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DIVISION OF FRUITS & HORTICULTURAL TECHNOLOGY
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Annual Report 2023

Division of Fruits & Horticultural Technology
ICAR-Indian Agricultural Research Institute
New Delhi-110 012

Annual Report 2023

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Supervision and Guidance

Dr. O. P. Awasthi
Head
Division of Fruits and Horticultural Technology
ICAR-IARI, New Delhi-110 012

Editorial Team

Dr Radha Mohan Sharma
Dr Nripendra Vikram Singh
Dr Kanhaiya Singh

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PREFACE

The fruit crops have registered a progressive growth trend during last one decade and production in the year 2023-24 is estimated to be 112.08 million tonnes outshining the last year production of 108.34 million tonnes by a margin of 3.45%. The fruit crops can play pivotal role in ensuring the nutritional security, doubling farmers' income and promoting sustainable and climate smart production eco-system in the country. The Division of Fruits and Horticultural Technology, ICAR-IARI, New Delhi has been in forefront in fruit research and development in the country, and conducting applied and strategic research on various aspects of crop improvement and production technology of fruit crops. Over five decades of research, the division has released ten varieties and two rootstocks in mango, six in citrus, five in grape, two in guava and one in papaya. Efforts to develop rootstocks for traits of interest has led to the identification of Pusa Srijan in guava. The development of improved varieties and production technology have paved the way for entrepreneurship in the field of fruit orcharding and the impact can be seen in different parts of the country where these have been adopted on a large scale.

During the period under report (January-December, 2023), two varieties in guava 'Pusa Aarushi' and 'Pusa Pratiksha' and one variety of Papaya 'Pusa Peet' were released by the CVRC. The mango improvement programme has resulted into the development of DNA barcodes for mango hybrids besides, identifying several QTLs governing fruit colour and firmness. In an *in vitro* mutagenesis study, the first report on modified *in-ovulo* DSE protocol was published which confirmed superiority of the DSE system in terms of higher embryo recovery and radiation tolerance over the ISE system. In grapes, *V. parviflora* has been found drought tolerant and resistant to powdery mildew. As many as 71 genotypes of guava, 48 grapes, 180 citrus, 6 papaya and 92 pomegranate genotypes were evaluated for different traits. Of these evaluated genotypes, 4 hybrids of guava, 2 colchiploids each of Mosambi and Kinnow, 1 acid lime, 1 sweet orange, 1 pomegranate genotype were found promising. In Production technology, long term trial on rootstock research in fruit crops such as mango, citrus, grape and guava is in progress to develop rootstocks for diversified agro-ecological regions and for tolerance to the various biotic (guava wilt) and abiotic stresses (drought, salinity, low temperature tolerance) and INM (mango). For the promotion of IARI released mango and guava varieties, commercial licensing/ MoA was signed with commercial private nurseries. Besides, the Division had multiplied 15,403 plants of different varieties of mandated fruit crops.

In Post Graduate education programme, 14 courses offered were offered to the M. Sc. and 08 courses to the Ph.D. students. In the sixty first convocation held during February 2022, 07 Ph.D. and 09 M. Sc. students were awarded degrees. Under the outreach programme, the developed varieties and technologies were displayed during the Kisan mela and the technologies were also disseminated through training and MGMG programmes. The scientists of the division were bestowed with several prestigious awards & recognitions, published over 33 research publications in peer-reviewed journals. I place on record our sincere thanks to Director ICAR-IARI, Joint Director (s) Research, Education and Extension for their continued support, constant guidance and encouragements. The Division is indebted to Chairmen and members of IRC & RAC who have rendered their suggestions for the overall development of the division. The division is also thankful to all external funding agencies which have provided assistance for undertaking different research and developmental activities. I congratulate the editorial team for bringing out this important publication.

(O. P. Awasthi)
Head

Executive Summary

The Division of Fruits & Horticultural Technology (FHT), ICAR-Indian Agricultural Research Institute, New Delhi is committed to carry out basic, applied, and strategic research on mandated crops (mango, citrus, guava, grape, papaya and pomegranate), education and extension in addition to producing quality planting materials of selected fruit crops. Basically, Division has been involved in the development of improved varieties and rootstocks, and refinement of production technologies for newly developed varieties/ emerging problems in fruit crops. The salient achievements of the Division of FHT in research, extension and education during 2023 are summarised below:

Mango hybridization using Amrapali as a female parent and Bhadauran, Tommy Atkins, Vanraj, Illaichi and Erwin as male donor parent resulted into the setting of 153 hybrid fruits. The evaluation previously developed 88 mango hybrids revealed that the Hybrid H-20-2 had produced the heaviest fruits (402 g) and the hybrid H-1-13 (25.06 ^{o}Brix) recorded the maximum TSS of fruit pulp. Mango hybrids *viz*., NH-17-1, NH-18-4, NH 20-2, NH-19-2, H-12-5, and H-3-2 were found to have attractive red coloration on fruit shoulder.

Polymorphic Hypervariable mango SSR (89) profile data of 24 mango hybrids bred at ICAR- IARI were translated into DNA barcode by separating the allele size for each locus. Several QTLs governing fruit colour and firmness in mango were also identified. QTLs governing the brightness (L^{*}) of fruit were located on Chr 2, 3, 4, 10, 15, and 17. Peel firmness observed at shoulder and bottom of mango fruit was associated with SNPs located on Chr 6, 11, and 20. Total 12 SNPs on Chr 11 at position ranging from 27.78 to 95.19 cM (R2 16.3-20.4) were identified which were having association with peel firmness at fruit shoulder. SNPs located on Chr 3, 4, 11, and 19 had an association with pulp firmness.

The carbohydrate metabolism- specific markers have been designed and amplified in regular and alternate bearing mango varieties on different rootstocks. Among amplified primers, the carbohydrate metabolism specific marker NMSPS2 had the highest allelic frequency (0.87). Twenty-five SSR primers were used to distinguish zygotic and nucellar Olour saplings. Out of 25 SSRs primers used, 7 SSRs (ESTD1, MiKV98, MiIIHR8095, MiIIHR1, MiIIHR2, ESTD10, LMMA8) were found to be polymorphic and can be used for distinguishing nucellar and zygotic saplings in Olour.

Eighty-five sweet scion citrus inter specific hybrids were evaluation for yield, fruit quality and reaction to greening bacteria, wherein a huge range for fruit weight (211.95-1010.50g), peel thickness (2.66-31.00mm), TSS (7.00°-14.17°B) and juice content (15.47-63.28%) was observed. The hybrid namely SCSH-8-11 proved most juicy (63.28%) followed by SCSH-5-6 (52.45%). The hybrid SCSH-5-6, besides having high juice recovery was also found to have very high TSS (14.17°B) content. None of the hybrids has shown the infestation of citrus psylla during 2023.

Sixteen inter specific acid citrus (12 hybrids and 04 open pollinated seedlings) hybrid were evaluated during 2023 for yield and fruit quality. The fruits of ACSH-7-13 tended to show the thinnest peel (1.23 mm) with higher juice (44.98%), TSS (9.5°B) and acid (6.14%) contents. Of these, only two hybrids namely ACSH -6-17 and ACSH-7-18 produced the low seeded fruits (8.20-9.00 seeds fruit^{-1}). The ascorbic acid content in the tested genotypes ranged from 24.16-46.80 mg 100ml^{-1}, being higher in ACSH-3-9, ACSH-6-17, ACSH -11-6, ACSH-5-2, ACSH-5-12 and OP-3-12 (41.50-46.80 mg 100ml^{-1}) genotypes. Three

hybrid rootstocks namely CRH 21-13, SCSH 9-19 and SCSH 17-12 were evaluated against *Phytophthora nicotianae*, the hybrid rootstocks, SCSH 9-19 proved highly susceptible, showing severe gummosis with lowest leaf relative water content, while CRH 21-19 proved tolerant.

Five pummelo accessions viz., IC-0628798, IC-0628799, IC-0628800, IC-0628801 and IC-0628802 evaluated for fruit characteristics exhibited significant variability amongst the tested accessions. The fruits in the accessions IC-628799 and IC-628800 were observed to have dark pink flesh and solid core of the fruits. The accession IC-628802 showed earlier maturity (September) and with higher TSS (>11^0Brix).

Reproductive characterization of the 39 colchiploids of Kinnow and 38 of Mosambi confirmed hyperploidy (increased rind thickness and reduced seeds/fruit). Initiation and completion of flowering and fruit maturity were late in colchiploids compared to Kinnow and Mosambi. Six tetraploids of Kinnow mandarin and five of Mosambi were identified based on cytological characterization using Flow Cytometry. A reduced seediness, budsport of Mosambi was identified in the second-generation colchiploids.

Evaluation of colchiploids was carried out for fruit morphological changes including seededness. Increased fruit weight and rind thickness were found in colchiploids of Kinnow mandarin and Mosambi. Seed content was found lower in colchiploids with late maturity of fruits. Two promising colchiploids of Mosambi, L_6P_{10} and L_7P_7 and two second generation kinnow colchiploids L_5P_{12} and L_5P_{13} were found promising. A chimeric branch of Mosambi, bearing corrugated fruits was identified in 2^{nd} generation colchiploids population of Mosambi sweet orange and might again be the mutagenic effect of colchicine.

The first report on modified *in-ovulo* DSE protocol was published which confirmed superiority of the DSE system in terms of higher embryo recovery and radiation tolerance over the ISE system. Probit analysis showed high radiation sensitivity of the ISE system (LD_{50}=54.31 Gy) over the *in-ovulo* nucellus explant-based DSE (LD_{50}=65.75 Gy) system. The result revealed that in DSE at the selected dose of 80 Gy, nearly 10% more embryogenesis and 57% more embryo production were noticed over ISE at 100 Gy suggest the. The DSE system had shorter days for germination and high plantlet recovery (4.35 and 2.0 folds, respectively).

The ethylene adsorbents $AgNO_3$ and $Ag_2S_2O_3$ exhibited significant effect on shoot organogenesis, foliar abscission and micro-shoot quality. The highest number of micro-shoots (2.14) was noted for treatment 17.66µM $AgNO_3$ followed by 5.88µM $AgNO_3$ (1.85), and the mean micro-shoot length was maximum (3.20 cm) for the treatment 17.66µM $AgNO_3$ followed by 29.43µM $AgNO_3$ (3.04 cm). Interaction among ethylene adsorbents and gelling agent had positive effect on number of microshoots, shoot length and chlorophyll content with the highest number of micro-shoot/explant (2.19) was recorded in 17.66µM $AgNO_3$+Phytagel™, whereas longest micro-shoot (3.36 cm) was recorded in 17.66µM $AgNO_3$+agar-agar.

The characterization of *Vitis parviflora* Roxb was undertaken, the bunch size is medium, having bluish-black colored skin of berries with about 20 °Brix TSS and containing 2-3 seeds in each berry, besides having good yielding capacity, thus, the berries contain all the desirable table purpose traits. Further, under field conditions, *Vitis parviflora* has been found free from foliar diseases and drought tolerant and *can* be explored as an important indigenous genetic resource in grape for both scion and rootstock breeding programs for disease and abiotic stress resistance, respectively.

Paleobotanical traits and cross compatibility studies in grapes germplasm was carried out. The pollen ultrastructure studies revealed that *Vitis parviflora* Roxb. and Dogridge were acolporate, which did not

germinate on *in vitro* media while other studied grape genotypes had tricolporated pollen, showed good pollen germination under *in vitro* condition. The pollen of the grape genotypes can be stored for up to one day only with an acceptable pollen germination (>30%) and up to seven days at 4°C, except for the 'Pearl of Csaba'. The most effective pollen storage conditions were found to be at –20°C and –196°C (in liquid N_2), enabling pollen storage for a period of up to 30 days.

The Forty-eight grape genotypes were evaluated for natural incidence of powdery mildew through artificial *in vitro* leaf inoculation (OIV455-1 scores). *Vitis parviflora*, Male Hybrid and Pusa Navrang were rated as extremely resistant (DSI = 0.41, OIV455-1 score =8.83), highly resistant (DSI = 7.25, OIV455-1 score =8.33) and resistant (DSI = 23.5, OIV455-1 score = 7.67) respectively, while, Pusa Trishar was rated as extremely susceptible (DSI = 0.88, OIV455-1 score =1.67) type. The total phenols content increased in all genotypes due to infection though the increase was more pronounced in resistant genotypes.

Twelve grape genotypes, including 7 scion cultivars were evaluated for drought tolerance, the *V. parviflora* followed by 110R, Male Hybrid, Dog Ridge and Pusa Navrang, registered higher growth under induced drought condition as compared to others. Among the scion genotypes, Pusa Navrang and Pusa Purple Seedless (4.95 to 4.54 mm and 4.27 to 3.83 mm, respectively) showed lower decrease in stem girth under induced drought condition. A sharp decline was recorded in leaf area under induced drought treatment in all the genotypes but Flame Seedless was worse affected whereas 110R, *V. parviflora*, Male Hybrid and Pusa Navrang showed some resilience to water stress.

A total of 71 genotypes including hybrids were evaluated and characterized during 2022-23 for different morpho-physiological traits. The highest fruit weight among all the selected standard check varieties and hybrids were recorded in GH-2017-7A (191.00 g). The lowest number of seeds/fruit was noticed in Lalit (161.11), which was at par with GH-2017-2C (222.33), and GH-2017-8E (225.67). Hisar Surkha was found to be the most soft seeded (8.55 kg/cm^2) variety, which was statistically at par with Allahabad Safeda (10.8 kg/cm^2) and GH-2017-6D (11.45 kg/cm^2). The highest pulp weight was recorded in GH-2017- 6D (184.57 g) having statistical similarity with GH-2017-8B(W) (172.08 g). The highest content of TSS was recorded in GH-2017-1F (12.54ºBrix), which was statistically at par with GH-2017-8E(W). The fruit pulp colour of Hisar Surkha (R54 B group), Lalit (R49 A group), GH-2017-8E(R) and others were found to have various shades of red colour. Among F_1s evaluated, the highest lycopene content (11.37 mg/100 g) was found in PP/BG-19-15-18. The purple pulped BG had maximum total anthocyanin content (8.881 mg/100 g) and the highest ascorbic acid was recorded in GH2017-4F (285.03 mg/100 g of pulp FW).

Two guava varieties Pusa Aarushi-a pink fleshed hybrid and Pusa Pratiksha- a white fleshed guava hybrid were released through CVRC. Besides, two other promising guava F_1s, HSU×SH-16-8-2 and HSU×SH-16-8-18 were identified. HSU×SH-16-8-2 is a pink pulped F_1 contains 5.806 mg/100g lycopene, 4.611 mg/100g total anthocyanins and 0.879 mg/100g total carotenoids. It has an average fruit weight 200.50 g, pulp thickness 14.06 mm, TSS 17.2°B, and ascorbic acid content 192.33 mg/100g. HSU×SH-16-8-18 is a white pulped F_1 having an average fruit weight 148.06 g, pulp thickness 14.75 mm, TSS 16.4°B and ascorbic acid content 124.17 mg/100g.

The phenomenon of heterosis was studied using 6 inbred lines, namely, Pusa Nanha (PN), Pune Selection 3 (PS 3), P-7-2, P7-9, P-9-5 and P-9-12 on important traits. Most hybrids were observed with heterosis in a negative direction for plant height at flower initiation, at first fruit maturity, petiole length, length of internode and number of nodes to first flower, revealing a dwarfing effect in the F_1 hybrids. Many hybrids expressed heterosis in the desired direction for days to flowering and days to fruit maturity. In the

number of fruits per plant, heterosis in the desired direction was observed in most hybrids, and the best-performing hybrids were PS3 × P-9-5, PS3 × P-7-9, P-9-5 × PS3 and P-9-5 × P-7-9. The highest value of positive heterobeltiosis was recorded in the hybrid combination, P-9-5 × P-7-2 (24.04%). Yield, being the most important trait, exhibited the moderate heterosis. A few traits, like the lycopene and carotenoid contents of fruits, exhibited a wide range of average heterosis and heterobeltiosis.

The chemical treatment with Salicylic acid 100ppm in papaya tended to affect the number of pentandria flowers significantly. The highest mean value was observed for control plants (8.33), whereas it was lowest in the plants treated with salicylic acid 100ppm (3.16). Among the various chemical treatments, Salicylic acid 75ppm showed the highest pollen germination (28.5%), whereas it was found lowest in plants treated with thiourea 300ppm (20.86%). The pollen viability was highest in plants treated with salicylic acid 100 ppm (50.45%) and flowering-related parameters were positively influenced by the treatments of Salicylic acid 100 ppm.

The selected papaya mutants in M9 generation were evaluated with the lowest plant height (96.26 cm), plant height at flower initiation (63.32 cm), plant girth at first fruiting (64.42 mm), nodes to first flowering (46.42), days to flower initiation (76.82), length of middle internode (4.2 cm), length of petiole (82.22 cm) and plant spread in east-west direction (138.2 cm) was recorded in PM 04 while minimum plant spread in north south direction (138.8 cm) was recorded in PM 28.

Extensive explorations and collection of genotypes in pomegranate diversity hot spot regions of Uttarakhand, Himachal Pradesh and Jammu & Kashmir was carried out, besides, collecting the available pomegranate germplasm and cultivated varieties from ICAR-NBPGR Regional Stations (Bhowali and Shimla) and ICAR-Central Institute for Arid Horticulture, Bikaner. *In toto*, 70 exotic pomegranate genotypes, 15 indigenous pomegranate cultivars and 60 wild pomegranate genotypes were collected from different parts of the country. The collected hardwood cuttings of pomegranate genotypes were rooted under controlled conditions, among exotic pomegranate accessions the cutting success ranged between 16.67 to 100 % and among indigenous wild genotypes it ranged between 0 to 66.67%. Among cultivated indigenous pomegranate genotype the success ranged between 33.33 to 83.67%.

The physico-chemical analysis of 32 pomegranate fruits of wild and cultivated accessions collected from H.P. and Jammu was carried out. All the recorded morphological parameters for fruits of collected genotypes varied significantly with CV ranging from 3.329 (FSI) to 21.735 (Septa weight).

Similarly, TSS and titratable acidity also varied significantly among genotypes with the highest TSS 19.57° Brix (KVK-3) and the highest titratable acidity 7.41% (Parnot-6). One genotype from Uttarakhand (Nathuakhan village) was found promising for *anardana* purpose with high acidity and average fruit size above 200 g. Sixty wild, cultivated and exotic pomegranate genotypes were subjected to morpho-chemical and genetic characterization at nursery stage, the analysis revealed considerable diversity among leaf and petiole characteristics, physiological characters and contents of key biochemical compounds like phenols, proline.

To screen the pomegranate germplasm against biotic and abiotic stresses particularly against bacterial blight causing *Xanthomonas axonopodis* pv. *punicae*. Upon challenge inoculation, all the genotypes developed characteristic oily spot symptoms with incidence ranging from 10% (IC-318707) to 43.33% (‘Bhagwa’). Similarly, a preliminary pot culture experiment comprising of 15 pomegranate genotypes were

inoculated with *Ceratocystis fimbriata* ($1x10^8$ cfu/ml. The delayed wilting was observed in wild pomegranate genotypes IC-318706 and IC-318707 where as other genotypes started showing wilt symptoms within a month after first inoculation.

Reciprocal graft combinations were evaluated in citrus for soil moisture stress by using scion-rootstock interaction in contrasting citrus rootstocks, drought sensitive, *Citrus jambhiri* Lush cv. Jatti Khatti (JK) and drought tolerant, X639 (*C. reshni* Hort. ex Tan. × *Poncirous trifoliata*). The result showed that X639 rootstock grafted with X639 or JK scion showed least reduction in scion height, leaf number, leaf area, increase in root biomass and lower wilt score and drought injury index. The root traits significantly improved in plant combinations with X639 rootstock under water deficit.

To mitigate drought stress in citrus, single foliar spray of proline (30, 40 and 50mM) and spermidine (0.001, 0.01 and 0.1 mM) were tested in contrasting citrus genotypes X639 (drought tolerant) and cleopatra mandarin (drought susceptible). Priming treatments had significant impact on number of leaves, leaf wilt score and leaf drop only in Cleopatra mandarin. Dry shoot weight of X639 and dry root weight and other rooting parameters of Cleopatra mandarin were significantly higher with all priming treatments than control-drought stress.

The study on integrated nutrient management (INM) in newly developed mango hybrids revealed the highest yield (26.42 kg) NPK 75 % + AMF (250g) + *Azotobacter* (250g) followed by 24.76 kg in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). The highest number of fruits (35.86) was recorded in treatment NPK 75 % + AMF (250g) + *Azotobacter* (250g) followed by 33.24 in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). The maximum average weight of fruit (210.12 g) was recorded in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Irrespective of the INM treatment, among varieties the maximum yield (25.64 kg) was found in Pusa Arunima followed by Pusa Lalima (22.64 kg) and minimum (16.82 kg) in Pusa Pratibha.

For the promotion of IARI released mango and guava varieties, commercial licensing/ MoA was signed with a commercial private nursery-Shelter Agri-Horti Farms Private Limited and M/s Nirmal Nursery. Through this process, a revenue of Rs. 6,81,000/- has been generated as License fee. Besides, the Division of Fruits & Horticultural Technology had multiplied 15,403 plants of different varieties of mandated fruit crops, and sold to the growers, SAUs and nurserymen.

During the year 2023, a total 15 PG students including 3 M.Sc. and 12 Ph.D. students were admitted in the Division, 1 foreign student from Myanmar also took admission for her Ph.D. programme. Out of 15 students admitted during 2023, 4 secured IARI fellowship, 10 ICAR fellowship and 1 BIMSTEC fellowship. Total eight students including 7 Ph.D. and 9 M.Sc. students received degree during 61th Convocation of IARI, New Delhi. During 2023, two students from SKUAST, Jammu also completed their internship at the Division of F&HT, IARI, New Delhi. One Ph.D. student of the Division has also undergone exposure visit to Taiwan under NAHEP.

1. CROP IMPROVEMENT

1.1 Genetic Improvement of Fruit Crops for Desirable Horticultural Traits

1.1.1 Objective: Development of trait specific scion variety(ies) and rootstocks in mango

Drs Manish Srivastav, Jai Prakash, A. Nagaraja, Nimisha Sharma, NV Singh, G P Mishra (Genetics and Plant Breeding), Chavlesh Kumar, Rakesh Singh (NBPGR), Shruti Sethi (FS&PHT), Rakesh Bhardwaj (NBPGR), Dinesh Singh (PP), Amit Mitra S.V. (NIPB), Sachin Suroshe (Entomology)

1.1.1.1 Mango hybridization

Artificial hybridization was attempted in mango using five different cross combinations employing Amrapali as female parent and Bhadauran, Tommy Atkins, Vanraj, Illaichi and Erwin as male donor parent. A total of 491 panicles having 3,496 flowers were crossed, and finally obtained 153 hybrid fruits.

1.1.1.2 Evaluation of Hybrids

Mango hybrids (88 Nos.) were evaluated for 11 physico-chemical traits, of which the highest fruit weight was observed in hybrid H-20-2 (402.0 g) followed by hybrid H-20-1 (390.5 g). However, it was lowest in hybrid H-10-6 (57.6 g). Among hybrids belonging to different full-sib families, H-20-2, H-20-1, H-7-1 and H-1-5 had average fruit weight of more than 300 g, while in 25 hybrids, it ranged between 200 to 300 g and 54 hybrids had fruit weight between 100 to 200 g. Rest of the four hybrids had less than 100 g fruit weight. The highest total soluble solids (TSS) were observed in the hybrid H-1-13 (25.06 ^{o}Brix) followed by the hybrid H-3-6 (24.9 ^{o}Brix), whereas the lowest total soluble solids (TSS) was recorded in hybrid H-1-9 (12.8 ^{o}Brix). Mango hybrids *viz*., NH-17-1, NH-18-4, NH 20-2, NH-19-2, H-12-5, and H-3-2 had attractive red coloration on fruit shoulder and bore more than 200 g fruit weight with TSS content ranging between 19.5 to 21.5 ^{o}Brix (Fig.1).

NH 14-2

H 1-11

NH 1-5

NH 20-2

NH 18-4

NH 16-2

Fig. 1. Promising mango hybrids

1.1.1.3 DNA bar code of mango hybrids

Polymorphic HMSSR (89) profile data of 24 mango hybrids bred at ICAR- IARI, New Delhi considering the allelic variations of polymorphic markers were translated into DNA barcode by separating the allele size for each locus. DNA barcodes having different colours for representation of unique, rare and common alleles corresponding to all markers across the tested mango hybrids. DNA barcodes reported is based on novel HMSSR allelic variation. The unique hybrid-specific allele(s) for Mallika, NH-17-1, Pusa Deepshikha, Pusa Peetamber, Pusa Manohari, Amrapali, Pusa Lalima and H-2-14 were identified and validated. Out of 11 hybrid-specific unique alleles, only seven, *viz.*, HMSSR965 (150 bp; Mallika), HMSSR1382 (300 bp; NH-17-1), HMSSR2048 (300; Mallika), HMSSR2040 (330; Pusa Peetamber), HMSSR888 (450; Pusa Peetamber), HMSSR1218 (260; Pusa Deepshikha) and HMSSR1430 (380; Pusa Peetamber) could be validated (Fig. 2).

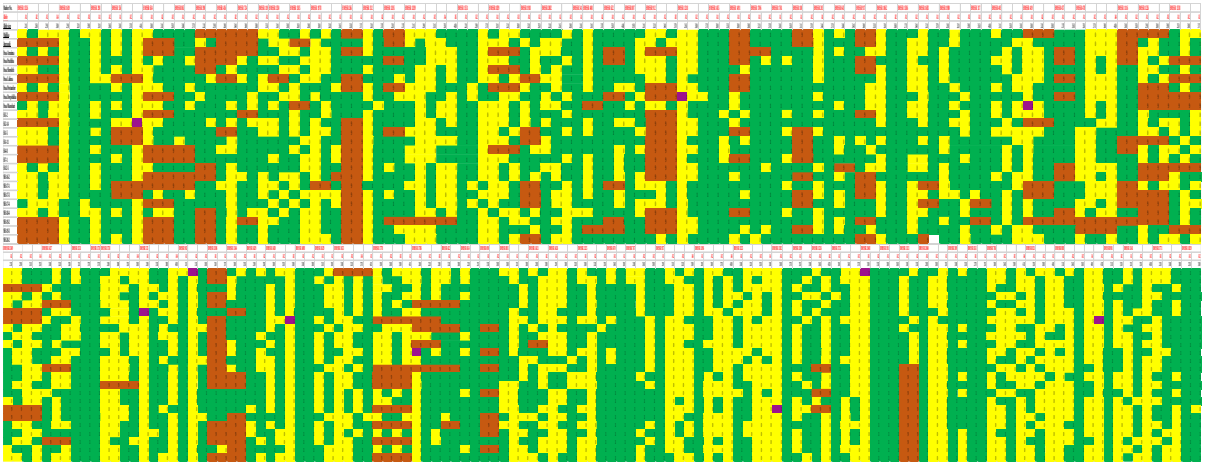


Fig. 2. DNA Barcode of 24 mango hybrids based on 89 HMSSRs (Unique alleles are in purple colour)

1.1.1.4 High-resolution genetic linkage map of mango

High-resolution genetic linkage map using Amrapali/Sensation hybrids and 4,613 SNPs was attempted. The integrated genetic recombination map using segregation data of female, male, and both parents reported here is unique and reasonably resolved. This is the first report globally for genetic recombination map purely based on bi-parental progeny population of Amrapali/ Sensation. Initially, we constructed two high-density linkage maps based on the segregation of female and male parents. A female map with 3,213 SNPs and male map with 1,781 SNPs were distributed on 20 linkages groups covering map lengths of 2,844.39 and 2,684.22cM, respectively. Finally, the integrated map was constructed comprising of 4,361 SNP markers distributed on 20 linkage groups, which consisted of the chromosome haploid number in *Mangifera indica* (n =20). The integrated genetic map covered the entire genome of *Mangifera indica* cv. Dashehari, with a total genetic distance of 2982.75 cM, and an average distance between markers of 0.68 cM. The length of LGs varied from 85.78 to 218.28 cM, with a mean size of 149.14 cM.

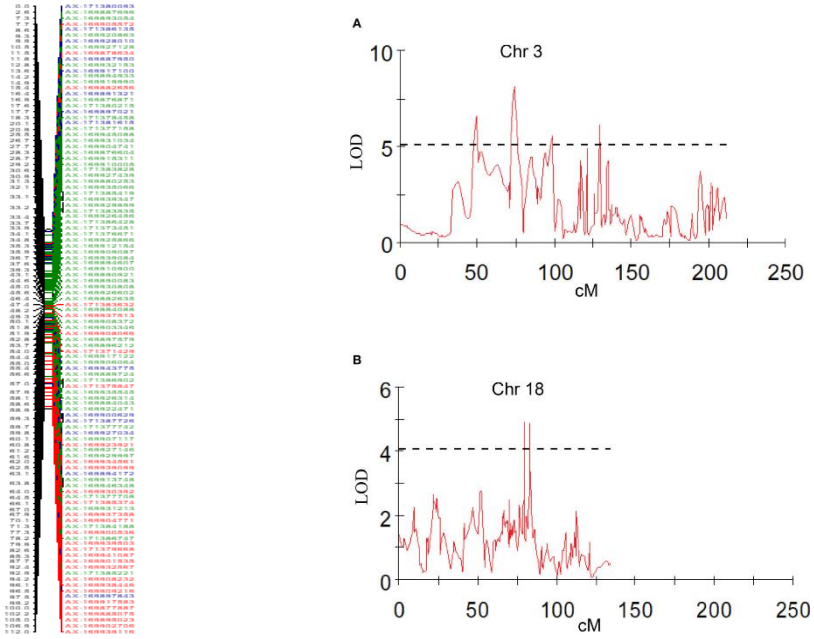


Fig. 3. Chr 17 and QTLs on Chr 3 & 18 associated with fruit colour

1.1.1.5 Identification of QTL(s) governing fruit colour and firmness in mango

Chromaticity coordinates observed on the shoulder, middle, and bottom portion of mango fruits revealed that the expression of a* indicative of red color on the shoulder was associated with Chr 3 housing four QTLs. One at 49.18 cM (6.31 to 6.72 LOD) explains 28.2 to 29.2% of phenotypic variation, the second at 73.79 cM (LOD 7.84 to 8.08) explaining 33.2 to 34.5% of phenotypic variance, the third QTL at 98.75 cM (5.43 to 5.59 LOD) and fourth at 129.83 cM (LOD 5.13 to 5.73) explain around 25.0% of phenotypic variation in the population. Two consistent QTLs identified on Chr 18 (79.42 and 83.20 cM) explain 19.9 to 25.2% phenotypic variations for b* of fruit bottom (LOD 4.14-5.56). QTLs governing the brightness (L^*) of fruit were located on Chr 2, 3, 4, 10, 15, and 17. Peel firmness observed at shoulder and bottom of mango fruit was associated with SNPs located on Chr 6, 11, and 20. Total 12 SNPs on Chr 11 at position ranging from 27.78 to 95.19 cM (R2 16.3-20.4) were identified which were having association with peel firmness at fruit shoulder. Similarly, eight SNPs hosted on Chr 11 at a position 8.69 to 94.82 cM (LOD 3.51 to 4.83; R2 16.6-22.6) consistently appeared with traits observed on fruit bottom. SNPs located on Chr 3, 4, 11, and 19 had an association with pulp firmness. SNPs located on Chr 11 at a position of 94.82 to 95.19 cM (LOD 4.54-7.42; R2 20.4-32.4) consistently appeared for pulp firmness observed at three different positions on the fruit and with the mean value (Fig. 3).

1.1.1.6 Primer generation and validation in different scion/rootstock combinations using genomic resources of mango

A total of 33 alleles were amplified among carbohydrate metabolism- specific markers, which varied from 2 to 3 alleles with a mean of 2.53 per locus. The major allelic frequency (Maf) ranged from the 0.40 to 0.87 among the carbohydrate metabolism specific markers with a mean value of 0.56 per locus. The carbohydrate metabolism specific marker NMSPS2 had the highest allelic frequency (0.87), while NMTPS9 had the lowest value (0.40). Cluster analysis revealed that scion grafted on Kurukkan rootstock clustered together except Pusa Arunima on Olour rootstock (Table 1).

Table 1. Genetic variability indices of the 13 polymorphic carbohydrate metabolism specific primers among the set of 15 scion/rootstock combinations of mango

S. No.	Marker ID	Annealing temp. (Ta) (°C)	Allele size (bp)	Maf	An	GD	Ho	PIC
1	NMAD1	55	200-210	0.60	2	0.48	0.00	0.36
2	NMAD2	55	240-250	0.57	2	0.49	0.47	0.37
3	NMAD3	55	250-260	0.73	3	0.43	0.00	0.39
4	NMAD4	55	240-250	0.53	2	0.50	0.27	0.37
5	NMAD6	55	170-180	0.53	3	0.55	0.13	0.46
6	NMCS1	55	900-910	0.47	3	0.64	0.00	0.57
7	NMCS2	55	700-710	0.47	3	0.63	0.00	0.56
8	NMCS3	55	500-510	0.60	3	0.55	0.13	0.48
9	NMSPS2	55	190-210	0.87	2	0.23	0.27	0.20
10	NMSPS3	55	160-170	0.57	2	0.49	0.47	0.37
11	NMSPS10	55	200-210	0.43	3	0.65	0.20	0.58
12	NMTPS1	55	180-200	0.50	2	0.50	0.47	0.37
13	NMTPS9	55	180-200	0.40	3	0.66	0.00	0.58
Mean				0.56	2.53	0.52	0.18	0.44

Where: Maf = major allele frequency, An = Allele number, GD = gene diversity, Ho = observed heterozygosity, PIC = polymorphism information content, These included major allele frequency, gene diversity, and number of alleles, PIC values and heterozygosity.

1.1.1.7 Mango Rootstock Improvement

1.1.1.7.1 Molecular characterization of progenies of Olour mango

Of the 25 SSR primers used to distinguish zygotic and nucellar Olour saplings. Out of 25 SSRs primers, 18 primers showed monomorphic banding pattern and generated alleles of equal size in all the studied Olour progenies while 7 SSRs were found to be polymorphic. ESTD1, MiKV98, MiIIHR8095, MiIIHR1, MiIIHR2, ESTD10, LMMA8 primers displayed polymorphic banding pattern among 20 studied progenies (Fig.4).

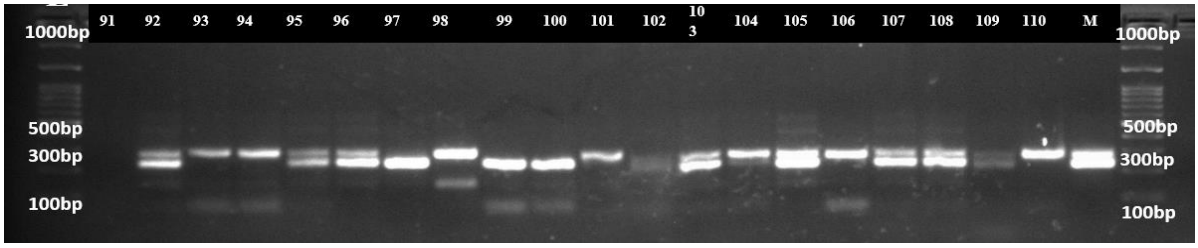


Fig. 4. Gel image of the MiKVR98 SSR profile of 20 'Olour' progenies and maternal 'Olour' plant

1.1.2 Objective: Development of trait-specific scion variety(ies) and rootstock(s) in citrus

Drs. Anil Kumar Dubey, O.P. Awasthi, Awtar Singh, R.M. Sharma, Nayan Deepak, Nimisha Sharma, Madhubala Thakre, Shruti Sethi (FS & PHT), Dinesh Singh (PP), Deeba Kamil (Plant Pathology), Sudhir Kumar (Plant Physiology), V.S. Rana (Agricultural Chemicals), G.P. Mishra (Genetics & Plant Breeding), Supradeep Saha (Agril. Chemicals), Gautam Chawla (Nematology)

1.1.2.1 Evaluation of different inter specific hybrid of sweet citrus for yield and fruit quality and Greening bacteria

During 2023, a total of 85 sweet citrus scion hybrids were evaluated, wherein a huge range for fruit weight (211.95-1010.50g), peel thickness (2.66-31.00mm), TSS (7.00°-14.17°B) and juice content (15.47-63.28%) was observed. Of the tested progenies, one hybrid namely SCSH-8-11 proved most juicy (63.28%) followed by SCSH-5-6 (52.45%). Besides, there were 11 hybrids which had the juice recovery between 45.00-50.00%. The hybrid SCSH-5-6, besides having high juice recovery was also found to have very high TSS (14.17°B) content (Fig. 5). From the whole population of bearing hybrids, 20 hybrids were selected to be used as a female parent for backcrossing with sweet oranges for further improvement (Table 2). None of the hybrids has shown the infestation of citrus psylla during 2023.

Fig. 5. Hybrid SCSH-5-6 (Pummelo × Pusa Sharad)

Table 2. Evaluation of sweet citrus scion hybrids

Hybrid	Fruit weight (g)	Peel thickness (mm)	TSS (°B)	Juice (%)	No of Seed	Acidity (%)	Embryony	Overall acceptability (Out of 10)
SCSH-3-6	1010.50	13.46	13.17	28.72	96.67	0.87	Monoembryonic	9.0
SCSH-3-7	220.93	7.14	13.50	36.07	26.33	0.90	Monoembryonic	9.5
SCSH-3-15	332.61	4.46	12.17	42.94	42.00	1.28	Monoembryonic	7.5
SCSH-5-3	493.93	4.41	15.00	38.98	36.67	0.64	Monoembryonic	9.5
SCSH-5-5	514.22	6.42	14.33	43.37	53.67	1.49	Monoembryonic	8.5
SCSH-5-6	299.21	3.35	14.17	52.45	52.00	1.88	Monoembryonic	6.0
SCSH-6-4	738.00	5.94	9.17	30.45	44.00	1.08	Monoembryonic	7.0
SCSH-6-6	447.30	31.00	8.77	48.10	31.33	1.49	Monoembryonic	5.0
SCSH-7-2	283.20	8.01	12.17	34.36	31.00	0.81	Monoembryonic	9.0
SCSH-7-7	332.90	5.47	12.17	35.34	47.33	0.85	Monoembryonic	9.5
SCSH-8-15	661.00	4.08	9.83	45.94	32.33	1.73	Monoembryonic	6.0
SCSH-8-11	313.33	5.36	8.67	63.28	31.0	2.77	Monoembryonic	5.6
SCSH-9-2	211.95	4.71	14.67	30.93	37.67	1.37	Polyembryonic	8.5
SCSH-9-3	710.33	6.61	11.17	32.43	50.67	1.37	Monoembryonic	8.0
SCSH-9-7	431.07	5.69	12.17	45.27	31.00	1.28	Monoembryonic	8.5
SCSH-11-3	295.30	3.70	12.00	42.55	46.33	2.13	Monoembryonic	5.0
SCSH-11-5	461.20	2.66	11.83	38.23	51.00	1.28	Monoembryonic	9.0
SCSH-11-8	447.03	5.25	11.17	45.84	13.67	2.01	Polyembryonic	6.5
SCSH-13-4	425.54	6.91	13.17	45.33	29.67	1.72	Monoembryonic	8.5
SCSH-13-12	868.72	6.72	11.17	35.49	61.67	1.57	Monoembryonic	9 .0
SCSH-19-5	378.94	4.87	13.67	43.92	30.00	1.34	Monoembryonic	9.0

1.1.2.2 Evaluation of different inter specific acid citrus hybrid for yield and fruit quality

During 2023, sixteen acid citrus genotypes (12 hybrids and 04 open pollinated seedlings) were evaluated, the fruits ACSH-7-13 tended to show the thinnest peel (1.23 mm) with higher juice (44.98%), TSS (9.5°B) and acid (6.14%) contents (Table 3, Fig. 7). Of these, only two hybrids namely ACSH -6-17 and ACSH-7-18 produced the low seeded fruits (8.20-9.00 seeds fruit^{-1}). The ascorbic acid content in the tested genotypes ranged from 24.16-46.80 mg 100ml^{-1}, being higher in ACSH-3-9, ACSH-6-17, ACSH -11-6, ACSH-5-2, ACSH-5-12 and OP-3-12 (41.50-46.80 mg 100ml^{-1}) genotypes.

Fig. 6. ACSH 7-13 hybrid

Table 3. Evaluation of acid citrus scion hybrids

Genotype/ Hybrid	Fruit weight (g)	Peel thickness (mm)	Seeds/ fruit	Juice (%)	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100 ml)
ACSH-3-2	87.16gh	2.62ef	41.20bc	39.63c	8.9cefd	5.52f	34.02h
ACSH-3-8	74.92i	2.55ef	26.60gh	39.39dc	8.4gfh	5.50f	37.06g
ACSH-3-9	122.31ba	3.11dc	46.40ba	31.52gf	8.9cefd	5.12h	42.18d
ACSH-6-17	88.54gh	2.86ed	8.20i	28.94g	8.7efd	4.90i	45.02c
ACSH-7-18	110.13dce	2.38gf	9.00i	47.18b	8.3gfh	5.48gf	27.68k
ACSH-7-13	74.20i	1.23h	22.00h	44.98b	9.5cb	6.14c	24.64ml
ACSH-9-1	82.92ghi	2.60ef	36.20dce	47.09b	7.3j	6.60a	39.26f
ACSH-9-13	79.35hi	2.04g	49.00a	31.13gf	7.8jih	5.47gf	31.52j
ACSH-11-6	126.50ba	3.69a	34.60dfe	44.03b	8.0gih	5.73ed	46.80a
CRH-7-4	74.74i	2.05g	34.80dfe	34.86fe	8.4gfh	5.73ed	27.44k
ACSH-5-2	122.93ba	2.36gf	22.60h	46.58b	8.7efd	6.26c	46.16b
ACSH-5-12	99.51fe	3.16bdc	34.60dfe	33.84fe	7.6ji	5.38gf	42.26d
OP-3-10	111.39dc	3.04dc	36.40dce	36.39dce	8.0gih	5.32g	24.16m
OP-3-11	90.89gf	3.39bac	34.00fe	35.55de	8.6gef	5.40gf	33.14i
OP-3-12	103.30de	3.54a	41.00bc	28.30g	9.2cebd	5.86d	41.50e
OP-3-13	119.16bc	3.49ba	38.60dce	34.35fe	9.5cb	5.68e	31.50j
ALC-2	131.76a	2.82ed	30.20gf	47.43b	9.3cbd	5.79ed	20.76o
Pusa Abhinav	40.28k	0.95ih	11.4i	56.13a	9.7b	6.62a	23.20n
Pusa Udit	37.47k	0.83i	11.8i	59.98a	10.5a	6.43b	13.58p
KSL	58.70j	1.17ih	40.2dc	19.02h	7.6ji	3.74	24.93l
LSD ($P \leq 0.05$)	10.81	0.34	5.94	3.97	0.67	0.16	0.59

1.1.2.3 Hybridization using different parents for scion and rootstock improvement

During March, 2023, a total of 248 flowers were crossed for scion improvement using 8 cross combinations (Table 4), while for rootstock improvement, 501 flowers were crossed using 12 cross combinations (Table 5).

Table 4. Details of crosses made for scion improvement

Cross Combination	Flower crossed	Fruit set after 15 days (%)	Fruit set after 30 days (%)
ASSH-11-13 × Pusa Abhinav	60	65.00	41.00
SCSH-15-3 × Mosambi	36	22.22	12.00
SCSH-9-2 × Mosambi	08	75.00	45.23
Mosambi × PS-1	47	31.92	22.35
PM3 × Sunkokan	20	90.00	65.25
PM3 × PS1	25	84.00	62.00
Sunkokan × Mosambi	34	32.00	11.32
ACSH- 5-12 × Pusa Abhinav	18	61.11	22.54
Total (08)	248	57.65*	35.21*

*Average

Table 5. Details of crosses made for rootstock improvement

Cross Combination	Flower crossed	Fruit set at 15 DAP (%)	Fruit set at 30 DAP (%)
Sour orange × Rangpur lime	67	25.37	13.00
Yama Mikan × X639	124	45.16	15.32
Yama Mikan× Troyer citrange (TC)	41	63.41	41.00
Rangpur lime × X639	11	45.45	30.23
Sour orange × X639	33	33.33	16.00
Sour orange × TC	36	80.55	65.23
Sour orange × Cleopatra mandarin	27	100.00	56.00
Cleopatra mandarin × TC	36	16.66	9.21
Small fruited mandarin × X639	26	46.15	22.34
SMF × Troyer citrange	62	46.77	16.00
CRH 7-4 × X639	13	92.30	63.50
Attani -1× Troyer citrange	25	44.00	22.21
Total (12)	501	53.26*	30.83*

*Average

1.1.2.4 Exploitation of natural mutants (grapefruit and Daisy)

Three mutants of Redblush namely RB-1, RB-2 and RB-3 and one mutant of Daisy (Daisy-6) tangerine have been multiplied and planted for further evaluation under replicated trial.

1.1.2.5 Multiplication of promising hybrids for replicated trial

Two acid citrus hybrids (ACSH-3-2 and ACSH-7-3), found promising have been multiplied for replicated trial.

1.1.2.6 Screening of rootstock hybrids against salinity and phytophthora stresses

Three hybrid rootstocks namely CRH 21-13, SCSH 9-19 and SCSH 17-12 were evaluated against *Phytophthora nicotianae* (inoculated through slit method) in comparison to contrasting rootstocks (susceptible: Jatti Khatti and tolerant X639). Of the three hybrid rootstocks, SCSH 9-19 proved highly susceptible, showing severe gummosis with lowest leaf relative water content, while CRH 21-19 proved tolerant (Fig. 7-8).

Fig. 7. *Phytophthora nicotianae* inoculation

X 639 CRH21-13 SCSH 9-19 SCSH 17-12 Jatti Khatti

Fig. 8. Gummosis in the inoculated rootstocks

1.1.2.7 Evaluation of rootstock hybrids

A total of 25 citrus rootstock hybrids were evaluated for their embryony status, wherein only three rootstocks (CRH-14-4, CRH-18-18 and CRH-20-11) were found polyembryonic for further testing against salinity and *Phytophthora nicotianae* (Table 6).

Table 6. Evaluation of citrus rootstock hybrids

Genotype/ Hybrid	Fruit weight (g)	Peel thickness (mm)	Seeds/ fruit	Juice (%)	TSS (°B)	Acidity (%)	Embryony
CRH-14-4	223.00	7.51	39	28.77	9.50	1.83	Polyembryonic
CRH-14-5	229.33	6.58	41	43.16	10.37	1.46	Monoembryonic
CRH-14-8	127.50	3.82	27	36.18	9.00	1.21	Monoembryonic
CRH-16-7	265.91	7.58	23	33.54	11.20	2.41	Dead seeds
CRH-16-11	284.65	2.99	29	41.33	8.27	1.54	Monoembryonic
CRH-16-16	272.10	2.57	27	55.79	9.73	2.15	Monoembryonic
CRH-17-14	373.97	4.56	38	39.60	10.07	1.43	Monoembryonic
CRH-17-16	546.62	3.66	37	41.63	9.27	1.62	Monoembryonic
CRH-18-6	138.76	5.58	29	25.93	9.80	2.35	Monoembryonic
CRH-18-15	458.67	9.99	9.53	28.13	22.67	2.05	Monoembryonic
CRH-18-18	497.35	5.41	57	36.53	10.47	1.66	Polyembryonic
CRH-19-14	292.67	3.16	34	35.35	10.40	1.41	Monoembryonic
CRH-20-11	323.25	7.05	23	41.22	10.27	1.77	Polyembryonic
CRH-20-15	404.84	7.73	42	27.88	10.57	3.18	Monoembryonic
CRH-20-17	314.72	6.25	37	37.50	10.07	2.13	Monoembryonic
CRH-20-18	115.93	4.56	15	35.86	12.93	2.54	Monoembryonic
CRH-21-10	247.59	3.28	44	35.21	8.53	2.52	Monoembryonic
CRH-21-14	350.51	2.05	54	46.57	8.07	1.60	Monoembryonic
CRH-22-8	519.04	6.40	56	48.71	8.33	2.09	Monoembryonic
CRH-22-11	209.57	2.43		37.25	9.13	2.09	Dead seeds
CRH-23-5	405.37	10.48	30	33.96	9.07	2.37	Monoembryonic
CRH-23-6	304.09	4.57	23	37.97	9.37	2.26	Monoembryonic
CRH-23-9	309.05	7.58	40	41.53	8.57	2.65	Monoembryonic
CRH-23-10	587.38	6.07	35	43.88	9.70	1.90	Monoembryonic
CRH-22-13	245.02	4.77	25	43.43	8.50	1.96	Monoembryonic
CRH-23-14	166.24	6.85	32	31.46	10.07	2.77	Monoembryonic

1.1.2.8 Evaluation of superior pummelo clones for different horticultural traits

Five pummelo accessions viz., IC-0628798, IC-0628799, IC-0628800, IC-0628801 and IC-0628802 evaluated for fruit characteristics exhibited significant variability amongst the tested accessions. The fruits in the accessions IC-628799 and IC-628800 were observed to have dark pink flesh and solid core of the fruits. The accession IC-628802 showed earlier maturity (September) and with higher TSS (>11^{0}Brix).

The colchicine treatment at 0, 0.10 and 0.20% concentration and 12, 18 and 24 hours duration, significantly affected the morphological, physiological and cytological characteristics in the pummelo seedlings. A few seedlings were treated with 0.1 and 0.2% colchicine concentration flowered only after four months of seed sowing with no fruit setting. None of the colchicine treatment of pummelo seeds could induce stable tetraploids as confirmed by flow cytometry.

1.1.2.9 Multiplication and field planting of superior pummelo clones

Five grafts of each of the five pummelo accessions were multiplied for field planting and further evaluation. Additionally, fruits of three pummelo accessions were collected from Bihar and their seeds were sown in the nursery for their detailed characterization and evaluation.

1.1.2.10 Bud wood and seed treatment of Kinnow and Mosambi using colchicine

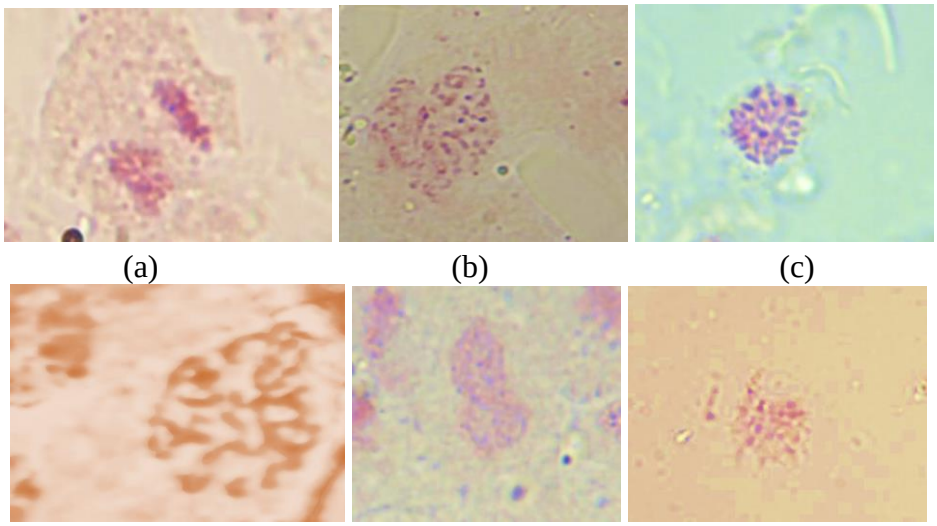
The budwood and seeds of Kinnow and Mosambi were not treated with colchicine, but for the identification of tetraploids and triploids of Kinnow and Mosambi, bold and aborted seeds were sown. The germination in aborted seeds was lesser (15%) than bold seeds (47%). Further, the germination was better in seeds of Mosambi than Kinnow mandarin. Three tetraploid and one triploid seedlings of Kinnow and six of Mosambi survived in the field.

1.1.2.11 Crossing of tetraploids with diploids to develop triploid Kinnow

From the previous year's crossing programme, 14 tetraploid seedlings of Mosambi were planted and 10 survived in the field. In Kinnow, 18 tetraploid and 8 triploid seedlings were planted and three and one seedlings survived, respectively. Five hundred and thirty-four crosses of tetraploids × diploids of Mosambi and 504 crosses of tetraploids × diploids of Kinnow were attempted to produce the triploids. Initial fruit set was good in both the crosses, but due to sudden rise in temperature, the crossed fruits dropped, hence no fruit could be harvested.

1.1.2.12 Observations on fruit setting in tetraploid and diploid and reciprocal crosses

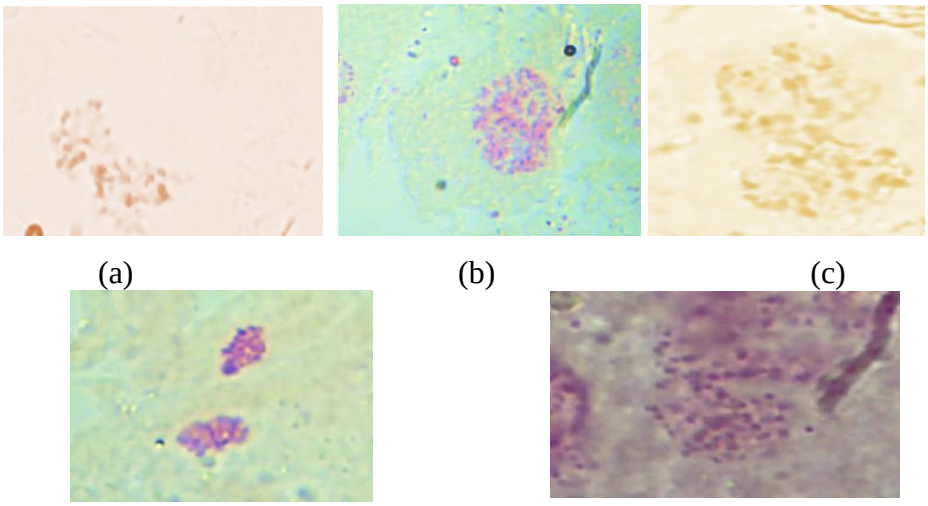
Reproductive characterization of the 39 colchiploids of Kinnow and 38 of Mosambi confirmed hyperploidy (increased rind thickness and reduced seeds/fruit). Initiation and completion of flowering were late in colchiploids compared to the wild type of Kinnow and Mosambi. The colchicine treatment generally delayed fruit maturity in the developed colchiploids of Kinnow and Mosambi. In the second-generation colchiploids, hyperploidy was recorded, and solid tetraploids were identified based on morphological, physiological, cytological and molecular characterization as well as flow cytometry. Six tetraploids of Kinnow mandarin and five of Mosambi were identified based on cytological characterization (Fig. 9-10). Additionally, three stages of meiosis cell division were also identified in the second generation colchiploid population. Reproductive characterization of the second generation colchiploids of Kinnow and Mosambi confirmed hyperploidy. Also, colchi-mutants were observed in both these cultivars, particularly for reduced seediness, a budsport of Mosambi was identified in the second-generation colchiploids, which was having different types of fruit morphology (Fig. 11).



(a) (b) (c)

(d) (e) (f)

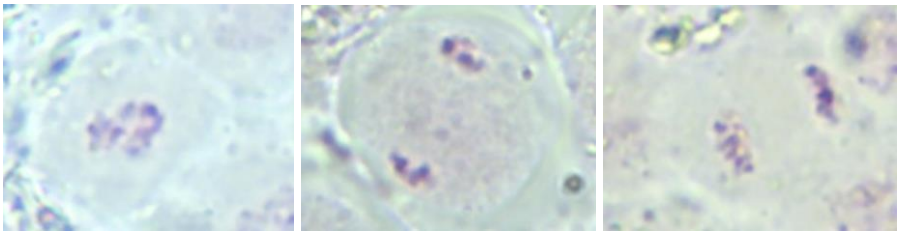
Fig. 9. Putative tetraploids observed cytologically in second-generation of Kinnow mandarin colchiploids, L_1P_1(a), L_1P_2(b), L_3P_{11}(c), L_3P_{12}(d), L_5P_{10}(e) and L_5P_{11}(f)



(a) (b) (c)

(d) (e)

Fig. 10. Putative tetraploids observed in second generation Mosambi colchiploids L_6P_9(a), L_6P_{11}(b), L_6P_{12}(c), L_7P_9(d) and L_7P_{13} (e)



(a) (b) (c)

Fig. 11. Different cell division from wild type (control) plant buds. Diakinesis (a), telophase (b) and anaphase 1 (c)

1.1.2.13 Morpho -physiological characterization of field planted putative triploids

Six putative triploids of Kinnow, planted in 2020-21 and four planted in 2021-22 were characterized morphologically, exhibiting dwarfing trait except two seedlings. Preliminary identification of three triploids (TxD/20/1, TxD/20/2, TxD/20/7) was done by Flow Cytometry (Fig. 12 (a, b, c) and Table 7-8).

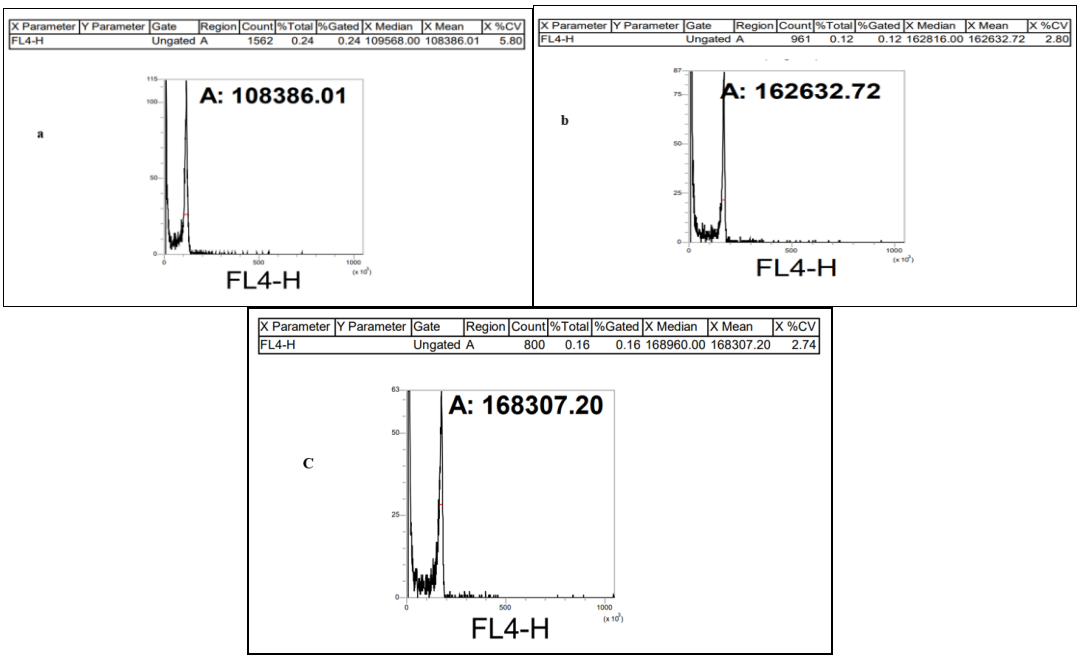


Fig. 12. Flow cytometry histogram of diploid plant (a) and genotype T X D/20/1 (b), TXD/20/2 (c) (triploid) of Kinnow

Table 7. Confirmation of tetraploids of Kinnow and Mosambi by Flow Cytometry

S. No.	Colchiploid	X Mean	Inference
1	Ex-1-5 (Kinnow mandarin)	175550.61	Tetraploid
2	Ex-1-9 (Kinnow mandarin)	158362.83	Mixoploid
3	Ex-2-11 (Kinnow mandarin)	161572.21	Mixoploid
4	Ex-2-20 (Kinnow mandarin)	181205.66	Tetraploid
5	I-1-4 (Mosambi)	186805.66	Tetraploid
6	Control (Kinnow mandarin)	104122.79	Diploid
7	Control (Mosambi)	88176.37	Diploid

Table 8. Confirmation of triploidy in the hybrids of Tetraploid x diploid Kinnow mandarin

S. No.	Cross combination	X Mean	Inference
1	T×D/20/1	162632.72	Triploid
2	T×D/20/2	168307.20	Triploid
3	T×D/20/3	141084.94	Not confirmed
4	T×D/20/4	151198.36	Not confirmed
5	T×D/20/6	142720.86	Not confirmed
6	T×D/20/7	148214.86	Triploid
7	T×D/21/1	144934.70	Not confirmed
8	T×D/21/3	151718.50	Not confirmed
9	T×D/21/4	153649.45	Not confirmed
10	T×D/21/5	161994.18	Not confirmed
11	Kinnow control	101072	Diploid

1.1.2.14 Fruit setting in tetraploid and diploid and reciprocal crosses

Fruit weight was generally higher in colchiploids of Kinnow mandarin and Mosambi. Increased rind thickness in these two citrus cultivars can be considered a reliable marker for the identification of hyperploids in the colchicine treated population. Seed content was generally lower in colchiploids and in general, the colchiploids were observed as late maturing. Two colchiploids, L_5P_{12} and L_5P_{13} from the second generation colchiploid population of Kinnow mandarin exhibited stability for early maturity, less seeds and higher fruit weight continuously for four years (Fig. 13). Similarly, two colchiploids L_6P_{10} and L_7P_7 of Mosambi exhibited stability for reduced seed content over the four years of evaluation. The colchiploid Mosambi also exhibited the presence of navel at the distal end of the fruits (Fig. 14). A chimeric branch of Mosambi, bearing corrugated fruits was identified in 2nd generation colchiploids population of Mosambi sweet orange and might again be a mutagenic effect of colchicine (Fig. 15).

Fig. 13. A colchi-mutant of Kinnow, exhibiting earlier maturity over three years

(a) (b) (c)

Fig. 14. Presence of navels in Mosambi fruits, a new characteristics

Fig. 15. A chimeric branch of second generation of Mosambi colchiploid bearing corrugated fruits

1.1.2.15 *In vitro* mutagenesis for induction of solid mutants in Kinnow mandarin

To induce solid mutants in Kinnow mandarin, the explants were subjected to ascending irradiation doses from 20-160 Gy using standardized novel cellular totipotency techniques, direct somatic embryogenesis (DSE) and indirect somatic embryogenesis (ISE). Probit analysis showed high radiation sensitivity of the ISE system (LD_{50}=54.31 Gy) over the *in-ovulo* nucellus explant-based DSE (LD_{50}=65.75 Gy) system. The result revealed that in DSE at the selected dose of 80 Gy, nearly 10% more embryogenesis and 57% more embryo production were noticed over ISE at 100 Gy. The detailed findings of the above results suggest the superiority of the DSE system in terms of higher embryo recovery and radiation tolerance over the ISE system. The DSE system had shorter days for germination and high plantlet recovery (4.35 and 2.0 folds, respectively). The difference in the chlorophyll pattern of individual regenerants in both systems revealed its single-cell origin. There are no reports on solid mutant induction through *in vitro* mutagenesis in citrus and this is the first report on modified *in-ovulo* DSE protocol (Fig. 16).

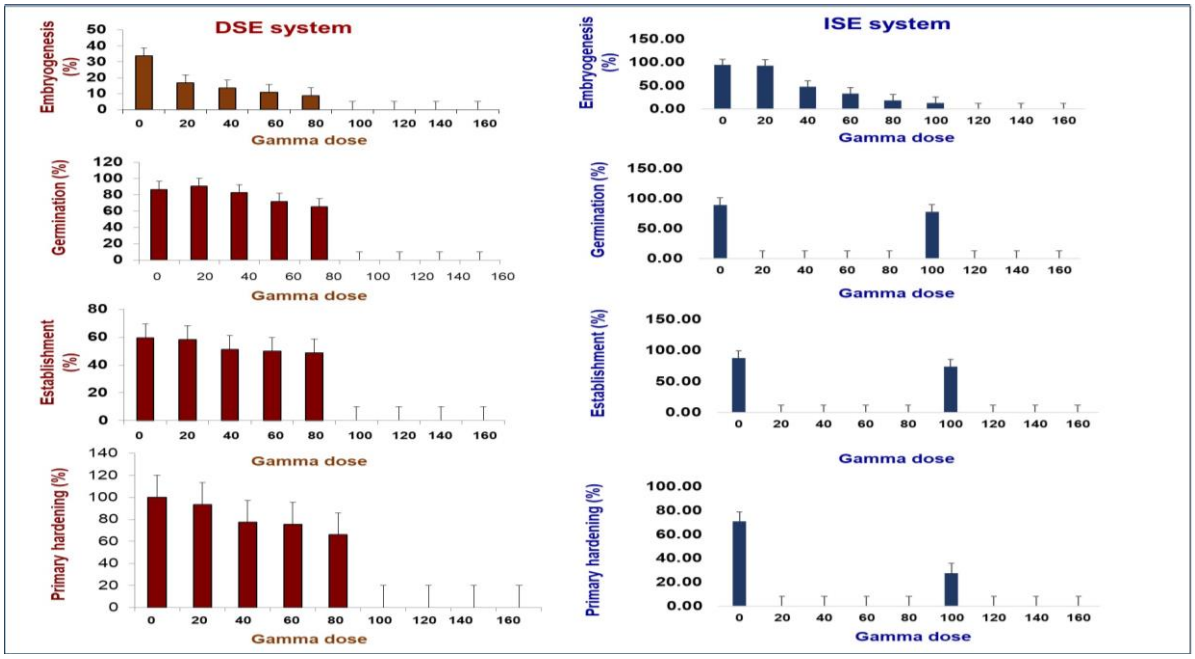


Fig. 16. Effect of gamma irradiation on somatic embryogenesis, germination, establishment and primary hardening of DSE and ISE system in Kinnow mandarin

1.1.2.16 Effect of ethylene adsorbents on micro-shoot of sweet orange (*Citrus sinensis* L.) cv. Mosambi

The results on the effect of ethylene adsorbent and gelling agent on shoot organogenesis, foliar abscission and micro-shoot quality with supplementation of ethylene adsorbents in the form of $AgNO_3$ and $Ag_2S_2O_3$ exhibited significant effect on micro-shoot development, control of micro-shoot/leaf abscission and quality of the micro-shoots. Ethylene absorbents and their interaction with gelling agent significantly affected the different parameters, though gelling agent individually had non-significant effect on different parameters except micro-shoot/leaf abscission rate.

Among the tested ethylene adsorbents, $AgNO_3$ proved superior to $Ag_2S_2O_3$ in inducing increased number and length of the regenerated micro-shoots. In contrast, $Ag_2S_2O_3$ controlled leaf abscission, and improved the quality of micro-shoots with higher total leaf chlorophyll content. The highest number of micro-shoots (2.14) was noted for treatment 17.66µM $AgNO_3$ followed by 5.88µM $AgNO_3$ (1.85), which were significantly different compared to other treatments. The mean micro-shoot length was maximum (3.20 cm) for the treatment 17.66µM $AgNO_3$ followed by 29.43µM $AgNO_3$ (3.04 cm). The control rate of micro-shoot/leaf abscission (3.96) and leaf chlorophyll content (3.40 mg g^{-1} FW) were recorded highest with 20µM $Ag_2S_2O_3$ followed by 40µM (3.93, 3.20mg g^{-1} FW, respectively), proving superiority over other treatments.

Interaction among ethylene adsorbents and gelling agent levels were statistically similar except the highest and the lowest values (Table 9). The highest number of micro-shoot/explant (2.19) was recorded in the treatment combination 17.66µM $AgNO_3$+Phytagel™, whereas longest micro-shoot (3.36 cm) was recorded in 17.66µM $AgNO_3$+agar-agar. Highest content of total leaf chlorophyll (3.47 mg g^{-1} FW) was noted for 20µM $Ag_2S_2O_3$+Phytagel™.

Table 9. Effect of different ethylene absorbents and gelling agents on micro-shoot proliferation in sweet orange cv. Mosambi.

Treatment	Mean No. of micro-shoots/explant		Mean micro-shoot length (cm)	
	Agar-agar	Phytagel™	Agar-agar	Phytagel™
Control	1.31^{c}	1.49^{bc}	1.52^{c}	1.34^{c}
$AgNO_3$ (µM)				
5.88	1.85^{bac}	1.84^{bac}	3.06^{ba}	2.98^{ba}
17.66	2.10^{a}	2.19^{a}	3.36^{a}	3.04^{ba}
29.43	1.73^{bac}	1.79^{bac}	3.06^{ba}	3.02^{ba}
STS (µM)				
20	1.71^{bac}	1.93^{ba}	3.07^{ba}	2.99^{ba}
40	1.81^{bac}	1.65^{bac}	3.04^{ba}	2.69^{b}
60	1.83^{bac}	1.86^{bac}	2.80^{ba}	2.96^{ba}
Mean	0.05		0.07	
LSD (P≤0.05)	0.56		0.67	

1.1.3 Objective: Development of improved scion and rootstock trait-specific scion variety (ies) in grape.

Drs Jai Prakash , Chavlesh Kumar, Madhubala Thakre, NV Singh, Rakesh Singh (NBPGR)

1.1.3.1 Hybridization

Hybridization was attempted among desirable rootstock genotypes and indigenous wild species *viz*., *Vitis parviflora* × Dogridge, *Vitis parviflora* × Salt Creek and *Vitis parviflora* × Male Hybrid, while in cultivated group only Pusa Swarnika and Pusa Navrang were included. A total of 500 flowers were crossed among each of cross combination. All cross combinations have set seeds except the *Vitis parviflora* × Dogridge. The harvested seeds were sown in the portrays for raising the hybrid seedlings. The hybrid seedlings (25 nos.) of *Vitis parviflora* × Male Hybrid were undertaken for their morphological and molecular characterization.

1.1.3.2 Germplasm maintenance

The scion and rootstock genotypes were maintained at the experimental vineyard. The rooted cuttings of *V. ficifolia* (EC452206) and *V. riparia* (EC 452207) were planted in the field gene bank. Besides, 100 cutings of each of *Vitis parviflora*, Dogridge, Salt Creek and Male Hybrid were raised for rootstock studies and graft-compatibility studies.

1.1.3.3 Germplasm characterization

The *Vitis parviflora* Roxb. is an indigenous Himalaya wild apple widely distributed in the northwestern Himalayan states *viz*., Himachal Pradesh and Uttarakhand. The *Vitis parviflora has* unique ampelographic traits, having distinct leaf morphology with high trichome density in the adaxial surface, semi-reflexed stamens with non-functional pollen grains. The bunch size is medium, having bluish-black colored skin of berries with about 20 °Brix TSS and containing 2-3 seeds in each berry, besides having good yielding capacity, thus, the berries contain all the desirable table purpose traits. Further, under field conditions, *Vitis parviflora* has been found free from foliar diseases like anthracnose and powdery mildew. Under the induced drought stress conditions, the *Vitis parviflora* has shown better moisture stress (drought) tolerance than commercial rootstocks like Dogridge and Salt Creek. Therefore, *Vitis parviflora* can be explored as an important indigenous genetic resource in grape for both scion and rootstock breeding programs for disease and abiotic stress resistance, respectively.

1.1.3.4 Paleobotanical and cross-compatibility studies

Understanding the paleobotanical traits and cross compatibility studies of available germplasm is important for initiating the grape breeding. The pollen ultrastructure, germinability and pollen storage behaviours of ten grape genotypes were undertaken. The ultrastructure studies, conducted through scanning electron microscope (SEM), revealed that *Vitis parviflora* Roxb. and Dogridge were acolporate, which did not germinate on *in vitro* media while remaining eight grape genotypes had tricolporated pollen, showed good pollen germination under *in vitro* condition. The pollen storage studies deciphered that the pollen of most of the grape genotypes can be stored for up to one day only with an acceptable pollen germination (>30%) while it could be storage for up to seven days at 4°C, except for the 'Pearl of Csaba'. The most effective pollen storage conditions were found to be at –20°C and –196°C (in liquid N2), enabling pollen storage for a period of up to 30 days. In cross-compatibility studies, *V. parviflora* × Pusa Navrang and *V. parviflora* × Salt Creek showed high cross-compatibility, offering potential use for grape rootstock breeding. Besides, self-pollinated flowers from *V. parviflora* and *V. parviflora* × Dogridge could not set berries, which indicated that *V. parviflora* have only functionally female flowers. Thus, in the functionally female genotype, the tedious emasculation is not required. However, this genotype restricts their use as female parent in the conventional grape breeding program.

1.1.3.5 Screening for powdery mildew resistance/tolerance in grape

The Forty-eight grape genotypes were evaluated for natural incidence of powdery mildew (Fig. 16) through artificial *in vitro* leaf inoculation (OIV455-1 scores). Leaves were sampled during April (healthy phase) and mid-August (peak disease occurrence) for the biochemical analysis (total phenols, MDA content, POD, PPO, etc.). *Vitis parviflora*, Male Hybrid and Pusa Navrang were rated as extremely resistant (DSI = 0.41, OIV455-1 score =8.83), highly resistant (DSI = 7.25, OIV455-1 score =8.33) and resistant (DSI = 23.5, OIV455-1 score = 7.67) respectively, while, Pusa Trishar was rated as extremely susceptible (DSI = 0.88, OIV455-1 score =1.67) type. The total phenols content increased in all genotypes due to infection though the increase was more pronounced in resistant genotypes namely, *V. parviflora* (5.42 mg/ g FW), Male Hybrid (5.12 mg/ g FW) and Pusa Navrang (4.70 mg/ g FW), coupled with higher POD and PPO activities.

Fig. 16. Powdery mildew incidence on field (natural) grown *V. parviflora* and Black Muscat

1.1.3.6 Response of grape genotypes to induced drought stress

Twelve grape genotypes, including 7 scion cultivars *viz*., Pusa Navrang (PN), Pusa Aditi (PA), Pusa Trishar (PT), Pusa Swarnika (PS), Pusa Urvashi (PU), Pusa Purple Seedless (PPS) and Flame Seedless (FS) and 5 rootstocks *viz*., 110R, St. George (SG), Dogridge (DR), *Vitis parviflora* (VP) and Male Hybrid (MH) were studied to know the response of grape scion and rootstock genotypes response towards well-watered (WW) and induced-drought (ID) conditions. Self-rooted grape genotypes were exposed to 21 days of induced drought by completely withholding the water up from 70% to 25% volume water content (VWC), while well-watered control counterparts were kept for comparison which was maintained at 70% VWC. The moisture in the pots were evaluated regularly using Pro Check moisture meter. The vine length of all selected genotypes was significantly reduced with the decrease in water availability (Table 10). A significant decrease in vine length from 70.33 cm to 41.01 cm was recorded in PT (41.68 % reduction) followed by Flame Seedless (72.7 to 14 cm, 35.15% reduction) and PS (84.71 to 58.64 cm, 30.77% reduction). However, lower decrease was found in Pusa Purple Seedless (43.69 to 37.51 cm) and Male Hybrid (86.64 to 76.81 cm). The highest overall plant height under ID condition was recorded in *V. parviflora* followed by 110R, Male Hybrid, Dog Ridge and Pusa Navrang, representing the vigorous growth of rootstock over scion varieties. Noticeable decline was recorded in the stem girth (mm) for genotypes subjected to ID compared to WW vines. Among the scion genotypes, Pusa Navrang and Pusa Purple Seedless (4.95 to 4.54 mm and 4.27 to 3.83 mm, respectively) showed lower decrease in stem girth compared to WW conditions followed by Pusa Urvashi and Pusa Swarnika. Among the rootstocks, *V. parviflora* (5.80 and 5.81 mm) showed almost no difference between the water stress treatments followed by 110R (3.88 to 3.59 mm) and Male Hybrid (5.58 to 5.17 mm). This indicates the growth performance superiority of rootstock over scion. Under WW condition, the highest root length was observed in Pusa Purple Seedless (41.23 cm), followed by *V. parviflora* (36.44 cm) and110R (33.53 cm); however, under ID condition the root length was significantly increased in all the genotypes (Table 10) as a plant's adaptive response towards moisture stress.

Highest number of leaves per plant was recorded in 110R (103.15) followed by Male Hybrid (84.52) and Pusa Navrang (78.04) under controlled condition, while it decreased significantly under water stress condition but with similar trend (Table 10). Sharp decline was recorded in leaf area under ID treatment showing substantial detrimental effect of drought on leaf area. Flame Seedless was worse affected with the highest leaf area decrease (51.92 %) followed by Pusa Trishar (26.50%). On contrary, 110R, *V. parviflora*, Male Hybrid and Pusa Navrang could able to manage the water stress with 7.92, 11.67, 14.22 and 14.74 % decrease in leaf area, respectively.

Table 10. Effect of induced drought stress on number of vine length, stem girth, longest root length, leaves per plant, average leaf area, on some grape genotypes

Sl. No.	Genotype	Vine Length (cm)		Stem girth (mm)		Length of longest root (cm)		Number of leaves per plant		Av. leaf area (cm^2)	
		WW	ID	WW	ID	WW	ID	WW	ID	WW	ID
1	PN	89.08^{cd}	74.56^{de}	4.95^{bc}	4.54^{fg}	33.33^{e-h}	36.44^{c-f}	78.04^{cd}	62.66^{fg}	34.53^{def}	29.44^{gh}
2	PA	77.29^{bc}	55.52^{e-h}	5.14^{efg}	4.1^{j}	30.58^{g-j}	35.93^{bcd}	61.71^{fgh}	43.77^{jkl}	34.64^{def}	26.07^{hi}
3	PT	70.33^{ab}	41.01^{ef}	5.51^{gh}	4.31^{kl}	25.54^{kl}	35.06^{c-g}	55.72^{hi}	38.25^{lm}	36.3^{cd}	26.68^{hi}
4	PS	84.71^{abc}	58.64^{ef}	5.37^{cde}	4.35^{ij}	24.35^{l}	30.62^{hij}	62.33^{fg}	50.27^{ij}	36.16^{cde}	27.25^{hi}
5	PU	79.9^{ab}	65.45^{de}	5.57^{def}	4.55^{hi}	28.48^{jk}	34.42^{d-h}	68.06^{ef}	48.37^{jh}	39.21^{c}	29.44^{gh}
6	PPS	43.69^{ef}	37.51^{fgh}	4.27^{kl}	3.83^{l}	41.23^{b}	47.64^{a}	56.17^{ghi}	35.17^{mn}	27.32^{hi}	21.57^{jk}
7	FS	72.7^{de}	47.14^{gh}	4.45^{fgh}	3.73^{k}	28.23^{jkl}	32.81^{f-i}	43.58^{kl}	31.5^{n}	39.67^{c}	19.07^{k}
8	110R	96.39^{fgh}	80.57^{h}	3.88^{b}	3.59^{def}	33.53^{e-h}	38.71^{bc}	103.15^{a}	89.86^{b}	33.3^{d-g}	30.66^{fg}
9	SG	74^{de}	57.68^{e-h}	4.56^{fg}	4.11^{ij}	28.34^{jk}	33.8^{d-h}	64.36^{ef}	40.47^{lm}	36.37^{cd}	25.05^{ij}
10	DR	90.32^{cd}	76.24^{efg}	4.95^{bc}	4.23^{fg}	29.34^{ijk}	37.01^{cde}	77.55^{d}	62.69^{fg}	37.3^{cd}	29.9^{gh}
11	VP	106.02^{a}	89.8^{a}	5.8^{a}	5.81^{bc}	36.44^{c-f}	38.74^{bc}	65.61^{ef}	56.97^{gh}	61.49^{a}	54.31^{b}
12	MH	86.64^{ab}	76.81^{bc}	5.58^{cd}	5.17^{efg}	31.25^{g-j}	36.86^{c-f}	84.52^{bc}	70.07^{e}	37.25^{cd}	31.95^{efg}
	Mean	80.93 ±15	63.42 ±15.87	5.01 ± 0.58	4.36 ±0.6	30.89 ±4.51	36.50 ±4.04	68.4 ±14.94	52.51 ±16.13	37.8 ±7.78	29.37 ±8.36
	CV%	18.54	25.03	11.58	13.77	14.61	11.11	21.85	30.72	20.59	28.58
LSD (P≤0.05)	Genotype (G)	5.720		0.376		2.763		4.646		3.034	
	Treatment (T)	2.33		0.153		1.128		1.897		1.238	
	G×T	8.08		0.531		3.908		6.571		4.291	

1.1.4 Objective: Development of guava varieties for desirable horticultural traits (yield, quality and processing traits)

Drs. A. Nagaraja, A.K. Goswami, Madhubala Thakre. Alka Joshi (FS&PHT), Amitha Mithra S.V. (NIPB), Chavlesh Kumar, VS Rana (AC), Shalini Gour (FS&PHT) and Suneha Goswami (Biochemistry), Amrita Das (PP), Vishal Somvanshi (Nematology) and Rakesh Singh (NBPGR)

1.1.4.1 Improvement of guava for yield, quality and processing traits

1.1.4.1.1 Evaluation and characterization of guava hybrids and genotype

A total of 71 genotypes including hybrids were evaluated and characterized during 2022-23 for different morpho-physiological traits. The highest fruit weight among all the selected standard check varieties and hybrids were recorded in GH-2017-7A (191.00 g), which was statistically at par with GH-2017- 8B(W) (175.67 g), GH-2017-8E(W) (163.67 g) and GH-2017-8E(R) (160.33 g), while it was lowest in GH-2017-2A (99.67 g) without any significant difference with GH2017-8B(R) (103.00 g). The lowest number of seeds/fruit was noticed in Lalit (161.11), which was at par with GH-2017-2C (222.33), and GH-2017-8E (225.67), while the highest number of seeds was recorded in GH-2017-8B(W) (391.33) statistically, which was at par with GH-2017-7A (305) and GH-2017-4F (301). Of the selected guava genotypes, the lowest seed weight was recorded in Lalit (1.44 g) without exhibiting significant variation with GH-2017-2A (2.06 g). Guava hybrids GH-2017-8B (W) show the highest seed weight (4.7 g), which was statistically similar with GH-2017-1F (3.81 g).

Hisar Surkha was found to be the most soft seeded (8.55 kg/cm^2) variety, which was statistically at par with Allahabad Safeda (10.8 kg/cm^2) and GH-2017-6D (11.45 kg/cm^2), while in GH-2017-3F had most hardy seeds (23.72 kg/cm^2) without having significant difference GH-2017-2C (20.09 kg/cm^2). The highest pulp weight was recorded in GH-2017- 6D (184.57 g) having statistical similarity with GH-2017-8B(W) (172.08 g). The lowest pulp weight was recorded in Lalit (92.29 g) followed by Allahabad Safeda (93.16 g) and GH-2017-2A (94.13 g) without having significant difference. The highest pulp: seed weight ratio was recorded in GH-2017-8E (W) (72.7), which was similar statistically with GH-2017-2C (64.66) and Lalit (64.5). GH-2017-4C (27.42) and GH-2017-8B(R) (27.76) were found to have very low pulp: seed weight ratio. The highest content of TSS was

recorded in GH-2017-1F (12.54°Brix), which was statistically at par with GH-2017-8E(W) (12.41° Brix) however it was lowest in GH-2017-8C (8.89° Brix) without having significant difference with Lalit (9.2° Brix). The highest titratable acidity was recorded in GH-2017-8B(R) (0.66%), which was statistically at par with GH2017-4F (0.62%) and Lalit (0.61%). The guava hybrids GH-2017-8E(R), GH-2017-2A, GH-2017-5C, GH-2017-8C, GH-2017-6D and GH-2017-2C were found to have fruits with low acid content (0.41-0.42%). Among the tested genotypes, peel colour of Allahabad Safeda, Lalit and GH2017-1F was yellow green (YG151 A), whereas, Hisar Surkha, was under yellow group (Y11 A) and Shweta (Y158D), genotypes GH-2017-8E(R), GH-2017-5C, GH-2017-7A and GH-2017-8B(W) were of yellow green (YGN144 B group) in colour. Other guava hybrids which fall under yellow green colour were GH-2017-8E(W) (YG154 A group) and GH-2017-2A, GH-2017-4C, GH-2017-6C, GH-2017-2C, GH-2017-6D, GH-2017-8C, GH-2017-3F, GH-2017-8B(R) and GH-2017-4F (YG145 A group) . Under yellow white fruit pulp (YW155 B group), Allahabad Safeda, Shweta (YW8 B) and GH-2017-8E(W) (YW158 B group), whereas, Hisar Surkha (R54 B group), Lalit (R49 A group), GH-2017-8E(R) (R48 B group), GH-2017-2A (R38 B group), GH2017-4C, GH-2017-4F (R38 A group), GH-2017-5C, GH-2017-6C, GH-2017-6D, GH2017-2C and GH-2017-1F (R39 B group), GH-2017-8C (R47 C group), GH-2017-3F (R49 A group) and GH-2017-8B(R) (R55 B group) were found to have various shades of red colour. Only GH-2017-7A (Y11 D group), GH-2017-8B(W) (Y155 A group) fell in yellow group (Fig. 17).

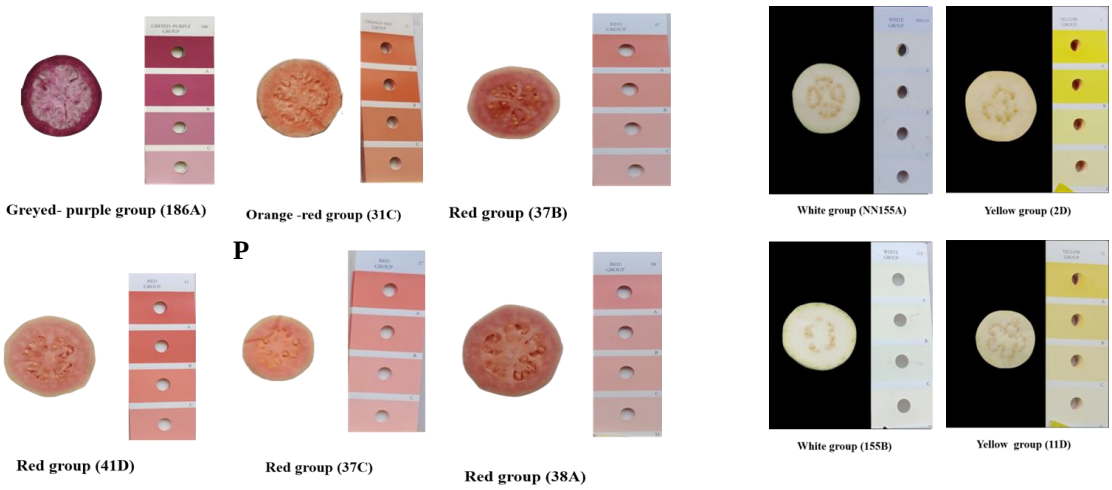


Fig. 17. Pulp colour groups and different shades of colour

There were two groups, pigment-rich and pigment-deficient. All coloured pulped guava genotypes belonged to pigment-rich group and white pulped guava genotypes belonged to pigment-deficient group. Among guava parents, HSU (pink pulped) had maximum lycopene content (11.82 mg/100 g) and PP (pink pulped) had 3.10 mg/100 g lycopene. White pulped guava parents PPT and SH had very less lycopene content. Although, BG had coloured pulp i.e. purple with 0.495 mg/100 g lycopene content which was very similar to white pulped guava genotypes. Among F_1s, the highest lycopene content (11.37 mg/100 g) was found in PP/BG-19-15-18 followed by PP/BG-19-20-4 (9.73 mg/100 g), PP/BG-19-15-1 (7.66 mg/100 g), PP/BG-19-20-12 (7.42 mg/100 g) and PP/HSU-19-17-8 (6.93 mg/100 g) (Fig. 18). The purple pulped BG had maximum total anthocyanin content (8.881 mg/100 g), significantly higher than the four parents and F_1s. Pink pulped parents, HSU, and PP had total anthocyanins content of 2.64 mg/100 g and 0.301 mg/100 g, respectively. Among F_1s, PP/BG-19-19-6 (4.03 mg/100 g) and PP/BG-19-15-18 (3.70 mg/100 g) had higher total anthocyanins content. Among F_1s, red pulped F_1s had higher total anthocyanins (1.24-4.03 mg/100 g) than white pulped F_1s (0.18-0.71 mg/100 g). Thus, no F_1 with anthocyanin content as high as the BG was recovered, though

both the pink and purple pulped parents and F_1s contained anthocyanins. Among the various guava genotypes, the highest ascorbic acid was recorded in GH2017-4F (285.03 mg/100 g of pulp FW), which proved similar statistically with Allahabad Safeda (243.33 mg/100 g of pulp), however, it was lowest in Hisar Surkha (145.77 mg/100 g of pulp) with statistical similarity with GH-2017-8E(R) (156.82 mg/ 100 g of pulp).

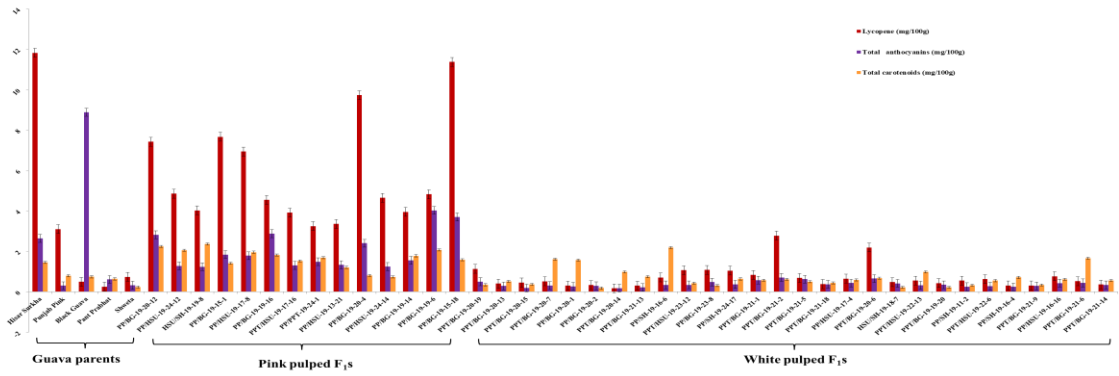


Fig. 18. Lycopene, total anthocyanins, and total carotenoids content

The highest antioxidant activity was recorded in Shweta (15.07 µM TE/g FW) showing similarity statistically with Allahabad Safeda (12.88 µM TE/g FW) and (GH-2017-8E (W) (8.67 µM TE/g FW). However, lowest antioxidant activity was noticed in GH-2017-6D (2.7 µM TE/g FW) without any significant difference with that of GH-2017-6C (3.37 µM TE/g FW). The flavouring compounds identified were 2,4-hexadienal, α-pinene, betatrans-ocimene, tert-butylbenzene, nopinene, 1-octanal, 1-undecyne, benzoic acid, ethyl ester, tert-butylbenzene, (3z)-3-hexenyl, 3-methylbutanoate, copaene, dodeconoic acid, caryophyllene, cinnamylalcohol, acetate, acetic acid, decyl ester, octanoic acid, cyclohexane, 4-hexyn1-ol, 2-hexanal, oxime-methoxy-phenyl, heptanal, ethyl ester, beta lonone, benzene-2-propenyl, sabinene, limonine, carene, beta-transocimene, ethyl-3-phenylpropanoate, methylgorlate, pthalic acid, butyl-2-propenyl ester 1-bromo-1-ethoxy methoxymethyl, 1-hexanol, benzene, furan-2-ethyl, toluene, cyclohexanol, 4(1,1-dimethylethyl), hexanoic acid, hexadeconoic acid and 2-hexenylester. The leaf morphological characters leaf shape, twisting, curvature of mid rib, degree of curvature of mid rib, relief of surface, shape of tip, leaf colour, colour of midrib on lower side of fully developed leaf showed distinct pattern among 253 F_1s. The oblong shape of fully developed leaves was predominantly present in all the parental combinations. There was dominance of absence of curvature of midrib of fully developed leaf character. In general, the smooth relief of surface was predominantly present among all the parental combinations. As far as the shape of leaf tip is concerned, obtuse leaf tip of fully developed leaves was predominantly present among 253 F_1s. Irrespective of the leaf colour of parents, the green colour of fully developed leaves showed dominance for F_1s of each parental combination. The cream colour of midrib on lower side was predominant among 253 F_1s of various parental combinations except one F_1(PP/HSU-19-24-8) which had reddish coloured mid rib on lower side (Fig. 19).

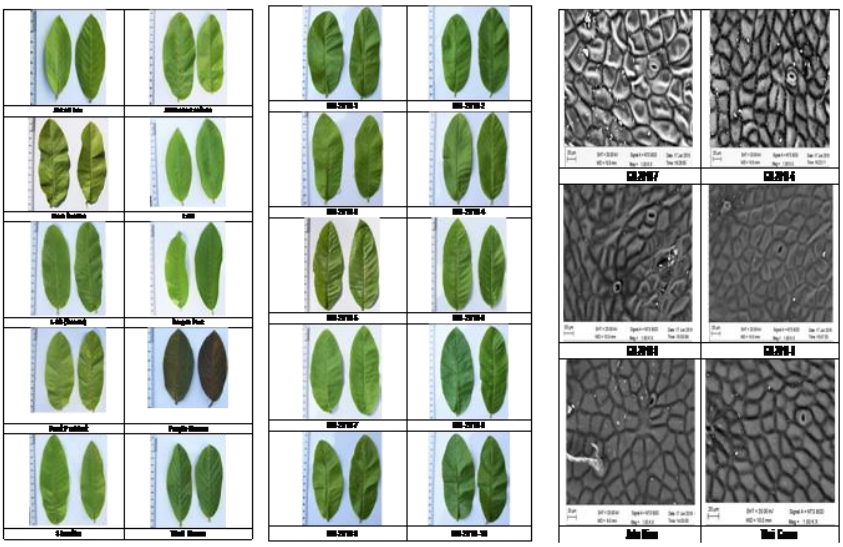


Fig. 19. Leaf morphological characters of guava genotypes

1.4.1.2 Hybridization among the potential parents (both inter and intra specific) for development of mapping populations

Under the guava improvement programme, hybridization in guava was done as per diallel mating design by involving the ten best combiner genotypes with superior desirable traits. Varieties/ genotypes used in crossing were Allahabad Safeda, L-49, Pant Prabhat, Lalit, Shweta, Hisar Safeda, Hisar Surkha, Arka Kiran, Punjab Pink, Purple guava, Thai Pink, Thai guava, Allahabad Surkha, Arka Amulya, Dhawal, Lalima and Apple colour. A total of thirty-five cross-compatible desirable combinations, and a total of 1124 flowers were crossed during the reporting period.

Fig. 20. Guava parental genotypes used for diallel mating

1.1.4.2.1 Identification of promising F_1s

Two promising guava F_1s, HSU×SH-16-8-2 and HSU×SH-16-8-18 were identified. HSU×SH-16-8-2 is a pink pulped F_1 contains 5.806 mg/100g lycopene, 4.611 mg/100g total anthocyanins and 0.879 mg/100g total carotenoids. It has an average fruit weight 200.50 g, pulp thickness 14.06 mm, TSS 17.2°B, and ascorbic acid content 192.33 mg/100g. HSU×SH-16-8-18 is a white pulped F_1 having an average fruit weight 148.06 g, pulp thickness 14.75 mm, TSS 16.4°B and ascorbic acid content 124.17 mg/100g (Fig. 21).

Fig. 21. Promising guava hybrids

1.1.4.3 Molecular characterization of guava genotypes.

Primers for the genes of lycopene pathway i.e. *PSY*, *PDS*, *ZDS*, and *CRTISO* were designed and some of them *viz.*MB1, NP2, P12ZDS, and P18ZDS were amplified. RNA sequencing of two contrasting white and pink pulp guava genotypes for the identifications of candidate genes for fruit quality and pulp pigment parameters were also completed. The fruit of guava genotypes - 7A (Hisar Safeda × Purple Guava) (white pulp) and 2F (Pant Prabhat × Arka Kiran) (pink pulp) were collected at the early (after 72 days from day of anthesis), mid (after 90 days from the day of anthesis), and ripe stages (after 95 days from the day of anthesis). RNA sequencing was done for pink and white pulp guava genotypes. Differentially expressed genes were identified from annotated data using the early stage as a reference and constructed venn diagram of differentially expressed genes (Fig. 22).

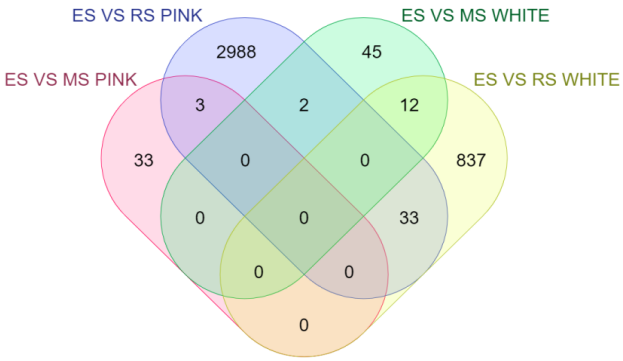


Fig. 22. Venn diagram of differentially expressed genes at different maturity stages

1.1.4.4 Release of guava hybrids

1. "Pusa Pratiksha" (Hisar Safeda × Purple Guava)

Improved hybrid for commercial cultivation in NCT Delhi and NC Region. Recommended by State Seed Sub Committee for Agricultural & Horticultural Crop, Govt. of NCT of Delhi vide No. F.10 (1) (2)/SI/TA/Sub-Committee /2017 - 18/220-266 Dated: 17/01/2023. Pusa Pratiksha is large

fruited (176-190 g), soft-seeded and white pulped genotype having minimum seed core, excellent nutritional & fruit quality traits over the commercial var. Allahabad Safeda (Fig. 23).

Fig. 23 Pusa Pratiksha

2. "Pusa Aarushi" (Pant Prabhat × Arka Kiran)

Pusa Aarushi is pink pulped, low-seeded genotype, having excellent fruit quality traits over commercial variety Allahabad Safeda, and suitable for table and processing purposes. It is having large fruit size (190-240 g), high total soluble solids (12.50 to 13.6° Brix) ascorbic acid (156.82-179.23 mg/100 g of pulp), high total flavonoids (94.53-110.22 µM TE/g FW) and antioxidant activity (7.9-8.9 µ Mol Trolox/ 100 g) with low acid content (0.39-0.41%) (Fig. 24).

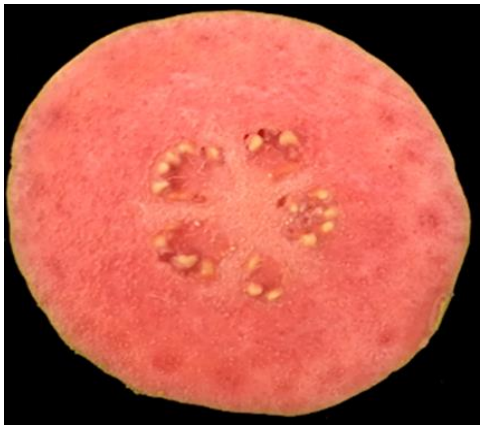


Fig. 24. Pusa Aarushi

1.1.5 Objective: Genetic improvement of papaya variety (ies) for desirable horticultural traits

Drs Jai Prakash, A.K. Goswami, K. Singh, Dharmendra Singh (Genetics and Plant Breeding, IARI), S.K. Sharma (RS-IARI, Pune), Savarni Tripathi (RS-IARI, Pune), K. Chandrashekar (RS-IARI, Pune), Basawaraj (RS-IARI, Pune) and Swati Saha (RS-IARI, Pune)

1.1.5.1 Heterosis estimation in papaya

The phenomenon of heterosis was studied using 6 inbred lines, namely, Pusa Nanha (PN), Pune Selection 3 (PS 3), P-7-2, P7-9, P-9-5 and P-9-12 on important traits. Most hybrids were observed with heterosis in a negative direction for plant height at flower initiation, at first fruit maturity, petiole length, length of internode and number of nodes to first flower, revealing a dwarfing effect in the F_1 hybrids. Whereas, in the case of stem diameter, heterosis in the positive direction was recorded for the majority of hybrids. Earliness is an essential trait for improvement in papaya, and it was found that many hybrids expressed heterosis in the desired direction for days to flowering and

days to fruit maturity. For the fruiting zone, very low heterosis was observed in hybrids over the mid and better parents. In the number of fruits per plant, heterosis in the desired direction was observed in most hybrids, and the best-performing hybrids were PS3 × P-9-5, PS3 × P-7-9, P-9-5 × PS3 and P-9-5 × P-7-9. In the fruit yield, the value of relative heterosis ranged from -13.22 (PN × PS3) to 39.74 (P-9-12 × P-7-2) per cent. The hybrid combinations exhibiting the highest value of mid-parent heterosis in the positive direction were P-9-12 × P-7-2 (39.74%), P-9-5 × P-7-2 (34.49%), PN × P-7-2 (27.09%) and P-9-12 × P-7-9 (26.87%). The range of better parent heterosis for the trait varied from -37.01 (PN × PS3) to 37.14 % (P-9-12 × P-7-2). The highest value of positive heterobeltiosis was recorded in the hybrid combination, P-9-5 × P-7-2 (24.04%), followed by P-9-12 × P-7-9 (22.44%) and P-7-2 × P-9-12 (18.30 %). Yield, being the most important trait, exhibited the moderate heterosis, and it was observed that the cross combinations involving P-7-2, P-9-5, and P-9-12 as female parents resulted in better heterosis responses in a desirable direction. So, heterosis in yield mainly arose due to an increase in fruit number and not an increase in fruit size or weight. In the case of antioxidants like phenols and flavonoids, moderate heterosis was recorded, and it was found that crosses involving parents P-9-5, P-7-9 and P-9-12 produced more heterotic combinations for the trait. A few traits, like the lycopene content of fruits, exhibited a wide range of average heterosis (-62.09 to 185.86%) and heterobeltiosis (-67.65 to 162.81%). Similarly, the total carotenoid content of fruits also had a wide range of average heterosis (-48.35 to 141.19%) and heterobeltiosis (-66.41 to 83.73%). Traits like the fruit cavity index expressed mid-parent heterosis and heterobeltiosis only in a negative direction. Except for total carotenoids and lycopene, all the fruit quality traits were observed with a moderate range of heterosis.

1.1.5.2. Impact of plant growth regulators on flowering in relation to cold tolerance in papaya

An experiment was carried out to know the effect of PGRs on flowering of papaya var. Pusa Peet during 2022-23 in insect-proof net house and open field conditions with foliar application of two levels each of Salicylic acid (75 and 100 ppm) and Thiourea (250 and 300 ppm). The growth conditions and chemical treatments have shown marked significance on flowering parameters. The mean number of carpelloid flowers was recorded 4.8 in the net house conditions and 5.5 under open conditions. Among the treatments, the plants taken as control recorded the highest number of carpelloid flowers. In contrast, it was the least in the plants treated with salicylic acid 100 ppm (3.83), which was found statistically similar to other chemical applications like salicylic acid 75 ppm (4.58) and thiourea 250 ppm (4.58). It was observed that there was no significant effect of growth conditions on the number of pentandria flowers. The mean number of pentandria flowers was recorded to be 4.5 in the net house conditions, whereas it was observed to be 5.03 in the open conditions. The chemical treatments tended to affect the number of pentandria flowers significantly. The highest mean value was observed for control plants (8.33), whereas it was lowest in the plants treated with salicylic acid 100ppm (3.16). Among the possible interactions, the combination G_1C_2 (3.00) recorded the least number of pentandria flowers, while it was highest in the combination G_1C_0 (9.00). The data gives a clear indication that there is no influence of growth conditions on the length of flowers observed for the study in papaya. The longest flower was observed in the control plants (4.87 cm) which was statistically similar to the flower length of the plants treated with salicylic acid 100ppm (4.75cm). The shortest flower was observed in the treatment of thiourea 250ppm (3.81cm). Considering all the possible interactions, the longest flower was observed in the treatment C_0G_1 which was found not to be statistically significant to any other treatments. The shortest plant was observed in the interaction G_1C_3 (3.5cm) which is statistically at par with many other combinations like G_1C_2 (4.37cm), G_1C_4 (4.75cm), G_2C_0 (4.5cm), G_2C_1 (4.37cm), G_2C_3 (4.12cm) and G_2C_4 (4.5cm).

The highest plant breadth was recorded in the control plants (4.87cm) but it was statistically at par with the results given by the chemical treatment salicylic acid 100ppm (4.75cm). The least

values were recorded for the treatment of thiourea 250ppm (3.81cm). Among various interactions, the maximum flower breadth was recorded for the combination G_2C_1 (2.8cm) which is statistically dissimilar to all other combinations. The lowest mean plant breadth was recorded for the combination G_1C_3 (1.92cm). The growth conditions did not show any significant impact on pollen germination. The pollen germination in the net house (23.05%) and open conditions (24.94%) was statistically at par. Among the various chemical treatments, Salicylic acid 75ppm showed the highest pollen germination (28.5%), whereas it was found lowest in plants treated with thiourea 300ppm (20.86%). Considering all the interactions of growth conditions and chemical treatments, the highest pollen germination was recorded in the combination G2C1 (31.33%), which was statistically similar to the combination G1C3 (27.90%). The lowest pollen germination was recorded in the combination G2C4 (15.06%), which was statistically at par with the combination of G2C3 (16.91%) Compared to other treatments, the pollen viability was highest in plants treated with salicylic acid 100 ppm (50.45%). However, flowering-related parameters were positively influenced by the treatments of Salicylic acid 100 ppm.

1.1.5.3 Evaluation of mutant

The seeds of the papaya P-7-2 were treated with gamma rays 0.1, 0.15, 0.2, 0.25 and 0.3 kGy, of which two mutants viz. PM 04 and PM 28 were selected from lower doses 0.10 kGy and 0.15 kGy, showing dwarf stature and bearing height in M8 population were selected and evaluated in M9 generation. The lowest plant height (96.26 cm), plant height at flower initiation (63.32 cm), plant girth at first fruiting (64.42 mm), nodes to first flowering (46.42), days to flower initiation (76.82), length of middle internode (4.2 cm), length of petiole (82.22 cm) and plant spread in east-west direction (138.2 cm) was recorded in PM 04 while minimum plant spread in north south direction (138.8 cm) was recorded in PM 28. The tallest plant (126.78 cm), plant height at flower initiation (86.4 cm), plant girth at first fruiting (76.32 mm), nodes to first flowering (61.32), days to flower initiation (92.32), length of middle internode (5.2 cm), length of petiole (102.42 cm) and plant spread in east-west direction (156.8 cm) and north-south direction (168.6 cm) were found in control (P 7-2).

1.1.6 Objective: Sustainable use of genetic variability in pomegranate for crop improvement

Drs N.V. Singh, O.P. Awasthi, Nimisha Sharma, Kumar Durgesh (Genetics & Plant Breeding), Deeba Kamil (Plant Pathology), Mahesh Kumar (Plant Physiology), N.C. Gupta (ICAR-NIPB)

1.1.6.1 Survey, exploration collection and propagation of pomegranate germplasm

Collection of wild, cultivated and exotic pomegranate genotypes : To Fast-track pomegranate improvement programme, extensive explorations have been conducted in pomegranate diversity hot spot regions of Uttarakhand (Nainital, Almora and Pithoragarh), Himachal Pradesh (Kullu, Mandi, Solan, Chamba, Shimla and Sirmaur) and Jammu & Kashmir (Ramban, Rajauri and Doda) (Fig. 25) besides, collecting the available pomegranate germplasm and cultivated varieties from ICAR-NBPGR Regional Stations (Bhowali and Shimla) and ICAR-Central Institute for Arid Horticulture, Bikaner. *In toto*, 70 exotic pomegranate genotypes, 15 indigenous pomegranate cultivars and 60 wild pomegranate genotypes were collected from different parts of the country. Two material transfer agreements (MTA) have been signed with ICAR-NBPGR, New Delhi and ICAR-CIAH, Bikaner for the exchange of pomegranate germplasm with the aim of establishment of Field Gene Bank at IARI, New Delhi.

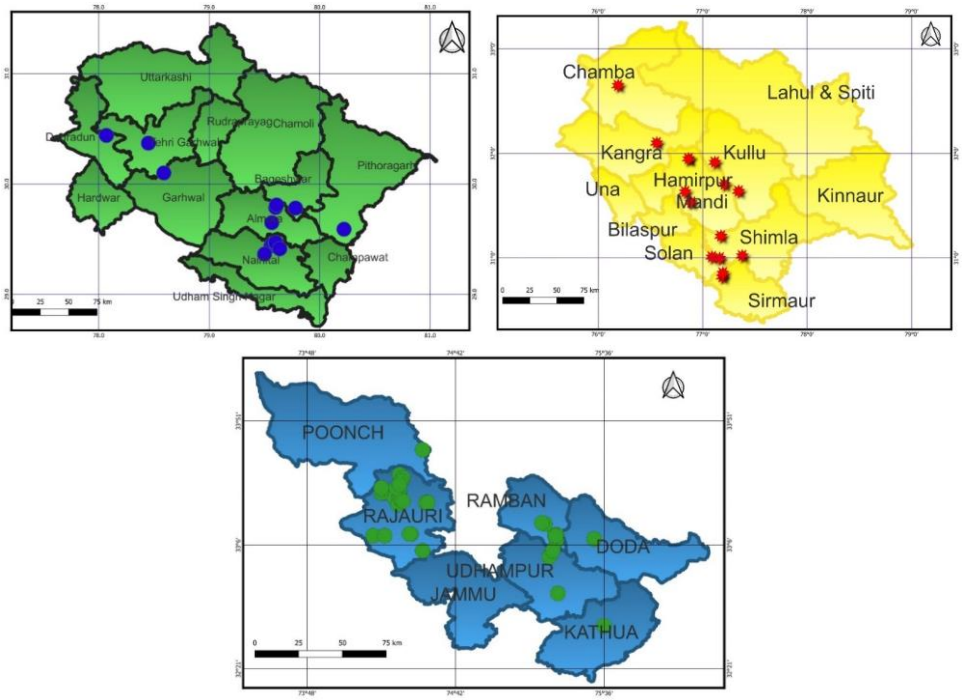


Fig. 25. Distribution map of wild pomegranate

1.1.6.1.1 Propagability of collected pomegranate genotypes:

The collected hardwood cuttings of pomegranate genotypes were rooted under controlled conditions, among exotic pomegranate accessions the cutting success ranged between 16.67 to 100 % and among indigenous wild genotypes it ranged between 0 to 66.67 %. Among cultivated indigenous pomegranate genotype the success ranged between 33.33 to 83.67%.

1.1.6.2 Morphological and biochemical characterization of germplasm

Physico-chemical characterization of fruits of collected pomegranate genotypes: The physico-chemical analysis of 32 pomegranate wild and cultivated accessions collected from H.P. and Jammu was carried out (Table 11, Fig. 26). The weight of the fruits has registered CV of 13.17 with range of 789.633 (‘Chawla’) to 31.033 g (Chenaini 1). All the recorded morphological parameters for fruits of collected genotypes varied significantly with CV ranging from 3.329 (FSI) to 21.735 (Septa weight).

Fig. 26. Variability among fruits, flower, aril and juice among collected pomegranate genotypes

Table 11. Variability in fruit morphological features among collected pomegranate genotypes

Genotype	Fr. Wt. (g)	Fr. Length (mm)	Fr. Len. w/ Crown (mm)	Fr. Dia. (mm)	Rind Thick (mm)	Septa Wt. (g)	Rind Wt. (g)	Total Aril Wt.	Fruit Shape Index	Aril/Rind
1	789.633^{a}	95.700^{ab}	112.300^{a}	110.200^{a}	3.233^{bcdef}	62.177^{abc}	318.733	406.707	0.868^{ef}	1.276^{abcde}
2	507.067^{b}	87.000^{bcd}	107.100^{ab}	96.767^{bcde}	3.500^{abcd}	67.307^{a}	182.767^{bcd}	254.530^{b}	0.899^{cdef}	1.394^{abcde}
3	556.767^{ab}	92.567^{abc}	112.267^{a}	98.200^{bcd}	3.533^{abc}	65.443^{ab}	203.150^{ab}	285.207^{ab}	0.942^{abcdef}	1.405^{abcde}
4	514.067^{b}	89.233^{abc}	106.800^{ab}	97.567^{bcd}	4.200^{a}	55.597^{abcde}	198.100^{bc}	257.590^{b}	0.914^{bcdef}	1.298^{abcde}
5	400.600^{c}	87.500^{bcd}	103.767^{ab}	88.433^{def}	3.533^{abc}	47.143^{cdef}	149.400^{de}	194.883^{cd}	0.990^{abc}	1.306^{abcde}
6	407.000^{c}	88.267^{abcd}	104.367^{ab}	91.150^{cdef}	3.967^{ab}	45.487^{def}	161.283^{cde}	198.083^{c}	0.968^{abcde}	1.235^{abcde}
7	510.500^{b}	89.467^{abc}	107.533^{a}	97.600^{bcd}	3.800^{ab}	58.053^{abcd}	194.673^{bc}	255.210^{b}	0.916^{bcdef}	1.312^{abcde}
8	293.767^{de}	83.467^{cd}	101.167^{ab}	86.033^{ef}	3.533^{abc}	41.410^{ef}	108.010^{fg}	141.867^{de}	0.970^{abcde}	1.313^{abcde}
9	367.000^{cd}	88.000^{abcd}	107.033^{ab}	89.333^{def}	3.833^{ab}	49.600^{bcdef}	141.020^{ef}	174.347^{cd}	0.985^{abcd}	1.236^{abcde}
10	620.333^{a}	99.933^{a}	110.300^{a}	106.267^{ab}	3.667^{ab}	55.130^{abcde}	240.677^{a}	321.933^{a}	0.941^{abcdef}	1.335^{abcde}
11	560.233^{ab}	98.267^{ab}	111.233^{a}	101.500^{abc}	3.833^{ab}	56.827^{abcde}	219.067^{ab}	282.033^{ab}	0.968^{abcde}	1.287^{abcde}
12	212.267^{e}	76.833^{de}	95.567^{bc}	81.267^{fg}	3.900^{ab}	35.880^{fg}	79.560^{gh}	95.427^{efg}	0.952^{abcde}	1.188^{abcde}
13	62.567^{g}	48.133^{ghij}	62.533^{defgh}	48.167^{ijk}	2.600^{efgh}	2.990^{i}	25.150^{i}	33.437^{h}	0.999^{abc}	1.329^{abcde}
14	97.733^{g}	58.833^{fg}	66.133^{defg}	59.667^{h}	2.533^{efgh}	7.213^{hi}	35.080^{i}	54.220^{fgh}	0.986^{abc}	1.546^{abcd}
15	83.500^{g}	56.100^{gh}	70.767^{de}	53.500^{hijk}	2.567^{efgh}	5.647^{i}	29.480^{i}	46.110^{fgh}	1.048^{a}	1.589^{abc}
16	87.600^{g}	52.567^{ghi}	69.667^{def}	56.133^{hi}	2.533^{efgh}	3.743^{i}	33.730^{i}	48.333^{fgh}	0.936^{bcdef}	1.433^{abcde}
17	60.733^{g}	51.000^{ghi}	62.233^{defgh}	53.200^{hijk}	2.600^{efgh}	3.983^{i}	24.130^{i}	31.200^{h}	0.960^{abcde}	1.291^{abcde}
18	31.033^{g}	37.767^{j}	53.700^{h}	44.833^{jk}	2.233^{gh}	0.603^{i}	12.443^{i}	16.577^{h}	0.843^{f}	1.319^{abcde}
19	45.300^{g}	38.800^{j}	57.400^{gh}	43.167^{k}	2.000^{h}	2.820^{i}	16.473^{i}	24.590^{h}	0.898^{cdef}	1.493^{abcde}
20	61.167^{g}	46.767^{ghij}	60.433^{efgh}	49.233^{hijk}	2.567^{efgh}	5.050^{i}	26.250^{i}	28.137^{h}	0.950^{abcdef}	1.071^{cde}
21	64.300^{g}	49.667^{ghij}	61.433^{defgh}	50.067^{hijk}	2.633^{efgh}	5.040^{i}	27.400^{i}	30.150^{h}	0.992^{abc}	1.104^{bcde}
22	77.500^{g}	52.567^{ghi}	65.700^{defg}	51.967^{hijk}	2.467^{fgh}	6.427^{i}	30.750^{i}	38.633^{h}	1.012^{ab}	1.260^{abcde}
23	70.667^{g}	52.367^{ghi}	67.500^{defg}	53.267^{hijk}	2.733^{defgh}	5.467^{i}	29.933^{i}	32.410^{h}	0.983^{abcd}	1.104^{bcde}
24	76.133^{g}	52.467^{ghi}	67.500^{defg}	51.967^{hijk}	3.200^{bcdef}	4.897^{i}	35.300^{i}	34.480^{h}	1.010^{ab}	0.981^{e}
25	86.933^{g}	53.600^{ghi}	69.400^{def}	54.867^{hij}	2.567^{efgh}	5.993^{i}	37.033^{i}	42.640^{gh}	0.977^{abcd}	1.151^{abcde}
26	111.433^{fg}	54.133^{gh}	72.567^{d}	59.700^{h}	2.800^{cdefg}	5.320^{i}	42.017^{hi}	61.980^{fgh}	0.907^{bcdef}	1.556^{abc}
27	43.033^{g}	44.900^{hij}	57.933^{fgh}	49.267^{hijk}	2.800^{cdefg}	2.563^{i}	18.427^{i}	21.100^{h}	0.908^{bcdef}	1.139^{abcde}
28	53.133^{g}	42.000^{ij}	56.367^{gh}	47.800^{ijk}	2.667^{efgh}	2.717^{i}	23.143^{i}	25.573^{h}	0.878^{def}	1.119^{bcde}
29	92.800^{g}	53.433^{ghi}	69.433^{def}	56.667^{hi}	2.367^{gh}	5.110^{i}	32.530^{i}	53.430^{fgh}	0.943^{abcdef}	1.631^{ab}
30	64.267^{g}	49.633^{ghij}	61.900^{defgh}	49.733^{hijk}	3.467^{abcd}	3.203^{i}	29.817^{i}	29.730^{h}	0.998^{abc}	0.998^{de}
31	92.400^{g}	52.567^{ghi}	65.700^{defg}	56.967^{hi}	2.400^{gh}	4.367^{i}	32.867^{i}	54.227^{fgh}	0.923^{bcdef}	1.668^{a}
32	203.933^{ef}	69.033^{ef}	87.333^{c}	73.633^{g}	3.300^{bcde}	23.073^{gh}	79.840^{gh}	99.943^{ef}	0.937^{bcdef}	1.255^{abcde}
LSD (p≤0.05)	**49.054**	**6.101**	**5.942**	**5.627**	**0.402**	**8.268**	**19.634**	**27.217**	**0.055**	**0.277**

Similarly, TSS and titratable acidity also varied significantly among genotypes with the highest TSS 19.57° Brix (KVK-3) and the highest titratable acidity 7.41% (Parnot-6). The brix acid ratio or maturity index (BAR or MI) varied significantly among genotypes with maximum BAR in var 'Chawla' (41.80) and minimum in the wild genotype Parnot-6 (2.44). Interestingly, the BAR of all the wild types is below 10 and for cultivated types it varied between 20.98 to 41.80 (Fig. 26).

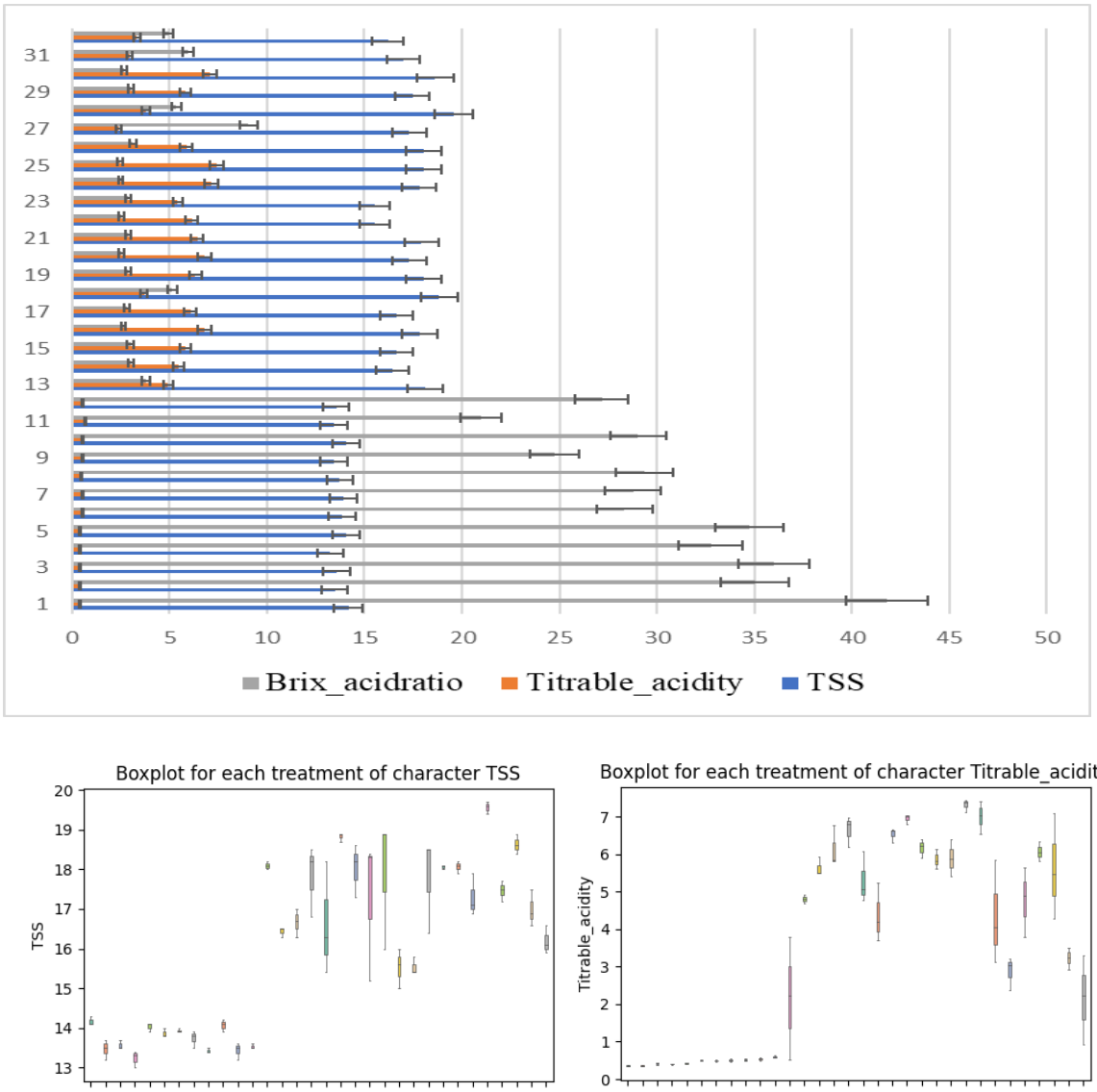


Fig. 27. Brix, acidity and BAR of fruit juice of collected pomegranate genotype

Morpho-chemical and genetic characterization of collected pomegranate genotypes: Sixty wild, cultivated and exotic pomegranate genotypes were subjected to morpho-chemical and genetic characterization, the analysis revealed considerable diversity among leaf and petiole characteristics, physiological characters and contents of key biochemical compounds like phenols, proline. The leaf shape ranging from broad elliptic to lanceolate, leaf tip from round to acute and petiole colouration from less than 25% to more than 50% (Fig. 28, Table 12).

Table 12. Leaf and petiole dimensions of collected genotype

Leaf character	Geno. variance	Phen. variance	Env. variance	CV(%)	PCV (%)	GCV (%)	Heritability	Genetic adv (%)
Leaf length (cm)	1.179	1.748	0.569	14.992	26.273	21.576	0.674	36.501
Leaf width (cm)	0.137	0.233	0.096	17.817	27.781	21.315	0.589	33.690
Petiole length (cm)	0.003	0.007	0.004	21.058	28.643	19.415	0.459	27.110

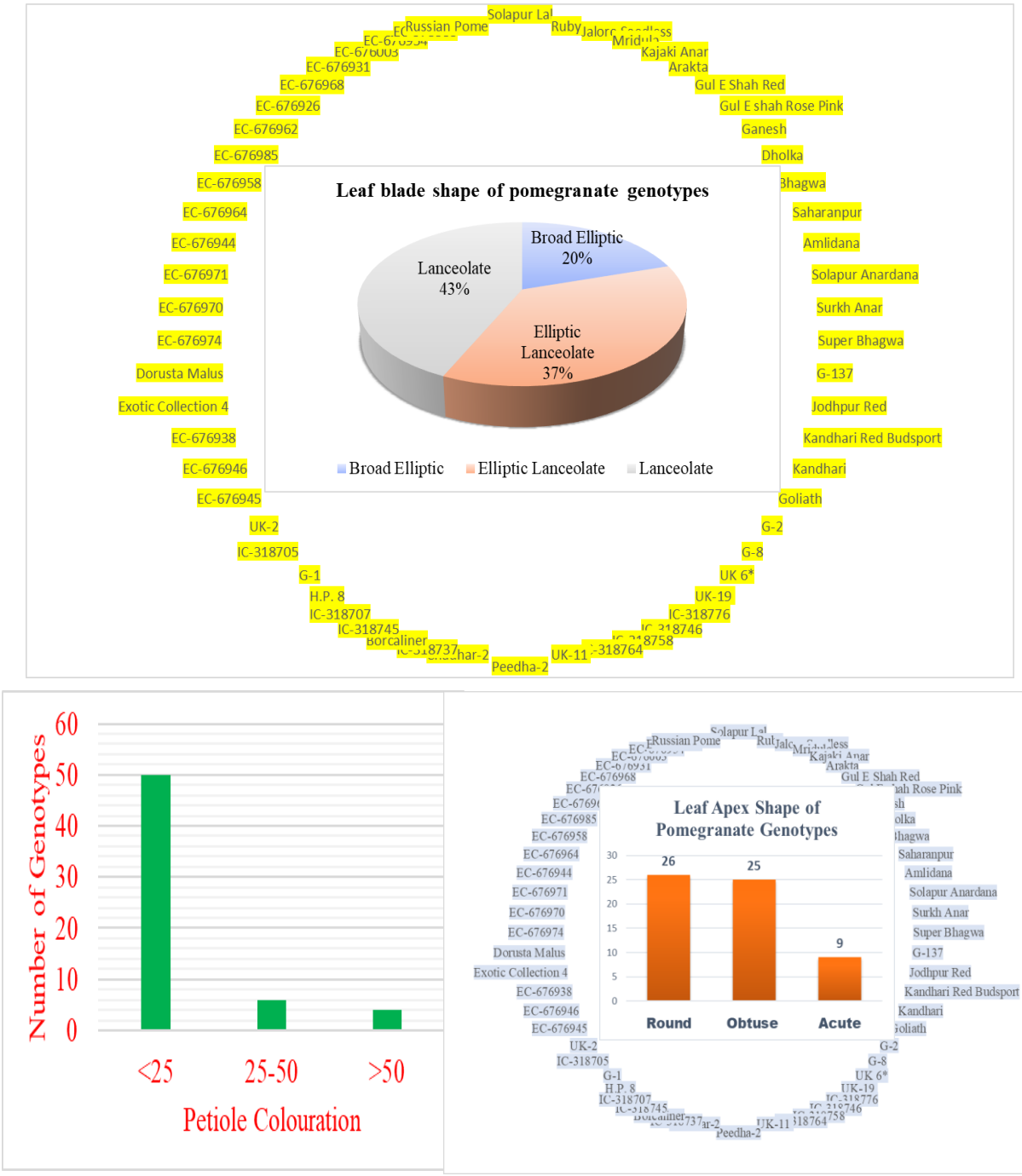


Fig. 28. Leaf morphologcial characteristics of pomegranate genotypes

The leaf chlorophyll and carotenoid contents varied significantly among the genotypes with the range of 4.340 (EC-973333) to 1.73 mg/g FW (Chadhar) and 4.169 (EC-973333) to 1.497 (Chadhar), respectively (Table 13-14, Fig. 29). Photosynthesis and other related gaseous exchange parameters also varied significantly among genotypes (Fig. 30).

Table 13. Leaf chlorophyll and carotenoid contents of pomegranate accessions

Genotype	Chl. a + Chl. b (mg/g FW)	Carotenoid (mg/g FW)	Genotype	Chl. a + Chl. b (mg/g FW)	Carotenoid (mg/g FW)
Solapur Lal	2.826^{jk}	2.711^{q}	Peedha-2	2.455^{o}	2.330^{y}
Ruby	3.330^{e}	3.446^{f}	Chadha	1.173^{g}	1.497^{g}
Jalore Seedless	2.239^{s}	2.666^{qr}	IC-318737	1.749^{a}	2.688^{qr}
Mridula	2.826^{jk}	2.567^{tu}	Bosckalinsi	1.290^{e}	1.700^{e}
Kajaki Anar	2.113^{v}	1.947^{d}	IC-318745	2.728^{l}	3.945^{a}
Arakta	2.314^{r}	2.690^{qr}	IC-318707	1.726^{a}	1.946^{d}
Gul-e-Shah Red	1.916^{y}	2.514^{vw}	H.P. 8	2.417^{pq}	2.687^{qr}
Gul-e-Shah Rose Pink	2.711^{l}	2.488^{w}	G-1	2.969^{h}	3.514^{e}
Ganesh	1.391^{d}	2.020^{c}	IC-318705	2.791^{k}	3.826^{c}
Dholka	2.893^{i}	2.654^{r}	UK-2	2.662^{m}	3.299^{h}
Bhagwa	3.382^{d}	3.542^{e}	EC-676945	2.200^{tu}	2.661^{r}
Saharanpur	2.230st	3.219^{i}	EC-676946	3.377^{d}	3.177^{j}
Amlidana	2.538^{n}	2.582st	EC-676938	2.461^{o}	3.034^{m}
Solapur Anardana	3.050^{g}	3.423^{f}	Exotic Coll. 4	2.504^{n}	3.084^{l}
Surkh Anar	2.216^{stu}	3.261^{h}	Dorusta Malus	2.901^{i}	2.786^{p}
Super Bhagwa	2.746^{l}	3.226^{i}	EC-676974	2.021^{x}	2.400^{x}
G-137	2.053^{w}	2.254^{z}	EC-676970	3.482^{c}	3.367^{g}
Jodhpur Red	2.739^{l}	2.615^{s}	EC-676971	3.021^{g}	2.788^{p}
Kandhari Red Budsport	3.029^{g}	3.026^{m}	EC-676944	2.444^{op}	2.617^{s}
Kandhari	2.513^{n}	2.858^{o}	EC-676964	2.108^{v}	2.217^{z}
Goliath	1.200^{f}	1.578^{f}	EC-676958	2.092^{v}	2.243^{z}
G-2	2.718^{l}	3.122^{kl}	EC-676985	2.515^{n}	3.283^{h}
G-8	1.777^{z}	2.093^{b}	EC-676962	2.797^{k}	3.113^{kl}
UK-6	3.312^{e}	3.681^{d}	EC-676926	2.193^{u}	3.185^{j}
UK-19 Nath Gola Ran.	3.667^{b}	3.908^{b}	EC-676968	2.842^{j}	2.949^{n}
IC-318776	2.961^{h}	3.456^{f}	EC-676931	3.643^{b}	3.134^{k}
IC-318746	1.671^{b}	2.535^{uv}	EC-676003	2.818^{jk}	2.924^{n}
IC-318758	3.197^{f}	2.784^{p}	EC-676954	3.799^{a}	3.424^{f}
IC-318764	1.585^{c}	2.079^{b}	EC-973333	4.340	4.169
UK-11 Jal Dulhar	2.410^{q}	2.484^{w}	Russian Pome	1.942^{y}	2.164^{a}
LSD (p≤0.05)	**0.032**	**0.016**	**LSD (p≤0.05)**	**0.028**	**0.031**

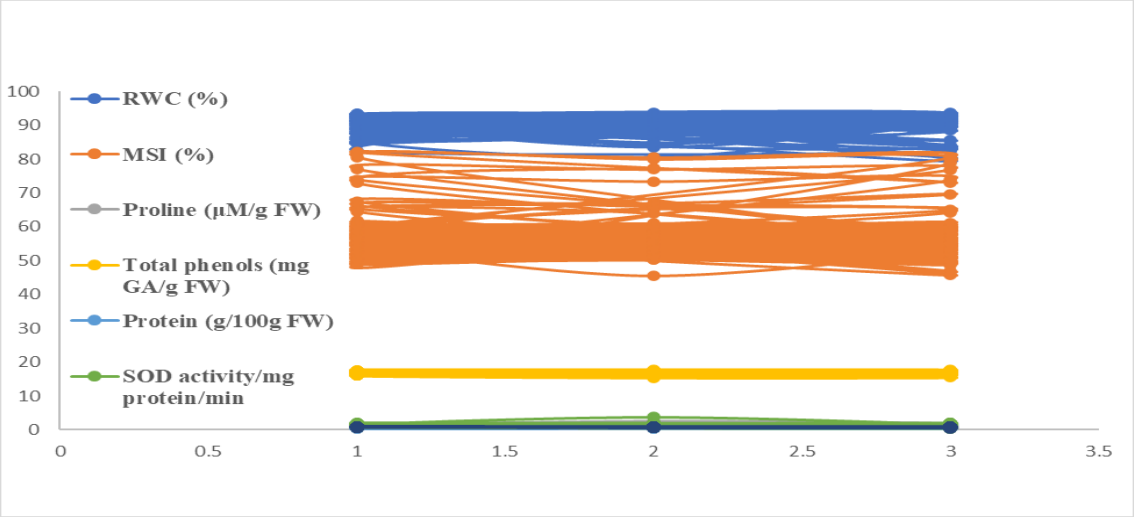


Fig. 29. Physiological and biochemical variations among collected pomegranate genotypes

1.1.6.3 Molecular characterization of pomegranate germplasm including creation, validation and utilization of available genomic resources (SSRs, mi-RNA SSRs, Hv SSRs, EST-SSRs, Genome and transcriptome resources) for germplasm characterization

A set of 25 polymorphic SSRs and HvSSRs have been used to estimate the genetic diversity among the 60 pomegranate genotypes. *In toto*, 52 SSR markers including hypervariable SSRs have been screened and based on their ability to differentiate genotypes 25 were selected for diversity analysis study.

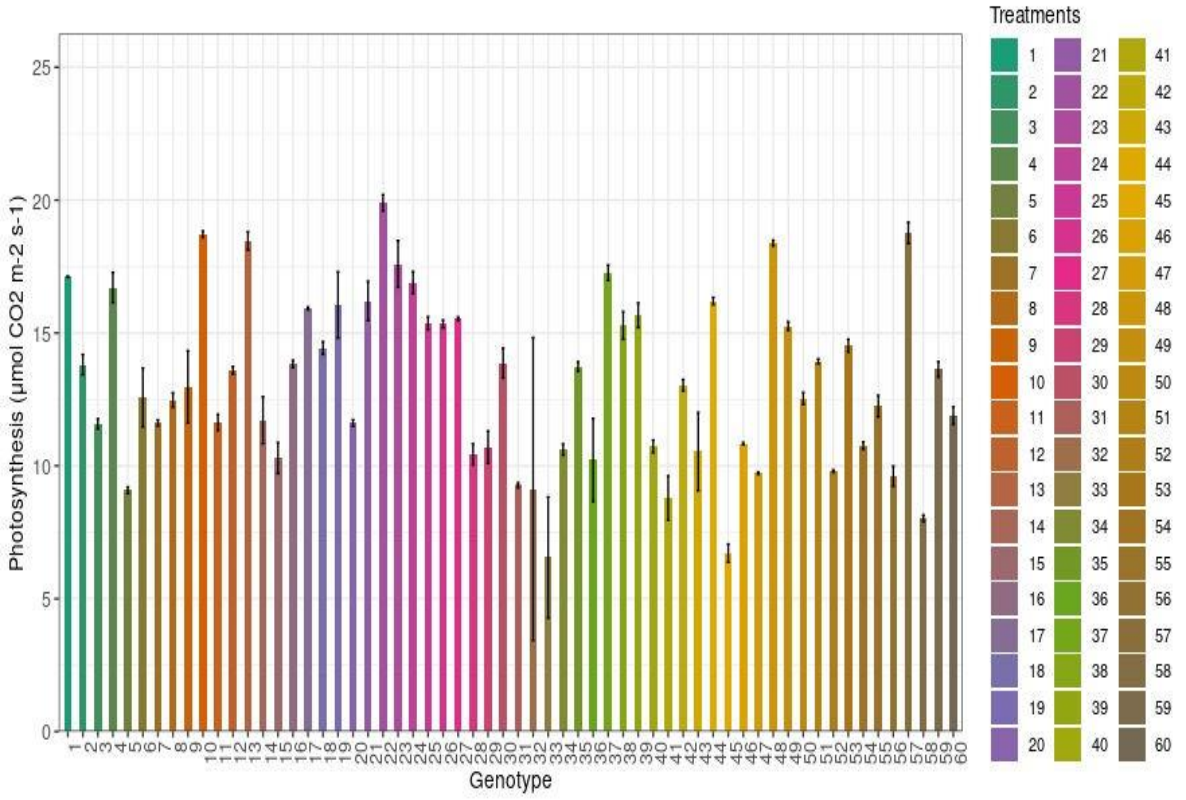


Fig. 30. Variable photosynthetic rate among the collected pomegranate genotypes

1.1.6.4 Screening of pomegranate germplasm against *Xanthomonas axonopodis* pv. *punicae*, *Ceratocystis fimbriata,* root knot nematode and salinity

Fig. 31. *Xanthomonas axonopodis* pv. *punicae* infection on wild pomegranate leaves

To screen the pomegranate germplasm against biotic and abiotic stresses particularly against bacterial blight causing *Xanthomonas axonopodis* pv. *punicae*, the pure cultures of this pathogens were established from the infected tissue samples of pomegranate collected from different parts of the country namely Maharashtra, H.P. and Jammu. Similarly, pure culture of *Ceratocystis fimbriata* has also been maintained after isolation of pathogen from the infected pomegranate tissues. Preliminary screening using 15 genotypes have been have been conducted in an isolated chamber with controlled environment facility (Fig. 31). The *Xanthomonas axonopodis* pv. *punicae* containing NGA broth serially diluted to have the inoculum load of 1 x 10^{7-8} cfu/ml, cultured on NGA broth and sprayed three times at 48 hrs. interval on nursery plants of different pomegranate genotypes covered with 50 microns transparent polythene with pin holes to maintain humidity (RH 95±5% and Temperature 28 ±2°C). All the genotypes developed characteristic oily spot symptoms with incidence ranging from 10% (IC-318707) to 43.33% (‘Bhagwa’). Similarly, a preliminary pot culture experiment comprising of 15 pomegranate genotypes were inoculated with *Ceratocystis fimbriata* (1x10^{8} cfu/ml, a loopful pathogen cultured on PDA broth, diluted broth poured twice at fortnight interval @25ml/kg potting mixture). The delayed wilting was observed in wild pomegranate genotypes IC-318706 and IC-318707 where as other genotypes started showing wilt symptoms within a month after first inoculation.

2. Production Technology

2.1 Development of technologies for enhancing productivity and improving quality of fruit crops

Drs O. P. Awasthi, A. K. Dubey, R. M. Sharma, Kanhaiya Singh, A. Nagaraja, A.K. Goswami, Nimisha Sharma, Madhubala Thakre, Nayan Deepak G., Chavlesh Kumar, K.K. Pramanik, A. K. Shukla, Santosh Watpade and Natash Gurang

2.1.1 Objective: Rootstock research on fruit crops for dwarfness and improved fruit quality

2.1.1.1 Manipulation of canopy vigour in mango scion cultivars using rootstocks

Drs A. K. Dubey, R. M. Sharma, Nayan Deepak and Nimisha Sharma

2.1.1.1.1 Growth yield and fruit quality of vigorous and semi vigorous mango varieties on different rootstocks

The performance of three semi vigorous IARI released mango cultivars (Pusa Arunima, Pusa Surya and Amrapali) was assessed on five polyembryonic rootstocks (PAM 1, K 3, PAM 2, Kurukkan and Olour). Of the tested rootstocks, Olour proved most vigorous rootstock for Pusa Arunima (267.88 m^3 CV), Pusa Surya (204.63 m^3 CV) and Amrapali (165.53 m^3 CV). Kurukkan rootstock proved most productive for Pusa Arunima (69.27 Kg $tree^{-1}$) and Amrapali (80.63 Kg $tree^{-1}$), while similar result in Pusa Surya (52.09 Kg $tree^{-1}$) was noticed on Olour rootstock. Within the cultivar, all the rootstocks were found statistically similar in respect of fruit size. The similar results were observed for TSS contents in Pus Arunima and Pusa Surya, however, TSS was registered statistically higher in Amrapali on Kurukkan and K 3 (20.97°B in each) rootstocks than other rootstocks. The content of titratable acids did not differ significantly in Pusa Arunima due to rootstocks, however, in Pusa Surya and Amrapali, the lowest acidity was recorded on Olour rootstock. The fruits of Pusa Surya and Amrapali showed the lowest content of acid, while all the rootstocks were found similar statistically in Pusa Arunima. The rootstock showed the highest content of ascorbic acid in Pusa Arunima (33.92 mg/100g pulp) and Pusa Surya (30.40 mg/100g pulp) with no significant difference with K 3 and PAM 1, respectively. The rootstocks Kurukkan, K 3 and PAM 1 proved similar statistically to have the higher ascorbic acid content in the fruit of Amrapali (Table 14).

The nutrient concentration (P, K, Ca and S) was significantly influenced in the leaves of mango varieties by rootstocks tested (Table 15). PAM 2 and K 3 proved better for nutrient accumulation in the leaves of Pusa Arunima and Amrapali, while in Pusa Surya, the similar results were obtained on PAM 1 rootstock.

Table 14. Rootstock influence on the fruit quality of semi vigorous mango cultivars

Cultivar/Rootstock	Yield (Kg/tree)	Fruit weight (g)	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100g)
Pusa Arunima					
PAM 2	51.59b	239.77c	23.77a	0.19dc	33.92dc
Kurukkan	69.27a	215.25dc	22.10ba	0.18de	29.33dfe
Olour	45.42cb	195.95dc	22.07bac	0.15def	27.50gfe
K 3	27.59ed	192.63dc	22.53ba	0.14def	29.33def
PAM 1	31.24ed	210.43dc	23.27a	0.17de	24.75gfh
Pusa Surya					
PAM 2	23.75e	337.00ba	18.93e	0.32a	30.40dce
Kurukkan	23.08e	324.33ba	19.53ed	0.32a	26.60gfe
Olour	52.09b	309.00ba	19.43ed	0.25bc	20.43h
K 3	21.76e	383.00a	18.40e	0.33a	22.80gh
PAM 1	36.87cd	321.33ba	18.33e	0.28ba	29.45def
Amrapali					
PAM 2	52.31b	168.97d	19.13ed	0.13ef	42.19b
Kurukkan	80.63a	166.13d	20.97bdc	0.19de	45.24ba
Olour	76.43a	213.73dc	18.93e	0.10f	35.58c
K 3	56.12b	169.30d	20.97bdc	0.13ef	50.83a
PAM 1	49.59b	178.70dc	20.07edc	0.13ef	47.78ba
LSD ($P \leq 0.05$)	12.41	61.75	2.01	0.06	5.64

Table 15. Rootstock influence on the leaf nutrient concentration of semi vigorous mango cultivars

Cultivar/Rootstock	Phosphorus (%)	Potassium (%)	Calcium (%)	Sulphur (%)
Pusa Arunima				
PAM 2	0.295a	0.53a	3.31e	0.187cfde
Kurukkan	0.236cb	0.41cb	2.99g	0.179gh
Olour	0.249b	0.37cd	2.98g	0.180gfh
K 3	0.293a	0.33e	3.44g	0.187gcfde
PAM 1	0.241cb	0.39cb	3.21f	0.172h
Pusa Surya				
PAM 2	0.174f	0.41b	3.57c	0.181gfe
Kurukkan	0.207d	0.40cb	2.25i	0.183fgde
Olour	0.151g	0.34ed	3.24f	0.181gf
K 3	0.234c	0.37cbd	3.52c	0.190cd
PAM 1	0.233c	0.33e	3.73b	0.213a
Amrapali				
PAM 2	0.216d	0.39cb	2.95g	0.202b
Kurukkan	0.173f	0.34ed	3.20f	0.189cde
Olour	0.211d	0.38cb	3.56c	0.194cb
K 3	0.167f	0.31e	3.92a	0.202b
PAM 1	0.188e	0.33e	2.72h	0.192c
LSD (*P≤ 0.05*)	0.013	0.04	0.06	0.08

In this experiment, the performance of two vigorous mango varieties (Mallika and Dashehari) was assessed on three rootstocks (PAM 2, Kurukkan and Olour). The tree vigour of scion varieties was not influenced significantly by the rootstocks, however, the rootstocks gave the significant impact on fruit quality attributes (Table 16). Olour proved best rootstock to improve the fruit quality of Dashehari and Mallika, however, the heaviest fruits of Mallika were recorded, while grown on PAM 2 rootstock.

Table 16. Rootstock influence on yield and fruit quality of vigorous mango varieties

Variety/Rootstock	Yield	Fruit weight (g)	Pulp weight (g)	Pulp (%)	TSS (°B)	Acidity (%)	Ascorbic acid (mg/100g)
Dashehari							
K-5	35.44dc	141.00c	97.30d	70.29bc	19.97c	0.29ba	28.33c
Kurukkan	17.45d	141.50c	107.58d	76.06c	20.33c	0.25c	28.35c
Olour	64.22ba	183.67b	138.50c	75.51ba	20.93c	0.25c	29.58cb
Mallika							
K-5	86.15a	274.00a	180.17b	66.89c	22.00b	0.25c	32.62b
Kurukkan	63.65ba	236.67a	167.50b	71.37bac	21.90b	0.28b	33.08b
Olour	57.28bc	266.33a	196.50a	71.72bac	23.23a	0.31a	37.00a
LSD (*P≤ 0.05*)	24.37	38.28	13.50	5.48	1.23	0.02	3.51

2.1.2.2 Screening of mango rootstocks under drought

In the first experiment, one-year-old polyembryonic mango rootstock genotypes were exposed to normal irrigation and drought conditions for 28 days. The higher decrease in leaf area (LA) and leaf area ratio (LAR) was found in Kurukkan (25.92%) and K-5 (17.76%), respectively. Moreover, all the genotypes showed an increase in specific leaf area, being higher in OLOP-6/2 and Kurukkan (>12). Genotypes OLOP-Z-6/2 and OPK-3-7/12 showed a decrease in specific leaf weight, while rest witnessed an increase under drought. The shoot dry weight decreased in all genotypes ranging from 22.72% in Kurukkan to 81.89% in OLOP-6/2, while root dry weight showed less decline in K-5 (18.67%), and both Kurukkan and K-5 inhibited less whole plant dry

weight under moisture deficit. Root surface area (RSA) increased under drought in K-5 and OLOP-Z-6/2, but others exhibited a reverse trend. Except OLOP-Z-6/2, rest of the genotype showed an enhancement in a number of root tips (NRT), but higher in K-5 (100%) under water deficit. Genotype K-5 and Kurukkan showed a lesser decline in photosynthetic rate (*A*), while transpiration rate (*E*) was inhibited more in K-5 (61.0%). Total phenol content (TPC) and sugar content (TS) upregulated highest in Olour and K-5, respectively. Polyphenol oxidase activity (PPO) increased in all the genotypes under water deficit and a higher increase was recorded in OLOP-6/2 (>300%). Malondialdehyde (MDA) and hydrogen peroxide (H_2O_2) showed the upregulation in all the genotypes with a lower increase in Kurukkan for MDA and K-5 for H_2O_2 under water stress.

2.1.1.3 Evaluation of sweet orange scion varieties on newly developed rootstocks

Drs R. M. Sharma, A. K. Dubey, Sudhir Kumar (Pl. Phy.) and V. K. Sharma (SSAC)

To standardize the rootstock(s) for IARI released sweet orange cvs. Pusa Sharad and Pusa Round, their performance was assessed on seven rootstocks (RLC-6, RLC 7, C 35, X 639, Yama Mikan, Soh Sarkar and Jatti Khatti). RLC-6 and C 35 rootstocks proved most vigorous for Pusa Sharad (157.49-190.19 m^3 CV) and Pusa Round (138.37-173.95 m^3 CV) (Table 17). Rootstock RLC-7 proved most productive rootstock for Pusa Sharad (68.56 Kg $tree^{-1}$) and Pusa Round (50.23 Kg $tree^{-1}$) sweet oranges. RLC-7 rootstock also yielded the heaviest fruits of Pusa Sharad (301.66g), while Yama Mikan and C 35 proved similar statistically to produce the heavier fruits of Pusa Round (242.44-248.93g) than other rootstocks. Karna Khatta rootstock proved effective to produce fruits of Pusa Sharad with thinnest peel (2.91 mm) and higher TSS (9.76°B) and juice contents (57.25%) with no significant difference with C 35 (for TSS) and RLC 6 (for juice content) rootstocks. In Pusa Round cultivar, RLC 6 and X 639 tended to show the higher TSS contents (9.76-10.04°B) statistically than other rootstocks. The highest juice content in the fruits of Pusa Round (54.66%) was registered on X 639, having similarity statistically with RLC 6 and RLC 7 rootstocks (Table 18).

Table 17. Rootstock influence on tree vigour and leaf nutrient status of sweet orange

Treatment	Plant height (m)	Canopy volume (m^3)	Sodium (%)	Potassium (%)	Phosphorus (%)	Sulphur (%)	Calcium (%)
Pusa Sharad							
RLC-6	4.13a	190.19a	0.19edc	0.79f	0.31c	0.26c	2.91a
C 35	3.82bac	157.49bac	0.201ba	0.95c	0.29ef	0.24ed	2.64c
X 639	3.82bac	158.66bac	0.182f	0.56h	0.28gf	0.19g	2.15g
Yama Mikan	3.60bdac	106.78edf	0.175g	0.64g	0.30ed	0.24ed	2.46e
Soh Sarkar	3.68bac	124.94edc	0.187edf	0.80f	0.30d	0.23e	2.38f
RLC-7	3.79bac	139.54bdc	0.203a	1.18a	0.27ih	0.31a	2.46e
Jatti Khatti	3.80bac	151.26bac	0.197bac	0.99c	0.33b	0.27c	2.44e
Pusa Round							
RLC-6	3.64bdac	138.37bdc	0.181gf	1.18a	0.28gh	0.29a	1.99i
C-35	3.84ba	173.95b	0.182f	0.91d	0.27ih	0.19g	1.31k
X-639	3.02fe	74.44gf	0.195bc	0.67g	0.32c	0.20f	2.53d
Yama Mikan	3.14de	67.37gf	0.186ef	0.77f	0.24j	0.20f	2.75b
Soh Sarkar	3.29dec	92.44ef	0.193dc	0.98c	0.36a	0.23e	1.66j
RLC-7	2.53f	37.03g	0.191edc	1.08b	0.27i	0.31a	2.03h
Jatti Khatti	3.34bdec	97.37edf	0.191edc	0.84e	0.34b	0.24d	1.66j
LSD (*P≤ 0.05*)	0.54	44.14	0.007	0.03	0.01	0.01	0.04

Table 18. Rootstock influence on yield and fruit quality of sweet orange

Cultivar/ Rootstock	Yield (Kg/tree)	Fruit weight (g)	Peel thickness (mm)	TSS (°B)	Juice (%)	Ascorbic acid (mg 100 ml juice)	Acidity (%)
Pusa Sharad							
RLC-6	45.18cd	216.32ed	3.18d	9.68bac	57.30a	49.01bac	0.78bcd
C-35	50.00cb	248.428b	4.57bc	10.08a	50.66bdc	44.38dc	0.91a
X-639	38.70ed	225.55cebd	3.62cd	9.04bdc	53.06bac	42.84de	0.73ecd
Yama Mikan	45.57cd	225.32cebd	3.85bcd	9.70bac	52.96bac	35.13f	0.83ba
Soh Sarkar	48.33cb	223.41ced	2.91d	9.76ba	57.25a	50.55ba	0.77bcd
RLC-7	68.56a	301.66a	5.79a	8.02e	49.51dc	51.47a	0.80bc
Jatti Khatti	56.38b	241.73cb	4.45bc	9.2bdc	52.56bac	35.88f	0.73ecd
Pusa Round							
RLC-6	33.90ef	209.95ed	3.16d	10.04a	54.28bac	37.54fe	0.78bcd
C-35	25.97f	248.93b	3.69cd	8.74ed	50.13bdc	48.23bdac	0.66e
X 639	35.14e	202.37e	2.91d	9.76ba	54.66ba	43.22de	0.69ed
Yama Mikan	38.47ed	245.03cb	4.77ba	8.96dc	47.33d	45.12bdc	0.70ecd
Soh Sarkar	37.07ed	215.84ed	4.41bc	8.16e	50.61bdc	36.03f	0.68ed
RLC-7	50.23cb	242.44cb	3.56cd	8.52ed	53.91bac	33.19f	0.63e
Jatti Khatti	48.17cb	230.01cbd	4.36bc	8.44ed	51.43bdc	33.08f	0.85ba
LSD ($P \leq 0.05$)	8.57	24.38	1.06	0.77	5.07	5.78	0.10

2.1.1.4 Modulation of abiotic stress effect in citrus

Drs. O.P. Awasthi, R. M. Sharma, A. K. Dubey, O.P. Awasthi, Sudhir Kumar (Pl. Phy.) and V. K. Sharma

2.1.1.4.1 Rootstock mediated alteration in citrus scion cultivars under NaCl stress

Citrus cultivar Pusa Sharad grafted on eleven different rootstocks viz., *Jatti khatti*, X–639, CRH–12, NRCC–1, NRCC–2, NRCC–3, NRCC–4, NRCC–5, Troyer citrange, CRH–47 and Cleopatra mandarin were evaluated for varying levels of water salinity stress of 30 and 60 mM of sodium chloride (NaCl) including control. The findings of the study revealed that Pusa Sharad grafted onto Cleopatra mandarin, X–639, CRH–47, NRCC–1, and NRCC–3 rootstocks exhibited the least reduction in scion height, leaf area ratio, root-to-shoot ratio, total chlorophyll content, total carotenoid content, photosynthesis rate, stomatal conductance, internal CO_2 concentration, and transpiration rate compared to other rootstocks. Therefore, rootstock selection can enhance salt-tolerance potential by increasing pigment content and strengthening the photosystem (Fig. 32).

Fig. 32. Rootstock induced grade scale of salt damage index (SDI) of sweet orange scion Pusa Sharad as A. No damage B. Medium damage C. High damage D. Acute damage

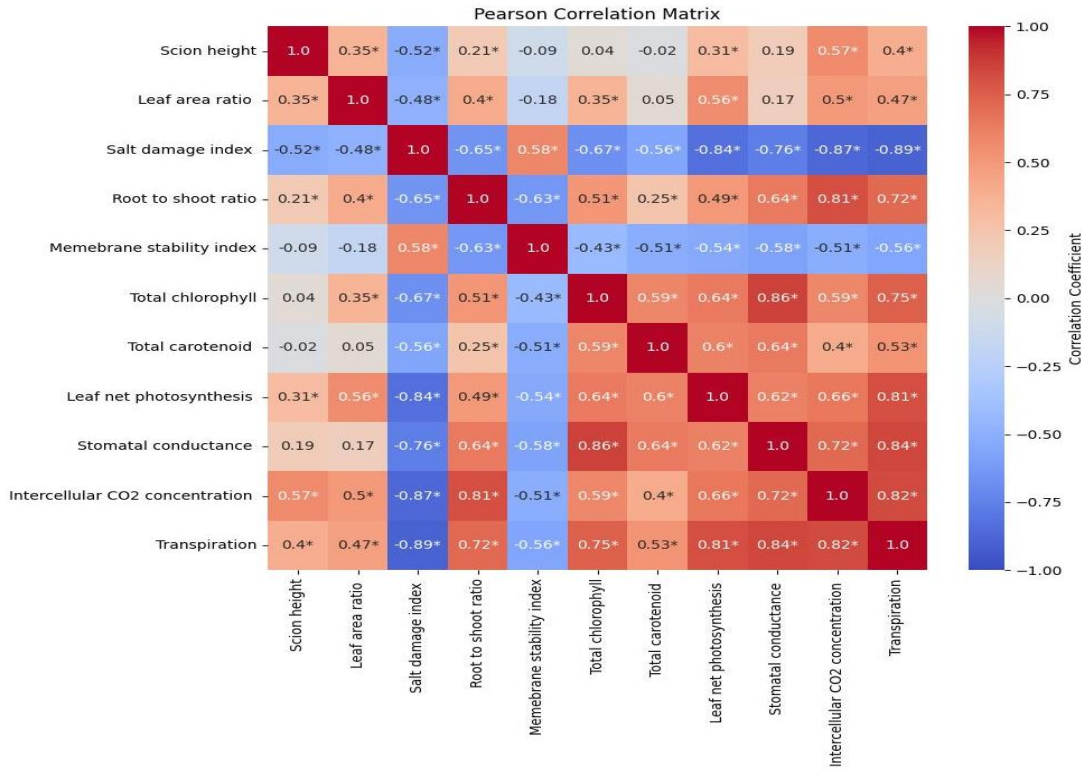


Fig. 33. Pearson's correlation matrix in the scion of PS grafted onto 11 different rootstocks at control, 30 mM and 60 mM of NaCl stress. SH: Scion height, LAR: Leaf area ratio, SDI: Salt damage index, RSR: Root to shoot ratio, CHL: Total chlorophyll, CAR: Total carotenoid, PHO: Leaf net photosynthesis, SC: Stomatal conductance, ICC: Internal CO_2 concentration and T: Transpiration rate

2.1.1.4.2 Drought stress management through citrus rootstock genotypes

Drs. A.K Dubey, R. M. Sharma, V. K Sharma (SSAC), Anil Dahuja (Biochem) and Dr S, Lekshmi (PP)

Studies on reciprocal graft combination in citrus under drought conditions:

A study was conducted to understand the scion-rootstock interaction in contrasting citrus rootstocks, drought sensitive, *Citrus jambhiri* Lush cv. Jatti Khatti (JK) and drought tolerant, X639 (*C. reshni* Hort. ex Tan. × *Poncirous trifoliata*), responded to water deficit and re-watering through reciprocal grafting. The result showed that X639 rootstock grafted with X639 or JK scion showed least reduction in scion height, leaf number, leaf area, increase in root biomass and lower wilt score and drought injury index. The root traits significantly improved in plant combinations with X639 rootstock under water deficit. After re-watering, the plant combinations with X639 as rootstocks displayed good recovery as indicated by increase in scion and root traits. Further, X639 rootstock minimized reduction in leaf relative water content and membrane stability index under water deficit stress. Further, X639/X639 and X639/JK showed higher levels of total phenols (94.36; 82.13 mg GAE g^{-1} of FW) and lower level of proline content (41.36; 52.61 µmol g^{-1} of FW) as compared to JK/JK and JK/X639, respectively. JK/JK exhibited the highest lipid peroxidation and the lower catalase and glutathione reductase activities across various water regimes. Overall, X639 rootstock promoted scion growth, while JK rootstock enhanced scion survival, evident from leaf shedding and reduced leaf area. These findings provide valuable insights for citrus cultivation in areas with diverse water availability.

2.1.1.4.3 Drought mitigation through new generation chemicals in citrus

Drs., R. M. Sharma, A.K Dubey, Sudhir Kumar (PP) and V. K Sharma (SSAC)

To optimize concentration to mitigate drought stress, single foliar spray of proline (30, 40 and 50mM) and spermidine (0.001, 0.01 and 0.1 mM) was given after 8 days of induction of drought stress in contrasting citrus genotypes X639 (drought tolerant) and cleopatra mandarin (drought susceptible). Priming treatments had significant impact on number of leaves, leaf wilt score and leaf drop only in Cleopatra mandarin. The reduction in defoliation due to foliar priming treatments, compared to drought stress alone, ranged between 17% to 38% in Cleopatra mandarin. Foliar priming significantly improved fresh plant biomass under drought stress. Dry shoot weight of X639 and dry root weight of Cleopatra mandarin were significantly higher with all priming treatments than control-drought stress. Use of spermidine 0.1mM for foliar priming under drought stress in Cleopatra increased fresh root: shoot ratio significantly. Dry root: shoot ratio in both genotypes was at par for all priming treatments. Root parameters *viz.*, length, projected area, surface area, average diameter, root volume and number of root tips, forks and crossings were significantly higher in priming treatments in Cleopatra mandarin only (Fig. 34).

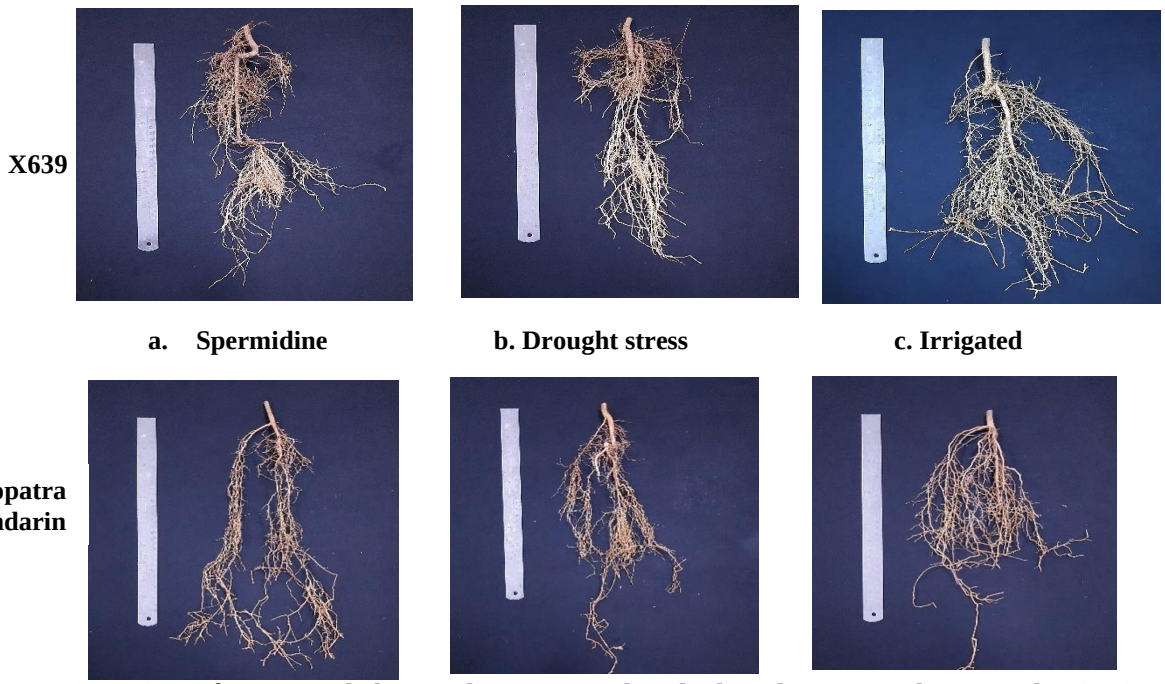


Fig. 34. Comparison of root morphology under a. Spermidine, b. drought stress and c. normal irrigation in contrasting genotypes, X639 (upper row) and cleopatra mandarin (lower row)

2.1.2 Objective: Evolving technologies for efficient input and canopy management in selected fruit crops

Drs Kanhiya Singh and Manish Srivastav

2.1.2.1 Effect of integrated nutrient management on newly developed mango hybrids

The application of 100 % recommended dose of fertilizers (RDF) alone and alongwith AMF (250 g) and *Azotobacter* (250 g), 75% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) and 50% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) was studied on mango hybrids. There was significant effect of INM treatments, mango cultivars and interaction effect of INM treatments and mango cultivars on tree height and canopy diameter. The maximum tree height (5.76 m) was recorded in treatment NPK 75 % + AMF (250g) + *Azotobacter* (250g) followed by NPK 100% + AMF (250g) + *Azotobacter* (250g) while minimum (3.67 m) was recorded in treatment T8. Among cultivars, the maximum tree height (4.86m) was found in Pusa Arunima, and minimum (4.37 m) in Pusa Pratibha.

The maximum canopy diameter in north-south direction (3.56 m) was recorded in treatment NPK 75 % + AMF (250g)+ *Azotobacter* (250g) followed by 3.42 m in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). Among the cultivars, the maximum canopy diameter in north- south direction (3.42 m) was found in Pusa Arunima and it was minimum (2.45 m) in Pusa Pratibha. Maximum canopy diameter in east-west direction (3.66 m) was recorded in treatment NPK 75 % + AMF (250g)+ *Azotobacter* (250g) followed by 3.52 m in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). Among cultivars, maximum canopy diameter in east-west direction (3.42 m) was found in Pusa Arunima and minimum (2.42 m) in Pusa Pratibha. The highest number of fruits (35.86) was recorded in treatment NPK 75 % + AMF (250g)+ *Azotobacter* (250g) followed by 33.24 in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). Among varieties, the highest number of fruits/plant (36.44) was recorded in Pusa Arunima and lowest (26.92) in Pusa Pratibha. The maximum weight of fruit (210.12 g) was recorded in treatment NPK 75% + AMF (250g)+ *Azotobacter* (250g) followed by 190.22 g in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit weight (220.12 g) was found in Pusa Arunima followed by Pusa Shreshth (172.42 g) and minimum (132.24 g) in Pusa Pratibha. The highest yield (26.42 kg) was recorded in the treatment NPK 75 % + AMF (250g)+ *Azotobacter* (250g) followed by 24.76 kg in treatment NPK 100% + AMF (250g) + *Azotobacter* (250g). Among varieties, Pusa Arunima was proved to be the most productive (25.64 kg) followed by Pusa Lalima (22.64 kg), and it was minimum (16.82 kg) in Pusa Pratibha. Application of NPK 75% + AMF (250g) + Azotobacter (250g) per plant was found most effective to improve yield and NPK content in leaves as compared to other treatments.

3. Agreements/ Commercial Licensing of Pusa mango varieties under Outreach Programme (ORP) on Up-scaling of New Mango Varieties and details of MoA for different fruit crops

Drs Jai Prakash, Sanjay Kumar Singh, Manish Srivastav and Kanhiya Singh

Commercial Licensing of six IARI Mango varieties namely, Pusa Arunima Pusa Surya, Pusa Lalima, Pusa Pratibha, Pusa Peetamber and Pusa Shreshtha was done with M/s Shelter Agri-Horti Farms Pvt. Ltd., Kolkata, West Bengal to facilitate establishment of Mother block of 1000 Plants. The two lots of the scion were supplied during September and November 2023.

Visited mother blocks of the M/s S. L. Orchard, Panchkula for monitoring and guidance

4. Intellectual property

4.1 Varieties developed and commercialized

Table 19. Details of varieties developed and commercialized (Table 19)

S. No.	Name of the Technology/MoA Signed	Brief of the technology/ Details	TRL Level	Road map/ Time line for commercialization
1.	**Pusa Aarushi** (Pant Prabhat × Arka Kiran)	It is a smooth-skinned pink pulp guava hybrid having excellent nutritional quality, high yield potential and fruit quality traits with very soft seeded character.	7	MoA signed with M/s. Nirmal Nursery, Uttarakhand.
2.	**Pusa Pratiksha** (Hisar Safeda × Purple Guava)	It is a white pulp guava hybrid having an excellent flavour and fruit quality traits like with a very soft seeded character.	7	MoA signed with M/s. Nirmal Nursery, Uttarakhand
3.	MoA signed between M/s S.L. Orchards, Haryana and ICAR- IARI, New Delhi	MoA signed for commercialization of Pusa Lalima, Pusa Pitamber, Pusa Pratibha and Pusa Shreshth mango hybrids	9	A revenue of Rs. 5,31,000/- has been generated as License fee from licensee Ms. Shelter Agri-Horti Farms, Pvt. Ltd., West Bengal

4.2 Planting material multiplied

Division of Fruits & Horticultural Technology has multiplied the 15403 plants of different varieties of mandated fruit crops (Table 20), and sold to the growers, SAUs, technology partners and nurserymen.

Table 20. Details of planting materials multiplied and sold during 2023.

Crop & variety	Type of planting material	Quantity
Mango		
Amrapali	Grafted Plants & scion	2267
Mallika	Grafted Plants & scion	854
Pusa Arunima	Grafted Plants & scion	1737
Pusa Surya	Grafted Plants & scion	426
Pusa Lalima	Grafted Plants & scion	787
Pusa Pratibha	Grafted Plants & scion	488
Pusa Shrestha	Grafted Plants & scion	820
Pusa Peetamber	Grafted Plants & scion	561
Pusa Manohari	Grafted Plants & scion	820
Pusa Deepshikha	Grafted Plants & scion	23
Citrus		
Kagzi Kalan	Sapling (Air layered)	1224
Pusa Round	Grafted Plants	202
Pusa Sharad	Grafted Plants	300
Pusa Udit	Sapling & Seedling	76
Pusa Abhinav	Sapling & Seedling	82

Pusa Arun	Grafted Plants	64
Pusa Lemon-1	Sapling & Seedling	05
Grapes		
Pusa Navrang	Saplings/rooted cuttings and cuttings	2164
Pusa Urvashi	Saplings/rooted cuttings and cuttings	06
Pusa Trishar	Saplings/rooted cuttings and cuttings	747
Pusa Aditi	Saplings/rooted cuttings and cuttings	562
Pusa Swarnika	Saplings/rooted cuttings and cuttings	11
Pusa Purple Seedless	Saplings/rooted cuttings and cuttings	25
Guava		
Pusa Aarushi	Saplings (Grafted Plants)	587
Pusa Pratiksha	Saplings (Grafted Plants)	557
Papaya		
Pusa Nanha	Seedling	08

5. Linkages and Collaboration

Four collaborative research projects were operational in the Division of Fruits & Horticultural Technology during the period of report (Table 21)

Table 21. List of the collaborative projects.

S N	Name of project	PI	Collaboration
1	DBT- Identification of QTL(s) for fruit quality trait(s) in mango (*Mangifera indica* L.)	Dr Manish Srivastav	ICAR- NBPGR, New Delhi ICAR- NIPB, New Delhi
2	Network project on Functional Genomics and Genetic Modification- Mango	Dr S.K. Singh	ICAR- NIPB, New Delhi ICAR- CISH, Lucknow ICAR- IIHR, Bengaluru
3	Genetic Improvement of Fruit Crops for Desirable Horticultural Traits	Dr S.K. Singh & Dr. A.K. Dubey (w.e.f 13/12/2022)	ICAR- NBPGR, New Delhi ICAR-CPRI, Shimla Dr YS PUH&F, Solan ICAR-NIPB, New Delhi
4	Development of Technologies for enhancing productivity and improving quality of Fruit Crops	Dr O.P. Awasthi	ICAR-IARI Regional Station, Amartara Cottage, Shimla ICAR-IARI Regional Station, Kalimpong, Darjeeling

6. Education

a. Summary of UG and PG education

During the year 2023, total 15 PG students including 3 M.Sc. and 12 Ph.D. students taken admission in the Division. Total 16 students including 7 Ph.D. and 9 M.Sc. students received degree during IARI Convocation, New Delhi in the Bharat Ratna Shri C Subramanium Hall of NASC. PG students actively participated in seminar/ symposia organized by different societies and brought laurel to the division by winning awards and recognition. Our students actively participate in sports and cultural activities organized by IARI and ICAR.

b. No. of students admitted

A total of 15 students got admitted in the FHT Division including 03 of M Sc and 12 of Ph D (Table 22)

Table 22. Details of students admitted during 2023

S. No.	Name of student	Roll No.	M Sc / Ph D
1	Ms Sushma Kumari	22028	M Sc
2	Ms. Ankita Kashyap	22030	M Sc
3	Mr. Prabhanshu Mishra	22029	M Sc
4	Mr. Ladup Lepcha	12694	Ph D
5	Mr. R. Prabhanjan B.	12695	Ph D
6	Ms. Abeer Ali	12696	Ph D
7	Ms. Prashita Rao	12697	Ph D
8	Mr. Asheesh Kumar	12698	Ph D
9	Ms. Pooja	12699	Ph D
10	Mr. Kuldeep Kumar	12700	Ph D
11	Ms. Ishu Kumari	12701	Ph D
12	Ms. Sangeeta	12702	Ph D
13	Ms. Kalieswari K.	12703	Ph D
14	Ms. Damini	12704	Ph D
15	Ms. Phyu Phyu Lei Yi	12894	Ph D

(c) Fellowships secured by the students (other than IARI Fellowship)

Table 23. Details of fellowships secured by the students

S. No.	Name of student	Name of Fellowship	Awarding Agency
1	Ms. Sushma Kumari	JRF	ICAR
2	Ms. Ankita Kashyap	JRF	ICAR
3	Mr Prabhanshu Mishra	JRF	ICAR
4	Mr Laduplepcha	SRF	ICAR
5	Mr R. Prabhanjan B.	SRF	ICAR
6	Ms. Abeer Ali	SRF	ICAR
7	Ms. Prashita Rao	SRF	IARI
8	Mr. Ashish Kumar	SRF	IARI
9	Ms. Pooja	SRF	ICAR
10	Mr. Kuldeep Kumar	SRF	IARI
11	Ms. Ishu Kumari	SRF	ICAR
12	Ms. Sangeeta	SRF	IARI

13	Ms. Kalieswari K.	SRF	IARI
14	Ms. Damini	SRF	ICAR
15	Ms. Phyu Phyu Lei Yi	BIMSTEC	Ministry of External Affairs

(d) Students awarded with degrees during 2022 Convocation

A total of sixteen students were awarded with the degree including 07 of Ph D and 09 of M Sc (Table 23).

Table 24. Details of students awarded with the degrees

S. No.	M. Sc/ Ph. D	Name of the student	Name of Chairman, Advisory Committee	Title of Thesis
1	M.Sc.	Kalieswari K.	Dr Kanhaiya Singh	Bioactive compounds and antioxidant activities of papaya (*Carica papaya* L.) hybrids
2	M.Sc.	Amina Shukoor	Dr Jai Prakash	Morpho-physio-biochemical and molecular characterization of maternal Olour mango progenies
3	M.Sc.	Hatkari Vittal	Dr Nimisha Sharma	Impact of different rootstocks on carbohydrate metabolism and nutrient contents in regular and irregular mango (*Mangifera indica* L.) varieties
4	M.Sc.	Gulshan Kumar	Dr Manish Srivastav	Characterization of promising mango hybrids using DUS descriptor and new hyper variable SSR markers
5	M.Sc.	Vasudev N.	Dr Awtar Singh	Induction of autotetraploids in pummelo [(*Citrus maxima* (Burm.) Merr.]
6	M.Sc.	Akshay	Dr Madhubala Thakre	Characterization for morphological traits and pigment variations in selected guava F_1s during winter season
7	M.Sc.	Abeer Ali	Dr Bikash Das	Standardization of biomass mulching for improving fruit yield and quality of guava (*Psidium guajava* L.) under rainfed uplands of Jharkhand
8	M.Sc.	Vasanth Vinayak Vara Prasad N.	Dr V.B. Patel	Understanding the fruit cracking mechanism in bael (*Aegle marmelos* L.) Corea.) using biochemical and RNA-seq approach
9	M.Sc.	Amar B.A.	Dr Kanhaiya Singh	Optimization of scion age and time of grafting in jackfruit (*Artocarpus heterophyllus* LAM.) under eastern plateau hill region
10	Ph.D.	Satyabrata Pradhan	Dr S.K. Singh	*In vitro* regeneration and salinity tolerance studies on mono-and poly-embryonic mango (*Mangifera indica* L.) genotypes
11	Ph.D.	Preeti Singh	Dr Jai Prakash	Studies on heterosis and inheritance of horticultural traits in papaya (*Carica papaya* L.)
12	Ph.D.	Ashok Kumar Mahawer	Dr R.M. Sharma	Studies on the resistance mechanism of citrus canker

13	Ph.D.	Manikrao Darhsna Kadam	Dr A.K. Dubey	Abiotic stress tolerance studies on citrus rootstock hybrids
14	Ph.D.	Naveen Kumar Maurya	Dr A. K. Goswami	Physio-biochemical and molecular characterization of papaya genotypes under low temperature stress
15	Ph.D.	Kuldeep Pandey	Dr Manish Srivastav	In vitro regeneration and genetic transformation studies on mango (*Mangifera indica* L.)
16	Ph.D.	Nayan Deepak G.	Dr A. Nagaraja	Biochemical analysis, identification and expression profiling of ascorbic acid (vitamin C) biosynthesis genes in guava (*Psidium guajava* L.)

(e) Research Scholars registered in different universities for Ph.D.: Nil

(f) Awards and Recognitions received by the students

(i) Ms. Theivanai, M., conferred with Budding Scientist Award (2023) for her Ph.D. Thesis by Indian Society of Horticultural Research Development in a Progressive Horticulture Conclave (2024) organised by Navsari agriculture University, Navsari during 18-20 January 2024.

(ii) Received Best Oral Presentation award in Progressive Horticulture Conclave-2023, organized by G.B. Pant University of Agriculture and Technology, Pantnagar, during 3-5 February 2023.

(iii) Mr. Kripa Shankar nominated for overseas training at the **University of Western Australia** (UWA), Perth between 03-03-2023 to 20-03-2023, sponsored by NAHEP-CAAST

(g) Events organized by student club of the Division: Nil

7. Internship & mentorship by the Scientist

During 2023, five students outside the ICAR-IARI, New Delhi have completed their internship (Table 25).

Table 25. Details of interns

S. No.	Student's name	University	Topic	Duration	Mentor
1	Mr. Shivam Bains	Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu	Physico-chemical properties of an *ex-situ* collection of wild and cultivated pomegranate genotypes and visit to Plant Phenomics Centre & CCF	Nov 3 – Dec 4, 2023	Dr. N.V. Singh
2	Mr. Abhiraj Kumar	Sher-e-Kashmir University of Agricultural Sciences & Technology, Jammu	Management of Citrus germplasm	Nov 3 – Dec 4, 2023	Dr. R.M. Sharma
3	Ms. Anshika Singh	Manav Rachna International Institute of Research and Studies, Faridabad	Identification of tetraploids and triploids of Kinnow mandarin and Mosambi sweet orange using cytological and Flow cytometry techniques	January 9 – June 13, 2023	Dr. Awtar Singh

8. Awards and Recognitions received by the Scientist

Category wise

a) ICAR/National Awards: 1

Table. 26 Details of awards received by the Scientists

S. No.	Name of the Scientist	Name of the Award	Awarding agency	Nature of award (Medal/ Certificate/ amount of Cash price)	Achievement for which the award was given (Life-time achievement/ any specific discover / technology etc for which the award was given)
1.	Dr. O. P. Awasthi	Outstanding Teacher Award.	Indian Society of Horticultural Research Development	Medal & Certificate	Outstanding Teacher Award

b) Fellowship/Associateship of National academies

c) Fellowship of Professional societies of the relevant Discipline

d) Best Poster awards: nil

e) Other awards/ Recognition

The other awards and recognitions are summarized in Table 27.

Table 27. Awards/ Recognitions

S. No.	Details	Organization	Scientist
1	Editor of the Indian Journal of Horticulture	Indian Academy of Horticultural Sciences, New Delhi	Dr. R.M. Sharma
2	Member Editorial Board-2023, Pusa Surabhi	Indian Agricultural Research Institute, New Delhi	Dr. R.M. Sharma
3	Member Institute Management Committee	ICAR-CCRI, Nagpur	Dr. R.M. Sharma
4	Member, Board of School	Nagaland University	Dr. R.M. Sharma

9. Budget Estimates

a) Head-wise budget received and expenditure under EFC: An amount of Rs 57.50 Lacs was received by the Division as General Head.

b) **Budget received from external grant**

Division of Fruits & Horticultural Technology was allowed to utilize the funds of previous year by the funding agency i.e. DBT (Table 28).

Table 28. External grant received

S. No.	Name of the project	Name of the PI	Name of the Co-PIs	Duration (From--- to ----)	Sanctioned budget	Budget Received by the Division during the year 2022	Institutional charge for 2021-22
1.	Identification of QTL(s) for fruit quality trait(s) in mango (*Mangifera indica* L.)	Dr. Manish Srivastav	Dr. SK Singh Dr NK Singh Dr Nimisha Sharma Dr Rakesh Singh	13.09.2018 to 31.12.2022	80.64 Lakhs	Nil	Rs. 29,597 as interest on capital deposited in Bharat Kosh, Govt. of India
2.	Evaluation of effect of POLY-4 (Polyhalite) on Kinnow mandarin	Dr. Kanhaiya Singh	Dr. O. P. Awasthi Dr. Jai Prakash	2022-2025	64.03 Lakhs	20.90 Lakh	3.51 lakh

c) **Revenue generated**

The total revenue of Rs 25.38 Lacs/= was generated through the sale of planting materials (Rs. 14..25 lacs) and the fruit auction of experimental orchards (Rs.11.09 Lacs).

10. Publication

a) Research and review Publications (in peer reviewed NAAS rated journals only)

S. N.	Bibliography of Publication	NAAS Rating (2023)	Impact Factor (Thomson Reuters)
1.	Murugan, T., Awasthi, O. P., Singh, S. K., Chawla, G., Solanke, A, U., Kumar, S. and Jha, G. (2023). Molecular and histological validation of modified in ovulo nucellus culture based high competency direct somatic embryogenesis and amplitude true- to-the-type plantlet. recovery in Kinnow mandarin. *Frontiers in Plant Science*, 14:.01-17,DOI 10.3389/fpls.2023.1116151.	12.63	5.6
2.	Srivastav, M., Radadiya, N., Rmamachandra, S., …….Singh, N.K. (2023). High resolution mapping of QTLs for fruit color and firmness in Amrapali/Sensation mango hybrids. *Frontiers in Plant Science*, 14: 1135285.	12.63	5.6
3.	Singh NV, Sharma J, Dongare MD, Gharate R, Chinchure S, Manjunatha, N., Parashuram, S., Patil, P.G., Babu, K.D., Mundewadikar, D.M., …..Marathe, R.A. (2023). *In vitro* and in planta antagonistic effect of endophytic bacteria on blight causing *Xanthomonas axonopodis* pv. *punicae*: a destructive pathogen of pomegranate. *Microorganisms*, 11(1):5. 10.3390/microorganisms11010005	10.93	4.5
4.	Singh, N., Sharma, R.M. Dubey, A.K., Awasthi, O.P., Porat, R., Saha, S., Bhardwaj, C., Sevanthi, A.M., Kumar A., Sharma, N. and Carmi, N. (2023). Harvesting maturity assessment of newly developed citrus hybrids (*Citrus maxima* Merr. _ *Citrus sinensis* (L.) Osbeck) for optimum juice quality. *Plants*, 12: 3978. https://doi.org/ 10.3390/plants12233978.	10.66	4.5
5.	Chand, L., Sharma, N., Sharma, R. M., Pandey, R., Sathee, L. and Dubey, A. K. (2023). Physio-biochemical and growth response of contrasting reciprocal grafting in citrus under water deficit and rehydration. *Journal of Plant Growth Regulation*, https://doi.org/10.1007/s00344-023-11179-6.	10.64	4.8
6.	Singh N., Sharma, R. M., Dubey, A. K., Awasthi, O. P., Saha, S., Bharadwaj, C., Sharma, V. K., Sevanthi, A. M., Kumar, A. and Deepak. (2023). Citrus improvement for enhanced mineral nutrients in fruit juice through interspecific hybridization. Journal of Food Composition and Analysis, 119, https://doi.org/10.1016/j.jfca.2023.105259.	10.52	5.5
7.	Shivran, M., Sharma, N.*, Dubey, A.K., Singh, S.K., Sharma, N., Muthusamy, V., Singh, N., Jain, M., Kumar, N., Singh, B.P., Singh, N. and Sharma, R.M. (2023). Scion/Rootstock interaction studies for quality traits in mango (*Mangifera indica* L.) varieties. *Agronomy*. 13 (1): 204.	9.95	3.95
8.	Vittal, H., Sharma, N., Dubey, A.K., Shivran, M., Singh, S.K., Meena, M.C., Kumar, N., Sharma, N., Singh, N., Pandey, R. and Bollinedi, H. (2023). Rootstock-mediated carbohydrate metabolism, nutrient contents, and physiological modifications in regular and alternate mango (*Mangifera indica* L.) scion varieties. *Plos One*, 18(5): e0284910.	9.75	3.75
9.	Mahawer, A. K., Dubey, A. K., Awasthi, O. P., Singh, D., Dahuja, A., Sevanthi, A. M., Kumar, A., Goswami, A. K., Sharma, N.,	8.92	2.92

	Yadav, J., Kesharwani, A. K., Kashyap, A. S., Kulshreshtha, A., Singh, R. P., Morade, A. and Sharma, R. M.2023. Elucidation of Physio- Biochemical Changes in *Citrus* spp. incited by *Xanthomonas citri* pv. *citri*. *Horticulturae,* 9: 324. https: // doi. org/ 10. 3390/ horticulturae 9030324		
10.	Thakre, M., Hanamant, S., Ram, M.K., Senapati, R., Rudra, S. G., Saha, S., Nagaraja, A., Verma, M.K., Krishanan, S. G., Varghese, E. and Sevanthi, A.M. (2023). Pigment composition analysis of fruit pulp in the recombinant progenies reveals the polygenic nature of pulp color inheritance in guava (*Psidium guajava* L.). *Tree Geneticsand Genomes*, 19(2):20.	8.4	2.4
11.	Saxena, V., Bharti, M.K., Kumar, P., Singh, J. and Patel, V.B., 2023. Effect of zinc uptake on alcohol dehydrogenase, protein and mineral contents of hydroponically grown chickpea (Cicer arietinum). *Journal of Plant Nutrition*, *46*(6):867-876.	8.28	2.28
12.	Lal, N., Singh, A., Kumar, A., Marboh, E.S., Gupta, A.K., Nath, V. and Pandey, S.D. (2023). Hurdles in developing hybrids: experience from a decade of hybridization. *Euphytica,* 219:106 https://doi.org/10.1007/s10681-023-03234-w.	8.19	2.19
13.	Ankad, H., Dhillion, A., Thakre, M., Senapati, R., Kumar, R., Nayan Deepak, G., Nagaraja, A., Verma, M.K., Krishnan, S. G. and Mithra, A. (2023). Breeding for pulp colour in Guava: current status and opportunities. *The Journal of Horticultural Science and Biotechnology*, https://doi.org/10.1080/14620316.2023.2251995.	7.92	1.92
14.	Sharma, N., Shivran, M., Singh, N., Dubey, A.K., Singh, S.K., Sharma, N., Gupta, R., Vittal, H., Singh, B.P., Sevanthi, A.M. and Singh, N.K. (2023). Differential gene expression associated with flower development of mango (*Mangifera indica* L.) varieties with different shelf-life. *Gene Expression Patterns*, 47:119301	7.49	1.49
15.	Kumar, G., Srivastav, M.*, Sreekanth, H.S., Kumar, C., Prakash, J., Singh, S.K. 2023. SSR assisted identification of mango (Mangifera indica L.) hybrids and development of DNA barcodes. *Indian Journal of Genetics and Plant Breeding*, 83(03): 437-445.	7.34	1.34
16.	Kumar, S., Awasthi, O. P., Pandey, Renu., Dubey A. K. and Sharma, R. M. (2023). Production performance and Fruit quality of Gamma irradiated mutants of "Kinnow" mandarin (Citrus nobilis Loureiro x Citrus deliciosa Tenora). *Erwerbs-Obstbau* . https://doi.org/10.1007/s10341-023-00832-9.	7.21	1.21
17.	Shivran M, Sharma N*, Sharma N, Muthusamy V, Dubey AK, Singh SK, Singh BP, Kumar N, Sevanthi AM, Singh N and Singh N K. (2023). Development of ripening gene specific markers and their association with shelf-life in mango varieties. *National Academy of Science Letters*, https://doi.org/10.1007/s40009-023-01207-0.	6.65	0.65
18.	Kripa Shankar, Awasthi, O.P., Dubey, A.K., Singh, A., Prakash, J. and Doltabadian, A. (2023). Rootstock mediated alteration in morphology and photosystem in sweet orange (*Citrus sinensis*) scion cv. Pusa Sharad under NaCl stress. *Indian Journal of Agricultural Sciences*, 93 (10): 1103–1107. https://doi.org/10.56093/ijas.v93i10.139420.	6.37	0.37
19.	Prusty, Reena, Awasthi, O. P*., Singh, S. K. and Kanika. 2023. In vitroshoot organogenesis in sweet orange (*Citrus sinensis* L.) cv. Mosambi and the effect of ethylene adsorbents on micro-shoot quality. *Plant Cell, Tissue and Organ Culture*, 153 (3): 1-13	6.37	0.37

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20.	Sandeep, Dubey, A. K., Sharma, N., Awasthi, O. P., Sharma, R. M. and Dahuja, A.2023. Genotypic differences in root architecture and physiological characteristics in mango *(Mangifera indica*) under drought. *Indian Journal Agricultural Sciences*, 93 (8): 868–874	6.37	0.37
21.	Maurya, N. K., Goswami, A. K.*, Singh, S. K., Prakash, J., Goswami, S., Chinnusamy, V., and Pradhan, S. (2023). Thermal stress-induced physiological and biochemical alterations in papaya genotypes. *Indian Journal of Horticulture*, 80(1): 86-92.	6.00	--
22.	Prusty, Reena., Awasthi, O. P*., Singh, S. K. and Bharadwaj, C. 2023. Indirect somatic embryogenesis in sweet orange cv. "Mosambi".2023. *Indian Journal of Horticulture*, 80 (1): 17-24.	6.00	--
23.	Sagore, B., Singh, K., Jai Prakash, Srivastava, V., Vignesh, M. and Yadav, B. K. (2023). Elucidating the effect of plant bioregulators on embryo maturation for shortening the breeding cycle in papaya. *Indian Journal of Horticulture*, 80(3): 233-238.	6.00	--
24.	Sharma, N., Sharma, R.M. and Dubey, A.K. (2023). Production and verification of lemon× acid lime hybrid populations via embryo rescue. *Indian Journal of Horticulture*, 80(1):24-9.	6.00	-
25.	Sharma, R. M., Dubey, A. K., Awasthi, O. P., Sharma, V. K. and Kumar, A. (2023). Long-term performance of grapefruit cultivars on different rootstocks. *Indian Journal of Horticulture*, 80 (1): 73-79.	6.00	--
26.	Vittal, H., Sharma, N., Shivran, M., Sharma, N., Dubey, A.K., Singh, S.K., Sharma, R.M., Singh, B.P., Bollinedi, H., Meena, M.C., Pandey, R. (2023). Impact of carbohydrate metabolism pathways on bearing habit of mango (*Mangifera indica* L.) genotypes. *Journal of Horticultural Sciences*, 18(1):122-7.	6.00	--
27.	Mahawer, A.K., Sharma, R.M., Dubey, A.K., Awasthi, O.P., Singh, D., Dahuja, A. Mithra, S.V.A.C.R. and Kumar, A. 2023. Effect of weather parameters and citrus genotypes on the occurrence of citrus canker incited by *Xanthomonas citri* pv. *citri*. *Indian Phytopathology*, https://doi.org/10.1007/s42360-023-00606-z.	5.95	--
28.	Kumar, G., Srivastav, M.*, H.S., S., Prakash, J., Singh, S. K. and Patel, V.B. (2023). Elucidating Diversity among Mango (Mangifera indica L.) Hybrids based on Morphological Characters using DUS Guidelines. *Indian Journal of Plant Genetic Resources*, DOI: 10.61949/0976-1926.2023.v36i03.07.	5.54	--
29.	Awachare, C., Karunakaran, G., Madhavi, M., Sakthivel, T., Shivashankara, K.S., Singh, N.V., Raigond, P., Shilpa, P. and Muralidhara, B.M. (2023). Studies on biochemical profiling of 72 avocado (*Persea americana* Mill.) accessions. *The Pharma Innovation Journal*, 12:40-44.	5.23	--
30.	Awachare, C., Karunakaran, G., Madhavi, M., Sakthivel, T., Shivashankara, K.S., Singh, N.V., and Muralidhara, B.M. (2023). Studies on morphological characterization of 72 avocado (*Persea americana* Mill.) accessions. *The Pharma Innovation Journal*, 12: 1970-75.	5.23	--
31.	Sagore, B., **Singh, K.,** Jai Prakash, Singh, S. K., Srivastava, V., Vignesh, M. and Yadav, B. K. (2023). Effect of plant growth regulators on fruit quality of papaya. *The Pharma Innovation Journal*, 12(8):481-485	5.23	--
32.	Vittal, H., Sharma, N. and Shivran, M. (2023). Impact of rootstock via carbohydrate metabolism and nutrients on bearing habit of fruit	4.64	--

	crops. *Mysore Journal of Agricultural Sciences,* 57(1)		
33.	Grace, U.M., Verma, M.K., Singh, S.K., Patel, V.B., Sharma, V.K., Sethi, S., Pandey, R., Mir, A.I. and Kumar, C., (2023). Elemental Variation of Berry Mineral Nutrient Content in Early Maturing Grapes Genotypes Grown Under Sub-tropical Climate. *Grape Insight* :81-88.	--	--

b) List of Research papers published in Conference, Symposia and Other (Only papers):

i. Shivran M and **Sharma N.** 2022. Molecular basis of shelf-life in fruit crops: A Review. *Mysore Journal of Agricultural Sciences*, 56 (3): 29-39. (NAAS-4.8)

ii. Hatkari V, **Sharma N**, Shivran M, Singh S K, Dubey A K, Bollinedi H, Meena M C, Pandey R and Singh N K. 2022. Impact of carbohydrate metabolism changes on bearing habit of mango (*Mangifera indica* L.). In: *DBT sponsored Int. Conference on Recent Progress in Biological Science*. pp.27-30. March 3-5, 2022.

iii. Prakash J and Chaitra T S 2022 Breeding Strategies for climate smart fruit crops, 48-53, p.204Souvnier and Abstract book (Ed.). In: *National Seminar on Climate Resilient Horticulture: Adaption and Mitigation Strategies*, August 13-14, 2022 at Nalanda, Bihar.

c) List of Books / Chapter in books

1. Goswami A K, Kumar N, Goswami S, Kumar C, Vinutha T, Awasthi O P. 2023. Next generation molecular tools for accelerating the breeding efficiency in horticultural crops - A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. ISBN 978 81 701972 63, 202 p.
2. Goswami A K, Kumar N, Kumar C, Goswami S, Vinutha T, Singh N V, Singh S, Namita, Jat GS, Awasthi O P. 2023. Advances in experimental designs and genomics for tailoring horticultural crops- A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. TB -ICN: 313/2023, 266 p.
3. Pal R K, Prakash J, Dey S S, Saikia A, Patel V B, Deka, B C. 2023. 10th Indian Horticulture Congress - Unleashing Horticultural Potential for Self-Reliant India. Souvenir cum Lead & Oral Paper Abstracts, College of Veterinary Science Campus, Assam Agricultural University, Khanapara, Guwahati, Assam, India from 06-09, Nov, 2023, organized by the Indian Academy of Horticultural Sciences, 260 p.
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5. Singh N P, Kumar M, Singh N V, Singh Y. 2023. Climate resilient agriculture for sustainable production. Today and Tomorrow's Printers and Publishers, New Delhi, 295 p. ISBN: 9789391734633.
6. Karunakaran G, Nayan Deepak G, Muralidhara B M, Nagaraja A, **Thakre M,** Rajendiran S, Rani A T, Madhu G S. 2023. Introduction to plant nursery. **In:** *Training manual on "Skill development in nursery management of horticulture crops".* Eds. Karunakaran, G., Rajendiran, S., Muralidhara, B. M., Nayan Deepak G., Rani, A. T., Madhu, G. S., Arivalagan, M. Division of Fruit Crops, ICAR-IIHR, Bengaluru and Central Horticultural Experiment Station, Chettalli, Kodagu pp: 1-9.
7. **Sharma N**, Dubey A K and Ravishankar R. 2023. *Mango Nutrigenomics for Nutritional Security*. pp.1-15 Compendium of Crop Genome Designing for Nutraceuticals (Eds. Kole *et al*.) Springer, Nature.

8. Kumar C, Goswami A K, Singh N V and Prakash, J. 2023. Application of New Plant Breeding Techniques in Grapes for Trait Specific Varietal Development. **In:** Goswami A K, Kumar N, Goswami S, Kumar C, Vinutha T, Awasthi O P (Eds.), Next generation molecular tools for accelerating the breeding efficiency in horticultural crops - A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. ISBN 978 81 7019 72 63. pp.62-67.
9. Chadha K L, Patel V B, Singh, S K, Prakash J, Dey S S. 2023. Horticulture for Health, Livelihood and Economy (edited). Kruger Brentt Publishers UK. 405 p. Ltd. ISBN 978-1-78715-256-4.
10. Parashuram S, Roopa Sowjanya P, Babu K D, Singh N V, Patil P G. 2023. Pomegranate genetic resources: conservation and utilization. **In**: Fruit and nut crops, Handbooks of crop diversity: conservation and use of plant genetic resources, P. E. Rajasekharn, V. R. Rao (eds.), Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-99-1586-6_18-1
11. Goswami, A.K. Goswami S, Kumar C, Chandana M R. 2023. New paradigm in guava breeding programme: Global Scenario. **In:** Goswami, A.K., Kumar, N., Goswami, S., Kumar, C., Vinutha, T., Awasthi, O.P. (Eds.), Next generation molecular tools for accelerating the breeding efficiency in horticultural crops - A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. ISBN 978 81 7019 72 63. pp.68-78.
12. Kumar L, Patel S S, Paradkar V K, Kumar C, Tiwari U, Jain S, Mehra P, Nishant, Tiwari R K, Kumar N, Sharma T, Goswami A K. 2023. "Souvenir and Abstract Book" 7th National Convention: AGRIVISION- 2023 "Sustainable Agriculture for a Self-Reliant India" May 05-06, 2023 at National Agricultural Science Complex, New Delhi.Pp:95
13. Singh N V, Kumar C, Goswami A K. 2023. Importance and scope of plant tissue culture in fruit crops especial reference to crop improvement. **In:** Goswami, A.K., Kumar, N., Goswami, S., Kumar, C., Vinutha, T., Awasthi, O.P. (Eds.), Next generation molecular tools for accelerating the breeding efficiency in horticultural crops - A Training Manual. ICAR-Indian Agricultural ResearchInstitute, New Delhi India. ISBN 978 81 7019 72 63. pp.94-99.
14. Singh N V, Kumar C, Goswami A K. 2023. Application of Tissue Culture in Fruit Improvement Program: Utility & Limitations. **In:** Goswami, A.K., Kumar, N., Kumar, C., Goswami, S., Vinutha, T., Singh, N.V., Singh, S., Namita., Jat, G.S., and Awasthi, O.P. (Eds.), Advances in experimental designs and genomics for tailoring horticultural crops- A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. TB -ICN: 313/2023 pp. 37-47.
15. Goswami A K, Goswami S, Kumar C, Chandana M R, Jadhav P J, Pramannik K, Saini S, Thakre M, Sushravya M K. 2023. Framework for Guava Breeding Programs: A Global Perspective. **In:** Goswami, A.K., Kumar, N., Kumar, C., Goswami, S., Vinutha, T., Singh, N.V., Singh, S., Namita., Jat, G.S., and Awasthi, O.P. (Eds.), Advances in experimental designs and genomics for tailoring horticultural crops- A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. TB -ICN: 313/2023 pp 88-104.
16. Thakre M, Akshay, Pooja, Poonam, Jagga S, Kumar C. 2023. Understanding the molecular and metabolic pathways involved in pigment synthesis in horticultural crops. **In:** Goswami, A.K., Kumar, N., Kumar, C., Goswami, S., Vinutha, T., Singh, N.V. Singh, S., Namita., Jat, G.S., and Awasthi, O.P. (Eds.), Advances in experimental designs and genomics for tailoring horticultural crops- A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi India. TB -ICN: 313/2023 pp. 167-175.
17. Kumar C, Goswami A K, Singh N V, Thakre M, Prakash J. 2023. Genomic- aided Grape Breeding. **In:** Goswami, A.K., Kumar, N., Kumar, C., Goswami, S., Vinutha, T., Singh,

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19. Srivastava V, Gowthami R, Shirbhate K D, Singh M, Gaya C, Sagore B, Singh K. .2023. Embryo rescue technique in wide hybridization. In: Plant Genetic Resources Management-Theory and Practices. Gautam *et al*. (Eds). ICAR- NBPGR New Delhi, pp. 325-331
20. Theivanai M, Awasthi O P. 2023. Auxin induced non-embryogenic callus induction in Kinnow mandarin (Eds. Kaur S., Padaria J.C., Mandal P.K., Dr. Bhattacharya R., Mondal T.K., Kumar A., Sinha S.K., Singh A.K., Rao M. and Begam S.) pp-317.ISBN No: 978-81-956825-0-8.
21. Awtar Singh 2023. Polyploidization in fruit crops: Development, Characterization and Utilization. (In): Goswami, A.K., Kumar, N., Goswami, S., Kumar, C., Vinutha, T. 2023. Next generation molecular tools for accelerating the breeding efficiency in horticultural crops - A Training Manual (SERB Karyashala). ICAR-Indian Agricultural Research Institute, New Delhi India, pp. 117-125.
22. Awtar Singh 2023. Applications of Polyploidy in Fruit Crops. (In): Goswami, A.K., Kimar, N., Kumar, C., Goswami, S., Vinutha, T., Singh, N.V., Singh, S., Namita, Jat, G.S. and Awasthi, O.P. Advances in experimental designs and genomics for tailoring horticultural crops-A Training Manual. ICAR-Indian Agricultural Research Institute, New Delhi, India. 75-87.

d) List of Popular article(s)

1. Singh A. 2023. Some good practices for genetic enhancement and conservation as well as assuringsustained farmer's income. *Indian Citriculture* 1: 80-84.
2. Kumar R, Sharma N, Dubey A K and Sharma R M. 2023. Role of phonological and pomological traits incharacterization of citrus cultivars. *Indian Citriculture* 1:39-46.
3. Hatkari V, Sharma N, et al. 2023. Fruit Crop pest and disease management: biological controlagents. *NESA News Letter* 26:1-3
4. Sharma N, Hatkari V, Shivran M, Dubey A K and Ravishankar R. 2023. Nutragenomics: social political and regulatory issue. *NESA News letter* 26:1-3.
5. हरे कृष्ण, अरविन्द कुमार सिंह, नृपेंद्र विक्रम सिंह और मनोज कुमार सिंह 2023. नवंबर-दिसंबर में बागों में कार्यकलाप. फल-फूल, नवंबर-दिसंबर, 42 -47
6. Sharma, J., Pokhare, S., Singh, N. V., Manjunatha, N., Mallikarjun, M.H. and Marathe, R. A. 2023. Advisory for pomegranate crop hit by unseasonal rains and hail storm. https://nrcpomegranate.icar.gov.in/files/Advisory/129.pdf
7. Patil, P.G., Parashuram, S., Singh, N.V., Sowjanya, R. and Marathe, R.A. 2023. Pomegranate genome and its prospects for breeding elite pomegranate varieties. *Just Agriculture* 3:200-206 (e-ISSN: 2582-8223)
8. Sharma J, Maithy A, Singh N V, Mallikarjun, Manjunatha N, Pokhare S. 2023. Bimonthly Pomegranate Advisory for Bearing Orchards (Feb-Mar 2023). pages.1-8. https://nrcpomegranate.icar.gov.in/files/Advisory/127.pdf.
9. Damale R D, Parashuram S, Roopa Sowjanya P, Babu K D, Singh N V, Marathe R A. 2023. ICAR डाळिंबाच्या व्यावसायिक जाती आणि त्यांची वैशिष्ट्ये (Pomegranate commercial varieties and their features in Marathi). *Krishi Sahkaar*, 1st Jan, 2023.

10. Pokhare S, Sharma J, Maity A, Singh N V, Mallikarhun, Manjunatha N, Gogan M. 2023. Advisory for bearing pomegranate orchard (Aug-Sept) https://nrcpomegranate.icar.gov.in/files/Advisory/141.pdf
11. Sharma J, Maity A, Singh N V, Mallikarjun, Manjunatha N, Pokhare S, Gogan M. 2023. Bimonthly Pomegranate Advisory for Bearing Orchards (August-September 2023). https://nrcpomegranate.icar.gov.in/files/Advisory/140.pdf
12. Sharma J, Maity A, Singh N V, Pokhare S, Mallikarjun H, Manjunatha N, Gogaon M. 2023. Chaudhari D T, Pokhare S. 2023. Bimonthly Pomegranate Advisory for Bearing Orchards (June-July 2023). https://nrcpomegranate.icar.gov.in/files/Advisory/138.pdf
13. Sharma J, Maity A, Singh N V, Pokhare S, Mallikarjun, Manjunatha N, Gogaon M. 2023. Bimonthly Pomegranate Advisory for Bearing Orchards (Apr-May 2023). https://nrcpomegranate.icar.gov.in/files/Advisory/131.pdf
14. Roopa Sowjanya P, Parashuram S, Singh N V, Patil P G, Marathe R A. 2023. Pomegranate genome sequence: Application and uses. *TerraGreen*. 15: 50-52 ISBN:0974-5688.

11. Trainings/workshop/seminar organized

The details of trainings organized are presented in Table 29.

Table 29. Details of trainings organized

S. No.	Name of programme	Training/ workshop/ seminar	Duration (from.to.)	Nature of trainees (Students, Scientists, teachers, farmers, etc. Please specify)	Number of trainee (s)		
					Male	Female	Total
1.	World Bank – ICAR Funded, National Agricultural Higher Education Project (NAHEP), Centre for Advanced Agricultural Science and Technology (CAAST) Sponsored, Students Training program on "Advances in experimental designs and genomics for tailoring horticultural crops"	Training	01st to 12th December 2023 at Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi – 110 012	Students	--	--	52
2.	DST- Science and Engineering Research Board (SERB) Karyashala on "Next Generation Molecular Tools for Accelerating the Breeding Efficiency in Horticultural Crops"	Workshop	3rd to 10th October, 2023 at Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi – 110 012	Students	--	--	25

3	World Bank – ICAR Funded, National Agricultural Higher Education Project (NAHEP), Centre for Advanced Agricultural Science and Technology (CAAST) Sponsored, Students Training program on "Learning Genomic Tools and Techniques for Improvement of Vegetable Crops"	Training	10th – 20th November, 2023 organized by the Division of Vegetable Science, ICAR-Indian Agricultural Research Institute, New Delhi-12	----	--	--	--
4	Incubation training programme on *In vitro* propagation of pomegranate cvs. Bhagwa and Super Bhagwa including biohardening	Incubation training on commercialized technology	22-26 May, 2023 at ICAR-NRC on Pomegranate, Solapur	Staaf of Department of Hort., Govt. of Karnataka	3	2	5

12. Participation by scientists in scientific meetings, etc.

The details of scientific meetings attended by the divisional scientists are mentioned in Table **30.**

Table 30. Scientific meetings attended by the divisional scientists

S. No.	Detail	No.
(i)	**In India**	
	Seminars	10
	Scientific meetings	5
	Workshops	5
	Symposia	1
	Any other	6
(ii)	**Abroad**	Nil

13. Extension activities

The Divisional scientists were involved in the various extension activities for the transfer of technologies (Table 31).

Table 31. Extension activities undertaken

S. No.	Activities	Scientist
1	Participation in MGMG programme	Drs Awtar Singh, R.M. Sharma, A.K. Goswami, Nimisha Sharma, Madhubala Thakare
2	Exhibition stall for Mango Festival from 7th -9th July, 2023 at Delhi Haat, New Delhi	Drs Manish Srivastav, Jai Prakash, Nimisha, NV Singh
3	Krishi Vigyaan Mela-2023.	Dr. Chavlesh Kumar
4	Training lectures delivered (10)	Divisional Scientists
	Delivered 10 Radio Talks and 16 TV talks	Divisional Scientists

14. Staff Position

A Scientific

1 Dr. O.P. Awasthi, Principal Scientist
2 Dr. Manish Srivastav, Principal Scientist
3 Dr. Awtar Singh, Principal Scientist
4 Dr. A. K. Dubey, Principal Scientist
5 Dr. R.M. Sharma, Principal Scientist
6 Dr. Kanhaiya Singh, Principal Scientist
7 Dr. Jai Prakash, Principal Scientist
8 Dr. A. Nagraja, Principal Scientist
9 Dr. N.V. Singh, Senior Scientist
10 Dr. A.K. Goswami, Senior Scientist
11 Dr. Nimisha Sharma, Senior Scientist
12 Dr. Madhubala Thakre, Senior Scientist
13 Dr. Nayan Deepak G., Scientist
14 Dr. Chavlesh Kumar, Scientist

B Technical

1 Mr. D. P. Singh, T-5
2 Mr. Sanjay Kumar, T-4
3 Mr. Deepak, T4
4 Mr. Arvind, T-2
5 Mr. Hans Raj Meena, T-3
6 Mr. Nikhil, T-3
7 Mr. Jagananth Singh, T-4
8 Mr. Dinesh, T-2

C Administrative

1 Mrs.Usha Sehgal
2 Mrs. Om Prabha, AAO
3 Mr. Sanjay Kumar Asst.
4 Mr. Shayam Sunder, UDC
5 Mr. Vinod Kumar Rai, UDC

D Supporting

1. Mr. B.N. Rai
2. Mr. Rambir Singh
3. Mr. Parmeshwar
4. Mr. Khem Singh
5. Mr. Ravinder Kumar
6. Mr. Rabi Khan
7 Mr. Ramesh Chand
8. Mr. Sh. Ramesh Kumar
9. Mr. Raj Kumar Poddar
10 Mr. Jagdish
11 Mr. Sunil Kumar
12 Mr. Vijay Kumar
13 Mr. Rajender Singh
14 Mrs. Rajbala
15 Mr. Ranjeet Rai

15. Divisional Committees

क **समितियाँ**

बजट और अनुसंधान समिति

डा. ओ. पी. अवस्थी, अध्यक्ष
डा. अवतार सिंह, प्रधान वैज्ञानिक - सदस्य
डा. कन्हैया सिंह, प्रधान वैज्ञानिक - सदस्य
डा. जय प्रकाश, प्रधान वैज्ञानिक - सदस्य
श्रीमती ओम प्रभा, स. प्र. अ. - सदस्य
डा. चवलेश कुमार, वैज्ञानिक - सदस्य सचिव

राजभाषा कार्यान्वन समिति

डा. ओ. पी. अवस्थी, अध्यक्ष
डा. कन्हैया सिंह, प्रधान वैज्ञानिक - नोडल अधिकारी
डा. मनीष श्रीवास्तव, प्रधान वैज्ञानिक - सदस्य
श्री अरविंद, वरिष्ठ तकनीकी - सदस्य
श्री विनोद कुमार राय - सदस्य सचिव

प्रक्षेत्र उपज नीलामी समिति

डा.- कन्हैया सिंह, प्रधान वैज्ञानिक - अध्यक्ष
डा. (श्रीमती) मधुबाला ठाकरे, वरिष्ठ वैज्ञानिक - सदस्य
श्री डी. पी. सिंह, प्रक्षेत्र प्रभारी - सदस्य
श्रीमती ओम प्रभा, स. प्र. अ. - सदस्य सचिव

तकनीकी सेल

डा. ओ. पी. अवस्थी, अध्यक्ष
डा. मनीष श्रीवास्तव, प्रधान वैज्ञानिक - सदस्य
डा. एन. वी. सिंह, वरिष्ठ वैज्ञानिक - सदस्य
श्रीमती ऊषा सहगल, निजी सचिव - सदस्य सचिव

बिल्डिंग और परिसर रखरखाव समिति

श्रीमती ओम प्रभा, स. प्र. अ.- अध्यक्ष
श्री संजय कुमार, वरिष्ठ तकनीकी सहायक - सदस्य
श्री दिनेश , तकनीकी- सदस्य सचिव

कर्मचारी कल्याण समिति

डा. अवतार सिंह, प्रधान वैज्ञानिक - अध्यक्ष
डॉ. निमिषा शर्मा - सदस्य
श्री विनोद कुमार राय, - सदस्य
श्री अरविंद, तकनीकी सहायक - सदस्य
श्रीमती ओम प्रभा,स.प्र.अ. - सदस्य सचिव

ख सेक्शन/यूनिट/सेल

नोडल अधिकारी, AICRP (फल),
नोडल अधिकारी, विभागीय वेबसाइट
पौधशाला एवं उत्तक संवर्धन प्रयोगशाला
स्नातकोतर प्रयोगशाला

स्टोर खरीद नीलामी समिति

डा. अमित कुमार गोस्वामी - अध्यक्ष
श्री डी. पी. सिंह, प्रक्षेत्र प्रभारी - सदस्य
श्री संजय (भंडार)
श्रीमती ओम प्रभा, स. प्र. अ. - सदस्य सचिव

स्वच्छ भारत अभियान समिति

डा. राधा मोहन शर्मा - नोडल अधिकारी
डा. (श्रीमती) मधुबाला ठाकरे, वरिष्ठ वैज्ञानिक - सदस्य
श्रीमती ओम प्रभा, स. प्र. अ. - सदस्य
श्री दीपक, वरिष्ठ तकनीकी सहायक - सदस्य सचिव

प्रक्षेत्र प्रबंधन समिति

डा. ओ. पी. अवस्थी, अध्यक्ष
डा. जय प्रकाश, प्रधान वैज्ञानिक - सदस्य
श्री डी. पी. सिंह, प्रक्षेत्र प्रभारी - सदस्य
श्री संजय कुमार, वरिष्ठ तकनीकी सहायक - सदस्य सचिव

प्रौद्योगिकी विस्तार समिति

डा. राधा मोहन शर्मा, प्रधान वैज्ञानिक - अध्यक्ष
डा. (श्रीमती) मधुबाला ठाकरे, वरिष्ठ वैज्ञानिक - सदस्य
श्री डी. पी. सिंह, प्रक्षेत्र प्रभारी - सदस्य
श्री दीपक, वरिष्ठ तकनीकी सहायक - सदस्य सचिव

व्याख्यान कक्ष समिति

डा. मनीष श्रीवास्तव, प्रधान वैज्ञानिक - अध्यक्ष
श्री हंसराज मीणा - सदस्य

वाहन

श्रीमती ओम प्रभा,स.प्र.अ. - अध्यक्ष
श्री रमेश - सदस्य
श्री विनोद - सदस्य सचिव

ऑफिसर इन चार्ज

डा. राधा मोहन शर्मा
डा. कन्हैया सिंह, प्रधान वैज्ञानिक
डा. एन. वी. सिंह, वरिष्ठ वैज्ञानिक
डा. (श्रीमती) मधुबाला ठाकरे, वरिष्ठ वैज्ञानिक

कार्यिकी प्रयोगशाला	डा. जय प्रकाश, प्रधान वैज्ञानिक
मृदा एवं उत्तक विश्लेषण प्रयोगशाला एवं केन्द्रीय प्रयोगशाला	डा अमित कुमार गोस्वामी, वरिष्ठ वैज्ञानिक
सम्भागीय लाइब्रेरी	डा. (श्रीमती) निमिषा शर्मा, वरिष्ठ वैज्ञानिक
व्याख्यान कक्ष समिति	डा. मनीष श्रीवास्तव, प्रधान
सम्भागीय समिति कक्ष	श्रीमती ऊषा सहगल, निजी सचिव - सदस्य सचिव
वाहन	श्रीमती ओम प्रभा,स.प्र.अ.

(डा. ओ. पी. अवस्थी)
अध्यक्ष

Division of Fruits & Horticultural Technology ICAR-Indian Agricultural Research Institute New Delhi-110 012