6. Crop Improvement

Genetic improvement of crops is undertaken to notify high-yielding varieties and hybrids, as the case may be, with the in-built tolerance to major abiotic and biotic stresses. Hybrids/varieties are notified based on their respective adaptability to defined agro-ecologies and could be brought into seed chain for making available quality seed to farmers for ensuing seasons.

In rice five hybrids and six varieties, in wheat eight varieties, in barley two varieties, in maize 16 hybrids/ composites, four varieties of pulses and five of oilseeds have been released during the year.

Cereals

The Central Sub-committee of Crop Standards, Notification and Release of Varieties released five **rice** hybrids— INDAM 200-017, US 312, 27P 11, CRHR 32 and Rajalaxmi and six varieties — IGKVR 1, IGKVR 2, Chinsurah Rice 1, CR Dhan 501, CR Dhan 601 and RC Maniphou 1. And State Variety Release Committees have recommended 25 varieties for eight states.

For the first time, a long-duration rice hybrid CR Dhan 701 (CRHR 32) has been developed for the irrigated-and-shallow lowlands; this will also be suitable

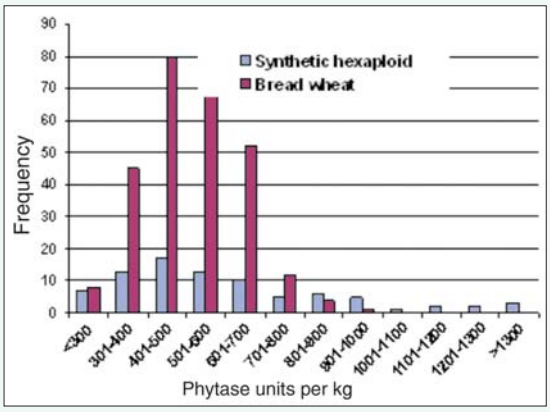
Rice varieties released

Variety/hybrid	Grain-type	Reaction to pests/diseases	Recommended state/region
Central releases			
CR Dhan 501	LB	MR- Bl	Semi-deep water areas of Uttar Pradesh, Asom
CR Dhan 601	MS	R-Bl, RTV, MR-BS	Boro areas of Odisha, West Bengal, Asom
CRHR 32	MS	R-Bl	Rainfed shallow areas of Bihar, Gujarat
IGKVR 1	LB	R- Bl, GM	Irrigated areas of Chhattisgarh, Madhya Pradesh, Odisha
IGKVR 2	LS	MR-Bl, BLB, BPH, WBPH.	Irrigated areas of Chhattisgarh
INDAM 200-017	LB	MR-Bl, SB, LF	Irrigated areas of Maharashtra, Andhra Pradesh
Chinsurah Rice	LS	MR-Bl, WBPH	Irrigated areas of West Bengal
Rajalaxmi-	LS	MR-Bl, BLB, SB, BPH	Boro areas of Asom, Odisha
RC Maniphou 11	LS	R-Bl	Irrigated hilly areas of Meghalaya, Manipur
US 312	MS	R-Bl, MR-BS	Irrigated areas of Bihar, Uttar Pradesh, West Bengal, Tamil Nadu, Karnataka
27P11	MS	—	Irrigated areas of Karnataka, Maharashtra
State releases			
Akshaya	MS	MR-Bl, ShBl, BS	Rainfed shallow areas of Andhra Pradesh
BhavapuriSannalu	MS	MR-Bl, BLB, BS	Rainfed shallow areas of Andhra Pradesh
Jagtial Mahsuri	MS	MR-Bl, BLB, BPH, GM	Irrigated areas of Andhra Pradesh
Karimnagar Samba	MS	MR-Bl,BLB, ShBl, BS	Irrigated areas of Andhra Pradesh
Motigold	MS	—	Irrigated areas of Andhra Pradesh
Sonal	MS	—	Irrigated areas of Andhra Pradesh
Sugandha Samba	MS	R-Bl	Irrigated areas of Andhra Pradesh
Vamsadhara	MS	MR-Bl	Rainfed shallow areas of Andhra Pradesh
Maheshwari	LS	R-Bl, GMMR-BS	Irrigated areas of Chhattisgarh
Indira Barani Dhan1	MS	T-SB	Limited water situations of Chhattisgarh
NAUR 1	LS	MR-Bl, BLB, ShR, SB	Irrigated areas of Gujarat
MugadSiri 1253	—	MR-Bl	Irrigated areas of Karnataka
Raksha	MB	MR-Bl	Irrigated areas of Karnataka
Pratheeksha	LB	R-Bl, MR-ShBl, BS, BPH, GM	Irrigated areas of Kerala
Vytilla 8	MB	—	Saline areas of Kerala
Bhalum 3	LB	MR –SB	Rainfed upland areas of Meghalaya
Bhalum 4	LB	R-Bl, MR-SB	Rainfed upland areas of Meghalaya
Megha SA 1	SB	R-Bl, MR-SB	Rainfed shallow areas of Meghalaya
Megha SA 2	LB	R-Bl, MR-SB	Rainfed shallow areas of Meghalaya
Luna Sampad	MB	R-Bl, MR-ShBl, BS,SB, BPH, LF	Saline areas of Odisha
Luna Suvarna	LS	R-Bl, MR-ShBl, BS, SB, BPH, LF	Saline areas of Odisha
NuaChinikamini	SB	R-RTV, GM, MR-Bl, BS, SB	Rainfed shallow areas of Odisha
Phalguni	LS	R-Bl, GM, LF,MR-RTV, ShBl, BS, GLH, SB, BPH, WBPH	Rainfed upland areas of Odisha
Reeta (CR Dhan 401)	LB	R-Bl, WBPH	Rainfed shallow areas of Odisha
NDR 2065	LB	R-Bl, WBPH, GM	Irrigated areas of Uttar Pradesh

R: Resistant; MR: Moderately resistant; SB: Short bold; MB: Medium bold; MS: Medium slender; LB: Long bold; LS: Long slender; SS: Short slender; Bl: Blast; BLB: Bacterial leaf blight; RTV: Rice tungro virus; ShBl: Sheath blight; BS: Brown spot; GLH: Green leaf hopper; SB: Stem borer; BPH: Brown planthopper; WBPH: White backed planthopper; GM: Gall midge; LF: Leaf folder.

Wheat with higher phytase

Higher phytase activity in wheat-grains may result in extensive phytate degradation in human stomach and consequently enhanced micronutrient bioavailability. More than 400 wheat genotypes including synthetic hexaploids were used to assess genetic variability for phytase levels. There were 3.4-fold differences in



varieties developed in India and 5.9-fold variations in synthetic hexaploids. Variation was from 284 phytase units/kg to 962 phytase units/kg in the released varieties and in the synthetic hexaploids, it was from 255 phytase units/kg to 1,518 phytase units/kg. Synthetic hexaploids with higher phytase levels can be used to enhance diversity in enzyme levels in bread and durum wheats.

for coastal shallow lowlands. This hybrid gave 20% higher yield than the popular lowland variety Swarna. It is found moderately resistant to rice tungro disease, sheath blight and leaf blast, and is resistant to green leafhopper. It can be grown in wet and dry seasons.

Candidate gene marker SC 1246 and SSR marker SC 390 for Rf 4 locus on rice chromosome 10 and SSR marker SC 364 and SC 368 for Rf 3 locus on chromosome 1 were developed and were validated in 200 known restorers and 34 maintainers (93.2%) along with the reported markers for Rf 3 and Rf 4 loci.

In rice, a set of 12 hyper-variable SSR markers (HRM 12469, HRM 20866, HRM 11570, HRM 16006, HRM 24217, HRM 23595, HRM 24383, HRM 18770, HRM 25754, HRM 16606, HRM 6740 and HRM 13131) possessing high polymorphic information content values (> 0.75) have been identified, suitable for heterosis prediction.

Eight **wheat** varieties – HD 2985, HD 2987, HS

Wheat variety DPW 621-50 is suitable for timely sown irrigated condition

507, HI 1563, WHD 943 (d), NIAW 1415, DPW 621-50 and WH 1080 – have been released.

Two **barley** varieties have been released for commercial cultivation. Two-row malt barley DWR 73 has been recommended for cultivation in the north-western plains zone (Punjab, Haryana, western Uttar Pradesh, Delhi and Rajasthan) under irrigated late-sown conditions, where, so far, no malt-type barley variety was available. And UPB1008 has been recommended as feed-barley for rainfed timely sown conditions of the northern hills zone (Uttarakhand, Himachal Pradesh and Jammu and Kashmir).

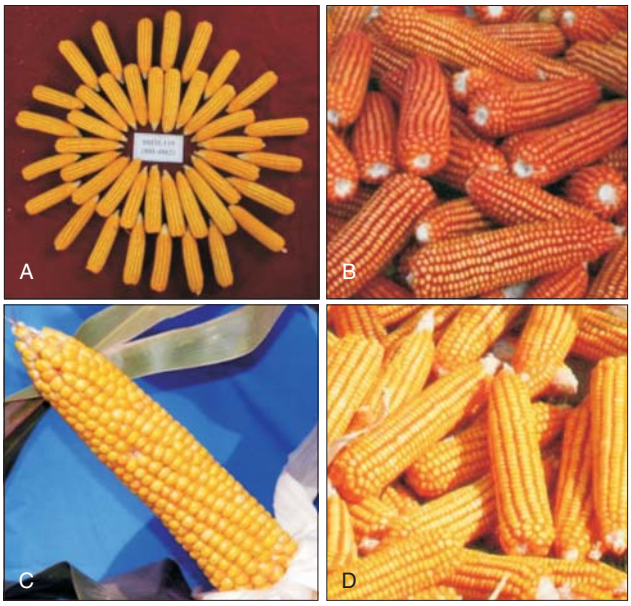
Two-row malt barley variety DWR 73

Sixteen **maize** hybrids/composites have been released for different agroclimatic conditions of the country. Of these, 8 public sector hybrids are DMH 119, PMH 4, PMH 5, Vivek 39, Vivek 43, KMH 22168, HQPM

Wheat varieties released

Variety	Area of adoption	Production condition
HD 2985 (Pusa Basant)	North-eastern plains zone	Late sown irrigated
HD 2987 (Pusa Bahar)	Peninsular zone	Timely sown rainfed and restricted irrigation
HS 507 (Pusa Suketi)	Northern hills zone	Timely sown irrigated and rainfed
HI 1563 (Pusa Prachi)	North-eastern plains zone	Late sown irrigated
WHD 943 (d)	North-western plains zone	Timely sown irrigated
NIAW 1415 (Netravati)	Peninsular zone	Timely sown rainfed and restricted irrigation
DPW 621-50 (PBW 621, DBW 50)	North-western plains zone	Timely sown irrigated
WH 1080	North-western plains zone	Timely sown rainfed

(d) = durum wheat



Maize hybrids/composites : *A.* DHM 119; *B.* PMH 5; *C.* HSC 1; *D.* PMH 5

4 and HSC 1, and one public sector composite variety is Shatak 9905 for drylands in Maharashtra. And rest are proprietary hybrids – KMH 25K60, Kaveri 50, MCH 36, Bisco 855, Bisco 555, Bisco 111 and 900 M Gold.

Pulse crops

Four high-yielding pulse varieties – Ujjawala (IPCK 2004-29) of *kabuli* **chickpea** for the central zone, IPM 02-3 of **mungbean** for spring in the north-western plains zone and IPM 02-14 for summer in the south zone, and IPF 4-9 of **fieldpea** for Uttar Pradesh— have been released and notified for cultivation.

Early-duration 18 **pigeonpea** hybrids were developed involving 7 early-maturing CMS lines — AL 101 A, ICP 2089 A, PA 163 A, UPAS 120 A, CORG 990047 A, CORG 990052 A and GT 290 A — and 12 restorers — AK 261504R, AK 261322R, AK 261506R, 250083R, 261322R, 250173R, 250157R, 250165R, 261345R, 261429R, 261394R and 261409R.

Oilseeed crops

Three **groundnut** varieties, Girnar 3, Kadiri Harit Andhra and GPBD 5, have been notified; and GJG-HPS 1 has been notified for Gujarat. **Castor** variety DCS 107 released for all castor-growing areas of the country recorded 11% yield increase over DCS 9, and is found resistant to *Fusarium* wilt. **Sunflower** hybrid CO 2 with 39% oil content has been released for Tamil Nadu.

Commercial crops

Sugarcane Co 0124 (a mid-late maturing variety) and Co 0239 (an early-maturing variety) have been released for commercial cultivation in the north-western zone.

An early-maturing c**otton** (*Gossypium arboreum*) variety CNA 1003 (Roja) has been released for rainfed

Field view of cotton CNA 1003

areas of the south zone. It is a medium- to long-staple cotton variety comparable to upland genotypes for seed-cotton yield and fibre quality. It is synchronous in boll-bursting with seed-cotton yield potential of 1.4-2.0 tonnes/ha. Its full-scale spinning test indicates that the variety spins well at 20s counts with CSP of 2030.

CSHG 1862, a GMS-based *hirsutum* hybrid released for the irrigated north zone, recorded an overall mean seed-cotton yield of 2.1 tonnes/ha. This hybrid is capable of spinning at 40s counts, and has been found superior by +24.4% and +11.9 % in yield over qualifying test hybrids, HHH 433 and HSHH 16.

Cotton cultivars are notified for commercial cultivation in the country – CICR 1 (CISA 310), CNHO 12, CICR 3(CISA 614), LH 2076, Phule 688 (RHC 688), SVPR 4, HD 432, H 1236 and H 1098 (Improved).

Dark-brown linted multispecies derivative of cotton MSH 53

A unique dark-brown linted multispecies derivative MSH 53 has been developed by introgression breeding. Its plant has open canopy and leaves with long pedicels that allow direct penetration of sunlight; minimizing bollworm attack.

In Karnataka, *Fusarium* wilt, caused by *Fusarium oxysporum* f.sp. *nicotianae*, is emerging as an endemic disease on FCV **tobacco**-crop. Using Speight G.33 and Dixie Bright 101 as resistant donors, *Fusarium*-wilt-resistant line FCH 222 has been developed. This line recorded the highest grade out-turn, exhibiting about 39% higher values over variety Kanchan.

The Oriental tobacco variety, Tungabhadra, a pure-line selection from locally grown strain, identified for rainfed cultivation in the low rainfall tracts of Karnataka and Andhra Pradesh in poor and marginal soils, showed yield potential of about 767 kg/ha; comparable to check varieties, Izmir (624 kg/ha), Xanthi (522 kg/ha) and Komo (585 kg/ha). It is acceptable to local farmers and traders also because of its favourable

Tungabhadra tobacco

traits like higher yields, consistency in qualilty and aroma characters.

A *tossa* **jute** (*Corchorus olitorius)* variety, JRO 2407, was developed by selection from KEN/SM/024 × JRO 524 following the pedigree method. Its ideal sowing time is early March, and it matures in 140-150 days. The variety has good fibre strength and showed resistance to major diseases (root rot and stem rot) and pests (semilooper, stem weevil and yellow mite).And a white jute (*C. capsularis*) variety, KJC 7, developed by selection from KC 1 × JRC 212 following pedigree method, is found suitable for all white jute-growing areas of the country. Ideal time for its sowing is early March to early April, and it matures within 120 days.

Kenaf (*Hibiscus cannabinus*) variety JBM 75 is sown between mid-April and mid-May, and it matures within100 days. Incidences of major pests (spiral borer, aphid, mealy bug and white-fly) and diseases (root-rot and stem-rot) were found comparatively lesser on this variety than check HC 583.

Roselle (*Hibiscus sabdariffa*) JRR 07 is a promising variety for roselle-growing belt of India. It matures within 140 days. It showed resistance to major diseases (foot rot and stem rot) and pests (aphid, mealy bug and white-fly). And other variety AMV 7 has been found ideal for sowing in mid-May to mid-June, and it showed tolerance to moisture stress to a great extent. It matures within 130-135 days. Incidences of major diseases (leaf rot, foot and stem rot) and pests (jassids, aphids, mealybug, semilooper and white-fly) were lesser than check HS 4288.

Interspecific hybridization of kenaf

F_1 seeds of interspecific hybrid between *Hibiscus cannabinus* and its wild progenitor *H. surattensis* were harvested, and hybrid-plants could be grown successfully. The hybrids showed intermediate morphological features like semi-lobed leaf and less number of bristles, and exhibited high degree of sterility. Yellow colour of *H. surattensis* flowers dominated over pale-yellow of *H. cannabinus.* Interspecific hybrids by crossing diploid *H.cannabinus* with wild tetraploid species *H. radiates* and *H. acertosella* have also been developed.

Fruit crops

Important commercial cultivars of **mango** from north India were characterized by SSR markers for generating SSR (microsatellite)-based barcodes with 18 SSR loci. Distribution maps of *Spondias pinnata, S. acuminata, S. mangifera, S.glabra, Ziziphus rugosa, Z. oenoplia, Z. jujube, Z. mauritiana, Z. xylopyrus, Z. glabra* and *Z. napeca* generated by Indian Bioresource Information Network (IBIN) at the district and taluka level for the peninsular states situated along the Western Ghats region were developed. Screening of 26 accessions in pot has indicated that accessions Chinia and Padathi were resistant to root-lesion nematode; and Sannachenkadali, Pisang Berlin, Chinia, Matti, Chengalikodan, Jamulla Pellam, Padathi and Tongat were resistant to root-knot nematode, while Padathi was found resistant to both the nematodes.

The cultivars, Early Red, Mcintosh, Criterian and Scarlet Spur in **apple**; Dixi Red, Early Red June and Red Globe in **peach**; CITH-Cherry 5 and CITH-Cherry 7 in **cherry**; Coratina and Leccino in **olive**; cluster type elite **walnut** collections such as CITH-W 426 and CITH-W 427 are some of the important germplasm lines which have shown great potential in terms of yield and quality. In apple, variety CITH Lodh has been found very promising under mid to high hill conditions of Uttarakhand and fits well in changing climatic scenario. The variety is a regular-bearer, high-yielding (28-32 tonnes/ha), early to mid-maturing with superior quality red colour fruits. In cherry, 29 genotypes were evaluated for yield and quality. Among genotypes, CITH Selections, namely CITH-C 05, CITH-C 06, CITH-C 07 and CITH-C 09, which recorded fruit yield of 9.74-17.29 tonnes/ha, while cv. Doble, Awal No. 1, Van and Mishri were found superior in yield, quality, fruit size and weight, and showed great potential for commercialization.

In order to incorporate papaya ring spot virus (PRSV) resistance in **papaya**, hybridization was carried out between Surya × *V. cauliflora*. Three hybrid progenies (R_2P_2, R_4P_1 and R_5P_2) were found tolerant to 'PRSV' have been further sibmated and seedlings were field planted. These hybrid progenies have castor type leaf with fruits resembling papaya. In mango, H 564 (Amrapali × Janardhan Pasand) and H 2803 (Dashehari × Eldon) were found promising based on fruit quality (colour, TSS and fruit weight), while H 1886 showed tolerance to anthracnose.

Guava Purple and Lalit were identified as potential donors for pink pulp colour. Pink pulped guava varieties, HAPSI 35 and HAPSI 46, were found suitable for nectar preparation, while nectar prepared from HAPSI 16 retained vitamin C for six months. In **Avocado**, CHES A 1, in chirounji C 7 bunch type fruiting with higher yield, in pummelo CHESP 8 with higher fruit weight (1.3 kg), spherical shape, higher pulp content

(58.59%), dark red colour and moderate number of seeds and higher yield (200-300 kg/tree), in rambutan red colour accessions, CHESR 27 and CHESR 26, and in passion fruit, yellow colour accessions, CHESPF 4 and CHESPF 7, with higher fruit weight (95-100 g) and higher yield (110-120 fruits/vine) were identified.

Plantation crops

Coconut hybrid, IND 058S × IND 042S, with a yield of 140 nuts/palm/year and copra yield of 4.66 tonnes/ha has been identified for release. A superior selection, IND 045, with uniformly green coloured fruits, higher endosperm content of 300 g and copra content of 180-200 g has been identified. This population also performs well under rainfed condition with an annual yield of 110 nuts/palm.

Coconut hybrid IND 058S × IND 042S yields 140 nuts/palm/year

Of the 16 tall **arecanut** hybrids, Shrivardhan × Sumangala, Shriwardhan × Mangala and Mohitnagar × Sumangala exhibited higher yield potential. Among 21 **cocoa** hybrids grown under arecanut in high-planting densities, hybrid SCA 6 × ICS 6 appears promising and recorded >2 kg dry bean yield/tree/year. Three hybrids, VTLCH 2, VTLCH 3 and VTLCC 1, showed high performance and adaptability both under arecanut and coconut shades.

In **cashew**, hybrids H 43, H 66, H 68, H 125 and H 126 gave annual yield of 5.20, 6.25, 6.55, 5.95 and 5.70 kg/tree, respectively, with a cumulative yield of 35.33, 34.61, 35.55, 37.60 and 34.39 kg/tree for seven harvests.

Vegetable crops

In **tomato**, two triple resistant F_1 hybrids (Arka Samrat and Arka Rakshak), bacterial blight, ToLCV, early blight with a yield potential of 101-119 tonnes/ha were identified for release.

In **onion**, a tri-parental derived synthetic variety, Arka Bheem, with red to pinkish red elongated globe-shaped bulbs of 120 g weight and yield potential of 47 tonnes/ha with 130 days maturity has been identified. A white onion variety, Arka Swadista, suitable for fermented preservation with uniform white oval globe

Arka Bheem onion matures in 130 days

bulbs (weight 35-40 g) and TSS of 18-20 % and yield potential of 16-18 tonnes/ha in 105 days maturity have been identified. Bhima Shakti and Sel. 126 (IARI) were identified for release in Zone III (Delhi, Uttar Pradesh, Haryana, Bihar and Punjab), Zone IV (Rajasthan and Gujarat), Zone V (Madhya Pradesh, Chhattisgarh and Odisha) and Zone VI (Maharashtra, Karnataka and Andhra Pradesh) and Bhima Shweta for release in Zone III, V and VI. In garlic, temperate garlic VGP 5 (VPKAS, Almora) is identified for release in Zone I (Jammu and Kashmir, Himachal Pradesh and Uttarakhand), Bhima Purple (DOGR) was identified for release in Zone III, and VI and G 189 (NHRDF) was identified for release in Zone III, IV and VI.

Arka Sharath, a bushy **frenchbean** variety with smooth pods suitable for steamed beans with a pod yield of 18.5 tonnes/ha in 70 days was identified. A **cowpea** variety, Kashi Unnati, was identified and recommended for agroclimatic Zone IV. This variety is dwarf and bush type, photoperiod-insensitive, early-maturing and suitable for sowing in both spring-summer and rainy seasons. It flowers in 40-45 days and pods become ready for harvesting in 50-55 days. The pods are green, cylindrical, pulpy and free from parchment. The variety is resistant to golden mosaic virus and has a yield potential of 150 q/ha. **Okra** Kashi Kranti, has been identified and recommended for Zone IV. It takes 40-42 days for 50% flowering; fruits 8-10 cm long, 10-12 g in weight, dark green with five ridges. The variety has a yield potential of 90 q/ha. Kashi Gaurav **chilli** variety has been identified and recommended for Zone II. The plants are bushy, tolerant to thrips and mites, dark green foliage, good combiner, 50% flowering at 35-40 days after transplanting, dark green fruits when young and dark red when ripe, 9-11 cm long, 1.1-1.2 cm thick, pendant and pungent with a yield (red ripe) potential of 110 q/ha.

In *lablab* bean, a bush vegetable poded variety, Arka Soumya, with a pod yield potential of 19 tonnes/ha in 90 days has been identified. A new triploid seedless **watermelon** variety, Arka Madhura, having a yield potential of 60 tonnes/ha with TSS of 14% and suitable for protected cultivation has been identified. An early

cauliflower variety, Arka Spoorthi, with good quality compact curds, weighing 332 g ready for harvesting in 54-56 days with a yield potential of 166 q/ha and moderately resistance to alternaria and downy mildew has been identified for release.

Potato and tuber crops

The advanced evaluation trial conducted with cassava mosaic disease (CMD) resistant **cassava** hybrids revealed that seven lines, CMR 1, 70, 73, 106, 109,120 and 129, showed stability in yield (35-40 tonnes/ha) and high starch content (25-30%). In cassava, clone CPT 32 recorded highest (6.1%) true protein content, followed by CPT 13 (5.9%) and CPS 30 (5.2%) on dry-weight basis as compared to 1.9% in M4 and 2.2% in Sree Padmanabha.

The white-fleshed clones of **sweet potato**, IGSP 22 and IGSP 10-6, were identified as the best with respect to tuber yield of 21-30 and 18-27 tonnes/ha respectively. In **yams**, accession Da 11 recorded highest true protein content of 13.3 and 4.0% on dry- and fresh-weight basis respectively. Da 11 and Da 68 also exhibited field tolerance to anthracnose disease. In **aroids**, seven advanced hybrid selections of *Amorphophallus* having stability in yield (38-42.5 tonnes/ha), good cooking quality and free from diseases were identified. In addition, four early harvestable *Amorphophallus* hybrids with excellent cooking quality, namely Am H 1, Am H 1(b), Am H 5 and Am H 102 suitable for 7th month harvest, have also been identified. Thirty hybrids of **taro** including a novel dwarf type with a mean yield of 12.5 tonnes/ha and good cooking quality were isolated from hybrid progeny.

In **potato**, clone YY6/3 C-II has been registered as an elite genotype having PVY extreme resistant gene in triplex state. The transgenic potatoes with durable resistance to late blight and suitable for cold chipping have been developed.

Spices

The registration of **nutmeg** accession A 9-71 (IC 537220, INGR 10142) as a source of high sabinene (45.0%) in nutmeg oil and 41.9% in mace oil has been done at the NBPGR, New Delhi. Evaluation of F_1 hybrids of **cardamom** indicated that three genotypes (IC 584097, IC 584098, IC 54722) were high-yielding (20-40%) than Appangala 1 and Njalani Gold.

Floriculture

In **gladiolus**, 4 new varieties, namely Punjab Flame, Punjab Elegance, Punjab Lemon Delight and Punjab Glance, were developed at the PAU, Ludhiana and two new *chrysanthemum* varieties, Kaul and Khoshoo, at the NBRI, Lucknow. In **tuberose**, hybrid 1 × 6-1 with high yield potential and tolerance to nematode was identified. In gladiolus, hybrids IIHRG 11 and IIHRG 12 were found promising for cut flowers. In **rose**, a long-stalked (65-75 cm lengh), red variety Arka Swadesh, with high yield potential (145 flowers/stalk/m^2/year) has been identified. Two promising **Crossandra** hybrids selections – Arka Shreeya (orange red colour) and Arka Shravy – were also identified.

Medicinal and aromatic plants

A high-yielding cultivar Vallabh Medha of **mandukparni** (*Centella asiatica*) was identified. Fresh herbage yield (12,331 kg/ha) and dry herbage yield (2,113 kg/ha) of this variety were far more than the local variety (2,050 and 392 kg/ha respectively), besides higher active ingredients. Among mucuna selections, IIHR PS 15 with long duration, IIHR PS 6 with medium duration and IIHR PS 14 with short duration recorded significantly higher yield and high L-dopa yield/plant. In **Coleus**, a promising hybrid, Hy 08-53, recorded significantly higher root yield (60.22g) and higher forskolin yield/plant (0.58 g). In **ashwagandha**, IIHR-WS 3 was found to be the best yielder (11.65 q/ha).

Mandukparni (*Centella asiatica*) variety Vallabh Medha

Biotechnology

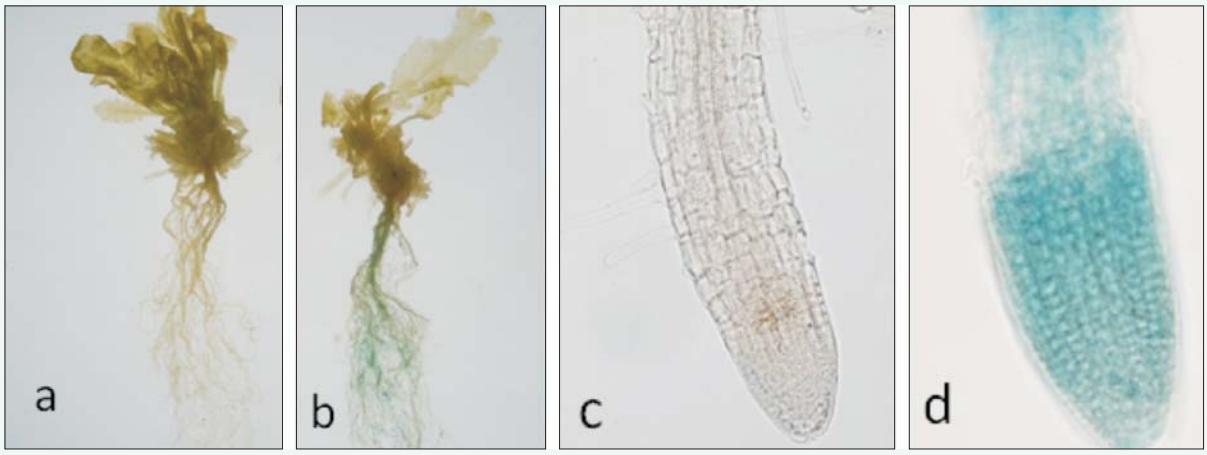
Transgenic cotton with chitinase gene: *G. arboreum* cv. PA 255 susceptible to grey mildew was transformed with chitinase gene isolated from tetraploid cotton. T_1 progenies have been confirmed for gene amplification and integration. Chitinase activity assay also confirms the transgenicity of the plants.

Sugarcane: A novel constitutive ubiquitin promoter named *Port ubi2.3* has been isolated from *Porteresia coarctata*, a perennial halophytic grass. The sequence similarity of *Port ubi2.3* with maize *ubi1* is 47.1%, and with sugarcane *ubi9* and rice *ubi 1* is 27.5% and 29.2%. Port ubi2.3 promoter: Gus fusion was constructed, and it transformed rice, sugarcane, tobacco and *Arabidopsis*. In rice and sugarcane, the expression was higher than that of *CaMV35S* or Maize *Ubi1* promoters, and in tobacco and *Arabidopsis*, there was very low or no expression. Six deletions of this regulatory region were fused with *gus* gene. The deletion 2 (promoter with proximal *intron*) showed two times higher expression in tobacco and in sugarcane, and in rice, it was equal to *Port ubi2.3* promoter. This promoter named as *Port ubi882* has been found to be stem specific. This isolated sequence can be used as a promoter for transgene expression both in monocots and dicots.

Protocol for *Agrobacterium*-mediated genetic transformation was standardized to develop transgenic

Nematode-responsive root-specific promoters

The promoters were characterized and their genome-wide expression analyses were undertaken to identify nematode-responsive and root-specific genes. Co-expression networks for these identified genes were studied to further strengthen the evidence of their role during nematode infection. Further, the promoter region of the selected gene was cloned into the pORE vector to transform wild-type *Arabidopsis* plants by *Agrobacterium*-mediated transformation. The histochemical GUS assay was used to validate its role in nematode infection. This promoter, when mobilized to *Arabidopsis* plants, resulted in nematode-responsive root-specific GUS expression. No GUS expression was observed in the aerial parts of the plant.



Histochemical staining for GUS activity in *Arabidopsis* plants, containing the nematode-responsive root-specific promoter, infected by root-knot nematode *Meloidogyne incognita* : *a*, Transgenic uninfected *Arabidopsis* line; *b*, Transgenic *Arabidopsis* line subjected to root-knot nematode infection; *c*, Magnified view of the root mass of the uninfected transgenic *Arabidopsis* line; *d*, Magnified view of the root mass of the transgenic *Arabidopsis* line subjected to root-knot nematode infection. Note the strong expression of GUS reporter gene (indicated by blue colour)

sugarcane with *Cry1Ab* gene in the top-borer-susceptible variety CoLk 8102. Six transformants were developed and were found positive by the PCR and GUS test. Insect bioassay indicated a weight loss of 30-50% in the larvae feeding on the leaves of the transformed plants as compared to control plants.

DNA fingerprinting

Microsatellite markers were generated in greengram (124), sesame (132) and bittergourd (20) for identification of new STMS (sequence tagged microsatellite site) loci. DNA fingerprinting of pomegranate (64) using 16 ISSR (inter-simple sequence repeat) primers and of cotton using five STMS loci was undertaken.

Four DNA bar-coding loci, matK, rbcl, trnH/psbA and psbK/psbI, from *Corchorus* (7 species) were sequenced for deciphering species relationships. For the development of transgenic detection tool, multiplex PCR assays were standardized for *cry1Ac* gene, *CaMV 35S* promoter, *npt II* marker gene, endogenous *SRK* gene, and for specific events like MON531 and MON15985 in *Bt* transgenics of cotton, brinjal, cauliflower, okra, rice and potato. Quantification of NK 603 and MON 810 events was carried out in maize using *adh* and *nk* and *hmg* event-specific genes with RT-PCR. A database to enable data curation and further characterization, and user-friendly web forms for query, deposition and submission of genomic data has been designed.

Transgenic fieldpea HUDP 15 optimized: Total genomic DNA was isolated from 64 putative T_2

Allele-mining for abiotic stress tolerance in rice

Using rice Affymatrix DNA chips, through transcriptome profiling, 877 differentially expressed genes were identified. Of these, 57 known and 31 unknown abiotic stress-tolerant genes were validated through semi-quantitative RT-PCR.

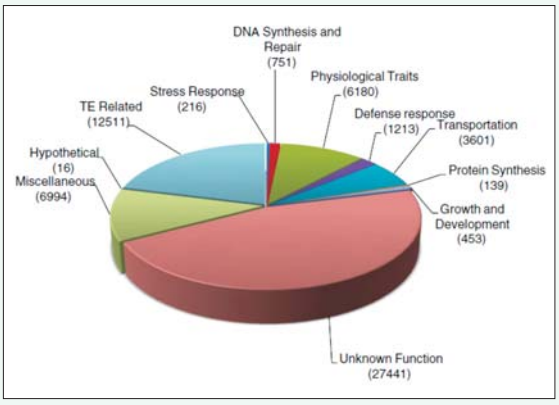
Whole genome transcriptome sequencing using Next-generation Illumina Solexa Genome Analyzer, identified 8,634 differentially expressed genes in Nagina22 seedlings under drought and 2,274 transcripts in the salt-tolerant Basmati rice variety CSR30 under salinity stress.

Varied genome sizes of wild jute

Significant variations ($P \leq 0.05$) in genome sizes (2C values) among *Corchorus* wild species were noticed. The lowest 2C value was observed in *C. fascicularis* (0.384 pg), and the highest was in *C. pseudo-olitorius* (0.712). Although *C. aestuans* had low nuclear DNA content, its 2C value (0.396 pg) was significantly ($P \leq 0.05$) higher than that of *C. fascicularis.* In *C. pseudo-capsularis*, *C. trilocularis* and *C. tridens*, the 2C values were 0.408, 0.425 and 0.443 pg. Interestingly, it was noticed that there was an increase in nuclear DNA content by about 85 % in *C. pseudo-olitorius* over the smallest nuclear DNA-containing wild species *C. fascicularis*.

Indian scientists decoded pigeonpea genome sequence

A group of thirty-one Indian scientists from the ICAR Institutes, State Agricultural Universities and Banaras Hindu University have decoded genome of pigeonpea, the second most important pulse-crop of India. This is the first plant genome,sequenced entirely through a network of Indian institutions. Availability of its genome sequence will accelerate development of new varieties and hybrids with enhanced productivity by making use of germplasm resources in a way similar to rice genome. A total of 47,004 protein-coding genes have been



Different categories of genes in the 511 Mb of pigeonpea genome sequence. Unknown category includes genes unique to pigeonpea and those showing matches with hypothetical category genes of other species

identified in the pigeonpea genome; of which 1,213 are for disease resistance and 152 are for tolerance to drought, heat and salinity. The genome sequence has been used to develop a large number of pigeonpea DNA markers, which have been experimentally validated for high rate of variation in pigeonpea varieties.

transgenic fieldpea lines (cv. HUDP 15), and PCR conditions were optimized using primers specific to *RNAi* gene, *CaMV 35S* promoter, *npt II* marker and *intron* for molecular characterization. PCR results showed that only *intron* specific primers could detect eight positive lines. Plants showing positive amplification with *intron*-specific primers were selected for Southern hybridization using AF531160 gene specific biotin labelled probe. Result indicated strong hybridization with plasmid DNA, and out of 8 PCR positive plants, only one plant (D-23-1-4) was found positive to Southern hybridization.

DNA barcodes of coccinellids: *Brumoides suturalis*, *Chilocorus nigrita*, *Cheilomenes sexmaculata*, *Coccinella septempunctata*, *Coccinella transversalis*, *Cryptolaemus montrouzieri*, *Curinus coeruleus*, *Harmonia axyridis*, *Henosepilachna vigintioctopunctata*, *Hyperaspis maindroni*, *Illeis cincta*, *Rodolia amabilis* and *Scymnus* (*Pullus*) *latemaculatus* DNA barcodes were generated by submitting all relevant information with the iBOL(BOLD2.5) system. The phylogeny of these species was generated based on the molecular characters by bioinformatic tools.

***In-vitro* grafting in safflower:** Both *in-vitro* and *in-situ* grafting experiments were undertaken to overcome rooting problem of elongated shoots; two of the grafted plants have survived transplantation. *In-vitro* derived shoots were grafted onto seedling-derived rootstocks. After about two weeks, the scion and the stock fused, and the plant was transferred to a mixture of vermiculite and soilrite.

Transformation in sunflower: In sunflower, transformation for conferring resistance to sunflower necrosis disease through deployment of *TSV-CP* and *CP-AS* gene(s) has been accomplished via *Agrobacterium*-mediated transformation of cotyledons from mature seeds. The plants are in various stages (T_0, T_1, T_2) of testing.

Seed technology

Hybrid seed production technology in Indian mustard: The seed production technology for the first-ever Indian mustard hybrid NRC Sankar Sarson (NRCHB 506) has been standardized. Optimum sowing date of the parental lines is recommended as the third week of October, and optimum planting ratio of male to female is 2:8. Following this, an average hybrid seed yield of 2.4 tonnes/ha could be obtained.

Molecular markers for testing seed purity of hybrids: Among 50 SSR markers screened, two SSR markers were identified for each of three brinjal hybrids Pusa 9, Pusa 5 and Kashi Komal for ensuring hybridity as well as to assess the extent of selfed seeds in the hybrid seed-lots. Hybridity of maize hybrids HQPM1, Vivek QPM 9 and Vivek Hybrid 9 was also established using markers.

Sugarcane quality seed for farmers

Seed production of newly released sugarcane varieties, Co 98014, Co 0118, Co 0238, Co 0239 and Co 0241 were undertaken under the revolving fund scheme of the mega seed project. A total of 2,782 quintal seeds were supplied to farmers and sugar mills in Punjab, Haryana, Uttar Pradesh, Bihar and Madhya Pradesh from the Karnal Regional Centre.

Seed production in bittergourd hybrids: Hybrid seed production technology for bittergourd hybrids Pusa Hybrid 1 and 2 was standardized under open field and net-house conditions. The plants grown under net-house showed longer pollen and stigma receptivity. They produced more crossed fruits (2-4 fruits /vine) with higher fruit weight (15-20 g /fruit), seed yield (seed yield 2 kg/100 m^2). Among the growth regulators compared, GA_3 at 50 ppm, Etherel at 100ppm, NAA at 200 ppm were found most promising for modification of sex expression in bittergourd. Spraying these chemicals at three-leaf and tendril initiation stages, and at three stages, at three-leaf, tendril initiation and bud stage were more effective than a single spray at three-leaf stage.

Horticulture: Disease-free quality planting material

(3,122,900) and seeds (31,405.26 q) of different horticultural crops produced to distribute to the farmers and state departments were as follows:

Crop	Planting material/seed produced
Fruit crops	862,741 (number)
Plantation crops	1,032,616 (number)
Spices	152,000 (number), 130.0 q
Potato	29,882 q
Tuber crops	958,600 (number), 824.0 q
Medicinal plant	9,951 (number), 11.93 q
Ornamental plants	107,000 (number)
Vegetables	476 q
Mushroom	81.33 q

Pollinators

In a survey conducted on pigeonpea in Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra, three species of *Xylocopa* (*X. aestuans, X. latipes* and *Xylocopa* sp.), five species of *Megachile* (*M. lanata, M. bicolor, M. anthracina, M. carbonaria* and *M. hera*), *Lasioglossum* sp., *Ceratina (Pithitis) binghami, Apis florea*, *A. dorsata* and *Trigona* sp. and on unidentified *Halictid* were found pollinating the crop. On gingelly crop, *Apis dorsata* and *A. cerana indica* were common pollinators in Tamil Nadu. On sunflower, *Apis dorsata, Apis cerana indica*, *Apis florea* and *Trigona iridipennis* were dominant pollinators.

Apis cerana foraging on *Hibiscus mutabilis*

Yield improvement through pollinators and predators: Naturally maintained (pesticide-free) pigeonpea ecosystem supported a wide variety of natural enemies like hymenopteran parasitoids (Braconidae, Ichneumonidae, Vespidae, Scoliidae etc.) and predators (Coccinellidae, Mantidae, Chrysopidae, Gomphidae-dragonflies, Clubionidae (sac spiders) and Araenidae) when compared with the fields sprayed with pesticides of Gulbarga, Bidar and Raichur areas of Karnataka. In the non-traditional pigeonpea area of Karnataka, Singapore cherry, *Muntingia calabura*, *Spermacoce hispida* and *Euphorbia heterophylla* supported all species of honey-bees, and *Centrosema pubescens* supported only carpenter-bees. In a replicated field trial of intercropping pigeonpea (cv. TTB 7) 10 rows, alternatively with marigold (cv. Local) 2 rows and sunflower (cv.KBSH 53) 2 rows indicated that both marigold and sunflower served as attractant crops for pollinators and natural enemies when compared with the sole crop of pigeonpea. Pod damage by *Helicoverpa*, pod-flies and pod-bugs was relatively less in intercropped pigeonpea.