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DIVISION OF FRUITS & HORTICULTURAL TECHNOLOGY
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Annual Report 2021

Division of Fruits & Horticultural Technology
ICAR-Indian Agricultural Research Institute
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PREFACE

The total production of fruit crops in the country during 2021 was around 107.51 million metric tonnes with an average productivity of 15.28 million tonnes/ha from an area of 7.01 million ha. Having attained food security, India is fast developing as nutritionally secure nation and 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. The development of improved varieties and production technology by the Division have paved the way for entrepreneurship in the field of fruit orcharding.

During the period under report four varieties of mango (Pusa Lalima, Pusa Pratibha, Pusa Peetamber and Pusa Shresth), two of grapes (Pusa Aditi and Pusa Urvashi) and one each of acid lime (Pusa Abhinav) and sweet orange (Pusa Round) was released by the Central Variety Release Committee (CVRC). To develop varieties for trait of interest such as low seeded Kinnow mandarin and Sweet orange efforts are under way to achieve the desired characteristics through mutation breeding. In guava promising pink fleshed hybrids GH-2016-8F, HSU×SH-16-8-2 and HSU×SH-16-8-18 have been identified. Further to widen the genetic base, 35 Exotic guava genotypes were introduced from USDA.

In mango, ripening gene specific SSRs loci (MSL-8 and MSLC-13) have been identified while in papaya, molecular markers PKBT 5, SDP and PMSM 2 found useful for the identification of male and hermaphrodite plants among dioecious and gynodioecious genotypes.

In the frontier area of Production technology, long term rootstock trial in fruit crops such as mango, citrus, grape and guava is in progress to develop rootstocks for High Density orcharding (HDO) and for tolerance to the various biotic (guava wilt) and abiotic stresses (drought, salinity, low temperature tolerance). In citrus X639 was identified as potential rootstock for drought tolerance. Under INM trial in mango, NPK 100 % + AMF (250g) + *Azotobacter* (250g) enhanced fruit yield.

Under Outreach Programme (ORP) commercial licensing of six Pusa mango varieties was initiated. For promotion of developed varieties, vegetatively propagated plants were sold to the growers, SAUs and nurserymen. A revenue of Rs 9.34 lakhs was generated through the sale of planting materials. The technologies developed by the Division are being disseminated through Kisan Mela, MGMG, training programmes and outreach programme.

In Post Graduate education programme, total 18 PG students including 8 M.Sc. and 10 Ph.D. students took admission. In the sixtieth convocation held during February 2021, 03 Ph.D. and 06 M. Sc. students were awarded degrees.

The scientists of the division were bestowed with several prestigious awards & recognitions, published 15 research papers in scientific peer reviewed journals.

I would like to thank Director ICAR-IARI, Joint Director (s) Research, Education and Extension for their continued support, constant guidance and encouragements. 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 2021 are summarised below:

Crop Improvement

Artificial hybridization was attempted. 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 772 panicles having 6217 flowers were crossed. During the period, total 63 hybrids belonging to different cross combinations have been evaluated for different physico-chemical attributes. Hybrids, namely, NH-17-2, NH-18-4, NH-20-2, H-3-2 and H 14-2 had attractive red peel colouration of differential magnitude on fruit surface. For rootstock improvement programme, a total of 91 panicles (275 flowers) were used for crossing with various combinations of the polyembryonic mango Olur, Kurrukan, Bappakai, M 13-1. An attempt was made to characterize and evaluate the progenies of Olour mango (28) based on physiological and biochemical traits, and a significant level of variability was observed in 28 hybrids.

During 2021, half-sibs of Amrapali mango (125 Nos.) have been evaluated for horticultural traits. Of the five mango collections from Nimbadoor area of Tamil Nadu, Nim 2 showed the brilliant red peel colour under Delhi conditions. During the period, 120 Hyper-variable SSRs and 80K SNPs have been validated in mango. Besides, SSR and SNP based genetic linkage maps were constructed for mango genotypes. In mango, the ripening gene specific SSRs loci (MSL-8 and MSLC-13) have been identified, those can be used in marker-assisted breeding for fruit-quality traits associated with shelf-life.

In citrus, a total of 23 cross combinations (05 of sweet scion, 07 of acid scion and 11 of rootstocks) were attempted, and 946 flowers were crossed during February-March, 2021. Of the nineteen citrus rootstocks/ hybrids, screened against 50mM NaCl induced salinity, only 14 hybrids have shown tolerance.Yield and fruit quality of eight acid citrus scion hybrids (acid lime × lemon) have been assessed during 2021, of these two acid citrus hybrids (ACSH-3.2/18 and ACSH-9-13/18) were appeared to be highly precocious and immune to citrus canker.In the evaluation of seven lemon collections, in comparison to Pusa Lemon -1 and Kagzi Kalan cultivars, LS-8 tended to show the highest content of juice acid, proving similarity statistically with Pusa Lemon-1 and LS-9 fruits. Among the six lemon cultivars, Eureka excelled for highest TSS and acid contents, which was statistically at par with Pusa Lemon-1, Saverle and Hill lemon. In the evaluation of tangerines and Minneola, The fruits of W. Murcott had the thin peel and low acid content. W. Murcott and Kinnow proved equally good for juice content. In the evaluation of pummelos, accessions 628798 bore thin-skinned and the accessions 628799 and 628800 bore dark red-fleshed fruits with solid core.

The first and second generation colchiploids of Kinnow mandarin and Mosambi were characterized for growth and flowering traits. Identified putative tetraploids behaved as solid tetraploids continuously for fourth year. To produce triploids, 430 flowers of putative second-generation tetraploids of Kinnow and 433 of Mosambi were pollinated with the respective diploid pollen. Very low seedling survival and seedling growth obtained in the tetraploid x diploid hybrids. Besides, the protocol for mass multiplication and *in vitro* induced mutagenesis was standardized in Kinnow. Simultaneously, the *in vitro* organogenesis protocol for multiplication of sweet orange cv. Mosambi by use of different PGRs and silver compounds containing ethylene inhibitors was also standardized.

In grapes, a total of 14 cross combination having 179 panicles (12,060 flowers) crossed. In rootstock breeding, crossing among the *Vitis* spp. genotypes, namely, *V. parviflora* × Dogridge (*V. champini*), and *V. parviflora* × Salt Creek (*V. champini*) were attempted. Of the various hybrids, evaluated 03 grape hybrids (Hyb. 16/2A-R1-P9, Hyb. 16/2A-R1-P14 and Pusa Swarnika) have been found promising against the check variety 'Black Muscat'. These hybrids showed superiority for economic traits like loose bunch, bold berry, early maturity and high TSS with regard to check Black Muscat.

In guava, a total 870 flowers were crossed including 21 cross combinations, and raised1160 hybrids. A total of 35 guava genotypes in the form of seeds were introduced from USDA, Hilo through NBPGR. All the collected seeds were sown in poly bags and seedlings were raised for further planting in field. Of the various guava hybrids evaluated, Of the red/pink fleshed hybrids evaluated, thre hybrids namelyGH-2016-8F,HSU×SH-16-8-2and HSU×SH-16-8-18 proved potential, having excellent fruit and nutritional qualities.

In papaya, a total of 10 SCAR and RAPD markers were used in 48 papaya plants of 6 genotypes namely 3 gynodioecious and 3 dioecious for the sex identification at early stage. Molecular markers PKBT 5, SDP and PMSM 2 found useful for the identification of male and hermaphrodite plants among dioecious and gynodioecious genotypes. In papaya, five papaya hybrids namely, P-7-15 x Pune Selection 3, P-7-15 x P-7-2, P-7-15 x P-9-12, P-7-15 x Pusa Nanha and Red Lady were evaluated for different horticultural parameters under insect proof net-house. Of these, P-7-15 as maternal female parents hold immense potentiality towards development of a commercial papaya hybrids. Hybrid P-7-15 x Pune Selection 3 have higher fruiting zone, average fruit weight, early fruit maturity and higher per plant fruit yield with improved antioxidant activities.

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, having dwarf stature and bearing height in M6 population.

PRODUCTION TECHNOLOGY

In the evaluation three semi vigorous mango varieties 'Pusa Arunuma', 'Pusa Surya' and 'Amrapali' of on five polyembryonic rootstocks, K-5 or 'K-2' rootstocks proved dwarf. The highest TSS in Pusa Surya was obtained on K-5, while Olour, K-3 and K-2 produced fruit with higher TSS in Amrapali. TSS was not influenced in Pusa Arunima by rootstocks. In semi- vigorous cultivars (Mallika and Dashehari), rootstock impacted tree volume. Vigorous trees were observed in case of Mallika on Kurakkan, while reverse trend was noticed for Dushehari. Overall, 'Dushehari'-'Olour' and 'Mallika'-'Kurakkan' had highest fruits/tree, but without showing significant difference with 'Mallika'-'K-5'.

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 seven rootstocks. Over all, RLC-6 and RLC-7 proved most vigorous rootstocks for Pusa Sharad and Pusa Round, respectively. RLC-6 rootstock proved to be the most productive rootstock for Pusa Sharad and Pusa Round cultivars. Of the eight citrus rootstocks evaluated against drought stress, X639 rootstock proved most tolerant followed by RLC 1. Overall, Cleopatra mandarin proved most susceptible to drought stress.

The INM practice was standardized in three mango hybrids, wherein, maximum fruit weight was found in Pusa Arunima followed by Pusa Lalima and minimum in Pusa Pratibha. Maximum fruit yield was recorded in treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit yield was found in Pusa Arunima followed by Pusa Lalima and minimum in Pusa Pratibha.

During 2021, commercial licensing of six Pusa mango varietieswas initiated under Outreach Programme (ORP) on Up-scaling of New Mango Varieties. Simultaneously, seven varieties including four of mango

(Pusa Lalima, Pusa Pratibha, Pusa Peetamber and Pusa Shresth), two of grapes (Pusa Aditi and Pusa Urvashi) and one each of acid lime (Pusa Abhinav) and sweet orange (Pusa Round) have been Developed by the Division and released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Agricultural Crops, and notified through Gazette of India. Besides, eight varieties including two of mango (Pusa Deepshikha and Pusa Manohari), two of grapes (Pusa Swarnika and Pusa Purple Seedless) and one each of sweet orange (Pusa Sharad), pummelo (Pusa Arun) and lemon (Pusa Lemon 1) developed by the FHT Division have been released Delhi State Seed Sub-Committee for Agricultural & Horticultural Crop, Govt. of NCT of Delhi.

During 2021, a total of 12556 plants of different varieties of mandated fruit crops were multiplied, and sold to the growers, SAUs and nurserymen, and generated the total revenue of Rs 14.38982 Lacs/= through the sale of planting materials (Rs. 9.34,882 Lacs) and the fruit auction of experimental orchards (Rs. 5.041 Lacs).

THE GRADUATE SCHOOL

During the year 2021, total 18 PG students including 8 M.Sc. and 10 Ph.D. students taken admission in the Division. Total eight students including two Ph.D. and six M.Sc. students received degree during IARI Convocation, New Delhi. A total of 17 students were awarded with the fellowship, from ICAR, New Delhi. A total of five scientists were awarded with various awards and fellowships. A total of 15 research papers were published, of which 02 were in 8-10 NAAS rating, and 12 were in 6-8 NAAS rating. Simultaneously, Divisional scientists also published 13 book chapters and 03 popular articles. The faculty members attended 13 seminars/symposia and remained involved in various extension activities.

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

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1.1.1.1 Mango hybridization using potential parents

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 was attempted. Total 772 panicles having 6217 flowers were crossed. (Table 1).

Table 1. Details of hybridization work attempted during March, 2021

S. No.	Cross	No. of panicles crossed	No. of flowers crossed	Final recovery (02.07.2021)
1	Neelum × Dashehari	123	752	30
2	Neelum × Eldon	35	240	8
3	Dashehari × Neelum	6	46	0
4	Amrapali × Tommy Atkins	106	739	19
5	Amrapali × Ellaichi	96	1294	60
6	Amrapali × Pusa Arunima	163	1310	45
7	Amrapali × Maya	55	469	18
8	Amrapali × Vanraj	88	169	11
9	Mallika × Tommy Atkins	72	589	5
10	Totapari × Vanraj	27	169	4
	Total	772	6217	204

1.1.1.2 Evaluation of mango hybrids for different traits

During the period total 63 hybrids belonging to different cross combinations were evaluated for different physico-chemical attributes. The maximum fruit weight was noted in H-14-2 (403.2 g) followed by H-1-5 (352.6 g), H-1-11 (327.58 g) and NH-20-2 (326.65 g). Hybrids, namely, NH-16-2, H-1-5 and NH-20-2 bore more than 200 g fruit weight with nearly 70 per cent pulp content (Table 2 - 3). Hybrids, namely, NH-17-2, NH-18-4, NH-20-2, H-3-2 and H 14-2 had attractive red peel colouration of differential magnitude on fruit surface.

Table 2. Variation among hybrid progenies

Parameters	**2021-22**		
	Min.	**Max.**	**Mean**
Fruit weight (g)	86.57	403.20	219.60
Fruit length (mm)	66.91	140.49	103.70
Fruit width (mm)	45.44	84.82	65.13
Fruit thickness (mm)	41.22	77.30	59.26
Pulp weight (g)	40.61	231.25	135.93
Stone weight (g)	16.49	57.60	37.04
Peel weight (g)	16.67	59.31	37.99
Pulp (%)	45.01	72.40	70.07
Peel Thickness (mm)	0.43	1.940	1.185
Stone length (mm)	50.06	107.40	78.73
Stone width (mm)	18.56	44.05	31.30
Stone thickness (mm)	13.44	128.99	71.21

Table 3. Better performing mango hybrids

Hybrid	Fruit Wt. (g)	TSS (°Brix)	Pulp (%)
H 1-5	352.66	20.75	72.49
H 1-11	327.58	18.25	66.57
H-3-2	213.45	19.70	68.33
H-14-2	403.91	24.01	65.22
NH 16-2	200.18	21.44	73.80
NH 18-4	279.10	23.39	67.51
NH 19-2	200.45	23.02	69.54
NH 20-2	326.65	16.15	71.66
NH 17-1	188.46	21.06	59.49

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

Maternal half-sib of Amrapali mango was generated and during the period 68 open pollinated new stones of Amrapali have been raised in the gaps. In addition, 125 half-sibs have been evaluated for horticultural traits related to vegetative growth, leaf parameters, flowering and fruiting (Table 4). Total 102 trees flowered and fruit obtained from only 76 trees. The variation observed among maternal half-sibs of Amrapali is given here under in Table 4.

Table 4. Performance of maternal half-sibs of Amrapali

Trait		Min.	Max.	Mean
Fruit weight (g)		85.17	341.92	174.32
Fruit length (cm)		63.16	127.28	88.53
Fruit Girth (cm)		45.13	73.14	57.16
Fruit firmness (*N*)	Top	0.27	3.73	2.48
	Mid	0.35	4.46	2.97
	Bottom	0.30	3.60	2.34
Peel Firmness (*N*)	Top	0.86	10.09	5.46
	Mid	1.03	10.67	6.58
	Bottom	0.87	8.87	5.28
Pulp Firmness (*N*)	Top	0.034	0.71	0.41
	Mid	0.09	0.61	0.38
	Bottom	0.05	0.64	0.42
Peel colour	*L**	36.9	64.87	52.23
	*a**	-4.96	33.25	9.18
	*b**	17.71	54.25	35.37
Pulp Colour	*L**	33	47.78	38.35
	*a**	5.68	28.46	19.44
	*b**	23.56	47.10	40.05

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. Two collections shoed unique traits in terms of fruit shape in Nim. 1 was highly twisted and elliptical, however, in Nim 2 the fruit peel developed brilliant red colour under Delhi conditions. The maximum fruit weight (210.5 g) was also noted in Nim. 2 (Table 5).

Table 5. Physico-chemical parameters of mango collections

Name	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	TSS (°Brix)
Nim. 1	185..2	13.2	4.4	18.6
Nim. 2	210.5	12.2	6.3	20.1
Nim. 3	156.8	7.2	5.3	19.4
Nim. 4	80.0	6.6	5.2	16.5
Nim. 5	152.5	9.4	6.1	18.2
Nim. 6	101.5	7.6	5.1	21.2

1.1.1.5 Validation of SSRS and SNPs in mango

During the period 120 Hyper-variable SSRs and 80K SNPs have been validated in mango. In total, 558 unique HMSSRs markers with an estimated amplicon size of 200–350 bp were used for the polymorphism survey between parents Amrapali and Sensation. Out of 558 HMSSRs, 160 (28.67%) were found to be polymorphic between the parental lines Amrapali and Sensation. Out of 160 polymorphic MSSRs, thirty-three SSRs showed aa, bb or bb, aa allelic patterns and were expected to segregate in a 1:0 ratio in the hybrid progeny population. These HMSSRs have been further used for the ascertainment of hybrid progenies derived from Amrapali and Sensation cross as all hybrid progenies were expected to be heterozygous for these specific loci. Out of which eight HMSSRs have been finally selected for hybridity testing of progenies obtained from Amrapali x Sensation cross. While analysing the SSR profiles of hybrid progenies, it was observed that the amplicon size ranged between 180 to 330 bp. However, confirmation of hybridity of progenies ranged between 30.85 and 93.61% (Fig 1 and Table 6).

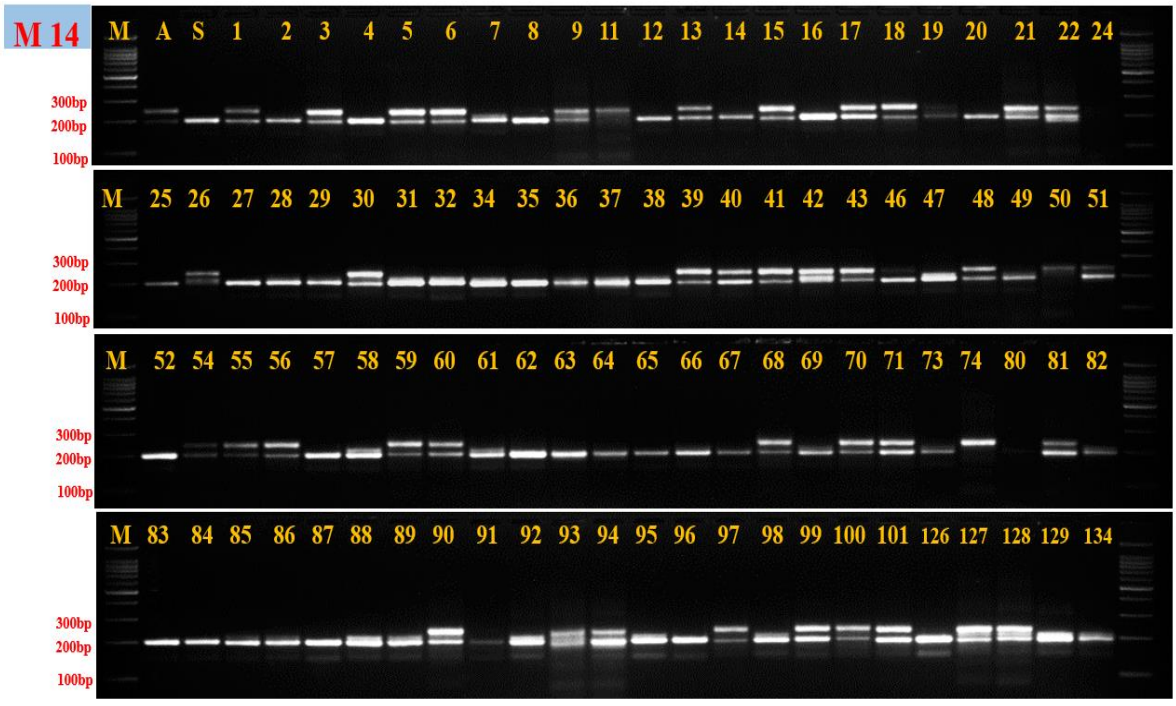

Fig. 1. SSR (M14) profile of 92 mango hybrids.

Table 6. Details of HMSSR, allelic pattern, segregation ration, and parentage confirmation of F1 progeny population (Amrapali/Sensation)

HMSSR Code	Sequence	Allelic pattern		Expected allelic pattern in progeny	Expected segregation ratio	Observed segregation ratio	Parentage confirmation
		Female	Male				
M15	R:GGCTTGTTTTCCAAGCAGAA L:CTCTCCAAAGTGAGTTAAAATGAGC	aa	bb	ab	1:0	0.89:011	89.36
M17	R:GGTGATGTCAGCATGCATTT L:CTGATCCGACCACTTGGAAT	aa	bb	ab	1:0	0.81:0.19	81.91
M73	R:GCAAATTGTGTGCAGAGGAG L:GCGAGGATTCTGCTGTTTTC	aa	bb	ab	1:0	0.88:0.12	88.29
M88	R:GGAGCCAAGTGGGTCTCATA L:CTCAATTACTGCCCAACGTG	aa	bb	ab	1:0	0.61:0.39	61.70
M109	R:TGCTTAATTTCATGCCCACA L:ATGCCCATGTTCAACCCTAC	aa	bb	ab	1:0	0.90:0.10	90.43
M177	R:ACCTTGGATGAGGTTTGCTC L:AACGCAATTGTGGGATAGGA	bb	aa	ab	1:0	0.53:0.47	53.19
P125	R:CACTGCCTTTGTCTGGAAGAG L:GGTGTCCGACTGTAAGGATGA	aa	bb	ab	1:0	0.93:0.07	93.61
P73	R:TTTGGTTGCCAAGGCTTCTA L:CCTAGGTACATTCCAGGGGTA	bb	aa	ab	1:0	0.31:0.69	30.85

1.1.1.6 SSR based genetic linkage map construction

The polymorphic SSR markers (160) were used for genotyping of the mapping population consisting of F_1 full sib individuals. Marker loci exhibited various patterns in the parental lines and the mapping population. Therefore, they have been classified into three groups based on the number of alleles per locus, *viz.*, two, three and four alleles per locus. In the two alleles per locus class, 16 HMSSRs showed heterozygous pattern in both the parents (ab x ab), 29 HMSSRs have shown heterozygous pattern in female and homozygous pattern in male (ab x aa or bb), 12 HMSSRs shown homozygous pattern in female and heterozygous pattern in male (aa or bb x ab) and 33 markers have shown homozygous alleles in both the parental lines (aa x bb).

SSR based linkage mapping was performed with JoinMap 4.1. There were less available markers for each segregating groups, which resulted in only three linkage groups. Out of 49 HMSSRs, seven markers, *viz.*, N14, N13, N12, P166, M68, N7 and N8, were anchored on the three linkage groups. Linkage group 1 was the largest with the total map length of 30.5 cM with three markers N13, N12 and N14 at 0, 20.8 and 30.5 cM positions, respectively. Similarly, linkage group 2 had a map length of 20.6 cM, and M68 and P166 markers were mapped on LG. While the linkage group 3 was the smallest, with the map length of 16.7 cM, and mapped with the two markers N7 and N8 at the 0 and 16.7 cM positions, respectively. Linkage group 1 has the lowest marker interval of 9.7 cM, followed by the LG 3 (16.7 cM), and the maximum loci interval was 26.6 cM in LG 2. Attempt to generate the 20 linkage groups using microsatellite data was unsuccessful due to the insufficient number of polymorphic markers segregating in specific fashion to achieve even distribution of markers over 20 chromosomes.

1.1.1.7. SNP based genetic linkage map construction

The SNP genotyping data of F_1 progenies using 80K SNP Gene Chip have been used and a set of 5,520 SNPs showing heterozygous allelic pattern for female parent and homozygous allelic pattern for the male parent. These SNPs were expected to segregate in a 1:1 ratio. After filtration of data, 686 SNP markers without rare allele and 100% base call rate was used for linkage mapping and finally 492 SNPs have been mapped across 20 linkage groups (LG) (Fig 2).The cumulative genetic map distance was

4974.1 cM, with an average distance between two adjacent markers of 12.1 cM. The number of SNPs mapped per LG ranged from 8 (LG 20) to 50 (LG 7), with an average of 24.6 per LG. However, a total of 10 LGs possessed more than 25 markers per LG.

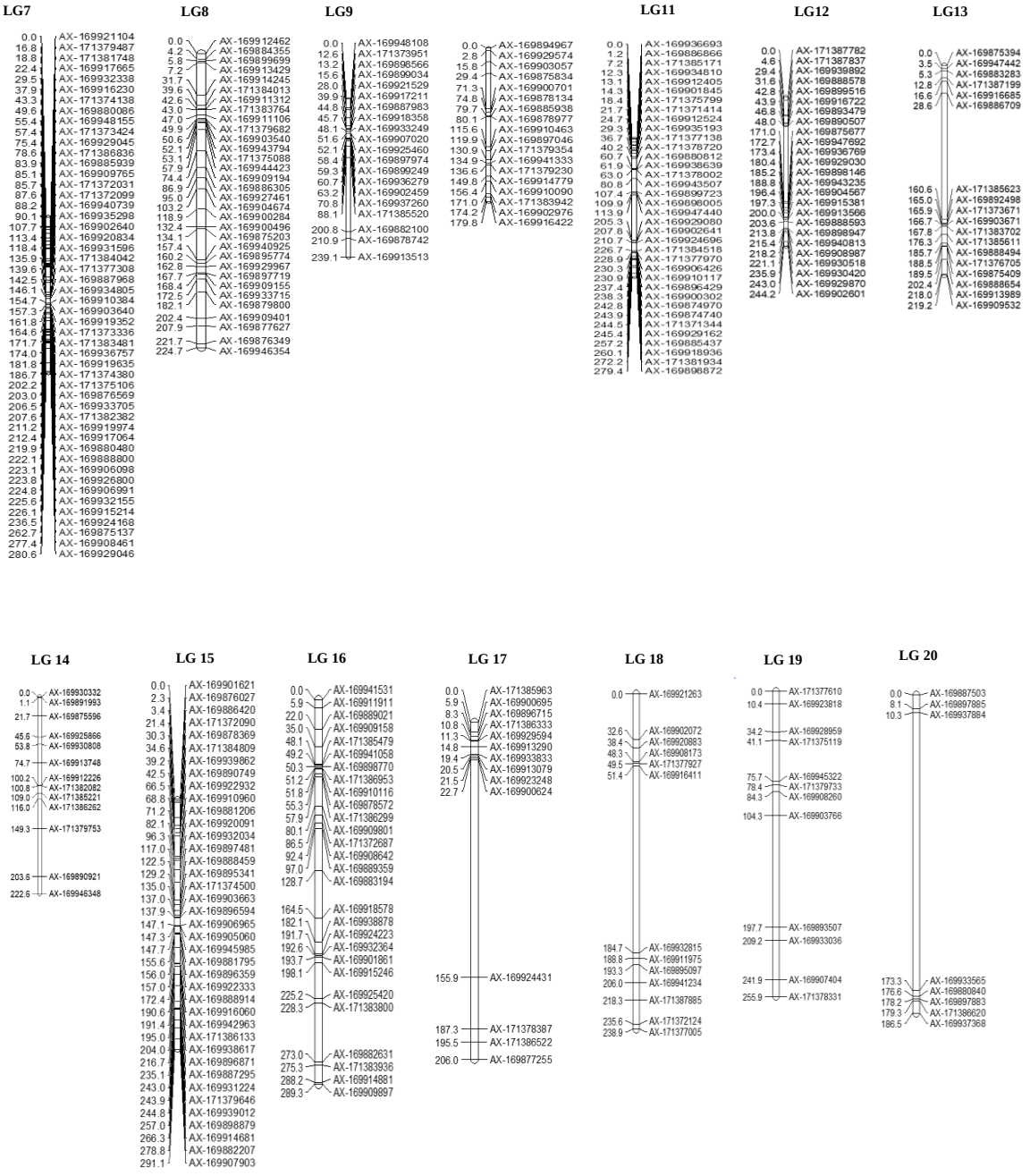

Fig. 2. SNP marker based genetic linkage map with 20 LGs

1.1.1.8 Grouping of mango genotypes based on maturity groups

Mango genotypes of varying shelf-life (long, medium and short) grouped separately into different clusters (Figure 3) based on ripening gene specific primers (Table 7). Strong association of simple sequence repeats loci (SSRs) MSL-8 and MSLC-13 with physiological loss in weight (PLW) and titratable acidity was observed. Therefore, these ripening gene specific SSRs loci could be used in marker-assisted breeding for fruit-quality traits associated with shelf-life.

Table 7. Details of ripening Genes, simple sequence repeats (SSRs) used for primer synthesis and validation

S. No.	Nucloeotide Sequence/Contig /Conserved domain	Gene associated	SSRs details	No. of primers synthesized & validated	Primer used for validation
1	mRNA ripening sequence 1	*3-ketoacyl-coA thiolase* B	2	1	MSL-1
2	mRNA ripening sequence 2	*acyl-activating enzyme 1, peroxisomal*	2	1	MSL-2
3	mRNA ripening sequence 3	*acyl-lipid omega-3 desaturase*	3	1	MSL-3
4	mRNA ripening sequence 4	*desiccation-related protein PCC13-62*	2	1	MSL-4
5	mRNA ripening sequence 5	*Lipoxygenase*	3	1	MSL-5
6	mRNA ripening sequence 6	*DMR6-LIKE oxygenase*	3	1	MSL-6
7	mRNA ripening sequence 7	*Uncharacterized transcription factor for ripening*	2	1	MSL-7
8	mRNA ripening sequence 8	*zinc finger protein ZAT10-like*	2	1	MSL-8
9	mRNA ripening sequence 9	*Uncharacterized transcription factor for ripening*	3	1	MSL-9
10	mRNA ripening sequence 10	*helicase-like transcription factor*	1	1	MSL-10
11	mRNA ripening sequence 11	*Uncharacterized TF*	1	1	MSL-11
12	mRNA ripening sequence 12	*Uncharacterized TF*	2	1	MSL-12
13	mRNA ripening sequence 13	*Uncharacterized TF*	2	1	MSL-13
14	Contig1	*Lipoxygenase*	2	1	NMSLC-1
15	Contig2	*omega-3 fatty acid desaturase*	3	1	NMSLC-2
16	Contig3	*desiccation-related protein PCC13-62-like*	3	1	NMSLC-3
17	Contig4	*1-aminocyclopropane-1-carboxylic acid oxidase (aco1 gene)*	4	1	NMSLC-4
18	Contig5	*3-ketoacyl-coA thiolase B*	6	1	NMSLC-5
19	Contig6	*ethylene receptor (ERS1)*	7	1	NMSLC-6
20	Contig7	*Chitinase*	2	1	NMSLC-7
21	Contig8	*1-aminocyclopropane-1-carboxylate synthase*	3	1	NMSLC-8
22	Contig9	*endo-1,4-beta-glucanase (cel gene)*	2	1	NMSLC-9
23	Contig10	*poly(A)-binding protein (pabp gene)*	2	1	NMSLC-10
24	Contig11	*sucrose-phosphate synthase (sps gene)*	2	1	NMSLC-11
25	Contig12	*beta-galactosidase*	5	1	NMSLC-12
26	Contig13	*Alternative oxidase*	5	1	NMSLC-13
27	Contig14	*alcohol dehydrogenase 2 gene*	12	1	NMSLC-14
28	Conserved domain	*Expansins*	38	8	EXPM-1 to EXPM-8

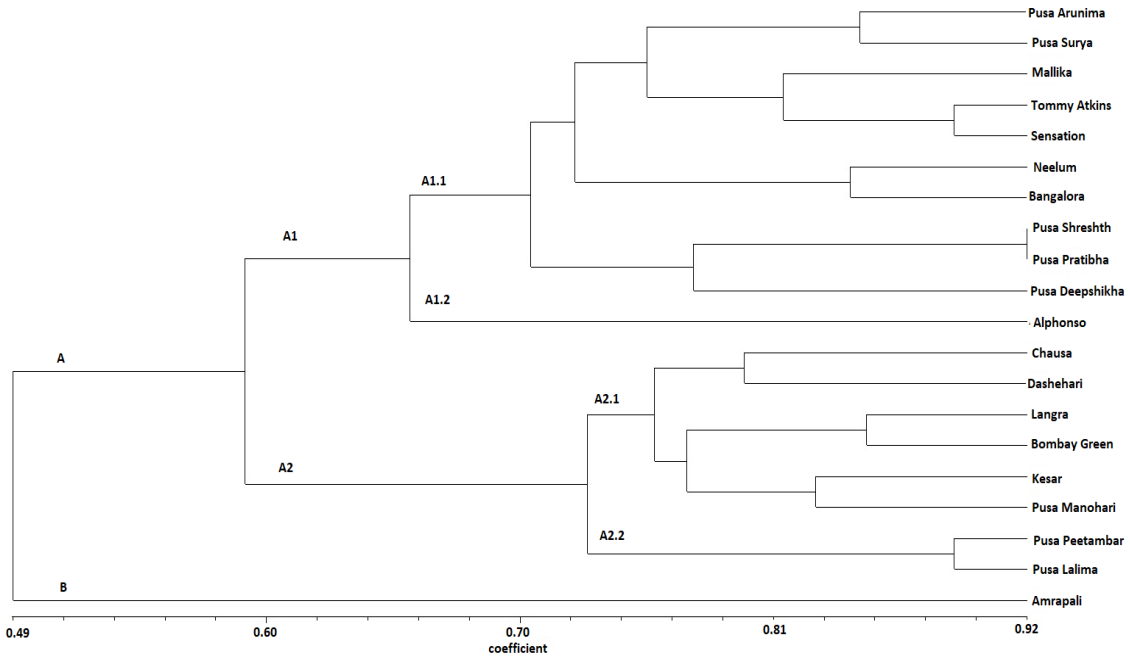

Fig. 3. Dendrogram of 20 mango genotypes based on shelf-life specific primers

1.1.1.9 Mango Rootstock improvement through hybridization involving parents for dwarfness and abiotic stresses in mango

Total 91 panicles (275 flowers) were used for crossing with various combinations of the polyembryonic mango Olur, Kurrukan, Bappakai, M 13-1. Out of total crossed flowers, fruit set were recorded in 41 (Olour × Kurukan), 21(Olour × Bappakai),17 (Bappakai × 13-1), 14 (Bappakai x Olour),and subsequently 11 seedlings [3 (Olour × Kurukan), 5 (Bappakai × 13-1), 3 (Bappakai x Olour)],were recovered for further evaluation from 15 harvested fruits.

1.1.1.9.10 Physiological and biochemical characterisation of progeny population of Olour mango

Among rootstocks, Olour has better compatibility with several improved cultivars and having several desirable features such as polyembryony which produce nucellar seedlings those true to the types and uniform in size. An attempts were made to characterize and evaluate the progenies of Olour mango (28) based on physiological and biochemical traits. A significant level of variability was observed in 28 hybrids. The minimum stomatal density was observed in OP-17-15 (518.67 stomata/mm^2) in comparison with Olour sapling (617.30 stomata/mm^2) and the maximum stomatal density was observed in OP-17-56 (746.67/stomata/mm^2). The minimum photosynthetic rate (4.490 µmol CO_2 m^{-2} s^{-1}) was observed in OP-17-47 in comparison with Olour sapling (6.293 µmol CO_2 m^{-2} s^{-1}) and maximum photosynthesis rate was observed in OP-17-39 (14.483 µmol CO_2 m^{-2} s^{-1}) followed by OP-17- 34 (11.517 µmol CO_2 m^{-2} s^{-1}).

Minimum stomatal conductance was found in OP-17-5 (0.030 Mmol m^{-2} s^{-1}) and maximum stomatal conductance was found in OP-17-34 (0.220 Mmol m^{-2} s^{-1}) as compare to Olour sapling (0.090 Mmol m^{-2} s^{-1}). The minimum transpiration rate was recorded in OP-17-90 (0.520 m mol H_2O m^{-2} s^{-1}) and maximum transpiration rate was recorded in OP-17-39 (4.553m mol H_2O $m^{-2}s^{-1}$). The minimum leaf internal CO_2 concentration was recorded in OP-17-19 (147 µmol $mol^{-1}m^{-2}s^{-1}$) followed by OP-17-26 (155.33 µmol $mol^{-1}m^{-2}s^{-1}$) Olour sapling showed leaf internal CO_2 concentration of 217.00 µmol $mol^{-1}m^{-2}s^{-1}$ and maximum leaf internal CO_2 concentration was recorded in OP-17-40 (274 µmol $mol^{-1}m^{-2}s^{-1}$). Lower stomatal density, less photosynthetic and transpiration rate indicates dwarfism in the

plant. In the present study, the maximum photosynthetic and transpiration rate was found in the progeny OP-17-39 which is a vigorous in growth as compared to Olour.

The maximum total leaf phenolics was recorded in OP-17-11(3660 mg/100 g. f wt) followed by OP-17-58 (3650 mg/100 g. f wt) whereas minimum total leaf phenolic compounds were recorded in OP-17-41 (2040 mg/100 g. f wt) as compared with Olour (3063.33 mg/100 g. f wt).The maximum leaf flavonoids content was in OP-17-58 (256.56 mg/100 g. f wt.) followed by OP-17-57 (248.68 mg/100 g. f wt.) and minimum leaf flavonoids content was recorded in OP-17-41(123.86 mg/100 g. f wt) as compared with Olour (206.167 mg/100 g. f wt.). The high content of phenolics and flavonoids indicate about dwarfness and biotic stress resistance in the plant.

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

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1.1.2.1 Breeding for sweet citrus for enhanced nutritional properties

Six sweet citrus scion hybrids (Pummelo x sweet orange) were examined for growth, yield and fruit quality. Hybrids SCSH—5/2016, SCSH-7-2/12, SCSH-11-15/12, SCSH-19-5/14 produced encouraging results with respect to moderate fruit weight (282.83-620.67 g), higher juice content (45.16% to 48.86%) as compared to PS-2 (female parent) (23.41%). These orangelo also had moderate acidity content (1.60% to 1.96%) but much higher than female and male parents. All these hybrids had much leaser seeds (<34 seeds/fruits) than pummelo (female parent). All hybrids produced lesser seeds/fruit than female parent but higher than male parent (Table 8).

Table 8. Performance of sweet scion citrus hybrids

Hybrids /parent	Fruit weight (g)	Juice (%)	Seeds/fruit	Peel thick (mm)	TSS (^{0}B)	Acidity (%)	Vit C (mg/100)
SCSH-3-14/15	369.12	51.34	40.00	7.85	8.23	2.65	46.81
SCSH-3-15/16	343.41	47.07	29.67	4.92	8.23	2.62	36.05
SCSH-4-9/17	511.37	48.92	49.33	8.84	8.27	2.26	35.33
SCSH-5-5/16	620.67	48.86	36.67	5.59	9.30	1.96	35.33
SCSH-11-15/12	427.85	48.89	30.00	4.75	9.27	2.60	34.25
SCSH-19-5/14	282.83	45.16	30.00	4.18	8.33	2.01	31.92
SCSH-9-2/16	356.35	46.23	27.00	3.73	7.03	1.66	4.45
PS-2 (female)	844.74	23.41	100.67	12.82	11.07	0.64	77.65
Mosambi (male)	137.37	44.17	17.00	2.66	8.07	0.45	32.28
LSD (p≤ 0.5)	42.56	4.78	18.91	1.23	0.95	0.03	6.90

1.1.2.2 Performance evaluation of Red Blush grapefruit mutants

These three different typed of grapefruit were noticed from population of grapefruit cultivar Redblush. These all three lib sports were assessed for quality traits and season of ripening with Redblsuh cultivar planted in same area. It was observed that all these limb sports were different with original Redblush with regard to quality traits (colour of juice vesicles, acidity, fruit weight, vitamin C content) as well season of ripening. Limb sport RBLS-1 had deep red juice colour than Redblsuh but much higher peel thickness (7.09 mm as of 4.64 mm in Redblush) and lesser juice content (34.32%). Another two limb sports (RBLS-2 and RBLS-3) has moderate size fruit (315.18 g and 329.79 g), deep pigmentation on

pee as well deep red juice colour, thin peel thickness (3.29 mm; 4.26 mm), higher ascorbic acid content 50.57 and 39.27 mg/100 ml juice) than Redblush. More importantly, all these limb sports mature much earlier than original Redblush (First week of October) and produced seedless fruits (Table 9-10 and Fig. 4).

Table 9. Comparative performance of grapefruit Redblush mutants over standard Redblush harvested during September (21.09.2021)

Characters	Redblush mutant						
	RB	RBLS-1	% change	RBLS-2	% change	RBLS-3	% change
Fwt (cm)	295.30	506.30	71.45	315.18	6.73	329.69	11.65
FL(mm)	78.30	107.00	36.65	93.67	19.63	88.33	12.81
FW (mm)	88.30	111.70	26.50	98.33	11.36	88.67	0.42
Juice (ml)	143.30	174.70	21.91	141.33	-1.37	161.67	12.82
Juice %	48.70	34.30	-29.57	45.12	-7.35	49.06	0.74
Pth (mm)	4.60	7.90	71.74	3.29	-28.48	4.26	-7.39
Seeds/fruit	6.30	1.70	-73.02	0.33	-94.76	2.00	-68.25
TSS (^{0}B)	8.00	7.90	-1.25	7.67	-4.13	8.00	0.00
Acidity (%)	1.00	1.10	10.00	0.90	-10.00	1.13	13.00
Vitamin C (mg /100 ml juice)	36.60	45.70	24.86	50.57	38.17	39.27	7.30

Table 10. Comparative performance of grapefruit mutants with cultivar Redblush harvested during October (26.11.2021)

Characters	Redblush mutant						
	RB	RBLS-1	% change	RBLS-2	% change	RBLS-3	% change
Fwt (cm)	282.80	386.60	36.70	259.70	-8.17	361.10	27.69
FL(mm)	76.30	101.40	32.90	80.00	4.85	91.70	20.18
FW (mm)	83.00	98.40	18.55	81.40	-1.93	91.90	10.72
Juice (ml)	135.70	158.00	16.43	132.30	-2.51	174.70	28.74
Juice %	48.40	41.10	-15.08	52.10	7.64	48.40	0.00
Pth (mm)	4.90	6.60	34.69	3.60	-26.53	3.90	-20.41
Seeds/fruit	7.70	0.00	-100.00	2.30	-70.13	1.30	-83.12
TSS (^{0}B)	7.50	7.60	1.33	7.60	1.33	7.10	-5.33
Acidity (%)	1.00	1.00	0.00	0.90	-10.00	1.10	10.00
Vitamin C (mg/100 ml)	33.90	43.30	27.73	39.30	15.93	43.60	28.61

Redblush RBLS-1

RBLS-2 RBLS-3

Fig. 4. Variation in colour, rind thickness and core diameter in grapefruit limb sports and original Redblush

1.1.2.3 Breeding of acid citrus for canker tolerance and summer fruiting

Yield and fruit quality of eight acid citrus scion hybrids (acid lime x lemon) has been assessed during 2021 (Table 11-12). Two acid citrus hybrids (ACSH-3.2/18 and ACSH-9-13/18 appeared to be highly precocious and showing immunity to citrus canker. These acid hybrids also exhibited moderate fruit size (67.07 g and 73.77 g), respectively. Compared to check (Pusa Abhinav), > 74% and 90% bigger fruits were found in ASCH-3-2/2018 and ASCH-9-13/18. Both hybrids were found to bear fruits twice a year but both hybrids produced much lesser juice content (19.08% and 18.12%).

Table 11. 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	67.07	59.13	47.95	6.00	9.08	32.80	2.11
ACSH-3-5/18	160.16	106.08	64.85	9.80	6.15	22.00	2.22
ACSH-5-12/18	66.82	69.24	44.35	9.20	14.01	27.20	2.31
ACSH-7-13/18	65.75	69.62	44.19	8.60	12.76	25.00	1.55
ACSH-7-14/18	195.87	99.64	65.20	26.00	13.12	65.60	3.35
ACSH-9-1/18	90.76	67.46	50.63	20.20	22.37	30.80	2.39
ACSH-9-13/18	73.77	60.00	49.96	6.20	8.12	62.20	1.40
ACSH-11-13/18	111.84	75.65	52.82	31.20	28.11	14.80	1.36
Pusa Abhinav	38.45	35.65	40.12	18.20	47.25	15.33	1.59
Konkan SL	40.42	42.56	36.45	10.26	26.38	32.83	1.35
LSD (p≤ 0.5)	7.5	4.56	3.89	0.23	2.26	2.8	0.23

Table 12. Comparative performance of limo (acid lime x lemon hybrid) with their parents

Character	TSS (^{0}B)	Acidity (%)	Fruit /tree	Season of fruiting	Reaction to canker
ACSH-3-2/18	6.74	4.84	156	Twice	Immune
ACSH-3-5/18	7.40	5.38	45	Once	Immune
ACSH-5-12/18	5.60	3.28	89	Once	Immune
ACSH-7-13/18	6.44	4.30	150	Twice	Immune
ACSH-7-14/18	6.36	3.61	56	Once	Immune
ACSH-9-1/18	7.24	6.40	79	Once	Immune
ACSH-9-13/18	5.40	5.25	125	Once	Immune
ACSH-11-13/18	5.67	5.43	75	Once	Immune
Pusa Abhinav	7.56	6.85	125	Twice	Susceptible
Konkan SL	7.50	5.23	253	Twice	Immune
LSD (p≤ 0.5)	0.85	0.88	-		

1.1.2.4 Performance evaluation of lemon

During 2021, the performance of seven lemon collections existing at our field was evaluated in comparision to Pusa Lemon -1 and Kagzi Kalan cultivars (Table 13). Of the studied genotypes, the highest fruit weight was recorded in LS-3 (86.52g), but was found statistically at par with Pusa Lemon-1. The fruits of LS-10 had the thinnest peel (0.89mm), which was statistically at par with the peel thickness of Pusa Lemon-1, LS-7 and Kagzi Kalan fruits. The lowest number of seeds was noticed in the fruits of LS-8 (13.40 seeds/fruit) without any significant difference with the fruits of LS-4 and LS-7. The fruits of LS-8 were most juicy (52.08%), however, it was found statistically at par with most of the collections tested, except LS-5. The content of juice TSS was highest in Pusa Lemn-1 (7.96°B) having similarity statistically with LS-7, LS-8, LS-9, LS-10 and Kagzi Kalan (7.56° -7.86°B). The fruits of LS-8 tended to show the highest content of juice acid (52.08 %), proving similarity statistically with Pusa Lemon-1 and LS-9 fruits.

During 2021, six lemon cultivars were evaluated taking Kagzi Kalan as check variety (Table 14). Hill Lemon tended to show the highest fruit weight (178.07g) and peel thickness (3.68 mm) with lowest number of seeds (9.00 seeds/ fruit) statistically. The fruits of Eureka had the thinnest peel (0.92 mm) having similarity statistically with Kagzi Kalan and Saverle. The fruits of Assam Lemon and Hill Lemon proved low seeded (9.00-9.40 seeds/fruit), while Eureka produced most seedy fruits (40.80 seeds/fruit). Kagzi Kalan yielded the fruits with highest juice content (44.67%) with no significant difference with the fruits of Assam Lemon and Saverle. Eureka excelled for highest TSS (8.30°B) and acid (5.40%) contents, which was statistically at par with Pusa Lemon-1, Saverle and Hill lemon.

Table 13. Field performance of lemon collections during summer season

Lemon collection/ cultivar	Fruit weight (g)	Peel thickness (mm)	Seeds/ fruit	Juice (%)	TSS (°B)	Acidity (%)
Pusa Lemon-1	78.13[ba]	1.11edc	28.80b	49.53a	7.96a	5.45ba
LS3	86.52[a]	1.23bc	30.20b	48.82a	7.10c	4.79ed
LS4	72.52[bc]	1.37bac	16.20d	47.12ba	7.36bc	4.94edc
LS5	66.98[dc]	1.57a	33.20ba	39.65b	7.38bc	4.61e
LS7	59.09[d]	1.15bedc	16.80dc	48.05ba	7.56ba	5.15bdc
LS-8	66.89dc	1.23bdc	13.40d	52.08a	7.76ba	5.61a
LS-9	65.76dc	1.41ba	21.60c	50.58a	7.86a	5.30bac
LS-10	59.40d	0.89e	37.40a	47.05ba	7.7ba	5.12bdc
Kagzi Kalan	57.87d	1.06ed	28.60b	44.67ba	7.66ba	5.17bc
LSD ($P \leq 0.05$)	9.93	0.27	5.04	8.93	0.44	0.38

Table 14. Field performance of lemon cultivars during summer season

Lemon collection/ cultivar	Fruit weight (g)	Peel thickness (mm)	Seeds/ fruit	Juice (%)	TSS (°B)	Acidity (%)
KagziKalan	57.87b	1.06c	28.60c	44.67a	7.66b	5.17ba
Assam Lemon	59.86b	1.66b	9.40e	38.63ba	6.6dc	4.86b
Eureka	41.66b	0.92c	40.80a	36.21b	8.30a	5.40a
Konkan Seedless	56.01b	1.84b	17.20d	33.58b	6.40d	3.94c
Saverle	55.32b	1.13c	38.80b	37.96ba	6.94c	5.21ba
Hill lemon	178.07a	3.68a	9.00e	33.32b	7.72b	5.15ba
LSD ($P \leq 0.05$)	10.38	0.29	3.24	7.63	0.52	0.44

1.1.2.5 Tangerine/Minneola/Sweet orange

The performance of Dancy and W. Murcott tangerines, and Minneola tangelo was assessed taking Kinnow as check variety (Table 15). Minneola yielded the heaviest fruits (287.66g) with lowest number of seeds (11.00 seeds/ fruit). The fruits of W. Murcott had the thinnest peel (2.15mm) statistically. W. Murcott and Kinnow proved equally good for juice content (46.10-51.80%), while it was lowest in Dancy (23.72%). The fruits of Dancy and W. Murcott proved similar statistically in respect of low acid content (0.63-0.70%). The highest content of ascorbic acid was recorded in the juice of Minneola (53.86 mg/100 ml), closely followed by W. Murcott and Kinnow. Due to infestation of psylla insect, no fruit set was recorded in Dancy-6 tangerine (already reported with low tendency to produce granulated fruits) during 2021, however, it was multiplied and planted further for replicated trial.

Table 15. Field performance of newly introduced varieties of citrus fruit

Fruit	Fruit weight (g)	Seeds/fruit	Juice (%)	Peel thickness (mm)	Acidity (%)	TSS (°B)	Ascorbic acid (mg/100g juice)
Dancy	159.83c	16.20bc	23.72c	3.09b	0.63c	7.38a	45.62b
W-Murcott	194.84b	18.40ba	46.10ba	2.15c	0.70c	7.70a	52.27a
Minneola	287.66a	11.00c	39.18b	3.39a	0.86b	6.64a	53.86a
Kinnow	205.48b	23.60a	51.80a	2.90b	0.97a	7.60a	51.74a
LSD (*P≤ 0.05*)	34.86	6.13	11.01	0.23	0.07	NS	4.46

1.1.2.6 Rootstock breeding for *Phytophthora* and salt tolerance

Of the ninteen citrus rootstocks/ hybrids (Sunkokan × Kinnow, Sunkoakn × Pummelo, Sunkokan × Mosambi, Pummelo × Sacaton, Pummelo × Troyer and Soh Sarkar) screened against 50mM NaCl induced salinity, only 14 hybrids have shown tolerance (Table 16). The seediness and polyembryony are two most desirable characteristics for a commercial rootstock in addition to having objective specific trait (tolerance or resistance against intended factor). So, citrus hybrids, which have come into bearing in 2021 were tested for number of seeds and embryony status. Of the 20 hybrids tested, only 09 rootstocks (CRH 21-9, CRH 21-13, SCHS 9-19, SCHS 15-7, CSH 17-12, CSH 17-19, SCSH 3-14, SCSH 3-15 and CRH 7-4)) have shown polyembryony. CRH 7-4 rootstock has been found quite hardy, bearing fruits 2-3 times with dwarf and compact growth.

Table 16. List of salinity tolerant hybrids

Hybrid	Initial leaves	Final leaves	Per cent change
Sun × Kin-1	116	220	89.66
Sun × Kin-3	85	150	76.47
Sun × Kin-4	56	120	114.29
Sun × Kin-7	22	40	81.82
Sun × Kin-8	26	50	92.31
Sun × Kin-9	66	130	96.97
Sun × PS-3	78	133	70.51
Sun × PS-4	88	144	63.64
Sun × PS-6	56	80	42.86
Sun × MOS-3	65	82	26.15
Sun × MOS-4	73	162	121.92
Sun × MOS-6	187	310	65.78
Pum ×Troyer-360	55	110	100.00
Pummelo x Sacaton-1	16	32	100.00

1.1.2.7 Hybridization using different *Citrus* species for scion and rootstock improvement

During February-March, 2021, a total of 23 cross combinations (05 of sweet scion, 07 of acid scion and 11 of rootstocks) were were attempeted (Table 17).

Table 17. Crosses made in February –March 2021

Cross	Flowers crossed	Fruit set at 15 DAP (%)	Fruit set at 30 DAP (%)
MOS × PM3	84	2.38	0.00
MOS × RB	49	22.45	10.20
Kinnow × PM3	17	35.29	11.76
Kinnow × RB	21	61.90	47.62
Orangelo × MOS	13	100.00	76.92
KSL × PU	21	95.24	47.62
LS 1 × PA	45	93.33	33.33
KSL × PA	16	81.25	62.50
PA×LS-1	31	83.87	38.71
PU×LS-1	14	85.71	71.43
PU × KSL	09	66.67	22.22
PA × KSL	29	62.07	17.24
SFM × Troyer**	55	29.09	9.09
YM × Sac**	136	25.00	14.71
YM × X-639**	45	8.89	0.00
YM x Troyer**	32	56.25	18.75
RP× Sac**	114	29.82	21.93
RP × SO**	34	58.82	44.12
RP × X-639**	06	66.67	33.33
RP × Troyer**	95	52.63	26.32
SO × Troyer**	22	27.27	18.18
SO × RP**	19	63.16	31.58
Cleopatra × Troyer**	39	74.36	51.28
Total	946	55.74*	30.82*

*Average; **Rootstock

1.1.2.7 Collection and characterization of pummelo clones

The fruit size in the accessions 628798, 628799 and 628800 was found ideal (medium-sized). The accession 628798 (Fig. 5) bore thin-skinned (1.15 cm) and the accessions 628799 and 628800 (Plate 2) bore dark red-fleshed fruits with solid core.

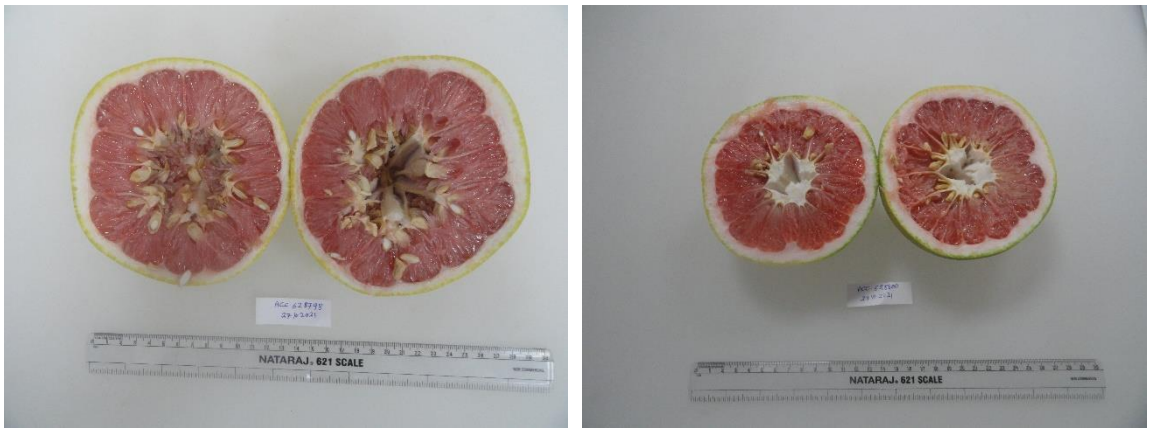

Fig. 5. Thin-rinded fruits and dark red-fleshed fruits

1.1.2.8 Ploidy manipulation in Kinnow mandarin and sweet orange using Colchicine: Characterization of first and second generation colchiploids of Kinnow mandarin and Mosambi

The number of nodes increased but internodal length decreased. Leaf length, width, notch percentage, leaf thickness increased and L:B ratio and petiole length decreased in majority of colchiploids. Leaf area, fresh weight, SLA, DFT, Succulency increased but dry weight decreased. Leaf chlorophyll fractions and total carotenoids increased in majority of colchiploids. Stomatal density decreased and guard cells length and width increased in majority of the colchiploids.

Mosambi colchiploids initiated flowering in the 4th week of February, with its peak between 4th week of February to the 2nd week of March and flowering was over by the 4th week of March. In Kinnow mandarin, the flowering started in the 4th week of February in a few colchiploids and its peak reached in the 3rd and 4th week of March and after that, flowering was over. Initiation and completion of flowering was earlier in Mosambi compared to Kinnow colchiploids.

Fruit weight was higher in most colchiploids compared to wild type. Rind thickness increased in majority of colchiploids and can be used as a reliable marker for hyperploidy. Seed content was generally higher in colchiploids. Identified putative tetraploids behaved as solid tetraploids continuously for fourth year. Colchiploids generally exhibited delayed fruit maturity compared to wild type.

1.1.2.9 Crossing of putative tetraploids with diploids of Kinnow and Mosambi

To produce triploids, 430 flowers of putative second-generation tetraploids of Kinnow and 433 of Mosambi were pollinated with the respective diploid pollen. Comparatively a better fruit set in Mosambi than Kinnow was recorded. Retention of fruits in Kinnow colchiploids (12.01%) was better compared to Mosambi colchiploids (6.74%). Eleven fruits of Kinnow and 14 of Mosambi were harvested (Fig. 6). One hundred sixty-five (165) crossed seeds of Kinnow and 150 of Mosambi were sown along with wild types and tetraploids and 36 seedlings of Kinnow and 42 of Mosambi were obtained. Seed germination was very poor in crosses (28% for Mosambi and 22% Kinnow). Seedling mortality was higher in the Kinnow crossed seeds (39%). Very low seedling survival and seedling growth obtained in the tetraploid x diploid hybrids.

Fig 6 . Tetraploid Mosambi fruit and Tetraploid × diploid Mosambi fruits

1.1.2.10 Induction of tetraploids in pummelo

For induction of tetraploidy in monoembryonic *Citrus* species, seeds of two pummelo accessions were treated with colchicine (0, 0.10% and 0.20%) for 8, 16 and 24 hours. Increasing colchicine concentration and longer duration delayed and reduced the seed germination. Both stimulatory and inhibitory effects of colchicine were observed on plant growth of both the accessions. Stem diameter and shoot internodal length decreased with increasing colchicine concentration and

treatment duration. The genetic diversity among the colchicine treated seedlings of pummelo along with their wild type was studied using 50 RAPD markers. Out of 50 RAPD primers used, 15 exhibited polymorphisms for the studied population of colchicine treated seedlings. Early flowering in pummelo seedlings (4-months old) raised from colchicine treated seeds (Fig. 7) can help in germplasm enhancement and shortening the juvenility period of citrus seedlings.

Fig. 7. Flowering in 4 months old pummelo colchiploid

Six putative mutants identified for dwarfing trait viz., G-20-5, EMS-M-3, Col-1 and Col-2 and low seeded mutants G-6-1, G-9-4 and G-39-3 (<10 seeds/fruit) were multiplied in-situ on *Jatii Khatti* rootstock for further evaluation and testing. Four plants of each mutant were raised. Cent per cent survival was recorded in all the multiplied mutants except G-39-3 in which none of the plants survived.

1.1.2.11 *In vitro* mutagenesis and validation of mutants using molecular markers in Kinnow mandarin.

Since premature abscission of micro-shoots emerging from the cultured nodal segments is major problem in Kinnow mandarin, *In vitro* regeneration was standardized. To resolve the problem explant maturity stages, culture media, growth regulator combinations and abscission related factors along with ethylene inhibitors (silver compounds) were evaluated. Among these, hardwood stage was observed as a proficient explant maturity stage to boost the vigorous early shoot emergence on MS (Murashige and Skoog) and MT (Murashige and Tucker) media added with GA_3 (Gibberellic acid) 10 mg L^{-1} and favorable result of delayed abscission was also noted in the same combination. Although BAP (6-Benzylaminopurine) 2.5 mg L^{-1} induced multiple shoots, severe abscission of micro-shoots were noticed. Further reduction in abscission rate and healthy shoot growth were observed when subculturing of micro-shoots was done in combination with MS + BAP 2.5 mg L^{-1}+ GA_3 10 mg L^{-1} + Silver thiosulfate (5 mg L^{-1}) supplemented medium. This modified procedure can be effectively utilized for mass multiplication as well as *in vitro* induced mutagenesis in Kinnow mandarin.

1.1.2.12 *In vitro* shoot organogenesis in sweet orange (*Citrus sinensis* L.) cv. Mosambi and the effect of ethylene adsorbents on micro-shoot quality.

The experiment was conducted to standardize the organogenesis protocol for multiplication of sweet orange cv. Mosambi by use of different PGRs and silver compounds containing ethylene inhibitors. The experiment was laid out in CRD with different treatment combinations replicated 4 times. Firstly, different conc. of BAP and kinetin was supplied with MS medium in combination to study their effect on shoot organogenesis.

Among the formulated combinations, BAP 2 mg L^{-1} and Kin 1.5 mg L^{-1} resulted in best shoot organogenesis with the highest response (81.40%), number. of micro-shoots/explant (2.06), mean micro-shoot length (1.30 cm) and number of leaves/micro-shoot (3.55) owing to synergistic effect of these factors but all the micro-shoot abscised within 10 days after culture initiation which is however due to the accumulation of ethylene within the cultured vessel during different steps of culture initiation (Explant preparation, treatment of explants etc). The effect of BAP in increment in shoot organogenesis may be attributed to the increase in nucleic acid and protein content, thereby leading to enhanced enzymatic activity within the cell and the ultimate increase in cell division, micro-shoot multiplication, micro-shoot length and number of leaves. To control this, 2 silver compounds were tried, silver nitrate (1, 3 and 5 mg L^{-1}) and silver thiosulfate (20,40 and 60 µM) and 2 gelling agents (agar-agar and gelrite) in combinations with the standardized (MS+BAP 2 mg L^{-1} + Kin 1.5 mg L^{-1}) were tried. Among this, $AgNO_3$ (5.88µM) to the medium containing Phytagel™ along with cytokinin (BAP 8.8µM and kinetin 6.97µM) led to significant reduction in shoot abscission rate (4.20), while 17.66µM $AgNO_3$supplementation improved No. of micro-shoots/explants (2.19) and micro-shoot length (3.36 cm) whereas$Ag_2S_2O_3$ at 20µM enhanced the total chlorophyll content (3.47 mg g^{-1} FW) three times as compared to control. None of the combinations recorded complete inhibition of micro-shoot/leaf abscission but $Ag_2S_2O_3$ (STS) was comparatively more effective than $AgNO_3$, as it improved the quality of micro-shoots and increased the cholorophyll content.

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

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1.1.3.1 Evaluation of grape hybrids

Three grape hybrids (Hyb. 16/2A-R1-P9, Banqui Abyad x Perlette; Hyb. 16/2A-R1-P14, Cardinal x Beauty Seedless; Pusa Swarnika, Hur x Cardinal) have been found promising against the check variety 'Black Muscat'. These hybrids showed superiority for economic traits like loose bunch, bold berry, early maturity and high TSS with regard to check Black Muscat. The seeded hybrids, namely, Hyb. 16/2A- R1-P9 (BA x Per) had big sized bunch (363.0 g), with berry weight of 3.93 g, 20.0Brix TSS, and 0.87% acidity, while Hyb. 16/2A-R1-P14 (Card x BS) had bunch weight of 332.25 g, high TSS (23.10 0Brix), and acidity of 0.91%. Both matured in the first week of June

Four grape hybrids (Hyb. 16/2A-R4-P7, Pusa Navrang x Hyb. 76-1; Hyb. 16/2A-R2P7, Pusa Navrang x Hyb. 76-1; Hyb. 16/2A-R3-P3, Pusa Navrang x Banqui Abyad; Hyb. 16/2A-R4-P9, Pusa Navrang x Black Muscat) are rich in total anthocyanins, phenolics, flavonoids and other berry quality traits. These hybrids were found superior in terms of bold berries, higher juice recovery, yield, and early maturity.

Twenty-nine diverse grape genotypes were assessed for their berry cracking tolerance based on morpho-physical, physiological, biochemical, mechanical and nutrient element properties. Genotypes 'Black Muscat', 'Black Prince' and 'Hur' were found more tolerant against the berry cracking as compared to commercial varieties like Flame Seedless, Perlette, Beauty Seedless and Cardinal. In vitro berry cracking ratio and water uptake by berries were found associated with traits related to the berry cracking. Based on the berry cracking ratio, genotypes 'Black Muscat', 'Black Prince' and 'Hur' were found more tolerant and 'Hy. 72-151', 'Flame Seedless', 'Cardinal' and 'Beauty Seedless' were most susceptible under *in vitro* conditions.

1.1.3.2 Hybridization

Hybridization work was attempted for achieving extra early maturity, seedless berries, bold berries and improved fruit quality. A total of 14 cross combination having 179 panicles (12,060 flowers) crossed. In rootstock breeding, crossing among the *Vitis* spp. genotypes, namely, *V. parviflora* × Dogridge (*V. champini*), and *V. parviflora* × Salt Creek (*V. champini*) were attempted.

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

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1.1.4.1 Hybridization

Hybridization in guava was done as per diallel mating design by involving ten best combiner genotypes with superior desirable traits. Thirty cross compatible desirable combination were used (Punjab Pink x Hisar Surkha , Punjab Pink x Black guava , Punjab Pink x Shweta, Punjab Pink x 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 x Pant Prabhat, Lalit x L-49, Lalit x Thai, Lalit x Hisar Safeda, L-49 x Punjab Pink, L-49 x Lalit, L-49 × Hisar Surkha, L-49 × Black Guava, L-49 × Arka Kiran, Allahabad Safeda × Black Guava, Allahabad Safeda × HisarSurkha, Allahabad Safeda × Punjab Pink, Allahabad Safeda × Lalit, Allahabad Safeda × Arka Kiran, Shweta × Black Guava and Shweta × Arka Kiran,) and total 870 flowers were crossed during this period. Out of thirty cross combinations, final fruit sets were noticed in 21 cross combinations. The seeds were raised and a total of 1160 numbers of F_1 population was produced. Guava germplasm blocks were maintained during the period.

1.1.4.2 Germplasm Collection

A total of 35 guava genotypes *viz*., Indonesian Seedless, Hong Kong White, Patillo, Pink Acid, Thailand Seedless, Golden, Pear, Ruby × Supreme, Hong Kong Pink, Puerto Rico 2, 138-T, 507, Kona 1, Waiakea, 270, Gushiken Sweet, J.B. White, Fan Retief, Ka Hua Kula, Beaumont, Poamoho Pink, Bon Dov, N90-53, Khao Niyom, Klom Amporn, Klom Sa Lee, Red Indians, Khao Sawaive, Holmberg, 157, Klom Toonklao, Pearl Guava, Less Seed Guava, Rica and HPSI41 as form of seeds were introduced from USDA, Hilo through NBPGR. All the collected seeds were sown in poly bags and seedlings were raised for further planting in field.

1.1.4.3 Hybrid Evaluation

The guava hybrids valuated, showed the wide variability in respect of anatomical, morphological and biochemical characters (Fig. 8-9). Of the red fleshed hybrids evaluated, GH-2016-8F (Thai × Punjab Pink) proved potential, having excellent fruit and nutritional qualities in respect of fruit weight (160-175 g), antioxidant activity (6.4-7.5 mg/100 g of FW), total flavonoids (84.53-110.22 µM TE/g FW), ascorbic acid (157.22-190.16 mg/100 g of pulp), total soluble solids (12.50 to 13.6^{o}Brix), phenolic content (121.57- 142.00 mg/100 g GAE of FW), titratable acidity (0.41-0.45%) and yield (40 t/ha) with very soft seeded character.

Fig. 8. Characterization of guava hybrids

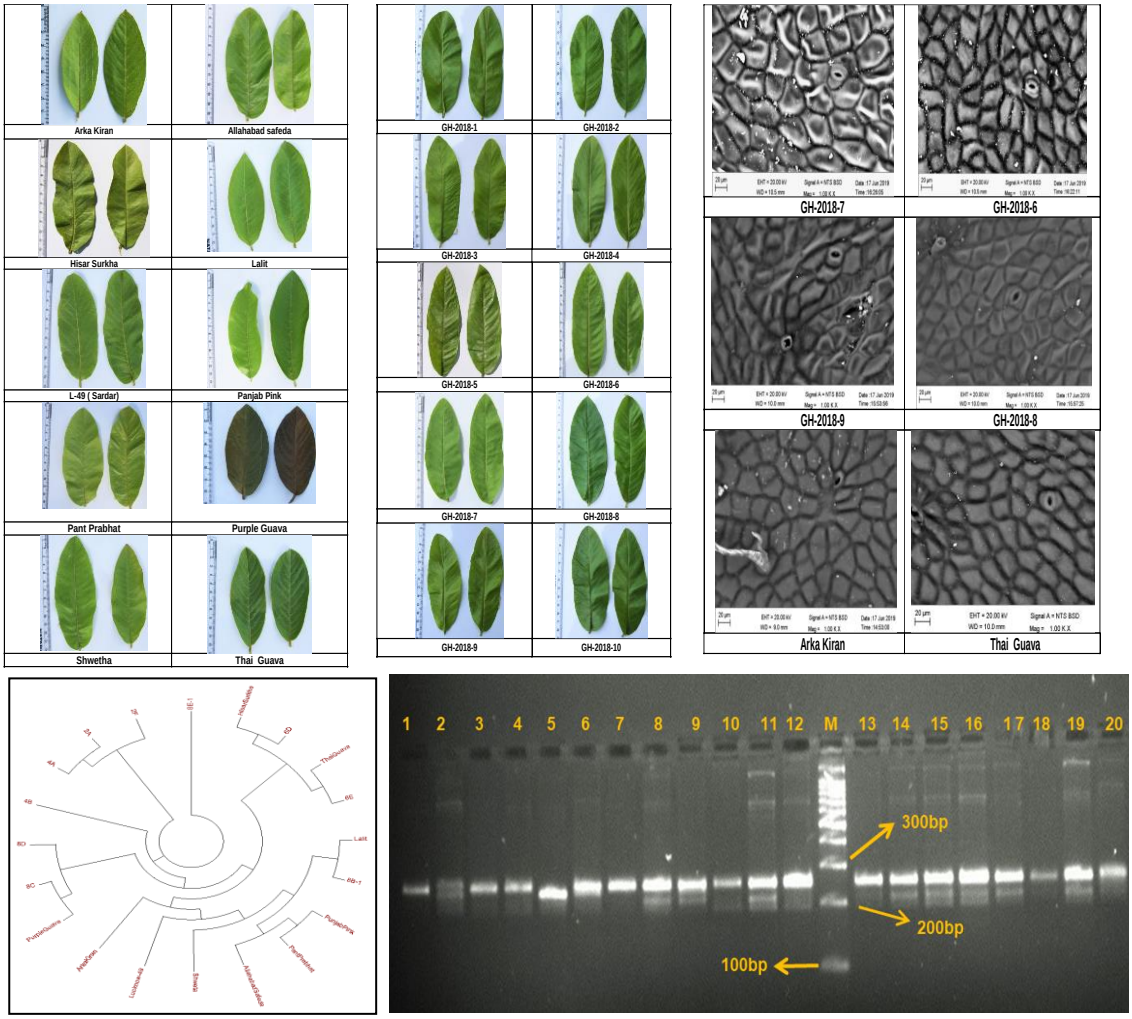

Fig. 9. Variability in leaf and stomatal characters and genetic relationship among of guava hybrids

The morpho-genetic characterization was attempted of 22 genotypes and showed considerable variations. Twenty-two guava genotypes and hybrids were also analyzed using GC-MS for flavouring compounds. To dissect the complex process of pulp colour development in guava a comparative transcriptome analysis between red pulp and soft seeded guava and white pulp hard seeded guava was done. For each contrasting genotypes samples from three different developmental stages viz., early ripening stage, mid ripening stage and late ripening stage were taken for expression profiling. The contrasting pulp colour is clearly visible in mid and late developmental stage of fruit development. A total of 18 samples were sent for RNA-seq which include three stages of the contrasting genotype with 3 biological replicates for each stage. After quality check de-novo transcriptome assembly was done using Trinity pipeline. A total of 251,345 transcripts were assembled with a N50 value of 1,530.

Of the various hybrids analysed for quality parameters, two hybrids namely pink pulped guava F_1, HSU×SH-16-8-2, and white pulped guava F_1, HSUxSH-16-8-18 were found promising (Fig.10) , as given hereunder:

HSUxSH-16-8-2 (pink pulped)

- Fruits weight: 154 g
- Fruit diameter: 6.5 cm

HSUxSH-16-8-18 (white pulped)

- Fruits weight: 177.3 g
- Fruit diameter:7.25 cm

• Fruit length: 6.53 cm	• Fruit length:7.23
• Core diameter: 4.03cm	• Core diameter: 3.46 cm
• Pulp thickness: 1.24 cm	• Pulp thickness: 2.0 cm
• TSS:15°B	• TSS: 15.1°B
• Acidity:0.426 %	• Acidity:0.448%
• Ascorbic acid:126.82mg/100g	• Ascorbic acid:121.53 mg/100g

Fig. 10. Promising hybrids of guava

The peel and pulp colour of Black guava belonged to greyed orange group 174A and 186B respectively. It had maximum total anthocyanin content (9.663 mg/100g), maximum total carotenoids content (0.730 mg/100g) and minimum lycopene content (0.517 mg/100g). LC-MS analysis indicates that delphinidin-3-glucoside, petunidn-3-glucoside and cyanidin-3-glucoside were present and responsible for purple pulp colour of Black guava (Fig. 11).

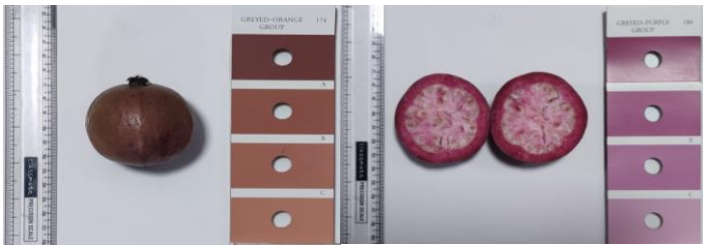

Fig. 11. Pulp and flesh colour intensities of Black guava

The *CHS* and *DFR* genes of anthocyanin pathway were selected for study. The primers for *DFR* gene, D4 and D5 amplified in Punjab Pink, but did not in case of Black guava. Similarly, in case of primers for *CHS* gene C1a, C1 and C3 amplified in Punjab Pink but not in Black guava. The PCR product sequenced and three sequences have been submitted to gene bank [1. BankIt2540470 seqpgdfrd5 (OM337779); 2. BankIt2541418 pgchsc1a (OM337780); 3. BankIt2541422 pgchsc3 (OM337781)].

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

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1.1.5.1 Identification of papaya sex through molecular markers

Total 10 SCAR and RAPD markers namely 71E, SDP, SMY 1, PKBT4, PKBT5, PMSM2, OPO-08, SCO-08, PVF 1, PVR 2 and SMY 1 were used in 48 papaya plants of 6 genotypes namely 3 gynodioecious (Red Lady, P-9-5, P-7-2) and 3 dioecious (Pune Selection 3, Pusa Nanha, Pusa Dwarf) for the sex identification at early stage. Among 10 SCAR-RAPD markers, only four markers viz, PKBT4, PKBT5, SDP, and PMSM2 were amplified for that particular sex loci and another one marker 71E yielded the amplification in all the 48 tested samples. Other five markers namely failed to amplify

any of the six genotypes tested. Among amplified SCAR markers PKBT5, SDP and PMSM2 showed higher level of accuracy. Another marker 71E amplified all the three sex types namely male, female and hermaphrodite and this marker can be taken as a control. This particular marker produced amplicons for all the three sex types at 1000 bp because sequence was present on autosomes but they were not polymorphic. The marker SDP amplified a fragment length of ~220 bp and it indicated the presence of *SEX1* gene (Fig. 12). In this marker desired bands were present in both male and hermaphrodite plants but no bands were obtained for female plants of both type of genotypes studied. Among the SCAR markers that produced sex polymorphism, PKBT 5 showed the 100% reliability in sex identification of papaya. This marker amplified at ~350 bp for both male and hermaphrodite plants and no bands were obtained for female plants. A robust male specific marker PMSM 2 (Papaya male specific marker 2) was precisely designed to detect the male specific regions in papaya genotypes. In RAPD-SCAR marker PMSM 2 amplification occurred at ~500 bp only in male but not in female and hermaphrodite plants may due to probable location of this marker on the male specific region of Y chromosome. Molecular marker PKBT 5, SDP and PMSM 2 can be commercially utilized for identification of male and hermaphrodite plants among dioecious and gynodioecious genotypes

1.1.5.2 Evaluation of papaya hybrids

Five papaya hybrids namely, P-7-15 x Pune Selection 3, P-7-15 x P-7-2, P-7-15 x P-9-12, P-7-15 x Pusa Nanha and Red Lady were evaluated for different horticultural parameters under insect proof net-house. There were significant differences among the evaluated papaya hybrids for desirable horticultural traits. The minimum plant height (69.5cm) at first flower initiation was noticed in hybrid P-7-15 x Pusa Nanha, followed by (71.25cm) P-7-15 x P-7-2, (73.33 cm) P-7-15 x Pune Selection 3 and maximum (85.15cm) in P-7-15 x P-9-12. The highest fruiting zone (167.25 cm) was recorded in hybrid P-7-15 x Pune Selection 3 followed by (147.25 cm) P-7-15 x P9-12, and (143.25 cm) in hybrid Red Lady and lowest fruiting zone (127.33cm) was observed in P-7-15 x Pusa Nanha. The minimum days to fruit maturity (132 days) was recorded in P-7-15 x Pune Selection 3, closely followed by the hybrid P-7-15 x P-7-2, (133.5 days) and most delayed fruit maturity (147.25 days) was recorded in Red Lady. The number of fruits per plant was maximum (45.67) in the hybrid P-7-15 x P-7-2 followed by (41.33) P-7-15 x P-9-12 and minimum (29.33) in P-7-15 x Pusa Nanha.

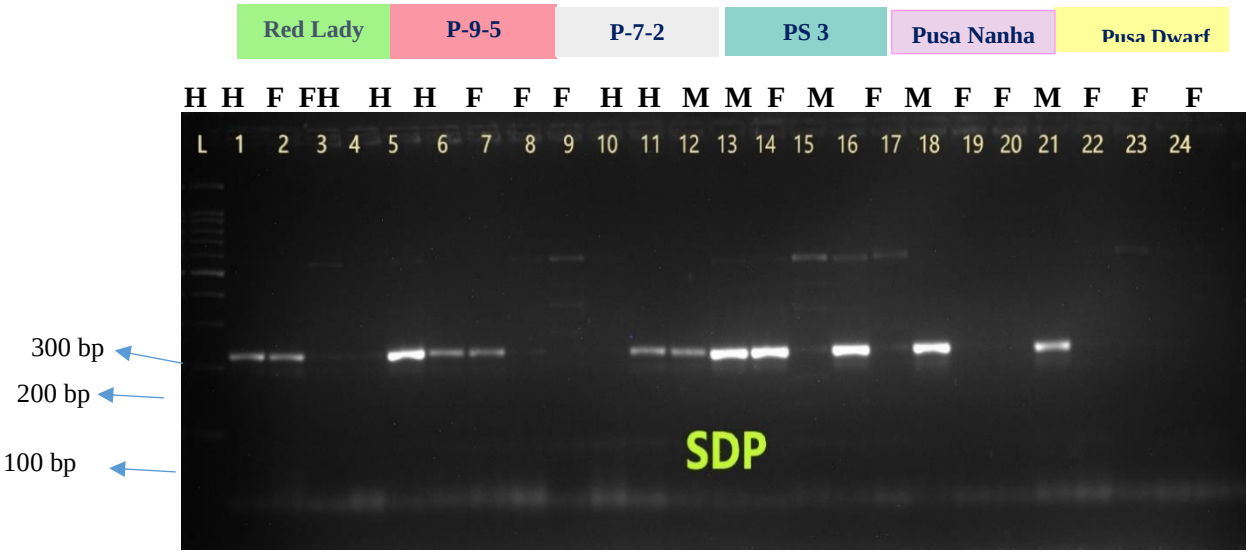

Fig 12. PCR amplification for the SCAR marker SDP for all papaya sex types. Genotypes names were depicting in the colour boxes, H- Hermaphrodite, F-female, L- 100bp ladder and numerical on gel image represents the samples number which were utilized in the experiment

The maximum average fruit weight (1588g) was recorded in P-7-15 x Pusa Nanha followed by (1495g) in P-7-15 x P-9-12, whereas it was lowest (1175g) in the hybrid P-7-15 x P-7-2. The hybrid Red Lady

had maximum TSS (13.6ºBrix) which was statistically similar to the P-7-15 x Pune Selection 3. However, minimum TSS (9.8ºBrix) was recorded in P-7-15 x Pusa Nanha. The total phenolic content and total flavonoids content in fruits were highest for the hybrid Red Lady followed by P-7-15 x Pune Selection 3. The highest amount of CUPRAC activity was in the P-9-5 (4.37µmol/g) and DPPH activity was maximum in hybrid Red Lady (36.22µmol/g) followed by (28.26µmol/g) P-7-15 x Pune Selection 3 and minimum (16.42µmol/g) in P-7-15 x P-7-2. Based on above finding, it is quite evident that genotype P-7-15 as maternal female parents holds immense potentiality towards development of a commercial papaya hybrids. Since, hybrid P-7-15 x Pune Selection 3 have higher fruiting zone, average fruit weight, early fruit maturity and higher per plant fruit yield with improved antioxidant activities may be evaluated in the open field condition.

1.1.5.3 Mutation breeding

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 M6 population were selected and evaluated in M7 generation. Minimum height (102.44 cm), plant height at flower initiation (70.34 cm), plant girth at first fruiting (64.25 mm), nodes to first flowering (52.44), days to flower initiation (84.52), length of middle internode (4.6 cm), length of petiole (74.24 cm) and minimum plant spread in east-west direction (132.4 cm) was noted in PM 04 and minimum plant spread in north-south direction (135.6 cm) was recorded in PM 28 followed by PM4 (146.4 cm) while maximum height (132.64 cm), plant height at flower initiation (92.24 cm), plant girth (74.36 mm), nodes to first flowering (64.2), days to flower initiation (98.44), length of middle internode (7.2 cm), length of petiole (94.25 cm) and plant spread in east-west direction (148.2 cm) and north-south direction (152.2 cm) was found in control (P 7-2). Maximum number of fruits (42.4) and width of fruit (12.22 cm) was recorded in PM 04 while maximum fruiting length (96.4 cm), weight of fruit (0.980 kg) and length of fruit (21.84 cm) was recorded in control (P 7-2). Minimum length of fruit cavity (14.24 cm) and width of fruit cavity (4.22 cm) and maximum pulp thickness (3.44 cm) and TSS (10.22º Brix) was recorded in PM 04 while minimum pulp thickness (2.52 cm) and TSS (8.44º 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

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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

Effect of five polyembryonic rootstocks on semi vigorous mango varieties 'Pusa Arunuma', 'Pusa Surya' and 'Amrapali'. Both rootstock and scion varieties as well their combined effect impacted tree growth in terms of canopy diameter, tree volume and height significantly (Table 18). Concerning variety only, 'Pusa Arunima' showed greatest tree growth, while lower values were found in 'Pusa Surya'. Considering rootstock individually, 'K-5' and 'K-2' inhibited tree growth. Combined influence of both scion and rootstock exhibited that rootstock K-5 or 'K-2' resulted lower tree vigour in all three cultivars. However, Olour and K-3 rootstocks were found vigorous for 'Pusa Arunima' and 'Pusa Surya' but variable results were obtained for dwarf cultivar 'Amrapali'. Yield per tree, yield efficiency and yield/meter canopy cover also influenced significantly by rootstock individually and jointly, though cultivar did not have significant difference. Excluding the effect of cultivar, fruits/tree and yield/tree were found higher either on 'K-2', Kurakkan' or 'Olour' rootstock, while it was 'K-2' which produced higher yield efficiency (YE) and yield per meter canopy diameter (YPCD). Furthermore, for 'Pusa Arunima', Kurakkan (27.13 kg) and 'K-2' (29.50 kg) rootstocks had higher yield/tree, while YE (0.25 kg/m^3 CV) and YPCD (1.66 kg/ m canopy diameter) was found highest on 'K-2' and 'Kurakkan' rootstock. 'Pusa Surya' exhibited higher fruits/tree and yield/tree on K-3 (65.00 fruits/tree) and K-2 (68.0 fruits/tree) rootstocks, while except rootstock K-5, all other excelled for yield/tree. Both YE and YPCD found highest on 'K-2' (0.54 kg/m^3 CV; 1.88 kg/m canopy diameter) for 'Pusa Surya' (Table 19).

Fruit quality traits also influenced significantly by rootstock and scion varieties individually and jointly. Combined effect witnessed superiority of 'K-2' and Kurakkan for 'Pusa Arunima for fruit weight', but rootstock failed to influence fruit weight in case of 'Amrapali' and 'Pusa Surya'. Rootstock failed to alter pulp content and pulp stone ratio in either scion variety. Acidity, TSS and ascorbic acid were also affected by scion cultivars, rootstocks and their interactions. The highest TSS in Pusa Surya was obtained on K-5, while Olour, K-3 and K-2 produced fruit with higher TSS in Amrapali. TSS was not influenced in Pusa Arunima by rootstocks (Table 20-21).

2.1.1.2 Effect of polyembryonic rootstocks on vigorous mango varieties 'Mallika' and Dushehari'

Canopy diameter (CD) was noy affected significantly by rootstocks, while rootstock impacted tree volume (TV) and height significantly in Mallika and Dushehari (Table 22). Vigorous trees were observed in case of Mallika on Kurakkan, while reverse trend was noticed for Dushehari. Olour promoted height in Dushehari, while inhibitory effect was observed for Mallika. Almost similar trend was noticed for tree volume. Varieties, rootstock alone or jointly also impacted fruits/tree, yield efficiency (YE), yield/tree and yield per meter canopy diameter (YPCD). Overall, 'Dushehari'-'Olour' and Mallika-Kurakkan had highest fruits/tree and YPCD but without showing significant difference with Mallika-K-5. Moreover, YE was found to be the highest in Mallika-Olour, which exhibited statistical similarity with Mallika-K-5, however, Dushehari-K-5 and Dushehari-Kurkkan had higher YE (Table 23). Rootstock and cultivar also impacted fruit quality traits significantly. 'Mallika' had higher fruit weight on Kurakkan which showed pairity with trees on Olour rootstocks, while rootstock failed to alter pulp content in Mallika. In case of Mallika, rootstock K-5 for highest stone weight and both Kurakkan and Olour for higher pulp stone ratio were found to have superiority over others. In Dushehari

pulp content was found highest on Kurakkan (61.47%), while it was K-5 on which highest pulp stone ratio (3.82) was noticed (Table 24).

Table 18. Plant height, canopy diameter and canopy volume of 14 years old three varieties of mango on five polyemebryonic rootstock.

Rootstock	Canopy diameter (East-West) (m)						Canopy diameter (North-South) (m)					
Variety												
	K-5	Kur	OL	K-3	K-2	Mean	K-5	Kur	OL	K-3	K-2	Mean
Pusa												
Arunima	4.27	4.83	5.33	5.35	4.57	4.45	4.47	4.73	5.22	5.20	3.98	4.07
Pusa Surya	3.43	4.80	4.82	3.45	3.14	4.01	3.15	4.35	4.44	3.25	3.02	3.91
Amrapali	3.50	4.48	4.78	3.82	2.85	4.22	3.03	4.18	4.40	3.13	4.03	4.12
Mean	3.73	4.70	4.97	4.20	3.52		3.55	4.42	4.68	3.85	3.67	
LSD (P≤ 0.05)												
Variety (V)				0.40			0.12					
Rootstock (R)				0.31			0.0.9					
V X R				0.70			0.18					
	Plant height (m)						Tree volume (m^3)					
Pusa												
Arunima	3.65	3.95	4.49	4.14	3.27	3.47	199.69	290.11	375.87	340.39	201.45	333.65
Pusa Surya	2.90	3.83	4.14	3.14	2.35	3.29	94.22	234.52	274.20	112.07	67.18	121.94
Amrapali	3.08	3.29	3.10	3.03	2.15	3.33	96.22	202.19	239.07	112.05	92.77	130.81
Mean	3.21	3.69	3.91	3.44	2.59		130.04	242.27	296.38	188.17	120.46	
LSD (P≤ 0.05)												
Variety (V)	NS						12.56					
Rootstock (R)	0.26						15.23					
V X R	0.59						35.50					

Table 19. 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	50.67	75.00	86.67	83.33	89.33	106.40	13.06	27.13	22.81	19.94	29.50	23.30
Pusa Surya	11.67	43.33	50.67	65.00	68.00	108.20	4.98	18.40	20.22	23.04	25.55	22.61
Amrapali	143.33	213.33	223.33	163.33	251.00	109.20	20.06	29.37	38.15	24.42	39.04	25.21
Mean	68.56	110.56	120.22	103.89	136.11		12.69	24.97	27.06	22.46	31.36	
LSD (P≤ 0.05)												
Variety (V)			NS						NS			
Rootstock (R)			23.44						2.35			
V X R			34.62						3.55			
	Yield efficiency (kg/m^3)						Yield (kg/m canopy diameter cover)					
Pusa												
Arunima	0.08	0.16	0.07	0.10	0.25	0.30	0.80	1.66	1.28	0.95	1.52	1.41
Pusa Surya	0.08	0.12	0.19	0.39	0.54	0.33	0.35	1.06	0.48	1.61	1.88	1.50
Amrapali	0.34	0.27	0.31	0.41	1.54	0.33	1.73	1.66	2.25	2.10	2.96	1.54
Mean	0.16	0.18	0.18	0.30	0.77		0.96	1.46	1.37	1.55	2.11	
LSD (P≤ 0.05)												
Variety (V)			NS						NS			
Rootstock (R)			0.05						0.16			
V X R			0.13						0.30			

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

Table 20. Variation in fruit quality traits of mango varieties grafted on different polyembryonic rootstocks

Rootstock				Fruit weight (g)						Pulp content (%)			
Variety	K-5	Kur	OL	K-3	K-2	Mean	K-5	Kur	OL	K-3	K-2	Mean
Pusa												
Arunima	257.16	363.38	264.02	247.2	333.28	197.66	61.38	66.36	62.52	63.58	65.98	62.40
Pusa Surya	407.37	422.76	395.10	362.48	380.24	219.56	58.08	58.11	57.21	62.28	62.16	63.85
Amrapali	143.21	136.372	171.26	158.164	159.00	216.18	63.36	60.64	69.49	68.85	64.37	60.19
Mean	215.06	213.94	205.14	203.81	217.72		63.255	59.945	60.467	66.715	60.362	
LSD (P≤ 0.05)												
Variety (V)				20.55						NS		
Rootstock (R)				NS						4.81		
V X R				29.80						8.83		
				Stone weight (g)						Pulp stone ratio		
Pusa												
Arunima	48.62	51.30	50.56	49.42	50.24	33.61	3.26	4.70	3.26	3.19	4.38	
Pusa Surya	52.13	51.56	50.86	40.08	52.45	33.13	4.62	4.85	4.51	5.76	4.56	
Amrapali	29.05	29.09	36.84	31.40	32.30	30.73	3.15	2.85	3.24	3.51	3.18	
Mean	33.82	33.55	30.80	32.74	31.54							
LSD (P≤ 0.05)												
Variety (V)				NS						0.23		
Rootstock (R)				NS						0.08		
V × R				6.06						0.40		

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 21. Variations in biochemical quality of fruits of mango varieties grafted on different polyembryonic rootstocks

				TSS (^{0}B)		
Rootstock	K-5	Kurakkan	Olour	K-3	K-2	Mean
Variety						
Pusa Arunima	22.96	23.42	23.30	23.44	22.76	24.05
Pusa Surya	21.86	19.76	20.34	19.30	20.32	23.89
Amrapali	22.30	23.66	24.18	24.54	25.26	23.04
Mean	23.25	23.13	23.86	23.70	24.35	
LSD (P≤ 0.05)						
Variety (V)				NS		
Rootstock (R)				1.29		
V × R				1.57		
Pusa Arunima	0.33	0.34	0.24	0.27	0.24	0.29
Pusa Surya	0.29	0.32	0.26	0.26	0.22	0.34
Amrapali	0.06	0.10	0.10	0.13	0.16	0.24
Mean	0.28	0.28	0.32	0.28	0.28	
LSD (P≤ 0.05)						
Variety (V)				0.05		
Rootstock (R)				NS		
V X R				0.8		
				Vitamin C content (mg /100 g pulp)		
Pusa Arunima	25.18	18.49	20.78	21.13	20.78	
Pusa Surya	23.60	16.91	22.54	18.49	23.07	
Amrapali	28.35	23.95	22.72	25.18	23.60	
Mean						
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).

Table 22. Tree growth and fruit yield of vigorous mango cultivars (Mallika and Dushehari) on five polyembryonic rootstocks

Cultivar/	Canopy diameter (E-W)				Canopy diameter (N-S)			
Rootstock	K-5	Kurakkan	Olour	Mean	K-5	Kurakkan	Olour	Mean
Mallika	5.23	4.85B	4.90	4.99	4.87	5.12	4.90	4.96
Dusherhari	3.70	3.98	5.75	4.47	3.73	4.33	4.80	4.28
Mean	4.95	4.51	4.73		4.79	4.38	4.70	
LSD (P≤ 0.05)								
Variety (V)			0.92				0.91	
Rootstock							0.74	
(R)			0.75					
V X R			1.31				1.28	
	Plant height (m)				Canopy volume (m^3)			
Mallika							305.6	
	4.28	5.38	3.99	4.55	361.65	462.15	2	376.47
Dusherhari							331.9	
	3.32	2.46	4.11	3.29	129.49	135.09	6	198.85
Mean							181.2	
	4.10	3.87	3.78		510.90	170.8	6	
LSD (P≤ 0.05)								
Variety (V)			0.62				32.23	
Rootstock							28.56	
(R)			0.50					
V × R			0.87				45.44	

Table 23. Variations in fruit yield in Mallika and Dushehari mango varieties grafted on different polyembryonic rootstocks

Cultivar/	Fruits/tree				Yield (kg/tree)			
Rootstock	K-5	Kurakkan	Olour	Mean	K-5	Kurakkan	Olour	Mean
Mallika	240.00	251.67	193.33	228.33	35.97	38.32	30.40	34.89
Dusherhari	260.00	180.00	330.00	256.67	63.49	52.53	90.90	68.97
Mean	250.00	215.84	261.67		55.36	48.10	52.33	
LSD (P≤ 0.05)								
Variety (V)		19.58				3.03		
Rootstock (R)		17.81				2.19		
V X R		27.60				4.19		
	Yield efficiency (kg/ m^3 CV)				Yield/ canopy diameter (kg/m)			
Mallika	0.23	0.18	0.23	0.21	1.86	2.02	1.44	1.77
Dusherhari	0.69	0.59	0.36	0.54	4.45	3.91	4.33	4.22
Mean	0.40	0.38	0.35		3.05	2.77	3.17	
LSD (P≤ 0.05)								
Variety (V)		0.08				0.52		
Rootstock (R)		0.07				0.47		
V X R		0.11				0.81		

Table 24. Variations in physical fruit quality traits in Mallika and Dushehari mango varieties grafted on different polyembryonic rootstocks

Cultivar/	Fruit weight (g)				Pulp content (%)			
Rootstock	K-5	Kurakkan	Olour	Mean	K-5	Kurakkan	Olour	Mean
Mallika	242.80	292.97	285.30	273.69	67.35	66.23	67.64	67.07
Dusherhari	152.53	146.16	147.06	148.58	57.45	61.47	52.74	57.22
Mean	197.67	219.57	216.18		62.40	63.85	60.19	
LSD (P≤ 0.05)								
Variety (V)		13.00				7.56		
Rootstock (R)		11.80				6.23		
V × R		18.33				10.65		
	Stone weight (g)				Pulp stone ratio			
Mallika	44.18	39.88	37.92	40.66	3.73	4.85	5.09	4.56
Dusherhari	23.04	26.39	23.54	24.32	3.82	3.43	3.29	3.51
Mean	33.61	33.14	30.73		3.78	4.14	4.19	
LSD (P≤ 0.05)								
Variety (V)		1.89				0.23		
Rootstock (R)		1.65				0.19		
V X R		2.72				0.41		

2.1.1.3 Effect of rootstock on fruit shelf life

To explore the quality rootstock which imparts 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 35 shelf-life-specific markers were designed from ripening genes like *expansin*, *polygalacturonase*, *ethylene insensitive*, *ethylene sensitive*, etc. 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.

2.1.1.4 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, while budded on different rootstocks (Table 25-26). Over all, RLC-6 and RLC-7 proved most vigorous rootstocks for Pusa Sharad (78.87m^3 canopy volume or CV) and Pusa Round (62.13 m^3 CV), respectively. In Pusa Round, the similar vigour was also recorded on Soh Sarkar rootstock with no significant difference with RLC-6. RLC-6 rootstock proved to be the most productive rootstock for Pusa Sharad (58.69 Kg/tree) and Pusa Round (40.93 Kg/tree) cultivars. RLC-6 yielded the heaviest fruits of Pusa Sharad (307.44g) and Pusa Round (271.81g), although it was similar statistically with Yama Mikan and Soh Sarkar in Pusa Sharad and C-35 in Pusa Round. The lowest peel thickness in the fruits of Pusa Sharad (3.96mm) was recorded on X-639 rootstock, which proved similar with rest of the rootstocks except C-35 and Soh Sarkar. However, in Pusa Round, the lowest peel thickness was observed on RLC-7 (3.75mm) without having any significant difference with rest of the rootstocks except Yama Mikan. C-35, X-639, Yama Mikan and Jatti Khatti

rootstocks were found similar statistically in resoect of having low seed numbers (22.80-25.80/fruit). In Pusa Round, RLC-7 and Yama Mikan rootstock proved equally effective statistically to produce the fruits with low seed numbers (18.00-19.40/ fruit). The content of juice in the fruits of Pusa Sharad (44.29%) was recorded, while grown on Yama Mikan without any significant difference with RLC-6, X-639 and RLC-7 rootstocks, however, in Pusa Round, the highest juice content (50.50%) was recorded on X-639 rootstock. Yama Mikan also tended to show the highest TSS content in Pusa Sharad (7.72°B) with no significant difference with RLC-6 and X-639, while C-35 and Yama Mikan proved equally effective to produce the fruits of Pusa Round with high content of TSS (7.12 -7.60°B). Soh Sarkar, Jatti Khatti and X-639 rootstocks contributed the low acid content in the fruits of Pusa Sharad (0.51-0.60%), while the similar response in Pusa Round (0.53-0.62%) was noticed, while grown on Soh Sarkar, Jatti Khatti and RLC-7 rootstocks. Yama Mikan proved best rootstock to improve the ascorbic acid in Pusa Sharad (40.44 mg/100 ml) and Pusa Round (40.96 mg/100ml) cultivars, although it was found statistically similar with Soh Sarkar too in later cultivar.

Table 25. Rootstock influence on fruit quality of sweet orange cvs. Pusa Sharad and Pusa Round

Rootstock/ Cultivar	Tree height (m)	Canopy volume (m^3)	Yield (Kg/tree)	Peel thickness (mm)	Juice (%)	TSS (B°)	Acidity (%)	Ascorbic acid (mg/100ml juice)
Pusa Sharad								
RLC-6	3.87a	78.82a	58.69a	5.62bdac	39.97bcd	7.14bdac	0.87a	24.82g
C-35	3.50bac	56.22bdc	35.53d	5.97bac	35.58ecd	7.06bdc	0.73bc	31.15efcd
X-639	3.44bac	65.43bac	41.66c	3.96d	41.03bc	7.48bac	0.60gfed	33.26bcd
Yama Mikan	3.24bdc	53.35bedc	30.04fe	5.46bdac	44.29ba	7.72a	0.69bcd	40.44a
Soh Sarkar	3.55bac	70.17ba	49.86b	6.71ba	32.07ed	6.72fde	0.58gef	28.34efg
RLC-7	3.46bac	66.24bac	37.19dc	4.82bdc	37.77bcd	6.32f	0.68ecd	30.45efcd
Jatti Khatti	3.87a	66.39bac	33.98de	4.41dc	34.04ecd	6.36fde	0.51g	31.68ecd
Pusa Round								
RLC-6	3.13bedc	50.11fedc	40.93c	4.45dc	40.48bc	6.28f	0.79ba	30.80efcd
C-35	2.66e	30.23g	27.33fg	4.56dc	40.67bc	7.60ba	0.68ecd	33.44bcd
X-639	3.06edc	37.27fedg	22.47gh	4.27dc	50.50a	6.92dec	0.66fecd	33.97bc
Yama Mikan	2.90ed	32.51fg	24.27gh	7.02a	41.93bc	7.12bdc	0.68becd	40.96a
Soh Sarkar	2.74e	36.23feg	33.81de	4.29dc	33.98ecd	6.80fde	0.62gefcd	37.84ba
RLC-7	3.62ba	62.13bac	22.00h	3.75d	37.06bcd	6.44fe	0.53g	29.04efgd
Jatti Khatti	3.45bac	51.04fedc	25.58fgh	5.12bdac	27.69e	6.30f	0.55gf	26.40fg
LSD ($P \leq 0.05$)	0.45	19.06	5.23	1.93	8.37	0.59	0.10	4.84

Table 26. Rootstock influence on leaf nutrient status of sweet orange cvs. Pusa Sharad and Pusa Round

Rootstock/ Cultivar	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Na (%)	Mn (ppm)
Pusa Sharad									
RLC-6	0.20a	1.75b	0.78g	0.59e	71.35hfg	9.79fed	12.92dc	0.13b	30.34a
C-35	0.18bac	1.37d	1.00c	0.66d	99.14ecd	10.31ced	10.17g	0.11cb	10.25hg
X-639	0.15d	1.06hg	1.26b	0.88a	90.17ef	11.28cb	14.71b	0.08ed	15.80e
Yama Mikan	0.19ba	1.62c	0.88e	0.67d	92.43efd	8.73fg	10.61fg	0.19a	13.84f
SohSarkar	0.19ba	1.85ba	0.94d	0.66d	132.11ba	9.25fe	17.68a	0.09cd	9.40hi
RLC-7	0.17bdc	1.21fe	0.62j	0.53f	65.06hg	10.85cbd	8.67h	0.10cbd	10.49g
JattiKhatti	0.15dc	1.90a	1.00c	0.65d	115.63bcd	9.79fed	11.26fe	0.08ed	17.69d
Pusa Round									
RLC-6	0.17bdc	1.83ba	0.82f	0.60e	154.35a	11.53b	13.75c	0.08ed	23.39b
C-35	0.16dc	1.85ba	1.02c	0.71c	129.72b	11.78b	13.58c	0.08ced	21.91c
X-639	0.15d	1.37d	1.00c	0.43g	65.08hg	13.36a	11.48e	0.04f	9.62hgi
Yama Mikan	0.16dc	1.14fg	1.30a	0.79b	117.10bc	13.95a	12.55d	0.07fed	17.95d
SohSarkar	0.17bdc	1.00h	0.68i	0.55f	52.64h	7.69g	7.13i	0.18a	8.72i
RLC-7	0.17bdc	1.84ba	0.76hg	0.59e	86.77efg	10.03ed	10.73fe g	0.06fe	23.21b
JattiKhatti	0.17bdc	1.26e	0.74h	0.58e	63.58hg	9.26fe	12.60d	0.04f	15.09e
LSD ($P \leq 0.05$)	0.02	0.10	0.04	0.03	24.09	1.08	0.86	0.03	0.91

2.1.1.5 Modulation of abiotic stress effect in citrus

2.1.1.5.1 Citrus rootstock germplasm evaluation against drought

Citrus genotype X639 reported significantly higher plant growth (4.25 cm) under drought conditions followed by RLC 1 (Table 27). Under drought stress, maximum leaf drop was reported in Grambhiri (18.5) which was non-significantly followed by RLC 2 and RLC 7. The lowest leaf drop was observed in X639 and same genotype reported to have maximum leaf growth after re-watering. The higher leaf wilt scores were observed in RLC 2 (4.50) and Grambhiri (4.13) under drought conditions, no leaf wilting symptoms were reported in X639 (Table 28-29 and Fig. 13).

Table 27. Plant height of citrus rootstock* under drought conditions**

Genotype	Normal	Drought	Re-water	Mean
Cleopatra mandarin	28.00^{k}	29.25^{jk}	29.88^{ijk}	29.04^{F}
Grambhiri	35.44^{gh}	36.00^{gh}	37.25^{fgh}	36.23^{DE}
RLC 1	45.50^{de}	48.13^{bcd}	49.38^{abcd}	47.67^{BC}
RLC 2	48.25^{bcd}	49.63^{abcd}	50.88^{abc}	49.58^{AB}
RLC 4	36.83^{fgh}	38.65^{fg}	41.13^{ef}	38.87^{D}
RLC 5	45.04^{de}	46.63^{cd}	47.88^{bcd}	46.51^{C}
RLC 7	33.75^{ghij}	34.50^{ghi}	36.50^{fgh}	34.92^{E}
Troyer citrange	33.55^{hij}	35.46^{gh}	36.25^{fgh}	35.08^{E}
X 639	47.88^{bcd}	52.13^{ab}	54.38^{a}	51.46^{A}
Mean	39.36^{B}	41.15^{A}	42.61^{A}	
LSD ($P \leq 0.05$)	G	T		G × T
	2.91	1.68		5.04

*G- Genotype; **T-Drought treatment

Table 28. Leaf wilt score of citrus genotypes under drought conditions

Genotype	Normal	Drought	Re-water	Mean
Cleopatra mandarin	1.00^{g}	3.38^{cd}	3.25^{cd}	3.31^{AB}
Grambhiri	1.00^{g}	4.13^{ab}	3.25^{cd}	3.69^{A}
RLC 1	1.00^{g}	3.00^{d}	2.00^{e}	2.50^{CD}
RLC 2	1.00^{g}	4.50^{a}	2.75^{d}	3.63^{A}
RLC 4	1.00^{g}	3.75^{bc}	2.00^{e}	2.88^{BC}
RLC 5	1.00^{g}	3.75^{bc}	1.75^{ef}	2.75^{BC}
RLC 7	1.00^{g}	3.75^{bc}	1.75^{ef}	2.75^{BC}
Troyer citrange	1.00^{g}	3.00^{d}	1.25^{fg}	2.13^{D}
X 639	1.00^{g}	1.00^{g}	1.00^{g}	1.00^{E}
Mean	1.00^{C}	3.36^{A}	2.11^{B}	
LSD ($P \leq 0.05$)	G	T		G × T
	0.40	0.22		0.68

Table 29. Per cent leaf number change under drought conditions

Genotype	**Leaf number change (%)**
Cleopatra Mand.	-26.67
Grambhiri	-29.88
RLC 1	-28.28
RLC 2	-20.06
RLC 4	-15.91
RLC 5	-14.29
RLC 7	-20.08
Troyer	-14.78
X 639	-4.31

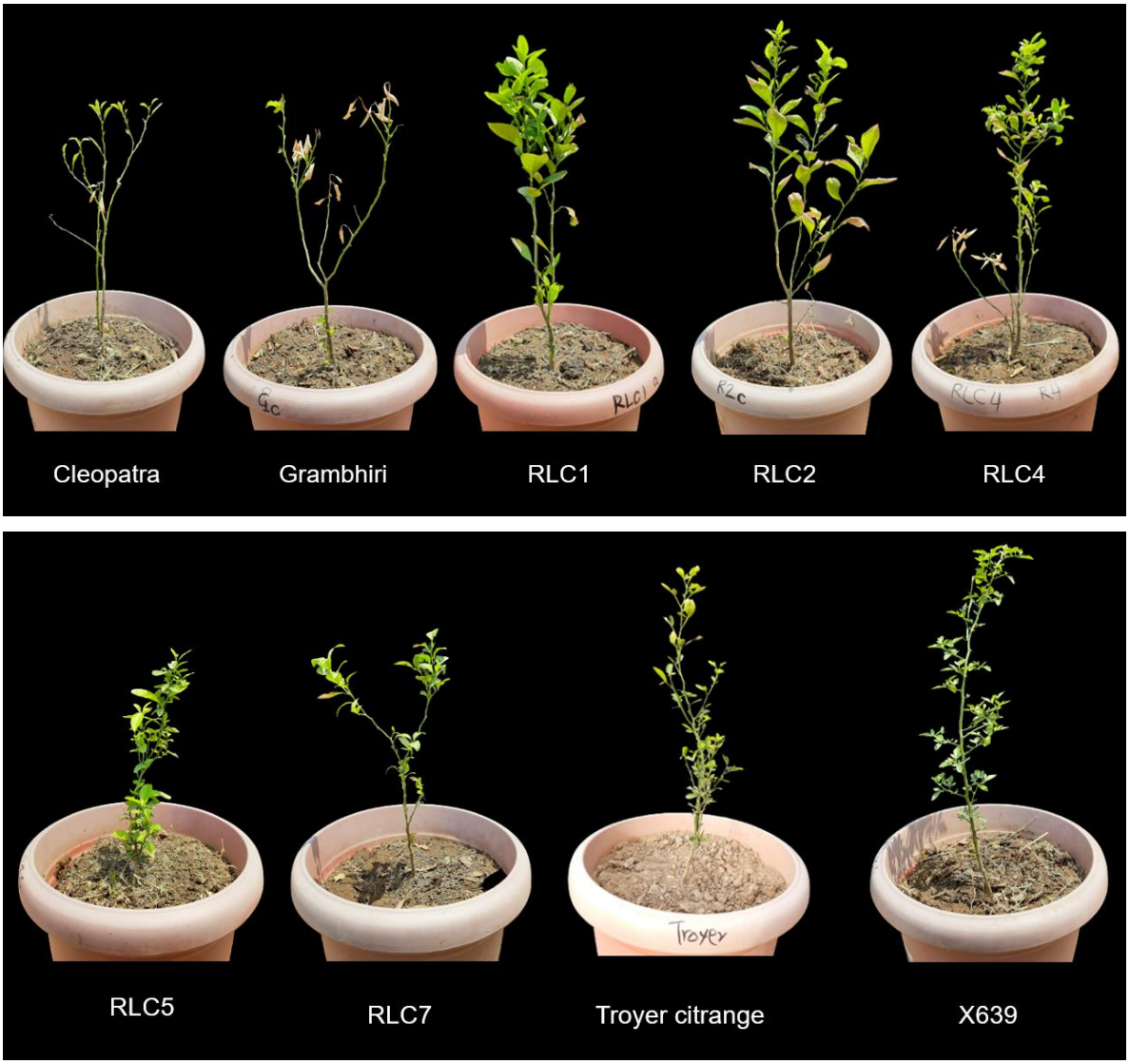


Fig. 13. Citrus rootstock genotypes after 21 days of drought stress

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

For evaluating the effect of different rootstock, a new rootstock trial with Kinnow as a scion have been initiated. Eight rootstocks viz., X-639, Cleoptera Mandarin, *Jatti Khatti*, NRCC-1, NRCC-2, NRCC-3, NRCC5 and CRH-12 raised in the nursery were field planted during September 2021 at a spacing of 6m x 6m. The plants will be budded *in situ* during the ensuing budding season for evaluating the effect of rootstock on various morpho-physiological characteristics.

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

2.1.2.1 Effect of integrated nutrient management on newly developed mango hybrids

The cent percent recommended dose of fertilizers (RDF) alone and alongwith AMF (250 g) and *Azotobacter* (250 g), 75% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) and 50% RDF alongwith AMF (250 g) and *Azotobacter* (250 g) 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 volume. Maximum height (4.85 m) was recorded in

treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by 4.32 m in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g) while minimum (3.60 m) in treatment T8. Among cultivars, maximum height (4.34 m) was found in Pusa Arunima and minimum (3.91 m) in Pusa Pratibha. Maximum canopy volume (71.60 m^3) was recorded in treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by 47.38 m^3 in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among cultivars, maximum canopy volume (68.35 m^3) was found in Pusa Arunima and minimum (24.81 m^3) in Pusa Pratibha. Maximum number of fruit (31.01) was recorded in treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by 29.50 in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties maximum number of fruit (36.77) was counted in Pusa Arunima and minimum (23.16) in Pusa Pratibha. Maximum weight of fruit (245.50 g) was recorded in treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by 216.71 g in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit weight (245.46 g) was found in Pusa Arunima followed by Pusa Lalima (200.00 g) and minimum (170.55 g) in Pusa Pratibha. Maximum yield of fruit (20.04 kg) was recorded in treatment NPK 100 % + AMF (250g) + *Azotobacter* (250g) followed by 18.09 kg in treatment NPK 75% + AMF (250g) + *Azotobacter* (250g). Among varieties, maximum fruit yield (20.79 kg) was found in Pusa Arunima followed by Pusa Lalima (17.185 kg) and minimum (11.298 kg) in Pusa Pratibha.

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)

- Initiated Licensing process of six IARI Mango varieties namely, Pusa Arunima Pusa Surya, Pusa Lalima, Pusa Pratibha, Pusa Peetamber and Pusa Shreshtha to M/s SL Orchards, Panchkula, Chandigarh.
- Initiated Licensing process with M/s Seven Star Fruits Pvt. Ltd (Mahyco Group) Nashik, for Pusa Arunima, Pusa Lalima and Pusa Shreshtha.
- Provided scion (1200) to Directorate of Horticulture, Himachal Pradesh for establishment of Mother blocks.
- Mother Blocks expansion was done for 2 hybrids of mango i.e. Pusa Shreshtha and Pusa Deepshikha in 1000sqm.

4. Intellectual property

4.1 Varieties developed

Seven varieties including four of mango (Pusa Lalima, Pusa Pratibha, Pusa Peetamber and Pusa Shresth), two of grapes (Pusa Aditi and Pusa Urvashi) and one each of acid lime (Pusa Abhinav) and sweet orange (Pusa Round) have been Developed by the Division and released by Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Agricultural Crops, and notified through Gazett of India vide Notification No. CG-DL-E-08042021-226407 dated 1.1.2021.

Mango

Pusa Lalima (Dashehari × Sensation)

Regular bearing variety, suitable for medium high density planting (6m × 6m). Fruits have red peel colour. Fruit size medium (209 g) having moderate TSS (19.7°B). The average yield is 12-16 tons/ ha. Pusa Lalima is suitable for export and domestic market, and has been released for commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Rajasthan, Punjab, Rajasthan, West Bengal, Jharkhand and Odisha.

Pusa Pratibha (Amrapali × Sensation)

Regular bearing variety, suitable for medium density planting (6m × 6m). Fruits have red peel colour. Fruits have high pulp content (70.7%) with moderate TSS (19.6°B). The average yield is 13-15 tons/ ha. Pusa Pratibha is suitable for export and domestic market, and has been released for commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Rajasthan, Punjab, Rajasthan, West Bengal, Jharkhand and Odisha.

Pusa Peetamber (Amrapali × Lal Sundari)

Regular bearing variety, suitable for medium density planting (6m × 6m). Fruits have yellow peel colour, and high pulp content (73.6%) with moderate TSS (18.8°B). The average yield is 12-16 tons/ ha. Pusa Peetamber nd has been released for commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, Madhya Pradesh, Rajasthan, Punjab, Rajasthan, West Bengal, Jharkhand and Odisha.

Pusa Shreshth (Amrapali × Sensation)

Regular bearing variety, suitable for medium high density planting (6m × 6m). Fruits have red peel and orange colour. Fruits have high pulp content (71.0%) with moderate TSS (20.0°B). The average yield is 12-16 tons/ ha. Pusa Shreshth is suitable for export and domestic market, and has been releasedfor commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Uttarakhand, Chhattisgarh, Himachal Pradesh, Madhya Pradesh, Punjab, Rajasthan, West Bengal, Jharkhand and Odisha.

Citrus

Sweet orange: Pusa Round (Clonal Selection)

Ready to harvest in second week of October. Fruits are round, medium in size (270.0g) with high TSS (10.0°- 13.0°B) and juice recovery (48.0%). Average yield is 14-18 tons/ha). Pusa Round has been released for commercial cultivation in Delhi, Uttar Pradesh, Bihar, UttaraKhand, Haryana, Punjab, Rajasthan and Union Territory of Jammu and Kashmir.

Acid lime: Pusa Abhinav (Clonal Selection)

Pusa Abhinav is harvested twice in a year (August-September and February –March). Fruits are round, moderate in size (34.6 g) having thin peel and high juice (56.92%) and acid content (7.7%). Average yield is 16-20 tons/ha. Pusa Abhinav has been released for commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Bihar, Uttarakhand, Madhya Pradesh, Haryana, Punjab and Rajasthan.

Grape

Pusa Urvashi (Hur × Beauty Seedless)

Pusa Urvashi is harvested in the second week of June. Berries are seedless and suitable for table use and for juice making. Average yield is 10.0-12.0 tons/ ha. Released for commercial cultivation in Punjab, Andhra Pradesh and Karnataka.

Pusa Aditi (Banqui Abyad × Perlett)

Pusa Aditi matures in first week of June, bearing larhe bunch (565 g), yellowish seedless berries with high TSS contents (18.6°B). Pusa Aditi has been released for commercial cultivation in National Capital territory of Delhi, Uttar Pradesh, Chhattisgarh, Madhya Pradesh, Punjab, Rajasthan, Telangana, Andhra Pradesh, West Bengal, Mizoram, Jharkhand and Odisha.

Pusa Lalima

Pusa Pratibha

Pusa Peetamber

Pusa Shreshth

Pusa Round

Pusa Abhinav

Pusa Urvashi

Pusa Aditi

Besides, eight varieties including two of mango (Pusa Deepshikha and Pusa Manohari), two of grapes (Pusa Swarnika and Pusa Purple Seedless) and one each of sweet orange (Pusa Sharad), pummelo (Pusa Arun) and lemon (Pusa Lemon 1) developed by the FHT Division have been released Delhi State Seed Sub-Committee for Agricultural & Horticultural Crop, Govt. of NCT of Delhi vide proceeding No. F.10(1)2YSI/TA/Sub-Committee/2017-18/2 332 2373 Dated: 12/02/2021.

Mango

Pusa Deepshikha (Amrapali × Sensation)

Average fruit yield is 13.99 t/ha which is double than Dashehari. Elongated oblong fruit with average weight of 265 g. It has better quality viz., high pulp content (70%), Fibre less, TSS (18.67%), acidity (0.33%), ascorbic acid (35.34 mg/100 g pulp) and B-carotene content (9483.3 ug per 100. Suitable for commercial cultivation in NCR Delhi.

Pusa Manohari (Amrapali × Lal Sundari)

Higher yield (16.1 t/ha) which is >2 times higher than Dashehari. Elongated oblong fruit with average weight of 223.4 g. Attractive greenish-yellow fruits with slight red tinge on shoulders. It is suitable for table as well as processing purposeswith 68.76% pulp, fibre less, 20.83% TSS, o.27% acidity, 39.78 mg/100 g pulp ascorbic acid and 9738 pg per 100 g pulp B-carotene content. Shelf life at room temperature is 6-7 days. Suitable for commercial cultivation in NCR Delhi.

Citrus

Sweet orange- Pusa Sharad (Clonal Selection)

Improved selection with average fruit yield of 37.41 kg/tree and 23.38/ha (4 times higher than that of Jaffa). Average fruit weight is 221.96 g with 47.95% juice content. It has higher TSS (10.13 °B) over standard check cultivars and is free from 32. Crop: Sweet Orange Variety: Pusa Sweet Orange Sharad (MS-5) granulation. Suitable for commercial cultivation in NCR Delhi

Acid lime- Pusa Udit (Clonal Selection)

Improved clonal selection with average yield of 52.28 t/ha which is three folds higher than the check Purbai lime. The average fruit weight is 38.23 g with higher juice recovery (48.51%), TSS (7.68%) and acidity (6.78%). The maturity is 180-200 days after flowering (Aug-Sep) and 160-180 days after flowering (Feb- March). Suitable for commercial cultivation in NCR Delhi

Pummelo- Pusa Arun

Suitable for NCT of Delhi. First seedless Pummelo mutant of India with high juice recovery. Higher fruit yield (45.55 kg/tree and 28.47 Uha) which is four folds higher than wild type

Pummelo (white fleshed). Juice has very low acidity (0.39% citric acid), high ascorbic acid (512 mg/lit juice) and high TSS (11. 10 °B). Fruit is ready to harvest 15 days earlier than other sweet citrus varieties of sweet orange, grape fruit and pummelo. Suitable for commercial cultivation in NCR Delhi

Lemon- Pusa Lemon-1

It has higher fruit yield (12.69 kg/tree; 6.93 tons/ha) which is 2.3 folds higher than the check Kagzi Kalan with average fruit weight of 67.42 g with juice content of 42.88%. Its harvesting starts 25 days earlier than Kagzi Kalan. Suitable for commercial cultivation in NCR Delhi.

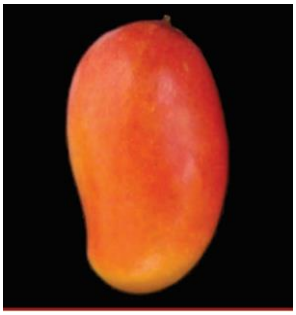
Grape

Pusa Purple Seedless (Pearl of Casba × Beauty Seedless)

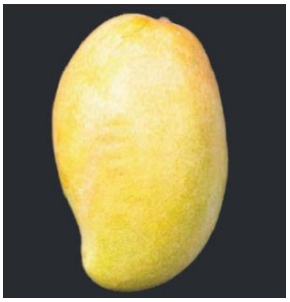
Suitable for cultivation in NCR, Delhi. Average yield is 8.6 kg per vine from 5-year-old vines trained on Kniffin system. Average yield is 14 t/ha if planted at 2x3 m spacing. It has purple longated bunch (350 g) with seedless berries suitable for table | purpose which have 20-23° Brix TSS. Veraison starts after 50-55 days from pruning and requires another 25-30 days for harvest. It |has extra early ripening behaviour and fruits are ready for harvest between 75-80 days after full bloom (extra-early maturing variety). Suitable for commercial cultivation in NCR Delhi.

Pusa Swarnika (Hur × Cardinal)

The average fruit yield is 16.71 t/ha which is 15.2% higher than check variety Perlette. It is a unique grape hybrid having early berry ripening habit, loose bunch, golden yellow coloured bold berries. Early maturing (75-78 DAFB) and suitable for subtropical climate. Bunches loose and medium to large in size (317 g). Berries are bold, large in size (4.14 g), round golden yellow colour, seeded with firm pulp. High TSS (20.71°Brix), mild acidity and ideal TSS/acid ratio. Moderately rich in nutraceutical properties like total phenolics (91.29 mg/100 g). total flavonoids (91.80 mg/100 g), and antioxidant properties assessed by DPPH, FRAP and CUPRAC assay. Suitable for table purpose, juice making and *Munnakka* preparation. Suitable for commercial cultivation in NCR Delhi.



Pusa Deepshikha

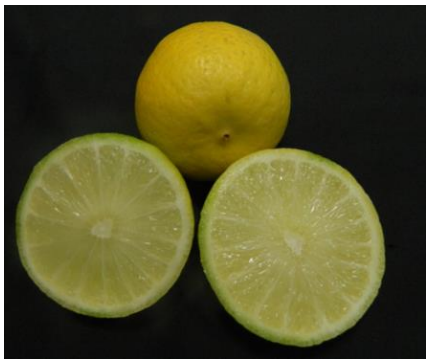


Pusa Manohari

Pusa Sharad

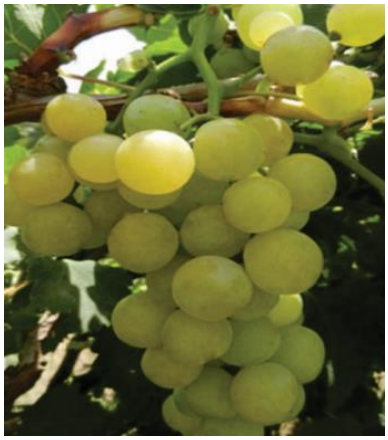
Pusa Udit

Pusa Arun



Pusa Lemon-1

Pusa Purple Seedless



Pusa Swarnika

4.2 Plants multiplied

Division of Fruits & Horticultural Technology has multiplied the 12556 plants of different varieties of mandated fruit crops (Table 30), and sold to the growers, SAUs and nurserymen.

Table 30. Details of planting materials multiplied and sold during 2021

Crop & variety	2021
Mango	
Amrapali	1884
Mallika	680
Pusa Arunima	1536
Pusa Surya	271
Pusa Lalima	881
Pusa Pratibha	456
Pusa Shrestha	389
Pusa Peetamber	321
Pusa Manohari	354
Pusa Deepshikha	34
Citrus	
Kagzi Kalan	1931
Pusa Round	167
Pusa Sharad	242
Pusa Udit	517
Pusa Abhinav	288
Pusa Arun	41
Grape	
Pusa Navrang	181
Pusa Urvashi	608
Pusa Trishar	1101
Pusa Aditi	335
Pusa Swarnika	111
Pusa Purple Seedless	79
Papaya	
Pusa Nanha	149

5. Linkages and Collaboration

Institutes/ Industry/ University, and details of collaboration

Table 31. List of the collaborative projects.

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

6. Education

(a) Summary of UG, PG education

During the year 2021, total 18 PG students including 8 M.Sc. and 10 Ph.D. students taken admission in the Division. Total eight students including two Ph.D. and six M.Sc. students received degree during IARI Convocation, 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 sport activities organized by IARI and ICAR and won medals for their performances in the events.

(b) No. of students admitted

A total of 18 students got admitted in the division including 08 of M Sc and 10 of Ph D (Table 32)

Table 32. Details of students admitted

S. No.	Name of Student	Roll Number	M.Sc./ Ph.D.
1	Kalieswari K	21467	M.Sc.
2	Amina Shukoor	21468	M.Sc.
3	Hatkari Vittal	21469	M.Sc.
4	Gulshan Kumar	21470	M.Sc.
5	Vasudeva N	21471	M.Sc.
6	Akshay	21472	M.Sc.
7	Abeer Ali	60071	M.Sc.
8	Vasanth Vinayak Vara Prasad N	60072	M.Sc.
9	Amar BA	60073	Ph.D.
10	Vishal Balasaheb Mhetre	11779	Ph.D.
11	Chaithra T S	11780	Ph.D.
12	Amulya S	11781	Ph.D.
13	Anagha P K	11782	Ph.D.
14	Kripa Shankar	11783	Ph.D.
15	Chandana M R	11784	Ph.D.
16	Mude Ramya Sree	11785	Ph.D.
17	Chukkamettu Anusha	11786	Ph.D.
18	Lal Chand	11787	Ph.D.

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

A total of 17 students were awarded with the fellowship, from ICAR, New Delhi (Table 33).

Table 33. Detail of students alongwith the source of fellowship secured

S. No.	Name of the student	Name of the Fellowship	Awarding Agency
1	Vishal Balasaheb Mhetre	ICAR- JRF- Ph.D.	ICAR, New Delhi
2	Chaithra T S	ICAR- JRF- Ph.D.	ICAR, New Delhi
3	Amulya S	ICAR- JRF- Ph.D.	ICAR, New Delhi
4	Anagha P K	ICAR- JRF- Ph.D.	ICAR, New Delhi
5	Kripa Shankar	ICAR- JRF- Ph.D.	ICAR, New Delhi
6	Chandana M R	ICAR- JRF- Ph.D.	ICAR, New Delhi
7	Mude Ramya Sree	ICAR- JRF- Ph.D.	ICAR, New Delhi
8	Chukkamettu Anusha	ICAR- JRF- Ph.D.	ICAR, New Delhi
9	Kalieswari K	ICAR- JRF- M.Sc.	ICAR, New Delhi
10	Amina Shukoor	ICAR- JRF- M.Sc.	ICAR, New Delhi
11	Hatkari Vittal	ICAR- JRF- M.Sc.	ICAR, New Delhi
12	Gulshan Kumar	ICAR- JRF- M.Sc.	ICAR, New Delhi
13	Vasudeva N	ICAR- JRF- M.Sc.	ICAR, New Delhi

14	Akshay	ICAR- JRF- M.Sc.	ICAR, New Delhi
15	Abeer Ali	ICAR- JRF- M.Sc.	ICAR, New Delhi
16	Vasanth Vinayak Vara Prasad N	ICAR- JRF- M.Sc.	ICAR, New Delhi
17	Amar BA	ICAR- JRF- M.Sc.	ICAR, New Delhi

(d) Students awarded with degrees during 2021 Convocation

A total of ten students were awarded with the degree including 02 of Ph D and 06 of M Sc (Table 34).

Table 34. Details of students awarded with the degrees

S. No.	M.Sc./ Ph.D.	Name of the student	Name of the Chairman, Advisory Committee	Title of the Thesis
1	M.Sc.	Rutuparna Senapati	Dr. Madhubala Thakre	Understanding the basis of pulp colour in Black guava (*Psidium guajava* L).
2	M.Sc.	Shivum	Dr. Kanhaiya Singh	Morphological, physiological, biochemical and molecular characterization of progenies of Olour mango.
3	M.Sc.	Sandeep Kumar Badhei	Dr. Awtar Singh	Morphogenetic characterization of second generation Kinnow mandarin colchiploids.
4	M.Sc.	Mukesh Shivran	Dr. Nimisha Sharma	Molecular studies on shelf-life in mango (*Mangifera indica* L.).
5	M.Sc.	Kiran K.N.	Dr. Awtar Singh	Morphogenetic characterization of second generation colchiploids of sweet orange cv. Mosambi
6	M.Sc.	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.
7	Ph.D.	Uwisize Marie Grace	Dr. Mahendra Kumar Verma	Identification of grape genotypes tolerant to berry cracking
8	Ph.D.	Sridhar Ramachandra	Dr. Manish Srivastav	QTL mapping for fruit quality traits in mango (*Mangifera indica* L.)

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

Table 35. Student registered in other University for Ph. D.

S. No.	Name of the research scholar	Name of the Principal Investigator	Title of the Thesis	University at which registered
1.	Mr. Shivam	Dr Kanhaiya Singh	Morphological, physiological, biochemical and molecular characterization of progenies of Olour mango	ICAR- IIHR Bangalore

f) Awards and Recognitions received by the students: Nil
g) Events organized by student club of the Division: Nil

7. Internship & Mentorship by the Scientist: Nil

8. Awards and Recognitions received by the Scientist

Category wise

a) ICAR/National Awards: Nil

b) Fellowship/Associateship of National academies: Nil

c) Fellowship of Professional societies of the relevant Discipline

Three scientists were awarded the fellowship of professional societies (Table 36).

Table 36. Fellowships of the professional societies

S. No.	Name of the Scientist	Fellowship/ Associateship	Name of the Academy
1.	Dr. Awtar Singh	Honorary Fellow-2020	Society for Horticultural Research and Development, Ghaziabad, Uttar Pradesh
2.	Dr. Manish Srivastav	Honorary Fellowship	Society for Horticultural Research and Development, Ghaziabad, Uttar Pradesh
3.	Dr Amit Kumar Goswami	Young Educator Award - 2021 Fellowship-2021	NEEDEF, Lucknow International Society of Noni Science

d) Best Poster awards: One student was awarded with Best Poster award (Table 37).

Table 37. Best poster award.

S.No.	Detail of the poster (all authors, title)	Presented in	First/second/ third
1	Thakre, M., Verma, M.K., Singh, Kanhaiya and Awasthi, O.P. 2021. Study on different harvesting dates of Kinnow under Delhi conditions, Best poster paper award	International e-conference on Postharvest Disease Management and Value Addition of Horticultural Crops during August 18-20, 2021; ICAR-IARI, New Delhi, India	First
2	Dr. Chavlesh Kumar, Best poster paper award	9th Indian Horticulture congress-2021 organized by Indian Academy of Horticultural Science at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. (Attended and presented through virtual mode)	First

e) Other awards/ Recognition

The other awards and recognitions are summarized in Table 38.

Table 38. Award received by the faculty

S. No.	Details	Organizaton	Scientist
1.	*In-silico* mining of ripening related genes for shelf-life studies in mango (*Mangifera indica* L.) Presenter-**Nimisha Sharma** **Authors: Nimisha Sharma**, Mukesh Shivran, Neha Sharma, Vignesh Muthusamy, Sanjay Kumar Singh, Anil Kumar Dubey and Nagendra Kumar Singh	International Conference on Postharvest Disease Management and Value Addition." in International E-Conference at ICAR-IARI, New Delhi, 18-20th August, 2021	**First**

9. Budget Estimates: Head wise budget received and expenditure under EFC:

Table 39. Budget allotted

S. No.	Head		Amount (Rs. in Lakhs)
1	Research & Operational	Research Exp.	37.00
		Operational Exp.	20.00
2	Administrative Expenses	Communication	0.10
		Repair & Maintenance (Equip., Veh. & Others)	8.67
		Others	4.61
3	Miscellaneous	HRD	0.60
		Misc.	4.67
Total			75.65

a) **Budget received from external grant**

Table 40. Budget received from external agencies

S.No.	Name of the project	Name of the PI	Name of the Co-PIs	Duration	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	13.13 Lakh	Rs. 1.0 Lakh as Institutional charges

b) **Revenue generated**

The total revenue of Rs 14.38982 Lacs was generated through the sale of planting materials (Rs. 9.34,882 Lacs) and the fruit auction of experimental orchards (Rs. 5.041 Lacs).

10. Publications

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

S. No.	Bibliography of Publication (in IJAS format)	NAAS Rating	Impact Factor (Thomson

		(2022)	Reuters)
1.	Mhetre, V.B., Patel, V.B., Singh, S.K., Verma, M.K., Kumar, C., Mishra, G.P., Dahuja, A. and Kumar, A. 2021. Influence of new generation plant bio-regulators on physio-biochemical alterations in grapes cv. Beauty Seedless. *Indian J. Hort*., 78(2): 198-204.	6.16	0.16
2.	Pradhan, Satyabrata, Singh, S.K., Srivastav, M., Prakash, J., Lal, S.K., Padaria, J.C., Goswami, A.K. and Maurya, N.K. 2021. Poly ethylene glycol mediated *in vitro* screening and physico-biochemical changes induced in mango callus due to moisture stress. *Plant Cell, Tissue and Organ Culture*. 145(1):55-172.	8.61	2.61
3.	Singh, P., Prakash, J., Goswami A.K., Singh, K. and Hussain Zakir 2021. Genetic variability and correlation studies for fruit quality and biochemical traits of papaya (*Carica papaya* L.) *RASSA Journal of Science for Society*, 3(3): 190-19.	NA	NA
4.	Mhetre, V. B., Patel, V. B., Singh, S. K., Verma, M. K., Mishra, G. P., Dahuja, A. and Kumar, C. 2021. Effect of new generation bio-regulators on anthocyanins and berryquality of grape cv. Beauty Seedless. *Indian J. Agric. Sci*., 91(6): 920-23.	6.37	0.37
5.	Kalal, P., Sharma, R.M., Dubey, A.K., Kamil, D., Lekshmy, S., Kumar, A. and Awasthi, O. P. 2021. Tolerance mechanism in hybrid citrus rootstock progenies against *Phytophthora nicotianae* Breda de Haan. *Indian Journal of Experimental Biology*, 59 (4): 248-258.	6.94	0.94
6.	Dubey, A. K., Gupta, A., Sharma, R. M., and Sharma, N. 2021. Immature embryo rescue, embryo germination, plantlets growth and establishing hybridity via SSR markers in hybrid progeny derived from polyemebryonic rangpur lime (*Citrus limonia*) × sour orange (*C. aurantium*). *Indian Journal of Agricultural Sciences* 91 (2): 279–82.	6.25	0.25
7.	Dubey, A. K., Sharma, R. M., Deepak and Kumar, A. 2021. Long term performance of mango varieties on five polyembryonic rootstocks under subtropical conditions: effect on vigour, yield, fruit quality and nutrient acquisition. *Sci. Hortic*., DOI: 10.1016/j.scienta.2021.109944.	9.46	3.46
8.	Kumar, S., Awasthi, O. P., Bharadwaj. C., Dubey, A. K., Singh, A and Pandey, R. 2021. Impact of ionising irradiation on physio-biochemical traits of Kinnow mandarin. *Indian Journal of Horticulture*, 78(2): 149-15	6.16	0.16
9.	Kumar, S., Awasthi, O. P., Bharadwaj, C., Dubey, A. K., Kumar, C. and Singh, K. 2021. Molecular characterization of Kinnow (*Citrus nobilis* Loureiro × *Citrus deliciosa* Tenora) mutants. *Indian Journal of Agricultural Sciences*, 91 (3): 364-368.	6.37	0.37
10.	Ramachandra S, Srivastav M, Singh SK, Mahato AK, Singh N, Arumugam N, Singh R and Singh NK. 2021. New genomic markers for marker assisted breeding in mango (*Mangifera indica* L.). *J Hort. Sci. Plant Biotech*. DOI: 10.1080/14620316.2021.1906760.	7.92	1.92
11.	Srivastav, M., Singh, S.K., Singh, J., Singh, S., Sharma, N., Ramachandra, S., Devi, R., Gupta, A., Mahato, A.K., Jayaswal, P.K., Singh, S. and Singh, N.K. 2021. New hyper-variable ssrs for diversity analysis in mango (*Mangifera Indica* L.). *Indian J. Genet. Plant Breed*., 81(1): 119-126.	6.51	0.51
12.	Nikhil, H.N., Goswami, A. K., Singh, S. K., Kumar., Goswami, S., Singh, R., Bharadwaj, C and Maurya, N. K. 2021. Assessment of morphological, physio-biochemical and genetic diversity of guava	0.21	6.21

	(*Psidium guajava* L.) hybrids and genotypes. *Indian Journal of Agricultural Sciences*, 91 (11): 1640–5.		
13.	Kumar, S., Awasthi, O. P., Bharadwaj, C., Dubey, A. K., Kumar, C. and Singh, K. 2021. Molecular characterization of Kinnow (*Citrus nobilis* Loureiro × *Citrus deliciosa* Tenora) mutants. *Indian Journal of Agricultural Sciences*, 91 (3): 364-368.	6.37	0.37
14.	Kumar, S., Awasthi., O.P., Dubey, A.K., Singh, A. and Pandey, R. 2021. Impact of ionising irradiation on physio-biochemical traits of Kinnow mandarin (*Citrus nobilis* Loureiro × *Citrus deliciosa* Tenora). *Indian Journal of Horticulture*, 78 (2):149-154.	6.16	0.16
15.	Kumar, S., Awasthi, O.P., Sharma, R.M. and Pradhan, S. 2021. Physiological and biochemical responses of Kinnow mandarin to EMS induced mutagenesis. *Indian Journal of Agricultural Sciences*, 91 (7): 67-71.	6.37	0.37

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

Sharma N, Shivran M, Sharma N, Muthusamy V, Singh S, Dubey AK and Singh NK. 2021. *In-silico* mining of ripening related genes for shelf-life studies in mango (*Mangifera indica* L.). Int. Conference on Postharvest Disease Management and Value Addition. ISBN: 81-7019-713-8. pp.178-182.

Gupta, S.K., Kumar, L., Singh, P., Kumar, R., Srivastav, A., Goswami, A.K., and Tiwari, R. 2021. Souvenir and Book of Abstract on "*Agriculture and Aatmnirbhar Bharat*" in 5th National Convention during 6th and 7th 2021 at Bharat Ratna C. Subramaniam Auditorium, NASC Complex, ICAR, Pusa Complex New Delhi-110 012. (Pp-96)

b) List of Books / Chapter in books

1. Singh, Y., Pandey, S. and Goswami, A. K. 2021. Ensuring Water Availability in Future through Revival of Indian Traditional Water Culture. DOI: http://dx.doi.org/10.5772/intechopen.99311.
2. Rajan, S., Srivastav, M. and Rymbai, H. 2021. Genetic Resources in mango. In: The Mango Genome (Ed. C. Kole). Springer, P. 45-73.
3. Srivastav, M., Singh, S.K. and Sharma, N. 2021. The Chloroplast Mango Genome. In: The Mango Genome (Ed. C. Kole). Springer, P. 187-194.
4. Dubey, A. K. and Sharma, R. M. 2021.Citrus In: Sub-Tropical Fruit Crops: Theory to Practical (Ghosh, S.N. and Sharma R. R.). (ISSN: 978-93-90611-01-0). Jaya Publishing House, Delhi (India):79-179
5. Prakash, Jai, Pal RK, Sharma RM, Khar Anil, Prakash G, Tripathi Vivek, Ranjan JK and Verma MK, 2021/11, Poster Papers Abstract Book on the 9th Indian Horticulture Congress, published by Horticulture for Health, Livelihoods and Economy, held at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India pp-18-21.
6. Verma M. K. and Grace Uwisize Marie Grace, 2021. Grape (*Vitis Vinifera*). In: Sub-Tropical Fruit Crops- Theory and Practical (Eds. S.N. Ghosh and R.R. Sharma), Jaya Publishing House, New Delhi. ISBN: 978-93-90611-01-0, 2021, Pages. 236-316.
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8. Ravishankar H, Sharma N and Singh VK. 2021. *Alternate Flowering in Mango*. pp.95-110. In: Kole C. (Eds) The Mango Genome. Compendium of Plant Genomes. Springer, Nature Cham. https://doi.org/10.1007/978-3-030-47829-2_6.

9. Tongyoo P, Duangjit J and Sharma N., Chunwongse J. 2021. *Molecular Mapping and Breeding in Mango.* pp.153-163.In: Kole C. (Eds) The Mango Genome. Compendium of Plant Genomes. Springer, Nature Cham. https://doi.org/10.1007/978-3-030-47829-2_9.

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11. Malik M, Sehgal M, Sharma N, Singh R V and Dey U. 2021. *Technological Breakthrough and Organic Farming: A Challenge for the* Farmer.s pp.67-74. In: Dey U. (Eds). E- Resource Book: "Pest Management in Organic Farming: Options and Challenges".

12. Shivran M, Sharma N, Sharma N, Muthusamy V, Singh S K and Dubey A K. 2021. Shelf-life studies in mango using molecular approach. pp. 96-98. In: Sehgal M. (Eds). E- Resource Book: "Microbial Biocontrol Agents-An Ecofriendly Pest Management Approach for Sustainable Agriculture".

c) List of Popular article(s)

1. Sharma N, Hatkari V, Shivran M, Singh SK and Dubey AK (2021). Understand bearing habit in fruit crops. NESA e-version December Issue, pp. 9-11.

2. Hatkari V, Sharma N, Shivran M, Singh SK and Dubey AK (2021). Biological control of pest and diseases through ICT (2021). NESA e-version July Iissue, pp. 12-13.

3. Shivran M, Sharma N, Singh S K, Dubey AK, Malik M, Vignesh M and Sharma N (2021). Aam me shelf jeevan ki jankari hetu aanvik taknik ka yogdan. Krish Sewa (Hindi article online).

11. Trainings/workshop/seminar organized: Nil

12. Participation by scientists in scientific meetings, etc.

The details of scientific meetings attended by the divisional scientists are mentioned in Table 41.

Table 41. Meetings attended

S. No.	Detail	Number only	Detail/description of each item	Scientist
(i)	**In India**			
	Seminars	04	Delivered lead lecture in National Webinar on "Indian jujube (Ber)" organized by ICAR-Central Institute for Arid Horticulture, Bikaner on 14.06.2021.	Dr. O.P. Awasthi
			Nursery management and common practices of nursery in horticulture. National CPWD Academy, Ghaziabad. March 23, 2021.	Dr. Kanhiya Singh
			9th Indian Horticulture Congress, 18-21, November, 2021 at Kanpur	Dr. Jai Prakash
			Attended Seminar organized by Plant Genomia, December, 2021.	Dr. Nimisha Sharma
	Scientific meetings	04	Under DBT Biotech KISAN Project as a Co-PI, attended meeting on 21.10.21	Dr O.P. Awasthi
			8th Group Discussion on ICAR-AICRP on Fruits.	Drs. A K Dubey/R M sharma/Manis Shrivastav/ Jai Prakash
			Annual review meeting of the ICAR-NPFGGM (Formerly NPTC) project.	Dr Manis Srivastav
			Attended review meeting of ICAR Network Project on Functional Genomics and Genetic Modification in Crops (November, 2021).	Dr. Nimisha Sharma
	Symposia	05	Horticulture for Next Generation in Eastern India, held at Sabour Agriculture University, Bihar, during August 5-6, 2021.	Dr. R.M. Sharma
			Attended International Webinar on Exchange on Biochemical and Molecular Techniques (BMT) Guidelines and Implementation of BMT in DUS (16-17th December, 2021. Participated in webinar on Agro-biodiversity conservation and use for climate resilience and livelihood improvement of small holder farmers by ICAR-VPKAS Almora, UK (23rd December, 2021). Attended International Conference on Postharvest Disease Management and Value Addition." at ICAR-IARI, New Delhi, 18-20th August, 2021. Attended 9th Indian Horticulture Congress-2021 "Horticulture for Health, Livelihoods and Economy Organized by IAHS (18-21th November, 2021) at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.	Dr. Nimisha Sharma

13. Extension activities

The Divisional scientists were involved in the various extension activities for the transfer of technologies (Table 42).

Table 42. Extension activities undertaken

S. No.	Activities	Scientist
1	Participation in MGMG programme	All Divisional Scientists
2	Participation in Pusa Krishi Vigyan Mela 2021	All Divisional Scientists
3	Training lectures	
	Strawberry and saffron cultivation on 01.04.2021 ANASTU (Online)	Dr R. M. Sharma
	Biotech Kisan Hub Project. Krishi Vigyan Kendra Mandkaula, Palwal (Haryana), on 01.09. 2021	Dr Kanhaiya Singh
	In training "Improved agricultural practices and postharvest management. CATAT, ICAR- Indian Agricultural Research Institute New Delhi, on 17.09. 2021.	Dr Kanhaiya Singh
	New Mango Varieties with special reference to Upper Gangetic Plains and their availability on 04.08.2021 during *Azadi ka Amrit Mahotsav*" Pusa Krishak-Viagyanik Aam Samvad under Biotech Kisan	Dr Manish Srivastav

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. Awtar Singh, Principal Scientist & Member
3. Dr. R. M. Sharma, Principal Scientist & Member
4. Dr Jai Prakash, Principal Scientist & Member
5. Mr. Satender Kumar, AAO-FHT & Member
6. Dr. A. K. Goswami, Scientist & Member Secretary

b) Board of Studies (BOS)

1. Dr. Manish Srivastav, Professor & Chairman
2. Dr S. K. Singh, Head & Special Member
3. Dr. O.P. Awasthi, Principal Scientist & Member
4. Dr. Jai Prakash, Principal Scientist & Member
5. Dr. Vertika Srivastav, Scientist & Member Secretary
6. Dr. Amrut S. Morade, 2nd Year, Students Representative

c) Deputation Committee: Nil

d) Technical Cell

1. Dr. S.K. Singh, Head & Chairman
2. Dr. K. Usha, Prof. & Member
3. Dr. Awtar Singh, Principal Scientist & Member
4. Dr. O. P. Awasthi, Principal Scientist & Member
5. Mrs. Usha Sehgal, PS to Head & Member Secretary

e) Store Purchase Committee

1. Dr. O. P. Awasthi, Pr. Scientist- Chairman
2. Dr. Jai Prakash, Pr. Scientist – Member
3. Mr. Chavlesh Kumar, Scientist - Member
4. Mr. Surinder Pal, T-7/8 - Member
5. Mr. Satender Kumar, AAO-FHT & Member Secretary

f) Farm Produce Auction Committee

1. Dr. A.K. Dubey, Pr. Scientist - Chairman
2. Dr. Manish Srivastav, Pr. Scientist - Member
3. Dr. A. K. Goswami, Scientist - Member
4. Farm In- charges (Main & Todapur Orchards) – Member
5. Mr. Satender Kumar, AAO, FHT- Member Secretary

g) Farm Management Committee

1. Dr. Awtar Singh, Pr. Scientist - Chairman
2. Dr. A. K. Dubey, Pr. Scientist - Member
3. Dr. Kanhaiya, Pr. Scientist - Member
4. Dr. Jai Prakash, Pr. Scientist – Member
5. Farm In- charges (Main & Todapur Orchards) – Member

h) Building and Premise Maintenance Committee

1. Dr. Kanhaiya Singh, Pr. Scientist - Chairman
2. Dr M. K. Verma, Pr. Scientist – Member
3. Dr. (Mrs.) Nimisha Sharma, Scientist – Member
4. Mr. Ram Bahadur T-5 – Member
5. Mr. G. P. Giri T-6 – Member Secretary

i) Technology Extension Committee

1. Dr. M.K. Verma, Pr. Scientist - Chairman
2. Dr. M.K. Verma R.M. Sharma, Pr. Scientist – Member
3. Dr. Manish Srivastav, Pr. Scientist – Member
4. Dr. A. Nagaraja, Sr. Scientist- Member
5. Farm In-charges (Main & Todapur Orchards)
6. Dr. Madhubala Thakre, Scientist – Member Secretary

j) Staff Welfare Committee

1. Dr. R. M. Sharma, Pr. Scientist – Chairman
2. Dr. (Mrs.) Nimisha Sharma, Scientist - Member
3. Mr. Nayan Deepak G. – Member
4. Mr. Dinesh Kumar, T-1-Member
5. Mr. Lalit Kumar, LDC- Member
6. Mr. Shish Pal Singh, Farm In-charge Main Orchard
7. Mr. Vinod Kumar Rai, LDC - Member
8. Mr. D.P. Singh, Farm In-Charge (Main & Todapur Orchards) – Member
9. Mr. Satender Kumar, AAO, FHT - Member Secretary

k) राजभाषा कार्यान्वन समिति

1. डा. संजय कुमार सिंह - अध्यक्ष
2. डा. कन्हैया सिंह, प्रधान वैज्ञानिक - सदस्य
3. डा. मनीष श्रीवास्तव, प्र. वैज्ञानिक –सदस्य
4. डा. निमिषा शर्मा - सदस्य
5. श्री दीपक कुमार, सदस्य
6. श्री. ललित कुमार - सदस्य सचिव

l) स्वच्छ भारत अभियान समिति

1. डा. राधा मोहन शर्मा - नोडल अधिकारी
2. डा. ए. नागाराजा, व. वै. –सदस्य
3. डा. (श्रीमति) मधुबाला ठाकरे –सदस्य
4. श्री सतेंदर कुमार, सप्रअ, सदस्य

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