43-7-7 (root length 13.67 cm and root weight 86g) and MF 38-1 (root length 11.00 cm and root weight 70g), were stable for fertility. Carrot lines, SH-C-11, SH-C-52, SH-C-51 and SH-C-141-1, were identified with yield potential of 396.66, 385.55, 382.22 and 380.00 q/ha, respectively and were superior to Nantes and Shalimar Carrot-1 in yield and beta carotene content.

In garden pea, Arka Apoorva, a dual purpose (whole pod and as salad) variety with crisp and sweet pods, 12tonnes green pod /ha yield in 90 days, combined resistance to powdery mildew and rust was identified for release. Of six advanced breeding lines for high temperature tolerance, Arka Ajit × Arka Sampoorna-

IPS-3BK recorded maximum pod yield (5.8tonnes/ha), followed by 7-6 × KTP-4-IPS-12BK (5.6tonnes/ha). In dwarf types, IIHR 18 × Oregon 1-2 gave maximum pod yield (5.6 tonnes/ha) in 90 days, whereas Arka Ajit and IIHR 544 recorded 4.4 and 2.35tonnes/ha, respectively.

In *kharif*, Arka Ajit × Arka Sampoorna-IPS-3BK gave maximum pod yield (7.5 tonnes/ha) followed by IIHR 7-6 × KTP 4-IPS12BK (7.0 tonnes/ha). In dwarf types, IIHR 18 × Oregon 1-2 recorded maximum pod yield (8 tonnes/ha) in 90 days, whereas in Arka Ajit and IIHR 544 it was 6.43 and 2.65 tonnes/ha, respectively.

In French bean, for the first time, an advanced breeding line (IC525260 × IC525283-07-1-6-5) resistant to Mung Bean Yellow Mosaic Virus (MYMV) was identified and successfully field demonstrated. It has yield potential of 17.5tonnes/ha and 42 pods /plant. French bean, IIHR PB-1, IIHR PB-2, IIHRPB-7 (pole types) and rust resistant (IIHR 31 and Arka Anoop) were crossed and evaluation of F_1 progenies showed rust resistance to be a dominant trait.

In watermelon, line 42-174 recorded no incidence of

French bean IC 525260 × IC 525283-07-1-6-5 showing resistance to MYMV

water melon bud necrosis virus (WBNV) and produced round striped fruits with red pulp and 8%TSS. Arka Manik, Arka Muthu, Sugar Baby and IIHR-14 (yellow fleshed) varieties were treated with 0.2, 0.3 or 0.4% colchicine with or without PEG at cotyledon stage for six consecutive days which gave rise to 804 tetraploids. These were selfed and advanced to next generation.

In *Momordica* species, a seedless interspecific hybrid (*M. dioica* × *M. cochinchinensis*) was developed combining the desirable attributes of spine gourd and sweet gourd in addition to production of seedless fruits of bigger size (>20g) compared to normal spine gourd (<15g).

In Onion, two F_1 hybrids (DOGR Hy-1 and DOGR Hy-2) suitable for *rabi* cultivation were developed. The bulbs of DOGR Hy-1 are light red and flat-globular, with early maturity and yield of 41.30 tonnes/ha, while bulbs of DOGR Hy-2 are dark red and globular, early in maturity and yield of 34.96tonnes/ha compared to Bhima Kiran (28.91 tonnes/ha).

Indian spinach (Basella), CARI Poi Selection, is a new variety of Poi or Indian spinach (*Basella alba* L.), was developed through mass selection from local germplasm. It has broad and glossy leaves, short internodes and high yield (55-60 tonnes/ha) compared to local types (35-38 tonnes/ha).

Tuber crops

Potato, Kufri Gaurav and Kufri Garima were notified for commercial cultivation. Nine advanced hybrids for early and medium maturity were introduced.

Mushroom

Eight superior varieties of white button mushroom (DMR-Button-03), brown button mushroom (DMR-Button-06), paddy straw mushroom (DMRO-247, DMRO-484), shiitake mushroom (DMR-Shiitake 38, DMR-Shiitake-388), milky mushroom (DMR-Milky 334) and *Macrocybe gigantean* (DMR-Macrocybe-01) were recommended for release.

Flower crops

In gladiolus, Arka Amar, a hybrid (Watermelon Pink × Aarti) selection, blooms in 72 days, bears 101 cm long spikes with double rows of florets, resistant to *Fusarium* wilt, and Arka Kesar, a hybrid (Vink's Glory × Sagar) selection, blooms in 61 days, bears 111 cm long spikes and moderately resistant to *Fusarium* wilt were released. In addition, Punjab Beauty, Punjab Dawn, Punjab Pink, Elegance, Punjab Flame, Punjab Glance and Punjab Lemon Delight from PAU, Ludhiana; Phule Ganesh and Phule Neelrekha from MPKV, Rahuri; were identified for release.

In tuberose, Arka Sugandhi, a dwarf hybrid with field tolerance to root knot nematode and ideal for planting in beds was identified for release. The florets open at a time on the spike and the prominent stigma adds to the beauty. Phule Rajani, a new variety, was identified for cultivation in Maharashtra.

In Chrysanthemum, the cultivars, Anmol, Himanshu and Flash Point, for pot culture; Lucido, Red stone, Spacer, Autumn Eyes and Flash Point for early blooming; Coffee, Dark Eyes and Maghi for late blooming; Bindiya, Yellow Charm and Gum Drop for no-pinch and no-stake type; Gumdrop, Mother Teresa, Shyamal, Aprajita, Red Devil, Autumn Joy and Shobha, for late spring/early summer blooming were found suitable.

In marigold**,** Bidhan Mariold 1 (yellow) and Bidhan Marigold 2 (orange) were heat tolerant and suitable for round-the-year production in West Bengal.

In alstroemeria, Tiara and Aladdin with long rachis

and appealing colour were found suitable for cut flowers.

In orchids, the cross *Cymbidium* 'Red Beauty' × *Cym* 'Golden Elf' identified with novel colour combination and early flowering was suitable for pot cultivation. A clone derived from *C. lowianum* × *Cym*'Show Girl' with prolific and mid-season flowering was selected.

Spices

In turmeric, two nematode tolerant accessions Acc. 48 (31.94 tonnes/ha) and Acc. 79 (31.94 tonnes/ha) were developed and included for multi locational trials.

In fenugreek, Ajmer Fenugreek 3 (AFg 3) with 11.13% higher seed yield (1288 kg/ha) than Hisar Sonali (control) was identified for national release.

Medicinal and aromatic crops

In ashwagandha, a promising variety, Arka Ashwagandha, was identified for high dry root yield (11.95 q/ha) and total withanolide content (0.580%).

Biotechnology and tissue culture

Fruit crops

In mango, gene *WD*, encoding repeat proteins involved in WD40-bHLH-myb transcriptional complex was sequence characterized. The presence of *FLT*, member of multigene family, under the control of constans (*CON*), a photoperiod responsive gene, was identified in 18 mango cultivars. The *FLT* gene sequence analysis based on BLAST homology search compared 100 per cent identity with *Litchi chinensis FT1* and *FT2* genes with Dashehari mango for reverse primer for a short sequence. Real time assay evinced the upregulation of *FLT.*

In banana, EST SSR markers were designed from transcriptome analysis for both *Musa acuminata* (Calcutta 4) and *M. balbisiana* (Bee Hee Kela). In guava, linkage map was developed with a total of 160 SSR markers with two mapping population, viz. Kamsari (K), Local Purple (LP) and Allahabad Safeda (AS). In pomegranate, a total of 171 loci were used for designing SSR primers and these were characterized by evaluating the genetic diversity of 12 genotypes. In okra, 55 SSR markers were standardized using 10 gentoypes. In onion and carrot, markers were validaed to identify male sterility. In onion, Mk primers were employed to differentiate onion A and B line.

Multiple hybrid plantlet development through somatic embryogenesis and ECS was successfully accomplished in hybrid embryos of Marabale x PisangJajee (AAB × AA). DNA fingerprints of 14 unique land races of *Musa* representing AAA, AAB, ABB and AB genome was developed using SSR and ISSR markers. Putative transgenic cultures of Rasthali transformed with AMP gene for incorporating resistance to *F. oxysporum* f. sp. *cubense* (race 1) showed lower vascular discoloration compared to the control plants.

In grapes, hybridity of progenies in Seyve Villard (downy mildew resistant) and Thompson Seedless was confirmed using microsatellite markers. These plants were established in field for further evaluation. The EST and sequence databases of grape were analysed in silico and 165 genes were predicted to be uniquely expressed in response to salt. One hundred genes contained conserved domains like DNA binding and enzymatic functions. Five genes, which include transcription factors were also selected for their functional analysis.

In papaya, somatic embryogenesis from immature seeds of Surya variety resulted in rooting and establishment of plantlets *in vitro* which were transferred to the field. The RNAi approach was initiated for deriving PRSV resistance in papaya.

In guava, endochitinase gene was introgressed in guava for wilt resistance through *Agrobacterium* mediated transformation.

In pomegranate, maximum sprouting (80.0%) in explants was observed on medium (MS basal medium + NAA+ adenine sulphate + arginine+ activated charcoal), whereas MS basal medium + BAP + NAA, showed sprouting in 9.5 days. Maximum proliferation of established culture with 3.56 cm shoot length was observed when sprouts were inoculated on medium containing basal medium + nutrient supplementation 3 + Zeatin + NAA. For *in vitro* rooting of micro shoots, auxins along with activated charcoal and low salt basal medium played critical role.

Plantation crops

In oil palm, immature inflorescence collected below the 15th leaf axil was the best explant. It was possible to induce callus from immature male inflorescence in 3-6 months. The primary callus obtained was subcultured after every 4-6 months, gradually reducing the concentration of auxins.

An effective method for determining the pollen quality of oil palm in terms of viability and germinability was standardized. Among the dyes, 2, 5-Diphenyl Tetrazolium Bromide dye was best for testing pollen viability. A media consisting of 2.5% sucrose, 100ppm H_3BO_3 and PEG (10%) was most effective for oil palm, as it produced maximum pollen germination with a tube length of 317.88 µm. The oil palm pollen grains stored at –20° C in a deep freezer could retain maximum viability and germination.

In areca nut, maximum pollen germination (75%) was observed when incubated at room temperature (28-30°C) prior to cryopreservation. Rhizogenesis in tall varieties was enhanced by treating the meristemoid-derived plantlets in medium supplemented with NAA for four weeks, followed by sub-culturing in a hormone-free media. For overcoming the palm-to-palm variation in amenability for callus induction and somatic embryogenesis, individual responsive palms in GBGD, CGD, MGD, COD and PHOT cultivars were identified for multiplication.

Vegetable crops

In tomato, transgenic lines (Arka Vikas) containing coat protein gene (for resistance to PBNV), chitinase + PGIP double genes (for resistance to early and late blight), *Cry1Aa3* and *Cry2A*Bt genes and different RNAi constructs (*jhamt*, *chy*, *sp* for resistance to tomato fruit-borer), novel vacuolar pyrophosphatase gene (for drought and salinity tolerance) were produced. An anthocyanin-rich tomato line was also developed using engineered *rosea* and *delila* genes from *Antirrhinum majus*.

Homozygous T_2 plants of the 36 independent events of *rd29A*::*AtDREB1A*/*CBF3* transgenic tomato plants carrying single transgene copy to drought were imposed to stress for 7, 14 and 21 days. A total of 22 events showed enhanced drought tolerance and increased survival under drought stress.

In chilli, variety G4, a chitinase + PGIP construct was mobilized and preliminary analysis showed resistance to *Colletotrichum* and delayed disease development.

In brinjal, Arka Keshav (purple long back ground), *Cry2A*Bt transgenic advanced lines showed resistance to infective stages of freshly hatched first instar neonate larvae of brinjal shoot- and fruit-borer, *Leucinodes orbonalis* Guenee, upon resistance phenotyping. A novel method of screening for *Bt* resistance was also developed.

Tuber crops

Whole genome sequencing of Indian strain of *Phytophthora infestans* (A2 mating type) causing late blight and *Ralstonia solanacearum* causing brown rot of potato was completed.

Saffron

Stigma like structures were developed under *in-vitro* conditions from half ovary explants in saffron. ❑