ANNUAL REPORT 2022

DIVISION OF FRUITS & HORTICULTURAL TECHNOLOGY
ICAR - INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI - 110012

TB-ICN:347/2024

Annual Report
2022

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

Annual Report 2022

Printed: October 2023

Supervision and Guidance

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

Editorial Team

Dr Anil Kumar Dubey
Dr Radha Mohan Sharma
Dr Nripendra Vikram Singh

Acknowledgements

We acknowledge the help received from the Director, Joint Director (Research), ICAR-IARI and the Scientific staff of the Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110 012

Correct citation: Annual Report 2022, Division of Fruits and Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India.

TB-ICN:347/2024

IARI website: www.iari.res.in

CONTENTS

PREFACE

The total production of fruit crops is estimated to be 108.34 million tons in the year 2022 as compared to 107.51 million tons in the year 2021. The importance of fruit crops in improving the nutritional, livelihood security and country's economy has been well established. 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 promising varieties in mango, citrus, grape, guava and Papaya. The development of improved varieties and production technology have paved the way for entrepreneurship in the field of fruit orcharding. The impact of this can be seen in different parts of the country where different states have adopted the varieties on a large scale. During the period under report, two varieties in guava Pusa Aarushi, Pusa Pratiksha and in Papaya Pusa Peet was released by SVRC. In a QTL mapping / GWAS for horticultural traits in mango, three high density linkage maps having 2,912, 1,699 and 2,624 SNPs have been constructed. In a mutagenesis study, three putative triploids (T×D/20/1, T×D/20/2, T×D/20/7) in Kinnow have been identified. In grape wild *Vitis* species of *V. himalayana*, Parthenocissus (EC452215), *V. ficifolia* (EC452206) and *V. riparia* (EC 452207) were collected and planted in the field gene bank.

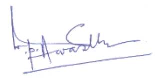
In Production technology, long term trial on rootstock research in fruit crops such as mango, citrus, grape and guava is in progress to develop rootstocks for diversified agro-ecological regions and for tolerance to the various biotic and abiotic stresses. In citrus, hybrid SCSH 17-12 (Pummelo × Sweet orange) has shown tolerance against the NaCl (50 mM) induced salinity. Besides INM trial in the newly released varieties in mango is in progress. For the promotion of IARI released mango varieties, commercial licensing/ MoA was signed with commercial private nurseries. Besides, the Division had multiplied 25,124 plants of different varieties of mandated fruit crops, and sold to the growers, SAUs and nurserymen.

In Post Graduate education programme, 14 courses offered were offered to the M. Sc. and 08 courses to the Ph.D. students. In the sixtieth convocation held during February 2022, 03 Ph.D. and 06 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 19 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 Chairman and members of IRC 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 within the stipulated time.



(O. P. Awasthi)
Head

EXECUTIVE SUMMARY

The Division of Fruits & Horticultural Technology (FHT), ICAR-Indian Agricultural Research Institute, New Delhi maintained its leadership role in basic, applied, and strategic research on mandated crops (mango, citrus, guava, grape and papaya), 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 2022 are summarised below:

Artificial hybridization in mango was attempted employing using different desirable parents and total 467 panicles having 3,864 flowers have been crossed. Hybrids from different cross combinations were evaluated and based on physico-chemical attributes hybrids, namely, H-14-2, H-1-5, NH-18-4 and NH-20-2 were found superior for fruit weight and pulp content. Hybrids, namely, H-3-2, H-4-8, H-14-2, NH-17-2, NH-18-4 and NH-20-2 had red/ purple coloration on fruit shoulder- a preferred trait for export purposes. Maternal half-sibs of Amrapali (13) showed improved horticultural traits compared to mother Amrapali, and parentage of 16 open pollinated half-sibs of Amrapali was confirmed. Hyper-variable mango SSRs (100) developed from whole genome sequence of Amrapali were validation. Out of 100 HMSSRs, 89 (94.68%) were polymorphic and used for diversity analysis in mango. Using 80K genic-SNP genotyping data and phenotyping values of 92 bi-parental progenies three linkage maps based on segregation from female, male and both parents were constructed.

In citrus, a total of 592 flowers of 12 cross combinations (04 of acid scion, 02 of sweet scion and 06 of rootstocks) were crossed. During October, 2022, the seeds of newly made crosses and bearing polyembryonic hybrid seeds were sown for the further evaluation for intended traits.In the evaluation of 16 sweet hybrids (Pummelo × Mosambi), the mineral nutrients P, K, Ca, Mg, Fe, Zn, Mn, Cu, Na and Cl in the fruit juice were ranged from 60.76- 251.07 ppm, 574.67-1195.47 ppm, 153.60-122.67 ppm, 23.68-101.76 ppm, 1.65-7.37 ppm, 1.28-2.97 ppm, 0.51-1.24 ppm, 0.46-0.84 ppm, 18.40-45.87 ppm and 17.04-289.68 ppm, respectively. Of the three mutants of Redblush grapefruit evaluated, RB-2 and RB-3 proved statistically at par for TSS content (10.10°-10.46°B). RB-1 and RB-2 bore the thin peeled fruits (3.25-3.52 mm). The highest juice content was registered in the fruits of RB-2 (54.97%). The fruit quality of twenty acid scion hybrids/ cultivars showed the significant variations in respect of physico-chemical traits. The highest juice content was recorded in the fruits of ACSH-5-15/18 (52.86%) without having significant difference with ACSH-7-14/18 hybrid. The fruits of Pusa Abhinav were found low seeded (14.56 seeds/ fruit). The hybrid ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18 and Konkan SL yielded the fruits with statistically significant thin peel (1.03-1.57 mm) over others. The highest content of titratable acid was recorded in the juice of Pusa Abhinav (6.65%). Only two hybrids namely ACSH-3-2/18 and ACSH-3-15-18 along with Konkan SL and Pusa Abhinav bore the fruits twice. Of the studied genotypes, two hybrids (ACSH-3-4/18 and ACSH-3-14-18) were tolerant, eight were immune (ACSH-3-2/18, ACSH-3-15/18, ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18, ACSH-7-14/18, ACSH-7-15/18, ACSH-9-1/18 and Konkan SL) and only one (Pusa Abhinav) was susceptible to citrus canker.

Of the five bearing pummelos, accession IC-628798 bore thin-peeled fruits, and IC- 628799 and 628800 had the dark-fleshed fruits with solid core. For the production of triploids, a total of 534 crosses of Tetraploids × Diploids of Mosambi and 504 crosses of Tetraploids × Diploids of Kinnow were attempted. In the second generation of colchiploids, hyperploidy was recorded and solid tetraploids were identified. Seven Tetraploids of Mosambi and 4 of Kinnow were confirmed by cytological studies. Reproductive characterization of the second generation colchiploids of Kinnow and Mosambi had confirmed hyperploidy. Also, colchi-mutants were observed in both these cultivars, particularly for reduced seediness. From the diverse mutant Kinnow population developed over the years, mutants Col-1-19, Col-2-19 and EMS-M-3 were observed to be extremely dwarf and plant height ranged between 1.3-1.5 m as compared to wild type (3.1m).

Among the rootstock hybrids, four hybrids namely SCSH 17-12 and SCSH 9-19 (Pummelo × Sweet orange) and CRH 21-9 and CRH 21-13 (Pummelo × Troyer citrange) were evaluated against the NaCl (50 mM) induced salinity with other known genotypes (Cleopatra mandarin, X639 and Jatti Khatti). Of these hybrids, SCSH 17-12 was found tolerant, showing lesser effects of salinity over other rootstock hybrids/ genotypes. The seedlings of dwarf rootstock CRH 7-4 were raised for testing against salinity/ *Phytophthora*. Five more hybrids (SCSH -3-15, SCSH 9-5, SCSH 9-10, SCSH 9-19 and CRH 20-11) were identified polyembryonic.

In the attempt for standardization of *in vitro* mutagenesis in Kinnow mandarin, a comprehensive examination of different developmental stages confirmed the optimum explant development in 21-25 mm (Stage III) fruits during last week of May-First week of June. Identified ovule stage induced direct somatic embryos from micropylar cut end on induction medium containing DKW + kinetin 5.0 mg L^{-1} + malt extract 1000 mg L^{-1} (ME). Since the protocol can induce rapid single-cell origin of genetically stable *in vitro* regenerants in high frequency, it has an immense potential for induction of solid mutants, besides crop improvement, mass multiplication and virus elimination in Kinnow mandarin. A reliable protocol for *in vitro* shoot organogenesis in sweet orange was standardized using different explants (epicotyl, cotyledon and root), PGRs and carbon sources on indirect embryogenesis was carried out. Callusing was significantly higher in the combination of MS + 2,4-D (1.5 mg L^{-1}) + BAP (1.0 mg L^{-1}) + ME (500 mg L^{-1}) with epicotyl proved best for callusing (90.89 and 83.72%), callus FW (0.83 and 0.67 g), callus TW (0.84 and 0.68 g), and callus DW (0.08 and 0.05 g), as compared to others. Embryogenesis (59.09%) and germination (33.61%) were achieved best in MS + BAP (2 mg L^{-1}) + NAA (0.1 mg L^{-1}) + ME (500 mg L^{-1}). Among different carbon sources, 5% glycerol supplemented with the same treatment combination proved best in inducing the highest number of SE/ callus mass (73.26), SE (65.27%) and plantlet formation (68.77%). The protocol standardized can be used for indirect embryogenesis for different genotypes.

In the scion breeding of grapes, 187 panicles having 11346 flowers were crossed, including the genotypes, Pearl of Csaba, Flame Seedless, Perlette, Pusa Navrang, etc. In rootstock breeding, 645 flowers were crossed involving *Vitis parviflora* × Dogridge, *Vitis parviflora* × Salt Creek and *Vitis parviflora* × Male Hybrid. For the augmentation of grape germplasm, the dormant cuttings of *Vitis* species *viz*., *V. himalayana*, Parthenocissus (EC452215), *V. ficifolia* (EC452206) and *V. riparia* (EC 452207) were collected from NBPGR RS, Phagli (H.P.).

Twenty-two grape hybrids and genotypes developed in the background of 'Pusa Navrang' were evaluated for juice purpose. Hybrids 16/2A-R4-P9, 16/2A-R2-P7, 16/2A-R4-P7 and 16/2A-R3-P3 have been identified as potential for juice purpose. The maximum juice recovery was recorded in hybrid 'Hyb.16/2A-R4P9 followed by 'Hyb. 16/2A-R4P7'.

Hybridization in guava was done as per Diallel Mating Design by involving ten best combiner genotypes with intended traits. Thirty cross compatible desirable combinations were used, and total 870 flowers were crossed. Of these, final fruit set was recorded in 21 cross combinations. The seeds of hybrid progenies were sown and a total of 1160 No. of F_1 population was raised and transplanted in the field for further evaluation. A total of 17 genotypes were augmented and conserved. Guava F_1 populations were evaluated for physio-biochemical traits. The highest contents of TSS (12.54ºBrix), titratable acidity (0.66%) and ascorbic acid content (285.03 mg/100 g of pulp) were recorded in GH-2017-1F. The highest total flavonoid content was recorded in hybrid GH-2017-6C (92.53 mg/100 g FW). Total sugar content and total soluble proteins was highest in GH-2017-1F (9.09%) and GH-2017-2A (16.65 mg/ml), respectively. Of the various F_1 hybrids, pink pulped HSUxSH-16-8-2 and white pulped HSU×SH-16-8-18 were found promising. Thirty-two genotypes and hybrids were also analysed using GC-MS for their flavouring compounds. The major compounds identified were *hexenol*, *ethyl acetate*, *benzldehydes*, *3Z-hexenyl acetate 3-phenylpropyl acetate*, *butylated hydroxytoluene, β-caryophyllene*, *caryophyllene oxide, nerolidol* and *globulol,* besides the several fractions were also present in minor and trace amounts. For the augmentation of germplasm, 23 exotic guava genotypes were introduced from the USDA, Hio, USA through NBPGR, New Delhi, and planted in the field gene bank. Besides, 20 new guava genotypes were also collected from the State Agricultural Universities, private and public nurseries.

Pusa Peet (P-7-2) papaya is a near homozygous, yellow pulp, gynodioecious papaya variety has been developed and recommended by State Seed-Committee for Agricultural and Horticultural Crops, Government of N.C.T. of Delhi for release. Pusa Peet is highly productive (36-41 kg/plant) bearing medium sized fruits (972-1035 g) having 11.0° to 12.1° Brix total soluble solids. The evaluation of papaya parents with their hybrids was carried out 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 and 30 hybrids (reciprocal crosses of parents) for 9 important horticultural traits. The plant height at flower initiation in parents and hybrids ranged from 59.67 cm to 95.67 cm. Parents, PN (63.0 cm) followed by P-9-12 (78.67 cm) were recorded with shortest plant height at flowering stage, whereas, P-7-9 (95.67 cm) followed by PS 3 (83.67 cm) were observed with tallest plants. Number of fruits per plant was maximum in PS3 x P-9-5 (44.67) followed by PS3 x P-7-9 (44.0) and P-9-5 x PS3 (41.67). For fruit yield and related traits like fruit weight, fruiting zone and number of fruits per plant, parents, PS3, P-7-2 and P-7-9 along with hybrids P-9-12 x P-7-2 and PS3 x P-7-9, were identified as better performers. The seeds of the papaya P-7-2 were treated with gamma rays 0.10, 0.15, 0.20, 0.25 and 0.30 kGy. Two mutants *viz*., PM 04 and PM 28, selected from two lower doses 0.10 kGy and 0.15 kGy were outstanding with dwarf stature. The maximum number of fruits (38.2), width of fruit (10.48 cm), pulp thickness (3.34 cm) and TSS (10.25º Brix) and the minimum length and width of the fruit cavity (12.31 cm, 4.12 cm, respectively) were recorded in PM 04.

The performance of mango varieties (Pusa Arunima, Pusa Surya and Amrapali), grafted on five polyembryonic rootstocks (K-2, K-3, K-5, Kurakkan and Olour) was assessed. Over all Pusa Arunima proved most vigorous statistically. K-2 rootstock imparted the dwarfness to all the varieties tested. Pusa Arunima on K-5 and Kurukkan (151.67-156.67 fruits/ tree) and Amrapali on K-2 (191.67 fruits/ tree) were found at par in respect of number of fruits/tree. Similarly, significantly higher yields of Pusa Arunima were recorded on K-5, Kurakkan, K-3 and K-2 (22.38-24.95 Kg/ tree) rootstocks and Amrapali on K-2 (28.53 Kg/tree) rootstock with no significant difference. The tree vigour, fruit yield and quality of two newly released cultivars of sweet orange (Pusa Sharad and Pusa Round) were significantly influenced, while budded on different rootstocks. Over all, C 35 and Yama Mikan rootstocks proved dwarf for Pusa Sharad. The similar effect for Pusa Round was noticed on C 35, X 639, Yama Mikan and Soh Sarkar with no significant difference, while RLC-7 behaved as a vigorous rootstock for the scion varieties tested. RLC-6 and C 35 rootstocks proved high yielding for Pusa Sharad (17.34 Kg/ tree) and Pusa Round (20.70 Kg/ tree), respectively. The rootstocks C 35, X639 and Yama Mikan proved equally good statistically to impart higher TSS in the fruit juice of Pusa Sharad (8.10°-8.22°B) and Pusa Round (8.00°- 8.30°B). In long term evaluation trial.

Of the nine citrus rootstocks screened against three weeks drought stress, X639 proved to be the most tolerant rootstock, while Cleopatra mandarin was found highly susceptible to drought. In order to identify the drought mitigating plant bioregulators (PBRs) in citrus rootstocks, eight PBRs *viz*., 24 epibrassinolide (0.001mM), γ-aminobutyric acid (100mM), gycine betaine (1.00 mM), jasmonic acid (2.38 mM), proline (30 mM), salicylic acid (1mM), SNP + NaHS (0.1mM) and spermidine (0.001mM) were studied on contrasting rootstocks namely Cleopatra mandarin (drought susceptible) and X639 (drought tolerant), applied through foliar priming one week after withholding irrigation. Foliar priming treatments significantly affected number of leaves in Cleopatra mandarin, but not in X639. Priming treatments with proline (PRO), sperimidine (SPD) and salicylic acid (SA) significantly reduced the leaf wilting and leaf drop (ranging from 17 to 51%) in Cleopatra mandarin at the end of drought stress.

The study on integrated nutrient management in newly developed mango hybrids was made using recommended dose of fertilizers (RDF) alone (100%) and alongwith AMF (250 g) and *Azotobacter* (250 g), 75% RDF along with AMF (250 g) and *Azotobacter* (250 g) and 50% RDF alongwith AMF (250 g) and *Azotobacter* (250 g). Maximum yield of fruit (25.64 kg) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 23.45 kg in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit yield (25.45 kg) was found in Pusa Arunima followed by Pusa Lalima (22.25 kg) and Pusa Pratibha (16.35 kg).

For the promotion of IARI released mango varieties, commercial licensing/ MoA was signed with commercial private nurseries. Through this process, a revenue of Rs. 4,50,000/- has been generated as License fee. Besides, the Division of Fruits & Horticultural Technology had multiplied 25,124 plants of different varieties of mandated fruit crops, and sold to the growers, SAUs and nurserymen.

During the year 2022, a total 19 PG students including 7 M.Sc. and 12 Ph.D. students were admitted in the Division. Total eight students including two Ph.D. and six M.Sc. students received degree during 60^{th} Convocation of IARI, New Delhi. Out of 49 on roll PG students, 24 secured fellowships other than IARI fellowship, and remaining 25 PG students received IARI fellowship. During 2022, five students outside the ICAR-IARI, New Delhi have completed their internship.

One Principal Scientist Dr A. K. Dubey was awarded with the prestigious fellowship of NAAS during 2022. A total of 19 research papers/review articles were published in NAAS rated journals ranging from 6.00 to 12.58, besides other publications. The scientists of the FHT Division have attended several scientific meetings/seminars, and extended the technologies through electronic and print media.

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, Sanjay Kumar Singh, Jai Prakash, A. Nagaraja, Nimisha Sharma, 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 using potential parents

Artificial hybridization was attempted using seven different cross combinations employing Amrapali as female donor and Tommy Atkins, Vanraj, Janardan Pasand, Adman Collection, Kensington, Maya and Irwin as male donor parents. Total 467 panicles having 3,864 flowers have been crossed. The fruit retention on 16.07.2022 was 2.01 % (Table 1).

Table 1. Details of hybridization work attempted during March, 2022.

S. N.	Cross	No. of panicles	No. of flowers	Final retention on 16.07.22
1	Amrapali × Tommy Atkins	104	911	39
2	Amrapali × Vanraj	102	835	17
3	Amrapali × Janardan Pasand	100	856	4
4	Amrapali × Andaman Coll.	41	342	6
5	Amrapali × Kensington	25	202	5
6	Amrapali × Maya	52	392	3
7	Amrapali × Irwin	43	326	4
	Total	467	3,864	78

1.1.1.2 Evaluation of mango hybrids for different traits

During the period total 54 hybrids belonging to different cross combinations have been evaluated for different physico-chemical attributes. The maximum fruit weight was noted in H-14-2 (385.10 g) followed by H-1-5 (344.60 g, NH-20-2 (288.65 g) and H-18-4 (265.66 g). Hybrids namely H-14-2, NH-16-2, H-1-5, H-18-4 and NH-20-2 bore more than 200 g fruit weight and had higher pulp content ~70 per cent. Hybrids, namely, H-3-2, H-4-8, H-14-2, NH-17-2, NH-18-4 and NH-20-2 had red/ purple coloration on fruit shoulder. Similarly, significant variation in fruit shape, pulp colour, total soluble solids and pulp content was observed among mango hybrids (Table 2).

Table 2. Better performing mango hybrids

Hybrid	Fruit Wt. (g)	TSS (^{o}Brix)	Pulp (%)
H 1-5 (Amrapali × Sensation)	344.60	21.50	70.15
H-14-2 (Amrapali × Sensation)	385.10	20.20	68.38
NH 18-4 (Amrapali × Sensation)	265.66	22.40	68.22
NH 20-2 (Amrapali × Sensation)	288.65	19.10	69.37

1.1.1.3 Development and evaluation of maternal half-sib (s) of Amrapali mango

Total 131 maternal half-sibs have been evaluated for horticultural traits *viz*., vigour, leaf, flowering, fruiting and fruit quality parameters. Significant variations were observed for different traits among half-sibs. In addition, parentage of 16 maternal half-sibs have been confirmed.

1.1.1.4 Evaluation of germplasm /clones/ open -pollinated seedlings in mango.

Five collections from Nimbadoor area of Tamil Nadu have been evaluated for different horticultural traits. The collections Nim. 1 had unique twisted fruit having 174.5 g fruit weight and Nim 2 had medium sized fruit (184.5 g) with bright jasper red colour and TSS of 20.5^{o} Brix (Table 3).

Table 3. Physico-chemical parameters of mango collections.

Name	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	TSS (ºBrix)
Nim. 1	174.5	13.8	4.9	17.4
Nim. 2	184.5	9.9	5.3	20.5
Nim. 4	65.24	5.6	4.4	16.4
Nim. 5	152.5	9.4	6.1	16.2
Nim. 6	93.4	7.02	4.7	20.3

1.1.1.5 Validation of SSRS and SNPs in mango

One-hundred hyper-variable SSRs have been validated on a set of 24 mango genotypes. Out of 100 Hypervariable Mango SSRs (HMSSRs), 89 (94.68%) were polymorphic, 5 (5.31%) were monomorphic and 6 could not be amplified. The 89 polymorphic HMSSRs have been used for the profiling of 24 mango hybrids. A total of 1,861 alleles were detected with an amplicon size ranging from 130 (HMSSR965) to 450 bp (HMSSR888 and HMSSR1526). The number of alleles detected ranged from 2 to 5 with an average of 3.47 alleles per primer pairs.

The PIC value of the SSR markers, which is a measure of allele diversity at a locus, ranged from 0.04 to 0.72. The highest PIC was observed with the HMSSR1289 (0.72) while, the lowest was observed with HMSSR1382 (0.04). The HMSSR loci (20), *viz*., HMSSR634, HMSSR888, HMSSR803, HMSSR1839, HMSSR1427, HMSSR1778, HMSSR1758, HMSSR1653, HMSSR1196, HMSSR767, HMSSR478, HMSSR1771, HMSSR405, HMSSR2082, HMSSR1338, HMSSR1980, HMSSR786, HMSSR1326, HMSSR1349 and HMSSR1289 exhibited PIC value ≥ 0.50, another 10 HMSSRs were having PIC value ranged from 0.40 to 0.49 indicating their usefulness in discriminating mango genotypes (Table 4).

Table 4. Details of polymorphic HMSSR loci used for genotyping of mango hybrids along with their expected heterozygosity (H_e), observed heterozygosity (H_o), major allelic frequency (M_{af}) and polymorphism information content (PIC).

S N	Code	H_e	H_o	M_{af}	PIC
1	HMSSR 1326	0.6658	0.2857	0.4643	0.6083
2	HMSSR 1619	0.5356	0.9583	0.5208	0.4301
3	HMSSR 298	0.2491	0.2917	0.8542	0.2181
4	HMSSR 556	0.4363	0.4737	0.7105	0.3765
5	HMSSR 634	0.5694	0.6667	0.5833	0.5045
6	HMSSR 865	0.4800	0.8000	0.6000	0.3648
7	HMSSR 390	0.5000	0.7143	0.5000	0.3750
8	HMSSR 436	0.2188	0.2500	0.8750	0.1948
9	HMSSR 724	0.4986	0.6316	0.5263	0.3743
10	HMSSR 1350	0.4907	0.3182	0.5682	0.3703
11	HMSSR 1585	0.5000	0.0000	0.5000	0.3750
12	HMSSR 1978	0.5605	0.6087	0.5435	0.4733
13	HMSSR 266	0.5000	1.0000	0.5000	0.3750
14	HMSSR 312	0.1528	0.1667	0.9167	0.1411
15	HMSSR 1205	0.4985	0.7222	0.5278	0.3742

16	HMSSR 1289	0.7684	0.9130	0.3043	0.7298
17	HMSSR 1551	0.5694	1.0000	0.5000	0.4768
18	HMSSR 1839	0.6050	0.1000	0.5000	0.5270
19	HMSSR 1918	0.4983	0.2353	0.5294	0.3741
20	HMSSR 2082	0.6589	0.5833	0.3958	0.5847
21	HMSSR 408	0.2676	0.3182	0.8409	0.2318
22	HMSSR 622	0.4012	0.5556	0.7222	0.3207
23	HMSSR 807	0.4444	0.4167	0.6667	0.3457
24	HMSSR 912	0.3400	0.2000	0.8000	0.3142
25	HMSSR 1218	0.3924	0.4167	0.7500	0.3414
26	HMSSR 1455	0.4861	0.8333	0.5833	0.3680
27	HMSSR 1491	0.5000	0.3333	0.5000	0.3750
28	HMSSR 1706	0.4962	0.8261	0.5435	0.3731
29	HMSSR 1761	0.4688	0.7500	0.6250	0.3589
30	HMSSR 180	0.5000	1.0000	0.5000	0.3750
31	HMSSR 203	0.3047	0.3750	0.8125	0.2583
32	HMSSR 643	0.4395	0.6522	0.6739	0.3429
33	HMSSR 917	0.4082	0.4286	0.7143	0.3249
34	HMSSR 1062	0.2188	0.2500	0.8750	0.1948
35	HMSSR 1586	0.2778	0.3333	0.8333	0.2392
36	HMSSR 1683	0.2449	0.2857	0.8571	0.2149
37	HMSSR 1980	0.6632	0.9167	0.3750	0.5891
38	HMSSR 317	0.4990	0.9545	0.5227	0.3745
39	HMSSR 405	0.6588	0.7826	0.3696	0.5843
40	HMSSR 419	0.4474	0.6316	0.6842	0.3681
41	HMSSR 457	0.5000	1.0000	0.5000	0.3750
42	HMSSR 478	0.6361	0.4762	0.5000	0.5754
43	HMSSR 1116	0.5000	1.0000	0.5000	0.3750
44	HMSSR 1226	0.5000	0.2308	0.6154	0.4078
45	HMSSR 1338	0.6605	0.6111	0.3889	0.5864
46	HMSSR 1349	0.7355	0.6842	0.3421	0.6871
47	HMSSR 1427	0.5952	0.7143	0.5476	0.5274
48	HMSSR 1531	0.4783	0.7917	0.6042	0.3639
49	HMSSR 1758	0.6078	0.4783	0.5217	0.5394
50	HMSSR 535	0.5747	0.7917	0.4792	0.4831
51	HMSSR 965	0.5148	0.8750	0.5417	0.4020
52	HMSSR 1306	0.4898	0.8571	0.5714	0.3698
53	HMSSR 1344	0.4911	0.7333	0.5667	0.3705
54	HMSSR 1429	0.4861	0.5833	0.5833	0.3680
55	HMSSR 1430	0.4523	0.2083	0.6875	0.3810
56	HMSSR 1498	0.5000	1.0000	0.5000	0.3750
57	HMSSR 1629	0.4783	0.0417	0.6042	0.3639
58	HMSSR 1653	0.6125	0.8696	0.5217	0.5433
59	HMSSR 1778	0.6094	0.3750	0.4375	0.5301
60	HMSSR 1786	0.4834	0.6316	0.6316	0.3893
61	HMSSR 422	0.4888	0.8500	0.5750	0.3693
62	HMSSR 454	0.4575	0.7083	0.6458	0.3528
63	HMSSR 690	0.5000	1.0000	0.5000	0.3750
64	HMSSR 803	0.5981	0.5417	0.4792	0.5141
65	HMSSR 1421	0.4234	0.1739	0.6957	0.3338
66	HMSSR 1426	0.3741	0.3333	0.7708	0.3363
67	HMSSR 2125	0.4523	0.5833	0.6875	0.3810
68	HMSSR 470	0.4783	0.7917	0.6042	0.3639

69	HMSSR 767	0.6424	0.9167	0.4583	0.5697
70	HMSSR 937	0.4939	0.6250	0.6875	0.4616
71	HMSSR 1196	0.6215	1.0000	0.5000	0.5534
72	HMSSR 1325	0.5530	0.4583	0.6042	0.4918
73	HMSSR 1382	0.0408	0.0417	0.9792	0.0400
74	HMSSR 1389	0.4234	0.1739	0.6957	0.3338
75	HMSSR 1526	0.3084	0.0000	0.8095	0.2608
76	HMSSR 1735	0.5391	0.7083	0.6042	0.4672
77	HMSSR 2048	0.0408	0.0417	0.9792	0.0400
78	HMSSR 191	0.5000	1.0000	0.5000	0.3750
79	HMSSR 1313	0.5000	0.0000	0.5000	0.3750
80	HMSSR 2040	0.1189	0.1250	0.9375	0.1151
81	HMSSR 309	0.4297	0.6250	0.6875	0.3374
82	HMSSR 563	0.4444	0.0000	0.6667	0.3457
83	HMSSR 786	0.6528	0.2500	0.5000	0.5994
84	HMSSR 821	0.5304	0.0417	0.5833	0.4414
85	HMSSR 888	0.5408	0.7083	0.6458	0.5048
86	HMSSR 901	0.2491	0.2917	0.8542	0.2181
87	HMSSR 1141	0.4609	0.2917	0.6875	0.3977
88	HMSSR 1771	0.6554	0.6667	0.4167	0.5817
89	HMSSR 1829	0.4991	0.9583	0.5208	0.3746
	Mean	0.4757	0.5487	0.6078	0.3940

Fig. 1. Variation in pulp colour of mango hybrids of IARI.

1.1.1.6 QTL mapping / GWAS for horticultural traits in mango.

Using SNP genotyping data and phenotyping values of 92 bi-parental progenies three linkage maps based on segregation from female, male and both parents were constructed. Total 3,043 SNPs heterozygous in female, 4,233 heterozygous in male and 2,752 heterozygous in both parents have been selected for linkage mapping. Total 20 linkage groups in each segregation category were identified. Finally, three high density linkage maps having 2,912, 1,699 and 2,624 SNPs have been constructed as female, male and female × male, respectively (Table 5).

Table 5. Genetic linkage map statistics.

LG	Female Map (Amrapali) (lm × ll)				Male Map (Sensation) (nn × np)				Female x Male Map (Amrapali x Sensation) (hk × hk)			
	SNP Markers	Map length (cM)	Gap size (cM)	SNP/ cM	SNP Markers	Map length (cM)	Gap size (cM)	SNP /cM	SNP Markers	Map length (cM)	Gap size (cM)	SNP/ cM
1	171	211.60	1.24	0.81	160	112.91	0.71	1.42	135	254.97	1.89	0.53
2	143	186.26	1.30	0.77	60	113.80	1.90	0.53	131	274.82	2.10	0.48
3	215	262.76	1.22	0.82	116	122.80	1.06	0.94	114	309.68	2.72	0.37
4	162	147.12	0.91	1.10	49	134.84	2.75	0.36	107	223.31	2.09	0.48
5	126	104.56	0.83	1.21	76	175.35	2.31	0.43	83	355.04	4.28	0.23
6	274	234.45	0.86	1.17	112	135.71	1.21	0.83	252	289.39	1.15	0.87
7	162	236.48	1.46	0.69	71	94.80	1.34	0.75	151	284.31	1.88	0.53
8	195	156.08	0.80	1.25	176	115.09	0.65	1.53	90	286.41	3.18	0.31
9	182	147.94	0.81	1.23	142	164.63	1.16	0.86	241	268.26	1.11	0.90
10	145	191.14	1.32	0.76	37	146.20	3.95	0.25	139	190.47	1.37	0.73
11	132	170.65	1.29	0.77	78	165.91	2.13	0.47	55	382.10	6.95	0.14
12	152	130.47	0.86	1.17	58	172.53	2.97	0.34	223	322.05	1.44	0.69
13	146	150.22	1.03	0.97	43	130.93	3.04	0.33	136	366.66	2.70	0.37
14	129	74.81	0.58	1.72	39	163.35	4.19	0.24	48	353.19	7.36	0.14
15	103	116.85	1.13	0.88	117	182.50	1.56	0.64	143	257.57	1.80	0.56
16	67	97.51	1.46	0.69	84	197.08	2.35	0.43	136	287.08	2.11	0.47
17	79	70.71	0.90	1.12	84	171.27	2.04	0.49	128	329.07	2.57	0.39
18	53	102.51	1.93	0.52	58	136.80	2.36	0.42	123	228.90	1.86	0.54
19	160	152.60	0.95	1.05	80	106.79	1.33	0.75	102	295.50	2.90	0.35
20	116	144.33	1.24	0.80	59	112.88	1.91	0.52	87	373.07	4.29	0.23
Total	2,912	3,089.0	22.12	19.48	1,699	2,856.1	40.92	12.53	2,624	5,931.8	55.74	9.31

1.1.1.7 Differential gene expression analysis

DGE studies of mango varieties Bombay Green and Totapuri revealed the key regulators present in bud and flower tissues during flower development stage were associated with fruit development and affect the shelf-life of the mango fruit. RNA-sequencing of contrasting genotypes having short and long shelf-life, was carried out. Comparative differential expression pathway studies of long shelf-life (Totapuri) and short shelf-life (Bombay Green) mango genotypes revealed a total of 177 highly differentially expressed genes. Out of 177 total genes, 101 genes from endoplasmic reticulum pathway and very few from gibberellins (3) and jasmonic acid (1) pathway were identified. Present research work aimed to study the carbohydrate metabolism pathway in regular and irregular mango genotypes of varying origin. A total of 30 primers were designed using *in silico* mining of four key genes like *citrate synthase*, *alcohol dehydrogenase*, *sucrose phosphate synthase* and *trehalose phosphate synthase*. These genes play important role in sugar and starch metabolism of mango. Of these specific primers, 14 showed polymorphisms among the genotypes studied. Gene diversity (GD), average number of alleles per locus (An), polymorphism information content (PIC) and major allele frequency (Maf) observed were 0.45, 2.14, 0.35, 0.59, respectively (Table 6). Cluster analysis grouped the mango genotypes irrespective of their bearing habit therefore; it is hypothesized that regular or irregular mango genotypes showed the enhancement in total sugars and reducing sugars content at the time of flower bud differentiation.

1.1.1.8 Functional genomics in mango

A total of 120 genes for different fruit traits like fruit weight, blush color, ripening, polyembryony, alternate bearing etc. were annotated from mango cv. Dashehari. These genes were manually searched for the available information in public domain or reported in other fruit crops. Data information was utilized for the Mango Genome Project.

1.1.1.9 Mango Rootstock Improvement

1.1.1.9.1 Hybridization involving parents for dwarfness and abiotic stresses in mango

During March 2022, total 196 panicles (639 flowers) were used for crossing with various combinations of the polyembryonic mango Olur, Kurrukan, Bappakai, M 13-1, and monoembryonic Amrapali, and subsequently 14 seedlings [9 (Olour x Kurukan), 3 (Bappakai x 13-1), 2 (Bappakai x Olour)], were recovered for further evaluation from 19 harvested fruits.

Table 6. Genetic variability indices of the 14 polymorphic carbohydrate metabolism specific primers among the set of 19 mango genotypes.

S N	Marker ID	Maf	An	GD	Ho	PIC
1	NMAD1	0.7105	2.0000	0.4114	0.5789	0.3267
2	NMAD2	0.5000	2.0000	0.5000	1.0000	0.3750
3	NMAD3	0.6579	2.0000	0.4501	0.6842	0.3488
4	NMAD4	0.5526	2.0000	0.4945	0.7895	0.3722
5	NMAD5	0.5000	2.0000	0.5000	0.8947	0.3750
6	NMAD6	0.6579	2.0000	0.4501	0.5789	0.3488
7	NMCS1	0.5526	2.0000	0.4945	0.5789	0.3722
8	NMCS2	0.4737	2.0000	0.5485	0.7368	0.4453
9	NMCS3	0.5000	3.0000	0.5000	0.5789	0.3750
10	NMSPS4	0.9474	2.0000	0.0997	0.1053	0.0948
11	NMSPS5	0.5526	2.0000	0.4945	0.8947	0.3722
12	NMSPS7	0.5789	2.0000	0.4875	0.7368	0.3687
13	NMTPS1	0.7105	2.0000	0.4114	0.5789	0.3267
14	NMTPS7	0.4474	3.0000	0.5886	0.6842	0.4997
	Mean	0.5959	2.1429	0.4593	0.6729	0.3572

Where: Maf = major allele frequency, An = Allele number, GD = gene diversity, Ho = observed heterozygosity, PIC = polymorphic information content

1.1.1.9.2 Identification of zygotic Olour progenies using SSRs markers

Total twenty SSRs primers were subjected to distinguish zygotic and nucellar saplings of Olour progenies (Fig. 2). Out of 20 SSRs primers, 13 primers showed monomorphic banding pattern while 7 SSRs viz., LMMA 2, LMMA 8, ESTD 6, MiIIHR 01, MiIIHR 02, MiIIHR 23 and MiIIHR 24 primers displayed polymorphic banding pattern and found to be informative and capable to differentiate zygotic and nucellar progenies of Olour mango. The identified polymorphic SSR markers were further used for differentiating the zygotic and nucellar progenies. Primers, viz. LMMA 8, ESTD 6, MiIIHR 01, MiIIHR 02, and MiIIHR 24 were more informative and could be used for distinguishing zygotic and nucellar progenies. Out of 90 Olour progenies population studied, 32 progenies were found zygotic (probable hybrids) and remaining were nucellar in origin.

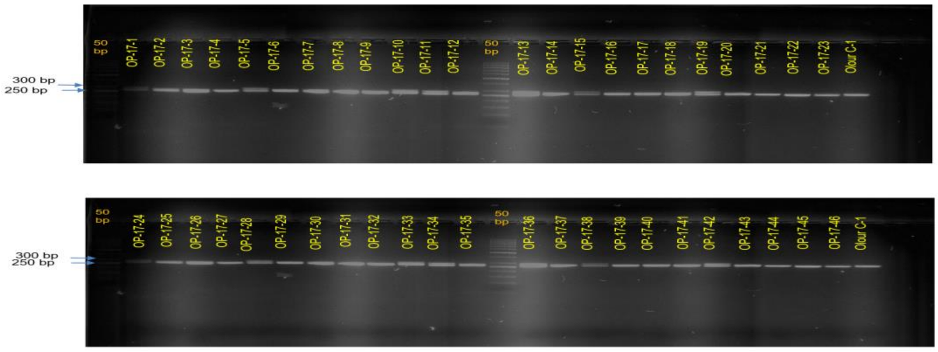


Fig. 2. Gel image of the LMMA8 SSR profile of Olour progenies

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 Breeding for sweet citrus for enhanced nutritional properties

The mineral nutrients P, K, Ca, Mg, Fe, Zn, Mn, Cu, Na and Cl in the fruit juice was found in the range of 60.76- 251.07 ppm, 574.67-1195.47 ppm, 153.60-122.67 ppm, 23.68-101.76 ppm, 1.65-7.37 ppm, 1.28-2.97 ppm, 0.51-1.24 ppm, 0.46-0.84 ppm, 18.40-45.87 ppm and 17.04-289.68 ppm among the hybrid genotypes and parental genotypes (Table 7). The highest P content was registered in SCSH-9-2/12 (114.69 ppm) among hybrids, however, it was significantly lower than male parent (Mosambi) and higher than female parent (Red Pummelo). The hybrid SCSH-9-10/12 outperformed in respect of K (1195.47 ppm), even better than parents. The content of juice Ca was significantly higher in SCSH-13-17/12 (662.40 ppm) having the similarity statistically with SCSH-9-2/12, however, it was highest in Red Pummelo (736 ppm). Of the tested progenies and parents, SCSH-5-10/12 proved the richest source of Mg (101.76 ppm). Among hybrid progenies, SCSH -9-6/12 proved superior for Fe content (6.53 ppm) closely followed by SCSH-5-10/12, however, its highest content (7.37 ppm) was noticed in female parent i.e. White Pummelo. SCSH -9-17/12 hybrid excelled for Zn (2.97 ppm) and Mn (1.24 ppm) contents, however, this was statistically at par with male parent and SCSH-9-6/12 in respect of Zn only. Two hybrids namely SCSH-7-2/12 and SCSH -9-6/12 proved equally good to have the highest juice Cu content (0.84 ppm in each), although was statistically at par with the female parent i.e. White Pummelo. The hybrids SCSH-9-6/12 and SCSH-9-10/12 outperformed for juice Na content (42.40-44.00 ppm). None of the hybrids could excel the male parent for Cl content (289.68 ppm), however among hybrid populations, it was highest in SCSH-5-10/12 (256.55 ppm).

1.1.2.2 Performance evaluation of Red Blush grapefruit mutants

Three mutants of Redblush grapefruit were studied for fruit numbers and fruit quality (Table 8). The mutant RB-1 was found to have higher number of fruits (200/ tree) next to standard Redblush. The fruits of RB-3 tended to show the higher fruit weight (395.24 g), fruit size (84.41 mm L x 101.14 mm W) and peel thickness (8.22 mm) statistically, however, it was statistically at par with standard Redblush in respect of fruit length. RB-2 and RB-3 proved similar statistically for high TSS content (10.10°-10.46°B). RB-1 and RB-2 were found to have the thin peel (3.25-3.52 mm) significantly than RB-3 and standard Redblush. All the mutants were low seeded than standard Redblush. The total juice was higher in the fruits of Redblush-3 and standard Redblush (137.40-150.30 ml), while its highest percentage was registered in the fruits of RB-2 (54.97%).

1.1.2.3 Breeding of acid citrus for canker tolerance and summer fruiting

The fruit quality of twenty acid scion hybrids/ cultivars showed the significant variations in respect of physico-chemical traits (Table 9-10). The highest fruit weight was recorded in ACSH-3-4/18 (116.79 g), while it was lowest in Pusa Abhinav (39.32g).The hybrid ACSH-7-14/18 yielded the bigger fruits (89.40 mm x 65.40 mm width) with hiher juice content (76.40 ml/ fruit), although the highest juice percentage was recorded in the fruits of ACSH-5-15/18 (52.86%) without having significant difference with ACSH-7-14/18 hybrid. The fruits of Pusa Abhinav were found low seeded (14.56 seeds/ fruit). The hybrid ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18 and Konkan SL yielded the fruits with thin peel (1.03-1.57 mm) statistically over others. The highest content of titratable acid was recorded in the juice of Pusa Abhinav (6.65%). Of the 10 hybrids, the highest number of fruits was recorded with ACSH-7-14/18 (40 fruits/ plant), which was third highest next to Konkan SL (320 fruits/ plant) and Pusa Abhinav (250 fruits/ plant). Only two hybrids namely ACSH-3-2/18 and ACSH-3-15-18 along with Konkan SL and Pusa Abhinav bore the fruits twice. Of the studied genotypes, two hybrids (ACSH-3-4/18 and ACSH-3-14-18) were tolerant, eight were immune (ACSH-3-2/18, ACSH-3-15/18, ACSH-5-12/18, ACSH-5-13/18, ACSH-5-15/18, ACSH-7-14/18, ACSH-7-15/18, ACSH-9-1/18 and Konkan SL) and only one (Pusa Abhinav) was susceptible to citrus canker.

1.1.2.4 Rootstock breeding for *Phytophthora* and salt tolerance

Four polyembryonic rootstock hybrids namely SCSH 17-12 and SCSH 9-19 (Pummelo × Sweet orange) and CRH 21-9 and CRH 21-13 (Pummelo × Tryer citrange) were evaluated against the NaCl (50 mM) induced salinity with other known genotypes (Cleopatra mandarin, X639 and Jatti Khatti). Of these hybrids, SCSH 17-12 was found tolerant, showing lesser effects of salinity over other rootstock hybrids/ genotypes. During 2022, the seedlings of dwarf rootstock CRH 7-4 (Fig.3) have been raised for testing against salinity/ *Phytophthora*. Simultaneously, 05 more hybrids (SCSH -3-15, SCSH 9-5, SCSH 9-10, SCSH 9-19 and CRH 20-11) were found polyembryonic, which shall be tested against said stresses during 2023. From the various polyembryonic × polyembryonic crosses made during 2021, twelve hybrids were isolated on the basis of trifoliate leaf character, including the parents Cleopatra mandarin × Troyer citrange (02 Nos.), small fruiting mandarin × Troyer citrange (06 Nos.) a Rangpur lime × Troyer citrange (04 Nos.), and planted for further evaluation.

1.1.2.5 Hybridization using different citrus species for rootstock and scion improvement

During February-March, 2022, a total of 592 flowers of 12 cross combinations (04 of acid scion, 02 of sweet scion and 06 of rootstocks) were crossed. During October, 2022, the seeds of newly made crosses and bearing polyembryonic hybrid seeds were sown for further evaluation for intended traits (Table 11). During, 2022, a total of 84 hybrid fruits were harvested, and extracted the 1060 seeds from these fruits, of which 1032 seeds were sown for raising the hybrid progenies (Table 12).

Fig. 3. CRH 7-4 rootstock plant in bearing

Table 7. Mineral nutrients in the juice of Pummelo × Mosambi hybrids and parental genotypes.

Hybrid/ Genotype	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Na (ppm)
SCSH-5-10/12	74.09^{hi}	789.60^{defg}	153.60^{j}	101.76^{a}	6.27^{bc}	0.63^{ghij}	0.53^{fgh}	29.87^{g}
SCSH-7-2/12	96.98^{fg}	733.60^{fg}	278.40^{hi}	78.08^{b}	2.11^{jkl}	0.51^{k}	0.84^{a}	38.13^{de}
SCSH-7-7/13	85.03^{gh}	806.13^{def}	457.60^{de}	67.84^{c}	3.79^{f}	0.72^{fg}	0.53^{fgh}	41.60^{bcd}
SCSH-9-2/12*	149.69^{c}	825.33^{de}	614.40^{bc}	26.24^{i}	1.85^{kl}	0.53^{jk}	0.49^{gh}	20.53^{h}
SCSH-9-6/12	94.59^{fg}	719.47^{fg}	336.00^{gh}	44.16^{efg}	6.53^{b}	0.83^{def}	0.84^{a}	44.00^{ab}
SCSH-9-10/12	94.21^{fg}	1195.47^{a}	384.00^{fg}	62.72^{c}	2.59^{hij}	0.56^{ijk}	0.76^{ab}	42.40^{abc}
SCSH-9-11/12	67.67^{hi}	920.80^{bc}	240.00^{i}	75.52^{b}	1.65^{l}	1.09^{b}	0.74^{abc}	33.60^{f}
SCSH-9-17/12	150.06^{c}	760.53^{defg}	457.60^{de}	45.44^{ef}	3.34^{fg}	1.24^{a}	0.61^{def}	26.67^{g}
SCSH-11-9/13	103.39^{f}	755.73^{efg}	374.40^{fg}	33.92^{h}	2.31^{ijk}	0.69^{gh}	0.46^{h}	40.27^{cde}
SCSH-11-11/12	74.34^{hi}	701.60^{g}	489.60^{d}	67.84^{c}	3.16^{fgh}	0.73^{efg}	0.55^{efgh}	38.67^{de}
SCSH-11-15/12	141.39^{cd}	581.33^{h}	460.80^{de}	40.32^{fgh}	2.20^{ijkl}	0.59^{hijk}	0.59^{efg}	41.07^{bcd}
SCSH-13-4/13	95.09^{fg}	921.07^{bc}	358.40^{g}	67.84^{c}	3.66^{f}	0.84^{de}	0.65^{cde}	27.73^{g}
SCSH-13-17/12	111.45^{ef}	724.53^{fg}	662.40^{b}	23.68^{i}	2.80^{ghi}	0.86^{cd}	0.52^{fgh}	37.07^{ef}
SCSH-15-7/12	60.76^{i}	829.60^{de}	387.20^{fg}	55.04^{d}	5.37^{de}	0.52^{k}	0.56^{efgh}	20.00^{h}
SCSH-17-8/14	93.96^{fg}	974.40^{b}	425.60^{ef}	51.20^{de}	3.60^{f}	0.96^{c}	0.72^{bcd}	18.40^{h}
SCSH-17-19/13	108.80^{f}	846.13^{cd}	595.20^{c}	45.44^{ef}	2.71^{ghij}	0.56^{ijk}	0.52^{fgh}	33.60^{f}
White Pummelo	192.33^{b}	768.80^{defg}	515.20d	37.12^{gh}	7.37^{a}	0.91^{cd}	0.76^{ab}	26.40^{g}
Red Pummelo	128.05^{de}	703.47^{g}	736.00^{a}	26.24^{i}	5.87^{cd}	0.65^{ghi}	0.56^{efgh}	45.87^{a}
Mosambi	251.07^{a}	574.67^{h}	156.80^{j}	80.00^{b}	4.80^{e}	0.88^{cd}	0.61^{ef}	41.60^{bcd}
LSD (P<0.05)	18.27	89.36	60.49	7.66	0.64	0.11	0.11	3.64
Range	60.76-251.07	574.67-1195.47	153.60-122.67	23.68-101.76	01.65-7.37	0.51-1.24	0.46-0.84	18.40-45.87

*Red Pumello × Mosambi

Table 8. Evaluation of Redblush grapefruit mutants.

Variant	No of fruits/ tree	Weight (g)	Fruit length (mm)	Fruit width (mm)	TSS (°B)	Peel thickness (mm)	Seeds (per fruit)	Juice (ml)	Juice (%)
RB-1	200	199.16^{c}	69.09^{b}	76.33^{c}	9.00b	3.52^{c}	0.8^{b}	102.60^{b}	51.58^{b}
RB-2	100	202.39^{c}	69.38^{b}	74.67^{c}	10.46a	3.25^{c}	1.6^{b}	110.20^{b}	54.97^{a}
RB-3	180	395.24^{a}	85.41^{a}	101.14^{a}	10.12a	8.22^{a}	0.4^{b}	137.40^{a}	34.72^{d}
Redblush (Standard)	210	308.78^{b}	81.37^{a}	89.20^{b}	8.20c	4.40^{b}	7.6^{a}	150.30^{a}	48.91^{c}
LSD (P<0.05)	NA*	55.60	8.11	5.52	0.78	0.45	2.12	25.38	0.75

*Not analysed statistically

Table 9. Comparative performance of limo (acid lime x lemon hybrid) with their parents.

Characters	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Juice (ml)	Juice (%)	Seeds/ fruit	Peel thickness (mm)
ACSH-3-2/18	62.52	53.09	49.60	15.23	23.58	63.00	2.19
ACSH-3-4/18	116.79	74.36	56.84	52.40	45.30	46.75	3.23
ACSH-3-14/18	91.77	70.44	51.37	37.20	39.95	36.25	2.61
ACSH-3-15/18	93.94	67.67	52.39	44.00	47.97	30.50	2.47
ACSH-5-12/18	79.20	76.68	45.48	27.40	30.96	27.25	1.57
ACSH-5-13/18	45.79	51.08	41.12	13.40	31.01	24.75	1.03
ACSH-5-15/18	69.41	53.44	47.82	37.00	52.86	31.25	1.06
ACSH-7-14/18	182.86	89.40	65.40	76.40	41.43	70.75	2.85
ACSH-7-15/18	101.78	72.10	52.73	49.80	50.82	32.75	1.94
ACSH-9-1/18	89.98	61.39	52.71	40.40	46.63	31.25	2.85
Pusa Abhinav	39.32	35.23	41.23	19.10	46.58	14.56	1.65
Konkan SL	56.23	43.25	35.45	12.36	23.56	45.23	1.35
LSD ($p \leq 0.5$)	13.30	3.23	3.24	1.96	5.80	8.80	0.55

Table 10. Comparative performance of limo (acid lime x lemon hybrid) with their parents

Character	TSS (^{0}B)	Acidity (%)	Fruit /tree	Fruiting season	Reaction to canker
ACSH-3-2/18	7.28	5.85	70	Twice	Immune
ACSH-3-4/18	6.68	5.89	8	Once	tolerant
ACSH-3-14/18	6.12	5.80	15	Once	Tolerant
ACSH-3-15/18	6.32	5.85	5	Twice	Immune
ACSH-5-12/18	6.08	3.67	8	Once	Immune
ACSH-5-13/18	6.20	5.42	25	Once	Immune
ACSH-5-15/18	6.00	5.42	25	Once	Immune
ACSH-7-14/18	6.08	4.48	40	Once	Immune
ACSH-7-15/18	6.00	5.16	28	Once	Immune
ACSH-9-1/18	6.96	6.10	35	Once	Immune
Pusa Abhinav	4.23	6.65	250	Twice	Susceptible
Konkan SL	7.06	5.28	320	Twice	Immune
LSD ($p \leq 0.5$)	0.27	0.18	-	-	-

Table 11. Crosses made in February –March 2022

Cross Combination	Flower crossed	Fruit set after 15 days (%)	Fruit set after 30 days (%)
ACSH-3-2 ×Pusa Abhinav	16	100	60.43
ACSH 11-14 ×Pusa Abhinav	14	80.00	40.28
KSL ×Pusa Abhinav	85	95.29	65.20
Pusa Abhinav × KSL	21	33.33	7.85
SCSH 11-15 ×Mosambi	46	58.70	30.25
SCHS 9-2 ×Mosambi	10	60.00	40.23
Yama Mikan × Sacaton	92	25.00	16.52
Rangpur lime × Sacaton	88	50.00	28.65
Small fruited mandarin × Sacaton	44	13.64	5.45
Small fruited mandarin × Troyer	51	9.80	2.24
Cleopatra mandarin × Troyer	63	33.33	25.45
Sour orange × Troyer	62	66.13	50.00
Total	592	52.10*	31.04*

***Average**

Table 12. Sowing of hybrid seeds of previous years crosses/ bearing hybrids

Cross /Hybrid	Number of fruits obtained	Number of seeds extracted	Number of seed sown
Cleopatra x Troyer	5	20	20
ACSH-3-2/18	20	215	215
CRH-7-4/18	15	145	145
CRH-21-13/2014	10	170	170
SCSH-3-14/2016	4	60	60
SCSH-3-15/2016	5	50	50
SCSH-9-2/2012	4	50	40
SCSH-9-5/2012	1	15	15
SCSH-9-10/2012	5	100	94
SCSH-17-19/2013	5	70	58
SCSH-20-11/2015	10	165	165

1.1.2.6 Evaluation of superior pummelo clones for different horticultural traits

Three superior clones of pummelo were collected. Five field planted accessions of pummelo were characterized for reproductive characteristics and the accession 628798 bore thin-skinned, and the accessions 628799 and 628800 bore dark-fleshed fruits with solid core.

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

For the identification of tetraploids and triploids of Kinnow and Mosambi, their bold and aborted seeds were sown separately. The germination was better in bold seeds compared to aborted seeds and in Mosambi compared to Kinnow seeds. Further, for the production of monoembryonic tetraploid parents to be used in breeding programme for triploid production, pummelo seeds were treated with varying colchicine concentrations, but the colchicine concentration tried for this was not suitable for induction of tetraploids in pummelo.

1.1.2.8 Crossing of tetraploids with diploids to develop triploid Kinnow

From the previous year crossing programme, 14 tetraploid seedlings of Mosambi were planted and 10 are surviving and in Kinnow, 18 tetraploid and 8 triploid seedlings were planted and three and one seedlings, respectively, are surviving. A total of 534 crosses of Tetraploids × diploids of Mosambi and 504 crosses of tetraploids × diploids of Kinnow were attempted to produce the triploids.

1.1.2.9 Observation on fruit setting in tetraploid and diploid and vice -versa crosses

Initial fruit set was good in both types of the crosses. Flowering initiation and completion were one week earlier in Mosambi colchiploids compared to Kinnow colchiploids. 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 and flow cytometry. Seven Tetraploids of Mosambi and 4 of Kinnow were confirmed by cytological studies (Fig. 4-5). 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.

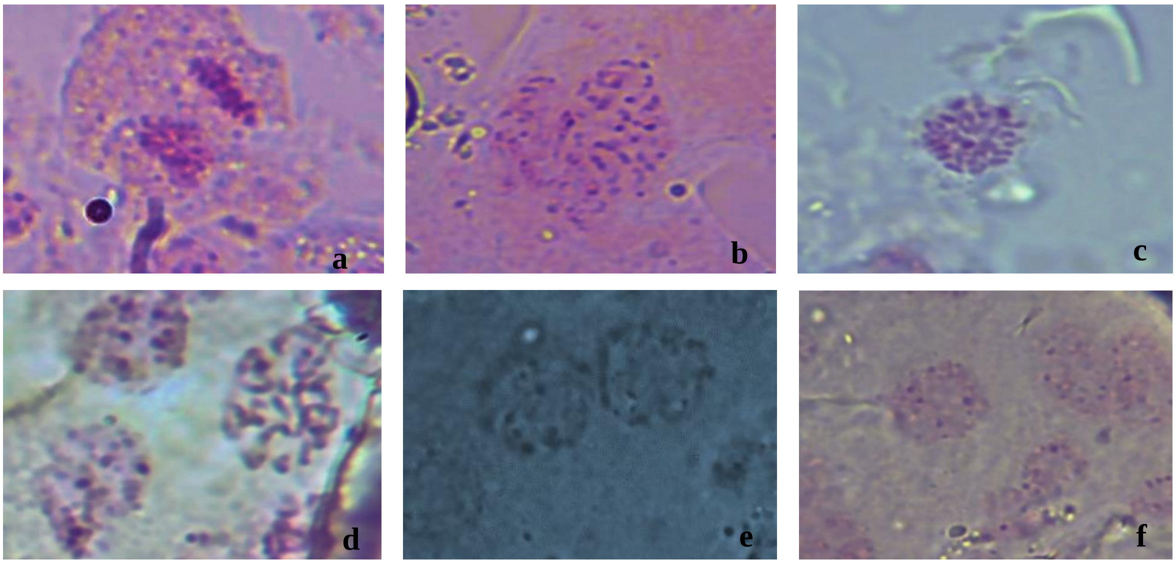


Fig. 4. Putative tetraploids observed in second generation Kinnow mandarin colchiploids, L1P1(a), L1P2(b), L3P11(c), L3P12(d) , L5P10(e) and L5P11(f)

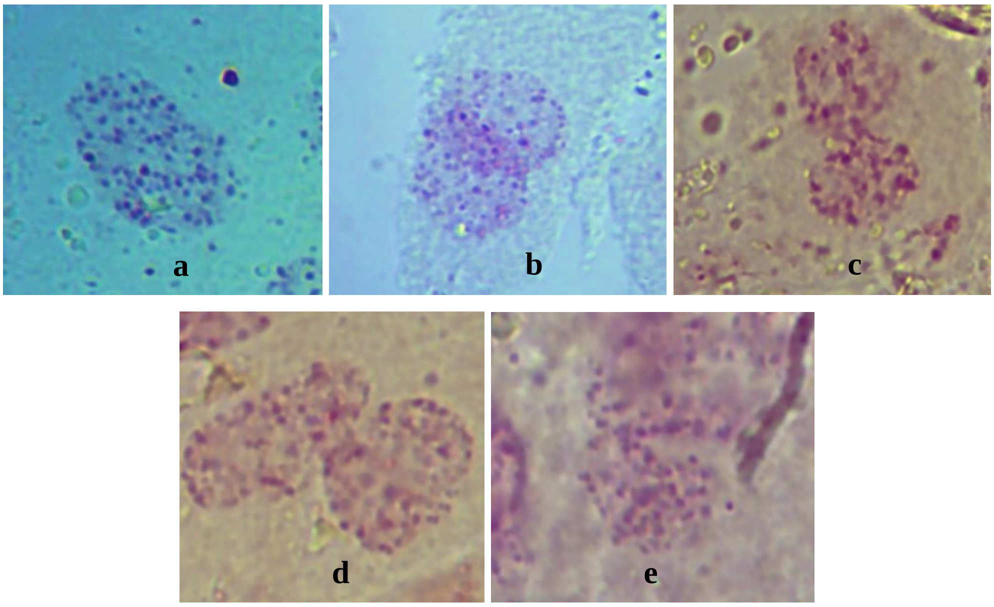


Fig. 5. Putative tetraploids observed in second generation Mosambi colchiploids L6P9(a), L6P11(b), L6P12(c), L7P9(d) and L7P13 (e).

1.1.2.10 Morpho-physiological characterization of field planted putative triploids

Six putative triploids of Kinnow, planted in 2020-21 and four planted in 2001-22 were characterized morphologically and they exhibited dwarfing growth except in two seedlings. Preliminary identification of three triploids (T×D/20/1, T×D/20/2, T×D/20/7) was done by Flow Cytometry (Fig. 6).

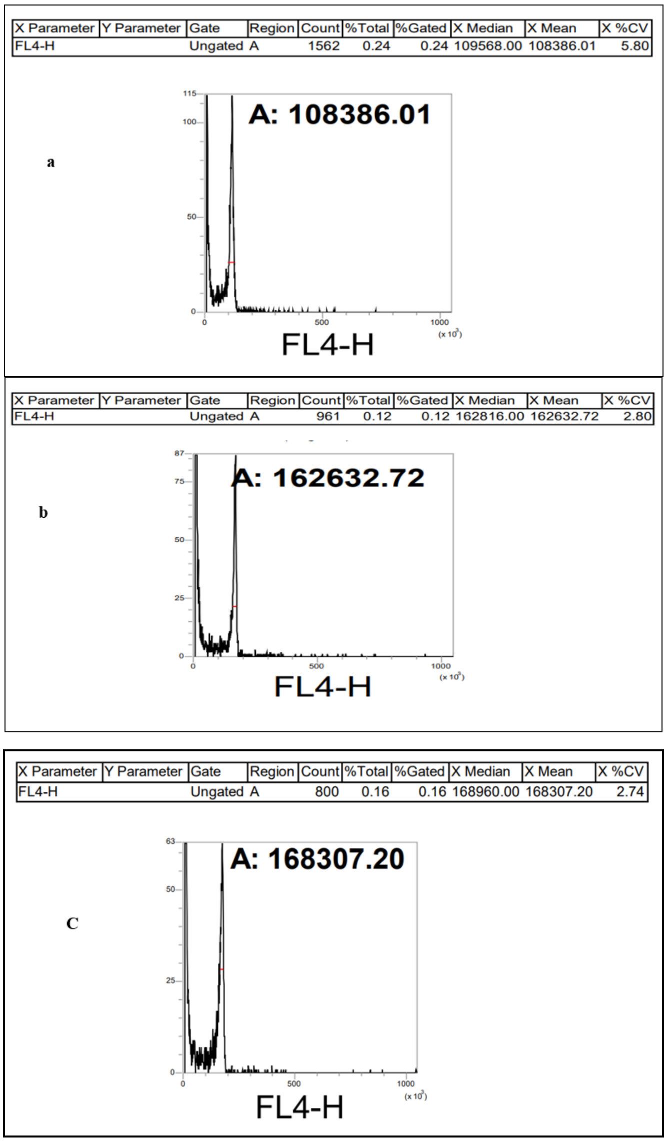


Fig. 6. Flow cytometry histogram of diploid plant (a) and genotype T × D/20/1 (b), T×D/20/2 (c) (triploid) of Kinnow mandarin

1.1.2.11 Mutagenesis studies in Kinnow

From the diverse mutant population developed over the years, mutants Col-1-19, Col-2-19 and EMS-M-3 showed characteristics similarity to the putative mutants developed during the year 2011. The mutants were observed to be extremely dwarf and plant height ranged between 1.3-1.5 m as compared to wild type (3.1m). The plants have entered into reproductive phase. Low seeded first generation mutants G-6-1and G-9-4 were multiplied and field plated during the year 2021 but none of the plants survived due to heavy infestation of *Citrus psylla*.

1.1.2.12 In *vitro* mutagenesis in Kinnow mandarin

Since the nodal explant gave poor response with respect to *in vitro* regeneration, modified *in-ovulo* nucellus culture technique was attempted. Comprehensive examination of different developmental stages confirmed the optimum explant development in 21-25 mm (Stage III) fruits during last week of May-First week of June. Identified ovule stage induced direct somatic embryos from micropylar cut end on induction medium containing DKW + kinetin 5.0 mg L^{-1} + malt extract

1000 mg L^{-1}. Simultaneously the same medium supported the maturation of somatic embryos. The matured embryos from above medium gave robust germination with bipolar conversion on Murashige and Tucker medium (MT) + gibberellic acid (GA_3) 2.0 mg L^{-1} + ά-naphthaleneacetic acid (NAA) 0.5 mg L^{-1}+ spermidine 100 mg L^{-1} + coconut water (CW) 10% (v/v). The bipolar germinated seedlings established well upon preconditioning in a bio regulator free liquid medium under light. Consequently, a cent percent survival of emblings was achieved on a potting medium containing cocopeat: vermiculite: perlite (2:1:1). Histological studies confirmed the single nucellus cell origin of somatic embryos by undergoing normal developmental events. ISSR genetic fidelity assessment confirms the genetic stability of acclimatized emblings. Since the protocol can induce rapid single-cell origin of genetically stable *in vitro* regenerants in high frequency, it has an immense potential for induction of solid mutants, besides crop improvement, mass multiplication and virus elimination in Kinnow mandarin.

1.1.2.13 In *vitro* shoot organogenesis in sweet orange (*Citrus sinensis* L.) cv. Mosambi Sweet orange

Standardization of a reliable protocol using different explants (epicotyl, cotyledon and root), PGRs and carbon sources on indirect embryogenesis was carried out. Callusing was observed to be significantly higher in the treatment combination of MS + 2,4-D (1.5 mg L^{-1}) + BAP (1.0 mg L^{-1}) + ME (500 mg L^{-1}) with epicotyl proved best for callusing (90.89 and 83.72%), callus FW (0.83 and 0.67 g), callus TW (0.84 and 0.68 g), and callus DW (0.08 and 0.05 g), as compared to others. Embryogenesis (59.09%) and germination (33.61%) were achieved best in MS + BAP (2 mg L^{-1}) + NAA (0.1 mg L^{-1}) + ME (500 mg L^{-1}). Among different carbon sources, 5% glycerol supplemented with the same treatment combination proved best in inducing the highest number of SE/ callus mass (73.26), SE (65.27%) and plantlet formation (68.77%). The protocol standardized can be used for indirect embryogenesis for different genotypes.

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

Drs S. K. Singh, M. K. Verma, V. B Patel, Jai Prakash , Chavlesh Kumar, Madhubala Thakre, Rakesh Singh (NBPGR)

1.1.3 .1 Hybridization

In scion breeding, 187 panicles having 11346 flowers were crossed, including the genotypes, Pearl of Csaba, Flame Seedless, Perlette, Pusa Navrang, etc. In rootstock breeding, 645 flowers were used for hybridization involving the cross combinations of *Vitis parviflora* × Dogridge, *Vitis parviflora* × Salt Creek and *Vitis parviflora* × Male Hybrid.

1.1.3 .2 Augmentation of germplasm

The dormant cuttings of different wild *Vitis* species *viz*., *V. himalayana*, Parthenocissus (EC452215), *V. ficifolia* (EC452206) and *V. riparia* (EC 452207) received from NBPGR RS, Phagli (H.P.) were planted in the pots. Identified one unique genotype having extra early maturity (15 May ~~2021~~) and loose bunches having a difference in the date of natural bud break by at least 20 days between the Extra Early genotype and the late genotype Pusa Seedless.

1.1.3.3 Evaluation of hybrids

Twenty-two grape hybrids and genotypes developed in the background of 'Pusa Navrang' were evaluated for juice purpose. Hybrids 16/2A-R4-P9, 16/2A-R2-P7, 16/2A-R4-P7 and 16/2A-R3-P3 have been identified potential for juice purpose. The improved hybrids have the better berry weight and yield potential than the tenturier berries. The maximum juice recovery was recorded in hybrid 'Hyb.16/2A-R4P9 followed by 'Hyb. 16/2A-R4P7' as compare to the 'Pusa Navrang'. In addition, it was also found superior in terms of bunch weight and vine yield per plant basis. The berries were tenturier in nature, seed and ready to mature by the 2nd week of June (Fig. 7).

(a)

(b)

Fig. 7. Grape hybrids (a)16/2A-R4-P9 and (b) 16/2A-R4-P7

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

Drs. A. Nagaraja, Drs 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 Hybridization

Hybridization in guava was done as per Diallel Mating Design by involving ten best combiner genotypes with intended traits. Thirty cross compatible desirable combinations (Punjab Pink × Hisar Surkha, Punjab Pink × Black guava , Punjab Pink × Shweta, Punjab Pink × Pant Prabhat, Hisar Surkha × Shweta, Pant Prabhat × Hisar Surkha, Punjab Pink × Thai, Punjab Pink × Hisar Safeda, Punjab Pink × Allahabad Safeda, Pant Prabhat × Lalit, Pant Prabhat × Punjab Pink, Pant Prabhat × Hisar Surkha, Pant Prabhat × Black Guava, Pant Prabhat × Red variant, Pant Prabhat × Arka Kiran, Lalit × Pant Prabhat, Lalit × L-49, Lalit × Thai, Lalit × Hisar Safeda, L-49 × Punjab Pink, L-49 × Lalit, L-49 × Hisar Surkha, L-49 × Black Guava, L-49 × Arka Kiran, Allahabad Safeda × Black Guava, Allahabad Safeda × Hisar Surkha, Allahabad Safeda × Punjab Pink, Allahabad Safeda × Lalit, Allahabad Safeda × Arka Kiran, Shweta × Black Guava and Shweta × Arka Kiran) were used, and total 870 flowers were crossed. Of these, final fruit set was recorded in 21 cross combinations. The seeds of hybrid progenies were sown and a total of 1160 No. of F_1 population was raised and transplanted in the field for further evaluation. Simultaneously, the guava germplasm block (16/19 & 16/20 blocks of main garden in 3.0-acre area) was maintained too during this period. Guava F_1 populations were evaluated for physio-biochemical traits.

1.1.4.2 Hybrid Evaluation

Guava genotypes and hybrids were evaluated based on morphological, biochemical and physiological parameters including nutrient and flavour profiling (Fig. 8). Guava genotypes and hybrids showed significant variations for different traits. The highest content of TSS (12.54ºBrix), total titratable acidity (0.66%) and total ascorbic acid content (285.03 mg/100 g of pulp) was recorded maximum in GH-2017-1F. Similarly, total phenolic content was recorded highest in Lalit (283.67

mg/100g GAE of FW), while hybrid GH-2017-6C exhibited the highest total flavonoids content (92.53 mg/100 g FW). The total carotenoids content in pulp was recorded maximum in Lalit (0.68 mg/100 g of FW). Total sugar content and total soluble proteins were registered to be the highest in GH-2017-1F (9.09%) and GH-2017-2A (16.65 mg/ml), respectively.

Thirty-two genotypes and hybrids were also analysed using GC-MS for their flavouring compounds (Fig. 9). The major compounds identified were *hexenol*, *ethyl acetate*, *benzldehydes*, *3Z-hexenyl acetate 3-phenylpropyl acetate, butylated hydroxytoluene, β-caryophyllene*, *caryophyllene oxide*, *nerolidol* and *globulol*, besides the several fractions were also present in minor and trace amounts.

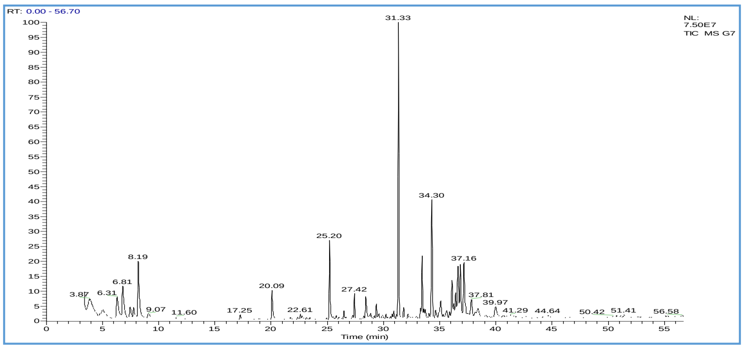


Fig. 8. Total ion chromatogram of flavouring

Pink pulped guava F_1, HSUxSH-16-8-2 and white pulped guava F_1, HSU×SH-16-8-18 were found promising (Table 13 & Fig. 10).

Table 13. Characteristics of promising guava hybrids

Fruit trait	Guava hybrid	
	HSU × SH-16-8-2	HSU × SH-16-8-18
Fruit weight	250.50 g	148.06 g
Fruit diameter	71.82 mm	66.69 mm
Fruit length	73.97 mm	61.93 mm
Core diameter	43.66 mm	31.20 mm
Pulp thickness	14.06 mm	14.75 mm
Peel colour	Yellow Green (YG115D)	Yellow Green (YG144C)
Pulp colour	Red (R40A)	White (NN155B)
TSS	17.2°B	16.4°B
Acidity	0.51%	0.45%
Ascorbic acid	192.33 mg/100g	124.17 mg/100g
Lycopene	5.81 mg/100g	0.18 mg/100g
Total anthocyanins	4.61 mg/100g	0.14 mg/100g
Total carotenoids	0.88 mg/100g	0.17 mg/100g

(a) **(b)**

Fig. 9. Fruits of (a) HSU × SH-16-8-2 and (b) HSU × SH-16-8-18 guava hybrid.

In all the 11 pink/red pulped F_1s, the amount of lycopene was greater than the amount of total anthocyanins. This indicates that, in the pink/red pulp colour of coloured guava F_1s, lycopene is contributing more as compared to total anthocyanins. Morphological characterization of 253 guava F_1s for different leaf parameters shows that leaf pigmentation of F_1s during winter was not correlated to the pulp colour and leaf colour of the parents. The segregation pattern for the trait, anthocyanin colouration of young leaf among F_1s indicated that the parents are heterozygous for the gene(s) governing the presence of this trait and are homozygous for the gene(s) governing the absence of this trait.

1.1.4.3 Differential gene expression analysis between red and white pulped soft seeded guava genotype

To have a detailed insight into the molecular crosstalk involved in the development of pulp coloration in guava, transcriptome of white and pink pulped guava was compared. The RNA isolated from three different stages of fruit development; the early (ES) middle (MS) and the ripened stage (RS). A total of 18 stage specific pair end libraries were generated and sequenced using Illumin NextSeq550 system. After quality trimming and removal of low-quality sequence, 391 million high quality reads belonging to 18 different libraries were used for generation of *de novo* reference transcriptome using Trinity assembler. A total of 251,345 transcripts belonging to 151,428 components/genes with N50 of 2709 bp were obtained. Benchmarking Universal Single-Copy Orthologs (BUSCO) analysis with lineage dataset viridiplantae Odb10 identified 97.18% of the BUSCO groups having complete gene representation (single-copy or duplicated), while 2.12% were only partially recovered, and 0.71% were missing in the assembled transcriptome. Trans Decoder was used to identify candidate protein coding regions within transcript sequences. A total of 76,901 protein coding transcripts were predicted and gene ontology assessment with Blast2GO assigned gene ontology terms to 55,258 transcripts. Further, to provide functional analysis of proteins InterProScan was done to classify them into families and predicting domains and important site. InterProScan (IPS) IDS were retrieved only for 70,022 transcripts and for the rest no hits were obtained.

1.1.4.4 Germplasm augmentation

The 90 Seedlings of 23 Extotic guava genotypes introduced from the USDA, Hio, USA through NBPGR, New Delhi were planted in the guava field gene bank. Besides, 20 new guava genotypes were also collected from the State Agricultural Universities, private and public nurseries for augmentation of the guava germplasm.

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

Drs Jai Prakash, A.K. Goswami, K. Singh, Dharmendra Singh (GPB, 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 Variety identified and released

Pusa Peet (P-7-2) cultivar, a segregating population of Honeydew x Tripura Local was developed and having semi-dwarf plant architecture, gynodioecious nature, early flowering type (71 DAP) with fruiting zone- 107 to 118 cm, fruit size-972 to 1035 g (medium), total soluble solids- 11.0 to 12.1 °Brix, pulp colour- yellow, fruit yield- 36 to 41 kg/plant under agro-climatic conditions of Delhi, fruits are fairly rich in antioxidants and suitable for high density planting with a spacing of 1.5 m x 1.5 m. Fruit yield gain per plant and per ha. over the check variety 'Pusa Nanha' were 46.63% and 16.33%, respectively. Reduction in seed rate was 66% as compared to check considering that there will be no male plant in field and all plants will produce fruits. Fruits become ready for first harvesting within eight to nine months after transplanting. The above variety 'Pusa Peet' has been identified and recommended for its release by IARI in 2022 as well as by the State Seed-Committee for

Agricultural and Horticultural Crops, Government of N.C.T., Delhi during its meeting on December 27, 2022.

1.1.5.2 Evaluation of papaya parents with their hybrids

Evaluation was carried out 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 and 30 hybrids (reciprocal crosses of parents) on 9 important horticultural traits. The plant height at flower initiation in parents and hybrids ranged from 59.67 cm to 95.67 cm. Parents, PN (63.0 cm) followed by P-9-12 (78.67 cm) were recorded with shortest plant height at flowering stage, whereas, P-7-9 (95.67 cm) followed by PS 3 (83.67 cm) were observed with tallest plants. Among hybrids, shortest plant height at flowering was recorded in P-9-5 x PS3 (59.67 cm) followed by PN x P-9-12 (63.33 cm) and P-7-2 x PN (65.33 cm). The maximum plant height among hybrids at flowering was observed in P-7-2 x P-7-9 (87.33 cm) followed by PS3 x P-7-9 (85.67 cm). The shortest internodal length was observed in the parent, PN (3.63 cm) followed by P-7-2 (5.17 cm), whereas the internodal length was maximum in P-7-9 (7.80 cm) followed by PS 3 (7.30 cm). In case of hybrids, the shortest internodal length was recorded in P-7-2 x PN (3.93 cm), followed by P-9-5 x PN (4.03 cm) and PN x P-7-2 (4.20 cm), whereas the intermodal length was maximum in hybrid, PS3 x P-7-9 (7.57 cm) followed by P-7-9 x PS3 (7.53 cm). Days to flower appearance was earliest in the hybrid P-7-2 x P-9-5 (74.67), which was statistically at par with the parent P-7-2 (78.67) and the hybrid P-7-2 x PN (79.67). Flower at lowest node emerged in the parent PN (26.33), followed by P-9-12 (31.0), in case of hybrids P-9-5 x PS3 (27.67) was observed with flower at lowest node, followed by P-9-12 x PN (28.0), PN x P-9- 12 (28.33) and P-9-5 x PN (28.67). Whereas, female flower at highest node appeared in the parent P-7-9 (40.33), followed by PS3 (37.67) and highest node P-7-2 x P-7-9 (38.33). Earliest fruit maturity was recorded in the parent P-9-5 (127.33) followed by P-7-2 (132.33), whereas fruit maturity took maximum time in the parent P-7-9 (143.67) followed by PN (139.33). In case of hybrids, P-9-5 x P-7-2 (120.67), followed by PN x P-9-5 (121.0). Whereas, hybrid, P-7-9 x P-9-12 (143.0) followed by P-9-12 x P-7-9 (142.67) and P-7-2 x P- 9-12 (141.0) showed delayed maturity among the hybrids. The fruiting zone was maximum in the parent PS3 (133.0 cm) followed by P-7-9 (126.67 cm), whereas it was minimum in the parent PN (64.33 cm) followed by P-7-2 (99.33 cm). Among hybrids, the fruiting zone was longest in PS3 x P-7-9 (131.0 cm) and hybrid, P-7-9 x PS3 (129.0 cm) also produced at par fruiting zone, whereas the smallest fruiting zone was found in P-9-12 x PN (59.33 cm). Number of fruits per plant was found to be maximum in PS3 x P-9-5 (44.67) followed by PS3 x P-7-9 (44.0) and P-9-5 x PS3 (41.67), whereas it was minimum in the hybrids, PN x P-7-2 (24.67) followed by statistically similar hybrids PN x P-9-12 (25.0) and P-7-2 x PN (25.0). The parent identified with maximum fruit weight was P-7-2 (1043 g) followed by P-9-12 (1038g), whereas it was found minimum in the parent PN (1001 g) followed by P-7-9 (1022 g). Fruit weight was found maximum in the hybrid, P-7-2 x P-9-12 (1075g) followed by P-9-12 x P-7-2 (1074 g) and PN x P-7-2 (1063 g). Whereas, the minimum value of fruit weight was recorded in the hybrids, P-7-2 x PN (1003 g), P-9-12 x PN (1005 g) and P-7-9 x PN (1006 g). The average fruit yield per plant in parents and hybrids varied from 24.20 kg to 56.98 kg. The parents recorded with maximum yield per plant with PS3 at top (53.49 kg) followed by P- 9-5 (46.07 kg), whereas it was lowest in PN (24.20 kg). The hybrid, P-9-5 x P-7-2 (56.98 kg) expressed highest yield followed by P-9-12 x P-7-2 (55.08 kg), whereas, the yield was lowest in hybrids, P-7-2 x PN (27.74 kg). Among all the parents under the study, PN was identified with shortest plant height and internodal length and for the same traits, hybrids like P-9-5 x PS3 and P-9-5 x PN exhibited the lowest desirable value. Earliness in terms of days to flowering, days to fruit maturity and number of nodes for flower initiation, was observed in parents, PN, P-9-12 and P-7-2, whereas, the F 1 hybrids exhibiting earliness were P-7-2 x PN, P-9-12 x PN, PN x P-9-12 and P-9-12 x P-9-5. For fruit yield and related traits like fruit weight, fruiting zone and number of fruits per plant, parents, PS3, P-7-2 and P-7-9 along with hybrids P-9-12 x P-7-2 and PS3 x P-7-9 were identified as better performers.

1.1.5.3 Bioactive compounds and antioxidant activities of papaya (*carica papaya l.)* hybrids

The present study aimed to analyze the bioactive compounds and antioxidant activities in nine papaya hybrids. Among all the nine hybrids, Pusa Nanha × PS-3 had the maximum TSS (11.7 °Brix), Pusa Nanha × P-9-12 had the highest ascorbic acid content (92.8 mg/100 g pulp), P-9-12 × P-9-5 had the highest concentration of total phenols (34.80 mg GAE/100 g) and P-9-12 × P-7-14 was found with maximum total flavonoids (37 mg QE /100 g).Hybrid P-9-12 × P-7-2 was found superior with respect to total carotenoids (4.88 mg/100g). Totally 18 carotenoids and carotenoid esters were identified in the papaya pulp through LC-MS. Three of these were hydrocarbon carotenoids, five were free xanthophylls, nine were xanthophyll esters, and one was a carotenal. Among these, five carotenoid fractions were quantified through LC-MS. Hybrid P-7-9 ×PS-3 had maximum β-carotene (2.091 mg/100g), P-9-12 × P-9-5 with maximum β-cryptoxanthin content(0.724 mg/100g), PusaNanha×PS-3 had the highest lycopene content(0.899 mg/100g)and P-9-12× P-7-14 which was found to have maximum zeaxanthin (0.315 mg/100g) and lutein content (0.269 mg/100g). Hybrid P-9-12 × P-7-14 had maximum CUPRAC antioxidant activity (9.11 µmol TE⁄g) while, Pusa Nanha × P- 9-5 had the highest DPPH antioxidant activity (1.85 µmol TE⁄g) and Superoxide dismutase activity (0.147 U mg-1 protein). The highest total soluble proteins were found in Pusa Nanha × PS-3 (3.48 mg/ml) followed by P-9-12 × P-7-2 with the highest catalase activity (0.145 µmol H2O2hydrolysed min-1 mg-1 TSP) and P-9-5 × P-7-9 had the maximum peroxidase activity (0.052 µmol min-1 mg-1 TSP). Based on the comparative analysis, three papaya hybrids P-9-12 × P-7-14, Pusa Nanha×P-9-12, and P-9-12 ×P-7-2 were found superior in terms of both bioactive compounds and antioxidant activities.

1.1.5.4 Evaluation of mutants

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. Two mutants viz. PM 04 and PM 28 were selected from two lower doses 0.10 kGy and 0.15 kGy which were particularly outstanding in vigour having dwarf stature and bearing height in M7 population were selected and evaluated in M8 generation. Minimum height (108.32 cm), plant height at flower initiation (66.46 cm), plant girth at first fruiting (62.42 mm), nodes to first flowering (48.62), days to flower initiation (8.72), length of middle internode (4.2 cm) and length of petiole (54.46 cm) was recorded in PM 04 while minimum plant spread in east-west direction (135.6 cm) and north south direction (138.8 cm) was recorded in PM 28 while maximum height (136.24 cm), plant height at flower initiation (88.22 cm), plant girth at first fruiting (72.86 mm), nodes to first flowering (66.54), days to flower initiation (96.24), length of middle internode (5.20 cm), length of petiole (64.12 cm) and plant spread in east-west direction (150.4 cm) and north-south direction (148.8 cm) was found in control (P 7-2). Maximum number of fruits (38.2) and width of fruit (10.48 cm) was recorded in PM 04 while maximum fruiting length (76.2cm), weight of fruit (0.940 kg) and length of fruit (18.42 cm) was recorded in control (P 7-2). Minimum length of fruit cavity (12.31 cm) and width of fruit cavity (4.12 cm) and maximum pulp thickness (3.34 cm) and TSS (10.25° Brix) was recorded in PM 04 while minimum pulp thickness (2.82 cm) and TSS (9.62° Brix) was recorded in control (P 7-2).

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, M. K. Verma, Kanhaiya Singh, V. B. Patel, 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

Effect of five polyembryonic rootstocks on semi vigorous mango varieties 'Pusa Arunima', 'Pusa Surya' and 'Amrapali'

The performance of mango varieties, grafted on five polyembryonic rootstocks are given in Table 14-16. 'Pusa Arunima' proved to be the most vigorous in respect of canopy diameters (4.67 m E-W and 4.54 m N-S), tree height (3.97 m) and canopy volume (184.06 m^3). The Olour rootstock was found most vigorous in terms of canopy diameter (4.81 m E-W), tree height (3.91 m) and tree volume (186.79 m^3), however, it was found at par with Kurakkan for canopy diameter (4.50 m E-W) and canopy volume (152.05 m^3). Pusa Arunima showed the highest canopy diameter (5.33 m E-W) on Olour followed by Kurakkan, K-3 and K-2 rootstocks having statistical similarity with Pusa Surya on Olour and Amrapali on Kurakkan rootstocks. In the other direction (N-S), highest canopy diameter of 'Pusa Arunima' was recorded on Olour (5.22 m), followed by Kurakkan and K-3. The similar observations were recorded in terms of tree height, however, Pusa Surya on Kurakkan was found statistically similar with Pusa Arunima on vigorous rootstocks. Over all, Pusa Arunima proved to be the most vigorous statistically in terms of canopy volume (261.48 m^3) over others. K-2 rootstock imparted the dwarfness to all the varieties tested (Table 7). The highest number of fruits (128.67/ tree), yield (22.62 kg/tree) an yield/ m canopy diameter (4.81Kg) was recorded in Pusa Arunima, although Amrapali was found statistically at par with Pusa Arunima in respect of fruits/ tree. Of the five rootstocks, K-2 excelled for number of fruits (140.00/ tree), yield (22.05 Kg/ tree), yield efficiency (0.37 Kg/m^3 CV) and yield/ m canopy diameter (7.39 Kg) over others (Table 15). Among the interactions, Pusa Arunima on K05 and Kurukkan (151.67-156.67 fruits/ tree) and Amrapali on K-2 (191.67 fruits/ tree) were found at par in respect of number of fruits/ trees. Similarly, significantly higher yields of Pusa Arunima were recorded on K-5, Kurakkan, K-3 and K-2 (22.38-24.95 Kg/ tree) rootstocks and Amrapali on K-2 (28.53 Kg/tree) rootstock with no significant difference. The highest yield efficiency (0.65 Kg/m^3) and yield/ m canopy diameter (12.72 Kg) was recorded in Amrapali, while grown on K-2 rootstock (Table 15). Pusa Arunima and Pusa Surya were statistically at par in respect of higher fruit weight (179.39-183.82 g) and acidity (0.29-0.31%) than Amrapali. On the other hand, the later variety was found to have the highest TSS (23.68°B) content statistically. K-3 and K-2 rootstocks excelled for fruit weight (197.41 g) and acid content (0.31%), respectively. Except Kurakkan, all the rootstocks were found statistically at par for TSS (22.23°-22.75°B) content. Among the interactions, higher fruit weight (225.10-230.10 g) was recorded for Pusa Surya on K-5 an K-3 rootstock. Amrapali proved to be superior for high TSS (23.28-24.90°B) on Olour and K-3 rootstocks, while highest content of titratable acid (0.42%) was recorded in the fruits of Pusa Surya, while grown on K-2 rootstock. The content of ascorbic acid was not influenced by either variety or rootstocks or their interaction (Table 16).

Table 14. Plant height, canopy diameter and canopy volume of 16 years old three varieties of mango on five polyembryonic rootstock

Rootstock Variety	Canopy diameter (East-West) (m)						Canopy diameter (North-South) (m)					
	K-5	Kur	OL	K-3	K-2	Mean	K-5	Kur	OL	K-3	K-2	Mean
Pusa Arunima	4.22	4.83	5.33	4.78	4.62	4.76	4.13	4.73	5.22	4.53	4.08	4.54
Pusa Surya	3.07	4.18	4.82	3.45	3.11	3.72	3.15	4.35	4.11	3.25	3.02	3.57
Amrapali	3.50	4.48	4.28	3.82	2.28	3.67	3.03	4.18	3.97	3.13	3.70	3.60
Mean	3.59	4.50	4.81	4.01	3.34		3.44	4.42	3.64	3.60	3.60	
LSD (P≤ 0.05)												
Variety (V)	0.44						0.36					
Rootstock (R)	0.58						0.46					
V x R	1.00						0.80					
	Plant height (m)						Tree volume (m^3)					
Pusa Arunima	4.05	4.00	4.50	4.37	3.05	3.97	146.079	190.80	261.48	191.30	130.62	184.06
Pusa Surya	3.10	4.00	4.20	3.00	2.25	3.19	60.94	135.36	173.41	74.11	45.85	97.93
Amrapali	3.15	3.40	2.50	3.00	2.45	2.86	56.78	130.00	125.48	76.64	47.93	87.37
Mean	3.10	3.56	3.91	3.44	2.70		87.93	152.05	186.79	114.01	74.80	
LSD (P≤ 0.05)												
Variety (V)	0.24						26.85					
Rootstock (R)	0.32						34.67					
V x R	0.55						60.05					

Each data represents the mean value n=5 samples. Values are representing different letters are significant at P ≤ 0.05 (Tukey's honest significance test)

Table 15. Variation in fruiting density, yield efficiency, yield and yield per meter canopy cover of semi vigorous mango varieties grafted on different polyembryonic rootstocks.

Rootstock	Fruit/tree						Yield (kg/tree)					
Variety	K-5	Kurakkan	Olour	K-3	K-2	Mean	K-5	Kurakkan	Olour	K-3	K-2	Mean
Pusa Arunima	156.67	151.67	103.33	96.67	135.00	128.67	23.03	23.40	19.34	22.38	24.95	22.62
Pusa Surya	36.67	31.00	105.00	48.33	93.33	62.87	7.56	7.32	12.93	9.76	12.68	10.05
Amrapali	100.67	113.33	106.67	108.33	191.67	124.13	14.65	15.12	15.71	15.54	28.53	17.91
Mean	98.00	98.67	105.00	84.44	140.00		15.08	15.28	15.99	15.89	22.05	
LSD ($P \leq 0.05$)												
Variety (V)	30.26						3.89					
Rootstock (R)	23.44						5.03					
V x R	53.50						8.71					
	Yield efficiency (kg/m^3)						Yield (kg/m canopy diameter cover)					
Pusa Arunima	0.16	0.12	0.07	0.13	0.19	0.13	5.38	4.79	3.65	4.87	5.36	4.81
Pusa Surya	0.14	0.06	0.07	0.14	0.28	0.14	2.46	1.84	2.68	3.01	4.08	2.81
Amrapali	0.31	0.12	0.15	0.20	0.65	0.29	4.30	3.52	3.59	4.09	12.72	5.64
Mean	0.20	0.10	0.10	0.16	0.37		4.05	3.38	3.31	3.99	7.39	
LSD ($P \leq 0.05$)												
Variety (V)	0.06						0.21					
Rootstock (R)	0.08						0.16					
V x R	0.14						0.37					

Each data represents the mean value n=5 samples. Values are representing different letters are significant at $P \leq 0.05$ (Tukey's honest significance test)

Table 16. Variations in fruit weight and biochemical quality of fruits of mango varieties grafted on different polyembryonic rootstocks.

Rootstock Variety	**K-5**	**Kur**	**OL**	**K-3**	**K-2**	**Mean**
Fruit weight (g)						
Pusa Arunima	144.64	154.05	186.12	239.36	172.76	179.39
Pusa Surya	225.10	230.10	121.79	202.13	139.97	183.82
Amrapali	145.26	125.73	148.2	150.75	153.43	144.67
Mean	171.67	169.96	152.04	197.41	155.39	
LSD (P≤ 0.05)						
Variety (V)				11.81		
Rootstock (R)				15.24		
V x R				26.40		
	TSS (ºB)					
Pusa Arunima	23.04	21.1	22.74	22.7	22.90	22.50
Pusa Surya	21.46	20.16	20.6	20.70	20.60	20.70
Amrapali	23.02	23.04	24.9	23.28	24.2	23.68
Mean	22.51	21.43	22.75	22.23	22.57	
LSD (P≤ 0.05)						
Variety (V)				0.73		
Rootstock (R)				0.95		
V x R				1.64		
	Acidity (%)					
Pusa Arunima	0.31	0.33	0.28	0.33	0.30	0.31
Pusa Surya	0.26	0.31	0.23	0.24	0.42	0.29
Amrapali	0.18	0.18	0.16	0.22	0.21	0.19
Mean	0.25	0.27	0.22	0.26	0.31	
LSD (P≤ 0.05)						
Variety (V)				0.03		
Rootstock (R)				0.03		
V x R				0.06		
	Vitamin C content (mg /100 g pulp)					
Pusa Arunima	24.23	20.33	21.56	24.55	25.36	23.21
Pusa Surya	22.65	23.56	24.58	24.32	23.47	23.72
Amrapali	26.89	23.58	24.98	24.56	23.58	24.72
Mean	24.59	22.49	23.71	24.48	24.14	
LSD (P≤ 0.05)						
Variety (V)				NS		
Rootstock (R)				NS		
V x R				NS		

Each data represents the mean value of 15 fruit samples. Values are representing different letters are significant at P ≤ 0.05 (Tukey's honest significance test).

2.1.1.2 Scion-rootstock interaction study for quality traits in mango

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

To explore rootstock which could impart better quality traits in mango varieties, we studied the interactive effect of the scion and rootstock using five mango varieties grafted on three rootstocks. A total of 25 physico-chemical parameters were studied in the five grafted varieties viz., fruit weight, yield efficiency, fruit per plant, pulp percent, total soluble solids (TSS), acidity, physiological loss in weight (PLW), peel thickness, respiration rate, etc. were known to be altered through scion-rootstock interaction (Fig.10). Among the five mango varieties, Olour rootstock proved to be the best to improve the fruit quality and shelf-life. A total of 35 shelf-life-specific markers were validated. Of these specific primers, 24 showed polymorphism among the studied genotypes. Gene diversity (GD), allele per locus (An), polymorphism information content (PIC), and major allele frequency (MAF) observed were 0.43, 2.00, 0.34, and 0.63, respectively. Cluster analysis clearly showed that scion grafted on Kurukkan and Olour rootstock have more similarity and scion varieties grafted on K-5 rootstock grouped together. A total of eight simple sequence repeats loci (SSRs) markers were associated with eight physiological traits. Strong association of SSR loci NMSLC-12 and NMSLC-14 with yield efficiency and fruit weight with a phenotypic variance of 85 and 70 %, respectively were observed.

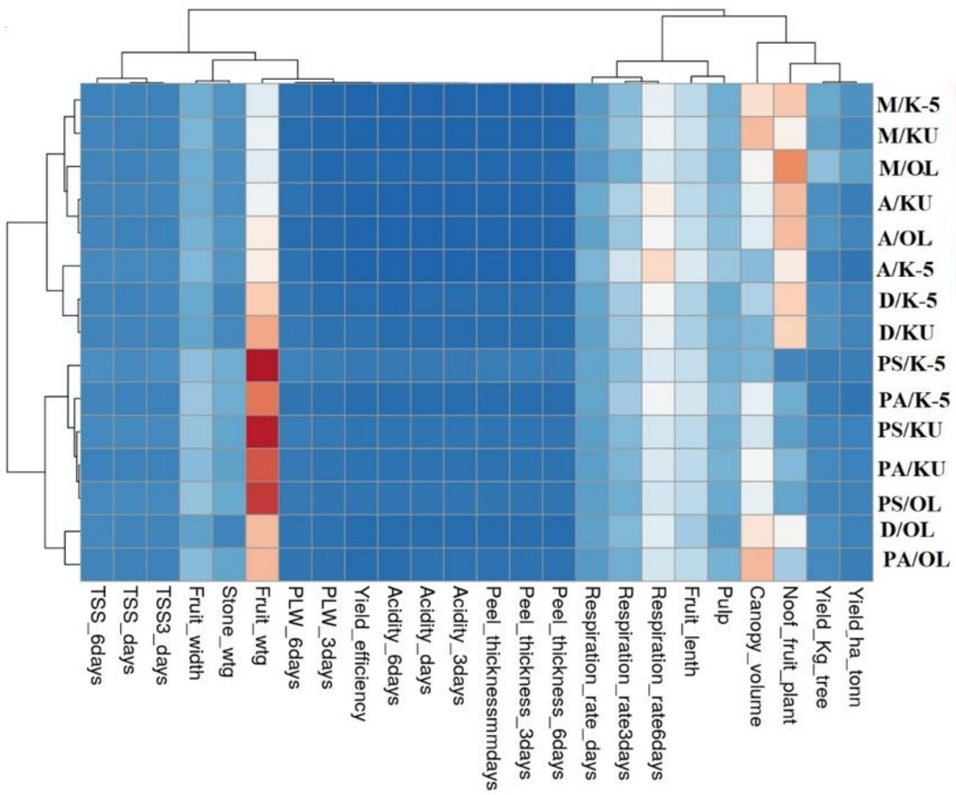


Fig.10. Heatmap and hierarchical clustering for fruit quality traits of scion/rootstock combinations in mango varieties. PA; Pusa Arunima, PS; Pusa Surya, A;Amrapali, D;Dashehari, M; Mallika, OL;Olour, KU;Kurukkan, K-5

2.1.1.3 Rootstock research for managing tree vigour and abiotic stress for improving yield and fruit quality

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

Evaluation of sweet orange on potential rootstocks for tree vigour, yield and fruit quality

The tree vigour, fruit yield and quality of two newly released cultivars of sweet orange (Pusa Sharad and Pusa Round) were significantly influenced by budding on different rootstocks. Over all, C 35 and Yama Mikan rootstocks proved dwarf for Pusa Sharad. The similar effect for Pusa Round was noticed on C 35, X 639, Yama Mikan and Soh Sarkar with no significant difference, while RLC-7 behaved as a vigorous rootstock for the scion varieties tested. The heavier fruits of Pusa Sharad (244.27-256.21g) were yielded on RLC-6, Soh Sarkar and Jatti Khatti statistically. The fruits of Pusa Round were noticed heavier (2023.64-210.78 g) on C 35, X639 and Jatti Khatti rootstocks. RLC-6 and C 35 rootstocks proved high yielding for Pusa Sharad (17.34 Kg/ tree) and Pusa Round (20.70 Kg/ tree), respectively. RLC-6 and RLC-7 rootstocks produced the fruits with thinnest peel of Pusa Sharad (2.66 mm) and Pusa Round (2.38 mm) fruits, respectively (Table 17)

The highest juice content in the fruits of Pusa Sharad (54.74%) was recorded while grown on C 35 rootstock. The similar observation in Pusa Round was observed on X639, however, it was statistically similar with RLC-6, C 35, Yama Mikan and Soh Sarkar. The rootstocks C 35, X639 and Yama Mikan proved statistically at par in imparting higher TSS in Pusa Sharad (8.10°-8.22°B) and Pusa Round (8.00°- 8.30°B). The trees of Pusa Sharad, while grown on Jatti Khatti rootstock yielded the fruits with highest acidity (0.84%) with no significant difference with RLC-6, C35 and X639. Pusa Round, Jatti Khatti also showed the similar results with highest juice acidity (0.86%), but it was statistically at par with rest of the rootstocks except Yama Mikan rootstock. Jatti Khatti rootstock yielded the fruits of both the cultivars with high ascorbic acid (61.46-69.59 mg/ 100 ml juice) (Table 18).

2.1.1.4 Performance of Kinnow mandarin on different rootstocks for yield and quality parameters.

Drs O.P. Awasthi, A.K. Dubey, R.M. Sharma, Nayan Deepak and Natasha Gurung

For evaluating the effect of different rootstock, a new rootstock trial with Kinnow as a scion had been initiated. Eight rootstock *viz*., X-639, Cleoptera Mandarin, *Jatti Khatti*, NRCC-1, NRCC-2, NRCC-3, NRCC5 and CRH-12 were field planted during September 2021 at a spacing of 6 x 6 m and budded in situ with Kinnow as scion. Efforts were also made to collect rootstock form Arunachal Pradesh and three rootstocks viz., Samphola, Tasi and Khasi mandarin were selected and raised *in situ*.

2.1.1.5 Modulation of abiotic stress effect in citrus

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

2.1.1.5.1 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)

Of the nine citrus rootstocks screened for three weeks against drought stress, X639 proved to be the most tolerant rootstock, while Cleopatra mandarin was found highly susceptible to drought. Citrus genotype X639 reported significantly highest relative shoot increment (RSI) of 8% under drought conditions followed by RLC 1. At the end of drought stress and rewatering, all rootstock genotypes were observed for negative leaf change (-12% to -62%), except X639 and RLC-1. Potential stomatal conductance index, a function of stomata pore area and density, was highest in X639 (3.03) under drought stress. Under drought stress conditions, leaf gas exchange parameters *viz.*, *A*, *E*, and g_s were significantly higher in X639, while drought sensitive genotype Cleopatra mandarin registered the lowest values for these parameters. Relative water content (RWC) and membrane stability index (MSI) was significantly higher in X639 (75.89% and 56.94%) and RLC-4 (67.90% and 54.79%) under drought stress. Significantly highest chlorophyll ‘a’, total chlorophyll content and chlorophyll stability index was reported in X639 followed by RLC-4 under drought stress. Leaf anti-oxidant enzymes (superoxide dismutase and peroxidase) activity under drought stress were higher in X639 than others rootstocks.

2.1.1.5.2 Drought mitigation through new generation chemicals in citrus

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

In order to identify the drought mitigating plant bioregulators (PBRs) in citrus rootstocks, eight PBRs *viz*., 24 epibrassinolide (0.001mM), γ-aminobutyric acid (100mM), gycine betaine (1.00 mM), jasmonic acid (2.38 mM), proline (30 mM), salicylic acid (1mM), SNP +NaHS (0.1mM) and spermidine (0.001mM) were studied on contrasting rootstocks namely Cleopatra mandarin (drought susceptible) and X639 (drought tolerant), applied through foliar priming one week after withholding water. Foliar priming treatments significantly affected number of leaves in Cleopatra mandarin, but not in X639. Priming treatments with proline (PRO), sperimidine (SPD), salicylic acid (SA) significantly reduced the leaf wilting and leaf drop (ranging from 17 to 51%) in Cleopatra mandarin at the end of drought stress. Priming with PRO, SA and SPD significantly increased the percentage of fully open stomata (87%, 76% and 57% respectively) compared to drought stress in both genotypes. In Cleopatra mandarin, SPD, PRO, and SA had significantly higher chlorophyll fluorescence (0.575, 0.563 and 0.565 respectively), while SPD had significantly lower canopy temperature of 39.0ºC compare to drought stress (CF=0.454 and CT=43.93ºC). CF in X639 remained unchanged due to priming treatments. During drought stress, significantly higher RWC (>72%) was recorded in Cleopatra mandarin with foliar priming of PRO, SA and SPD with better MSI. However, RWC and MSI in X639 was at par in all priming treatments. Priming treatments of jasmonic acid -2.4mM (JA), PRO, SA and SPD showed significantly higher chlorophyll ‘a’, chlorophyll ‘b’ and total chlorophyll under drought stress in both genotypes. Similar trend was observed for chlorophyll stability index too, which was more than 51% in these treatments. Significantly lower MDA content (<5.50 micromoles/gram) in Cleopatra leaves was reported with priming of PRO, SA and SPD, while in X639, it was significantly lower in JA, PRO, SA and SPD treatments (Fig.11).

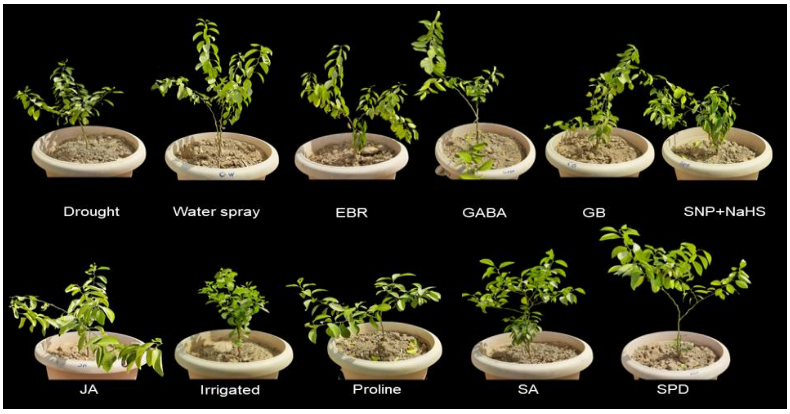


Fig. 11. Comparative influence of new generation chemicals on Cleopatra rootstock under drought stress (EBR- 24 epibrassinolide; GABA- γ-aminobutyric acid; GB- gycine betaine; SNP + NaHS- sodium nitroprusside + sodium hydrogen sulfide; JA- jasmonic acid; SA- salicylic acid; SPD- spermidine)

Table 17. Rootstock influence on tree vigour, yield and physical fruit quality of sweet orange cvs. Pusa Sharad and Pusa Round

Rootstock/ Cultivar	Tree height (m)	Canopy volume (m^3)	Fruit weight (g)	Yield (Kg/tree)	Peel thickness (mm)	Seeds/ fruit
Pusa Sharad						
RLC-6	3.87a	78.82a	256.21a	17.34ba	2.66ed	16.80fegd
C-35	3.50bac	56.22bdc	180.50f	4.51dfe	2.89edc	16.00fg
X-639	3.44bac	65.43bac	196.77ced	17.05b	3.03bdc	16.20feg
Yama Mikan	3.24bdc	53.35bedc	220.23b	5.50	3.31bc	20.40fecd
SohSarkar	3.55bac	70.17ba	249.47a	14.97b	3.37bac	23.00bc
RLC-7	3.46bac	66.24bac	222.07b	4.07dfe	3.01bdc	29.20a
Jatti Khatti	3.87a	66.39bac	244.27a	7.82dc	3.88a	19.40fecd
Pusa Round						
RLC-6	3.13bedc	50.11fedc	183.96fe	6.13dfce	3.27bc	25.20ba
C-35	2.66e	30.23g	203.64cd	20.70a	3.37bac	20.80becd
X-639	3.06edc	37.27fedg	210.78cb	7.24dce	3.56ba	21.40bcd
Yama Mikan	2.90ed	32.51fg	183.09fe	9.76c	3.24bc	14.20g
SohSarkar	2.74e	36.23feg	191.42fed	2.87f	3.38bac	20.60fbecd
RLC-7	3.62ba	62.13bac	185.31fe	5.87dfe	2.38e	16.40feg
Jatti Khatti	3.45bac	51.04fedc	206.10cbd	4.05fe	3.05bdc	22.80bc
LSD ($P \leq 0.05$)	0.45	19.06	16.17	3.75	0.56	4.64

Each data represents the mean value of 15 fruit samples. Values are representing different letters are significant at P ≤ 0.05 (Tukey's honest significance test).

Table 18. Rootstock influence on fruit quality of sweet orange cvs. Pusa Sharad and Pusa Round

Rootstock/ Cultivar	Juice (%)	TSS (B°)	Acidity (%)	Ascorbic acid (mg/100ml juice)
Pusa Sharad				
RLC-6	49.37^{bdc}	7.14^{de}	0.81^{bac}	64.20b
C-35	54.74^{a}	8.10^{a}	0.77^{bac}	68.11a
X-639	50.05^{bc}	8.22^{a}	0.81^{bac}	60.19cd
Yama Mikan	49.54^{bdc}	8.00^{ba}	0.70^{c}	57.55de
SohSarkar	49.56^{bdc}	7.14^{de}	0.73^{bc}	56.39e
RLC-7	50.28^{bc}	7.00^{e}	0.74^{bc}	58.08cde
JattiKhatti	45.49^{d}	7.34^{dce}	0.84^{a}	69.59a
Pusa Round				
RLC-6	50.82^{bac}	7.04^{e}	0.87^{a}	51.22f
C-35	48.81^{bdc}	8.30^{a}	0.82^{ba}	55.44e
X-639	51.33^{bac}	8.10^{a}	0.79^{bac}	56.07e
Yama Mikan	53.04^{ba}	8.00^{ba}	0.70^{c}	55.23e
Soh Sarkar	50.79^{bac}	7.40^{dce}	0.79^{bac}	56.28e
RLC-7	47.32^{dc}	7.52^{dc}	0.77^{bac}	57.55de
Jatti Khatti	49.05^{bdc}	7.62^{bc}	0.86^{a}	61.46cb
LSD ($P \leq 0.05$)	4.39	0.44	0.10	3.70

Each data represents the mean value of 15 fruit samples. Values are representing different letters are significant at P ≤ 0.05 (Tukey's honest significance test)

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

Drs Kanhiya Singh, Manish Srivastav, Sanjay Kumar Singh and V. B. Patel

2.1.2.1 Effect of integrated nutrient management on newly developed mango hybrids

The recommended dose of fertilizers (RDF) alone (100%) 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) were applied as per the treatment. There was significant effect of INM treatments, mango cultivars and interaction effect of INM treatments and mango cultivars on plant height and canopy diameter. Maximum height (5.06 m) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 4.67 m in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g) while minimum (3.67 m) in treatment T8. Among cultivars, maximum height (4.55m) was found in Pusa Arunima and minimum (4.07 m) in Pusa Pratibha. Maximum canopy diameter in north- south direction (3.26 m) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 2.78 m in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among cultivars, maximum canopy diameter in north- south direction (3.29 m) was found in Pusa Arunima and minimum (2.19 m) in Pusa Pratibha. Maximum canopy diameter in east-west direction (3.44 m) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 2.80 m in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among cultivars, maximum canopy diameter in east- west direction (3.36 m) was found in Pusa Arunima and minimum (2.15 m) in Pusa Pratibha.

Maximum number of fruit (35.6) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 33.66 in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties maximum number of fruit (36.95) was counted in Pusa Arunima and minimum (26.76) in Pusa Pratibha. Maximum weight of fruit (241.76 g) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 216.83 g in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit weight (218.28 g) was found in Pusa Arunima followed by Pusa Lalima (204.44 g) and minimum (180.36 g) in Pusa Pratibha. Maximum yield of fruit (25.64 kg) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 23.45 kg in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit yield (25.45 kg) was found in Pusa Arunima followed by Pusa Lalima (22.25 kg) and minimum (16.35 kg) in Pusa Pratibha. Maximum TSS of fruit (20.04 ^{0}Brix) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 20.01 ^{0}Brix in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties maximum TSS (20.04 ^{0}Brix) was found in Pusa Lalima followed by Pusa Shreshth (20.1 ^{0}Brix). Minimum acidity in fruit (0.17%) was recorded in treatment NPK 100 % + AMF (250g)+ *Azotobacter* (250g) followed by 0.21 % in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g).

3. Agreements/ Commercial Licensing of Pusa mango varieties under Outreach Programme (ORP) on Up-scaling of New Mango Varieties

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 to M/s SL Orchads, Panchkula, Chandigarh, Facilitated established Mother block of 300 Plants.
- M/s Seven Star Fruits Pvt. Ltd (Mahyco Group) Nashik, for Pusa Arunima, Pusa Lalima and Pusa Shreshtha through ZTMU, ICAR-IARI, New Delhi through MOA, Facilitated establishment of Mother block of 150 Plants.
- MoA with M/s Dev Bhoomi Enterprises, Dharmawala, Dehradun, Uttarakhand for commercial multiplication (5000 scion given during 2022)

- Provided scion (7500) to Directorate of Horticulture, Himachal Pradesh for establishment of Mother blocks in Kangra and Bilaspur and 1500 to Joint Director, Horticulture, HETC, Basti, U.P.
- MoA signed between M/s S.L. Orchards, Haryana and ICAR- IARI, New Delhi for the commercialization of Pusa Lalima, Pusa Pitamber, Pusa Pratibha and Pusa Shreshth mango hybrids, and a revenue of Rs. 4,50,000/- has been generated as License fee.

4. Intellectual property

Division of Fruits & Horticultural Technology has multiplied the 25,124 plants of different varieties of mandated fruit crops (Table 19), and sold to the growers, SAUs and nurserymen.

Table 19. Details of planting materials multiplied and sold during 2022

Crop & variety	Number of plants multiplied
Mango	
Amrapali	1950
Mallika	9300
Pusa Arunima	5530
Pusa Surya	1750
Pusa Lalima	2453
Pusa Pratibha	556
Pusa Shrestha	375
Pusa Peetamber	675
Pusa Manohari	2465
Pusa Deepshikha	70
Citrus	
Kagzi Kalan	1021
Pusa Round	178
Pusa Sharad	262
Pusa Udit	315
Pusa Abhinav	294
Pusa Arun	11
Grape	
Pusa Navrang	947
Pusa Urvashi	108
Pusa Trishar	510
Pusa Aditi	354
Pusa Swarnika	180
Pusa Purple Seedless	138
Papaya	
Pusa Nanha	325
Pusa Peet	137

5. Linkages and Collaboration

Four collaborative research projects were operational in the Division of Fruits & Horticultural Technology during the period of report (Table 20).

Table 20. List of the collaborative projects

S. No.	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 2022, a total of 19 PG students including 7 M.Sc. and 12 Ph.D. students were admitted to the Division. Total eight students including two Ph.D. and six M.Sc. students received degree during 60th Convocation of IARI, New Delhi in the Bharat Ratna Shri C Subramanium Hall of NASC. The chief guest of the convocation, the Union Minster of Agriculture and Farmers Welfare, Shri Narendra Singh Tomar applauded the significant contributions made by the students and exhorted the students for entrepreneurship development, and appealed for taking up farming as a profession. Out of 49 on roll PG students, 24 secured fellowships other than IARI fellowship, and remaining 25 PG students received IARI fellowship. 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 the sport activities organized by IARI and ICAR, and won medals for their performances in the events.

b. No. of students admitted

A total of 19 students got admitted in the division including 07 of M Sc and 12 of Ph D (Table 21)

Table 21. Details of students admitted

S N	Name of Student	Roll Number	M.Sc./ Ph.D.
1	Ms. Pooja	21652	M.Sc.
2	Prabhanjan Bhanudas Rane	21653	M.Sc.
3	Laya P	21654	M.Sc.
4	Raushan Kumar	21655	M.Sc.
5	Harshit Kumar	21656	M.Sc.
6	Madhumathi V	60105	M.Sc.
7	Saikat Dey	60106	M.Sc.
8	Mukesh Shivran	12060	Ph.D.
9	Bhupendra Sagore	12061	Ph.D.
10	Shikha Jain	12063	Ph.D.
11	Shikha Saini	12064	Ph.D.
12	Ajay Kumar	12065	Ph.D.
13	Parth Janardhan Jadhav	12066	Ph.D.
14	Aditya Dnyaneshwar Ingole	12067	Ph.D.
15	Poonam Maurya	12068	Ph.D.
16	Ravi Venkanna Babu Maddela	12069	Ph.D.
17	Bindu Praveena Ravipati	12214	Ph.D.
18	Nongthombam Devachandra	12215	Ph.D.
19	Shubham Jagga	12227	Ph.D.

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

A total of 24 students were awarded with the fellowship, of which only 23 students received the fellowship from ICAR, New Delhi, and only one student could get the same from UGC, New Delhi (Table 22).

Table 22. Detail of students alongwith the source of fellowship secured

S. No.	Name of the student	Name of the Fellowship	Awarding Agency
1	Mukesh Shivran	ICAR- JRF- Ph.D.	ICAR, New Delhi
2	Bhupendra Sagore	UGC- JRF- Ph.D.	UGC, New Delhi
3	Shikha Jain	ICAR- JRF- Ph.D.	ICAR, New Delhi
4	Shikha Saini	ICAR- JRF- Ph.D.	ICAR, New Delhi
5	Ajay Kumar	ICAR- JRF- Ph.D.	ICAR, New Delhi
6	Parth Janardhan Jadhav	ICAR- JRF- Ph.D.	ICAR, New Delhi
7	Ravi Venkanna Babu Maddela	ICAR- JRF- Ph.D.	ICAR, New Delhi
8	Vishal Balasaheb Mhetre	ICAR- JRF- Ph.D.	ICAR, New Delhi
9	Chaithra T S	ICAR- JRF- Ph.D.	ICAR, New Delhi
10	Amulya S	ICAR- JRF- Ph.D.	ICAR, New Delhi
11	Anagha P K	ICAR- JRF- Ph.D.	ICAR, New Delhi
12	Kripa Shankar	ICAR- JRF- Ph.D.	ICAR, New Delhi
13	Chandana M R	ICAR- JRF- Ph.D.	ICAR, New Delhi
14	Mude Ramya Sree	ICAR- JRF- Ph.D.	ICAR, New Delhi
15	Chukkamettu Anusha	ICAR- JRF- Ph.D.	ICAR, New Delhi
16	Kalieswari K	ICAR- JRF- M.Sc.	ICAR, New Delhi
17	Amina Shukoor	ICAR- JRF- M.Sc.	ICAR, New Delhi
18	Hatkari Vittal	ICAR- JRF- M.Sc.	ICAR, New Delhi
19	Gulshan Kumar	ICAR- JRF- M.Sc.	ICAR, New Delhi
20	Vasudeva N	ICAR- JRF- M.Sc.	ICAR, New Delhi
21	Akshay	ICAR- JRF- M.Sc.	ICAR, New Delhi
22	Abeer Ali	ICAR- JRF- M.Sc.	ICAR, New Delhi
23	Vasanth Vinayak Vara Prasad N	ICAR- JRF- M.Sc.	ICAR, New Delhi
24	Amar BA	ICAR- JRF- M.Sc.	ICAR, New Delhi

b) Students awarded with degrees during 2022 Convocation

A total of ten students were awarded with the degree including 04 of Ph D and 06 of M Sc (Table 23).

Table 23. Details of students awarded with the degrees

S N	M.Sc./ Ph.D.	Name of the student	Name of the Chairman, Advisory Committee	Title of the Thesis
1	Ph.D.	Ms. Uwisize Marie Grace	Dr M.K. Verma	Identification of Grape Genotypes Tolerant to Berry Cracking.
2	Ph.D.	Mr. Sridhar Ramachandra	Dr Manish Srivastav	QTL mapping for fruit quality traits in mango (*Mangifera indica* L.).
3	Ph.D.	Ms. Preeti Singh	Dr. Jai Prakash	Studies on heterosis and inheritance of horticultural traits in papaya (*Carica papaya* L.)
4	Ph.D.	Mr. Naveen Kumar Maurya	Dr Amit Kumar Goswami	Physiochemical and molecular characterization of papaya genotypes under low temperature stress.
5	M.Sc.	Ms. Rutuparna Senapati	Dr Madhubala Thakre	Understanding the basis of pulp colour in Black guava (*Psidium guajava* L).

6	M.Sc.	Mr. Shivam	Dr Kanhaiya Singh	Morphological, physiological, biochemical and molecular characterization of progenies of Olour mango.
7	M.Sc.	Mr. Sandeep Kumar Badhei	Dr Awtar Singh	Morphogenetic characterization of second generation *Kinnow* mandarin colchiploids.
8	M.Sc.	Mr. Mukesh Shivran	Dr Nimisha Sharma	Molecular studies on shelf-life in mango (*Mangifera indica* L.).
9	M.Sc.	Mr. Kiran K.N.	Dr Awtar Singh	Morphogenetic characterization of second generation colchiploids of sweet orange cv. Mosambi.
10	M.Sc.	Mr. Bhupendra Sagore	Dr Kanhaiya Singh	Effect of plant growth regulators on hastening embryo maturation and fruit quality of papaya (C*arica papaya* L.) Var. Pusa Nanha.

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

d) Awards and Recognitions received by the students

1. **Best Poster Presentation Award:** Gulshan Kumar, Manish Srivastav, Chavlesh Kumar, Shreekanth H.S., Kuldeep Pandey, Jai Prakash, Vinod and Sanjay Kumar Singh. 2022. Molecular characterisation of mango hybrids using microsatellite markers under the Theme II: Genetic Resources & Crop Improvement in the National Seminar on “Horticulture for Sustainable Development, Nutritional & Livelihood Security” held at Uttar Banga Krishi Vishwavidyalay, Pundibari, Cooch Behar, West Bengal during 26-27 May, 2022.
2. **Best Poster Presentation Award:** Gulshan Kumar, Manish Srivastav, Chavlesh Kumar, Shreekanth H.S., Kuldeep Pandey, Jai Prakash, Vinod and Sanjay Kumar Singh. 2022. Identification of Unique SSRs alleles and their validation in mango. 2nd Indian Horticulture Summit-2022 on “Horticulture for Prosperity and Health Security” organised by Society for Horticultural Research and Development at Navsari Agricultural University, Navsari, Gujarat during 27-29 April, 2022.

e) Events organized by student club of the Division: Nil

7. Internship & Mentorship by the Scientist

During 2022, five students outside the ICAR-IARI, New Delhi have completed their internship (Table 24).

Table 24. Details of interns

S N	Student's name	University	Topic	Duration	Mentor
1	Ms. L. Rajeshwari	Manonmaniam Sundaranar University, Tirunelveli, Tamil Nadu	SSR Marker Based Parentage Confirmation in Mango	July 18 July - 17 August, 2022	Dr Manish Srivastav
2	Ms. Joshita Bhatia	Amity University, Noida	Artificial Hybridization and Molecular Characterization of Mango Hybrids/ Germplasm	January, 12 - May 31, 2022	Dr Manish Srivastav
3	Ms. Anmol Saini	Amity University, Noida	Characterization of mango genotypes	January 3 - May 15, 2022	Dr. Jai Prakash
4	Ms. Aleesha Ahmad	School of Bioscience, Mar Athanasios College for Advanced Studies, Tiruvalla, Kerala	Identification of nucellar seedlings of mango through molecular marker	14 March -15 June, 2022	Dr. Jai Prakash
5	Ms. Mansi Vats	Amity University, Noida	Floral biology of papaya	April 11 - May 31, 2022	Dr. Jai Prakash

8. Awards and Recognitions received by the Scientist

Category wise

a) ICAR/National Awards: Nil

b) Fellowship/Associateship of National academies

Only one scientist could achieve the fellowship of NAAS during 2022 (Table 25).

Table 25. Fellowship of national academy.

S. No.	Name of the Scientist	Fellowship/ Associateship	Name of the Academy
1	Dr A. K. Dubey	NAAS Fellowship	National Academy of Agricultural Sciences

c) Fellowship of Professional societies of the relevant Discipline

Two scientists were awarded the fellowship of professional societies (Table 26).

Table 26. Fellowship of Professional societies

S. No.	Name of the Scientist	Fellowship/ Associateship	Name of the Academy
1.	Manish Srivastav	Honorary Fellowship	Indian Society for Horticultural Research and Development, Ghaziabad, Uttar Pradesh
2.	Dr Amit Kumar Goswami	Fellowship	Society for Community Mobilization for Sustainable Development (MOBILIZATION)

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	Associate Editor, International Journal of Horticultural Science, Hungry	International Journal of Horticultural Science, Hungry	Dr. A.K. Dubey
2	Editor of the Indian Journal of Horticulture	Indian Academy of Horticultural Sciences, New Delhi	Dr. R.M. Sharma
3	Member Editorial Board-2023, Pusa Surabhi	IARI, New Delhi	Dr. R.M. Sharma
4	Member selection committee of Sikkim University under CAS promotion from Associate Professor to Professor (Hort.), Sikkim as Member Vice Chancellor’s nominee, held on 12.04.2022	Sikkim University	Dr. R.M. Sharma
5	Member selection committee for the post of Asstt. Scientist (Hort.) at CCSHAU, Hisar as Expert Member, held on 8.10.2022	CCSHAU, Hisar	Dr. R.M. Sharma
6	DG, ICAR Nominee, Subject Expert-Assessment Committee for Scientist of Horticulture (Fruit Science)	ICAR-CRIDA, Hyderabad, Telangana	Dr Manish Srivastav

9. Budget Estimates

a) Head-wise budget received and expenditure under EFC: An amount of Rs 34.80 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.N.	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

c) **Revenue generated**

The total revenue of Rs 26.217 Lacs was generated through the sale of planting materials (Rs. 18.13 Lacs) and the fruit auction of experimental orchards (Rs. 8.087 Lacs).

10. Publication

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

S. N.	Bibliography of Publication	NAAS Rating (2022)	Impact Factor (Thomson Reuters)
1	Gangappa N D, Singh C, Verma M K, Thakre M, Svanthi A M, Singh R, Srivastav M, Raghunandan K, Chukkamettu A, Yadav V and Nagaraja A. 2022. Assessing the genetic diversity of guava germplasm characterized by morpho-biochemical traits. *Frontiers in Nutrition*, doi:10.3389/fnut.2022.1017680.	12.58	6.58
2	Goswami A K, Maurya N K, Goswami S, Bardhan K, Singh S K, Prakash J, Pradhan S, Kumar A, Chinnusamy V, Kumar P, Sharma RM, Sharma S, Bisht, D S and Kumar C. 2022. Physio-biochemical and molecular stress regulators and their crosstalk for low-temperature stress responses in fruit crops: A review. *Frontiers in Plant Science*.13.	11.75	5.75
3	Pandey K, Karthik K, Singh S K, Vinod, Sreevathsa R and Srivastav M. 2022. Amenability of an *Agrobacterium tumefaciens*-mediated shoot apical meristem-targeted *in planta* transformation strategy in Mango (*Mangifera indica* L.). *GM Crops & Foods*, 13 (1): 342-54	9.07	3.07
4	Prusty R, Awasthi, O. P., Singh, SK and Kanika. 2023. *In vitro* shoot 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 DOI:10.1007/s11240-023-02499-2.	8.71	2.71
5	Megha R, Singh S K, Srivastav M, Prakash J, Saha S and Pradhan S. 2022. Physico-chemical characterization and biochemical profiling of mango genotypes during different fruit development stages. *South African Journal of Botany* 149: 476-86.	8.32	2.32
6	Singh S K, Srivastav M, Prakash J, Saha S and Pradhan S. 2022. Physico-chemical characterization and biochemical profiling of mango genotypes during different fruit development stages. *South African Journal of Botany* 149: 476-86.	8.32	2.32
7	Maurya N K and Goswami A K, Goswami S, Singh S K, Prakash J, Chinnusamy V and Pradhan S. 2022. Physiochemical response of papaya genotypes exposed to low temperature regimes. *Indian Journal of Experimental Biology* 60(08): 615-27.	6.82	0.82
8	Shivran M, Sharma N, Sharma N, Muthusamy V, Dubey A K, Singh SK, Singh BP, Kumar N, Sevanthi AM, Singh N and Singh NK. 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.	6.6	0.40
9	Kundu, M., and Dubey A K. 2022. Impact of x ray exposure on *in vitro* pollen viability and seed development pattern in different interspecific crosses of citrus. *National Academy Science* Letters. https://doi.org/10.1007/s40009-022-01136-4.	6.6	0.40

10	Mahanti K K, Srivastav M, Singh S K and Dinesh M R. 2022. Inter and intra-specific crossability studies on Mangifera species. *Indian Journal of Agricultural Sciences* 92(4): 536-40.	6.37	0.37
11	Kadam D M, Dubey A K, Sharma RM, Morade A, Sharma N and Bhardwaj C. 2022. Response of citrus (*Citrus* sps.) rootstock hybrids to PEG induced drought under hydroponic system. *Indian Journal of Agricultural Sciences* 92 (10): 1230–36.	6.37	**0.37**
12	Singh K, Awasthi O P, Singh Awtar, Prusty Reena and Yadav Prachi. 2022. Irradiation effect on leaf sclerophylly, gas exchange and stomata in sweet orange (*Citrus sinensis*). *Indian Journal of Agricultural Sciences* 91 (2): 37-41.	6.37	0.37
13	Lal N, Singh Awtar, Kumar A, Marboh E S, Jayswal D K, Pandey S D and Nath V. 2022. Effect of temperature, flowering time and inflorescence length on yield and productivity of litchi (*Litchi chinensis*) cv. 'Shahi'. *Indian Journal of Agricultural Sciences* 92 (5): 611–14.	6.37	0.37
14	Singh P, Prakash J, Singh SK, Goswami AK and Hussain Z. 2022. Heterosis for seed and seedling traits in papaya. *Indian Journal of Horticulture* 79 (2):127-35.	6.00	--
15	Grace U M, Verma M K, Singh S K, Patel V B, Sethi S, Kumar C… and Karoshi, P. 2022. Variation of anthocyanin, phenolics, flavonoids and antioxidants in grape genotypes. *Indian Journal of Horticulture* 79(2): 237-42.	6.00	--
16	Senapati R, Thakre M, Nagaraja A, Verma M K, Krishnan GS, Sevanthi AM and Saha S. 2022. Black guava (*Psidium guajava* L.): Morphological, biochemical and molecular characterization for pulp colour. *Annals of Plant and Soil Research* 24(3): 429-33	5.22	--
17	Pandey K, Kishor A, Singh A, Singh S K, Sreevathsa R, Srivastav M. 2022. Assessment of In vitro regeneration ability of mango genotypes. *Current Advances in Agricultural Sciences* 14(2): 175-79.	5.12	-
18	Shikha Jain and Jai Prakash 2022. Off season flowering in mango (*Mangifera indica* L.). *RASSA Journal of Science for Society* 4 (2&3): 132-35	-	-
19	Mhetre V B, Patel V B, Singh S K, Mishra G P, Verma M K, Kumar C ... and Siddiqui, M. W. 2022. Unraveling the pathways influencing the berry color and firmness of grapevine cv. Flame Seedless treated with bioregulators using biochemical and RNA-Seq analysis under semi-arid subtropics. *Food Chemistry: Molecular Sciences 5*, 100116.	-	3.42

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

1. 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)

2. 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.

3. Prakash J and Chaitra T S 2022 Breeding Strategies for climate smart fruit crops, 48-53, p.204. Souvnier 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. Qayoom S, Burman R R, Goswami, A K, Sharma R, Bhat A, Sahu S, Mahra G S. 2022. Transforming Agriculture for Self - Reliant India. International books & Periodical supply service New Delhi. ISBN: 9789394023338 Pp: 371
2. Shivran M, Sharma N, Sharma N, Muthusamy V, Singh S K, Dubey A K, Singh N, Sevanthi A M and Singh N K. 2022. *In-silico* mining of ripening related genes for shelf-life studies in mango (*Mangifera indica* L.). (Eds. Singh et al., 2022 Management of Postharvest Diseases and Value Addition of Horticultural Crops. Today and Tomorrow's Printers and Publishers, New Delhi. pp 388), pp.141-146 ISBN: 9789391734008.
3. Singh, S. K., Pradhan, S., Krishna, H., Alizadeh, M., Kumar, C., Singh, N. V., et al., (2022). Development of Abiotic Stress Resistant Grapevine Varieties. In *Genomic Designing for Abiotic Stress Resistant Fruit Crops* (pp. 61-159). Cham: Springer International Publishing.
4. Goswami A K, Goswami S, Vinutha T, Singh S K and Praveen S. 2022. Biofortification: A Remedial Approach Against Malnutrition in Rural and Tribal Population. In: *Homocysteine Metabolism in Health and Disease* (pp. 97-111). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-16-6867-8_5. Online ISBN978-981-16-6867-8.
5. Singh S K, Pradhan S, Goswami, A K and Maurya N. 2022. Biotechnological intervention in horticultural crops under changing climate. In: *Souvenior and abstract book of National Seminar on Climate Resillent Horticulture: Adaptation and Mitigation Stratigies*. pp: 25-43.
6. Burman R R, Mahra G S, Singh R, Sahu S, Joshi P and Goswami A K. 2022. Multimedia Based ICTs for Smart Agriculture: Prospects, Challenges and Way Ahead. In: *Book entitled "Transforming Agriculture for Self - Reliant India*". International books & Periodical supply service New Delhi. ISBN: 9789394023338 pp: 129-142.

d) List of Popular article(s)

1. Megha R, Sanjay Kumar Singh, Vinay Kalia, Manish Srivastav and Babita Yadav. 2022. Eco-friendly management of fruit fly in mango. Indian Horticulture, May- June 2022: 27-29.
2. Vittal Hatkari, Nimisha Sharma, Mukesh Shivran, Anil Kumar Dubey and Sanjay Kumar Singh (2022). Carbohydrate metabolism: key regulators of flowering in fruit crops. NESA news letter 25(4):pp.1-3. ISSN NO. 0974-6056.
3. Thakre M, Nagaraja A, Kumar C and Goswami A K. 2022. *Amrood me phasal niyantran: vidhi evam Salaah.* Prasaar Doot. 48-49.
4. Senapati R, Thakre M, Akshay, Hanamant, Nagaraja A, Verma M K, Saha S, Amitha Mithra S V, Krishnan S G. 2022. Anthocyanins: Beyond human nutrition practical applications of anthocyanins. Plantica 5(109): 1000-1007.
5. Senapati R, Thakre M and Badhei S. 2022. Paclobutrazol: A multipurpose triazole in fruit crops. Agriculture & Environment e-Newsletter 4(1): 388-391.
6. Senapati R. and Thakre M. 2022. Arctic Apple: The franken fruit or apple of your eye. Agriculture & Environment e-Newsletter 4(6): 615-617

11. Trainings/workshop/seminar organized

The details of trainings organized are presented in Table 29.

Table 29. Details of trainings organized

S N	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.	Natural Farming-Modern Technology; Coordination and Implementation	National Convention	May 20–21, 2022 at National Agriculture Science Complex, ICAR, New Delhi	Students, Scientists, teachers and farmers	248	92	340
2.	National Seminar	Agriculture and More: Beyond 4.0	May 26th - 28th, 2022 at National Agriculture Science Complex, ICAR, New Delhi	Students, Scientists, teachers, farmers			609

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**	**Number**	**Detail/description of each item**	**Scientist**
i	In India			
1	Seminars	2	National Seminar on Climate Resilient Horticulture: Adaption and Mitigation Strategies, August 13-14, 2022	Dr. Jai Prakash
2	Scientific meetings	7	Screening committee to review the proposals of varieties received for placing before the Institute Variety Identification Committee (IVIC). Academic Council, ICAR- IARI, New Delhi. 8^{th} Group Discussion on ICAR-AICRP on Fruits. 14^{th} Annual review meeting of the ICAR-NPFGGM (Formerly NPTC) project.	Dr Manish Srivastav
			Attended Divisional Research Committee (DRC) at Amity University, Noida on 13.04.2022 @ 16.12.2022. Attended meeting for finalization of DUS guidelines for Lemon and Pummelo in PPVFRA, NASC Complex Attended meeting on behalf of School Co-ordinator with Hungarian delegation at 11.00 am in M. S. Swaminathan Library.	Dr O.P. Awasthi
3	Workshops	1	IX GD of AICRP (Fruits), held virtually mode during March 2022	Dr A.K. Dubey/ Dr R.M. Sharma/ Dr. Jai Prakash
4	Symposia	4	International Conference on Recent Progress in Biological Science organized by DBT at Department of Zoology, Ayya Nadar Janaki Ammal College, Sivakasii, Tamil Nadu, 2022.	Dr. Nimisha Sharma
			Delivered oral presentation at International conference on Radiation Biology from January 19-21, 2022 Bikaner, Rajasthan on "^{14}C-labeling technique for discerning the role of old leaves in emergence of floral buds in Kinnow (*Citrus nobilis* Lour × *Citrus deliciosa* Tenora)". Delivered oral presentation at International conference on Advances in Agriculture and Food System towards Sustainable Development Goals during 22-24 August 2022. Development of coloured guava varieties as bio-fortified guava. Oral presentation in Advances in agriculture and food system towards sustainable development goals during 22-24 August 2022. Banglore, India.	Dr. Madhubala Thakare Dr. Madhubala Thakare Dr. Madhubala Thakare
ii	<u>Abroad</u>	Nil	Nil	Nil

13. Extension activities

The Divisional scientists were involved in the various extension activities for the transfer of technologies (Table 30).

Table 30. Extension activities undertaken

S. No.	Activities	Scientist
1	Participation in MGMG programme	Dr Awtar Singh and Dr Nimisha Sharma
2	Participation in Pusa Krishi Vigyan Mela 2022	All Divisional Scientists
3	Demonstration of Divisional activities during educational tour of B.Sc. (Ag.) students of Birsa Agriculture University	Dr Madhubala Thakre
4	Training lectures	
	नींबू वर्गीय फलों की उन्नत तकनीकियाँ, काटेट द्वारा संचालित कार्यक्रम "जिला सवाई मधौंपुर राजस्थान के किसानों के लिए औद्यानिकी फसलों का उत्पादन एवं प्रसंस्करण" (20.12.2022) जो कार्यक्रम कटेट द्वारा 16-22 दिसम्बर 2022 के बीच में आयोजित कराया गया	डा आर एम् शर्मा
	"खरीफ फसलों में अधिक उत्पादन और लाभ हेतु उन्नत सश्य प्रबंधन" जो नेकपुर बुलंदशहर (उ प्र) में मई 29, 2022 को आयोजित हुआ	डा जय प्रकाश ऐवम डा चवलेश कुमार
5	Delivered 17 Radio Talks and 15 TV talks	Divisional Scientists

14. Staff Position

A	**Scientific**
1	Dr. S. K. Singh, Principal Scientist
2	Dr. Manish Srivastav, Principal Scientist
3	Dr. Awtar Singh, Principal Scientist
4	Dr. O. P. Awasthi, Principal Scientist
5	Dr. A. K. Dubey, Principal Scientist
6	Dr. R. M. Sharma, Principal Scientist
7	Dr. M. K. Verma, Principal Scientist
8	Dr. Kanhaiya Singh, Principal Scientist
9	Dr V. B Patel Principal Scientist
10	Dr. Jai Prakash, Principal Scientist
11	Dr. A. Nagaraja Principal Scientist
12	Dr. A. K. Goswami, Senior Scientist
13	Dr. Nimisha Sharma , Senior Scientist
14	Dr. Madhubala Thakre, Senior Scientist
15	Dr. Nayan Deepak G, Scientist
16	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

a) **DBRC**

1. Dr S.K Singh, Head & Chairman
2. Dr. O. P. Awasthi, Principal Scientist & Member
3. Dr. Kanhiya Singh, Principal Scientist & Member
4. Dr V.B. Patel, Principal Scientist & Member
5. Mrs. Om Prabha, AAO-FHT & Member
6. Dr. Chavlesh Kumar, Scientist & Member Secretary

b) **BOS**

1. Dr Manish Srivastav, Professor & Chairman
2. Dr. O.P. Awasthi, Head & Special Member
3. Dr. R.M. Sharma, Principal Scientist & Member
4. Dr. Madhubala Thakre, Senior Scientist & Member
5. Dr Chavlesh Kumar, Scientist & Member Secretary
6. Sh. Kripa Shankar, Ph.D. 3rd Year, Students Representative

c) Deputation Committee: Nil

d) **Technical Cell**

1. Dr S.K. Singh, Head & Chairman
2. Dr Manish Srivastav, Prof. & Member
3. Dr V.B. Patel, Principal Scientist & Member
4. Dr Jai Prakash, Principal Scientist & Member
5. Mrs. Usha Sehgal, PS to Head & Member Secretary

e) **Store Purchase Committee**

1. Dr. V.B. Patel, Pr. Scientist- Chairman
2. Dr. Jai Prakash, Pr. Scientist – Member
3. Mr. Nayan Deepak, Scientist - Member
4. Mr. D.P. Singh, Tech. Officer & Farm-In-Charge - Member
5. Mrs. Om Prabha, AAO, FHT - Member Secretary

f) **Farm Produce Auction Committee**

1. Dr. A.K. Dubey, Pr. Scientist - Chairman
2. Dr. V.B. Patel, Pr. Scientist - Member
3. Dr. Chavlesh Kumar, Scientist - Member
4. Sh. D. P. Singh, Farm In- charge (Main & Todapur Orchard) – Member
5. Mrs. Om Parbha, AAO, FHT- Member Secretary

g) **Farm Management Committee**

1. Dr. O. P. Awasthi, Pr. Scientist - Chairman
2. Dr. R.M. Sharma, Pr. Scientist - Member
3. Dr. Jai Prakash, Pr. Scientist & Nursery In- charge - Member
4. Mr. Sanjay Kumar, Sr. Technical Assistant – Member
5. Mr. D. P. Singh, Farm In-Charge (Main &Todapur Orchards) – Member Secretary

h) **Building and Premise Maintenance Committee**

1. Dr. O. P. Awasthi, Pr. Scientist - Chairman
2. Dr A.K. Goswami, Scientist – Member
3. Dr. (Mrs.) Nimisha Sharma, Scientist – Member
4. Mr. Nikhil T-III – Member
5. Mr. Arvind, Technical Assistant – Member Secretary

i) **Technology Extension Committee**

1. Dr. R.M. Sharma, Pr. Scientist - Chairman
2. Dr. M.K. Verma, Pr. Scientist – Member
3. Dr. V.B. Patel, Pr. Scientist – Member
4. Dr. (Mrs.) Madhubala Thakre, Scientist - Member
5. Mr. Deepak, Sr. Technical Assistant – Member
6. Mr. Arvind, Technical Assistant - Member Secretary

j) **Staff Welfare Committee**

1. Dr. Awtar Singh, Pr. Scientist – Chairperson
2. Dr. M.K. Verma, Pr. Scientist- Member
3. Dr. (Mrs.) Nimisha Sharma, Scientist - Member
4. Mr. . H. R. Meena, Technical Assistant - Member
5. Mr. Vinod Kumar Rai, LDC - Member
6. Mr. D.P. Singh, Farm In-Charge (Main &Todapur Orchards) – Member
7. Mrs. Om Prabha, AAO, FHT - Member Secretary

k) **Seminar Hall, Conference Room & Lecture hall Maintenance**

1. Dr. A.K. Goswami, Scientist-Chairman
2. Mr. Nayan Deepak, Scientist – Member
3. Mr. Deepak, Technical – Member
4. Mr. Dinesh, Technical- Member
5. Mr. Sanjay Kumar, Sr. Technical Assistant – Member Secretary

l) **राजभाषा कार्यान्वन समिति**

1. डा. संजय कुमार सिंह - अध्यक्ष
2. डा. कन्हैया सिंह, प्रधान वैज्ञानिक - सदस्य
3. डा. वी.बी. पटेल, व. वैज्ञानिक –सदस्य
4. श्री. अरविन्द, तकनिकी – सदस्य
5. श्री. विनोद कुमार राय, अ. श्रे. लिपिक - सदस्य सचिव

m) **स्वच्छ भारत अभियान समिति**

1. डा. राधा मोहन शर्मा - नोडल अधिकारी
2. डा. ए. नागाराजा, व. वै. –सदस्य
3. डा. (श्रीमती) मधुबाला ठाकरे –सदस्य
4. श्रीमती ओम प्रभा, सप्रअ, सदस्य
5. श्री संजय कुमार, तकनीकी सहायक, सदस्य सचिव

n) **Library Management**

1. Dr. A.K. G**o**swami, Scient**ist- Chairman/In-ch**arge
2. Dr. Chavlesh Kumar, Scientist – Member
3. Mr. Dinesh, Technical Assistant – Member
4. Mrs. Usha Sehgal, PS to Head –Member Secretary

o) **Divisional Nursery Committee**

1. Dr. Jai Prakash, Pr. Scientist – Chairman
2. Dr. A.K. Goswami, Scientist – Member
3. Dr. Chavlesh Kumar, Scientist – Member

4. Mr. D.P. Singh, Farm In-Charge (Main & Todapur Orchards) – Member Secretary

p) **Official Documentation and Compilation Committee**

1. Dr. V.B. Patel, Pr. Scientist – Chairman
2. Mr. Nayan Deepak G., Scientist – Member
3. Dr. Chavlesh Kumar, Scientist – Member Secretary

q) **Vehicle In-charge**

1. Mr. Arvind, Technical. – In-charge
2. Mr. Nikhil, T.O. (in the absence of In-charge)
3. Mrs. Om Prabha, AAO, FHT – Member (in absence of both)

r) **संभागीय इंटरनेट सेवा समिति**

1. डा. अमित कुमार गोस्वामी, वैज्ञानिक -अध्यक्ष
2. श्री अरविंद, तकनिकी- सदस्य
3. श्रीमती ऊषा सहगल, संभागाध्यक्ष की निजी सचिव-सदस्य
4. डा. चवलेश कुमार, वैज्ञानिक- सचिव सदस्य

स्वच्छ भारत

एक कदम स्वच्छता की ओर

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