वार्षिक प्रतिवेदन

Annual Report

2020

भा. कृ. अनु. प.- केन्द्रीय नीबूवर्गीय फल अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद)

अमरावती रोड, नागपुर - 440 033 (महाराष्ट्र)

ICAR-Central Citrus Research Institute

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

Amravati Road, Nagpur - 440 033 (Maharashtra)

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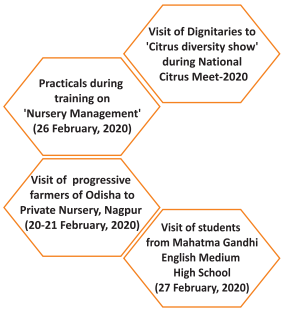

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Preface

Citrus fruits comprising of mandarins, sweet oranges, limes, lemons, grapefruits, pummeloes and many other close and distant relatives of genus Citrus are source of livelihood for millions of people in India. Due to wide adaptability of these fruit crops, they are grown to the length and breadth of the country. Citrus fruits are very widely used for daily cooking in homes, as dessert fruit and salads, in juice and processing industry, in pharmaceuticals, in aroma and perfume industry and in cosmetic products. India exports significant quantity of citrus fruits to neighbouring countries and 4-5% fruit is processed annually in organized industrial sector while huge quantity of lemons and limes are pickled annually in every household of India that is not accounted. Citrus fruits have unique place in human nutrition due to vitamin 'C' and 'B' and flavonoids, limonoids, phenols and anti-oxidants that strengthen immune system.

I am very happy to present annual report of the calendar year 2020 of ICAR-CCRI covering wide range of activities and achievements. During the year ICAR - CCRI continued its remarkable research endeavours. Molecular characterization of 66 acid lime and 15 lemon accessions were carried out using 45 InDel markers. Out of 45 markers, 27 and 24 were polymorphic in acid lime and lemon. The conventional breeding programmes yielded some interesting interspecific cross progeny.

In pest-management, modules were developed for effective management of fruit piercing moth (*Eudocima* spp.) and validated at two different farmers' fields in Nagpur districts during *Ambia* fruiting season at colour breaking stage. Nine new fungal endophytes (CFE-154 - CFE-162) were isolated from roots of Nagpur mandarin and sweet orange. The fungal endophytes which were found to have potential against controlling *Phytophthora nicotianae* were CFE-154, CFE-157 and CFE-162. Maximum inhibition was found in case of CFE-154 (*Rhytidhysteron rufulum*). Similarly, LAMP and RPA-based rapid and sensitive diagnostics have been developed for ICRSV, CTV and *Candidatus* Liberibacter asiaticus (Citrus greening) that are being used for certification purpose. Based on the morphological characters, different plant parasitic nematode genera *viz*., *Tylenchulus semipenetrans, Pratylenchus, Helicotylenchus* and *Hoplolaimus* were identified in Nagpur mandarin growing areas of Vidarbha region of Maharashtra.

In post-harvest management, polysaccharide based edible coatings i.e. Carboxylmethyl cellulose and Methyl cellulose with glycerol gave maximum juice recovery, lower PLW and better retention of vitamin C content in Nagpur mandarin during 21 days of storage under ambient condition. Nagpur mandarin fruits treated with Azoxystrobin @1000 ppm with Shellac coating and polythene liner retained better fruit quality. Other technologies developed for commercialization include osmotically dehydrated segments of Nagpur mandarin and sweet orange, low calorie santra barfi and ice-cream from Nagpur mandarin.

Under on-site DUS testing, observations were recorded on four acid lime, four mandarin and four sweet orange varieties planted under maintenance breeding. Five new varieties of sweet orange cultivars Hamlin, Pera, Natal, Valencia and Westin each on two rootstocks (from Brazil) on raised bed system with fertigation and four new introduced lemon varieties namely - Eureka, Lisbon, Bearss, Limeniero have been planted at CCRI.

Institute further expanded its activities at RRCC, Biswanath Chariali, Assam. In citrus germplasm repository, a total of 51 accessions including exotic, indigenous and wild species were planted. During the year 3 posts of scientists in horticulture discipline was sanctioned. One Young Professional (YP-II) was recruited. Farm building and tractor shed was constructed at RRCC. Institute generated revenue of Rs. 1,06,39,625/- through sale of planting material, seeds, rootstock saplings and fruit produce and from the revenue including interests on FDs, fees, sale of publication.

Extension activities were also carried out with full intensity. Under HORTSAP project, a total of 3200 Bulk SMS were sent through mobile to the registered citrus growers for the management of citrus, psylla, lemon butterfly, fruit piercing moth and fruit fly. Regular Pest advisories were also issued for the citrus growers through press notes in the local newspaper and WhatsApp messages. During 2020, five field visits and several online lectures were delivered through five different training programme on identification and management of insect pests and diseases of Nagpur mandarin and sweet orange. Institute organized in all 12 different trainings under Tribal sub-plan, SC Sub-Plan, training in NEH Region. Three-day "National Citrus Meet-2020" was organized during 10-12, January 2020 in collaboration with Assam Agricultural University, Jorhat, Assam; Central Agricultural University, Imphal and ICAR - Research Complex for North-Eastern Hill Region, Umiam, Meghalaya.Institute organized "Krishi Samwad" programme on 7th October, 2020 to create awareness among farmers about recently passed three historical bills on farm sector in the parliament. Parliamentary Standing Committee on Agriculture visited ICAR-CCRI, Nagpur as a study tour on 24th January, 2020. The committee consisting of 10 parliament members (Lok Sabha and Rajya Sabha) along with 4 officers and from ICAR side, Dr. R. K. Singh, ADG (Commercial Crops) and Dr. W.S. Dhillon, former ADG-I (Hort. Sci.) were present apart from all the scientists of the institute and invited progressive farmers.

All these activities were successfully carried out with the support from ICAR Head Quarters. I express sincere gratitude to Dr. Trilochan Mohapatra, Secretary DARE and Director General, ICAR, New Delhi for his support, guidance and visionary leadership. I place on record my deep sense of gratitude to Dr. Anand Kumar Singh, Deputy Director General (Hort. Sci.), ICAR, New Delhi for constant encouragement and guidance. I also thank Dr. M. S. Ladaniya, Former Director, ICAR-CCRI and Dr. W. S. Dhillon, Former ADG (Hort. Sci.-II) for driving all the tasks forward. I am thankful to Research Advisory Committee (RAC) for valuable guidance in research programmes. I thank all the scientists, officers and staff for their contributions in fulfilling the mandate of the institute. Finally, I want to thank scientists of editorial team and technical officer Ms. Lily Varghese, (CTO) and Shailesh Zalke, YP - II for compiling this report.

Nagpur
30th October, 2021

(Dilip Ghosh)
Director

1 Executive Summary

During the year 2020, ICAR-CCRI further expanded its plantation both at Nagpur as well as at Biswanath Chariali, Assam and executed its research programmes through different multi-disciplinary projects (in-house and externally funded), disseminated technologies through trainings, visits, demonstrations and commercialized technologies thus making an all round progress.

Research Achievements

Citrus genetic resources and improvement

To strengthen the genetic resource base and diversity, five newly introduced sweet orange varieties viz., Diller, Cara-Cara, Trovita strain, Delta, Salustiana and eight lemon varieties viz., Genoa, Frost Lisbon, Limonero fino, Verna, Limonero fino (IVIA 95), Frost Eureka, Villafranca nucellar, Bearss were planted at CCRI, Nagpur.

Out of forty-five evaluated elite acid lime germplasm, the accessions IC-285422, IC-322098 and IC-342350 recorded significantly highest weight (45.85, 44.45 and 45.48 g respectively), maximum juice content (51.24, 52.85, and 51.64% respectively) and highest yield (51.12, 52.25 and 53.72 t/ha respectively). In another acid lime evaluation trial, consisting of thirteen promising acid lime clones, KL-12 (52.8 g) and KL-21 (53.13 g) recorded the maximum fruit weight. However, the highest juice content was recorded in KL-23 (47.9%) and highest yield in KL-12 (52.12 t/ha).

Out of 17 Nagpur mandarin clones evaluated, the analysis of pooled data from 2014-19 revealed that all the clones except N_3 were at par in yield and one clone N_4 is commercially seedless. Among elite clones of Darjeeling mandarin highest fruit weight (151 g) and yield was recorded in DM-11 (18.56 t/ha) and highest juice content was found in DM-13 (43.16%). The data on evaluation of elite Sikkim mandarin revealed that the highest fruit weight was recorded in SM-7 (154 g) and the highest fruit yield was recorded in SM-8 (19.12 t/ha) and SM-7 (18.6 t/ha). Among the sweet orange clones, TM-33 recorded maximum fruit weight (183.12 g), juice content (37.65%) and yield (21.25 t/ha). Similarly within the elite pummelo clones, highest fruit weight was observed in P-3 (1027 g) and highest yield in P-5 (80.25 t/ha). Under the on-site DUS testing, observations were recorded on four acid lime, four mandarin and four sweet orange varieties planted under maintenance breeding.

Six exotic sweet orange varieties were *in vitro* shoot tip grafted on Rough lemon rootstock and the maximum success was observed in Natal (42.09%). The autotetraploidy was induced using colchicine in four rootstocks viz., Alemow, Rangpur lime, SFS and Sweet lime. The survival percentage after planting in screen house was highest in Rangpur lime (4.62%) and the maximum morphological variation was observed in Alemow (12.1%). The data on autotetraploidy induction in citrus scions revealed that the highest survival was observed in US-145 pummelo (51.76%) and the explants treated with 0.1% colchicine for 24 h gave best results.

The triploidy was induced in Nagpur mandarin, sweet orange and Kinnow through endosperm rescue. High callus induction was observed in Kinnow and highest embryogenesis was obtained in MT+CH medium supplemented with 2,4-D (2 mg/l) and BA (5 mg/l). The maximum number of cotyledonary embryoids produced in MT + BA (0.25 mg/L) + CH (500 mg/L) + GA3 (1 mg/L). The efficient regeneration of plants from endosperm rescue and more number of putative triploids were obtained from MT + CH (500 mg) + 2,4-D (2 mg) followed by MT+CH+ 2,4-D+BA.

Molecular characterization of 66 acid lime and 15 lemon accessions were carried out using 45 InDel markers. Out of

45 markers, 27 and 24 were polymorphic in acid lime and lemon, respectively. The polymorphic information content (PIC) ranged from 0.0 to 0.51 with a mean of 0.16 for acid lime and from 0.0 to 0.53 with a mean of 0.24 for lemon. This information on genetic diversity will be used for improvement of acid lime and lemon.

Conventional and mutation breeding was attempted for the genetic improvement of scions and rootstocks. In scion improvement programme, 874 progenies from acid lime group, 27 progenies from sweet orange group and 420 progenies from pummelo and grapefruit groups were retrieved. In citrus rootstock improvement programme, a total of 228 progenies were transferred to primary nursery. In the mutation breeding programme, the seedlessness was observed in two pummelo mutants (5Gy), two sweet orange mutants (5Gy), one Kinnow mutant (40Gy), one acid lime NRCC-7 and one Nagpur Mandarin N-74 mutant.

Crop and resource management

Studies on evaluation of hybrid rootstocks (NRCC-2, 3, 4 and 5) has revealed that yield of Nagpur mandarin was maximum (15.43 kg/plant) in NRCC-5 rootstock. Fruit quality parameters did not indicate much variation on hybrids rootstocks as compared with rough lemon. Effect of Rangpur lime and Rough lemon rootstocks on performance of Nagpur mandarin at 6×3 m, 6×4 m, 6×5 m, 6×6 m spacing was evaluated. On area basis yield was highest (41.6 t/ha) and (40.5 t/ha) in 6×3 m spacing on the Rough lemon and Rangpur lime rootstock, respectively.

In raised-bed planting of Nagpur mandarin under high density with Rough lemon as rootstock, canopy volume was maximum (31.91 m^3) at 5x4 m spacing followed by 4.5×4.5 m (29.05 m^3) after 6 years. The maximum fruit yield (32.54 kg/plant) was recorded in 5×4.5 m spacing. Insect-pest population was higher in general at higher density. Nagpur mandarin was evaluated on Alemow *(C. macrophylla*) rootstock on raised-bed (planted during 2014) at 6x3 m and 6 x6 m spacing. The plant spaced at 6×3 m spacing showed plant height range from 4.10 m and better canopy volume (20.17 m^3). The fruit yield was 22.78 kg/plant (12.64 t/ha on area basis) at 6×3 m spacing treatment. Intercropping of vegetables (brinjal, bhindi, tomato) and marigold flowers was successful in the space between the beds.

Among different cvs. introduced from PAU, Punjab, Pineapple sweet orange has shown better plant height (3.73 m) while Blood Red had better canopy volume (19.96 m^3) in 6th year after planting. With respect to the growth of grapefruit, the highest plant height (4.28 m) and canopy volume (27.63 m^3) was recorded in Marsh seedless followed by Star Ruby. Among the sweet orange cultivars, the maximum fruit yield (25.62 kg/plant) was recorded in Blood Red followed by Jaffa (21.03 kg/plant) whereas, the minimum fruit yield (12.75 kg/plant) was recorded in Katol Gold. In grapefruit, the average fruit weight was maximum in Marsh Seedless (461.26 g) whereas, the maximum acidity (0.45%) and Vit. C (42.20 mg/100 ml) was recorded in Star Ruby.

Among sweet orange varieties introduced from Brazil (planted on raised bed in 2014), plant height (3.73 m) and canopy volume (17.51 m^3) were maximum in Hamlin on Volkameriana rootstock. The average maximum fruit yield (14.41 kg/plant) was recorded in Pera on Limocrova followed by Westin on Swingle (13.82 kg/plant). Maximum fruit weight (272.1 g) was recorded in LaneLate on rough lemon. The highest juice content (43.90%) and Vit.C (45.30 mg/100ml) was recorded in Valencia on Volkameriana followed by Pera on Limocrova (42.36% juice content). Whereas, maximum TSS content was noted in Mosambi on rough lemon followed by Mosambi on rangpur lime (11.67%). The granulation percentage was maximum in Hamlin on Volkameriana (95%) followed by Hamlin on Cleopatra (90%) in month of December as observed in late harvesting. No granulation was noted in Pera on Limocrova

and Volkameriana; Natal on Limocrova and Volkameriana; Valencia on Volkameriana; Westin on Limocrova.

Among 10 acid lime cultivars planted on raised-bed during 2015 for evaluation, highest canopy volume (18.80 m^3) was noted in Sai Sharbati while, minimum canopy volume (5.15 m^3) was in Chakradhar. NRCC-7 and NRCC-8 recorded canopy volume of 4.19 and 8.02 m^3, respectively. Highest fruit yield was recorded in PKM-1 i.e. 10.37 t/ha while in Vikram minimum fruit yield was recorded i.e. 0.99 t/ha. In lemon cvs. budded on Rough lemon and planted during 2016 on raised-bed, Assam lemon recorded maximum average fruit weight (170.60 g) and highest acidity (6.40%) with minimum TSS, Vit.C and juice content as 7.58%, (37.06 mg/100 ml) and 43.06% respectively, whereas the highest juice content (52.71%) and vit.C (48.48 mg/100 ml) were noticed in Baramasi lemon with minimum acidity (4.85%). Maximum fruit yield (31.07kg/plant) and productivity (17.24 t/ha) was recorded in Assam lemon followed by Kagzi Kalan. Canker incidence was observed only in Assam lemon (with 37% disease incidence on leaves and PDI 7.3). Other cultivars (Pant lemon, Kagzi Kalan, Baramasi lemon) were found free from canker, while insect-pest incidence varied among cultivars.

Exotic mandarin varieties (planted on raised bed during 2015) showed better fruiting during this year. Average fruit weight (161.35 g) and acidity (1.35%) was recorded maximum in W. Murcott. Whereas, maximum TSS (8.30%) and juice content (55.65%) was recorded maximum in Daisy. Vit. C (44.12mg / 100 ml) content was maximum in Pearl Tangelo with minimum acidity. Maximum fruit yield was recorded in Pearl Tangelo i.e. 7.54 t/ha. Flame grapefruit and Frost Owari mandarin were planted (5 lines each) during August, 2015. Flame grapefruit variety recorded a mean canopy volume of 6.62 m^3, 2.62 m plant height while Frost Owari had 4.6 m^3 canopy volume with 2.5 m plant height.

In high density planting experiment with cv. Pramalini (seedling plants), 10 year old plants at 5x5 m recorded maximum canopy volume and stock girth. Plant height was higher with decrease in plant spacing and was highest in 2.5x 2.5 m spacing. Highest leaf N and P was recorded in 5x 2.5 m. Highest light interception was recorded at 2.5x2.5 m spacing indicating utilization of maximum PAR light and thus more yields. Fruit yield was 24.43 kg / plant and 39.09 t /ha at 2.5x2.5 m spacing (1600 plants / ha density) while at 5x5 m spacing (with density of 400 plants / ha) yield was 47.58 kg /plant and 19.03 t/ha. There was not much variation in fruit quality parameters between various spacings. Although citrus canker incidence was more at 2.5x2.5 m spacing, it could be managed with regular sprays of COC.

In another experiment, Nagpur mandarin on Rangpur lime rootstock (planted in 2012) recorded yield of 24.98 kg /plant at 3x1 m spacing (density of 3333 plants / ha) and on area basis yield of 83.28 t / ha. At conventional 6x6 m spacing, yield of 106.52 kg/plant was recorded, but on area basis it was 29.59 t/ha. Plantation at higher density produced fruits with little less TSS and higher acidity as compared lower plants density at to 6x6 m and 6x3 m spacing. This could probably be attributed to higher penetration of light within and around the canopy of plants at lower density with wider spacing (6x6 m and 6x3 m).

In acid lime "Kagzi" budded on Rangpur lime rootstock, the pattern of results was similar with low per plant yield at high density but very high yields on area basis. At 3x1 m spacing (density 3333 plants/ha) per plant yield was nearly 18 kg while on area basis it was more than 60 t / ha. There was not much difference in fruit quality parameters at different plant density. In another experiment on Nagpur mandarin with canopy architecture engineering, at 2x2 m spacing (density of 2500 plants / ha) with trellising support

to branches, yield was nearly 34 kg/plant but on area basis it was 86.42 t / ha.

Foliar application of 2, 4-D at lower concentrations on *Ambia* crop of Nagpur mandarin at flowering stage enhances the fruit retention, yield and physico-chemical parameter in Nagpur mandarin. Among all the concentrations 10 ppm of 2,4-D ethyl ester 38% EC showed desirable results in fruit yield parameters followed by 15 ppm of 2,4-D ethyl ester 38% EC and 10 ppm of 2,4-D amine salt 58% SL over other concentrations.

In the Precision citriculture through enhanced water and nutrient use efficiency in Nagpur mandarin, GPS-based sampling (soil samples and index leaves) was done and subsequently GIS-based variograms were developed for canopy volume (m^3) and fruit yield (kg/tree). Based on the biometric observations of plant canopy volume, the production management zones viz., High, Medium and Low were delineated and accordingly the drip irrigation and fertigation arrangement were scheduled. The mean number of fruits per plant, fruit weight and yield (t/ha) recorded in High production zone was 148.1 g and 8.91 t/ ha. The mean number of fruits per plant, fruit weight and yield (t/ha) recorded in Medium and Low production zones was 195, 143.1 g and 7.73 t/ha and 188, 121.2 g and 6.31 t/ha respectively.

For the development of INM-module for sustained productivity of citrus, optimum nutrient requirement of Mosambi sweet orange was standardized. The maximum fruit yield of 61.2 kg/tree (17.0 t/ha) was observed with treatment T_5 ($N_2P_2K_2$, 800g N – 200g P_2O_5-400g K_2O/tree). Highest juice content, TSS and TSS/acidity ratio were observed with the same treatment. A contract research project entitled Studies on Agrocel-based potassium schoenite (Mahalaabh) in citrus has been initiated. Initial results suggested that plants receiving with 100% of potassium schoenite through fertigation (T_5) showed higher vegetative growth response in terms of plant height (2.78 m), N-S spread (1.54 m) which is at par with treatment T_3), E-W spread (1.58 m), canopy volume (3.54 m^3) and fruit yield (59.27 kg/tree or 16.53 t/ha).

Further, one demonstration of CCRI technologies on rejuvenation of Khasi mandarin has been initiated at Umdenla-ang basti, Sohkhwai village of Umling Block, P.O. Nongpoh of Ri-Bhoi district since October, 2020.

Plant protection

Pest management modules developed for better management of fruit piercing moth (*Eudocima* spp), were validated at two different farmers field in Nagpur district during *Ambia* fruiting season at colour breaking stage. Module-III consisting of sachets of Acephate (@ 2/tree) + foliar application of Petroleum spray oil @ 2% at 10 days interval followed by Neem oil @ 1% and pongamia soap @ 2% was found effective in reducing the fruit drop due to fruit sucking moth during colour breaking stage (mid September / early October to second fortnight of November) effectively (60-70 % reduction).

Under HORTSAP project, a total of 3200 Bulk SMS were sent through mobile to the registered citrus growers for the management of citrus psylla, lemon butterfly, fruit piercing moth and fruit fly. Regular Pest advisories were also issued for the citrus growers through press notes in the local newspaper and WhatsApp messages. During the year, five field visits and several online lectures were delivered in five different training programme on identification and management of insect pests and diseases of Nagpur mandarin and sweet orange.

Pathogenicity assessment of *Heterorhabditis indica* against citrus fruit piercing moth, *Eudocima materna* under laboratory conditions indicated that *H. indica* strain was capable of infecting and killing 3rd, 4th and 5th larval

instars of *E. materna* with fewer IJs concentrations. Pupae of *E. materna* appeared susceptible to *H. indica*. However, fully developed pupae were less susceptible to EPN than 3rd, 4th and 5th instar larvae. Reproduction potential of *H. indica* in larval instars of *E. materna* indicated successful reproduction in the 3rd, 4th and 5th larval instars of *E. materna* and their offspring were emerged from the larval cadavers. Overall results showed that *H. indica* represents a potential biological agent that may be used in the control of fruit piercing moth in citrus orchards as well as on weed host, *T. cordifolia*. The different concentrations of IJs per larva tested in this study showed optimal results in laboratory tests.

For assessing citrus greening bacterium population diversity, a total number of 441 *Candidatus* Liberibacter asiaticus (CLas) positive DNA samples (isolates) from 18 citrus growing states of India were used for screening of prophage types. All possible eight combinations of the three known prophage types (Type 1, Type 2 and Type 3) were detected using different prophage-specific PCR markers. The highest 117 samples (26.50%) harboured only Type 1 prophage, followed by 90 samples (20.4%) of the combination Type 1 + Type 2 prophage and 83 samples (18.8%) showed only Type 2 prophage. The combinations of all the 3 prophages i. e. Type 1 + Type 2 + Type 3 were noticed in 50 samples (11.3%). The number of CLas isolates lacking all three prophages was found to be 19 (4.3%). All the probable eight combinations were found in the states of Karnataka, Telangana, Maharashtra and Madhya Pradesh. In the Western part of India, in the state of Gujarat, only Type 2 prophage was found. By detection of Type 1, Type 2 and Type 3 prophages, CLas populations from eighteen citrus growing states were separated into two major Prophage Typing Groups (PTG1 and PTG2), and five subgroups (PTG1-A, PTG1-B, PTG2-A, PTG2-B and PTG2-C). PCR-based detection method using the primer pair CRIF/CRIR identified a CRISPR (clustered regularly interspaced short palindromic repeats) region in all the 3 types of prophages (Type 1/2/3). Thirteen CLas field isolates sampled from 6 states were found to have a CRISPR element based on the PCR assays and subsequent sequence analysis. Further HLB CLas genomic variation was tested by double-locus (DL) analysis, representing a tandem repeat number locus (trn1) and the above single nucleotide polymorphism locus (snp1). A total of 293 CLas isolates from 16 citrus growing states were analyzed through DL genotyping. Results showed that 187 isolates belonged to the DL genotype 1, 5 isolates to DL genotype 2, 96 isolates DL genotype 3 and 5 isolates belonged to DL genotype 4. Analysis revealed the maximum existence of DL genotype 1 followed by DL genotype 3 in India.

Total 25 isolates of rhizobacteria were isolated and purified from citrus rhizospheric soil, and then used for performing *in vitro* confrontation assay against *Phytophthora nicotianae*. Out of 25 isolatess, 10 were found promising showing more than 50 % inhibition in the dual culture assay. During the year, 9 numbers of new fungal endophytes (CFE-154 – CFE-162) were isolated from rhizospheric roots of various citrus varieties including Nagpur mandarin and sweet orange. The fungal endophytes which were found to have potential against controlling *P. nicotianae* were CFE-154, CFE-157 and CFE-162. Maximum inhibition was found in case of CFE-154 (*Rhytidhysteron rufulum*).

A SYBR-Green based quantitative RT-PCR assay for the detection of Indian citrus ringspot virus (ICRSV) has been standardized and validated with 48 field samples among which 30 field samples were observed moderately to highly positive using RT-qPCR. ICRSV positive samples were also analyzed by RT-PCR using CP and nucleic acid binding gene-specific primers for further authentication of developed RT-q PRC technique. Molecular detection and characterization of CLas and Citrus tristeza virus (CTV) isolates from Bhutan was also done. A total of fifty-one samples collected from the different citrus growing

regions of Bhutan were tested by PCR with CLas specific OI1/OI2c primer set and 14 samples were found positive. Similarly, coat protein Bhutanese CTV isolates were characterized based on sequences of p25 gene. The constructed phylogenetic tree with 1000 bootstrap value based on p25 in gene of 12 Bhutanese CTV isolates, revealed that nine Bhutanese isolates belonged to Genogroup III along with CTV isolates from Meghalaya and Andhra Pradesh state of India. 2S albumin protein has been isolated and purified from the seeds of pumpkin (*Cucurbita maxima*) and the effective antimicrobial concentration was determined based on in vitro experimental data against E. coli (DH5α). Virtual screening technique was used to identify a potential inhibitor molecules against putative cystine-binding protein from *Candidatus* Liberibacter asiaticus.

Based on the morphological characters, different plant parasitic nematode genera viz., *Tylenchulus semipenetrans, Pratylenchus, Helicotylenchus* and *Hoplolaimus* were identified in Nagpur mandarin growing areas of Vidarbha region of Maharashtra. The consolidated analysis from four locations showed that, amongst the plant parasitic nematodes, *T. semipenetrans* and *Pratylenchus* sp. were highly abundant (100%) followed by *Helicotylenchus* sp. (75%) and *Hoplolaimus* sp. (50%).

Post-harvest management and Value addition

Polysaccharide based edible coatings i.e. Carboxylmethyl cellulose and Methyl cellulose with glycerol recorded maximum juice recovery, lower PLW and better retention of vitamin C content in Nagpur mandarin during 21 days of storage under ambient condition. Nagpur mandarin fruits treated with fungicide Amistar @1000 ppm with Shellac coating and polythene liner retained better fruit quality. Nagpur mandarin juice thermo-sonicated at 55°C for 20 min and 60°C for 15 min showed better results in terms of limonin content, antioxidant activity and lower PME activity. Four technologies were developed viz., Osmotically dehydrated segments of Nagpur mandarin and Sweet orange, low calorie Santra Barfi and Ice-cream from Nagpur mandarin. Limonin content was 11.38 and 9.19 ppm in the juice of *Citrus indica* and a probable citrus hybrid, respectively. Total phenol content in juice (17.288 mg $GAEL^{-1}$) was higher in a probable hybrid. *Citrus indica* juice recorded 6.071 mg $GAEL^{-1}$ total phenols. Antioxidant potential was found higher in peel of *Citrus indica* by ABTS (6.65 $mmolL^{-1}$ trolox) and DPPH (8.60 $mmolL^{-1}$ trolox) assays and higher in peel of a probable hybrid by FRAP (4.65 $mmolL^{-1}$ trolox) assay. An attempt was made for the first time to assess the organic acids in citrus wild varieties juice of *Citrus jambhiri* and Citron. The main organic acids found were citric and malic acids while tartaric, benzoic, oxalic and succinic acids were in trace amounts.

Social Science

The perception of farmers regarding adopted technologies of ICAR-CCRI was measured using a Likert type perception scale developed for the purpose. Also the relative relationship between different income levels of farmers and their age of orchard and also contact with the Institute was explored using Correspondence Analysis (CA). The technique of Classification and Regression Tree (CART) was used to classify respondents into mutually exclusive and exhaustive sub-groups based on the dependent variable of income generated from citrus cultivation. Those farmers who had purchased planting materials from ICAR-CCRI, cited trustworthiness, brand value, longevity of orchards, less disease attacks as reasons behind their decision. Overall it was established that the most productive age of citrus plants on an average was 11-15 years and higher income was associated with contact with the Institute for guidance on citrus cultivation techniques.

Regional Research Centre for Citrus, Biswanath Chariali, Assam

Newly introduced varieties of sweet orange viz., Trovita, Delta, Saluatiana, Diller were planted as a new block on raised-bed planting system during November, 2020.

The evaluation of different commercial *Citrus* spp. on raised bed and flat bed systems was initiated during August 2017 with 13 different citrus varieties budded on rough lemon rootstock and planted at 5x3 m spacing. All the cultivars were showing excellent growth performance on both the planting systems and measurements of each cultivar showed the good plant heights, stock scion girth and canopy spread. Among mandarins, maximum plant height (4.77 m) was recorded in Nagpur mandarin (STG) followed by Khasi mandarin seedling (4.54 m) on raised-bed compared to flat bed (4.72 m, 4.45 m). Among sweet oranges, higher plant height was noted in Cutter Valencia (4.33 m) on raised-bed compared to flat bed (4.28 m) and similarly, canopy volume also was recorded maximum in Cutter Valencia (27.02 m^3) on raised-bed system. In Flame grapefruit maximum plant height was recorded on raised-bed (3.57 m) as compared to the flat system (3.35 m) as well as canopy spread was also recorded maximum on raised bed (21.36 m^3) compared to the flat bed (20.29 m^3). Among the sweet orange cultivars maximum average fruit weight was found in Mosambi (212.33 g) on raised-bed planting system; maximum juice content was recorded in Natal on raised-bed and flat bed (49.02% and 33.20%, respectively).

Three posts of scientists were sanctioned, recruited one Young Professional (YP-II) and constructed farm building and tractor shed at this new regional research centre.

Planting material produced

Under Institute nursery programme 1.92 lakhs disease-free planting material of citrus and 10 kg seeds of rough lemon were sold and revenue of Rs. 1,30,62,566 was generated.

Resource generation

Institute generated revenue of Rs. 24,74,011/- through sale of fruit and other products. Revenue including interests on FDs, fees, sale of publication and other sources was Rs. 16,60,891/-. Therefore, total revenue was Rs. 1,71,97,468/- during calendar year 2020.

Training /Skill development and Extension

Institute organized 10 trainings which included 1 training under Tribal Sub-Plan in NEH region and 2 trainings under SC Sub-Plan.

Important events organized by the institute

"National Citrus Meet-2020" was organized during 10-12, January 2020 at RRCC, Assam. International Women's Day was celebrated on 8th March, 2020. The following programmes were also organized: 130th Birth Anniversary of Dr. Bhimrao Ambedkar on 14th April, 2020; 36th Foundation day of CCRI on 28th July, 2020; Independence Day on 15thAugust, 2020; Hindi Saptaha during 14-21 September, 2020; "Krishi Samwad" programme on 7th October, 2020; 150th Birth Anniversary of Mahatma Gandhi on 2nd October, 2020; Dr. B. R. Ambedkar Maha Parinirvan Diwas on 6th December, 2020 and "Swachhata Pakhwada" from 16-31 December, 2020. The live telecast programme of PM Kisan Samman Nidhi was organized on 25th December, 2020 at the Institute.

On a study tour parliamentary standing committee on Agriculture consisting of ten members of parliament (Lok Sabha and Rajya Sabha) visited the Institute on 24th January, 2020.

Technologies commercialized

Signed MoU between ICAR-CCRI, Nagpur and M/s . Karunamaya Agrotech, Nagpur. (As incubatee under 'ABI' Project) for "High-tech nursery management for production of disease-free planting material in citrus" on 15th September, 2020.

Awards and recognition

During 2020, Dr. A. K. Srivastava, Pr. Scientist received Honorary Fellow of Society for Biotic and Environmental Research, Tripura; Outstanding Scientist Award in 9th International Scientist Awards on Engineering, Science and Medicine by V Dhood association, Trichy; Honorary Fellow of SHRD-2018 in Indian Horticulture Summit-2020; visiting scientist at Agricultural Research, Education and Extension Organization, Ministry of Agriculture, Tehran, Iran and Member, Editorial Board, Notulae Scientia Biologica, Romanian Academy of Science, Romania. Dr. A. K. Das, Pr. Scientist recognized as DBT representative for the Institutional Biosafety Committee (IBSC) at CSIR-NEERI, Nagpur and also at ICAR- CICR, Nagpur. Dr. G. T. Behere, Pr. Scientist received Scientist Award - 2020 by Dr. B. Vasantharaj David Foundation, Chennai. Dr. A. Thirugnanavel, Scientist received Best Poster Award at International Conference on Banana-2020. Dr. Anjitha George, Scientist received Young Scientist Award by Society for Biotic and Environmental Research, Tripura and also Young Scientists Award - 2020 by Dr. B. Vasantharaj David Foundation, Chennai. Dr. Kiran Kommu, Scientist received International Best Scientist Award in Crop Protection (Agri.) by RULA. Besides this the scientists have been recognized at various international and national forums.

वर्ष 2020 के दौरान, भा.कृ.अनु.प.-केन्द्रीय नीबूवर्गीय फल अनुसंधान संस्थान ने नागपुर के साथ-साथ बिश्वनाथ चरिआली, असम में नीबूवर्गीय वृक्षारोपण का विस्तार किया तथा विभिन्न बहु-विषयक परियोजनाओं (संस्थान एवं बाह्य वित्त पोषित), प्रशिक्षण द्वारा तकनीकी प्रसार, दौरा, प्रदर्शनी और प्रौद्योगिकी व्यवसायीकरण द्वारा अपने अनुसंधान कार्यक्रमों का निष्पादन कर सर्वांगीण प्रगती की है।

अनुसंधान उपलब्धियां

नीबूवर्गीय आनुवंशिक संसाधन और सुधार

आनुवंशिक संसाधन आधार और विविधता को मजबूत करने के लिए मोसंबी की पांच नई किस्में जैसे डिलर, कारा-कारा, ट्रोविटा स्ट्रेन, डेल्टा, सालुस्टियाना और लेमन की आठ किस्में जिनमें जेनोआ, फ्रॉस्ट लिस्बन, लिमोनेरो फिनो, वर्ना, लिमोनेरो फिनो (आईवीआईए 95), फ्रॉस्ट यूरेका, विलाफ्रैंका न्यूसेलर, बियर्स संस्थान में लगाए गए।

नीबू के पैंतालीस प्रजातियों का मूल्यांकन किया गया जिनमें आईसी-285422, आईसी-322098 और आईसी-342350 में सबसे अधिक वजन (क्रमशः 45.85 ग्राम, 44.45 ग्राम और 45.48 ग्राम), अधिकतम रस (क्रमशः 51.24 प्रतिशत, 52.85 प्रतिशत, और 51.64 प्रतिशत) के साथ अधिकतम उपज (क्रमशः 51.12, 52.25, 53.72 टन/हेक्टेयर) दर्ज की गई और नीबू के एक अन्य मूल्यांकन परीक्षण में तेरह आशाजनक नीबू क्लोन शामिल थे जिनमें से केएल-12 (52.8 ग्राम) और केएल-21 (53.13 ग्राम) ने अधिकतम फल वजन दर्ज किया जबकि अधिकतम रस मात्रा केएल-23 (47.9 प्रतिशत) में और अधिकतम उपज केएल-12 (52.12 टन/हे.) में दर्ज की गई।

मूल्यांकन किए गए 17 नागपुरी संतरा क्लोनों के 2014 से 2019 तक एकत्रित डेटा के विश्लेषण से पता चला कि एन-3 को छोड़कर सभी क्लोन उपज में समतुल्य पाये गये और एक क्लोन एन-4 व्यवसायिक रूप से बीज रहित पाया गया। दार्जिलिंग संतरा के क्लोनों में सबसे अधिक फल वजन (151 ग्राम) और उपज डीएम-11 (18.56 टन/हेक्टेयर) में दर्ज की गई और अधिकतम रस मात्रा डीएम-13 (43.16 प्रतिशत) में पाई गई। उत्कृष्ठ सिक्किम संतरा के मूल्यांकन आंकड़ों से पता चला कि अधिकतम फल भार एसएम -7 (154 ग्राम) में और अधिकतम फलोत्पादन एसएम -8 (19.12 टन/हेक्टेयर) और एसएम -7 (18.6 टन/हेक्टेयर) में दर्ज की गई। मोसंबी के क्लोनों में, टीएम-33 में अधिकतम फल भार (183.12 ग्राम), रस की मात्रा (37.65 प्रतिशत) और फलोत्पादन (21.25 टन/हेक्टेयर) दर्ज की गई। उसी प्रकार उत्कृष्ठ पमेलो क्लोनों पी-3 में अधिकतम फल भार (1027 ग्राम) और अधिकतम फलोत्पादन पी-5 (80.25 टन/हे.) में पायी गई। ऑन-साइट डीयूएस परीक्षण के तहत, अनुरक्षण प्रजनन के लिये लगाये गये चार नीबू ,चार संतरे और चार मोसंबी किस्मों पर अवलोकन दर्ज किए गए।

मोसंबी की छह विदेशी किस्मों को रफ लेमन मूलवृन्त पर इन विट्रो शूट टिप ग्राफ्टेड की गई जिसमें अधिकतम सफलता नटाल (42.09 प्रतिशत) में पायी गई। स्वचतुषगुणित (ऑटोटेट्राप्लोइडी) को चार मूलवृन्त, एलिमो, रंगपुर लाईम, एसएफएस और स्वीट लाईम में कोल्चीसिन का उपयोग करके प्रेरित किया गया। स्क्रीन हाउस में रोपण के बाद जीवित रहने का प्रतिशत रंगपूर लाईम (4.62 प्रतिशत) में सबसे अधिक और एलिमो (12.1 प्रतिशत) में अधिकतम रूपात्मक भिन्नता देखी गई। नीबूवर्गीय नवपल्लव में स्वचतुषगुणित (ऑटोटेट्राप्लोइडी) प्रेरण पर आकड़ों से पता चला है कि यूएस-145 पमेलो (51.76 प्रतिशत) में सबसे अधिक जीवितता देखी गई और 24 घंटे के लिए 0.1 प्रतिशत कोल्चीसिन के साथ उपचारित अन्वेषकों ने सबसे अच्छे परिणाम दिए।

भ्रूणपोष के माध्यम से नागपुरी संतरा, मोसंबी और किन्नो में त्रिगुणित (ट्रिपलोइडी) को प्रेरित किया गया। किन्नो में उच्च कैलस प्रेरण देखा गया और उच्चतम भ्रूणजनन 2,4-डी (2मिली ग्राम प्रति ली.) और बीए (5मिली ग्राम प्रति लीटर) के पूरक एमटी + सीएच माध्यम में प्राप्त किया गया। एमटी + बीए (0.25 मिली ग्राम प्रति ली.) + सीएच (500 मिली ग्राम प्रति ली.) + जीए3 (1 मिली ग्राम प्रति ली.) माध्यम में अधिकतम संख्या में बीजपत्रीय भ्रूणपोष उत्पादित हुआ। भ्रूणपोष से पौधों का कुशल पुनर्जनन और अधिक संख्या में त्रिगुणित एमटी + सीएच (500 मिलीग्राम) +2,4-डी (2 मिलीग्राम) तदोपरांत एमटी + सीएच +2,4-डी + बीए से प्राप्त हुये।

45 ईंडेल मार्करों का उपयोग करके 66 नीबू और 15 लेमन प्रजातियों के आणविक लक्षणों की पहचान की गई। 45 मार्करों में 27 और 24 क्रमशः नीबू और लाईम में बहुरूपी पाये गये। बहुरूपी सूचना सामग्री (पीआईसी) 0.0 से 0.51 के बीच 0.16 माध्य के साथ नीबू के लिए और लाईम के लिए 0.0 से 0.53 के बीच 0.24 माध्य के साथ दर्ज की गयी। इस आनुवंशिक विविधता की जानकारी का उपयोग नीबू और लेमन के सुधार के लिए किया जाएगा।

नवपल्लव और मूलवृन्त के अनुवांशिक सुधार के लिए पारंपरिक और उत्परिवर्तन प्रजनन का प्रयास किया गया। प्रजाति सुधार कार्यक्रम में, नीबू समूह से 874 वंशज, मोसंबी समूह से 27 वंशज,पमेलो एवं ग्रेपफ्रूट समूह से 420 वंशज प्राप्त किये गये। नीबूवर्गीय मूलवृन्त सुधार कार्यक्रम में कुल 228 वंशजों को प्राथमिक नर्सरी में स्थानांतरित किया गया। उत्परिवर्तन प्रजनन कार्यक्रम में दो पमेलो उत्परिवर्ती (5जीवाई), दो मोसंबी उत्परिवर्ती (5जीवाई), एक किन्नो उत्परिवर्ती (40जीवाई), एक नीबू एनआरसीसी-7 और एक नागपुरी संतरा एन.-74 उत्परिवर्ती में बीजहीनता देखी गई।

फसल और संसाधन प्रबंधन

संकर मूलवृन्त (एनआरसीसी-2,3,4 और 5) पर अध्ययन से पता चला है कि एनआरसीसी-5 मूलवृन्त में नागपुरी संतरे की उपज अधिकतम (15.43 किलोग्राम प्रति पौधा) पाई गई। फलों की गुणवत्ता के मानकों ने रफ लेमन की तुलना में संकर मूलवृन्त पर अधिक भिन्नता का संकेत नहीं दिया। नागपुरी संतरे के प्रदर्शन पर रंगपुर लाईम और रफ लेमन मूलवृन्त का प्रभाव 6×3 मीटर, 6×4 मीटर, 6×5 मीटर, 6×6 मीटर की दूरी पर मूल्यांकन किया गया। 6×3 मीटर की दूरी में रफ लेमन और रंगपुर लाईम मूलवृन्त पर क्षेत्र के आधार पर अधिकतम उत्पादन क्रमश: 41.6 टन प्रति हेक्टेयर और 40.5 टन प्रति हेक्टेयर दर्ज की गई।

रफ लेमन मूलवृन्त पर उच्च घनत्व के तहत मेढ़ प्रणाली में लगाये गये नागपुरी संतरे में अधिकतम छत्र आयतन 31.91 घन मीटर 5×4 मीटर की दूरी पर और 4.5×4.5 मीटर दूरी पर 29.05 घन मीटर 6 साल के बाद दर्ज किया गया। अधिकतम फल उपज 32.54 किग्रा प्रति पौधा 5×4.5 मीटर की दूरी में दर्ज की गई। उच्च घनत्व पर कीटों की संख्या सामान्य रूप से अधिक पायी गयी। नागपुरी संतरे का मूल्यांकन एलीमो (सी. मैक्रोफिला) मूलवृन्त पर मेढ़ प्रणाली पर 6×3 मीटर और 6×6 मीटर की दूरी पर वर्ष 2014 के दौरान लगाया गया। 6×3 मीटर की दूरी पर लगाए गए पौधों में अच्छी ऊंचाई 4.10 मीटर और बेहतर छत्र घनत्व 20.17 घन मीटर प्रदर्शित किया। 6×3 मीटर की दूरी पर लगाये गये पौधों में फलोत्पादन 22.78 किग्रा प्रति पौधा और क्षेत्रफल के आधार पर 12.64 टन प्रति हेक्टेयर देखी गई। मेढ़ के बीच में अंतर-फसल के रुप में सब्जियां (बैंगन, भिंडी, टमाटर) और गेंदा फूलों को लगाकर सफलता पूर्वक फसल ली गई।

6 वर्ष पहले लगाये गये पंजाब के विभिन्न प्रजातियों में पाईनएप्पल मोसंबी में अच्छी उंचाई (3.73 मीटर) जबकि ब्लड रेड में अच्छा छत्र आयतन (19.96 घन मीटर) देखा गया। ग्रेपफ्रूट किस्म मार्स बिजरहित में अधिकतम ऊंचाई (4.28 मीटर) और छत्र आयतन (27.63 घन मीटर) तदोपरांत स्टार रूबी में दर्ज की गई। विभिन्न मोसंबी प्रजाती में अधिकतम फलोत्पादन (25.62 किलोग्राम प्रति पौधा) ब्लड रेड में तदोपरांत जाफा में (21.03 किलोग्राम प्रति पौधा) दर्ज की गई, जबकि न्यूनतम फलत (12.75 किलोग्राम प्रति पौधा) काटोल गोल्ड में पायी गई। मार्स बिजरहित ग्रेपफ्रूट प्रजाती में औसत फल भार (461.26 ग्राम), अधिकतम अम्लियता (0.45 प्रतिशत) और विटामिन सी की मात्रा 42.20 मि.ग्राम प्रति 100 ग्राम पाया गया।

ब्राजील से लाये गये मोसंबी किस्म हेमलिन (वोल्कामरीना पर कलमित) जिसे वर्ष 2014 में मेढ़ पर लगाया गया, में अधिकतम ऊंचाई 3.73 मीटर और छत्र आयतन 17.51 घन मीटर पाया गया। औसत अधिकतम उपज (14.41किग्रा प्रति पौधा) लिमोक्रोवा पर कलमित पेरा में और उसके बाद स्विंगल पर कलमित वेस्टिन (13.82 किग्रा प्रति पौधा) में दर्ज की गई। रफ लेमन पर कलमित लैनलेट में अधिकतम फल भार (272.1 ग्राम) दर्ज किया गया। अधिकतम रस मात्रा (43.90 प्रतिशत) और विटामिन सी (45.30मि.ग्रा. प्रति100मि.ग्रा.) वोल्केमेरियाना पर कलमित वेलेंसिया में दर्ज की गई, इसके बाद लिमोक्रोवा पर कलमित पेरा में रस की मात्रा (42.36 प्रतिशत) दर्ज की गई। जबकि, अधिकतम कुल घुलनशील ठोस रफ लेमन पर कलमित मोसंबी में सबसे ज्यादा, उसके बाद रंगपुर लाईम पर कलमित मोसंबी में (11.67 प्रतिशत) दर्ज किया गया। वोल्केमेरियाना पर कलमित हैमलिन में अधिकतम दानेदारिता 95 प्रतिशत तदोपरांत क्लियोपेट्रा पर कलमित हैमलिन में 90प्रतिशत दिसंबर के महीने में पायी गई। लिमोक्रोवा और वोल्केमेरियाना पर कलमित पेरा लिमोक्रोवा और वोल्कमेरियाना पर कलमित नटाल वोल्कमेरियाना पर कलमित वेलेंसिया लिमोक्रोवा पर कलमित वेस्टिन में दानेदारिता नहीं देखी गयी।

वर्ष 2015 के दौरान मेढ़ पर लगाए गए नीबू की 10 किस्मों में, साई शरबती में अधिकतम छत्र आयतन (18.80घन मीटर), जबकि न्यूनतम छत्र आयतन (5.15घन मीटर) चक्रधर में दर्ज की गयी। एनआरसीसी-7 और एनआरसीसी-8 में छत्र आयतन क्रमश: 4.19 और 8.02 घन मीटर दर्ज की गई। अधिकतम फलोत्पादन पीकेएम-1 में 10.37 टन प्रति हेक्टेयर जबकि विक्रम में न्यूनतम फलोत्पादन 0.99 टन प्रति हेक्टेयर दर्ज की गई। वर्ष 2016 में मेढ़ पर लगाये गये रफ लेमन पर कलमित असम लेमन में न्यूनतम औसत फल भार (170.60ग्राम), अधिकतम अम्लता (6.40प्रतिशत) न्यूनतम कुल घुलनशील ठोस (7.58 प्रतिशत) के साथ रस की मात्रा 43.06 प्रतिशत और विटामिन सी की मात्रा 37.06 मिलीग्राम प्रति 100 ग्राम के साथ दर्ज की गई। जबकी अधिकतम रस की मात्रा (52.71प्रतिशत) और विटामिन सी (48.48 मिलीग्राम/100ग्राम) न्यूनतम अम्लता (4.85प्रतिशत) के साथ बारामासी लेमन में देखा गया। असम लेमन में अधिकतम फलोत्पादन (31.07 किग्रा प्रति पौधा) और उत्पादकता (17.24 टन प्रति हेक्टेयर) दर्ज की गई और उसके बाद कागजी कलान का स्थान रहा। कैंकर रोग प्रकोप केवल असम लेमन के पत्तियों पर 37 प्रतिशत और प्रतिशत रोग सूचकांक 7.3 पाया गया। अन्य किस्मों जिनमें पंत लेमन, कागजी कलान, बारामासी लेमन को कैंकर रोग से मुक्त पाया गया, जबकि कीड़े-मकोड़ों के प्रकोप में भिन्नता देखी गई।

वर्ष 2015 के दौरान मेढ़ पर विदेशी संतरा प्रजातियों को लगाया गया था जिसमें इस वर्ष अच्छा फलोत्पादन प्राप्त हुआ। डब्लू मरकॉट में फलों का अधिकतम भार (161.35 ग्राम) और अम्लियता 1.35 प्रतिशत दर्ज की गई जबकि डेजी में अधिकतम कुल घुलनशील ठोस 8.30 प्रतिशत और अधिकतम रस की मात्रा 55.65 प्रतिशत दर्ज की गई। पर्ल टेंजिलो में अधिकतम विटामिन सी की मात्रा (44.12 मिलीग्राम प्रति 100 ग्राम), न्यूनतम अम्लता के साथ दर्ज की गयी। पर्ल टेंजेलो में अधिकतम फलोत्पादन 7.54 टन प्रति हेक्टेयर दर्ज की गयी। अगस्त, 2015 के दौरान फ्लेम ग्रेपफ्रूट और फ्रॉस्ट ओवरी मैंडरिन (प्रत्येक में 5 लाइनें) लगाए गए थे। फ्लेम ग्रेपफ्रूट प्रजाति में औसत छत्र आयतन 6.62 घन मीटर, पौध ऊँचाई 2.62 मीटर दर्ज की गई, जबकि फ्रॉस्ट ओवरी में पौधे की ऊँचाई 2.5 मी के साथ छत्र आयतन 4.6 घन मीटर दर्ज की गई।

उच्च घनत्व रोपण पद्धति में अध्ययन के दौरान 10 वर्ष पुराने प्रमालिनी नीबू में अधिकतम छत्र आयतन और तने की मोटाई 5×5 मीटर दूरी पर दर्ज की गयी। पौधों के बीच की दूरी में कमी के साथ-साथ पौधौं की ऊंचाई बढते क्रम में 2.5×2.5 मीटर की दूरी पर अधिकतम पायी गयी। अधिकतम पर्ण नत्रजन एवं फास्फोरस की मात्रा 5×2.5 मीटर दूरी पर देखी गयी। अधिकतम प्रकाश अवरोधन 2.5×2.5 मीटर की दूरी पर दर्ज किया गया जिसमें पौधों द्वारा अधिकतम प्रकाश संश्लेषण उर्जा का उपयोग हुआ और अधिक फलोत्पादन प्राप्त हुआ। 2.5×2.5 मीटर की दूरी (1600 पौधे/हेक्टेयर घनत्व) पर फलोत्पादन 24.43 किलोग्राम प्रति पौधा और 39.09 टन प्रति हेक्टेयर जबकि 5×5 मीटर की दूरी (400पौधे/हेक्टेयर के घनत्व के साथ) फलोत्पादन 47.58 किलोग्राम प्रति पौधा और 19.03 टन प्रति हेक्टेयर पाया गया। विभिन्न अंतराल में पौधों को लगाने से फलों की गुणवत्ता के मानकों में अधिक अंतर नहीं पाया गया, हालांकि सीट्रस कैंकर का प्रकोप 2.5×2.5 मीटर की दूरी पर अधिक पाया गया, परंतु इसका प्रबंधन कॉपर ऑक्सीक्लोराईड के नियमित छिड़काव से किया जा सकता है।

एक अन्य प्रयोग में रंगपुर लाईम पर कलमित नागपुरी संतरा में (2012 में रोपित) 3×1 मीटर की दूरी पर (3333 पौधों प्रति हेक्टेयर की घनत्व) उपज 24.98 किलोग्राम प्रति पौधे और 83.28 टन प्रति हेक्टेयर पाया गया। परंपरागत 6×6 मीटर दूरी पर फलोत्पादन 106.52 किलोग्राम प्रति पौधा लेकिन क्षेत्रफल के आधार पर यह 29.59 टन प्रति हेक्टेयर पाया गया। 6×6 मीटर और 6×3 मीटर पर लगाये गये पौधों के तुलना में उच्च घनत्व वाले फलों में कुल घुलनशील ठोस में कमी और अधिक अम्लियता पाई गयी। यह संभवत: व्यापक दूरी (6×6 मीटर और 6×3 मीटर) पर लगाये पौधों के छत्र में अधिक रोशनी पहुंचने के कारण हो सकता है।

रंगपुर लाईम मूलवृन्त पर कलमित कागजी नीबू में इसी तरह के परिणाम देखे गये, जिसमें उच्च घनत्व पद्धति में प्रति पौधा कम उत्पादन लेकिन क्षेत्र के आधार पर अत्यधिक फलोत्पादन पाया गया। 3×1 मीटर की दूरी में (3333 पौधा प्रति हेक्टेयर) प्रति पौधा उत्पादन लगभग 18 किलोग्राम जबकि क्षेत्रफल के आधार पर यह 60 टन प्रति हेक्टेयर से अधिक पाया गया। विभिन्न घनत्व पर फलों की गुणवत्ता में कोई विशेष अंतर नहीं पाया गया। एक अन्य प्रयोग में 2×2 मीटर की दूरी (2500 पौधे प्रति हेक्टेयर) पर नागपुरी संतरे में छत्र प्रबंधन के साथ फलोत्पादन लगभग 34 किलोग्राम प्रति पौधा और क्षेत्रफल के आधार पर 86.42 टन प्रति हेक्टेयर पाया गया।

नागपुरी संतरे की अंबिया फसल पर बहार आने की अवस्था में 2,4-डी का कम सांद्रता पर पत्तियों पर छिड़काव करने से नागपुरी संतरे में फल धारण, उपज और भौतिक-रासायनिक मापदंडों को बढ़ाता है। सभी सांद्रताओं में 2,4-डी ईल एस्टर 38 प्रतिशत ईसी के 10 पीपीएम ने फल उपज मापदंडों में वांछनीय परिणाम दिखाए, इसके बाद 2,4-डी एथिल एस्टर 38 प्रतिशत ईसी के 15 पीपीएम और अन्य सांद्रता पर 2,4-डी अमिनो साल्ट 58 प्रतिशत एसएल के 10 पीपीएम ने अच्छे परिणाम दिखाये।

नागपुरी संतरे की उन्नत बागवानी के लिये पानी और पोषक तत्वों के उपयोग की क्षमता को बढ़ाकर, जीपीएस आधारित नमूने (मिट्टी और पत्ती के नमूने) एकत्रित कर जीआईएस आधारित वेरियोग्राम छत्र आयतन मात्रा (घन मिटर) और फलोत्पादन (किलोग्राम प्रति पौधा) के लिए विकसित किए गए। पौधों के छत्र आयतन बायोमेट्रिक अवलोकनों पर आधारित उत्पादन प्रबंधन क्षेत्र जैसे न्यूनतम, सामान्य और उच्च निरुपित कर उसके अनुसार बुंद-बुंद सिंचाई और उर्वरकिकरण व्यवस्था निर्धारित की गई। उच्च उत्पादन क्षेत्र में औसत फल संख्या प्रति पौधा, फल भार और फलोत्पादन (टन प्रति हेक्टेयर) क्रमश: 148.1 ग्राम और 8.91 टन प्रति हेक्टेयर दर्ज की गयी। मध्यम और न्यूनतम उत्पादन क्षेत्रों में प्रति पौधा फलों की औसत संख्या, फलों का वजन और उपज (टन प्रति हेक्टेयर), जो क्रमश: 195,143.1 ग्राम और 7.73 टन/हेक्टेयर और 188,121.2 ग्राम और 6.31टन/हेक्टेयर दर्ज की गई।

नीबूवर्गीय फलों के निरंतर उत्पादकता के लिए एकीकृत पोषक प्रबंधन मॉड्यूल को विकसित किया गया और मोसंबी स्वीट ऑरेंज के लिये सर्वोत्तम पोषक तत्वों की आवश्यकता को मानकीकृत किया गया। उपचार टी-5 (800 ग्राम नत्रजन,200 ग्राम फास्फेट,400 ग्राम पोटाश प्रति पौधा) द्वारा अधिकतम फलोत्पादन 61.2 किग्रा प्रति पेड़ (17.0 टन प्रति हेक्टेयर) देखा गया। अधिकतम रस मात्रा, कुल घुलनशील ठोस और अम्लता अनुपात उसी उपचार में देखा गया। नीबूवर्गीय फलों में एग्रोसेल-आधारित पोटेशियम सोहनाईड (महालाभ) के अध्ययन पर एक अनुबंध अनुसंधान परियोजना शुरू की गई है। प्रारंभिक परिणाम से पता चलता है कि (टी5) उर्वरकीकरण माध्यम से 100 प्रतिशत पोटेशियम सोहनाईड से उपचारित पौधों में पौध ऊंचाई (2.78 मीटर), उत्तर-दक्षिण प्रसार (1.54 मीटर जो उपचार टी3 के बराबर है), पूर्व पश्चिम प्रसार (1.58) के संदर्भ में उच्च वनस्पति विकास प्रतिक्रिया, छत्र आयतन (3.54 घन मीटर) और फलों की उपज (59.27 किग्रा प्रति पेड़ या 16.53 टन प्रति हे.) देखी गयी।

इसके अलावा, खासी संतरा बागान के पुर्नोद्धार के लिये संस्थान की एक तकनीकी का प्रदर्शन अक्टूबर, 2020 से उमडेनला-अंगबस्ती, गांव सोखवई, ब्लॉक उमलिंग, पोस्ट नोंगपोह, जिला री-भोई में शुरू किया गया है।

पौध सुरक्षा

नागपुरी संतरा के फल छेदक मॉथ (*यूडोसिमा स्पीसीज़*) के बेहतर प्रबंधन के लिए कीट प्रबंधन मॉड्यूल विकसित किये गये, जिसका अंबिया बहार के दौरान रंग बदलाव की अवस्था में नागपुर जिले के दो अलग-अलग किसानों के खेतों में

मूल्यांकन किया गया। सितंबर/अक्टूबर की शुरुआत से नवंबर के दूसरे पखवाड़े के दौरान मॉड्यूल-I।। में एसिफेट (2 पाउच प्रति पेड़)+ पेट्रोलियम आईल 2 प्रतिशत की दर से 10 दिनों के अंतराल में पत्ते पर छिड़काव के बाद नीम तेल 1प्रतिशत की दर से और पोंगामिया साबुन 2 प्रतिशत की दर से उपयोग कर फल चूसने वाले कीट के कारण फल गिरने की समस्या को 60-70 प्रतिशत तक कम किया जा सकता है।

उद्यानिकी कीट निगरानी एवं सुझाव परियोजना (हॉर्टसेप) के अंतर्गत पंजीकृत नीबूवर्गीय फलोत्पादकों को सिट्रस सिल्ला, लेमन बटरफ्लाई, फल छेदक मॉथ और फल मक्खी के प्रबंधन के लिए मोबाइल के माध्यम से कुल 3200 एसएमएस भेजे गए। स्थानीय समाचार पत्रों में प्रेस नोट और व्हाट्सएप संदेशों के माध्यम से नीबूवर्गीय फलोत्पादकों के लिए नियमित कीट नियंत्रण सलाह भी जारी की गई। वर्ष के दौरान, नागपुरी संतरा और मोसंबी के कीटों एवं रोगों की पहचान और उनके प्रबंधन पर पांच अलग-अलग प्रक्षेत्रों में प्रशिक्षण कार्यक्रमों का आयोजन तथा कई ऑनलाइन व्याख्यान दिए गए।

नीबूवर्गीय फल छेदक मॉथ, *यूडोसीमा मेटरना* के विरूद्ध प्रयोगशाला में *हेटेरोरेबडेटिस इंडिका* के रोगजनकता मूल्यांकन ने संकेत दिया कि *एच. इंडिका स्ट्रेन* कम आईजेएस सांद्रता में *युडोसिमा मेटरना* के तीसरे, चौथे और पांचवें लार्वा को संक्रमित कर मारने में सक्षम पाया गया। *ई. मेटरना* का प्यूपा *एच. इंडिका* के प्रति संवेदनशील पाया गया, हालांकि, तीसरे, चौथे और पांचवें इंस्टार लार्वा अवस्था की तुलना में पूरी तरह से विकसित प्यूपा ईपीएन के प्रति कम संवेदनशील पाये गये। *ई. मेटरना* के लार्वा अवस्था में *एच. इंडिका* की प्रजनन क्षमता ई. मेटरना के तीसरे, चौथे और पांचवें लार्वा अवस्था में सफल प्रजनन का संकेत देती है और उनकी संतान लार्वा मृत अवशेष से निकली थी। समग्र परिणामों से पता चला है कि *एच. इंडिका* एक संभावित जैविक एजेंट का प्रतिनिधित्व करता है जिसका उपयोग नीबूवर्गीय फलों के फल छेदक मॉथ के नियंत्रण के साथ-साथ खरपतवार पर स्थित *टी. कॉर्डिफोलिया* पर भी किया जा सकता है। इस अध्ययन में परीक्षण किए गए प्रति लार्वा आईजेएस की विभिन्न सांद्रता ने प्रयोगशाला परीक्षणों में उत्कृष्ट परिणाम दिखाए।

सिट्रस ग्रीनिंग जीवाणु जनसंख्या विविधता का आकलन करने के लिए, भारत के 18 नीबूवर्गीय फलोत्पादक राज्यों से कुल 441 *कैंडीडेटस लीबेरिबैक्टर एशियाटिकस* पॉजिटिव डीएनए सैंपल (आइसोलेट्स) का इस्तेमाल प्रोफेज प्रकारों की जांच के लिए किया गया। तीन ज्ञात प्रोफेज प्रकारों (टाइप1,टाइप2 और टाइप3) के सभी संभावित आठ संयोजनों को अलग-अलग प्रोफेज-विशिष्ट पीसीआर मार्करों का उपयोग करके पता लगाया गया। उच्चतम 117 नमूनों (26.50 प्रतिशत) ने केवल टाइप 1 प्रोफेज को आश्रय दिया, इसके बाद संयोजन प्रकार टाइप 1+टाइप2 प्रोफेज के 90नमूनों (20.4 प्रतिशत) और 83 नमूनों (18.8 प्रतिशत) ने केवल टाइप 2प्रोफेज दिखाया। सभी 3 प्रोफेज का संयोजन जैसे टाइप1+टाइप 2+ टाइप3, 50 नमूनों (11.3 प्रतिशत) में देखा गया। तीनों प्रोफेज रहित ग्रिनींग जिवाणु आइसोलेट्स की संख्या 19(4.3 प्रतिशत) पाई गई। सभी संभावित आठ संयोजन कर्नाटक, तेलंगाना, महाराष्ट्र और मध्य प्रदेश राज्यों में पाए गए। भारत के पश्चिमी भाग में, गुजरात राज्य में, केवल टाइप 2 प्रोफेज पाया गया। टाइप1+ टाइप2 और टाइप3 प्रोफेज का पता लगाकर, अठारह नीबूवर्गीय फलोत्पादक राज्यों से ग्रिनींग जिवाणु को दो प्रमुख प्रोफेज समुहों (पीटीजी1 और पीटीजी2) और पांच उपसमूहों (पीटीजी1-ए,पीटीजी1-बी,पीटीजी2-ए, पीटीजी2-बी और पीटीजी2-सी) में विभाजित किया गया। प्राईमर जोड़ी का उपयोग करते हुए पीसीआर-आधारित डिटेक्शन विधि से सभी 3 प्रकार के प्रोफेज (टाइप 1/2/3) में एक (सीआरआईएसपीआर) क्लस्टर किए गए नियमित रूप से इंटरस्पेस्ड शॉर्ट पैलिंड्रोमिक रिपीट क्षेत्र की पहचान की गई। 6 राज्यों से लिए गए तेरह ग्रिनींग आइसोलेट्स में पीसीआर तदोपरांत अनुक्रम विश्लेषण के आधार पर एक सीआरआईएसपीआर तत्व पाया गया। आगे ग्रिनींग जीनोमिक भिन्नता को डबल-लोकस (डीएल) विश्लेषण द्वारा जांचा गया, जिससे यह पता चला कि एक टेंडेम रिपीट नंबर लोकस (टीआरएन1) और एकल न्यूक्लियोटाइड बहुरूपता स्थान (एसओनपी1) का प्रतिनिधित्व करता है। डीएल जीनोटाइपिंग के माध्यम से 16 नीबूवर्गीय फलोत्पादक राज्यों से कुल 293 ग्रिनींग आईसोलेट का विश्लेषण किया गया। परिणामों से पता चला कि 187 आइसोलेट्स डीएल जीनोटाइप 1, 5 आइसोलेट्स डीएल जीनोटाइप 2 के लिए, 96 आइसोलेट्स डीएल जीनोटाइप 3 और 5 आइसोलेट्स डीएल जीनोटाइप 4 से संबंधित थे। विश्लेषण से पता चला कि भारत में डीएल जीनोटाइप 1 के बाद डीएल जीनोटाइप 3 अधिकतम पाये गये।

राइजोबैक्टीरिया के कुल 25 आइसोलेट्स को नीबूवर्गीय जड़ क्षेत्र मृदा से अलग किया गया और फिर *फाइटोफ्थोरा निकोसियाना* के विरुद्ध प्रयोगशाला में जांच की गयी। 25 आइसोलेट्स में से 10 को 50 प्रतिशत से अधिक अवरोध दिखाते हुए आशाजनक पाया गया। वर्ष के दौरान, नागपुरी संतरे और मोसंबी सहित विभिन्न नीबूवर्गीय किस्मों की जड़ से 9 नए कवक एंडोफाइट्स (सीएफई-154 -सीएफई-162) को अलग किया गया। कवक एंडोफाइट्स सीएफई-154, सीएफई-157 और सीएफई-162, *पी. निकोसियाना* को नियंत्रित करने में सक्षम पाये गये। सीएफई -154 (*राईटीडाईस्टरान रुफ्यूलूम*) के द्वारा सर्वोत्तम नियंत्रण पाया गया।

ईंडियन सिट्रस रिंगस्पॉट वायरस (आईसीआरएसवी) का पता लगाने के लिए एक एसवाईबीआर-ग्रीन आधारित मात्रात्मक आरटी-पीसीआर को मानकीकृत किया गया और 48 फील्ड नमूनों के साथ परखा गया, जिनमें से 30 नमूनों को आरटी-क्यूपीसीआर का उपयोग करके मध्यम से अत्यधिक सकारात्मक देखा गया। आईसीआरएसवी पॉजिटिव नमूनों का विश्लेषण आरटी-पीसीआर द्वारा विकसित आरटी-क्यू पीआरसी तकनीक के प्रमाणीकरण के लिए सीपी और न्यूक्लिक

एसिड बाइंडिंग जीन-विशिष्ट प्राईमरों का उपयोग करके किया गया। भूटान से ग्रिनींग और सिट्रस ट्रिस्टेजा विषाणु (सीटीवी) आइसोलेट्स का आणविक पहचान एवं लक्षण वर्णन किया गया। भूटान के विभिन्न नीबूवर्गीय फलोत्पादक क्षेत्रों से एकत्रित किए गए कुल 51 नमूनों का परीक्षण पीसीआर द्वारा ग्रिनींग विशिष्ट ओआई-1/ ओआई-2 प्राईमर समुह से किया गया जिसमें 14 नमूने सकारात्मक पाए गए। उसी तरह, भूटान सीटीवी आइसोलेट्स के कोट प्रोटीन की पहचान पी 25 जीन के अनुक्रमों के आधार पर की गयी। भूटान के 12 सीटीवी आइसोलेट्स के जीन में पी25 के आधार पर 1000 बूटस्ट्रैप मान के साथ निर्मित फाइलोजेनेटिक ट्री से पता चला कि नौ भूटानी आइसोलेट्स भारत के मेघालय और आंध्र प्रदेश राज्य के सीटीवी आइसोलेट्स के साथ जिनोग्रूप ।।। से संबंधित है। 2एस एल्ब्यूमिन प्रोटीन को कोहड़ा *(कुकुर्बिटा मैक्सिमा)* के बीजों से पृथक कर शुद्ध किया गया और ई. कोलाई (डीएच5ए) के विरुद्ध इन विट्रो प्रयोगात्मक डेटा के आधार पर प्रभावी रोगाणुरोधी सांद्रता निर्धारित की गई। वर्चुअल स्क्रीनिंग तकनीक का उपयोग *कैंडिडैटस* लिबेरिबैक्टेर एशियाटिकस से सिस्टीन-बाइंडिंग प्रोटीन के विरुद्ध संभावित अवरोधक अणुओं की पहचान करने के लिए किया गया।

रूपात्मक लक्षणों के आधार पर महाराष्ट्र के विदर्भ क्षेत्र के नागपुरी संतरा उत्पादक क्षेत्रों में विभिन्न पादप परजीवी सुत्रकृमी प्रजाती जैसे *टाइलेंकुलस सेमिपेनेट्रेंस, प्रेटिलिंक्स, हेलिकोटीलिंकस* और *होप्लोलेमस* की पहचान की गई। चार स्थानों के नमुनों के समेकित विश्लेषण से पता चला है कि पादप परजीवी सूत्रकृमि *टाइलेंकुलस सेमिपेनेट्रेंस* और *प्रेटिलिंकस* स्पीसीस 100 प्रतिशत *हेलिकोटीलिंकस* 75प्रतिशत और *होप्लोलेमस* 50 प्रतिशत पाये गये।

तुड़ाई उपरांत प्रबंधन एवं मूल्य संवर्धन

पॉलीसेकेराइड आधारित खाद्य कोटिंग्स यानी कार्बोक्सिलमिथाइल सेलुलोज और ग्लिसरॉल के साथ मिथाइल सेलुलोज ने सामान्य तापमान की स्थिति में भंडारण के 21 दिनों के उपरांत नागपुरी संतरे में अधिकतम रस, कम पीएलडब्ल्यू और अच्छी विटामिन सी की मात्रा दर्ज की गई। नागपुरी संतरे को एमिस्टर 1000 पीपीएम की दर से शेलैक कोटिंग और पॉलिथीन लाइनर के साथ उपचारित करनें पर फलों की गुणवत्ता बेहतर बनी रही। नागपुरी संतरा रस में लिमोनिन, एंटीऑक्सीडेंट और पीएमई की कम मात्रा के मूल्यांकन हेतु विभिन्न उपचारों में थर्मो-सोनिकेट 55 डिग्री सेल्सियस पर 20 मिनट और 60 डिग्री सेल्सियस पर 15 मिनट के लिए किये गये उपचार में सर्वोत्तम पाये गये। नागपुरी संतरे और मोसंबी के परासरण दाब पर सुखाये गये फांके, कम कैलोरी वाली नागपुरी संतरा बर्फी और आइसक्रीम बनाने की चार तकनीकों को विकसित किया गया। *सिट्रस इंडिका* के रस में लिमोनिन की मात्रा 11.38 और संभावित नीबूवर्गीय संकर में 9.19 पीपीएम दर्ज की गई। संभावित हाइब्रिड के रस में कुल फिनोल की मात्रा अधिकतम 17.288 मिलीग्राम प्रति जीएईएल और *सिट्रस इंडिका* रस में 6.071 मिलीग्राम प्रति जीएईएल दर्ज की गयी। *सिट्रस इंडिका* के छिलके में एंटीऑक्सीडेंट क्षमता अधिक (एबीटीएस 6.65 मोल प्रति ली. ट्रोलोक्स और डीपीपीएच 8.60 मोल प्रति ली. ट्रोलोक्स) पाई गई और संभावित हाइब्रिड के छिलके में भी अधिक (एफआरएपी 4.65 मोल प्रति ली. ट्रोलोक्स) पाया गया। नीबूवर्गीय जंगली किस्मों *सिट्रस जंभीरी* और *सिट्रोन* के रस में कार्बनिक अम्लों का आकलन करने के लिए पहली बार प्रयास किया गया और मुख्य कार्बनिक अम्ल साइट्रिक और मैलिक एसिड के साथ-साथ टार्टरिक, बेंजोइक, ऑक्जेलिक और सक्सिनिक एसिड भी पाये गए।

सामाजिक विज्ञान

भा.कृअनु.प.-के.नी.फ.अनु.सं. द्वारा विकसित की गई प्रौद्योगिकियों के बारे में किसानों के अनुभवों को जानने के लिए लिकर्ट प्रकार के धारणा पैमाने का उपयोग करके मापा गया, साथ ही किसानों के विभिन्न आय स्तरों और उनके बगीचों की उम्र और संस्थान के साथ उनके संपर्क के बीच संबंध का पता लगाने के लिए पत्राचार विश्लेषण (सीए) का उपयोग किया गया। वर्गीकरण और प्रतिगमन वृक्ष (सीएआरटी) की तकनीक का उपयोग नीबूवर्गीय फलोत्पादन से उत्पन्न आय के आश्रित के आधार पर उत्तरदाताओं को परस्पर अनन्य और संपूर्ण उप-समूहों में वर्गीकृत करने के लिए किया गया। जिन किसानों ने भा.कृ.अनु.प.-केनीफअनुसं. से पौध सामग्री खरीदी थी, उन्होंने विश्वसनीयता, ब्रैंड वैल्यू, बगीचों की लंबी उम्र, कम रोग संक्रमण को देखते हुये अपने निर्णय को सही बताया। कुल मिलाकर इस निर्णय पर पहुंचा गया कि नीबूवर्गीय फलोत्पादन की सबसे अधिक उत्पादकता उम्र औसतन 11-15 वर्ष तक होती है और नीबूवर्गीय फलोत्पादन के लिये संस्थान की विकसित तकनीकियों एवं मार्गदर्शन द्वारा उच्चतम आय पायी जा सकती है।

नीबूवर्गीय फलों के लिए क्षेत्रीय अनुसंधान केंद्र, बिश्वनाथ चरिआली, असम

नवंबर, 2020 के दौरान मोसंबी की नई किस्में, ट्रोविटा, डेल्टा, सालुआतियाना, डिलर को एक नए ब्लॉक में मेढ़ प्रणाली पर लगाया गया।

विभिन्न वाणिज्यिक नीबूवर्गीय प्रजातियों का मूल्यांकन अगस्त, 2017 के दौरान रफ लेमन मूलवृन्त पर कलमित 13 अलग-अलग नीबूवर्गीय प्रजातियों को मेढ़ और समतल बेड प्रणाली में 5x3 मीटर की दूरी पर लगाया गया। सभी प्रजातियों ने दोनों रोपण प्रणालियों में उत्कृष्ट विकास प्रदर्शन दिखाया और अच्छी औसत ऊंचाई, तने की मोटाई और छत्र आयतन देखा गया। संतरे में पौधे की अधिकतम ऊंचाई मेढ़ प्रणाली में एसटीजी नागपुरी संतरा में 4.77 मीटर, खासी संतरा में 4.54 मीटर तथा समतल प्रणाली में क्रमश: 4.72 मीटर, 4.45 मीटर दर्ज की गई। मोसंबी में मेढ़ प्रणाली पर पौधे की अधिकतम ऊंचाई कटर वेलेंसिया (4.33मीटर) में समतल प्रणाली (4.28मीटर) की तुलना में दर्ज की गई और इसी तरह, अधिकतम छत्र आयतन कटर वेलेंसिया (27.02 घन मीटर) में दर्ज किया गया। फ्लेम ग्रेपफ्रूट में समतल रोपण प्रणाली पर पौधे की ऊंचाई (3.35

मीटर) की तुलना में मेढ़ पर अधिकतम (3.57 मीटर) दर्ज की गई और साथ ही छत्र आयतन समतल रोपण प्रणाली (20.29 घन मीटर) की तुलना में मेढ़ प्रणाली पर भी अधिकतम (21.36 घन मीटर) दर्ज की गई। मेढ़ प्रणाली में लगाये गये मोसंबी की किस्मों में अधिकतम औसत फल भार (212.33 ग्राम) पाया गया नटाल में मेढ़ और समतल प्रणाली में अधिकतम रस की मात्रा (क्रमशः 49.02 प्रतिशत और 33.20प्रतिशत) दर्ज की गई।

वैज्ञानिकों के तीन पद स्वीकृत किए गए तथा एक यंग प्रोफेसनल (वाई पी-2) की नियुक्ती की गई और फार्म भवन और ट्रैक्टर शेड का निर्माण किया गया।

पौध सामग्री का उत्पादन

संस्थान पौधशाला कार्यक्रम के तहत नीबूवर्गीय फलों की 1.92 लाख रोगमुक्त पौध सामग्री और 10 किलो रफ लेमन के बीज बेचे गए और 1,30,62,566 रुपये का राजस्व अर्जित किया गया।

संसाधन निर्माण

संस्थान ने फल और अन्य उत्पादों की बिक्री के माध्यम से रु. 24,74,011/- का राजस्व अर्जित किया। सावधि जमा, फीस, प्रकाशन की बिक्री और अन्य स्रोतों पर ब्याज सहित राजस्व 16,60,891/- रुपये को मिलाकर कुल राजस्व 1,71,97,468/- रुपये कैलेंडर वर्ष-2020 में अर्जित किये।

प्रशिक्षण/कौशल विकास और प्रसार

संस्थान ने कुल 10 प्रशिक्षणों का आयोजन किया जिसमें उत्तर पूर्वी पहाड़ी क्षेत्र में जनजातीय उप-योजना के तहत 1 प्रशिक्षण और अनुसूचित जनजाती उप-योजना के तहत 2 प्रशिक्षण शामिल हैं।

संस्थान द्वारा आयोजित महत्वपूर्ण कार्यक्रम

क्षेत्रिय नीबूवर्गीय फल अनुसंधान केन्द्र, असम में 10-12 जनवरी, 2020 के दौरान "नेशनल सिट्रस मीट-2020" का आयोजन किया गया। 8 मार्च, 2020 को अंतर्राष्ट्रीय महिला दिवस, 14 अप्रैल, 2020 का डॉ. भीमराव अम्बेडकर की 130वीं जयंती का कार्यक्रम 15 अप्रैल, 2020 को आयोजित किया गया। 28 जुलाई, 2020 को के.नी.फ.अनु.सं. का 36वां स्थापना दिवस,15 अगस्त, 2020 को स्वतंत्रता दिवस,14-21 सितंबर, 2020 के दौरान हिंदी सप्ताह,7 अक्टूबर,2020 को "कृषि संवाद" कार्यक्रम, 2 अक्टूबर, 2020 को महात्मा गांधी की 150वीं जयंती, डॉ.बी.आर अंबेडकर महापरिनिर्वाण दिवस 6 दिसंबर,2020 और "स्वच्छता पखवाड़ा" 16-31 दिसंबर, 2020 तक का आयोजन किया गया। पीएम किसान सम्मान निधि का सीधा प्रसारण 25 दिसंबर,2020 को संस्थान में आयोजित किया गया।

कृषि संबंधी संसदीय समिति जिसमें 10 सांसद सदस्यों (लोकसभा और राज्य सभा) की समिति ने 24 जनवरी,2020 को संस्थान का दौरा किया इस दौरान संस्थान के समस्त अधिकारी उपस्थित थे।

तकनीकियों का व्यवसायीकरण

15 सितंबर,2020 को मेसर्स करुणामय एग्रोटेक, नागपुर के साथ "नीबूवर्गीय फलों के रोग मुक्त पौध सामग्री के उत्पादन के लिए उच्च नर्सरी प्रबंधन तकनीक" के लिये संस्थान द्वारा लाइसेंस प्राप्त तकनीक पर हस्ताक्षर किए गए। यह सुविधा मेसर्स करुणामय एग्रोटेक को प्रौद्योगिकी के लाइसेंसधारी के रूप में और एनएआईएफ परियोजना के तहत कृषि -व्यवसाय इनक्यूबेटर योजना के तहत स्टार्टअप इनक्यूबेटी के मदद के रूप में दी गई जब तक उन्हें पौध सामग्री बेचने के लिए अपना लाइसेंस (महाराष्ट्र राज्य कृषि विभाग से) प्राप्त नहीं हो जाता।

पुरस्कार और सम्मान

2020 के दौरान डॉ.ए.के.श्रीवास्तव, प्रधान वैज्ञानिक को जैविक और पर्यावरण अनुसंधान सोसायटी, त्रिपुरा का मानद फेलो मिला; वी. दोड एसोसियेशन, त्रीची द्वारा इंजीनियरिंग, विज्ञान और चिकित्सा पर 9वें अंतर्राष्ट्रीय वैज्ञानिक पुरस्कार में उत्कृष्ट वैज्ञानिक पुरस्कार; इंडियन हॉर्टिकल्चर समिट-2020 में एसएचआरडी-2018 के मानद फेलो; कृषि अनुसंधान, शिक्षा और विस्तार संगठन, कृषि मंत्रालय, तेहरान, ईरान के संपादकीय बोर्ड में विजिटिंग वैज्ञानिक और सदस्य, नोटुले सान्सीया बॉयोलोजिका, रोमानियाई विज्ञान अकादमी, रोमानिया। डॉ.ए. के. दास, प्रधान वैज्ञानिक को संस्थागत जैव सुरक्षा समिति सी.एस.आई.आर. नीरी, नागपुर और भा.कृ.अनु.प-सीआईसीआर, नागपुर ने डीबीटी प्रतिनिधि की मान्यता दी। डॉ. जी. टी. बेहरे, प्रधान वैज्ञानिक को डॉ. बी. वसंतराज डेविड फाउंडेशन,चेन्नई द्वारा वैज्ञानिक-2020 पुरस्कार प्राप्त हुआ। डॉ. ए. थिरूगनावेल, वैज्ञानिक को केले पर अंतर्राष्ट्रीय सम्मेलन-2020 में सर्वश्रेष्ठ पोस्टर पुरस्कार मिला। डॉ. अंजीता जॉर्ज, वैज्ञानिक को सोसाइटी फॉर बायोटिक एंड एनवायरनमेंटल रिसर्च, त्रिपुरा द्वारा यंग साइंटिस्ट अवार्ड और डॉ. बी. वसंतराज डेविड फाउंडेशन, चेन्नई द्वारा यंग साईटिस्ट अवार्ड-2020 भी दिया गया। डॉ. किरण कोमू, वैज्ञानिक को फसल संरक्षण (कृषि) में अंतर्राष्ट्रीय सर्वश्रेष्ठ वैज्ञानिक पुरस्कार आरयूएलए के द्वारा दिया गया। इसके अलावा विभिन्न अंतर्राष्ट्रीय और राष्ट्रीय मंचों पर वैज्ञानिकों को सम्मानित किया गया है।

2 ICAR-CCRI : A Profile

Genesis

Citrus crops *viz*., sweet oranges, mandarins, limes, lemons, grapefruits and pummelos are the important fruit crops in nutritional security of the country. Keeping in view the importance of citrus in livelihood of millions of people across the country, foundation stone of the institute was laid by Shri. P. V. Narasimha Rao, the then Defence Minister, Govt. of India on 28th July, 1985 in the presence of Shri. Shivajirao Nilangekar, Chief Minister of Maharashtra and Dr. K. L. Chadha, then Director, IIHR, Bengaluru. It started functioning as a Citrus Research Station and work started to develop the station from scratch. Later this station was upgraded and started functioning as independent National Research Centre for Citrus, Nagpur from 1st April, 1986. The institute located in the heart of Nagpur mandarin growing area of the country is in 36th year of its service to the nation. The 'NRC for Citrus' has been upgraded in October 2014 to the status of 'Institute' in the XII Plan and has been renamed as 'Central Citrus Research Institute' (CCRI) with a regional centre in Assam. Regional Research Centre for Citrus (RRCC) started functioning from March, 2017 in the campus of Biswanath College of Agriculture, AAU, Biswanath Chariali, Assam. RRCC would cater the research and development needs of citrus industry of entire northeast India. The institute is the country's only premier national organization exclusively mandated for citrus research, education and extension. Over the years it has emerged as the torch bearer for citrus research at national level and recognized at international level. ICAR-CCRI, Nagpur has been awarded ISO-9001:2015 Certification for adoption of standard operating procedures.

Location

The CCRI, Nagpur is located on Amravati Road (Kolkata-Mumbai National Highway 6). The ICAR-Affiliated National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Ginning Training Centre (GTC), a Regional Centre of Central Institute for Research on Cotton Technology (CIRCOT) and Regional Remote Sensing Centre (RRSC) of ISRO are in its close vicinity.

Mandate

- Basic, strategic and applied research on crop improvement, sustaining productivity, crop protection and utilization of citrus.
- Repository for genetic resources and scientific information on citrus.
- Nodal centre for training, quarantine, certification and supply of disease-free planting material of citrus.

The Central Citrus Research Institute (CCRI), Nagpur and its regional station (RRCC) at Biswanath Chariali playing major role to promote scientific and technological advancement in the growth of citrus industry in the country. The major challenges are unavailability of disease-free planting material, threat of citrus greening and other virus and virus-like diseases, climate change, scarcity of irrigation water and creating awareness among citrus growers and skill development.

Mission

The mission is to increase overall citrus production and productivity with intervention of innovative and high-tech citriculture. Sustainability, environmental protection and risk management are the key factors for future growth of citrus industry.

Vision

Increase average fruit productivity of citrus in the country from present level of 10 t/ha to 20 t/ha so as to meet demand of fresh fruit for export and domestic market and also for processing.

Management

Quinquennial Review Team (QRT), a high power committee constituted by ICAR reviews and provides guidance for new areas of research management and polices every 5 year.

A high powered Research Advisory Committee (RAC) comprising of eminent professionals and scientists guides

the institute on yearly basis for formulating its research policies and in planning research thrusts and strategies. The Institute Management Committee (IMC), constituted and mandated by the ICAR, supervises the functioning of the Institute with its meetings every year. Internal Committees such as, Institute Research Council (IRC), Purchase Committee, Library and Publication Committee, Official Language Committee and a Grievance Committee, to name a few, are operating for decentralization of management. The Institute Joint Staff Council promotes healthy interaction and congenial work environment.

Infrastructural Facilities

Central Citrus Research Institute, Nagpur is established on 250 acres of land out of which 190 acres is under plantation on which experiments are being conducted. Rest of the land is utilized under five different farm ponds for rain water harvesting, administrative-cum-laboratory building, staff quarters, screen and glass houses, shed nets, meteorological observatory, farm house, drip system, water storage tanks etc. Institute has constructed intake well in Ambazari lake and two pipe lines to carry water from lake to institute. Over the years the institute has created modern laboratories in different disciplines (see organogram). Research is being carried out in frontier areas of tissue culture, crop regulation and agro-techniques, plant nutrition, viral, fungal and bacterial diseases, insect-pest management, water management, extension, post-harvest technology etc. Some of the modern equipments available at the institute include Real time PCR, Advanced Photosynthesis System, Atomic Absorption Spectrophotometer, Multiplate Reader, HPLC, wide range of fruit and juice processing equipments etc.

Institute has a facility of Farmers' Hostel for residential training programmes of farmers and stakeholders.

An excellent library, especially on citrus, with a collection of 2089 Books and 1345 back volumes of research Journals has been established to support research, teaching and extension. Institute subscribes 24 Indian Journals, 3949 on-line Journals (CeRA) and provide internet services to all its scientists in their laboratories. Online literature search facility is also being provided under consortium of e-resources in Agriculture (CeRA) to the institute scientists. The library has been fully computerized by using the Koha software, a web-based integrated management system.

Major Achievements

Introduction of Varieties : New varieties of lemon (Baramasi, Pant lemon, Kagzi Kalan, Assam lemon, Bearss, Meyer, Villafranca, Frost Eureaka, Limonevo Fino, Verna, Frost Lisbon, Genoa); Sweet orange (Hamlin, Valencia, Pera Natal, and Westin on different rootstock combination and Diller Travita, Marrs Early, Salustiana, Dalta Blood Red, Jaffa and Pineapple, Newhall, Lanelet, Valencia of Olinda, and Washington navel, Cara-Cora on Rough lemon rootstock); grapefruit (Marsh seedless, Star Rubby, Red Blush, RioRed and Red Ruby); mandarin (Daisy, Clementine, Murcott, Michal, Pearl Tangelo, Feutrall's Early) and acid lime (Chakradhar, PDKV Bahar, Jaidevi, Phule Sarbati, Balaji) were planted on raised bed system with fertigation.

CCRI has 645 citrus germplasm accessions out of which 93 are from exotic sources and 552 from indigenous sources. Institute has also collected 7 endangered/wild citrus species. Institute has identified promising nine citrus varieties so far namely Nagpur mandarin seedless - 4, Acid lime - 7 and Acid lime - 8 with three exotic varieties *viz*. 'Pummelo US-145', 'Cutter Valencia' and 'Flame grapefruit'. Varieties NRCC Pummelo – 5, NRCC Grapefruit-6, NRCC acid lime – 7 and NRCC acid lime- 8 have been developed through indigenous material. *Citrus macrophylla* (Alemow) has been identified as a promising rootstock for Nagpur mandarin and acid lime for tolerance to *Phytophthora* diseases. Micro-budding technique has reduced cost and time in propagation and is being followed for commercial scale multiplication. With shoot-tip grafting (STG) technology it has become possible to clean elite high yielding material and propagate under insect-proof screen houses to provide disease-free planting material. Leaf nutrient standards and crop regulation techniques helped growers to get bumper yields of quality fruits.

During the period of 36 years, CCRI has made significant

contributions towards developing farmer-friendly technologies for the benefit of citrus growers. The institute has the best nursery in the country which is accredited as 3-Star nursery by National Horticulture Board. Complete protocol for disease-free planting material in polythene bags was developed and 3.25 million disease-free certified plants of good pedigree were supplied to growers across India so far. Successful demonstration of rejuvenation technology in the farmers' field resulted in increasing average yields from 6-7 t/ha to 10-11 t/ha. During last five years production on raised-bed with fertigation technologies of fertigation (saving 20-30% of fertilizers at 80% evaporation replenishment) have been developed for application of inputs at critical growth stages for saving of inputs. Mass talcum powder based production of *Trichoderma harzianum* native strain-44 for the control of *Phytophthora*. Biological and chemical control measures have been standardized for all important insect-pests. PCR based molecular diagnostic methods were developed for rapid and sensitive detection of CTV, ICRSV, CMBV, exocortis and greening pathogens. Complete post-harvest handling protocol has been developed to minimize losses from present 25% to less than 5% and technology has been commercialized.

Regional Research Centre for Citrus

The Regional Research Centre for Citrus (RRCC) with an area of 42.5 acres is located in the campus of Biswanath College of Agriculture, AAU, Biswanath Chariali, Assam. This facilitates close linkages of RRCC with Assam Agricultural University (Jorhat) and ICAR Research Complex for NEH Region, Umiam (Barapani), Meghalaya alongwith several institutions like CAU, Imphal (Manipur) and other universities of the region. The RRCC receives more than 2000 mm rainfall in a year while Nagpur receives 800-900 mm rainfall. Temperatures at Biswanath are 38 - 39^{0}C maximum, during summer while at Nagpur it is 46 to 47^{0}C maximum temperature.

Plantation and citrus germplasm bank : Varietal evaluation studies have been initiated during 2017 on raised-bed and flat bed (Plain field) planting system. So far 29 citrus varieties of sweet orange, mandarin, limes, lemon, grapefruit and pummelo have been planted. In field gene bank of citrus, a total of 51 accessions have been planted and some of them have started flowering and fruiting.

Farm infrastructure : Drip system has been installed having provision of fertigation. Tube well facility has been created. The RRCC has started functioning with basic infrastructure after renovation of old college building temporarily given by BNCA, in this, RRCC which has one room for administration, one Director's room one training hall, four laboratory rooms one store room and newly constructed farm house and implement shed.

Mera Gaon Mera Gaurav

Since last four years training, demonstrations and technology dissemination activities are continuing at two villages *viz*. Pachgaon, Umred Taluka, Nagpur District and Hetikundi, Karanja Taluka, Wardha District.

Thrust Areas

- Strengthening of Regional Research Centre for Citrus at Biswanath Chariali, Assam to meet regional research demand on Khasi mandarin, Assam lemon and Pummelo and conserve citrus bio-diversity in NEH region.
- Research on important areas like developing seedless citrus varieties for processing and table purpose through hybridization, selection, introduction programmes and biotechnological tools.
- Increasing input use efficiency for water and chemical fertilizers through precision citriculture, fertigation and water conservation.
- Research efforts to be focused for reducing cost of cultivation and increasing the production and farmer's income through improved soil health using organic manures, bio-fertilizers and bio-pesticides.
- This will ensure sustainability and risk management for increased productivity of citrus in years to come.

- Development of diagnostic kits for major pathogens
- Dwarfing rootstock to be developed and high density plantation technique to be standardized with agro techniques for increasing productivity.
- Production of healthy planting material.
- Technology commercialization and research partnership/collaboration with private companies to generate resources.
- Human resource development and dissemination of innovative technologies.

Budget (2020-21)

Institute Govt. Grant	Release	Expenditure	Utilization of Funds
1910.93 lakhs	1910.93 lakhs	1855.83 lakhs	97.12 %

Staff Strength (as on 31/12/2020)

	CCRI, Nagpur (HQ.)			RRCC, Assam (Regional Centre)			Total Sanctioned posts	Vacant posts
Category	Sanctioned posts	In Position	Vacant posts	Sanctioned posts	In Position	Vacant posts		
Director (RMP)	01	1	-	-	-	-	**1**	**-**
Scientific	19	14	5	3	-	3	**22**	**8**
Technical	20	18	2	-	-	-	**20**	**2**
Administrative	11	7	4	-	-	-	**11**	**4**
Supporting	10	8	2	-	-	-	**10**	**2**
Total	61	48	13	3	-	3	**64**	**16**

3.1 Genetic Resources and Crop Improvement

3.1.1 Collection, characterization, evaluation and screening of citrus germplasm

3.1.1.1 Collection and characterization of citrus germplasm

The main objective of this study was to enrich the National Active Germplasm Site for citrus at ICAR – CCRI, Nagpur. Twelve citrus accessions were collected from CHES, Chettalli during 2020. Seventy-two accessions including fourteen promising Galgal (*Citrus pseudolimon*) and eight Citron (*Citrus medica*) accessions were regenerated. Using the IPGRI descriptors, the 20 accessions each of rough lemon and Rangpur lime were characterized.

3.1.1.2 Evaluation of citrus germplasm

Acid lime

Elite planting material (seeds) of Kagzi lime was collected from the promising plants across acid lime growing areas in different surveys. Four sets of trials with 14 accessions in first set, 12 accessions in second set, 10 accessions in third set and 9 accessions in fourth set were planted. Based on last five years' data i.e. from 2014-15 to 2019-20, it was found that IC-285422 (45.85 g), IC-322098 (44.45 g) and IC-342350 (45.48 g) had significantly highest fruit weight along with fruit dimensions. Also juice content (51.24%, 52.85% and 51.64%) and yield (51.12, 52.25 and 53.72 t/ha, respectively) of these accessions was higher than other accessions over the year. Subsequently, all these three entries are under evaluation at AICRP as IC-285422 (NRCC Niboo-2), IC-322098 (NRCC Niboo-3) and IC-342350 (NRCC Niboo-5).

Mandarin cultivars

Evaluation of different mandarin cultivars was started in 2009-10 with eight cultivars *viz*. Darjeeling mandarin, Mudkhed mandarin, Nagpur mandarin seeedless-4 (N4), Khasi mandarin, Coorg mandarin, Kinnow mandarin along with control Nagpur mandarin. Pooled analysis of physico-chemical parameters of fruits for 2014-15 to 2018-19 revealed that Coorg mandarin (155 g) along with Mudkhed seedless (154 g) had the highest fruit weigh followed by N4 (140 g). Although the lowest fruit weight was observed in Kinnow (111 g), it has the highest TSS (11.27) and acidity (0.95). Significantly low seeds/ fruit were recorded in N4 (2.33) and was already released by ICAR – CCRI, Nagpur for commercial production.

Incidence of Insect-pests on exotic cultivars

Eighteen exotic cultivars were monitored at regular intervals for incidence of insect pests like citrus leaf miner (CLM), citrus blackfly and fruit sucking moth during Jan-Dec., 2020. Observations for different pests were recorded like; percent infestation on 10 cm twig for leaf miner, population/leaf for blackfly and % fallen fruits for FSM. Leaf miner infestation during *Ambia* was significantly lower in exotic cultivar US -145 Pummelo (7.59%), while it was highest in Cutter Valencia (23.47%). During *Mrig*, lowest infestation was observed on US 145 Pummelo (12.19%) followed by Kinnow (12.47%), Shamouti orange (12.60%) and Flame grapefruit (12.60%). Blackfly population during *Ambia* was lowest on TM-33 (8.88 /leaf) while it was highest on Shamouti orange (33.99/leaf). Percent fallen fruits due to fruit sucking moth infestation was significantly lowest in US-145 Pummelo (10.40%) followed by Pummelo-3 (11.11%).

3.1.2 Clonal selection

3.1.2.1 Nagpur mandarin

Clonal selection of Nagpur mandarin was started in 2003-04 with regeneration and planting of 54 clones. The trial was augmented with 17 clones in 2007-08 and further on 2009-10 with 27 clones. Subsequently, all the good performing entries were submitted to AICRP. Pooled analysis of physico-chemical parameters of fruits of submitted entries to AICRP for 2014-15 to 2018-19 revealed that except N4 all the accessions had yielded at par. Only N4 has commercial seedlessness.

3.1.2.2 Sikkim mandarin

Elite planting material (bud sticks) of Sikkim mandarin was collected during a survey in 2003 – 04, regenerated and subsequently planted in the field. A trial with eleven promising clones (SM-1 to SM-11) was started in year 2009-10. Observations for physico-chemical properties were started in 2013- 14. Pooled analysis of last five years' data i.e. from 2014 – 15 to 2019 – 20 revealed that SM-7 had highest fruit weight (154 g) along with fruit length (63.52 mm) and fruit diameter (71.59 mm). Significantly highest juice content was found in SM-11 (43.62%) with the lowest in SM6 (37.76%). There was significant difference in the juice acidity and TSS: acid ratio. Fruit yield was highest in SM-8 (19.12 t/ha) and at par with SM-7 (18.6 t/ha) and SM-1 (16.26 t/ha).

3.1.2.3 Darjeeling mandarin

Elite planting material (bud sticks) of Darjeeling mandarin was collected during a survey in 2003-04, regenerated and subsequently planted in field. A trial with five promising clones (DM-7, DM-8, DM-11, DM-13 and DM-16) was started in year 2009-10. Observations for physico-chemical properties were started in 2013-14. Pooled analysis of last five years' data i.e. from 2014-15 to 2019-20 revealed that DM11 had highest fruit weight (151 g) along with fruit length (58.48 mm) and fruit diameter (65.09 mm). However, highest juice content was found in DM-13 and the lowest was in DM-7. Fruit yield was highest in DM-11.

3.1.2.4 Sweet orange

It was found that TM-33 had significantly higher fruit weight (183.12 g) followed by Phule Mosambi (177.53 g) and Mosambi (154.15 g). The fruit juice content was highest in TM-33 (37.65%) followed by Kodur Sathgudi (36.86%) and M-4 (36.81%). Also, juice acidity was significantly higher in Kodur Sathgudi (0.27) followed by TM-33 (0.25) than other varieties. Highest yield was observed in TM-33 (21.25 t/ha) (Fig. 1) followed by M-3 (19.20 t/ha), M-8 (19.54 t/ha) and Phule Mosambi (19.15 t/ha).

Fig. 1 : High yielding Mosambai variety TM-33

3.1.2.5 Pummelo

It was found that P3 had the highest fruit weight (1027 g) and accordingly the fruit length, fruit breadth and fruit axial diameter were also highest albeit the fruit yield was highest in P5 (NRCC Pummelo-5) (80.25 t/ha) (Fig. 2). Although the fruit dimensions were same for P4, P5 and US – 145, there was vast difference in yield and TSS.

Fig. 2 : High yielding Pummelo variety NRCC Pummelo-5 released by CCRI, Nagpur

3.1.2.6 Acid lime

Elite planting material (seeds) of Kagzi lime was collected from the promising plants of central India region (Vidarbha, Marathwada, Western Maharashtra and

adjoining areas of Madhya Pradesh). A trial with seedling population of thirteen promising clones (KL2, KL4, KL6, KL7, KL9, KL11, KL12, KL15, KL16, KL21, KL22, KL23, KL24) was started in year 2003 – 04. Pooled analysis of last five years' data i.e. from 2014 – 15 to 2019 – 20 was done. It was found that KL – 12 (52.80 g) and KL – 21 (53.13 g) had significantly highest fruit weight along with fruit length and fruit breadth followed by KL – 24 (50.23 g). However, KL-23 has significantly highest juice content (47.94%) along with – 16, KL – 21 and KL – 24. Highest yield was found in KL – 12 (NRCC Acid Lime - 7), KL - 21 (NRCC Niboo - 4) and KL-24 (NRCC Acid Lime - 8). Subsequently, all these three entries are under evaluation at AICRP.

Sub Project : Citrus Repository at RRCC, Biswanath Chariali, Assam

It is proposed that RRCC, Assam would serve as a duplicate citrus germplasm conservation site. About 51 germplasm have been planted upto 2019. Although there was no augmentation in the collection due to COVID – 19 pandemic, the earlier planted germplasm has been well established.

3.1.3 On-Site DUS testing for registration of Citrus varieties with PPV& FRA

ICAR – CCRI, Nagpur is the nodal agency for on - site DUS testing for Registration of citrus varieties with PPV & FRA. The mandated crops are mandarin (*C. reticulata*), sweet orange (*C. sinensis*) and acid lime (*C. aurantifolia*). The maintenance breeding programme of citrus for mandated crops has been undertaken with following candidates

- Acid lime – Pramalini, Balaji, Sai Sharbati, Vikram, Sai Sharbati
- Mandarin – Nagpur mandarin, Coorg mandarin, Sikkim mandarin, Darjeeling mandarin
- Sweet orange – Mosambi, Sathgudi, Phule Mosambi, Clone TM – 33

3.1.4 *In-vitro* micrografting of exotic Sweet orange cultivars

Six exotic sweet orange cultivars *viz*. Cara Cara were *in-vitro* grafted on Rough lemon rootstock (Pineapple, Natal, Pera, Valencia, Blood red,). The maximum STG success was observed with Natal (42.09 %) and lowest success was recorded with Cara Cara (22.64 %) (Table 1).

Table 1 : STG of exotic Sweet orange cultivars

Sr. No.	Cultivar	Success %
1	Pineapple	29.94
2	Natal	42.09
3	Pera	26.47
4	Valencia	26.25
5	Blood Red	36.24
6	Cara-cara	22.64
CD (P=0.05)		5.016

3.1.5 Improvement of important commercial Citrus scions and rootstocks through *in vitro* techniques

3.1.5.1. Production of polyploids in Citrus

***In vitro* induction of auto tetraploids in commercial Citrus rootstocks with the use of Colchicine**

An *in vitro* experiment was carried out to induce tetraploids in citrus rootstocks with the use of colchicine chemical. Meristematically active, germinating seeds of commercially important rootstocks of Citrus (Alemow, Rangpur lime, SFS and Sweet lime) were treated with colchicine solutions consisted of eight treatments.

The results showed that colchicine compound severely and significantly affected the germination of citrus rootstocks. Across all colchicine treatments overall seedling survival was higher (52.29%) in Sweet lime, followed by Alemow (48.99%) and SFS (45.34%).

The survival % of treated seedlings after transfer to screen house (lab to land transfer) by mini grafting was highest in Rangpur lime (4.62%) followed by Alemow (4.318%), SFS (4.313%) and Sweet lime (4.275%). The morphological

variation percentage was highest in Alemow (12.10%) followed by Rangpur lime (9.81 %), Sweet lime (6.87%) and SFS (4.99%). The data revealed that 0.1% concentration of colchicine at 24 hrs expose was observed to be most efficient for tetraploid induction.

Induction of autotetraploids in Citrus scions by *in vitro* and *in vivo* techniques

An *in vitro* experiment was carried out in important commercial Citrus scions also to induce the autotetraploids with the use of colchicine. The germination percentages were highest with T_7 (control) and lowest with T_6 (0.3%, 24 hrs exposure) with the values of 91.32% (US Pummelo-145) and 16.32 (Kinnow) respectively. The differences were larger and highly significant. Across all the treatments, survival % recorded was highest in Pummelo-5 (52.87%) followed by US Pummelo-145 (51.76%), Grapefruit (44.81%) and Kinnow (40.67%). The results of colchicine treatments on plant height of scions revealed the highest plant height was found with T_7 (Control with 14 hrs exposure) and lowest with T_6 (0.3% with 24 hrs exposure) with mean values of 6.25 cm and 0.60 cm respectively. The differences were larger and highly significant. The survival of treated plants after minigrafting for lab to land transfer in the screen house, indicated that highest survival obtained in Pummelo-5 (4.38%) followed by Grapefruit 6 (4.22), Kinnow (3.53) and US Pummelo-145 (3.25). The differences among different treatments were statistically highly significant. Percent variation in plant morphology with colchicine is highest in Pummelo-5 (8.46%) followed by Grapefruit 6 (8.28%), US Pummelo-145 (5.37%), and Kinnow (4.13%) .

The data revealed that 0.1% concentration of colchicine at 24 hrs exposure was observed to be most efficient for tetraploid induction. Out of the 4 tested US Pummelo - 145 pummelo samples when confirmed via flow cytometry, 1 sample was certified as tetraploid. Out of the 3 tested P-5 samples when confirmed via flow cytometry, 1 sample was certified as tetraploid. Out of the 3 tested Kinnow samples when confirmed via flow cytometry, 1 sample was certified as triploid. Out of the 1 tested Kinnow sample when confirmed via flow cytometry, 1 sample was certified as pentaploid (Table 2).

Colchicine induced autotetraploids in Citrus scion and rootstocks through microbudding

The study describes the application of microbudding technique in combination with colchicine treatment for the development of autotetraploids citrus scions (US-145 Pummelo and Kinnow) and rootstocks (Alemow, SFS, Sweet lime). The results revealed that microbudding success was lower in all the tested cultivars, where the microbud was treated with colchicine at an younger/tender state i.e. 5 days after microbudding. Most of the early treated microbuds were killed before emergence of new flush/sprouts hence low microbudding success in all the cultivars which were treated at 5 days after microbudding. High percent of mortality of buds is noticed in microbuds treated earliest (5 day after microbudding) hence lower microbudding success. Highest microbuds were recorded in untreated control plants in all the cultivars. The observations were recorded on % of microbudding success, days taken for sprouting % variation in plant morphology. The results indicated that the percentage of microbudding was higher in control in all the tested cultivars, which ranged between 100% (US-145 Pummelo and Sweet lime), and lowest 75% (Kinnow). Maximum morphological variation obtained in earlier treated micro budded plants highest was recorded in Kinnow (33%) and at 5 days treatment followed by USA-

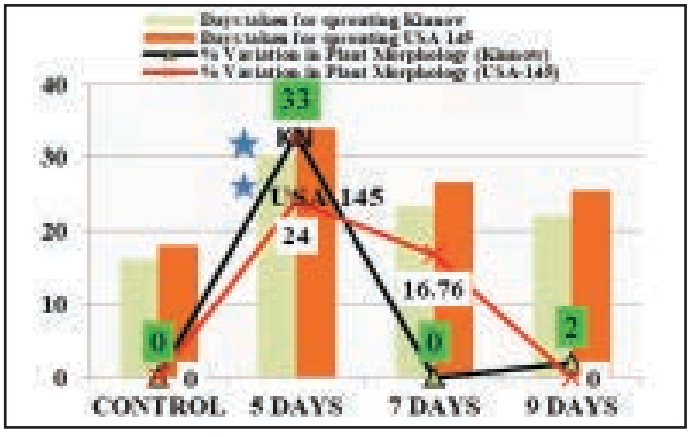


Fig. 3 : Induction of tetraploids / triploids with *in vivo* colchicine treatment via microbudding in citrus scions

Table 2 : Analysis of ploidy samples by flow cytometry

Sr. No.	Name of variety	No. of plant tested	1n	2n	3n	4n	5n	6n	Mixoploid
1	NM-Endosperm	16	2	--	3	--	--	--	--
2	NM (Seed colchicine)	1	--	--	--	--	1	--	--
2	P-5 (Seed colchicine)	3	--	--		1	--	--	
3	Kinnow (Seed colchicine)	3	--	--	1		--	--	1
4	US -145 Pummelo (Seed colchicine)	4	--	--	--	1	--	--	
5	Rangpur lime(Seed colchicine)	10	--	--	--	3	5	--	2
6	SFS (Seed colchicine)	4	--	--	1	--	1	2	--
7	Sweet lime (Seed colchicine)	6	--	--	--	--	--	--	3
8	Rough lemon(Seed colchicine)	5	--	--	--	1	--	--	--
9	Alemow (Seed colchicine)	3	--	3	--	--	--	--	--

145 (24%), Alemow (21%), Sweet lime (18.75%) and SFS (14.44%) (Fig. 3, 4). The microbudding success was higher in control, ranged between (75 to 100%). Earlier is the treatment, later is the micro bud emergence. Days taken for sprouting earliest in control (18 days) and in 5 days treatment (34 days). Earlier is the treatment higher is the variation. There is a delay in microbud emergence in all the treated plants, especially in plants treated 5 days after microbudding (36.27 days), which is correlated with more number of morphologically variant plants. Similar trend was recorded in SFS and Sweet lime highest variation in 5 days (14.44%) and (18.75%), days taken for sprouting (45.66 days) in SFS and 40.25 days in Sweet lime. There was pronounced delay in emergence of microbud, in all plants treated 5 days after microbudding (Fig. 3, 4).

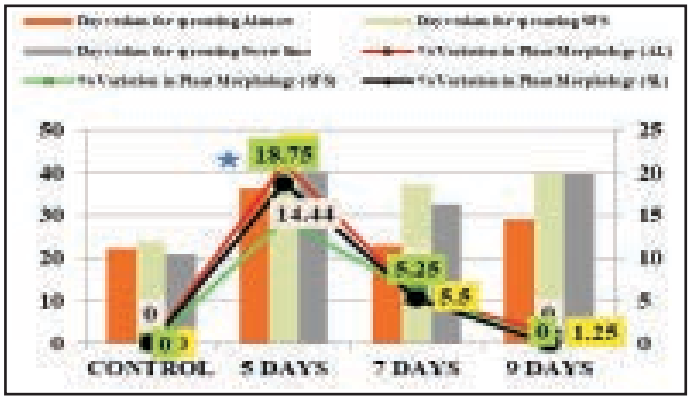


Fig. 4 : Induction of tetraploids/ triploids with *in vivo* colchicine treatment via microbudding in rootstocks

3.1.5.2 Induction of triploids by endosperm rescue, flow cytometry and cytogenetics in Nagpur mandarin, sweet orange and Kinnow

The creation of triploid Citrus hybrid is an important breeding strategy worldwide to develop new seedless commercial Citrus varieties. Natural triploids could be successfully regenerated by endosperm rescue via somatic embryogenesis. Regeneration from endosperm tissue is somehow technically challenging as the genotype, sampling times and culture media are main contributing factor for successful regeneration.

Influence of media on callus and embroids proliferation in Nagpur mandarin, Sweet orange and Kinnow

Callus was induced from cellular endosperm of *C. reticulata* (Blanco) cv. Nagpur mandarin and *C. sinensis* cv. Sweet orange and Kinnow mandarin (*C. nobilis* × *C. deliciosa*) excised 12 weeks post anthesis. The results indicated that high callus induction rates were obtained in NM (50.94) and in Kinnow (59.4) in MT + ME, whereas in Sweet Orange (50.45) in MS+CH+2,4-D(2mg)+ Kinetin (5mg/L), whereas highest rate of embryogenesis obtained in NM (62.98%) and in Kinnow (32.18) with MT+CH+2,4-D(2mg/L) medium, where as in Sweet orange maximum embryogenesis (79.16%) obtained in the medium MT+CH+2,4-D(2mg)+BA (5mg/L). In Sweet orange callus

induction response varied from 16.36% to 50.45%, and embryogenesis response from 20.17 to 79.16%. In Nagpur mandarin embryogenesis response varied from 9.35% to 62.98%. In Kinnow, embryogenesis response varied from 16.23% to 32.18%. Induction of embryogenesis was lowest in Kinnow (32.18%) compared to Sweet orange (79.16%) and Nagpur mandarin (62.98%).

Influence of media on morphogenesis of endosperm calli

Exogenous applications of gibberlic acid resulted in the stimulation of endosperm and increased morphogenesis towards the development of different stages of embryoids. In Nagpur mandarin and Kinnow medium supplemented with GA_3, BA, Casein hydrolysate and adenine sulphate increased the development of cotyledonary embryoids significantly. In case of Sweet orange significantly maximum number of cotyledonary embryoids produced in 2MT+BA(0.25mg/L)+ CH(500mg/L)+GA_3(1mg/L) which is devoid of Adenine sulphate. In general the next best medium in the stimulation of endosperm more towards morphogenesis of cotyledonaryembryoids in all the studied 3 Citrus scions was the same combination without Adenine sulphate followed by MT+BA (0.25mg/L) + CH (500mg/L) + GA_3 (1mg/L) (Fig. 5).

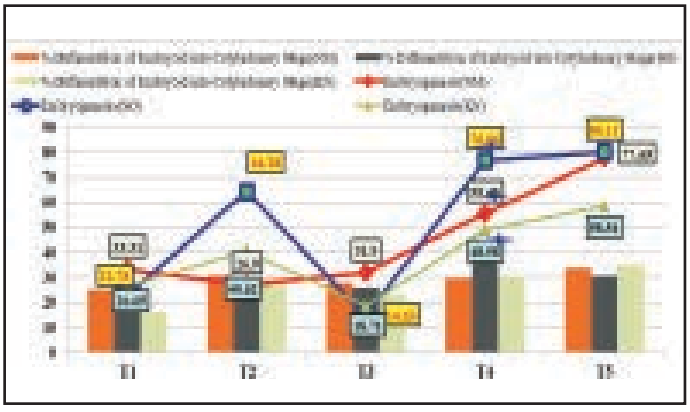


Fig. 5 : Influence of media on morphogenesis of endosperm calli of 3 Citrus scions

(T 1 -MT+ME(500mg/L)), (T 2-MT+CH(500mg/L)+2,4 -D(2mg/L)+BA(5mg/L)), (T3 -MT+CH(500mg/L) +2,4 -D(2mg/L)), (T4 -MS+ME (500mg/L)), (T5 -MS+CH(500mg/L)+2,4 -D(2mg/L)+ Kinetin(5mg/L))

Effect of phytohormones in root and shoot regeneration *in vitro*

Medium supplemented with GA_3 and adenine sulphate enhanced the shoot and root development in all the 3 scion species. Significant differences were found for all the parameters studied right from induction of shoots and roots for all the species. Complete plantlet regeneration obtained in Nagpur mandarin and Sweet orange from endosperm culture, but in Kinnow endosperm tissue not responded to regeneration may be further refinement and adjustment required in precisely standardizing the sampling time, culture media as the efficiency of endosperm response is genotype dependent in many species. Elongated strong shoots from *in vitro* endosperm rescued plants were minigrafted to five month old vigorous Rough lemon rootstocks. Total no. of 85 Nagpur mandarin plants transferred to greenhouse with 52% survival. Out of transferred Nagpur mandarin putative triploids, 20 plants are showing variation.Out of the 16 samples taken for confirmation by flow Cytometry (Table 2), three were certified as triploids from M/s. Ankur seeds Pvt. Ltd., Nagpur.

In all the 3 scion species studied, efficient regeneration of plants from endosperm rescue and more number of putative triploids obtained T2- MT+CH (500 mg)+ 2,4-D (2 mg) followed by MT+CH+ 2,4-D+BA.

***In-vitro* organogenesis from mature tissue explants of promising Citrus scion cultivars**

The influence of basal medium and different growth regulator on *in vitro* propagation of nodal explants from mature trees of Citrus rootstocks (Alemow, Rough lemon, SFS and Sweet lime) and Citrus scions (Pearl Tangelo and Daisy mandarin) was investigated. Several media combinations with BA, Kinetin, NAA and IBA were used to optimize the proliferation phase. Best results obtained in MS medium with BAP (2mg/L) and IBA (1mg/L). Significantly higher number of shoots per explant obtained and early induction of shoots, and maximum length of shoot obtained in T1(MS+IBA (1mg/L) +BAP (2mg/L). The difference in the number of shoots obtained among

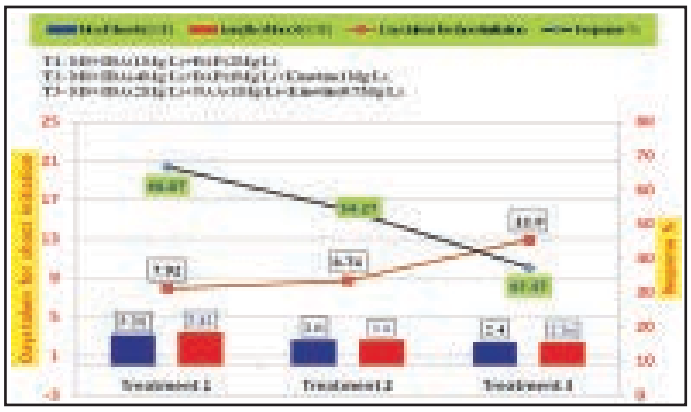


Fig. 6 : Cumulative effect of different shooting media and phytohormones on Citrus cultivars on different parameters

T1- MS+IBA(1Mg/L)+BAP(2Mg/L), T2-MS+IBA(4Mg/L) +BAP(1Mg/L)+ Kinetin(1Mg/L), T3-MS+IBA(2Mg/L) +NAA(1Mg/L)+Kinetin(0.5Mg/L)

different rootstock cultivars might be due to the difference in the genetic makeup. Among the different cultivars tried, the highest bud proliferation obtained in T1 (66.87) followed by T2 (54.27) and T3 (37.37). Early shoot induction (7.92 days) and maximum no. of shoots (3.21) obtained in treatment 1 (Fig. 6).

Effect of hormones on rooting of cloned shoots

The generated shoots were rooted in 3 different media. Roots were initially observed after 10- 15 days of culture in all the media, however, high percentage of cultivars with healthy roots was achieved with an ½ MS medium supplemented with IBA (5mg/L)+ NAA (1mg/L)+ 2 BAP with 0.01% charcoal (61.2%). Significant differences were found in rooting response among different treatments. The average number of roots were found to be significantly highest in ½ MS supplement with 2 BAP+ 5 IBA+1NAA+0.01% CC. Maximum mean number of roots obtained in T1 (4.46) followed by T2 (3.79) and T3 (2.54). Early root induction obtained in T2 (7.55) followed by T1 (8.07) and T3 (9.46). Mean treatment effect with length of the roots is highest in T3 (4.22 cm) (Fig. 7).

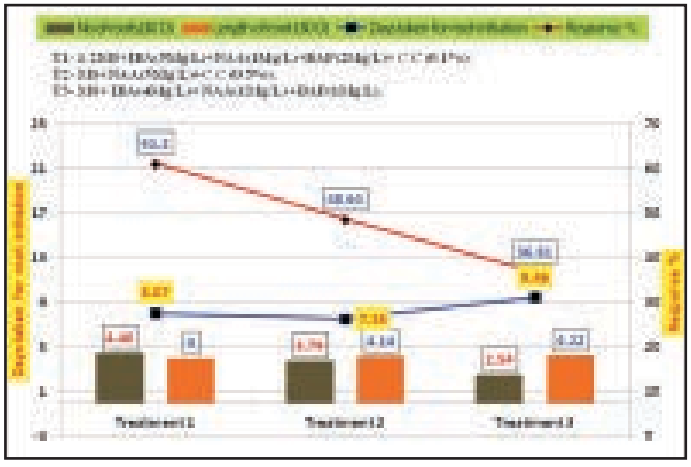


Fig. 7 : Cumulative effect of different rooting media and phytohormones on citrus cultivars on different parameters

(T1- 1/2MS+IBA(5Mg/L)+NAA(1Mg/L)+BAP(2Mg/L)+ C.C (0.1%)), (T2- MS+NAA(5Mg/L)+C.C (0.5%)), T3 - MS+ IBA(4Mg/L)+ NAA(1Mg/L) +BAP(1Mg/L))

3.1.6 Genetic improvement of citrus through hybridization

The year 2020 witnessed huge set-back due to COVID – 19 during flowering season and very meagre work could be possible due to countrywide lock down. However, hybridization programme progressed through transferring of 260 hybrid progenies of different crosses of previous year to the field (Table 3). There were 1035 different crosses attempted, which resulted in generating 874 progenies in acid lime group (Table 4). Very limited success was achieved in sweet orange group that 27 progenies could be recovered from 319 crosses (Table 5). Distant hybridization was attempted to develop segregating population using sweet orange, pummelo and grapefruit cultivars and clones from different cross combinations. Out of 743 different crosses only 420 progenies could be retrieved (Table 6).

Table 3 : Hybrid progenies of acid lime planted in field

Sr. No.	Parents (Hybrid)	No. of Plants
	Lemon Group	
01	Acid lime x Pant Lemon	66
02	Acid lime x Assam Lemon	174
03	Acid lime x Baramasi Lemon	20
	Total	**260**

Table 4: Results of different crosses in Acid lime group

Sr. No.	Cultivar	No. of crosses	No. of Fruits Harvested	No. of seeds Inoculated	No. of Plants in Tissue Culture/Nursery
	Lime and Lemon Group				
01	Acid lime x Baramasi lemon	186	06	22	22
02	Acid lime x Assam lemon	155	09	42	42
03	Acid lime x Kagzi Kalan	120	85	167	167
04	Acid lime x Pant lemon	65	27	123	123
05	Acid lime x Citron	209	75	201	201
06	Citron x Acid lime	132	34	97	97
07	Assam lemon x Citron	65	00	00	00
08	Citron x Assam lemon	63	11	57	57
09	Citron x Baramasi lemon	40	27	447	165
	Total	**1035**	**274**	**1156**	**874**

Table 5 : Results of different crosses in Sweet orange group

Sr. No.	Cultivar	No . of crosses	No. of Fruits Harvested	No. of seeds Inoculated	No. of Plants in Tissue Culture/ Nursery
01	M -3 x TM -33	97	00	00	00
02	Ruby Blood Orange x Hamlin	60	01	07	07
03	Cutter Valencia x Pera	75	02	11	11
04	Cutter Valencia x TM -33	21	01	04	04
05	Cutter Valencia x Blood Red	56	01	09	05
06	TM - 33 x Cutter Valencia	10	00	00	00
	Total	**319**	**5**	**31**	**27**

Table 6 : Results of different crosses in other citrus groups

Sr. No.	Cultivar	No. of crosses	No. of Fruits Harvested	No. of seeds Inoculated	No. of Plants in Tissue Culture/Nursery
01	US-145 x Flame Grapefruit	45	05	145	145
02	Cutter Valencia x Nagpur mandarin	45	00	00	00
03	TM-33 x Natal	46	00	00	00
04	TM-33 x Red Flush	65	00	00	00
05	TM-33 x US-145	140	00	00	00
06	TM-33 x Star Ruby	35	00	00	00
07	TM-33 x Flame Grapefruit	20	00	00	00
08	US-145 x Pera	40	02	175	175
09	TM-33 x Flame Grapefruit	70	00	00	00
10	Nagpur mandarin x Pera	40	07	28	28
11	Nagpur mandarin x Natal	83	09	37	37
12	Nagpur mandarin x Hamlin	42	14	35	35
13	Nagpur mandarin x Cutter Valencia	27	00	00	00
14	TM-33 x P-5	45	00	00	00
	Total	**743**	**37**	**420**	**420**

3.1.7 Genetic improvement of citrus rootstocks through hybridization

The hybridization was attempted to develop hybrid rootstocks tolerant to different biotic and abiotic stresses. A total of 512 flowers of different citrus species have been pollinated, out of which only 31 fruits were harvested. Some of the cross combinations like Rangpur lime x Sunki mandarin, Rangpur lime x Rough lemon, Rangpur lime x X-639 and Rough lemon x X-639 did not set a single fruit. The maximum number of seeds were excised from Rough lemon x Rangpur lime (170 seeds) and Rough lemon x Sour orange (124 seeds) crosses. Totally 321 seeds were isolated and they were inoculated in the MS media. Totally 321 plantlets were generated and 228 plants were transferred to the primary nursery. The details of the crossing and plants produced were mentioned in the Table 7.

3.1.8 Mutation Breeding in Citrus

Deriving the buds from MV1, budlings of the MV2 generation was raised last year and this year total 221 budlings were planted in the field (Table 8). After three years of planting a good fruiting was observed during the year under report. The physio-chemical parameters of fruits in different genotypes showed the symptoms of mutations. In Flame grapefruit the fruit size varied from 235 g to 420 g. Flavedo got thick than control and also in one case it remained green at maturity. In case of NRCC Grapefruit – 6 there was significant difference observed over control and PM-6/ 20 Gy (B1R3P19) had highest fruit weight. Seedlessness was observed in two pummelo mutant of 5Gy dosage. In sweet orange also two mutants were found to have seedlessness at 5 Gy dosage in Kinnow at 40Gy. Commercially seedless fruits were found in some treatments of acid lime Nagpur mandarin cv. N 74.

Table 7 : Hybridization for rootstock development at ICAR-CCRI, Nagpur

Sr. No.	Cultivar	No. of crosses	No. of fruits harvested	No. of seeds inoculated	No. of plants in Tissue Culture	No. of plants transferred in Nursery
1.	Rangpur Lime x Alemow	229	13	27	27	14
2.	Rough Lemon x Rangpur Lime	65	11	170	170	142
3.	Rangpur Lime x Rough Lemon	70	00	00	00	00
4.	Rangpur Lime x Sunki Mandarin	15	00	00	00	00
5	Rangpur Lime x X-639	41	00	00	00	00
6.	Rough Lemon x Sour Orange	15	07	124	124	72
7.	Rough Lemon x X- 639	77	00	00	00	00
	Total	**512**	**31**	**321**	**321**	**228**

Table 8 : Vegetatively propagated second generation probable mutants

Sr. No.	Genotype	Cultivar	5Gy	10 Gy	15 Gy	20 Gy	30 Gy	40 Gy
1.	Mandarin	Kinnow	04	07	08	04	03	09
		N-4	13	06	10	05	--	--
		N-74	10	09	08	06	--	--
2.	Grapefruit	Flame	05	07	09	01	03	--
		NRCC Grapefruit-6	00	04	00	03	01	--
3.	Pummelo	PM -5	09	08	01	07	08	06
4.	Sweet orange	TM -33	17	00	09	10	11	--
		Total	**58**	**41**	**45**	**36**	**26**	**15**

Incidence of insect-pests on citrus cultivars with different irradiation treatments

Two different beds planted with young plants of selected citrus cultivars exposed to different irradiation doses (5, 10, 15, 20, 30, 40 Gy) were observed for incidence of insect pests like leaf miner, blackfly, whitefly, aphids and thrips. In Kinnow cultivar, per cent leaf miner infestation, thrips/tapping, aphids/twig, blackfly/leaves and whitefly/leaves was recorded in the range of 4.27-8.86 %, 1.50–2.37, 2.50-4.12, 3.45-21.58 and 1.06-4.25, respectively. In TM-33 Cultivar, leaf miner infestation ranged between 3.72-7.30%, 1.25-2.58 thrips/tapping, 1.75-5.35 aphids/twig, 2.75-18.00 blackfly/leaves and 1.75-4.00 whitefly/leaves. Citrus leaf miner was the dominant pest on all the cultivars. The pest incidence levels observed on other cultivars like N-7, AL-7, N-4, N-74 are shown in Fig. 8.

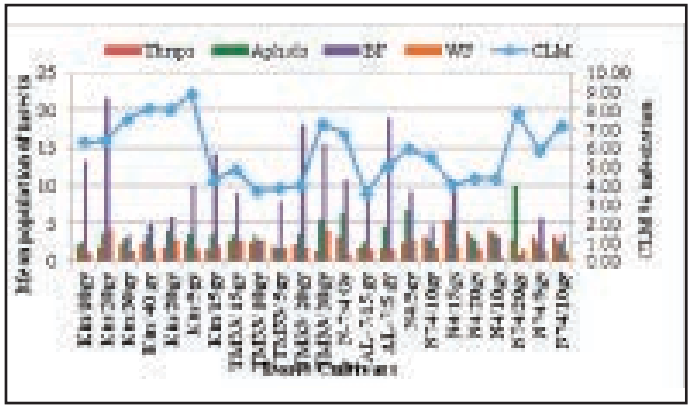


Fig. 8 : Incidence levels of major insect pest during January to December, 2020 on different cultivars exposed to different irradiation doses

3.1.9 Molecular characterization of citrus germplasm

3.1.9.1 Molecular characterization of acid lime and lemon germplasm

Total DNA was isolated from 66 acid lime and 15 lemon accessions using CTAB method. A total 45 InDel markers markers were taken based on the position of the chromosome. The size of the DNA fragments was estimated by using 100bp DNA ladder along with the PCR products. The PCR products were analysed on 4% ultra agarose gel. After screening all the InDel markers, 27 and 24 were found polymorphic in a acid lime and lemon respectively. Scoring was done based on the presence and absence of the bands and same data was used to construct the dendrogram using Darwin software v.6.0 (Fig. 9). No duplicates were found in case of lemon, whereas in acid

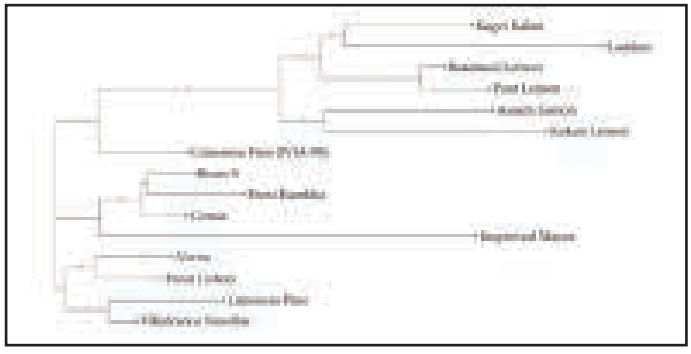


Fig. 9 : Dendrogram of Lemon accessions constructed based on the scoring of polymorphic markers using DARWIN software

3.2 Crop and Resource Management

3.2.1 Retrofitting of Citrus nursery phase for optimizing the production cost of planting stock

3.2.1.1 Effect of sowing dates on seed germination and growth parameters of Citrus rootstocks.

Germination was significantly higher in Rough lemon (94.63%) when sown in 2nd fortnight of August followed by Rangpur lime (85.5%) and Alemow (84.7%) with August 1st fortnight sowing directly in polybags (Fig. 10). In Rough lemon polyembryony % decreased with delayed sowing. Percent plant stand maximum in Rough lemon (90.38%) followed by Rangpur lime (82.54%) and Alemow (81.5%). Precocity in germination obtained in Rough lemon (14.54 days) followed by Alemow (15.44 days) and Rangpur lime (16.58 days). Maximum plant height obtained in Rough lemon (5.72 cm) followed by Alemow (5.60 cm) and Rangpur lime (3.56 cm).

3.2.1.2 Effect of direct sowing on nursery growth parameters before microbudding

A study conducted with all the 3 commercial promising rootstocks, by sowing rootstock seeds directly in the polybags having sterilized soil mixture, to restrict the nursery phase from 22 months period as being followed in traditional transplanting method to 12 to 13 months period by restricting/practicing the seed sowing directly in the polybags, which bypasses primary nursery phase for 6 months period.

Data recorded in all the 3 rootstocks for seedling height when they attained age of 5 months by direct sowing. Maximum mean seedlings height (41.8 cm) obtained in Rough lemon when seeds are sown directly in polybags followed by Rangpur lime (24.05 cm) and Alemow (23.27 cm). Maximum mean stem diameter (1.39 cm) obtained in Rough lemon followed by Alemow (1.31 cm) and Rangpur lime (1.12 cm).

In case of number of leaves maximum mean numbers of leaves (22.4) were obtained in Rough lemon followed by Rangpur lime (17.65) and Alemow (16.15) where the seeds are sown directly in polybags in the screen house. (Fig. 10)

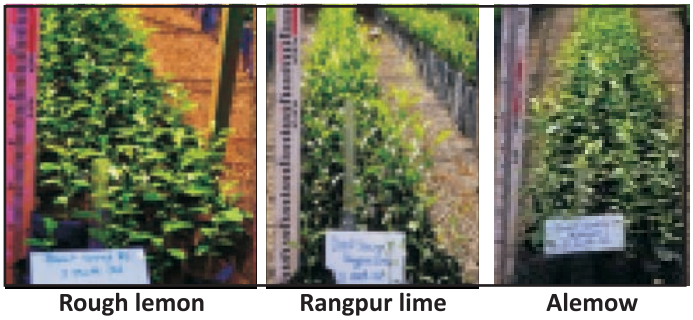


Fig. 10 : Direct sowing of Rough lemon, Rangpur lime and Alemow in polybags (three month old seedlings)

3.2.1.3 Effect of direct sown citrus rootstocks on success of microbudding

Rapid means of raising good rootstock seedling of Citrus plants have been a promising concern of nursery man and research workers all over the country. The present experiment was undertaken to study the growth of all the 3 rootstocks by raising directly in polybags by bypassing the primary nursery phase in propagation treys. The data revealed that significantly higher microbudding success and early microbuddable seedlings obtained when the seeds were sown directly in polybags inside the screen house compared to the seeds sown in trays and later transplanted to polybags. Significantly higher percentage of early microbuddable seedlings (84.8%) obtained in rough lemon followed by Rangpur lime (69.4%) and Alemow (69.1%). Microbudding success whether performed in screen house or net house directly in polybags was found better in Rough lemon (87.4%) followed by Rangpur lime (79.8%) and Alemow (73.5%). In tray transplanted rootstocks, microbuddable stage delayed by 3 months compared to directly sown seeds (Fig. 11 and 12).

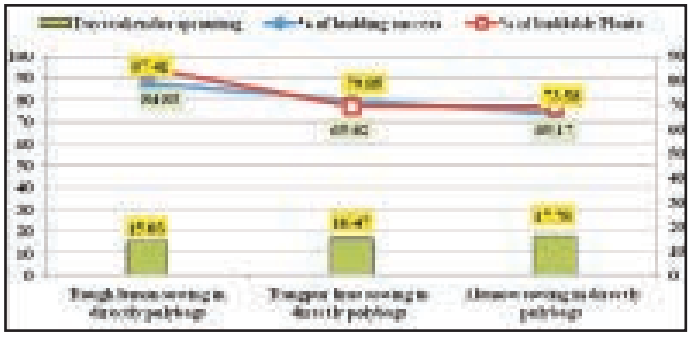


Fig. 11 : Effect of direct sown citrus rootstocks on percent of microbuddable seedling and microbudding success

Fig. 12 : Large scale multiplication of microbudding plants on Rough Lemon, Rangpur Lime and Alemow rootstocks

3.2.1.4 Effect of raising rootstocks in modified nursery conditions on growth pattern before commercial budding

The study was planned to study the growth of rootstocks seedling, under modified environment/nursery conditions vs traditional transplanting system before commercial

budding. The data revealed, significantly maximum seedling height (87.44 cm) obtained in Rough lemon seeds sown in trays and later transplanted (12 months old rootstock) in polybags when seeds are sown directly (81.28 cm), when the seedling was 6-7 months old. All the treatments differed significantly for total height, central girth and number of leaves. Even the central girth of two rootstocks was obtained the required optimum of 1.9 to 2.138 cm in 3 rootstocks studied (Alemow, Rangpur lime, Rough lemon) at around 6-7 months age itself when the sowing were done directly in polybags.

3.2.1.5 Effect of direct sown and transplanted rootstocks on commercial budding success

This study was undertaken to see the effect of raising the 3 commercial rootstocks directly in polybags by skipping the primary nursery phase of 6-8 months duration in propagation trays which is normally being followed in central India. It is apparent from the data the higher percentage of early buddable seedling (72.52%) and budding success (84.83%) obtained, when seeds were sown directly in polybags in just 6-7 months old Rough lemon rootstocks (Fig. 13-16).

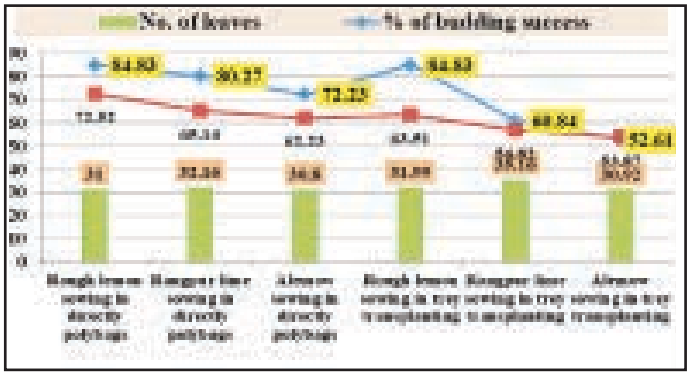
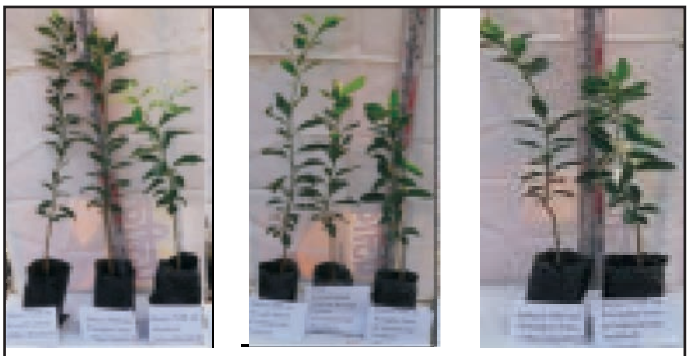


Fig. 13 : Effect of direct sown and transplanted rootstocks on commercial budding success

Fig. 14 : Root coiling while transplanting in traditional propagation method



Direct sown micro budded on 3 rootstocks | Direct sown micro budded on 3 rootstocks | Direct sown micro budded & commercial budded on Rangpur lime

Fig. 15 : Growth of Rough lemon and Rangpur lime in direct transfer Vs transplanted seedlings in normal budding

Fig. 16 : Growth of direct sown vs conventional budgrafts (Rough lemon) before release

3.2.1.6 Effect of size of microbud on success of microbudding and freedom from graft transmission pathogens

This study was planned to find out the optimum size of microbud that gives reasonable number of disease free plants and realistic degree of success in microbudding. Observations were recorded on success % and days taken for sprouting and also extent of cleaning from graft transmissible pathogens. In Nagpur mandarin, maximum mean microbudding success obtained (48%) with 2 mm microbud size followed by 4 mm (39%) and 3 mm (36%). Sprouting of microbud, was earliest in Nagpur mandarin (11.05 days) followed by Sweet orange (26.3 days) with bigger sized microbud. In these two cultivars (Nagpur mandarin, sweet orange) bigger the microbud size, earlier was the sprouting (inverse relation), but this trend was not

observed in Flame grape fruit, earliest sprouting occurred with smaller sized microbud (2 mm). In general, microbud sprouted earlier in Nagpur mandarin (10 -14 days), Flame grapefruit (15 - 22 days) and Sweet orange (26.3 - 30 days). The microbudding success percentage is directly proportional to the size of the bud in Sweet orange (84 to 90%) and Flame (45 to 66%) the trend is not the same in Nagpur mandarin (Fig. 17).

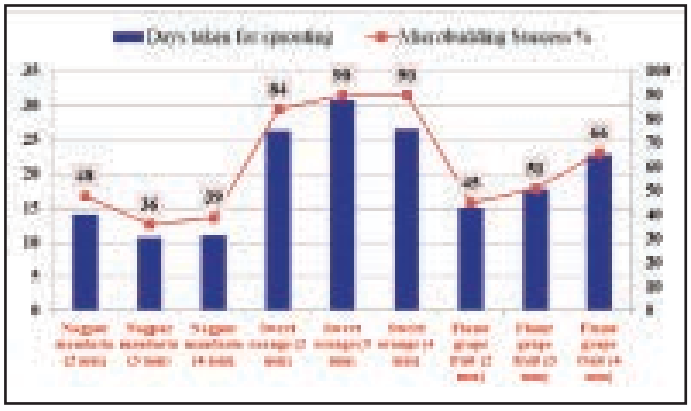


Fig. 17 : Effect of different size of microbud on success of microbudding

3.2.1.7 Microbudding of different promising Citrus exotic and indigenous cultivars

During 2020, 15 promising Citrus cultivars consisting of exotic and indigenous cultivars of sweet orange (Blood red, Jaffa, Hamlin, Valenica, Pera, Westin, Natal and Pineapple) Lemon (Pant lemon, Assam lemon and Baramasi lemon) and Mandrian varieties/Hybrids (Daisy and Pearl Tangelo), Calamondin and Kaffir lime were propagated to see the response of these cultivars with microbudding propagation to maintain as mother stock for early market release/supply of new varieties.

The data indicates maximum mean microbudding success obtained in Blood red Sweet orange (90%) and lowest success in Natal cultivar (36.47%). Precosity for microbud emergence was observed in Blood red (9 days) and delayed sprouting in Assam lemon (15.40 day). Growth rate of microbud after budding was faster/higher in Pant lemon (45.06 cm) followed by Kaffir lime (44.40 cm) within 2 months after microbud emergence. All the treatments differed significantly for all the parameters studied except for scion girth.

3.2.1.8 Field evaluation of STG derived planting stock Vs conventional bud graft in farmer's orchards

The distributed STG derived healthy planting stock established in farmers orchards located one at Susundri, Kalmeshwar (Nagpur) and another at Arvi, Wardha, were evaluated for field performance for vegetative growth and yield parameters. The results of trails on vegetative growth parameters and yield, indicated shoot tip grafted plants can either significantly superior or at in growth performance in terms of plant height, stem height and canopy volume compared with conventional budded plants or in comparison with microbudded plants. Further, field transferred STG plants performed true to type without negative characters of nucellar juvenility phase thus notably saving the time (Fig. 18).

Around 32 random samples of Nagpur mandarin were collected from farmer's orchard at Arvi, Wardha, for indexing of virus and greening bacterium diseases, out of 32 samples, 96.88% declared free from virus and virus like diseases and 93.76% tested negative for Greening bacterium. Around 10 random samples of Nagpur mandarin were collected from farmer's orchard at Susundri, Kalmeshwar, for indexing of Greening bacterium, out of the total samples 90% was tested negative for greening bacterium.

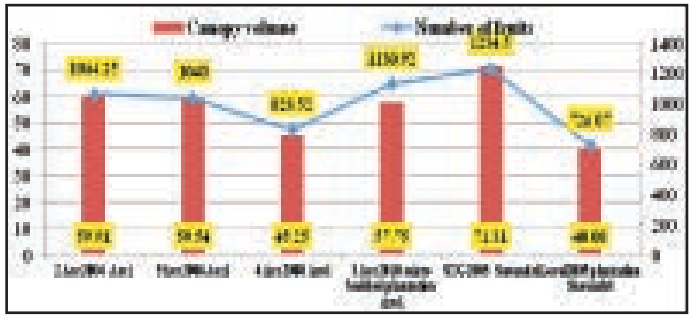


Fig. 18 : Field evaluation of STG conventional budded plants vs STG microbudded plants at Arvi, Wardha and Susundri, Kalmeshwar

3.2.2 Development of Agrotechniques

3.2.2.1 Rootstocks

Evaluation of hybrid rootstocks for Nagpur mandarin

Tree growth : Nagpur mandarin plants showed maximum canopy growth (270 m^3) on NRCC rootstock -4 and tree height was recorded maximum (9.12 m) on NRCC-5. Stock -

Scion ratio was recorded maximum (1.11) on NRCC rootstock-2 (Table 9).

Fruit yield and quality : Maximum fruit weight (149 g) was recorded on NRCC-3 rootstock followed by rough lemon (148 g). TSS content was noted to be higher (10.14%) with NRCC-4 as compared to other rootstocks. Acid content was recorded maximum on rough lemon (0.33%) where as lowest was recorded on NRCC-4. Juice content was highest on NRCC-4 (57.5%) followed by NRCC-5 (57.4%). Fruit yield was maximum (15 kg/plant, 6.42 t/ha on area basis) on NRCC rootstock-5 followed by rough lemon (Table 9).

Soil nutrient status: The soil macro nutrients N and P content were maximum i.e. 298.14 and 22.77 kg/ha respectively under NRCC-3 rootstock. The highest soil K was recorded (608.53 kg/ha) under NRCC-2 rootstock followed by NRCC-4 (574.93 kg/ha).

Disease Incidence: Gummosis incidence was found higher in Nagpur mandarin budded on NRCC-2, NRCC-4 and NRCC-5 rootstocks. Maximum propagule density (35/ cm^3 soil) of *Phytophthora* spp. was recorded in case of NRCC-5 rootstocks.

Effect of Rangpur lime and rough lemon rootstocks on performance of Nagpur mandarin under different spacings

Tree growth: The spacing 6×4 m showed better growth performance with respect to plant height (5m) than other spacings on rough lemon. Maximum canopy volume (62 m^3) was found in spacing 6×6m than other spacing. In Rangpur lime rootstock maximum plant height was recorded in 6×3 m i.e. 5.13 m and maximum canopy volume (39.79 m^3) was observed in spacing 6×6 m.

Fruit yield : During this year, heavy fruiting was noted in both the rootstock so maximum fruit weight (163.61 g) was recorded in rough lemon spaced at 6×6m whereas maximum TSS (9.24%) and acidity (0.33%) was observed in 6×3 m spacing. Vit C content was highest (40.77 mg/100 ml) and juice content was found to be maximum (53.19%) in 6×3m spacing. Maximum fruit yield of 41.60 kg/plant was recorded in 6×3m spacing followed by 39.73 kg/tree in 6×5m spacing. In case of Rangpur lime, maximum fruit yield (40.50 kg/ plant) was recorded in 6×6 m whereas the TSS was found maximum in 6×3m spacing than the other spacings.

Soil nutrient status: Soil nutrient status showed significant variation of K whereas N and P contents recorded non

Table 9 : Effect of different hybrid rootstocks on plant growth, fruit yield and quality of Nagpur mandarin

Rootstocks	Plant height (m)	Stock-Scion ratio	Canopy volume (m^3)	Fruit weight (g)	Rind thickness (mm)	TSS (%)	Acidity (%)	No. of seed/ fruit	Juice content (%)	Fruit yield (kg/plant)
NRCC-2	8.79	1.11	256	120	2.20	9.69	0.26	4	53	10
NRCC-3	8.36	1.03	224	149	2.65	9.48	0.31	8	52	12
NRCC-4	8.58	0.89	270	119	2.94	10.14	0.24	5	57.5	6
NRCC-5	9.12	1.00	261	130	2.21	8.58	0.27	4	57	15
Rough lemon	9.06	0.90	251	148	3.03	9.43	0.33	3	40	12
CD (P=0.05)	0.29	0.37	22.81	3.92	0.18	0.57	0.03	0.66	0.48	0.53

significant difference under rangpur lime rootstock. All the three macro nutrients showed significant variation under rough lemon rootstock in various spacings. The soil N and P was maximum in 6×4 m spacing i.e. 302.95 kg/ha and 22.4 kg/ha respectively while, K was highest in 6×3 m spacing under rough lemon rootstock.

3.2.2.2 Evaluation of citrus varieties on raised bed planting system

The raised-bed plantation prevents high soil moisture stress during monsoon thereby minimising the *Phytophthora* root rot infection. The data were collected during 2020 on growth, yield and quality characters of mandarin, sweet orange, grapefruit, pummelo, lemon and acid lime varieties planted on raised bed system bed (2.0 m width and 0.61 m height).

Evaluation of Nagpur mandarin on Alemow rootstock on raised bed system

Plant growth: The plant 6×3 m spacing showed maximum plant height of 4.10 m and better canopy volume 20.17 m^3. The bud union was smooth and compatible in all the plants. All the plants were in healthy condition without any disease symptoms in both the spacings.

Fruit quality and yield: The fruit quality data was recorded maximum with respect to average fruit weight and acidity in 6×6m spacing treatment whereas, juice content, vit. C, TSS and fruit yield was recorded better in 6×3 m spacing. The fruit yield was 22.78 kg/plant and 12.64t/ha at 6×3 m spacing treatment.

Soil nutrients status: All the soil nutrients were in optimum range. Soil N was recorded maximum in 6x6 m spacing whereas P and K were noted to be maximum in 6 x 3 m spacing.

Intercropping of vegetables : The raised bed citrus plantation has potential in intercropping of vegetables in furrow area. During 2020, vegetables such as tomato, brinjal, bhindi, cauliflower, cabbage and raddish were grown. The tomato, brinjal, bhindi and marigold flowers too had shown better performance with good productivity in a limited area (5030 sq.m). Transplanting of Brinjal seedlings of variety VNR harsh and NBH 1001 done in the month of june 2020 with a spacing of 90×60 cm recorded an average yield of nearby, 70 kg during the season. Total 350 plants of tomato variety Abhilash were planted in the month of January ,2020 at a spacing of 60×45 cm recorded and average yield of 75 kg tomato. An approximate of 17 kg bhindi, 20 kg cauliflower, 12 kg cabbage and 15 kg raddish were harvested (Fig. 19).

Evaluation of Nagpur mandarin under high density planting on raised bed system

Plant growth: Nagpur mandarin budded on rough lemon rootstock was planted with six different spacings (4.5 × 4.5, 5 × 4, 5 × 4.5, 5 × 5, 5.4 × 5.4 and 6 × 6 m) on raised during July, 2014. The analysis of the data revealed that the plant height was maximum (4.68 m) under 5×4 m spacing followed by 4.5×4.5 m (4.64 m) whereas it was minimum (3.98 m) in 6×6 m spacing. The canopy volume recorded significant variation among different spacings and it was

Fig. 19 : Intercropping of vegetables between raised - beds in high density planting system

6.0 ×6.0 m | 5.4 ×5.4 m | 5.0 ×5.0 m | 4.5 ×4.5 m

Fig. 20 : Effect of different spacings on plant growth of Nagpur mandarin on raised bed planting system

maximum under 5×4 m (31.91 m^3) followed by 4.5×4.5 m (29.05 m^3). The stock and scion girth was noted smooth and compatible growth.

Fruit quality and fruit yield : Significant variation was observed for yield and quality parameters among the treatments. The maximum fruit weight (166.68 g) was recorded in 5×4.5 m spacing whereas, the maximum TSS (8.05%) was recorded in 5×5 m spacing with minimum acidity (0.17%). The highest juice content and maximum Vit.C were observed in 6×6 m spacing followed by 5.4×5.4 m spacing. The maximum fruit yield (32.54 kg/plant) was recorded in 5×4.5m spacing, whereas the minimum fruit yield (12.72 kg/plant) was recorded in 5×4 m spacing. On area basis, maximum fruit yield of 14.46 t/ha was observed in 5×4.5m spacing followed by 5×5 m (11.20 t/ha) (Fig. 20).

Soil nutrient status : The data on soil nutrient stated that soil N ranged from 243.4-264.48 kg/ha, while P ranged from 36.40-42.75 kg/ha. The available soil N showed maximum under 4.5×4.5 m spacing where as it was minimum under 6×6 m spacing, almost similar trend was recorded with respect to P. Soil K ranged from 706.53-878.73 kg/ha in various spacing. Significantly the highest absorption of N and P was recorded in 4.5x4.5 m spacing whereas K recorded higher in 5x5 m spacing.

Insect pest incidence : Insect pest incidence was monitored during the year 2020. Psylla population was high in 4.5 x 4.5 m spacing (10.6/ 5 cm twig). Percent leaf miner infestation was also maximum in 4.5 x 4.5 m (47.9%) followed by 44.0% in 5 x 4 m.

Evaluation of sweet orange and grapefruit varieties on raised bed system

Plant growth : Among the sweet orange varieties, the maximum plant height (3.73m) was recorded in Pineapple when compared to other varieties. The maximum canopy volume (20 m^3) was recorded in Blood Red followed by Pineapple (16 m^3). The maximum stock-scion girth was observed in Katol Gold. In grapefruit, the highest plant height (4.28m) and canopy volume (27 m^3) were recorded in Red blush followed by Star Ruby (Table 10) .

Fruit yield and quality : The yield and fruit quality parameters varied significantly among the varieties (Table 10). The maximum fruit weight was recorded in Katol Gold (286 g) followed by Mosambi (232 g). The highest juice content (47%) was noted in Blood Red while minimum juice content was observed in Mosambi (41%). The maximum acidity (0.19%) and Vit. C (48.02 mg/100ml) contents were recorded in Pineapple and Jaffa, respectively. The highest TSS content (9.38%) was recorded in Katol Gold followed by Mosambi (9.30%). The maximum fruit yield (26 kg/plant) was recorded in Blood Red followed by Jaffa (21 kg/plant). Katol Gold orange recorded minimum yield (12 kg/plant).

In grapefruit, the average fruit weight was maximum in Marsh Seedless (461 g) whereas, the maximum acidity (0.45%) and Vit. C (42 mg/100ml) were recorded in Star Ruby. The highest juice content (42 %) and TSS contents (7.19 %) were noted in Red Blush. The maximum fruit yield (24 kg/plant) was recorded in Star Ruby and the varieties did not vary significantly (Table 10) (Fig. 21).

Soil nutrient status : The analysis of the soil data indicated significant variation with respect to all the macro nutrients. The soil N was in the range of 259.9-306.3 kg/ha. The P varied between the range of 38.08-48.72 kg/ha while, K range was 718.2-946.4 kg/ha.

Disease Susceptibility : No significant level of *Phytophthora* colonies were detected (in the selective media) from the rhizospheric soil samples collected from exotic sweet orange and grapefruit cultivars budded on various rootstocks on raised bed.

Insect pests and bioagents incidence in sweet orange and grapefruit cultivars on raised bed planting system were evaluated for insect pests and mite incidence during January-December, 2020. Psylla population was significantly maximum on pineapple (14.15/5 cm twig) while lowest on Mosambi (8.16). Cultivars *viz*., Pineapple, Mosambi and Red blush cultivars recorded highest leaf miner infestation of 10.72%, 11.45%, and 11.63%, respectively. Blackfly population of 7.78 adults/leaf and aphid population of 18.55/10cm twig was the highest incidence reported on Mosambi and Marsh seedless, respectively. Mite population was considerably lowest on Red blush cultivar (3.16 population / leaf).

Evaluation of exotic (Brazilian) sweet orange varieties on raised bed system

Plant growth : The plant height (3.73 m) and canopy volume (17.51 m^3) were maximum in Hamlin on Volkameriana rootstock, while stock-scion ratio was maximum in Valencia on Volkameriana. Pera on limocravo rootstock recorded minimum plant height (2.77 m). Plant canopy volume was minimum in Lane Late (2.69 m^3) on rough lemon rootstock.

Fruit yield and quality : Maximum fruit weight (272.1 g) was recorded in Lanelate on rough lemon, whereas Hamlin on Cleopatra recorded minimum (146.77 g) weight with maximum acidity (0.64%). The highest juice content (43.90%) and Vit.C (45.30 mg/100 ml) was recorded in Valencia on Volkameriana (Fig. 22). Pera on Limocrova recorded second highest (42.36%) juice content. Maximum TSS content (11.67%) was noted in Mosambi on Rough lemon followed by Mosambi on Rangpur lime. The average maximum fruit yield (14.41 kg/plant) was recorded in Pera on Limocrova followed on Westin on Swingle (13.82 kg/plant). When extrapolated on area basis, yield was 8.00 t/ha in Pera on Limocrova. Washington navel on rough lemon recorded minimum yields of 1.87 t/ha.

Table 10 : Plant growth, fruit yield and quality of sweet orange and grapefruit varietes on raised-bed planting system

Varieties	Plant height (m)	Stock scion ratio	Canopy Volume (m^3)	Fruit weight (g)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/100 ml)	No of seeds/ fruit	Rind thickness (mm)	Fruit yield (kg/plant)
Blood Red	3.53	1.17	20	178	47	7.83	0.18	45	4	3.51	26
Jaffa	3.44	1.05	14	190	45	7.83	0.17	48	12	2.92	21
Pineapple	3.73	1.18	16	220	44	7.73	0.19	46	17	2.97	13
Mosambi	3.48	1.10	14	232	41	9.30	0.12	36	13	3.50	18
Katol gold	2.97	1.19	11	286	43	9.38	0.15	40	16	3.84	12
CD (P=0.05)	0.125	0.056	0.917	2.044	2.681	0.263	0.047	1.784	3.209	NS	1.800
Star ruby	3.85	1.18	23	452	41	7.10	0.45	42	2	7.25	24
Red blush	4.28	1.14	27	365	42	7.19	0.42	37	2	8.89	23
Marsh seedless	3.82	1.17	22	461	40	6.67	0.32	37	3	8.58	23
CD (P=0.05)	NS	NS	1.448	1.657	0.878	0.106	0.004	0.291	0.086	0.293	NS

Fig. 21 : Grapefruit varieties showing heavy bearing on raised bed planting system

Soil nutrient status : Significant variation was observed with all the soil macro nutrients. The N, P and K content was ranged between 247.65-276.52%, 37.71-48.16% and 678.07 to 1153.13, respectively. The highest soil N was recorded under Westin on Limocrova (276.52%) while, soil P and K contents were maximum under Mosambi on Rough Lemon (48.16%) and (1153.13%), respectively.

Granulation : In *Ambia* season with delay in harvesting, fruit granulation percentage increased. The granulation % was maximum in Hamlin on Volkameriana (95%) followed by Hamlin on Cleopatra (90%) in month of December. The Westin on Swingle also showed 20% granulation in December. Hamlin is an early season variety while Westin is mid-season. No granulation was noted in Pera on Limocrova and Volkameriana, Natal on Limocrova and Volkameriana, Valencia on Volkameriana, Westin on Limocrova and Mosambi on Rough lemon and Rangpur lime during 2020 season.

Insect-pest infestation : Monitoring of Brazilian sweet orange varieties on raised bed for insect pests and mite incidence was done during January - December, 2020. The observations revealed that there was not much significant difference in susceptibility to citrus psylld infestation among the different varieties under study. The varieties, Westin on Limocrova, Westin on Swingle, Mosambi on Rough lemon and Mosambi on Rangpur lime were significantly at par wrt. maximum psylla infestation while it was lowest in Valencia on Volkameriana (7.38/5 cm twig), Hamlin on Volkameriana (7.79/5 cm twig) and 7.90/5 cm twig in Pera on volka. Blackfly adult population per leaf was the lowest in Natal on Volkameriana (4.81 per leaf) and in Hamlin on Cleopatra for leaf miner infestation (10.09 %). However, for mite susceptibility, Mosambi on Rangpur, Mosambi on Rough lemon and Pera on Volameriana recorded maximum mite population of 5.16, 5.17 & 4.48 per leaf, respectively during the period under study.

Evaluation of acid lime cultivars on raised-bed system

Plant growth : The maximum plant height (3.55 m) was recorded in PKM-1 (Jaidevi) followed by Pramalini (3.35 m) whereas minimum height was recorded in Balaji (2.85 m). Highest canopy volume (18.80 m^3) was noted in Sai

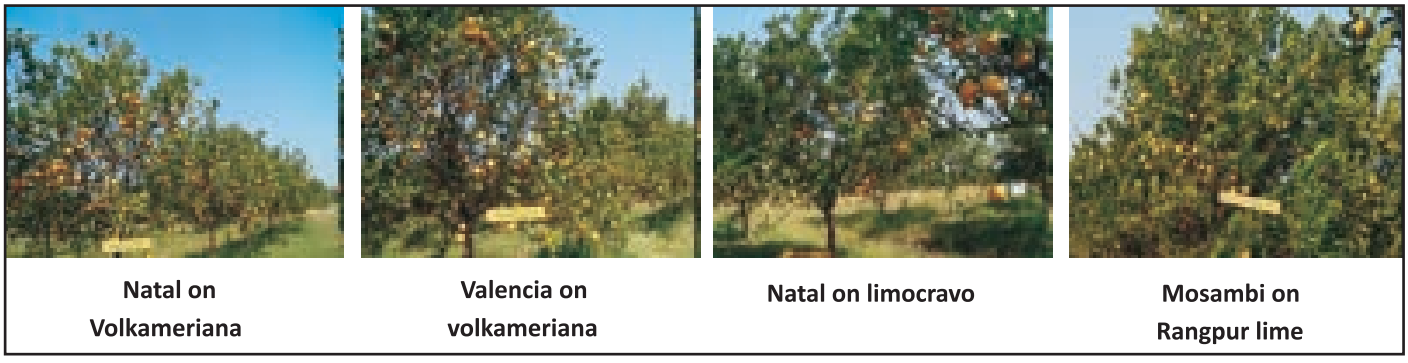


Fig. 22 : Exotic sweet orange cultivars on raised bed planting system

Sharbati while, minimum canopy volume (5.15m^3) was observed in Chakradhar (Fig. 23).

PDKV Bahar lime

Phule Sharbati

Sai Sharbati

Balaji

Fig. 23 : Acid lime cultivars on raised bed planting system

Fruit quality and yield : Maximum average fruit weight (46.36 g), TSS (7.20 %) with acidity (3.27 %) was recorded in PKM-1. Where as phule sharbati showed maximum Vit. C (32.27 mg/100 ml). NRCC-8 recorded maximum juice content (59.33%) followed by Sai sharbati (58.03%). Highest fruit yield was recorded in PKM-1 i.e. 10.90 t/ha while in Vikram minimum fruit yield was recorded (3.26 t /ha).

Soil nutrient status : The Soil nutrient status was evaluated in different cvs. This year soil nutrient status indicated significantly maximum N (306.8 kg/ha) in NRCC-8 and minimum N (225.4 kg/ha) in Pramalini in the experimental block. The soil P was recorded maximum in Sai Sharbati 33.79-46.9 kg/ha whereas K uptake was resulted to be maximum with Chakradhar 961.8 kg/ha.

Insect-pest infestation : Among the acid lime lines planted on block. no. 105, maximum psylla population was observed on NRCC-8 (3.47/5 cm twig) and it was significantly lower on Balaji (0.26), Pramalini (0.27) and PDKV Bahar lime (0.31). Higher leaf miner infestation of 17.60% was observed on PKM-Jaidevi and it was lower on 9.40% in PDKV Bahar lime. Thrips infestation was below the ETL ranging from 0.22-1.20/stem tapping and mite population ranged from 0.42-2.83 mites/leaf.

Disease susceptibility : Ten different acid lime cultivars planted in block no. 105 were evaluated under field conditions for the presence of bacterial canker infection. All the acid lime cultivars were budded on rough lemon rootstocks. Disease incidence on leaves ranged from 17.24-76.74 % in those acid lime clones and percent disease index (PDI) ranged from 3.45-12.8. Witches broom disease symptoms was observed in acid lime field during the month of March in some varieties which includes Balaji, Vikram, Sai Sharbati.

Evaluation of lemon cultivars on raised bed system

Plant growth : The Kagzi Kalan showed maximum plant height (2.86m) with maximum canopy volume (17.19 m^3). Whereas, Assam lemon recorded least plant height (2.69 m) and minimum canopy volume (13 m^3) (Table 11).

Fruit yield and quality : The lemon cultivar Assam lemon recorded maximum average fruit weight (172 g) and highest acidity (6.40%) with minimum TSS, Vit.C and juice content as (7.58%), (37.06 mg/100ml) and (43.06%) respectively. The highest juice content (52.71%) and vit.C (48.48 mg/100 ml) were observed in Baramasi lemon with minimum acidity (4.85%). Maximum fruit yield (31 kg/plant) and productivity (17.24 t/ha) was in Assam lemon followed by Kagzi Kalan (Table 11).

Soil nutrient status: Significant variation was observed for N and K, whereas P showed Non significance. The soil N range was 287.08-344.78 kg/ha in which Baramasi lemon has highest N content. P range was 22.29-28.78 kg/ha and Kagzi Kalan has maximum P content while, K range was 562.52-841.96 kg/ha and maximum in Pant lemon.

Disease incidence: Lemon cultivars were evaluated under field conditions for the presence of bacterial canker infection. Canker incidence was observed only in Assam lemon (with 36.95% disease incidence on leaves and PDI 7.35). Other cultivars (Pant lemon, Kagzi Kalan, Baramasi lemon) were found free from canker.

Evaluation of exotic mandarin varieties on raised bed

Plant growth : Nagpur mandarin seedless-4 recorded maximum growth with respect to plant height (4.47m) and canopy volume (14 m^3). Pearl Tangelo recorded minimum plant height (3.27 m) while W. Murcott recorded minimum canopy volume (8 m^3) (Table 12).

Fruit quality and yield : Exotic mandarin varieties showed better fruiting during this year. Average fruit weight (222 g), TSS (9.20%) and activity (0.27%) were maximum in Daisy. Where as, Vit. C (36 mg / 100 ml) was recorded maximum in Pearl Tangelo with minimum acidity (0.23%). Maximum fruit yield was recorded in Pearl Tangeleo i.e. 16 Kg/ plant (Table 12).

Soil nutrient status : The available soil macro nutrients were estimated in all the cvs. The soil N, P and K contents were 235.62-262.07 kg/ha, 34.72-39.95 kg/ha and 750.60 to 866.60 kg/ha, respectively. Maximum soil N was recorded under Clementine (262.07 kg/ha) while, soil P was maximum under Daisy (39.95 kg/ha) and soil K content was maximum (866.60 kg/ha) under Pearl Tangelo.

Granulation : The granulation % was maximum in Clementine and Michal. It was noted from the month of September. No granulation was noted in Daisy, Pearl tangelo and N4 mandarin in the year 2020.

Evaluation of 'Flame' Grapefruit and Frost Owari mandarin on raised bed system

Plant growth : Flame grapefruit canopy volume was 6.62 m^3 with 2.62 m plant height while Frost Owari had 4.59 m^3 canopy volume with 2.51 m plant height. All the plants were in healthy condition without any disease symptoms in both the crops.

Fruit quality and yield : Since the block is accommodated with mandarin and grapefruit with six line of each spp. Flame grapefruit and Frost Owari showed fruiting this year. The yield recorded in Frost owari (6.92 t/ha) and in Flame grapefruit (5.79 t/ha).

Insect-pest infestation : Insect pest incidence on Flame Grapefruit and Frost Owari cultivars were observed from January to December 2020 at fortnightly intervals. Psylla infestation recorded in the range of 4.2-5.14/5 cm twig during March to August. Infestation of leaf miner was lowest (1.42%) in October and highest (16.09%) in August on flame grapefruit cultivar. Aphid, thrips, white fly and mite population was recorded below the ETL. On Frost Owari infestation of psylla (1.2-6.4/5 cm twig), leaf miner (6.17-19.88%), thrips (0.00 -3.46/stem tapping), mites (1.85-3.8 / leaf) was also recorded.

Evaluation of grapefruit and pummelo cultivars on raised bed system

The plantation of varieties was done in the field during July, 2017. The varieties were NRCC grapefruit-6, NRCC Pummelo-5 and US Pummelo-145 at 6x3 m spacing.

Evaluation of plant growth data reveals that NRCC Grapefruit-6 showed maximum plant height (2.95 m), stock scion girth (30.8 cm, 26.14 cm) and canopy volume (12.55 m^3).

Fruit quality and yield: Average fruit weight (296.33 g), acidity (1.28%), TSS (8.30%) and juice content (56.64%) was recorded in NRCC grapefruit 6. In pummelo, maximum average fruit weight (1.64kg) and TSS (7.7%) was observed in US Pummelo-145 while Vit. C (42.6mg/100mg), juice content (31.92%) and acidity (1.216%) was recorded maximum in NRCC Pummelo-5. Maximum fruit yield was recorded in US Pummelo-145 i.e. 4.75 t/ha.

Insect-pest infestation : Pest incidence on NRCC grapefruit-6 cultivar was observed from January to March and June to December 2020. Infestation of leaf miner was in the range of 11.87 to 16.06%. Similarly in NRCC Pummelo-5 and US Pummelo-145 leaf miner infestation ranges from 8.37-13.16 % and 10.55-19.2%, respectively. Thrips population was relatively less on all these cultivars (1.5-4.92 /stem tapping) Citrus psyllid, blackfly, white fly, aphid and lemon butterfly incidence was also recorded below the ETL.

Evaluation of Lemon and Acid lime cultivars on raised bed system.

A new experiment was started in the block no. 106 during the month of February 2019. The three varieties were planted i.e. Lemino (seedless lemon), Ganganagar (Acid lime) and Konkan lemon with 6×3 m spacing. Average plant height ranged from 1.3 m – 2.2 m whereas, lemino noted maximum plant growth (2.2m) and stock and scion girth.

Evaluation of 3 year old nursery grafts of Nagpur mandarin on raised bed planting system

Three year old grafts (as maintained in nursery) of Nagpur mandarin were compared on raised bed planting system with conventionally planted Nagpur mandarin (as taken from the nursery in normal practice). The plants were also compared with flatbed system in the same block. Plant height varied from 1.8m (1 yr old) to 2.8m (3 yr old) plants whereas, raised bed shows more canopy volume than flat bed. All the plants are showing healthy growth and experiment is in progress (Table 13).

Fruit quality and yield: The fruit quality data was recorded maximum with respect to average fruit weight, juice content, Vit. C and TSS in Nagpur mandarin plants on

Table 11 : Plant growth, fruit yield and quality of different lemon cultivars on raised bed planting system

Varieties	Plant height (m)	Canopy volume (m^3)	Fruit wt (g)	No. of seeds / fruit	TSS (%)	Juice content (%)	Acidity (%)	Rind Thickness (mm)	Vit. C (mg/100 ml)	Fruit yield (kg/ plant)
Pant lemon	2.81	16	143	16	7.75	50.66	5.91	2.43	37.46	27
Assam lemon	2.69	13	171	17	7.58	43.06	6.40	3.26	37.06	31
Kagzi Kalan	2.86	17.19	155	30	7.89	51.98	5.76	2.41	45.17	29
Baramasi lemon	2.70	13	159	32	7.80	52.71	4.85	2.88	48.48	27
CD (P= 0.05)	0.05	NS	11.26	1.22	0.18	1.23	0.04	0.04	0.43	1.68

Table 12 : Plant growth, fruit yield and quality of exotic mandarin varieties on raised bed planting system

Varieties	Plant height (m)	Canopy volume (m^3)	Fruit weight (g)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/ 100 ml)	No of seeds/ fruit	Rind thickness (mm)	Fruit yield (kg/plt)
W. Murcott	3.53	8	134	45	8.00	0.26	24	8.72	2.51	13
Daisy	3.63	13	229	34	9.20	0.27	27	6.00	1.29	8
Pearl Tangelo	3.27	10	181	42	8.28	0.23	36	16.00	3.62	16
N-4(Seedless)	4.47	14	102	58	8.48	0.19	34	2.75	2.12	11
CD (P = 0.05)	0.24	0.07	3.04	2.59	0.10	0.004	2.20	1.57	0.36	0.87

raised bed (3 yr old) whereas, acidity was recorded maximum in Nagpur mandarin plants on flat bed (3 yr old). The fruit yield was recorded 1.59 kg/plant and 0.88 t/ha on raised bed plants (Table 13).

Monitoring of *Phytophthora* population under raised bed and flat bed field Conditions

Disease incidence : *Phytophthora* population was monitored regularly in 3-year old Nagpur mandarin plants budded on rough lemon rootstocks under raised bed and flatbed field Conditions. *Phytophthora* propagule counts were monitored from rhizosphere soil near the trunk. The avg. *Phytophthora* population density (propagule/ cc soil) was found minimum under raised bed condition (1.66 / cc soil) compared to the flat bed condition (9.2 /cc soil).

Diversity of plant parasitic nematodes under raised and flat bed field conditions

Based on the morphological characters, four plant parasitic nematodes (PPN) were identified from 3 year old and 1 year old nursery plants of Nagpur mandarin under both raised bed and flat bed field conditions. The PPN in order of abundance were *Hoplolaimus* > *Pratylenchus* > *Tylenchulus* > *Meloidogyne* spp. In addition, different free living nematodes such as rhabditids, dorylaimids were also identified. However, more number of *Hoplolaimus* (172 no. per 250 cc soil) and *Pratylenchus* (102 no. per 250 cc soil) population was observed in 3 year old Nagpur mandarin plants compared to flat bed plants (116 no. and 67 no. per 250 cc soil) respectively.

Evaluation of exotic sweet orange, grapefruit and lemon varieties on raised bed system

Six varieties of sweet orange i.e. Diller, Cara-cara, Trovita strain, Delta, Salustiana, Mars early and 2 varieties of grapefruits i.e. Rio red and star ruby were planted with the spacing of 6×3m. The initial growth performance was recorded and plant height Range from 1.1 (Cara-Cara) to 1.6m (Delta cvs.) whereas stock-scion growth recorded maximumwith Mars Early (1.8 and 16 cm).

Genoa, Frost Lisbon, Limonero fino, Verna, Limonero fino (IVIA 95), Frost eurekha, Villafrance Nucellar, Villafranca Nucellar, Bearss varieties of exotic lemon varieties were planted with the spacing of 6×3 m. The initial plant height growth was noted to be maximum (2.5 m) with frost Eureka whereas Verna recorded minimum (2.0 m).

3.2.2.3 Response of citrus trees to training, pruning and plant growth retardants with respect to management of canopy architecture, plant density and productivity

Effect of training and pruning on canopy and productivity of acid lime cv. 'Pramalini' under different planting densities

Soil physico-chemical properties

Soil properties *viz*. pH (7.87 to 8.06), electrical conductivity (0.426 to 0.548 dS/m) and organic carbon (1.09 to 1.44 %) showed considerable variation amongst different treatments. Considerable increase in electrical conductivity and organic carbon content was recorded over the last year. Highest content of soil organic carbon

was observed in 2.5 x 2.5 m spacing (1600 plants / ha) followed by 5x2.5 m (800 plants/ ha) and 5x5 m spacing (400 plants/ ha) treatments.

Soil fertility status and leaf nutrient content

The soil available macronutrients were in optimum range. All the nutrients revealed significant variation amongst the treatments. Plants at 2.5 x 2.5 m spacing had highest content of N, P and K while it was lowest in 5 x 5 m spacing (Fig. 24). Leaf nutrient contents significantly varied with respect to N (2.10-2.55%), P (0.082-0.10%) and K (2.20 to 2.27%). High leaf content of N and P was found in the plants spaced at 5 x 2.5 m. (Fig. 25).

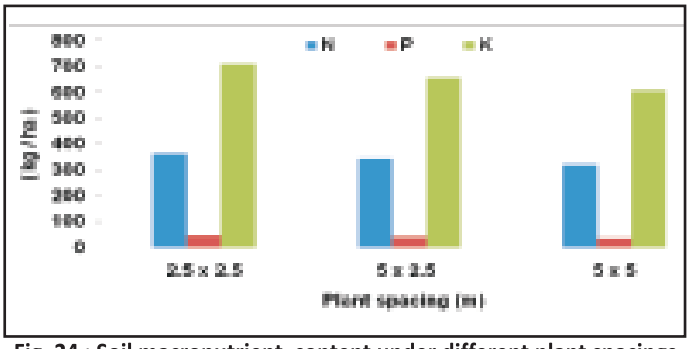


Fig. 24 : Soil macronutrient content under different plant spacings

Vegetative growth : All the growth parameters showed highly significant variation amongst the treatments. Plant height varied from 3.95 to 4.06 m, average plant spread from 2.45 to 4.28 m^3, canopy volume from 12.08 to 37.42 cu m and stem girth from 42.80 to 45.70 cm amongst the treatments. Plants spaced 5 x 5 m recorded highest values of canopy volume and stock girth. Plant height found to increase with the decrease in plant spacing and was highest in 2.5 x 2.5 m. (Fig. 26).

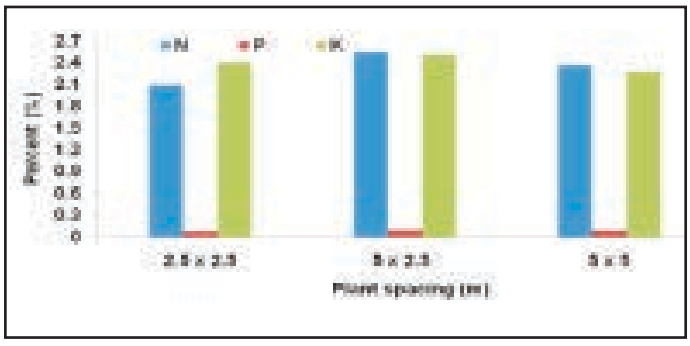


Fig. 25 : Leaf macronutrient content as affected by different spacings

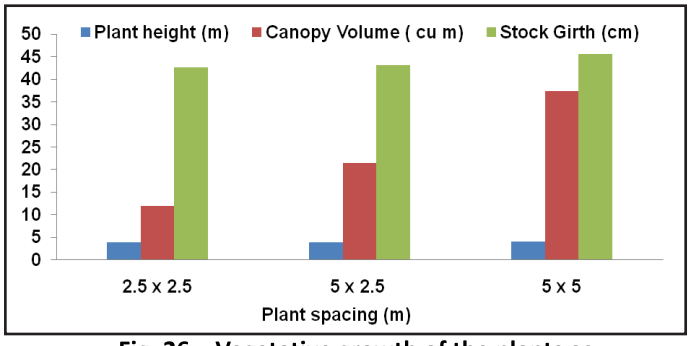


Fig. 26 : Vegetative growth of the plants as affected by different planting densities

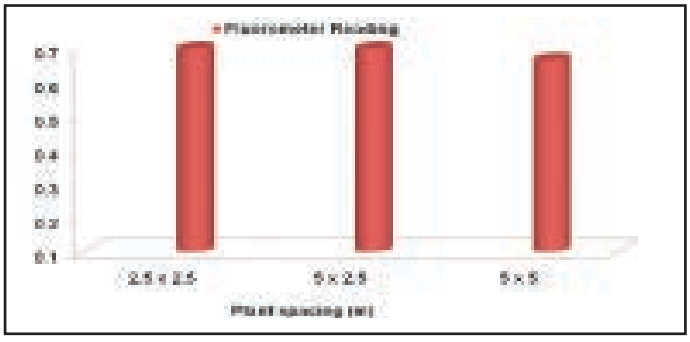


Fig. 27 : Chlorophyll content of the plants as affected by different planting densities

Table 13 : Plant growth of 1 year and 3 year old Nagpur mandarin plants on raised bed planting system

Varieties	Plant height (m)	Spread East -West (m)	Spread North - South (m)	Stock girth (cm)	Scion girth (cm)	Canopy volume (m^3)
Raised bed 3yr.	2.8	1.1	0.9	19	22	1.52
Raised bed 1 yr.	1.9	0.5	0.6	15	16	0.31
Flat bed 3 yr.	2.2	0.8	0.8	18	20	0.76
Flat bed 1yr.	1.8	0.4	0.5	16	14	0.20
CD (P = 0.05)	0.110	0.124	0.163	0.755	0.810	0.815

Leaf chlorophyll content was recorded with the help of Chlorophyll Fluorometer which showed significant variation amongst the treatments. Leaf chlorophyll content showed significant variation amongst the treatments. Highest chlorophyll content was observed in the leaves of the plants at 5 x 2.5 m spacing while it was lowest in 5 x 5 m treatment (Fig. 27).

Intensity of PAR light : Observations on intensity of PAR light as affected by different plant densities were recorded using Quantum Light Meter during November 2019 to March 2020 below the plant canopy in all the four directions. The readings were recorded in terms of Photosynthetic Photon Flux Density (PPFD). The pooled average data revealed highly significant variation amongst the treatments in all the directions. The pooled average data significantly varied from 98.81 to 297.3, 65.95 to 215.11, 117.03 to 218.50 and 139.75 to 249.70 µ mol/ m^2/s below the plant canopy in East, West, North and South direction, respectively. Highest light interception was observed in high density planting system where plants were spaced at 2.5 x 2.5 m spacing. Lowest interception was observed below the plants spaced at 5 x 5 m while it was intermediate in 5 x 2.5 m spacing treatments. Under 2.5 x 2.5 m spacing light interception was more in all the four directions i. e. space between two rows as well as plants while in 5 x 2.5 m spacing treatment it was higher in East & West direction i.e. space between two plants.

Fruit yield : Acid lime fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of July 2020 and measured in terms of number of fruits and weight of the fruit (Table 14) per plant. Fruit yield in terms number and weight of fruits significantly varied from 567 to 1078 fruits per plant and 24.43 to 47.23 kg/plant, respectively amongst the treatments. Highest fruit yield was observed in the plants spaced at 5 x 5 m (1078 fruits/plant) followed by 2.5 x 5 m (891 fruits/plant) and was lowest in 2.5 x 2.5 m (567 fruits/plant) spacing treatments. Weight of the individual fruit was highest in the plants at 5 x5 m (44.14 g) spacing. Fruit yield in terms of weight (t/ha) was two times higher under ultra high density plantation of 2.5 x 2.5 m (39.09 t/ha) as compared to the plants at normal spacing of 5x 5 m (19.03 t/ha).

Table 14 : Fruit yield of acid lime as affected by different plant spacings

Spacing (m)	No. of fruits/plant	Avg. fruit wt (g)	Fruit yield (kg/plant)	Yield (t/ha)
2.5 x 2.5	567	43.08	24.43	39.09
2.5 x 5	891	41.62	37.08	29.66
5 x 5	1078	44.14	47.58	19.03
CD (P=0.05)	79.501*	1.498*	4.201*	2.666*

Ultra High density (2.5x2.5 m) High density (2.5x5 m) Normal density (5x5 m)

Fig. 28 : Acid lime plants grown under different plant spacings / densities

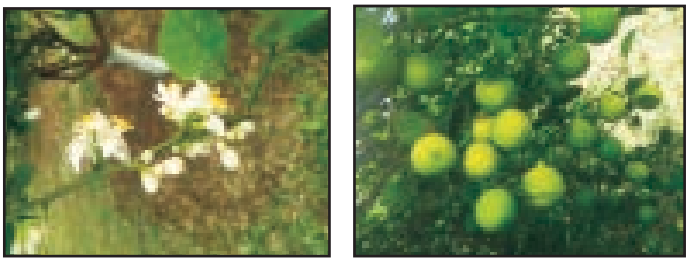


Fig. 29 : Fruiting and flowering in Acid lime

Fruit quality : Acid lime fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of July 2020 and analysed for different quality parameters. Fruit quality in terms of fruit length:breadth ratio; peel thickness, showed significant variation while it was non-significant in case of other parameters. Data showed that bigger size fruits as indicated by maximum length (45.91 mm) and breadth (41.94 mm) of the fruits were produced on the plants planted at 5x5 m spacing. While lowest peel thickness (1.63 mm) was recorded in 2 5x2.5 m treatment. Highest juice percent (49.82%) was found in 5x5 m spacing (Table 15).

Incidence of insect pests under different planting densities for Jan-Dec., 2020

Incidence of citrus leaf miner (*Phyllocnistis citrella* Stainton), blackfly (*Aleurocanthus woglumi* Ashby) and whitefly (*Dialeurodes citri* Ashmead) on acid lime cultivar grown under three different spacings 2.5m x 2.5m, 2.5m x 5m and 5m x 5m was recorded during flushing seasons *viz*., *Ambia, Mrig* and *Hasta* in 2020.

Results revealed that citrus leaf miner, blackfly and whitefly remained active during all flushing seasons *viz. Ambia, Mrig* and *Hasta* in 2020 irrespective of the spacing. Insect pest incidence was significantly higher in closer spacing. In 2.5x2.5 m planting density, % leaf miner infestation ranged from 18.12 (*Hasta*) to 27.46 (*Mrig*) while in spacing 2.5x5 m, % leaf miner infestation ranged from 10.30 (*Hasta*) to 20.85 (*Mrig*). In 5x5 m spacing, % leaf miner infestation ranged from 3.13 (*Mrig*) to 5.22 (*Ambia*). Blackfly population per leaf ranged from 6.44 (*Ambia*) to 24.10 (*Mrig*) in the spacing of 2.5x2.5 m, 3.87 (*Ambia*) to 13.44 (*Mrig*) in the spacing 2.5x5 m, and 1.31 (*Ambia*) to 7.94 (*Hasta*) in spacing of 5x5 m. Whitefly population per leaf ranged from 4.06 (*Hasta*), to 13.36 (*Mrig*), 2.83 (*Hasta*) to 8.00 (*Mrig*) and 1.06 (*Hasta*) to 4.65 (*Mrig*) in the spacing of 2.5x2.5 m, 2.5x 5 m, and 5x5 m respectively.

Incidence of disease : Acid lime plants under different spacing were evaluated under field conditions for the presence of bacterial canker infection. Canker incidence on leaves and disease intensity were found more in 2.5x 2.5 m and 2.5x5 m spacing compared to that of 5x5 m spacing.

3.2.2.4 Technology Demonstration on Canopy architecture management in citrus through training and pruning for higher density and increased productivity

Canopy management in Nagpur mandarin

Leaf and soil fertility status

Maximum content of leaf N (2.29%) and P (0.10%) was observed in the plants at 6x3 m while K (2.05%) was

Table 15 : Quality of acid lime fruits as affected by different plant spacings / densities

Spacing (m)	Length: Breadth Ratio	Peel thickness (mm)	Juice (%)	TSS (%)	Acidity (%)	Vit C (mg/100 ml juice)
2.5 x 2.5	1.11	1.63	48.26	7.83	7.31	21.84
2.5 x 5	1.09	1.74	46.60	7.94	6.46	22.08
5 x 5	1.09	1.82	49.82	8.01	6.59	22.24
CD (P=0.05)	0.016	0.115*	2.33	NS	0.463*	NS

highest in plants at 4x1 m spacings treatment (Fig. 30). Organic carbon content was highest (1.12 %) in 3 x 1 m spacing treatment (Fig. 31). Availability of soil nutrients *viz*., N (251.77 kg/ha), P (37.18 kg/ha) and K (837.20 kg/ha) was significantly high in 3 x 1 m, 3 x 2 m and 4 x 2 m spacing treatments, respectively (Fig. 32). Higher nutrient availability in close spacing plantation might be due to fact that nutrients were applied on per plant basis thus covering maximum rooting area below the plant canopy.

Vegetative growth of Nagpur mandarin plants

Vegetative growth parameters of Nagpur mandarin plants as indicated by plant height, plant spread and stock and scion girth were recorded. The results revealed that plant spread in East-West, North-South direction, average plant spread, height and canopy volume of the plant showed highly significant variation amongst the treatments (Fig. 33) Highest plant height was observed in the spacing of 4 x 2 m (4.78 m) followed 3 x 2 m (4.62 m)spacing. Plants planted at closer spacing have tendency to grow in upward direction. Plant spread in the direction of east-west, north-south, average spread and canopy volume was the highest in 6 x 3 m (26.66 m^3) spacing followed by 4 x3 (22.63 m^3), 4 x 2 (18.17 m^3) and 6 x 6 m (17.22 m^3) spacing treatment. Stock girth was highest in 6 x 3 m (46.82 cm) followed by (44.27 cm) (Fig. 33). Chlorophyll content in the leaves as indicated by fluorometer (SPAD values) readings, showed highly significant variation amongst the treatments. Highest Fluorometer readings were observed in the leaves at a spacing of 3 x 2 m followed by 3 x 1 m spacing and was lowest in 4 x 1 m spacing (Fig. 34).

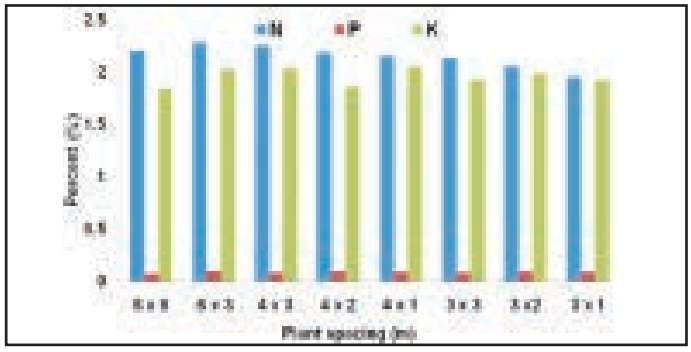


Fig. 30 : Leaf macronutrient content as affected by different planting densities

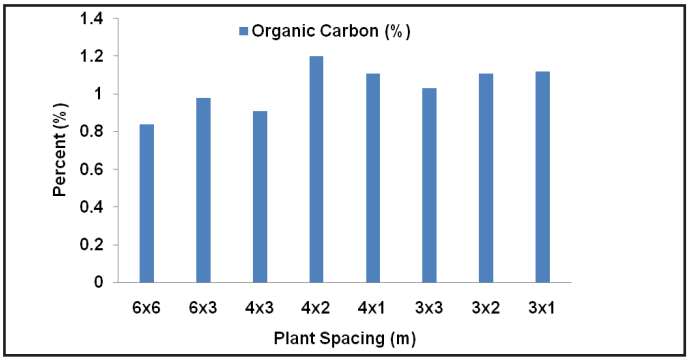


Fig. 31 : Organic carbon availability as affected by different planting densities

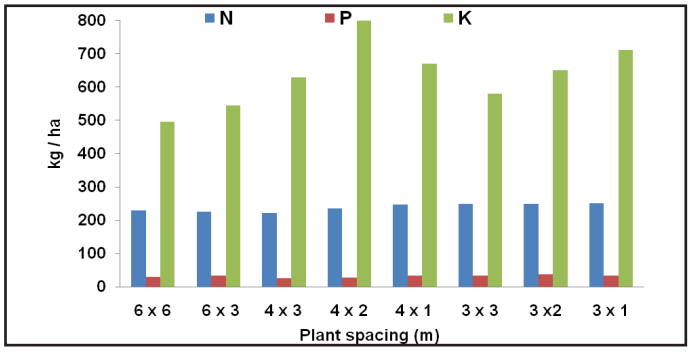


Fig. 32 : Soil macronutrient availability as affected by different planting densities

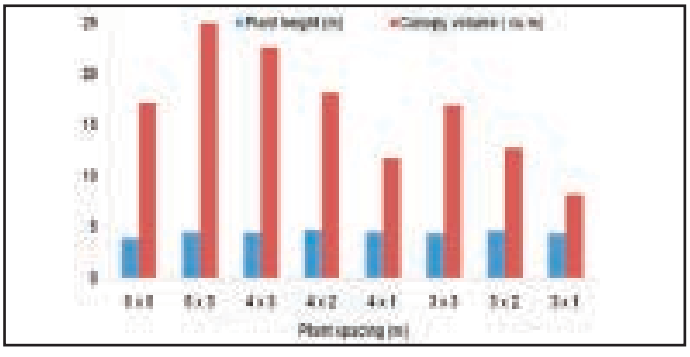


Fig. 33: Vegetative growth of the plants as affected by different planting densities

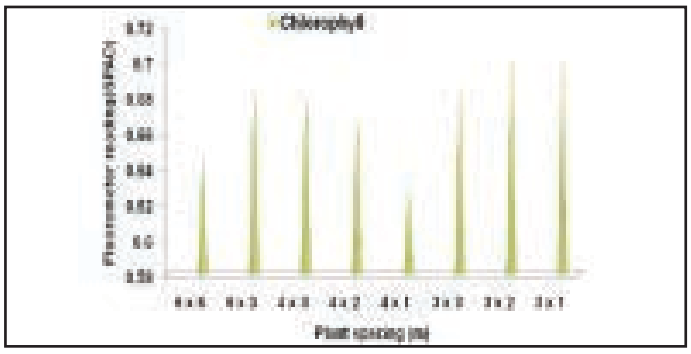


Fig. 34 : Chlorophyll content of the plants as affected by different planting densities

Intensity of PAR light

Observations on intensity of PAR light as affected by different plant densities were recorded using Quantum Light Meter (make Spectrum Technologies Inc., USA) below the plant canopy in all the four directions. The readings were recorded in terms of Photosynthetic Photon Flux Density (PPFD). The data revealed highly significant variation amongst the treatments in all the directions. Intensity of PAR light in terms of Photosynthetic Photon Flux Density (PPFD) significantly varied from 69.00 to 227.50, 232.25 to 1207.75, 85.00 to 1052.75 and 85.50 to 1002.75 µ mol/ m^2/s below the plant canopy in East, West, North and South direction, respectively. Highest light interception was observed in ultra-high density planting system where plants were planted at 3x1 m spacing. Lowest interception was observed below the plants spaced at 6 x 6 m.

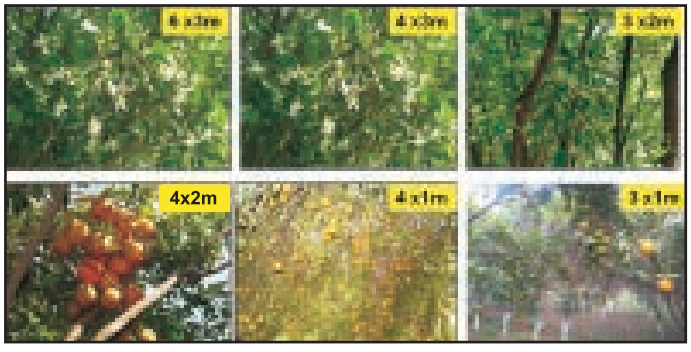


Fig. 35 : Flowering and fruiting at high density planting under different spacings

Fruit yield

Nagpur mandarin fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of December 2020 and measured in terms of number and weight of the fruits (Table 16). The data revealed highly significant variation was observed amongst different treatments. Fruit yield in terms of number and weights of fruit varied significantly from 172 to 677 with lowest in 4 x1 m (172) and highest in 6 x 6 m (677). Average fruit weight was highest in 6 x 3 m (163 g) and lowest in 3 x 1 m spacing (135 g). Fruit yield was substantially high in ultra-high density planting system (3x 1 m) (83.28 t/ha) followed by 4 x3 m spacing (61.70 t/ha) while lowest (29.59 t/ha) was observed in 6 x 6 m spacing (Table 16).

Fruit quality

Nagpur mandarin fruits (*Ambia bahar*) harvested during the month of November 2020 were analysed for different quality parameters. Fruit quality in terms of fruit length, breadth, peel thickness, Total Soluble Solids (TSS), Acidity and fruit juice percent showed significant variation. Data showed that bigger size fruits indicated by fruit length (70.17 mm) and breadth (74.97 mm) was in 3x1m spacing (Table 16). Juice recovery (46.69%) was maximum in 6 x 6 m and TSS (9.63^0 Brix) was maximum in the fruits of the plants spaced at 4 x 3 m spacing (Table 16).

Canopy management in Acid lime

Soil fertility and leaf nutrient status

Soil samples were collected from the active rootzone of the plants below the canopy, processed and analysed for different macronutrient content. The data showed significant variation in availability of most of the nutrients. Availability of major nutrients *viz*., N (343.81 kg/ha) and P (28.97 kg/ha) was highest in 3x1 m spacing while, K (690.67 kg/ha) was highest in 4x3 m spacing treatments. In general, plants planted with high density system recorded higher nutrient availability in soil (Fig. 36). Leaf samples were collected, washed, processed and analysed for nutrient analysis. The data revealed that all the major nutrients showed significant variation amongst the treatments.

Table 16 : Fruit yield and quality of Nagpur mandarin as affected by different planting densities

Spacing (m) and density	Fruit L:B ratio	Peel thickness (mm)	Juice (%)	TSS (^{0} Brix)	Acidity (%)	TSS/ Acid ratio	Vit C (mg/100 ml) juice	Fruit weight (g)	Yield (kg/ plant)	Yield (t/ha)
6 x 6 (277 pl/ha)	0.92	2.22	46.69	9.23	0.74	12.54	27.00	157.0	106.52	29.59
6 x 3 (555 pl /ha)	0.90	2.52	42.95	9.27	0.76	12.28	20.80	163.0	98.25	54.58
4 x 3 (833 pl/ha)	0.90	2.09	45.42	9.63	0.79	12.21	14.80	157.0	74.04	61.70
4 x 2 (1250 pl/ha)	0.94	2.44	43.40	9.10	0.84	10.84	21.80	148.0	42.41	53.02
4 x 1 (2500 pl / ha)	0.94	2.71	41.30	9.00	0.81	11.16	24.40	135.0	23.22	58.04
3 x 3 (1111 pl / ha)	0.92	2.44	40.89	9.30	0.83	11.25	22.20	141.0	43.57	48.41
3 x 2 (1666 pl / ha)	0.90	2.40	46.15	9.13	0.82	11.19	23.60	143.0	33.49	55.81
3 x 1 (3333 pl / ha)	0.93	2.62	42.58	9.00	0.81	11.14	25.20	135.0	24.98	83.28
CD (P=0.05)	0.08*	0.325	NS	0.298*	0.053	NS	4.577	7.489*	3.762*	4.254*

Leaf N, P and K content showed significant variation. Highest content of N (2.42%) and P (0.102%) was recorded in 6 x 3 m spacing while, K (2.10%) was observed maximum in the plants at 6 x 6 m spacing (Fig. 37).

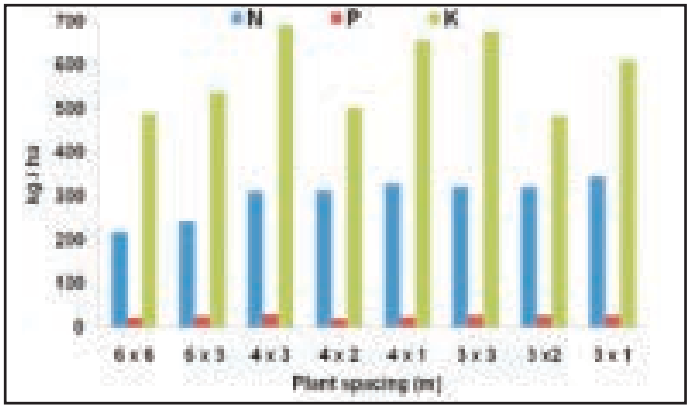


Fig. 36 : Soil macronutrient availability as affected by different planting densities

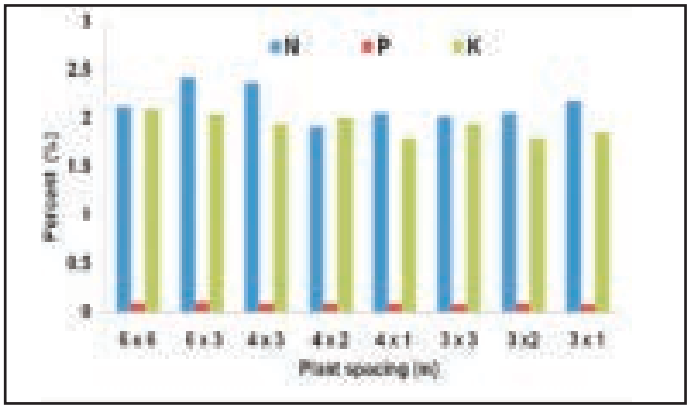


Fig. 37 : Leaf macronutrient content as affected by different planting densities

Vegetative growth of acid lime plants

All the growth parameters showed highly significant variation amongst the treatments Acid lime plants at 6x6 m spacing had excellent growth with highest canopy volume (44.96 m^3) followed by 6x3 m (33.04 m^3). Highest plant height (4.19 m) was recorded in 6x3 m. Highest stock girth (51.83 cm) was observed in 6 x 3 m.

Chlorophyll content in acid lime leaves as indicated by fluorometer readings, were recorded with the help of Chlorophyll Fluorometer which showed non-significant variation amongst the treatments. Highest readings were observed in the leaves of the plants at a spacing of 4x3 m closely followed by 6x6 m spacing and and was lowest in 3x3m spacing treatment .

Intensity of PAR light

Observations on intensity of PAR light as affected by different plant densities were recorded using Quantum Light Meter (make Spectrum Technologies Inc., USA) below the plant canopy in all the four directions. The readings were recorded in terms of Photosynthetic Photon Flux Density (PPFD). Intensity of PAR light were recorded using Quantum Light Meter in terms of Photosynthetic Photon Flux Density (PPFD). The values significantly varied from 69.50 to 136.75, 96.50 to 372.67, 64.67 to 105.58 and 93.58 to 169.50 µ mol/ m^2/s in East, West, North and South direction, respectively. Highest interception as observed in 3x1 m which decreased with the increasing plant spacing and was lowest in 6x6 m plant spacing.

Fig. 38 : Flowering and fruiting at high density plantation under different spacings

Fruit yield

Acid lime fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of July 2020 and measured in terms of number and weight of the fruits (Table 17). The data revealed highly significant variation amongst the treatments. Fruit yield in terms of number and weights of fruit significantly varied from 387 to 1778 fruits and 16.55 to 83.24 kg per plant, respectively amongst the treatments. Weight of the individual fruit was highest (50.12 g) in the plants planted at 3x2 m spacing. When the fruit yield was converted on area basis, totally different trend was observed. Fruit yield was substantailly high in ultra high planting system and recorded highest values (61.40 t/ha) in 3x1 m spacing followed by 4x1 m spacing (41.37 t/ha) treatments, while it was lowest (23.06 t/ha) in normally grown 6x6 m treatment.

Fruit quality

Acid lime fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of July 2020 and analysed for different quality parameters. Fruit quality in terms of fruit length, breadth, Total Soluble Solids (TSS), and fruit juice percent showed significant variation except peel thickness. Data showed that bigger size fruits as indicated by fruit length (48.11 mm) and breadth (44.91 mm) were produced on the plants at 3x2 m spacing, followed by 3x1 m spacing. Maximum fruit juice recovery (44.80%) and TSS (8.14) was observed in 6x6 m spacing treatment.

Incidence of insect pests

Insect pest incidence of citrus leaf miner, psylla, whitefly and blackfly were recorded on acid lime and Nagpur mandarin orchards at village-Nimji in different planting densities during Jan- Dec., 2020. Observations on% infestation for leaf miner, population/5 cm twig for psylla, adults count/ leaf for blackfly and whitefly were recorded during three flushing season *viz*., *Mrig, Hasta and Ambia* in the year 2020. At Nimji, different planting densities were 6x6 m, 6x3 m, 4x3 m, 4x2 m, 4x1 m, 3x3 m, 3x2 m and 3x1 m.

Table 17 : Fruit yield of the plants as affected by different planting densities in acid lime

Spacing (m) and density	No. of fruits/plant	Fruit weight(g)	Fruit yield (kg/plant)	Fruit yield (t/ha)
6 x 6 (277 pl/ha)	1778	46.83	83.24	23.06
6 x 3 (555 pl/ha)	1446	46.43	67.15	37.27
4 x 3 (833 pl/ha)	849	44.30	37.62	31.29
4 x 2 (1250 pl/ha)	610	45.28	27.62	34.49
4 x 1 (2500 pl /ha)	397	41.62	16.55	41.37
3 x 3 (1111 pl /ha)	451	47.25	21.37	23.74
3 x 2 (1666 pl/ha)	411	50.12	20.60	34.31
3 x 1 (3333 pl/ha)	387	47.55	18.4	61.40
CD (P=0.05)	145.75*	2.59*	7.12*	5.65*

Results showed that, the incidence of insect pests were more in closer spacing's as compared to recommended spacing (6x6 m) irrespective of cultivar and study location. In T_8 (3x1 m) of Nagpur mandarin, incidence of insect pests were significantly higher in close spacing, citrus leaf miner infestation was 16.65%,while blackfly was 9.50 population / leaf; Whitefly was 10.35 adults per leaf where as on acid lime cultivar, leaf miner infestation was 24.67 %, black fly population 15.95 /leaf and whitefly 10.34 adults / leaf was recorded significantly higher in closer spacing of T_8 (3m x 1m).

Architecture engineering for the canopy management in Nagpur mandarin

Leaf nutrient content and soil fertility status

Leaf samples of the plants grown under different planting densities were collected, processed and analysed for different nutrient analysis. The data revealed significant variation in the uptake of all the major nutrients by the plants. Plants at 6x 6 m spacing have highest content of leaf N (2.58%), while leaf P (0.094%) and K (2.03%) was highest in 6x3 (Fig. 39).

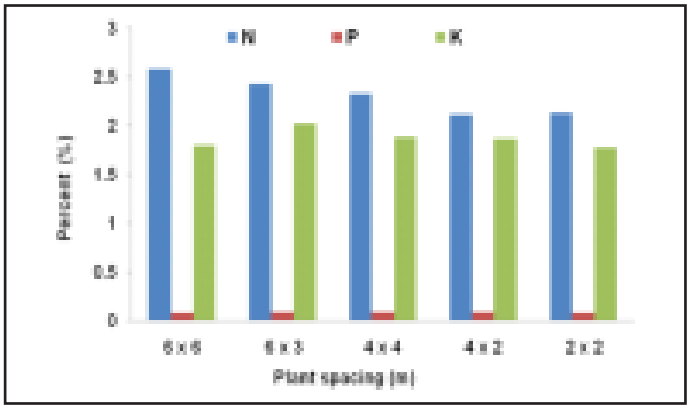


Fig.39 : Leaf nutrient content as affected by different planting densities

Vegetative growth of the plants

Vegetative growth of Nagpur mandarin plants as indicated by plant height, plant spread and stock and scion girth were recorded during January 2020. The results revealed that almost all the growth parameters showed highly significant variation amongst the treatment. Plants grown at 6x6m spacing had better vegetative growth performance in terms of highest plant spread (3.80 m) and canopy volume (28.99 m^3). Plants planted at the spacing of 2x2m also recorded considerably better growth performance and recorded highest plant height (4.17 m). Highest stock girth was in 6x6 m.

Chlorophyll content in the leaves as indicated by fluorometer readings, were recorded with the help of Chlorophyll Fluorometer which showed significant variation amongst the treatments. Highest readings were observed in the leaves of the plants planted at a spacing of 4x2 m (0.712) followed by 6x3 m (0.711) spacing and was lowest in 2x2 m (0.695) spacing treatment (Fig. 40) .

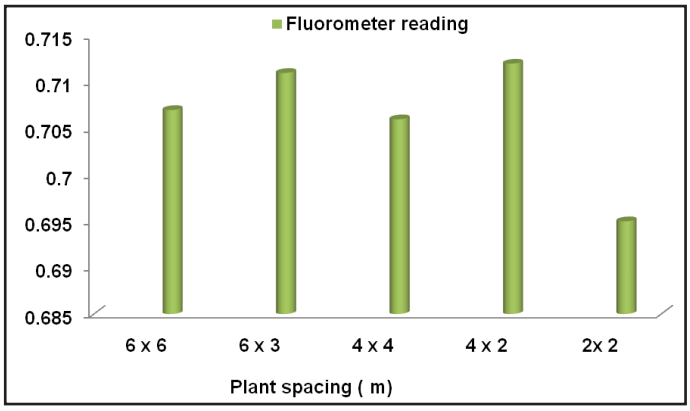


Fig. 40 : Chlorophyll content as affected by different planting densities

Intensity of PAR light

Intensity of PAR light as affected by different plant densities were recorded using Quantum Light Meter in terms of Photosynthetic Photon Flux Density (PPFD). The data significantly varied from 123.33 to 243.92, 66.33 to 122.58, 59.25 to 113.25, and 107.83 to 255.0PPDF in East, West, North and South directions, respectively. Highest light interception was observed in high density planting system where plants were spaced at 6x6 m spacing. Surprisingly, it was low in the plants spaced at 2x2 m spacing might be due to erected growth and lower leaf area of the plants (Table 18).

Fruit yield

Nagpur mandarin fruits (*Ambia bahar*) of all the plants grown under different treatments were harvested during the month of December 2020 and measured in terms of

number and weight of the fruits (Table 19). All the fruit quality parameters showed significant variation. Data revealed that the fruit yield in terms of number of fruits and fruit weight per plant varied from 189 to 772 and 34.57 to 142.48 fruits per plant, respectively. Highest fruit yield (t/ha) was found in 2x2 m spacing (86.42 t/ha) followed by 4x2 m (73.98 t/ha) and lowest was in 6x 6 m spacing (39.58 t/ha). The fruit yield (t/ha) was exceedingly high in plants spaced at 2x2 m spacing which was more than 2.18 times higher compared to normal spacing of 6 x 6 m.

Fig. 41 : Nagpur mandarin plant grown under different plant spacings

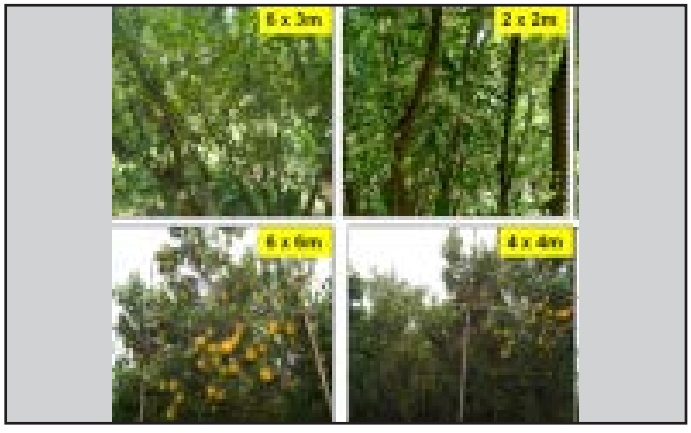


Fig. 42 : Flowering and fruiting at high density plantation of different spacings

Fruit quality

Fruits were harvested during December 2020 and analysed for various fruit quality parameters. All the fruit quality parameters showed no significant variation except fruit height, juice content, TSS and Vitamin C. The TSS (9.7^{0}B) was recorded highest in 6x6 m spacing followed by 6x3 m (9.3^{0}B) spacing and lowest in 2x2 and 4x2 m spacing (9.12^{0}B). Fruit acidity was highest in 6x 6 m (0.84%) and lowest in 4x4 m (0.79%). Juice content was highest in 6x3 m (45.61%) and lowest in 6 x 6 m (42.11%). TSS and acidity ratio was highest in 4 x 4 m (11.86) (Table 19).

Insect Pest Incidence

Insect pest incidence of citrus leaf miner, psylla, whitefly and blackfly were recorded on Nagpur mandarin orchard at Village-Mohpa in Nagpur district in different planting densities during Jan-Dec., 2020. Observations on % infestation for leaf miner, population/5 cm twig for psylla, adults count/ leaf for blackfly and whitefly were recorded during three flushing season *viz*., *Mrig, Hasta and Ambia* in the year 2020 at Mohpa, planting densities were 6x6m^{2},

Table 18 : Intensity of PAR light (Photosynthetic Photon Flux Density or PPFD) as affected by different planting densities in Nagpur mandarin

Treatments/ Plant spacing (m) and density	PPDF readings in open sunlight and below the plant canopy in different directions (µ mol/ m^{2}/s) (OR x 10 Foot Candles) (OR x 108 Lux)				
	Open Sunlight	East	West	North	South
6x6 (277 pl/ha)	1095.33	197.83	92.92	87.00	196.25
6x3 (555 pl/ha)		193.92	79.08	85.67	158.75
4x4 (625 pl/ha)		243.92	122.58	113.25	255.00
4x2 (1250 pl/ha)		138.58	78.08	78.92	153.08
2x2 (2500 pl/ha)		123.33	66.33	59.25	107.83
CD (P = 0.05)		66.43*	56.93*	94.34*	NS

Table 19 : Quality of the fruits as affected by different planting densities in Nagpur mandarin

Treatments (Spacing and density)	Fruit height (mm)	Juice content (%)	TSS (^{0}Brix)	Acidity (%)	Vitamin C (mg/ 100 ml juice)	TSS / Acid ratio	Fruit weight (g)	Fruit yield per plant (kg)	Fruit yield (t / ha)
6x6 (277 Pl / ha)	0.87	42.11	9.70	0.84	25.32	11.75	184.58	142.48	39.58
6x3 (555 Pl / ha)	0.89	45.61	9.38	0.82	24.96	11.46	182.69	129.52	71.96
4x4 (625 Pl / ha)	0.89	43.97	9.32	0.79	26.04	11.86	184.28	82.23	51.39
4x2 (1250 Pl / ha)	0.90	44.58	9.12	0.80	24.96	11.48	182.83	59.19	73.98
2x2 (2550 Pl / ha)	0.90	43.81	9.12	0.83	26.76	11.05	183.00	34.57	86.42
CD (P=0.05)	0.89*	3.11*	0.315	NS	1.316*	NS	NS	7.255*	7.784*

6x3 m, 4x4 m, 4x2 m and 2x2 m. Incidence of insect pests on Nagpur mandarin was significantly higher in closer spacing of T_5 (2x2m) where infestation level of psylla was 13.50population/5cm twig, Fruit sucking moth infestation was 48.52% and blackfly @15.75 population per leaf. The incidence of blackfly population (13.28/leaf) was higher among all pests.

3.2.2.5 Studies on dynamics of flowering and fruiting in citrus

Effect of 2,4-D and ethephon on deblossoming/ defruiting on *Ambia* crop flowering in Nagpur mandarin

This experiment was laid out at the Institute's experimental farm in twelve years old Nagpur mandarin budded on rough lemon with 6x6 m spacing. The treatments included foliar spray applications at full bloom stage (first week of February) of high concentrations of synthetic auxin 2,4-D (50, 100 and 150 ppm) and ethephon (750, 1000 and 1500 ppm). Watering to the plants was withheld till March to trigger the abscission of flowers and fruitlets (Fig. 43).

It was concluded that foliar application of high concentration of 2,4-D and ethephon in *Ambia* crop at full bloom stage enhances deblossoming/defruiting and defoliation in Nagpur mandarin. Among all the concentrations, ethephon 1500 and 1000 ppm *showed* desirable results in regulation of deblossoming/defruiting and defoliation followed by 2,4-D at 150 and 2,4-D 100 ppm over other concentrations and control. Defoliation in 2,4-D treatments was observed to be less compared to ethephon treatments indicating 2,4-D at higher concentration of 100 and 150 ppm at full bloom stage as better abscission agent compared to ethephon. Higher concentration of ethephon shows some deleterious effects like excessive defoliation on plant. Therefore, application of 2,4-D at 100 and 150 or ethephon at 1000 ppm seem to be promising defruiting agents in Nagpur mandarin for deblossoming/defruiting and defoliation.

Effect of thiourea and GA_3 on intensity of flowering in Nagpur mandarin

This experiment was conducted in an 11-year-old Nagpur mandarin orchard at Hetikundi in Karanja tehsil during the *Ambia* cropping season of 2020 to investigate the effect of thiourea and GA_3 on intensity of *Ambia* cropping in Nagpur mandarin. Foliar applications of thiourea (1-4 %) and GA_3 (10-40 ppm) were given on 28th January, 2020 and subsequent different yield parameters recorded during *Ambia* cropping of Nagpur mandarin (Table 20).

It is concluded that foliar application of thiourea and GA_3at *Ambia* flowering stage enhances the fruits yield in Nagpur mandarin. Among all the concentrations, thiourea 2 % and GA_3 20 ppm showed desirable results in all the fruits yield parameters followed by thiourea 3 % and GA_3 30 ppm over other concentrations. Therefore, application of thiourea 2 % and GA_3 20 ppm may be recommended for increasing fruit yield in Nagpur mandarin.

Effect of liquid formulations of 2,4-D on control of fruit drop and fruit size in Nagpur mandarin

This experiment was conducted on *Ambia* crop of Nagpur mandarin in block no. 44 with available liquid formulations of 2,4-D sodium salt 80% WP, 2,4-D ethyl ester 38% EC and 2,4-D amine salt 58% SL at 10 and 15 ppm concentrations. The sprays were applied four times on 28th February 2020, 29th March 2020, 16th August 2020 and 18th September 2020.

It was concluded that foliar application of 2,4-D at lower concentrations on *Ambia* crop of Nagpur mandarin at flowering stage enhances the fruit retention, yield and physico-chemical parameter in Nagpur mandarin. Among all the concentrations 2,4-D ethyl ester 38% EC 10 ppm showed desirable results in fruit yield parameters followed by 2,4-D ethyl ester 38% EC 15 and 2,4-D amine salt 58% SL 10 ppm over other concentrations. Therefore, application of liquid formulations of 2,4-D ethyl ester 38% EC @ 10 and 15 ppm can be alternatively used alongside 2,4-D sodium salt powder formulations for ease of convenience for the citrus growers for increasing fruit retention and fruit yield in Nagpur mandarin.

(A) (B) (C)

Fig. 43 : Effect of ethephon 750 ppm (A) 1000 ppm (B) 1500 ppm (C) 21 das after spraying

Table 20 : Effect of thiourea and GA_3 on intensity of *Ambia* crop flowering in Nagpur mandarin

Treatment	No. of flowers/meter shoot length	No. of fruit set/meter shoot length	Final retention/ meter shoot length	No. of fruits / plant	Fruit weight(g)	Fruit yield (Kg/plant)	Fruit yield (t/ ha)
Thiourea 1%	96	31 (32.29) *	15 (15.63)	711	128	91 (10.98) **	23
Thiourea 2%	102	47 (46.08)	22 (21.57)	865	148	128 (56.10)	29
Thiourea 3%	109	43 (39.45)	20 (18.35)	838	144	120 (46.34)	27
Thiourea 4%	98	38 (38.78)	18 (18.37)	799	140	112 (36.59)	24
GA_3 10 ppm	108	29 (26.85)	16 (14.81)	714	126	89 (8.54)	23
GA_3 20 ppm	106	48 (45.28)	23 (21.70)	855	146	124 (51.22)	28
GA_3 30 ppm	103	44 42.72	22 (21.36)	837	143	119 (45.12)	25
GA_3 40 ppm	107	32 (29.91)	21 (19.63)	775	132	102 (24.39)	23
Control	109	27 (24.77)	11 (10.09)	683	121	82 (00)	21
CD (P = 0.05)	NS	9.49	5.76	77.29	8.98	14.37	4.97
SE(m)	4.13	3.23	1.96	26.32	3.06	4.89	1.69
C.V.	7.91	16.97	20.69	6.69	4.47	9.07	13.45

*Figures in parantheses indicate per cent shedding of reproductive structures over initial observation.

**Figures in parantheses indicate per cent increase in fruit yield over control.

Table 21 : Effect of liquid formulations of 2,4-D on fruit retention and yield of *Ambia* crop in Nagpur mandarin

Treatments	No. of flowers/ meter shoot length	Fruit set/meter shoot length	Fruit retention				No. of fruits/ plant	Yield (Kg/ plant)	Yield (t/ha)
		25/02/20	29/03/20	30/04/20	18/09/20	29/10/20			
2,4-D sodium salt 80% WP (10 ppm)	109	57	47 (43.11)*	44 (40.36)	23 (21.10)	18 (16.51)	769	102 (21.14)**	24
2,4-D sodium salt 80% WP (15 ppm)	104	64	51 (49.03)	48 (46.15)	28 (26.92)	21 (20.19)	772	105 (25.00)	26
2,4-D amine salt 58% SL (10 ppm)	104	67	58 (55.76)	54 (48.08)	38 (36.53)	23 (22.11)	766	109 (29.76)	26
2,4-D amine salt 58% SL (15 ppm)	108	65	55 (50.92)	51 (47.22)	31 (28.70)	23 (21.12)	747	105 (25.00)	24
2,4-D ethyl ester 38% EC (10 ppm)	110	69	60 (54.54)	52 (47.27)	39 (35.45)	27 (24.54)	789	115 (36.90)	29
2,4-D ethyl ester 38% EC (15 ppm)	103	68	57 (55.33)	52 (50.48)	36 (34.95)	28 (27.18)	810	109 (29.76)	27
Control	107	66	42 (39.25)	37 (34.57)	18 (16.82)	12 (11.21)	676	84 (00)	20
CD (P=0.05)	NS	NS	10.00	8.20	6.54	7.58	34.55	5.57	4.15
SE(m)	4.49	3.40	3.34	2.74	2.18	2.53	11.54	1.86	1.39
C.V.	8.47	10.48	12.67	11.37	14.36	23.39	3.03	3.57	11.07

*Percent fruit set over the no. of flowers/meter shoot length

** Percent increase of fruit yield (kg/plant) over control

3.2.2.6 Precision citriculture through enhanced water and nutrient use efficiency in Nagpur mandarin

The studies on precision citriculture during 2020 were undertaken with 144 trees as grid points and geo-referenced through the GPS-based observations. Based on the production zones, the following three treatments were designed.

T_1 : High production zone : Irrigation with 80% water requirement along with 60 % RDF as fertigation

T_2 : Medium production zone : Irrigation with 90% water requirement along with 80% RDF as fertigation

T_3 : Low production zone : Irrigation with 100% water requirement along with 100 % RDF as fertigation

Growth of mandarin plants

The vegetative growth (plant height, stem height, N-S and E-W tree spread and stem girth) of plants was recorded during. Feb- Oct as per the production zones (Table 22). The mean plant height, stem girth, N-S spread, E-W spread and canopy volume of the plants in high production zone were observed as 3.28 m, 0.45 m, 2.25 m, 2.45 m and 8.32 m^3 respectively. The mean plant height, stem girth, N-S spread, E-W spread and canopy volume of the plants in medium and low production zones were computed as 2.99 m, 0.41 m, 2.18 m, 2.13 m and 6.90 m^3 and 2.70 m, 0.37 m, 1.87 m, 1.93 m and 5.61 m^3, respectively (Table 22). However, the coefficient of variation (CV) of plant height, stem girth, spread and canopy volume was lower within

Table 22 : Growth of mandarin plants under the various production zones

Production zone	Plant growth parameters				
	Plant height (m)	Stem girth (m)	Spread (m)		Canopy volume (m^3)
			N - S	E -W	
T_1: High production management Zone	4.06-2.35 (3.28)	0.60-0.27 (0.45)	3.60-1.20 (2.25)	4.10-1.60 (2.45)	15.54-1.66 (8.32)
T_2: Medium production management zone	3.95-1.66 (2.99)	0.53-0.22 (0.41)	3.30-0.90 (2.18)	3.60-0.80 (2.13)	13.57-1.31 (6.90)
T_3: Low production management Zone	3.50-1.30 (2.70)	0.55-0.17 (0.37)	3.10-0.60 (1.87)	3.50-0.70 (1.93)	11.99-1.09 (5.61)
CV (%) within M Zones					
HPMZ	10.6	7.8	10.9	15.5	7.7
MPMZ	14.2	5.7	9.6	16.4	8.2
LPMZ	13.3	7.9	13.5	19.5	12.9
CV (%) across M Zones	15.5	8.5	16.4	20.7	16.1

- HPZ, MPZ and LPZ stand for high production management zone, medium production management zone and low production management zone, respectively
- Figure in parenthesis indicates their mean values
- All the three data within each management zone were generated based on 48 sampling points

the production management zones compared to across the management zones. The variograms of the canopy volume (m^3) of mandarin plants under three management zone viz., high, medium and low production management zones are further shown (Fig. 44).

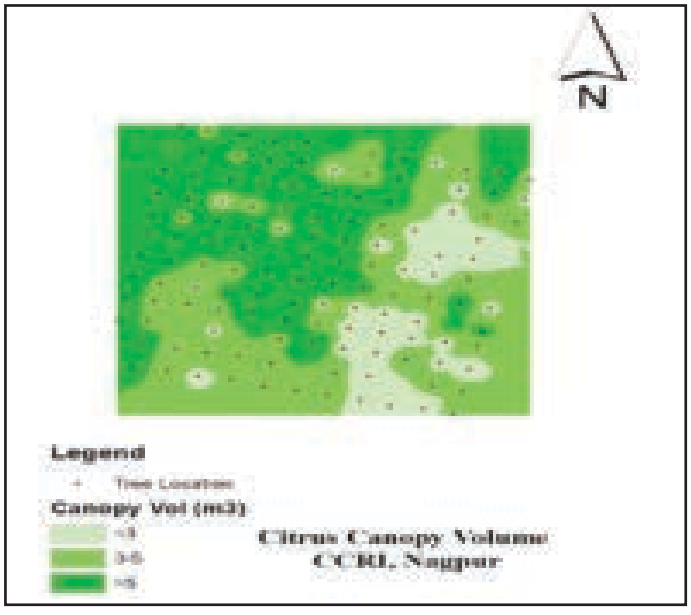


Fig. 44 : Variogram of canopy volume of the various zones

Soil fertility status

Analysis of soil samples collected from different geo-referenced points subjected to plant available nutrients appraisal and entire data were categorized zone-wise and results were presented more importantly as a function of coefficient of variation. The plant available nutrients in soil within each management zones were given as below : high production management zone ($KMnO_4$-N, 168.4 mg/kg, Olsen-P, 12.8 mg/kg, NH_4OAc-K, 186.4 mg/kg, DTPA-Fe, 15.4 mg/kg, DTPA-Mn, 11.8 mg/kg, DTPA-Zn, 1.18 mg/kg and DTPA-Cu, 1.40 mg/kg); medium management zone ($KMnO_4$-N, 169.3 mg/kg, Olsen-P, 10.1 mg/kg, NH_4OAc-K, 180.4 mg/kg, DTPA-Fe, 13.4 mg/kg, DTPA-Mn, 10.8 mg/kg, DTPA-Zn, 0.90 mg/kg and DTPA-Cu, 1.04 mg/kg); and low management zone ($KMnO_4$-N, 142.6 mg/kg, Olsen-P, 9.8 mg/kg, NH_4OAc-K, 158.3 mg/kg, DTPA-Fe, 11.2 mg/kg, DTPA-Mn, 9.6 mg/kg, DTPA-Zn0.88 mg/kg and DTPA-Cu, 1.02 mg/kg).

Changes in fruit quality parameters across production management zones

The variation in fruit weight, ranging from 148.1 g in high production management zone to as low as 130.2 g in low

management zone is an indication, how differential nutrient-supply-chain maintained across three production management zones are displaying their field performance (Table 23).

The variogram of the fruit yield (kg /tree) of mandarin in high, medium and low production management zones during 2020 was given (Fig. 45). The purpose of the precision cultivation using water and fertilizer inputs is to get good quality uniform fruits of larger diameters. The fruit size distribution observations were also recorded in all three zones of production. For this 170 fruits diameters were measured using vernier caliper (0.001 mm accuracy) in each zone. The grade size distribution is further explained graphically (Fig. 46).

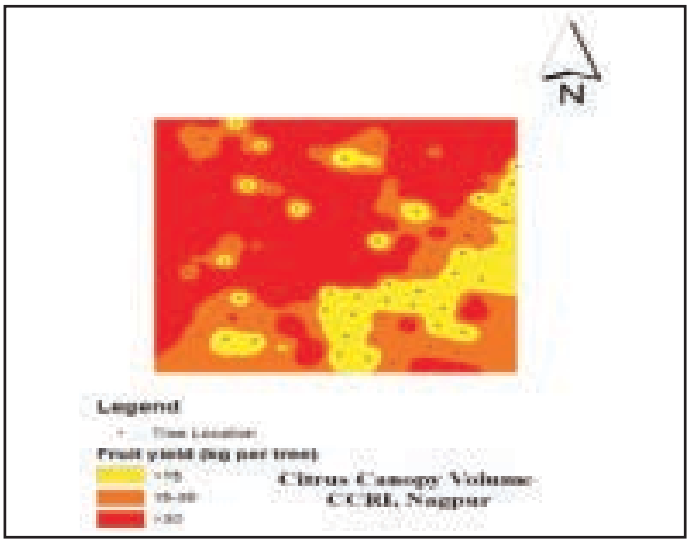


Fig. 45 : Variogram of fruit yield (kg/tree) in the various zones

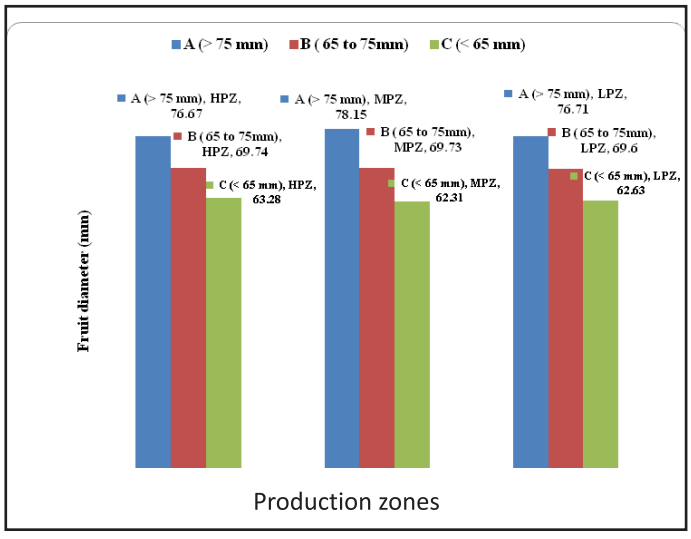


Fig. 46 : Fruit size distribution (%) in the various zones

Table 23 : Fruit weight and quality of Nagpur mandarin in various production zones

Production zone	Fruit weight	Fruit quality parameters		
	Fruit weight (g)	Juice (%)	TSS °(Brix)	Acidity (%)
T_1: High production management Zone	140.1 – 152.6 (148.1)	42.4 – 45.1 (43.6)	10.1 – 10.6 (10.3)	0.61-0.68 (0.64)
T_2: Medium production management zone	132.6 – 148.2 (139.6)	42.1 - 43.2 (42.1)	9.6 – 10.1 (9.8)	0.64 – 0.74 (0.69)
T_3: Low production management Zone	128.1 – 132.6 (130.2)	41.8 – 43.4 (42.0)	9.4 – 10.0 (9.6)	0.72 – 0.79 (0.75)
CV (%) within M Zones				
HPMZ	14.2	10.2	8.4	8.1
MPMZ	15.8	13.8	9.6	8.0
LPMZ	18.2	14.2	11.2	9.6
CV (%) across M Zones	16.6	12.4	10.0	8.7

-HPZ, MPZ and LPZ stand for high production management zone, medium production management zone and low production management zone, respectively.
-Figures in parenthesis indicate their mean values.
-All the three data sets within each management zone were generated based on 48 sampling points.

Changes in leaf macronutrients composition across production management zones

The changes in concentration of leaf nutrients were in accordance to plant available supply of nutrients under three contrasting production management zones (Table 24). These observation provided an insight, why high production management zone recorded higher yield and other associated fruit quality parameters. Interestingly, the CV was observed as 12.32%, 11.39% and 8.94%, respectively, within high production management, medium production management and low production management zone, respectively.

Changes in leaf micronutrients composition across production management zones

The leaf micronutrients composition across three different production management zones displayed a highly varying concentration as evident from their coefficient of variation of 8.2-9.8, 9.6-11.3%, 8.6-11.6% and 9.2-9.8% respectively, with regard to concentration of leaf Fe, leaf Mn, leaf Zn and leaf Cu (Table 25). High production management zone maintained significantly higher leaf micronutrients concentration compared to either medium production zone or low production management zone.

Table 24 : Changes in leaf macro- nutrients composition across different production management zones

Production zone	Leaf macronutrients concentration (%)		
	Nitrogen	Phosphorous	Potassium
T_1: High production management Zone	2.32 – 2.48 (2.39)	0.13 – 0.15 (0.14)	1.32 – 1.58 (1.40)
T_2: Medium production management zone	2.12 – 2.28 (2.21)	0.10 – 0.13 (0.11)	1.30 – 1.42 (1.38)
T_3: Low production management Zone	2.10 – 2.30 (2.16)	0.09 – 0.11 (0.10)	1.18 – 1.30 (1.24)
CV (%) within M Zones			
HPMZ	11.23	9.11	8.62
MPMZ	13.16	10.12	9.11
LPMZ	15.16	14.70	8.78
CV (%) across M Zones	12.32	11.39	8.94

-HPZ, MPZ and LPZ stand for high production management zone, medium production management zone and low production management zone, respectively.

-Figures in parenthesis indicate their mean values.

-All the three data sets within each management zone were generated based on 48 sampling points.

Table 25 : Changes in leaf micro-nutrients composition across different production management zones

Production zone	Leaf micronutrients (ppm)			
	Iron	Manganese	Zinc	Copper
T_1: High production management Zone	81.6 – 94.2 (87.6)	58.1 – 64.2 (60.9)	22.6 -26.5 (23.6)	11.1 – 12.4 (11.8)
T_2: Medium production management zone	75.8 – 82.9 (79.8)	52.3 – 61.5 (56.4)	20.1 – 22.1 (21.2)	10.1 – 11.4 (10.9)
T_3: Low production management Zone	61.9 – 79.2 (68.1)	50.1 – 63.2 (54.1)	19.6 – 21.2 (20.2)	11.4 – 12.8 (11.9)
CV (%) within M Zones				
HPMZ	9.2	11.3	8.6	9.2
MPMZ	8.2	9.6	10.2	9.8
LPMZ	9.8	10.8	11.6	9.2
CV (%) across M Zones	9.0	10.9	9.6	9.4

-HPZ, MPZ and LPZ stand for high production management zone, medium production management zone and low production management zone, respectively.

-Figures in parenthesis indicate their mean values.

-All the three data sets within each management zone were generated based on 48 sampling points.

3.2.2.7 Abiotic Stress management in cirtus

Effect of kaolin and calcium sulphate on sunscald of Nagpur mandarin

This study was conducted on 12 year old plants of Nagpur mandarin. The concentrations of anti-transpirants and sunray reflectants Kaolin (aluminium silicate) and Calcium sulphate at 2,4,6,8 and 10% were applied as foliar sprays along with untreated control on 22nd August, 13th September and 10th October 2020. The disordered and normal fruits of *Ambia* crop were collected at maturity in the month of November 2020 for *Ambia* crop and subjected to physicochemical analysis.

Maximum yield per plant (112.32 kg/plant) and total estimated yield per hectare (31.11 t/ha) was recorded in Kaolin 8 % followed by Kaolin 6 % (111.26 kg/plant and 30.82 t/ha respectively). The treatment Kaolin 10 % noted the minimum number of sun scalded fruits (12) and minimum per cent of sunscald (2.21 %) followed by Kaolin 8% (15 number of fruits sun scalded and 2.66 % of sunscald) over the control (64 number of fruits sun scalded and 13.10 % of sunscald) (Fig. 47). Calcium sulphate 8 and 10 % showed better control of sunscald disorder over control.

Maximum fruit weight (195.00 g) and fruit volume (193.00 cm^3) recorded in Kaolin 8 % followed by Kaolin 6 % (193.00 g and 191.00 cm^3 respectively) and minimum in control (172.33 g and 170.33 cm^{3}respectively). Maximum juice per cent was recorded in Kaolin 6 % (44.90 %) followed by Kaolin 10 % (44.39 %) and minimum in control (37.93%).

The treatment Kaolin 6 % noted maximum TSS (10.86%) followed by Calcium sulphate 10 % (10.63 %) and minimum in control (8.86 %). Maximum vitamin C recorded in treatment Kaolin 6 % (44.77 mg/100 ml of juice) followed by Kaolin 8% and Calcium sulphate 8% (44.03 mg/100 ml of juice) and minimum in control (35.88 mg/100 ml of juice).

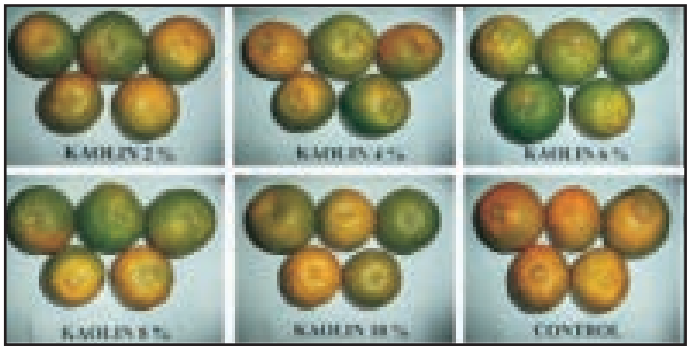


Fig. 47 : Effect of Kaolin on control of sun scald of Nagpur mandarin fruits

3.2.3 Development of INM-Module for Sustained Productivity of Citrus

3.2.3.1 Standardization of optimum nutrient requirement of Mosambi sweet orange

The fourth year of experimentation, was carried out in an 8-year-old orchard of Mosambi sweet orange (*Citrus sinensis* Osbeck) established at a spacing of 6m apart on TypicHaplustert soil. In all, as many nine treatments T_1 ($N_1P_1K_1$, 400g N-100g P_2O_5-200g K_2O/tree), T_2 ($N_1P_2K_2$, 400g N-200g P_2O_5-400g K_2O/tree), T_3 ($N_1P_3K_3$, 400g N- 300g P_2O_5-600g K_2O/tree), T_4 ($N_2P_1K_1$, 800g N-100g P_2O_5-200g K_2O/tree), T_5 ($N_2P_2K_2$, 800g N-200g P_2O_5-400g K_2O/tree), T_6 ($N_2P_3K_3$, 800g N-300g P_2O_5-600g K_2O/tree), T_7 ($N_3P_1K_1$, 1200g N-100g P_2O_5-200g K_2O/tree), T_8 ($N_3P_2K_2$, 1200g N-200g P_2O_5-400g K_2O/tree) and T_9 ($N_3P_3K_3$, 1200 g N-300g P_2O_5-600g K_2O/tree) . The treatment received uniform doses of micro nutrients and were tested a factorial randomized block design. The results obtained are briefly summarized as below:

Growth Response : Maximum increase in canopy volume was observed with treatment T_5(0.97 m^3increase in canopy volume over 2019-20) followed by treatment T_6 / T_7 (0.90/0.87 m^3 increase in canopy volume 2019-20). The treatments involving 1200g N/tree such as T_8/ T_9 (0.84 m^3 increase in canopy volume over 2019-20) with a minimum increase in canopy volume of 0.53-0.58 m^3 over 2019-20 with treatment T_1/T_2. These responses indicated balancing between N, P and K doses is important to harness maximum growth response, a pre-requisite to high fruit yield.

Response on Fruit Yield and Quality: Considering all the treatments, the net variation in fruit yield was observed are 44.6 kg/ tree (12.40 t/ha) with treatment T_1 to as high as 62.3 kg/ tree (17.31 t/ha) with treatment T_7 but statistically at par with either T_6 (61.2 kg/tree or 17.00 t/ha) or T_5 (61.2 kg/tree or 17.00 t/ha) suggesting the best treatment as T_5 (Table 26). Highest juice content, TSS and TSS/acidity ratio were observed with treatment T_5 (48.3% juice content, 0.44% acidity, 8.3% total soluble solids and TSS/acidity ratio of 18.86 on par with T_6 registering TSS/acidity ratio of 20.25). However, juice acidity remained unaffected with these fertilizer treatments. These results showed that all the fruit quality parameters were significantly better than these qualities with rest of the other treatments (Table 26).

Changes in soil fertility status: Plant available $KMnO_4$-N, Olsen-P and NH_4OAc-K varied from 118.1 to 130.6 mg/kg, 8.2 to 13.4 mg/kg and from 127.6 to 144.8 mg/kg, respectively, with treatment T_5 registering the maximum soil fertility (129.4 mg/kg $KMnO_4$-N though on par with treatments such as T_6, T_7, T_8 and T_9; 13.4 mg/kg Olsen-P and 144.8 mg/kg NH_4OAc-K). Similarly, all the plant available

Table 26 : Response of different treatments on fruit yield and quality of Mosambi sweet orange

Treatment	Fruit yield		Fruit quality (%)			
	(Kg/tree)	(t/ha)	Juice	Acidity	TSS	TSS/Acid ratio
T_1($N_1P_1K_1$)	44.6	12.40	44.2	0.40	7.1	17.75
T_2($N_1P_2K_2$)	47.2	13.12	44.6	0.42	7.2	17.14
T_3($N_1P_3K_3$)	47.8	13.28	45.2	0.40	7.4	18.50
T_4($N_2P_1K_1$)	50.3	13.38	46.1	0.42	7.5	17.85
T_5($N_2P_2K_2$)	59.3	16.48	48.3	0.44	8.3	18.86
T_6($N_2P_3K_3$)	61.2	17.00	47.8	0.40	8.1	20.25
T_7($N_3P_1K_1$)	62.3	17.31	48.4	0.41	7.7	18.78
T_8($N_3P_2K_2$)	60.8	16.90	46.1	0.46	7.8	16.95
T_9($N_3P_3K_3$)	60.4	16.70	47.1	0.48	7.7	16.04
CD (P=0.05)	5.8	1.12	1.10	NS	0.40	2.01

micronutrients showed a significant response (DTPA-Fe, DTPA-Mn and DTPA-Zn) in relation to different treatment, giving just a hint that how important is the balanced nutrition and how important is the relation between changes in macronutrients and micronutrients. Different plant available DTPA-Fe, DTPA-Mn and DTPA-Zn varied from 8.4 to 14.2 mg/kg, 7.8 to 11.2 mg/kg and from 0.72 to 0.93 mg/kg, respectively, with treatment T_5 registering maximum response evident from 13.2 mg/kg DTPA-Fe, 11.2 mg/kg DTPA- Mn and 0.93 mg/kg DTPA-Zn (Fig. 48). These observations suggested a strong influence macronutrients fertilization on plant available micronutrients supply levels in treated soil.

Response on leaf nutrient composition : Leaf N, P and K showed a variation of 2.12 to 2.46%, 0.09 to 0.13% and from 1.10 to 1.52%, respectively, with treatment T_5 as the most effective treatment registering 2.46% N, 0.13% P and 1.48% K, significantly superior to rest of the treatments including treatment T_1. Likewise, the Fe, Mn and Zn content of index leaves varied from 62.3 to 81.2 ppm, 51.2 to 61.2 ppm and from 22.3 to 27.3 ppm , respectively, with treatment T_5 displaying the best response (78.4 ppm Fe, 61.2 ppm Mn and 26.8 ppm Zn). Incidentally, the treatment T_5 proved to be the best treatment. The pattern of response on leaf nutrient composition was significantly influenced by plant available nutrient supply in soil (Fig. 49).

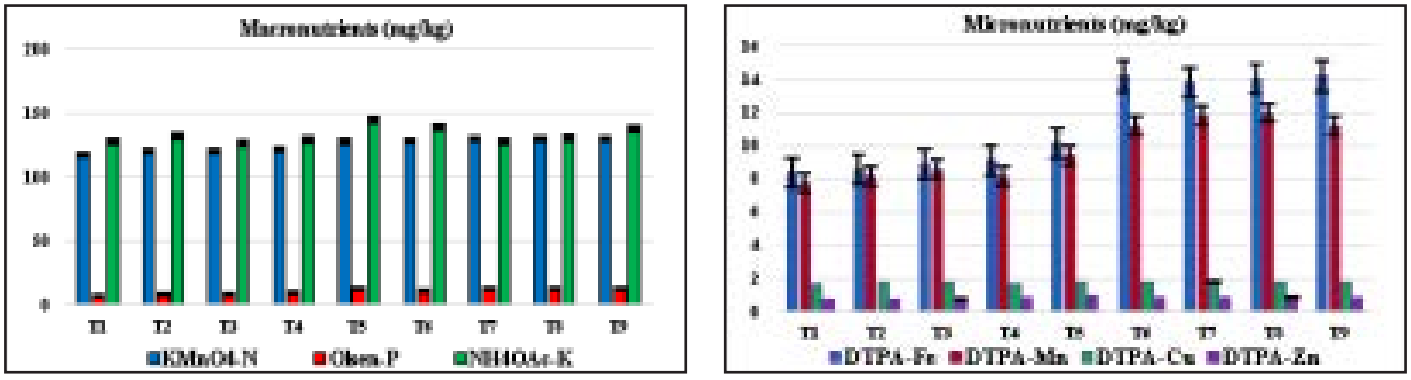


Fig. 48 : Changes in plant available supply of nutrients in soil in response of different treatments in Mosambi sweet orange

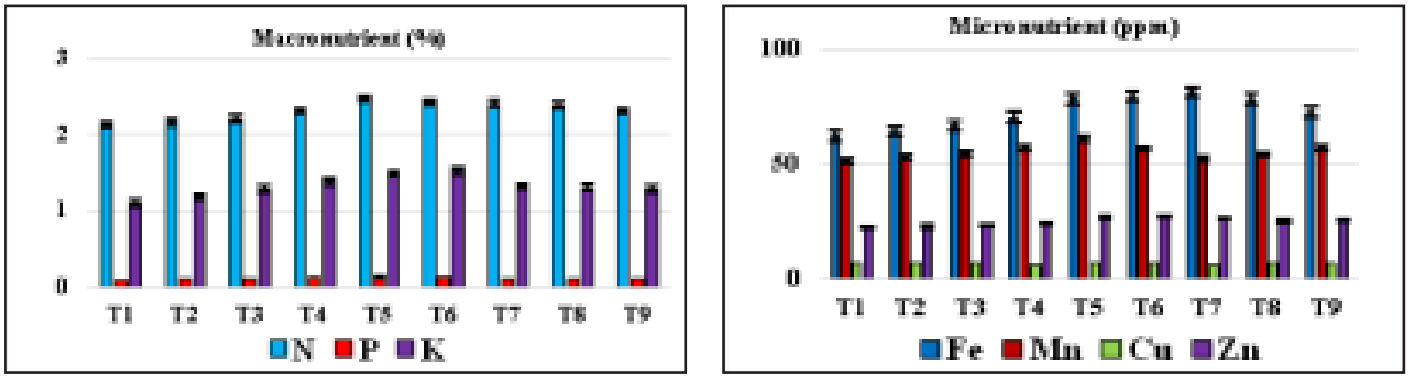


Fig. 49 : Changes in leaf nutrient composition in response to different treatments in Mosambi sweet orange

3.2.3.2. Development of Advanced Citrus Production Systems

The project was initiated during 2019-20 with the five objectives: i. phenology of flowering and fruiting as a function of hydroponic system, ii. Synchronization of water and nutrient requirement *vis-a-vis* crop phenophases, iii. Nutrient and water budgeting for ensured production, iv.maintaining a insect pest and disease free growing environment for extended plant performance and v. development of potentially climate-resilient citrus production system. The achievements of the year 2020 are highlighted as below:

The experiment with five modules of advance citrus production system was implemented during 2020. The initial samples of growing media were collected for soil fertility and microbial count analysis. The initial growth parameters after establishment of Nagpur mandarin budded on rough lemon rootstock for three months. The data generated are briefly presented as below:

Soil fertility status: The pH and EC of the samples varied from 7.3 to 7.8 and 0.26 to 0.34 dS/m, with the perlite + cocopeat- based growing media registered comparatively higher pH (7.7-7.8) and EC (0.30-0.34 dS/m) compared to pH (7.3-7.4) and EC (0.22-0.26 dS/m) of solarized soil potting mixture. Similarly, $KMnO_4$ - N, Olsen - P and NH_4OAc-K were far lower (84.7-85.4 mg/kg, 7.1-7.9 mg/kg and 79.2-84.6 mg/kg) than solarized potting mixture media (114.2-118.1 mg/kg, 9.7-9.8 mg/kg and 120-122.5 mg/kg). The DTPA extractable micronutrients (DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn) in all the modules involving solarized potting mixture registered a far higher values (11.2-11.9 mg/kg, 7.5-8.2 mg/kg, 0.80-0.88 mg/kg and 0.90-0.98 mg/kg) than perlite-cocopeat- based growing media (6.2-7.1 mg/kg, 4.2-4.6 mg/kg, 0.60-0.66 mg/kg and 0.70-0.77 mg/kg). These values are likely to undergo dynamic changes with execution of treatments and consequent, the growth of the treated plants.

Microbial load: The samples of growing media showed a large variation with respect to fungal count and bacterial count. Both fungal count as well as bacterial count were far lower (4-6 x 10^3 cfu/g growing media and 15-16 x 10^3 cfu/g growing media) in perlite + cocopeat-based growing media than potting mixture-based growing media (15-16x10^3 cfu/g growing media and 32-35 x 10^3 cfu/g growing media). With plant displaying their root growth, these microbial counts would undergo a dynamic changes.

Plant growth observation: The initial plant growth observation *viz*. plant height, stock girth, scion girth and number of leaves/plant were taken. After 3 months of growth without any treatments, the plant height, stock girth, scion girth and number leaves/plant varied from 58.9 to 62.2 cm, 7.9 to 9.0 mm, 37.2 to 41.5 and from 39.3 to 53.6, respectively, regardless of treatments with corresponding coefficient of variation of plant height, stock girth, scion girth and number leaves/plant were found to be 7.4%, 8.2%, 11.0% and 19.4%, respectively.

3.2.3.3. Studies on Agrocel-based Potassium Schoenite (Mahalaabh) in Citrus

The project was initiated in June, 2019 with three premier objectives: i. response of soil application of potassium schoenite rich source of potassium, magnesium and sulphur in 100% water soluble form in balanced proportion on plant growth, fruit yield, fruit quality and nutrient pool of soil, ii. response of foliar application of potassium schoenite on plant growth, fruit yield, fruit quality and nutrient pool of soil, iii. response of fertigation of potassium schoenite on plant growth, fruit yield, fruit quality and nutrient pool of soil.

The experiment was carried out experimental orchard (Block No 21) of ICAR-CCRI, Nagpur with eight treatments as per details:T_1 -Potassium schoenite 100 % K equivalent as soil application; T_2 - Potassium schoenite 75 % K equivalent as soil application; T_3 -Potassium schoenite 100 % K equivalent as foliar application; T_4 -Potassium schoenite 75 % K equivalent as foliar application; T_5-Potassium schoenite 100 % K equivalent as fertigation; T_6

-Potassium schoenite 75 % K equivalent as fertigation; T_7 - Muriate of potash 100 % K equivalent as fertigation and T_8 - Muriate of potash 75 % K equivalent as fertigation. Results are briefly summarized as below :

Response on plant growth : The plant growth attributing parameters such as plant height, tree spread (N-S and E-W) and canopy volume varied from 2.54 to 2.78 m, 1.48 to 1.56 m, 1.50 to 1.58 m and 2.99 to 3.54 m^3, respectively (Table 27). Among all the treatments, plants receiving with 100% of potassium schoenite through fertigation (T_5) showed higher vegetative growth response in terms of plant height (2.78 m), N-S spread (1.54 m which is at par with treatment T_3), E-W spread (1.58 m) and canopy volume (3.54 m^3). Treatment T_5 showed a highest response (0.53 m^3) of increase in canopy volume over 2019-20, which showed significance of increasing the bearing capacity of tree through greater canopy volume.

Response of fruit yield and quality

Considering all the treatments, the net variation in fruit yield was observed from 42.39 kg / tree (11.78 t/ha) with treatment T_2 to as high as 59.47 kg/tree (16.53 t /ha) with treatment T_6 but statistically at par with either T_5 (59.27 kg/tree or 16.53 t/ha) suggesting the best treatment as T_5. The mean effect of muriate of potash versus potassium schoenite when applied through soil application, showed no significant response. But, application of potassium schoenite when applied through either foliar application or through fertigation produced a far better response over soil application including muriate of potash. The similar trend was observed with different fruit quality parameters (Table 27).

The fruit quality parameters (Juice content, acidity and total solids) varied with statistically significant response associated with different treatments (Table 27). The net variation in juice content, acidity and total soluble solids (TSS) were observed as 42.1-44.2%, 0.62-0.76% and 8.6-9.7%, respectively. Highest fruit quality index was observed with treatment T_5 (44.2% juice content, 0.62% acidity and 9.7% total soluble solids), but statistically, significant with treatment T_6 (43.9% juice content, 9.4% total soluble solid and 0.62% acidity).

Table 27 : Effect of different doses of potassium schoenite versus muriate of potash on fruit yield and fruit quality parameters of Nagpur mandarin

Treatment	Fruit yield parameter				Fruit quality parameter		
	Fruit weight (g)	No. of Fruits/tree	Fruit yield (kg/tree)	Yield (t/ha)	Juice (%)	TSS (%)	Acidity (%)
T_1 ($PS_{100\% SA}$)	142.2	301	42.80	11.90	42.1	8.6	0.74
T_2 ($PS_{75\% SA}$)	144.2	294	42.39	11.78	42.8	8.7	0.76
T_3 ($PS_{100\% FA}$)	148.6	335	49.78	13.83	43.8	9.2	0.70
T_4 ($PS_{75\% FA}$)	145.3	312	45.33	12.24	43.1	9.0	0.72
T_5 ($PS_{100\% FN}$)	151.2	392	59.27	16.47	44.2	9.7	0.62
T_6 ($PS_{75\% FN}$)	150.2	396	59.47	16.53	43.9	9.4	0.62
T_7 ($MoP_{100\% FN}$)	140.6	305	42.83	11.90	42.1	8.9	0.72
T_8 ($MoP_{75\% FN}$)	140.4	311	43.66	12.14	42.4	8.7	0.74
CD (P=0.05)	2.1	65	4.21	1.16	1.10	0.80	0.10

T1 -Potassium schoenite 100 % K equivalent as soil application; T2 - Potassium schoenite 75 % K equivalent as soil application; T3 -Potassium schoenite 100 % K equivalent as foliar application; T4 -Potassium schoenite 75 % K equivalent as foliar application; T5 -Potassium schoenite 100 % K equivalent as fertigation; T6 -Potassium schoenite 75 % K equivalent as fertigation; T7 -Muriate of potash 100 % K equivalent as fertigation; and T8 -Muriate of potash 75 % K equivalent as fertigation.

Changes in available pool of nutrients : The changes in available supply of different nutrients to plants in response to application of potassium schoenite versus muriate of potash were observed displaying significant responses, evident from soil samples collected from within drip line of trees subjected to analysis of plant available nutrients (Table 28). The plant available nutrients like $KMnO_4$-N, Olsen-P, NH_4OAc-K in different treatments varied from 128.1 to 139.2 mg/kg, 10.8 to 14.3 mg/kg and from 148.2 to 169.4 mg/kg, respectively. Among various treatments, treatment T_5 was observed having maximum plant available nutrients which is statistically on par with treatment T_6 significantly inferior to T_5, but significantly inferior to T_5 again. Hence, T_5 and T_6 treatments expressed better response over rest of the other treatments. The changes in DTPA-Fe, DTPA-Mn and DTPA-Zn were observed to vary from 13.2 to 16.8 mg/kg, 9.1 to 10.2 mg/kg and from 0.80 to 1.08 mg/kg, respectively. Among all the treatments, plants received with 100% of potassium schoenite through fertigation (T_5 and T_6) showed almost same magnitude of response on plant available micronutrients varying from 16.2-16.8 mg/kg DTPA-Fe, 10.1-10.2 mg/kg DTPA- Mn and 0.98-1.08 mg/kg DTPA-Zn. However, muriate of potash proved to be far inferior to potassium schoenite, regardless of mode of application.

Changes in leaf nutrient composition

The changes in leaf nutrient composition followed a similar pattern of changes in soil fertility status as a function of quantity-intensity relationship, evident from analysis of 5-7 month-old leaf samples for different nutrients (Table 29). The changes in leaf nutrient composition in response to different treatments showed a statistically significant variation in leaf N, P, K, Fe, Mn and Zn, with an exception of Cu. The leaf N, P and K varied from 2.18 to 2.42%, 0.08 to 0.13% and from 1.42 to 1.78%, respectively, with treatment T_6 and T_5 as the most effective treatments significantly superior to rest of the other treatments. Similarly, treatment T_5 and T_6 both displayed response. These observations suggested for better superiority of potassium schoenite fertigation, since T_5 and T_6 displayed on par response, treatment T_6 using 75% RDF equivalent K could be considered as most effective treatment.

Table 28 : Changes in soil fertility status (plant available nutrients) in response to different treatments involving potassium schoenite versus muriate of potash

Treatment	Plant available macronutrients (mg kg^{-1})			Plant available micronutrients (mg kg^{-1})			
	$KMnO_4$-N	Olsen-P	NH_4OAc-K	DTPA-Fe	DTPA-Mn	DTPA-Cu	DTPA-Zn
T_1 ($PS_{100\% SA}$)	128.8	10.8	148.2	13.2	9.1	0.92	0.84
T_2 ($PS_{75\% SA}$)	128.1	11.2	148.8	14.4	9.2	0.88	0.80
T_3 ($PS_{100\% FA}$)	118.8	13.8	152.3	15.0	9.6	0.90	0.88
T_4 ($PS_{75\% FA}$)	120.7	14.3	154.1	14.9	9.5	0.87	0.86
T_5 ($PS_{100\% FN}$)	139.2	13.3	169.4	16.2	10.2	0.94	1.08
T_6 ($PS_{75\% FN}$)	130.0	13.1	162.8	16.8	10.1	0.96	0.98
T_7 ($MoP_{100\% FN}$)	128.1	13.0	150.8	14.2	10.0	0.90	0.87
T_8 ($MoP_{75\% FN}$)	130.0	12.8	151.2	14.8	9.6	0.98	0.86
CD (P=0.05)	3.2	1.1	4.1	1.2	0.25	NS	0.14

T1 -Potassium schoenite 100 % K equivalent as soil application; T2 - Potassium schoenite 75 % K equivalent as soil application; T3 -Potassium schoenite 100 % K equivalent as foliar application; T4 -Potassium schoenite 75 % K equivalent as foliar application; T5 -Potassium schoenite 100 % K equivalent as fertigation; T6 -Potassium schoenite 75 % K equivalent as fertigation; T7 -Muriate of potash 100 % K equivalent as fertigation; and T8 -Muriate of potash 75 % K equivalent as fertigation.

Table 29 : Changes in leaf nutrient status in response to different treatments involving various modes of application of potassium schoenite versus muriate of potash

Treatment	Leaf macronutrients (%)			Leaf micronutrients (ppm)			
	N	P	K	Fe	Mn	Cu	Zn
T_1 (PS $_{100\% SA}$)	2.19	0.11	1.48	76.5	38.3	8.1	20.8
T_2 (PS $_{75\% SA}$)	2.20	0.10	1.58	72.3	38.3	8.8	20.1
T_3 (PS $_{100\% FA}$)	2.30	0.10	1.46	78.1	41.1	9.2	25.4
T_4 (PS $_{75\% FA}$)	2.21	0.10	1.51	81.2	42.6	8.0	26.1
T_5 (PS $_{100\% FN}$)	2.42	0.12	1.68	89.4	48.2	9.0	25.4
T_6 (PS $_{75\% FN}$)	2.40	0.13	1.78	91.6	52.1	8.8	26.4
T_7 (MoP $_{100\% FN}$)	2.18	0.08	1.48	75.8	38.1	8.9	20.1
T_8 (MoP $_{75\% FN}$)	2.19	0.08	1.42	76.1	37.2	8.3	21.0
CD (P=0.05)	0.10	0.008	0.16	2.2	4.1	NS	2.1

3.2.4 Studies on physiological disorders of citrus fruits

Studies on causal factors of *Waywar* (wasteful) fruit disorder in Nagpur mandarin

Surveys were made in Nagpur mandarin orchards from Amravati and Nagpur districts in Maharashtra and Chhindwara district of Madhya Pradesh from July through November months of the fruit development stage in *Ambia* and *Mrig bahar*.

Association of citrus greening bacterium with *wayvar* affected Nagpur mandarin fruits

Leaf and fruit samples were collected from *Wayvar* affected Nagpur mandarin trees at Mohagaon village of Madhya Pradesh and Paratwada tehsil of Amravati district in Maharashtra during July-November, 2020. All the samples were analyzed for greening bacterium infection through already standardized PCR tests. Out of 36 samples tested, 12 samples were found positive for greening bacterium infection.

Studies on effect of zinc, phosphorus and plant growth regulators (GA_3 and 2,4-D) on *Waywar* (wasteful) fruit disorder of Nagpur mandarin

For this experiment a 12 year old Nagpur mandarin orchard located at Mohgaon village of Sausar tehsil in Chhindwara district of Madhya Pradesh was selected based on the incidence of *Waywar* disorder in 2020 cropping season of *Ambia bahar*. The trees were spaced at 6 x6 m, grafted on rough lemon rootstock. Another Nagpur mandarin orchard (12 year old) with same cultivation practices located at Bellaharatanda village of Arvi tehsil, Wardha district, Maharashtra was selected for the same study during 2020 cropping season of *Mrig bahar*. The developing fruits were closely observed during crop phenology. The extent of disorder, effect on fruit shape, size, yield and quality were observed by applying various nutrient and growth regulator treatments to reduce the disorder and to improve the yield and quality of Nagpur mandarin. The treatments were replicated four times in randomized block design for the statistical analysis. The *waywar* disordered (Fig. 50) and normal fruits were collected in August, 2020 and at maturity in the month of December 2020 from Sausar for *Ambia* crop and in the month of January and March 2021 from Bellaharatanda for *Mrig* crop and subjected to physic-chemical analysis.

The results indicated that application of additional doses of nutrient phosphorus imparted resistance in the plants against the *waywar* disorder. Association of citrus

greening bacterium was evident from the PCR detection reports. Similarly application of growth regulators GA_3 and 2,4-D at 15 ppm concentrations also reduced the incidence of the disorder and improved yield and quality of the fruits (Table 30 and 31).

Table 30: Effect of different treatments on control of fruit drop caused due to disorder and yield in *Ambia* crop of Nagpur mandarin at Sausar

Treatment	Number of fruits dropped			Number of fruits harvested per plant	Yield (kg/plant)	Yield (t/ha)
	Sep -20	Oct -20	Nov -20			
2,4 -D (15 ppm)	37	15	8	1,342	260	71.91
GA_3 (15 ppm)	37	13	7	1,449	238	65.93
Zinc sulphate ($ZnSO_4$) 0.5 %	34	16	9	1,271	198	54.82
Phosphorus @ 2 times more than RDF	36	17	9	1,161	207	57.47
Phosphorus @ 3 times more than RDF	36	17	8	1,225	219	60.83
Control	41	31	14	1,019	138	38.30
C D (P=0.05)	4.02	4.59	1.74	32.77	42.35	11.73
SE(m)	1.32	1.51	0.57	10.77	13.92	3.85

Table 31: Effect of different treatments to control waywar fruit disorder on fruit biochemical characteristics in *Ambia* crop of Nagpur mandarin at Sausar

Treatment	Juice (%)	TSS (%)	Acidity (%)	TSS/Acid ratio	Vitamin C (mg/100 ml)
2,4 -D (15 ppm)	51.53	8. 85	0.75	11.83	34.64
GA_3 (15 ppm)	59.97	9.32	0.72	12.84	35.72
Zinc sulphate ($ZnSO_4$) 0.5 %	51.04	8.77	0.75	11.68	34.80
Phosphorus @ 2 times more than RDF	50.06	8.80	0.75	11.27	34.47
Phosphorus @ 3 times more than RDF	50.74	9.05	0.87	10.36	34.80
Control	48 .10	8.05	0.67	11.33	32.95
C D (P=0.05)	3.24	0.38	0.08	0.99	NS
SE(m)	1.06	0.12	0.02	0.32	0.85

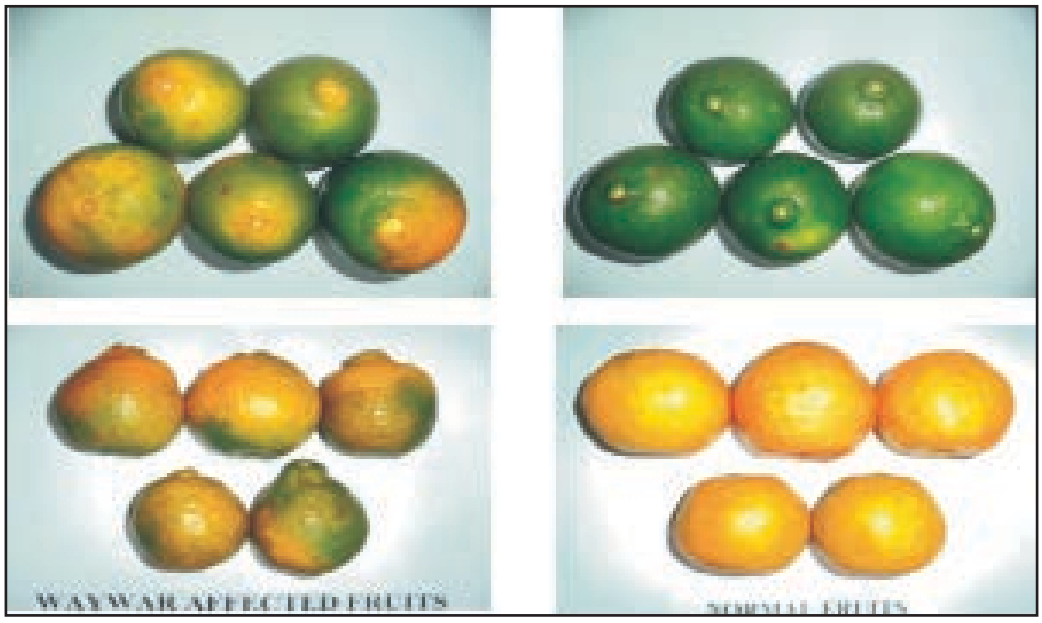


Fig. 50 : *Waywar* affected (Left) and normal fruits (Right) of Nagpur mandarin

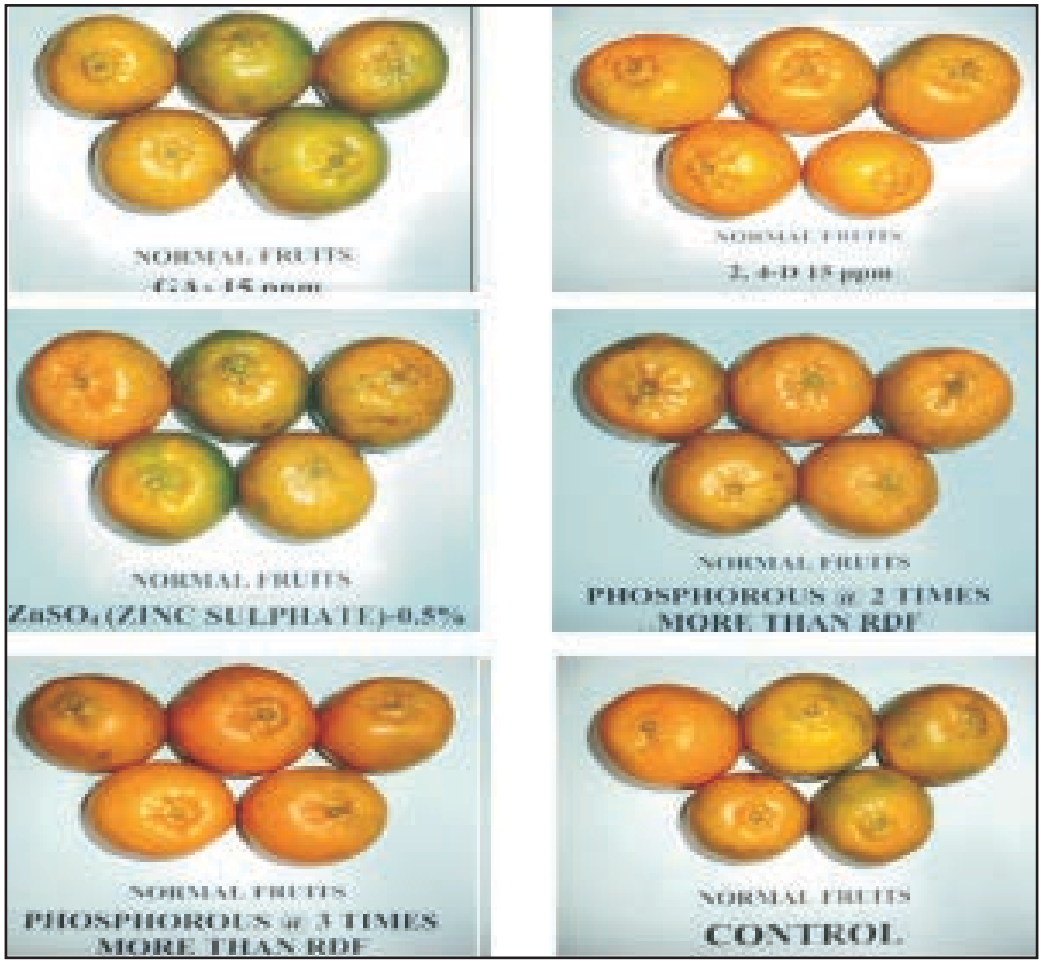


Fig. 51 : Effect of different treatments on fruit quality and control of *waywar* in Nagpur mandarin fruits

3.2.5 Demonstration of rejuvenation technology of citrus orchards

This project was initiated in 2020 to rejuvenate the declined and semi declined mandarin plants. After a survey of orchard a bearing orchard was selected which was found to be suitable for this study and orchard of Nimji village is fit for adoption for rejuvenation purpose. There were around 45 trees which were either in declined or near-decline stage with no to minimal fruiting of *Ambia* noticed. Initial soil and leaf samples were collected for base data and thereafter FYM and inorganic fertilizers were applied to all the plants.

Plant growth : The initial growth parameters recorded during the year. 7 years controlled plants have shown the significantly higher canopy growth (23.58 m^3) than 7 years decline plants (10.40 m^3). Tree height was noted maximum (3.93 m) in the 7 years controlled plants, comparing with 7 years decline plants i.e. 3.33 m. In case of stock-scion growth ratio it was maximum in 7 years controlled plants i.e. (1.04).

Similarly 18 years controlled plants have shown the significantly higher canopy growth (43.50 m^3) than 18 years decline plants which have (41.02 m^3). The height was noted maximum (5.24 m) in the 18 years controlled plants, comparing with 18 years decline plants i.e. (4.34 m). In case of stock-scion growth ratio it was maximum in 18 years controlled plants i.e. (1.07) (Table 32).

Fruit yield and quality : The fruit quality parameters recorded and noted in selected 7 years controlled and decline plants. The maximum average fruit weight was found in 7 years controlled plants (171.27 g) which was minimum in 7 years decline plants (163.60 g). The TSS content noted to be higher (8.53%) with 7 years controlled plants than the decline plants (7.87%). The maximum acidity was recorded with 7 years controlled plants (0.94%) with higher juice content (39.07%) whereas lower acid content (0.30%) with 7 years decline plants. The fruit yield was recorded maximum (16.82 kg/plant) on 7 years controlled plants and minimum in decline plants (7.81 kg/plant). Similar trend was observed in fruit length and diameter ratio, number of seeds and rind thickness also.

The fruit quality parameter noted in selected 18 years controlled and decline plants. The maximum average fruit weight was found in 18 years controlled plants (160.27 g)

Table 32 : **Plant growth, fruit yield and quality of Nagpur mandarin**

Plants	Plant ht. (m)	Stock-Scion ratio	Canopy vol. (m^3)	Fruit weight (g)	Fruit length and diameter ratio	No. of seeds/ fruit	TSS (%)	Juice cont. (%)	Acidity (%)	Rind thickness (mm)	Vit. C (mg/ 100 ml)	Fruit yield (kg/plant)	Fruit yield (t/ha)
7 years decline plants	3.33	1.06	10.40	163.60	0.88	20.33	7.87	33.94	0.30	2.59	29.17	7.81	3.15
7 years controlled plants	3.93	1.04	23.58	171.27	0.96	31.00	8.53	39.07	0.94	3.18	34.33	16.82	6.79
18 years Semi decline plants	4.37	1.55	41.02	158.07	0.94	28.67	7.93	36.50	0.25	2.84	26.40	13.51	5.34
18 years controlled plants	5.24	1.07	43.50	160.27	0.97	31.00	8.07	42.67	0.26	3.19	28.07	32.08	7.70
C D (P = 0.05)	0.331	0.392	10.319	NS	NS	9.474	0.296	5.282	NS	0.304	2.919	2.229	0.959

which was slightly low in 18 years decline plants (158.07 g). The TSS content noted to be higher (8.07%) with 18 years controlled plants than the decline plants (7.93%). The maximum acidity was recorded with 18 years controlled plants (0.26%) with higher juice content (42.67%) whereas lower acid content (0.25%) with 18 years decline plants. The fruit yield was recorded maximum (32.08 kg/plant) on 18 years controlled plants and minimum in decline plants i.e. 13.51 kg/plant. Similar trend was observed in fruit length and diameter ratio, Number of seeds/fruit and rind thickness also noted and it was recorded minimum in 7 years decline plants than other treatments.

Soil fertility status : The first year soil fertility status was analysed. The available soil nutrient status was different in regarding decline and controlled plants. In 7 years controlled plants available nutrients are found in more quantity i.e. N-226.01 kg/ha, P-15.08 kg/ha and K-446.13 kg/ha as compared to 7 years decline plants which is N-240.43 kg/ha, P- 15.08 kg/ha and K-446.13 kg/ha.

Similarly, 18 years controlled plants have shown the higher available soil nutrients i.e. N- 248.85 kg/ha, P- 24.64 kg/ha and K- 365.4 kg/ha. The 18 years decline plants have available soil nutrients which are N- 230.82 kg/ha, 16.35 kg/ha and 365.4 kg/ha. pH and EC showing similar amount of quantity on both aged category of plants.

Leaf nutrient status : The leaf nutrient status indicated variation in N, P and K uptake in declined and controlled plants. The Nutrient uptake was found maximum in 7 years controlled plants i.e. N - 2.06%, P- 0.10% and K- 2.11% than 7 years decline plant which is N- 2.06%, P- 0.10% and K- 2.11%. Similar results were found in 18 years controlled and decline plants. The 18 years controlled plants uptake more nutrient i.e. N-2.22%, P- 0.08% and K- 2.03% which is higher than 18 years decline plants, N-1.90%, P- 0.07%, and K-1.73%.

Diversity of plant parasitic nematodes in rejuvenation field of Nagpur mandarin

Based on the morphological characters, different plant parasitic nematode genera viz., *Pratylenchus, Tylenchulus*, *Helicotylenchus, Hoplolaimus* were identified. Among these, *Pratylenchus* was prominently recorded compared to other genera. In addition, different free living nematodes such as rhabditids, dorylaimids were also identified.

Demonstration of rejuvenation technologies for Khasi mandarin

Survey was made at Umdenlang basti, Sohkhwai village of Umling Block, P.O. Nongpoh of Ri-Bhoi district during mid October 2020. The Sohkhowai village has few old orchards (3-4 numbers only) which were planted as early as 1985-86. Later on around mid-1990s almost every household in the village started planting small (300 plants) to big (2000 plants) orchards with the seedlings distributed under the Watershed project of the state department. The seedlings were planted at 2 ft depth and without any FYM and fertilizers at planting or anytime afterwards. The initial harvests from these orchards were obtained after 5-6 years of planting. The fruits were sold in counts of 'pun' and each pun consisted of eighty numbers of fruits. During those years of first and second harvest from an orchard, about 06-70 puns were usually harvested from the small orchards whereas >150 puns were harvested from the big orchards. These fruits had a good demand in the nearest Nongpoh market as Sohkhwai mandarin.

Most of these orchards at Sohkhwai are at a declining phase. A general survey showed that many plants in the orchards are succumbing to dieback as an outcome of general neglect. Inadequate nutrition and as most of the plantings were done on the steep slopes without making half-moon terraces which caused soil erosion and leaching of nutrients due to the heavy rainfall, the plants became unhealthy, reduced bearing and died. Once the number of bearing plants reduced in an orchard, the farmer go for mixed planting and undesirable intercropping to meet his sustenance rather than rejuvenating the citrus plants. This further intensifies the nutrient deficit status of the orchard soils. Almost every orchard in the village has few guava plants, beetlenut, pineapple, jackfruit, banana, colocasia, ginger, *Citrus grandis*, etc. as mixed planting. The orchards

Fig. 52 : General view of the farmers field having die back problem at Ri-bhoi district, Meghalaya

whether big or small have only 10 - 40 bearing plants only and the size of the fruits have reduced over the years in these plants.

3.2.6 CHAMAN-Coordinated Programme on Horticulture Assessment and Management using GeoiNformatics: Phase II

3.2.6.1 Image based yield prediction model (App) evaluation

The evaluation trial was carried out in a citrus orchard at Nagpur district. In the months of November 2020 and January 2021, when the fruits of *Ambia* and *Mrig* crops were at physiological maturity, photos of the trees were taken following a systematic uniform random sampling procedure. Yield mapping was carried out measuring yield per trees. Using this data (the measured yield of the trees and the pictures samples, representing the yield distribution per tree), an image processing-based algorithm was developed at Centre for Environmental Sciences and Climate Resilient Agriculture (CESCRA), ICAR-IARI, New Delhi which predicts tree yield by analysing the pictures of the fruit bearing tree canopies at fruit physiological maturity. For the evaluation of the algorithm 142 trees were selected from different locations of Nagpur district.

The images were acquired using a hand-held commercial RGB digital camera, Sony Digital Camera 20 Mega pixels with up to 2048 x 1536 pixel images and focal length 5.8–23.2 mm. The images were taken between 10:00 and 14:00 in broad daylight to avoid any impact of sunlight illumination level. From the total of 450 images, some were distorted and a number of them had low contrast due to sunlight direction.

A total of 142 photos were used for image processing analysis. For yield mapping, the 142 trees were selected from three orchards. In Feb-March 2021, Nagpur mandarin *mrig bahar* were hand harvested and placed in plastic beneath the tree. All fruits from individual tree were collected together and weighed. Therefore, yield of all the trees was measured for yield mapping. This was a simple and quick method for yield mapping of the orchard. The recorded data are presented in table 1.0

The simulation model evaluated/verified on the basis of following-Bias, MSE, RMSE, MAE, RRMSE, RMAE and Model Efficiency.

Measured and predicted yields were analysed statistically for descriptive statistics such as mean, maximum, minimum, standard deviation (SD), coefficient of variation (CV), Bias, MSE, RMSE, RRMSE, MAE, RMAE, EF- Model efficiency.

The recorded Bias value of predicted and measured yield model was 39.43, which indicated that the model is under predicted. The measure MSE showed wide square (1812.26) error between actual and predicted value.

The higher value of RMSE 42.57 indicates the model moderately predicted the yield, all other measures i.e., RRMSE (0.66), MAE (39.43) , RMAE (.0662) also revealed moderate performance of the model. The EF (-1.52) negative value indicated that the model is over predicted and need further calibration for accurate prediction. These results indicated that potential yield could be predicted more accurately after further calibration.

Nagpur mandarin phenology data for three-year-old orchard : The experimental data were recorded during 2020, from three-year-old tagged Nagpur mandarin (*Citrus reticulata* Blanco) orchard. The recorded data showed that plant height of three-year-old orchard ranged between 164-211 cm.

The recorded data revealed that Nagpur mandarin has primary branches at 3 years of age 2-5, secondary 21-31 and tertiary were 69-168 whereas maximum recorded leaf area were 1.435 m^2 and minimum 0.856 m^2.

Dry matter of fruits and leaves of Nagpur mandarin

Results revealed the exponential growth of fruit dry matter in *ambia bahar* whereas at initial fruit set stage after end of petal fall dry matter of fruit were found (0.16 g) and during growth development stage the fruit dry matter increase till the physiological maturity of fruit (15 Nov -15 Dec) was recorded 74.54 g (Fig. 53).

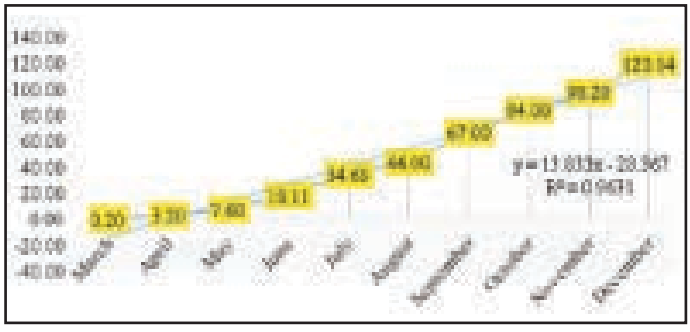


Fig. 53 : Fruit growth graph on fresh weight (g) basis of *Ambia bahar* (3.5 – 4.5 year old orchard)

Leaf area index of three-year-old orchard at fifteen days interval

Perusal of data revealed that from the beginning of the year (*Ambia bahar*) the leaf area index increased till next flowering induction. In the month of January, the leaf area index of plant was 1.268 m^2/m^2 and at every stage of observation the LAI increases ranging from (1.268-4.109 m^2/m^2).

3.2.7 Evaluation of different citrus varieties on raised and flat bed planting systems at RRCC, Biswanath Chariali, Assam

Evaluation of different commercial Citrus spp. on raised and flat bed systems

This experiment was initiated with different 13 citrus species budded on rough lemon rootstock and planted at 5x3m spacing during August, 2017.

Plant growth : All the cultivars were showing excellent growth performance on both the planting systems and measurements of each cultivar showed the average heights, stock scion girth and canopy spread. Among mandarins, maximum plant height (4.77 m) was recorded in Nagpur mandarin (STG) followed by Khasi mandarin seedling (4.54 m) on raised bed compared to flat bed (4.72 m, 4.45 m). Whereas, stock and scion girth was noted maximum in Nagpur mandarin seedless (N-4) (37.33cm, 44.83 cm) on both raised bed and flat bed systems (35.67 cm, 42.83 cm) than all the other treatments (Mandarin). Among sweet oranges, higher plant height was noted in Cutter valencia (4.33 m) on raised bed compared to flat bed (4.28 m) and similarly canopy volume also was recorded maximum in Cutter Valencia (27.02 m^3) on raised bed system. In Flame grapefruit maximum plant height was recorded on raised bed (3.57 m) as compared to the flat system (3.35 m) as well as canopy spread was also recorded maximum on raised bed (21.36 m^3) compared to the flat bed (20.29 m^3). With respect to pummelo, maximum plant height was observed in NRCC Pummelo-5 (4.17 m) on raised bed compared to flat system (3.63 m). Whereas, stock and scion girth was recorded maximum in US Pummelo-145 (39.83 cm and 39 cm) on raised bed. Among limes, maximum plant height was recorded in NRCC Acidlime-7 (5.15 m) with good stock scion girth (35.17 cm, 33.59 cm) on raised bed system. Hamlin, Blood red, Pineapple, NRCC Grapefruit-6, Assam lemon and Citron mutant were planted during August, 2018 in respective rows of experimental blocks on both raised and flat bed systems. Overall, the growth data in all the treatments indicated better growth performance on raised bed system as compared to traditional flat bed system in most of the treatments.

Fruit quality and yield : Among mandarins, maximum average fruit weight was recorded in Nagpur mandarin seedless -4 (165.96 g) followed by Nagpur mandarin (STG) (156.33 g) whereas, Nagpur mandarin seedless-4 resulted maximum Juice content, TSS and acidity (i.e. 43.19%, 7.10% and 0.53%) on raised bed compared to flat bed. In case of sweet oranges, maximum average fruit weight was

recorded in Cutter Valencia (276.33 g) on raised bed compared to flat bed (235.00 g) while the maximum acidity (0.51%) and Vit. C (43.79 mg/100 ml) recorded in mosambi. TSS (8.9%) and Juice content recorded maximum (42.72 %) in mosambi on raised bed compared to flat bed. Among the grapefruit varieties, average fruit weight, TSS and Acidity was recorded higher in NRCC Grapefruit -6 (469.33 g, 5.7 %, 0.39) on raised bed compared to the flame grapefruit in which the average fruit weight, TSS and acidity was recorded as 448.66 g, 5.4% and 0.32 on raised bed planting system. NRCC Pummelo-5 showed better performance on raised bed

Table 33 : Growth performance of citrus varieties on raised and flat bed system at RRCC

Row	Citrus Varieties	Height (m)	Girth (cm)		Spread (m)		Canopy Volume (m^3)	Yield (t/ha)
			Stock	Scion	E-W	N-S		
R1	Khasi mandarin (Grafted)	4.42 (4.65)	35.67 (37.17)	35 (35.46)	2.43 (2.54)	2.78 (2.77)	12.50 (13.40)	-
R2	Khasi mandarin (seedling)	4.54 (4.45)	34.33 -	33.67 -	2.38 (2.38)	2.39 (2.42)	11.57 (12.30)	-
R3	Nagpur mandarin (budded)	4.50 (4.35)	34.83 (38.17)	32.50 (35.17)	2.57 (2.56)	2.70 (2.54)	12.87 (12.04)	15.56 (14.89)
R4	Nagpur mandarin (STG)	4.77 (4.72)	32.5 (36.50)	31.17 (35.33)	2.81 (2.41)	2.71 (2.63)	18.69 (15.34)	17.00 (15.79)
R5	Nagpur mandarin seedless-4	4.47 (4.40)	37.33 (44.83)	35.67 (42.83)	3.05 (2.82)	2.58 (2.53)	20.48 (17.06)	25.78 (12.74)
	CD (P=0.05)	0.034 (0.062)	2.561 (3.010)	2.416 (2.404)	0.335 (0.297)	NS	0.073 (0.107)	-
R6	Cutter Valencia	4.33 (4.28)	38.83 (36.67)	38.17 (35.17)	3.22 (3.35)	3.60 (3.57)	27.02 (28.14)	17.89 (11.49)
R7	Mosambi	3.80 (3.98)	36.83 (40.33)	35 (39.17)	2.82 (2.81)	3.78 (3.74)	22.47 (23.14)	26.12 (20.03)
R11	Flame grapefruit	3.57 (3.35)	38.33 (37.83)	37.50 (36.00)	3.17 (2.96)	3.47 (3.72)	21.36 (20.29)	9.56 (3.52)
R12	NRCC Grapefruit-6	3.32 (2.97)	33.50 (28.33)	31.50 (26.83)	2.48 (2.61)	2.37 (2.49)	10.57 (10.48)	5.98 -
R13	NRCC Pummelo-5	4.17 (3.63)	36.83 (35.50)	32.33 (34.17)	2.48 (3.06)	2.37 (3.03)	12.74 (18.24)	4.94 (2.36)
R14	US Pummelo-145	4 (4.10)	39.83 (37.67)	39.00 (36.00)	3.48 (3.63)	3.55 (4.26)	27.93 (34.60)	2.37 -
R15	Assam lemon	2.48 (2.50)	22.67 (17.83)	21.33 (16.50)	2.12 (2.66)	2.05 (2.48)	5.84 (8.96)	3.06 (2.95)
R16	NRCC Acid lime-7	5.15 (4.33)	35.17 (30.17)	33.59 (33.83)	3.83 (3.63)	3.87 (3.21)	25.35 (27.50)	4.56 -
R17	NRCC Acidlime-8	4.93 (3.83)	34.17 (33.83)	29.83 (33.00)	3.65 (3.59)	3.90 (3.68)	30.37 (27.44)	10.21 (9.15)
R18	Citron mutant	3.15 (3.53)	34.00 (33.83)	30.50 (33.05)	3.48 (3.06)	3.68 (3.19)	21.92 (18.68)	7.25 (13.13)

* Figures in parentheses indicates flat bed data

than flat bed and other varieties. It had maximum average fruit weight, TSS, acidity and Vit. C content i.e. 1.82 kg, 7.60%, 0.51% and 45.4mg/100ml respectively. While contrast result was notices among limes and lemons. Maximum TSS was recorded in NRCC Acidlime-8 (7.5%) on flat bed and citron mutant (7.4%) on flat raised bed. Whereas, acidity ranges from 3.32- 3.52% in limes and 2.88-6.11% in lemons (Table 34). With respect to productivity, Nagpur mandarin budded show better productivity on raised bed (15.56 t/ha) than flat bed (14.89 t/ha). While in case of sweet orange, mosambi had good productivity i.e 26.2 t/ha on raised bed. In Limes NRCC-8

Table 34: Fruit quality of different citrus varieties on raised and flat bed system at RRCC

Varieties	Average fruit weight (g)	Fruit length (mm)	Fruit dia. (mm)	Rind thickness (mm)	No. of seeds / fruit	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/100ml)
Nagpur mandarin (budded)	144.00 (143.00)	65.94 (63.56)	70.96 (68.77)	2.96 (2.39)	10.00 (11.66)	39.48 (34.89)	7.3 (7.0)	0.44 (0.47)	23.45 (26.89)
Nagpur mandarin (STG)	156.33 (141.66)	61.69 (61.73)	72.37 (68.83)	3.20 (3.32)	12.66 (14.00)	31.98 (30.89)	7.8 (7.1)	0.20 (0.18)	21.56 (24.18)
Nagpur mandarin seedless-4	165.96 (159.32)	59.25 (65.85)	67.53 (72.45)	2.76 (2.40)	16.00 (14.13)	43.19 (39.46)	7.10 (6.8)	0.53 (0.49)	34.65 (33.98)
Cutter Valencia	276.33 (235.00)	74.49 (79.00)	77.47 (80.17)	4.50 (4.56)	6.66 (5.66)	30.45 (34.25)	6.9 (5.7)	0.25 (0.19)	41.5 (42.2)
Mosambi	232.33 (249.66)	73.43 (74.53)	73.64 (78.90)	3.49 (3.83)	25.33 (19.00)	42.72 (33.89)	8.9 (7.5)	0.51 (0.38)	43.79 (41.89)
Flame grapefruit	448.66 -	92.94 -	98.66 -	3.20 -	6.33 -	33.43 -	5.4 -	0.32 -	38.4 -
NRCC Grapefruit-6	469.33 -	91.69 -	100.11 -	2.82 -	15.66 -	27.6 -	5.7 -	0.39 -	36.4 -
NRCC Pummelo-5	1.82kg (1.15) kg	18.50 (17.41)	15.92 (17.5)	18.51 (17.41)	21 (70)	23.91 (42.52)	7.60 (7.55)	0.51 (0.39)	45.4 (45.2)
US Pummelo-145	1.034 kg -	140.23 -	134.79 -	25.36 -	45.23 -	49.89 -	5.8 -	0.25 -	39.10 -
NRCC Acidlime-7	- (61.6)	- (47.12)	- (46.54)	- (1.10)	- (10.4)	- (48.70)	- (6.9)	- (3.32)	- (31.4)
NRCC Acidlime-8	- 56.20	- 43.95	- 47.08	- 0.90	- 8.8	- 58.78	- 7.5	- 3.52	- 33.5
Assam lemon	144 (140.66)	92.05 97.05	54.34 (53.61)	4.39 (4.83)	3.50 (13.33)	36.5 (37.00)	7.2 (7.5)	5.92 (3.39)	34.72 (11.13)
Citron Mutant	144 (168.66)	85.19 (86.31)	59.53 (63.05)	5.67 (5.05)	6 (12.33)	36.5 (36)	7.4 (5.7)	6.11 (2.88)	18.51 (23.71)

* Figures in parentheses indicates flat bed data

Evaluation of different citrus varieties on raised bed and flat bed systems

Plant growth : This experiment was started during the year August, 2018 at RRCC, with row method (16plants/row) of Natal, Valencia, Pera, Jaffa, Westin, Mosambi, Star ruby, Red blush, Marsh seedless, Clementine and Petlur selection were spaced under 5x3 m spacing to evaluate its performance on raised bed and flat bed conventional method of planting. All the plants are budded on rough lemon rootstock. The growth performance of all the citrus spp. was recorded in very good condition. Among the sweet orange cultivars maximum plant canopy volume h was noted in Natal in both the planting system i.e.7.22 m^3 on raised bed and 6.99 m^3 on flat bed followed by Valencia in which the canopy growth was found 6.36m^3 on raised bed and 6.27 m^3 on flat bed. Marsh seedless grapefruit recorded higher canopy volume on raised bed and flat bed (9.02 and 8.66 m^3) than the other grapefruit cultivars. The canopy volume in Clementine was noted 4.10 m^3 and 4.69 m^3 on raised and flat bed, respectively Whereas the growth performance of Petlur selection did not showed much difference on raised and flat bed.

Fruit yield and quality: This year fruit quality data of sweet orange and grapefruit was recorded and it was noted that, in sweet orange cultivars maximum average fruit weight

Table 35 : Fruit quality of citrus varieties on raised and flat bed system at RRCC

Varieties	Average fruit weight (g)	Fruit length (mm)	Fruit dia. (mm)	Rind thickness (mm)	No. of seeds/ fruit	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/ 100 ml)
Natal	194.37 (262)	71.15 (73.8)	70.07 (79.11)	3.63 (3.16)	7.13 (6.00)	49.02 (33.2)	7.88 (5.7)	0.34 (0.32)	45.45 (45.2)
Valencia	197.51 -	71.23 -	71.50 -	4.02 -	4.23 -	43.92 -	7.03 -	0.63 -	40.99 -
Pera	195.88 -	75.17 -	69.12 -	3.91 -	5.04 -	46.91 -	7.50 -	0.55 -	38.34 -
Jaffa	212.33 -	77.08 -	75.47 -	2.89 -	12.00 -	34.47 -	7.93 -	0.46 -	39.17 -
Westin	198.42 (221)	79.60 (79.56)	78.80 (72.07)	4.06 (3.75)	5.25 (8.00)	31.93 (23.37)	6.25 (6.50)	0.14 (0.19)	41.29 (40.00)
Mosambi	211.41 -	70.94 -	73.41 -	2.82 -	20.75 -	34.74 -	10.03 -	0.57 -	38.49 -
Star Ruby	208.00 (501.6)	72.52 (99.16)	73.51 (101.47)	2.48 (7.47)	20.5 (6.5)	34.13 (31.16)	10.8 (5.5)	0.57 (0.32)	38.2 (49.00)
Red Blush	314.50 (401.0)	80.37 (92.07)	93.14 (97.33)	5.21 (3.36)	2.5 (3.0)	42.97 (37.13)	5.7 (5.6)	0.75 (0.38)	42.1 (40.00)
Marsh seedless	383.00 (533.33)	87.91 (90.69)	96.69 (102.99)	5.29 (6.75)	5.5 (5.60)	47.65 (22.65)	6.25 (5.5)	0.85 (0.32)	36.00 (45.00)
Clementine	139.33 -	89.5 -	100.87 -	6.54 -	3 -	40.21 -	5.75 -	0.73 -	32.5 -
Petlur Selection	59 -	46.38 -	47.73 -	1.62 -	9.4 -	48.56 -	6.7 -	3.26 -	33.4 -

* Figures in parentheses indicates flat bed data

was found in Mosambi (212.33 g) on raised bed planting system while in case of juice content maximum juice percentage was recorded in Natal on raised bed and flat bed (49.02% and 33.20%). As per the data recorded, maximum TSS (7.93%) was found in Jaffa. In case of acidity and Vit C content, maximum acidity (0.63%) was recorded in Valencia and Vit C (45.45 mg/100 ml) was found maximum in Natal. Among the grapefruit cultivars maximum average fruit weight (383 g) and juice content (47.65 %) was noted in Marsh seedless. TSS was found maximum in star ruby than all the other grapefruit cultivars. Whereas, Vit C was found maximum (42.1 mg/100 ml) in Red blush. In Clementine average fruit recorded 139.33 g and TSS was found 5.75% on raised bed and granulation was noted on flat bed. The fruit quality data of Petlur selection was recorded on raised bed. According to the data, average fruit weight was found 59 g,and TSS was recorded 6.7% (Table 35).

Evaluation of exotic mandarin and sweet orange varieties on raised bed planting system

A new experiment was started during the month of August, 2019 with the spacing of 5×3m on raised bed. Total Four varieties of sweet orange and mandarin were planted namely Few trails early, Daisy, Vernia, and W. Murcott in row method (12 plants/row). The initial plant height was recorded in range of 1.22-1.55m. Another four exotic sweet orange cultivars and mosambi were planted namely Salutiana, Delta , Trovita , Diller , Mosambi in row method (12 plants/row). The initial plant height was recorded as 0.87-1.14 m range. The growth performance of all the citrus varieties was recorded in very good condition.

Fig. 54 : Growth performance of different citrus varieties at RRCC, Biswanath Chariali

3.3 Integrated Pest and Disease Management

3.3.1 Integrated Insect Pest Management

3.3.1.1 Fruit sucking moth

Evaluation of efficacy of different insecticide repellents and botanicals combinations in the management of fruit piercing moth

Different modules consisting of repellants including acephate and phorate sachets as well as botanicals like Petroleum spray oil 2%, Neem oil 1%, Sweet flag extract 2% and pongamia soap 2% in different combinations at 10 days interval coinciding with colour breaking stage of Nagpur mandarin fruits were implemented at two locations *viz.*, Pipla Kinkheda and Susundri of Nagpur District during Ambia season 2020 two orchards *viz.*, Village-Pipla (Kinkheda) Taluka Kalmeshwar and Village-Susundri Taluka Mohapa of Nagpur District, during *Ambia* fruiting season at colour breaking stage. Observations on per cent fallen fruits due to fruit sucking moths at pre-treatment and at 10 days interval up to 30 days were recorded.

At Pipla (Kinkheda), percent fallen fruits before treatment were in the range of 23.61-49.06% . However, at 10 Days after Treatment (DAT), significantly lowest fruit drop was recorded in module–III (11.98%) and IV (17.07%) and similar results were also recorded in these modules at 20 and 30 DAT (Table 1). The pooled mean data from all the modules also shown the lowest fruit drops in module-III (12.44%) followed by module IV (17.87%) and V (19.67%) (Table 36).

Similarly on another field at Susundri, the pre-treatment fruit drops values ranged from 50 to 70.83%. Lowest percent fallen fruit were recorded in module IV (22.91%), III (24.40%) and VI (16.69%) at 10, 20 and 30 DAT, respectively. The pooled mean data showed significant lower fruit drop recorded in module-IV (24.17%) and III (25.75%) (Table 37).

Table 36 : Evaluation of different modules for the management of fruit piercing moth at village-Pipla (Kinkheda)

Treatments	Pre-treatments	10 DAT	20 DAT	30 DAT	Pooled mean
Module -I	33.09 (35.10)	25.08 (29.72)^{bc}	27.41 (31.35)^{b}	20.08 (26.14)^{b}	24.91 (29.41)^{c}
Module -II	32.35 (34.63)	23.95 (29.06)^{b}	24.73 (29.81)^{ab}	18.94 (25.63)^{b}	22.54 (28.30)^{bc}
Module -III	23.61 (29.06)	11.98 (19.95)^{a}	16.65 (23.12)^{a}	9.71 (18.02)^{a}	12.44 (20.57)^{a}
Module -IV	31.22 (33.90)	17.07 (24.30)^{ab}	20.94 (27.03)^{ab}	15.62 (23.03)^{ab}	17.87 (24.97)^{b}
Module -V	37.08 (37.48)	21.76 (27.44)^{ab}	23.06 (28.46)^{ab}	14.19 (21.97)^{ab}	19.67 (26.21)^{bc}
Module -VI	36.45 (36.49)	23.98 (28.90)^{b}	32.90 (34.93)^{b}	33.74 (35.47)^{c}	30.20 (33.27)^{d}
Module–VII (Control)	49.06 (44.43)	36.28 (36.91)^{c}	47.36 (43.39)^{c}	40.77 (39.48)^{c}	41.70 (41.06)^{e}
CD (p=0.05)	NS	7.66	8.03	7.46	3.76
CV (5%)	NS	18.39	17.34	18.53	7.30

Table 37 : Evaluation of different modules for the management of fruit piercing moth at Village-Susundri

Treatments	Pre-treatments	10 DAT	20 DAT	30 DAT	Pooled mean
Module -I	54.16 (47.79)	45.83 (42.60)^{b}	42.00 (40.37)^{bc}	40.00 (39.05)^{bc}	42.61 (40.74)^{bc}
Module -II	60.35 (51.11)	50.00 (45.00)^{bc}	25.83 (30.45)^{a}	27.70 (31.98)^{ab}	34.84 (35.98)^{ab}
Module -III	70.83 (61.40)	27.91 (31.83)^{a}	24.40 (29.33)^{a}	24.95 (29.94)^{a}	25.75 (30.48)^{a}
Module -IV	62.50 (52.66)	22.91 (28.57)^{a}	32.91 (34.82)^{ab}	16.69 (24.00)^{a}	24.17 (29.23)^{a}
Module -V	70.26 (60.87)	24.58 (29.66)^{a}	36.66 (36.96)^{ab}	43.12 (41.01)^{c}	34.78 (36.01)^{ab}
Module -VI	50.00 (45.00)	47.14 (43.35)^{bc}	31.54 (34.12)^{ab}	25.41 (30.09)^{a}	34.69 (35.93)^{ab}
Module–VII (Control)	65.00 (57.62)	55.41 (48.11)^{c}	55.53 (48.25)^{c}	54.99 (47.95)^{c}	55.31 (48.04)^{c}
CD (p=0.05)	NS	4.89	8.90	8.91	8.99
CV(5%)	NS	8.56	16.49	17.18	13.79

Pathogenicity of entomopathogenic nematode, *Heterorhabditis indica* against citrus fruit piercing moth, *Eudocima materna* (Linnaeus) under laboratory conditions

Pathogenicity of *H. indica* against larval instars of *E. materna*

Lab studies were conducted to study the infectivity of different concentrations of *H. indica* (10, 25, 50,100 and 200 IJs larva^{-1}) on *E. materna* larval stages (3rd, 4th and 5th). The experiments were carried out in insect breeding dish (50 × 15 mm) lined with sterile filter paper previously moistened with 350 µl of sterile distilled water for each treatment. In control treatments, only 500 µl of distilled water was added to the dishes. Larvae of *E. materna* were then individually placed in the dishes and pieces of fresh *T. cordifolia* leaves were provided as food, then the dishes were sealed with parafilm and incubated at 25 ± 1°C.

Results indicated that *H. indica* strain was capable of infecting and killing *E. materna* larvae (3^{rd,} 4th and 5th larval instars). The larval mortality was influenced by 3rd, 4th and 5th larval instars as nematode concentrations increased with mean mortality ranging from 26.6-100%, when they treated with 10 to 200 IJs larva^{-1} of the tested *H. indica* strain. There were significant differences in mortality among different IJ concentrations on 3rd, 4th and 5th larval instars after 24h of treatment. However, 100% mortality of all the larval instars was observed after 48 h of treatment at highest nematode concentration (200 IJs larva^{-1}) (Fig. 55).

Pupal susceptibility to *H. indica*

To study the infectivity of *H. indica* to pupae of *E. materna*, the different concentrations of IJs (10, 25, 50, 100 and 200 IJs pupa^{-1}) were suspended in 2.5 ml of distilled water and distributed evenly in the 100 ml plastic containers

containing the mixture of 90 cm^3 autoclaved sand and soil (1:1). Distilled water alone was added to the Control treatments. The single pupa was placed at 1 cm depth in each container. The containers were closed and incubated at 24 ± 2°C and 60 ± 5% RH.

Results showed that pupae of *E. materna* appeared susceptible to *H. indica*. Insect mortality recorded with 1-3 days old infected pupae revealed significant differences and greater mortality (>60%) at concentrations of 100 and 200 IJs $pupa^{-1}$ (Fig. 56). Fully developed pupae were less susceptible to EPN than 3rd, 4th and 5th instar larvae.

Reproduction potential of *H. indica* in larval instars

The larval instars (3rd, 4th and 5th) of *E. materna* infected with IJs of *H. indica* at different concentrations (50, 100, 200, 400 and 600 IJs $larva^{-1}$) were selected for reproduction assay. A total of ten numbers of each larval instar for each concentration were used in this assay. Five cadavers were selected randomly, rinsed with distilled water to remove adhering to the body surface. The cadavers were individually transferred onto the white trap and incubated at 25 ± 1 °C. The IJs that emerged from each cadaver were collected fifteen days after treatment in centrifuge tubes separately and the concentration of IJs was determined by serial dilution method.

Our results indicate that *H. indica* successfully reproduced in the 3rd, 4th and 5th larval instars of *E. materna* and their offspring were emerged from the larval cadavers. No significant difference was detected among different concentrations of IJs inoculated to 4th instar larvae on the reproduction of *H. indica.* However, significant difference was observed between 50 to 200 IJs and 400-600 IJs concentrations inoculated to 3rd instar larvae on the reproduction of *H. indica*. Significant difference was also detected among the five IJ concentrations inoculated to 5th instar larvae on the reproduction of *H. indica*. The reproduction of H. indica in 3rd instar larvae was significantly lower than that of 4th and 5th instar larvae (Fig. 57).

Overall results showed that *H. indica* represent potential biological agent that may be used in the control of fruit piercing moth, *E. materna* in citrus orchards as well as on weed host, *T. cordifolia*. The different concentrations of IJs per larva tested in this study showed optimal results in laboratory tests.

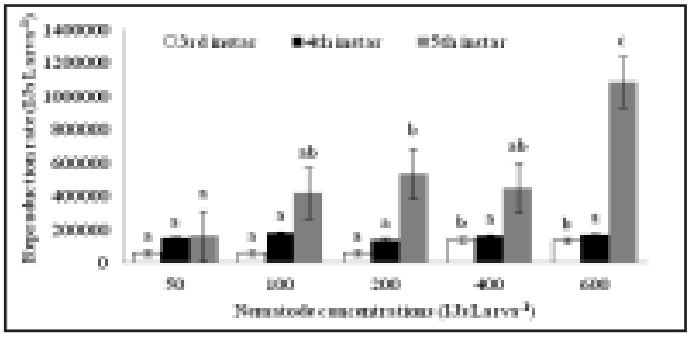


Fig. 57 : Reproductive potential of *Heterorhabditis indica* in different larval instars of *Eudocima materna* within five different concentrations in a laboratory assay. Bars with different letters indicate significant differences among reproduction rates of each larval instar (P ⩽ 0.05, Duncan's test).

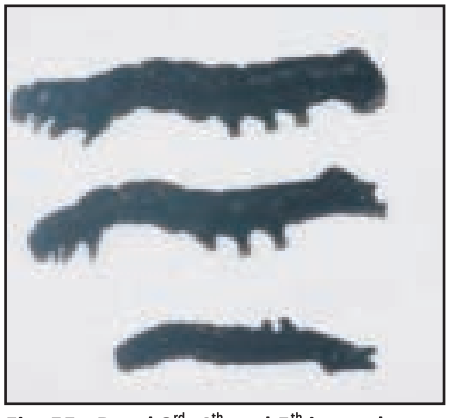


Fig. 55 : Dead 3rd, 4th and 5th instar larvae of *E. materna* infected by *H. indica*

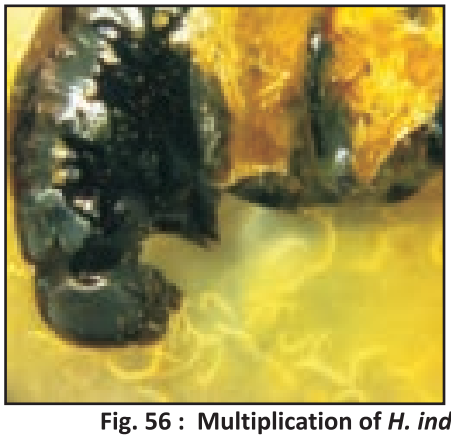


Fig. 56 : Multiplication of *H. indica* life stages inside the dead larva and pupa of *E. materna*

3.3.1.2 Horticulture Pest Surveillance and Advisory Project (HORTSAP)

Insect Pests

Two field visits during January to May 2020 and four field visits during July to December 2020 in selected orchards of three districts (Nagpur, Amravati and Wardha) comprising 10 Talukas and 23 Villages covering 52.19 ha area were conducted. A total of 7 monitors and 9 Scouts of respective orchards were given training on field identification of insect pest and damage symptoms on Nagpur mandarin. The pest identified and data entered by scouts and monitors were cross checked and validated for accuracy purpose. Global Positioning System (GPS) data of respective orchards visited were also taken. The online uploaded data entry records for the period of January to December, 2020 was compiled on Nagpur mandarin for 4 districts *viz*. Nagpur, Amravati, Wardha and Ahmednagar. The locations where insect pest incidence reaches above ETL in different months were documented, uploaded on NCIPM website and advisories were uploaded as a caution. A farmer training cum awareness programme on management of insect pest and diseases of citrus under HORTSAP project was jointly organized by ICAR-Central Citrus Research Institute (CCRI) and office of Divisional Joint Director of Agriculture, Nagpur Division, at Ranmangali Village, Taluka Bhivapur, District Nagpur on 28th February, 2020. Besides, lectures were delivered in five different training programmes organized by Director of Agriculture, Nagpur Division. In the month of April swarm of Stink bug (*Agonoscelis nubilis*) spotted in Narkhed Taluka of Nagpur district, management strategies were immediately suggested for the managements of sting bug. Highly destructive Swarms of desert locust also spotted for the first time in Vidarbha mainly in Amravati, Wardha, Nagpur district and farmers were alerted about preventive management strategies as per the Govt of India guidelines. Regular Pest advisories were issued to citrus growers through press notes in the local newspaper and WhatsApp messages, mobile SMS under HORTSAP project.

3.3.2 Integrated Disease Management

3.3.2.1 Consortia Research Platform (CRP) on vaccine and Diagnostics: Citrus viruses and greening bacterium

SYBR-Green based quantitative RT-PCR assay for the detection of Indian citrus ringspot virus Standardization of SYBR-Green-based RT-qPCR

The objective of this study was to develop reverse transcription-quantitative polymerase chain reaction (RT-qPCR) assays, based on coat protein (CP) gene-specific sequences for the detection and quantification of ICRSV by using SYBR-Green. Three sets of primer specific to CP gene were used for optimization; among these ICRSV-RT-3F/RT-3R primers provided a single amplicons (~164 bp) along with a sharp melt curve peak at 85.35°C was observed (Fig. 1A). Amplification was not observed in the healthy citrus plant (negative control) and non-template control (NTC). The second, EF-1α gene-specific primer (EF-1α-F/EF-1α-R) was used as an internal control, covering a fragment of ~185 bp. It provides the lowest Ct value (21.5± 3) for any sample tested, and a single amplicons with a melt curve peak at 83.99°C was observed (Fig. 58 A).

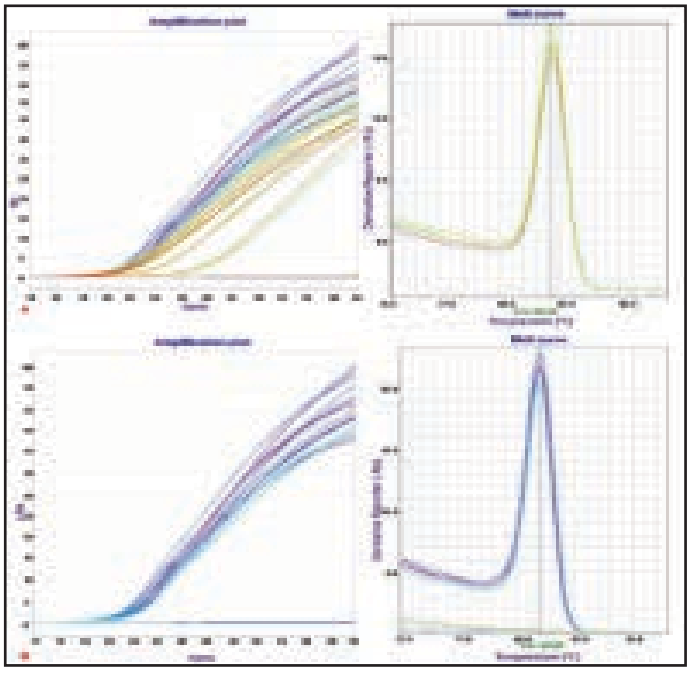


Fig. 58 A : Amplification plots and melting curves of representative samples: A, ICRSV Coat Protein; B, Internal control gene, EF-1α.

Standard curve for ICRSV gene: To generate a standard curve, a known amount of ten-fold diluted cRNA standard series ranging from 9.481 fmol ($5.709x10^9$) to 0.000948 amol ($5.709x10^2$) copies/µl and the respective Ct values obtained from (5.46 Ct) to (31.12 Ct) on amplification plot. The standard curve developed was highly specific and no primer dimer or non-specific amplification was observed in the analysis of the melting curve data (Fig. 58 B).

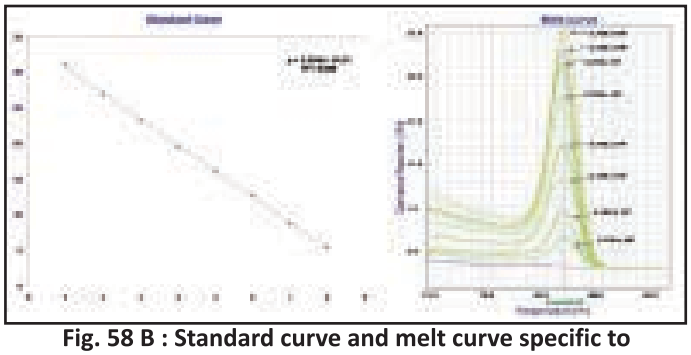


Fig. 58 B : Standard curve and melt curve specific to ICRSV obtained by a SYBR Green RT- qPCR assay.

Sensitivity and specificity of developed assay : To determine the sensitivity, same ten-fold cRNA dilution series was used to compare the detection limit of RT-qPCR and conventional RT-PCR. Detection limit up to 0.000948 amol ($5.709x10^2$) copies/µl for RT-qPCR and up to 0.948 amol/µl ($5.709×10^4$) copies/µl for RT-PCR were observed (Fig. 59). The specificity of the assays was analyzed using other major pathogens infecting citrus in India; extracted RNA from CTV, CYVCV and DNA from CYMV, *C*Las, and citrus phytoplasma along with the RNA of healthy citrus plant was used as a template. The reaction was performed in an optimal condition three times as described earlier, but no positive signal was obtained on the screen.

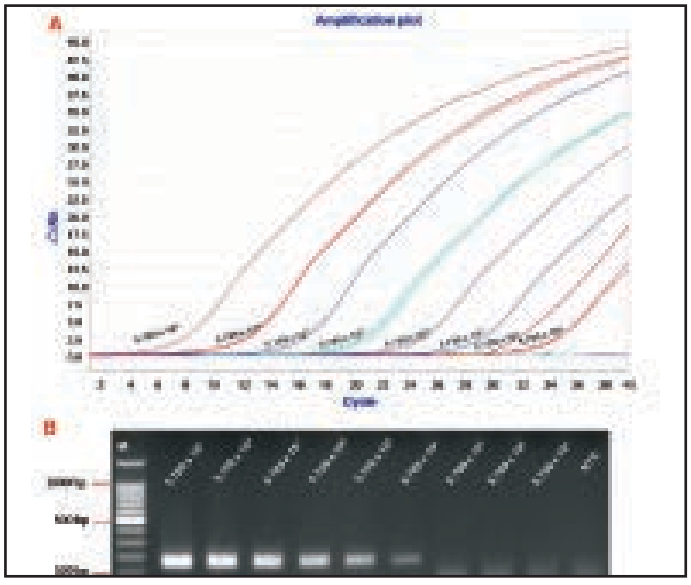


Fig. 59 : Sensitivity of coat protein gene based developed assay: A, Amplification plot of RT-qPCR assay using SYBR Green dye. B, Reverse transcription polymerase chain reaction (RT-PCR). Lane M, 100 bp DNA Ladder; lane 2 to 8, indicated the cRNA concentration in RT-qPCR assay starting from $5.709x10^9$ to subsequent ten-fold diluted up to $5.709x10^1$ respectively; and Lane -ve , non-template control.

Validation of developed assay : The RT-qPCR assay was validated with 48 field samples among which 30 field samples were observed moderately to highly positive using RT-qPCR. Further authentication of field samples as well as ICRSV positive mentioned samples were analyzed by RT-PCR using CP and nucleic acid binding gene-specific primers and amplified products ~978 bp and ~669 bp (Fig. 60) respectively.

Molecular detection and characterization of *Candidatus* Liberibacter asiaticus and Citrus tristeza virus isolates from Bhutan

PCR detection of CLas: A total of fifty-one samples collected from the different citrus growing regions of Bhutan were tested by PCR with *C*Las specific OI1/OI2c

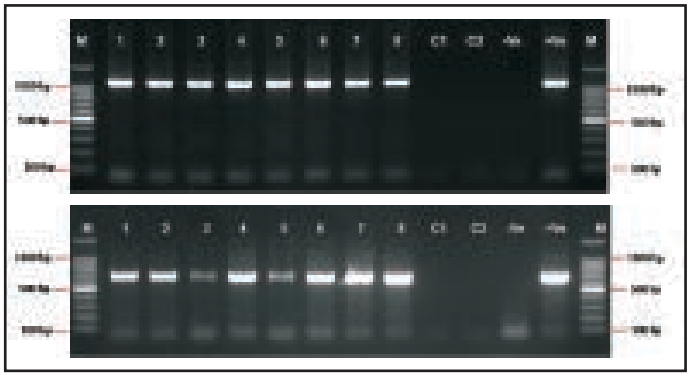


Fig. 60 : Validation of RT-qPCR assay using RT PCR of few representative field samples: A, Amplified PCR product of ICRSV coat protein gene; B, Amplified PCR product of ICRSV nucleic acid binding gene: Lane M,100 bp Ladder; Lane 1- 10, Field samples; Lane C1-C2, Healthy Plant; Lane -ve , non-template control; and Lane +Ve, ICRSV positive control.

primer set. The fourteen samples were found positive as it showed *C*Las specific expected ~ 1160 bp amplicons (Fig. 61).

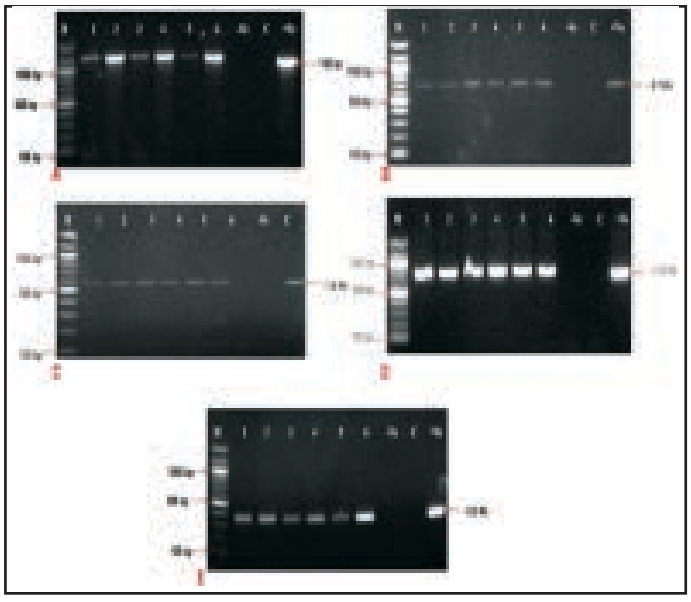


Fig. 61 : Agarose gel electrophoresis of PCR amplified product of Bhutanese *C*Las isolates: A, 16S ribosomal DNA (16S rDNA) gene of Bhutanese *C*Las isolates with primer set OI1/OI2c. B, 50S ribosomal subunit *rplA-rplJ* gene of Bhutanese *C*Las isolates with primer set A2/J5. C, CLIBASIA_01645 region of Bhutanese *C*Las isolates with primer set LapGP-1f/LapGP-1r. D, Prophage terminase gene (CLIBASIA_05610) of Bhutanese *C*Las isolates with primer set 766F/766R. E, Prophage terminase gene (CLIBASIA_05610) of Bhutanese *C*Las isolates with primer set CT3F/CT3R. Lane M, 100 bp DNA Ladder; lane 1 to 6 amplified product of representative Bhutanese isolates; lane -ve, reaction control; lane C, healthy plant control, and lane +ve, positive control.

CLIBASIA_01645 loci : The sequenced CLIBASIA_01645 regions of each isolates were analyzed to determine the variable tandem repeats for Indian isolates as reported by Ghosh et al. (2015). It was found that the CLas isolates from Bhutan segregated into Class-II and III (Fig. 62).

RT-PCR detection of CTV : Fifty-one samples collected from different regions of Bhutan were also tested for CTV by RT-PCR using different primer sets *viz.* CN150/CN151 (major coat protein gene, p25), *RBP-23F/R* (*RNA binding protein gene) and* AR18F/AR18R (*p18 gene).* A total of

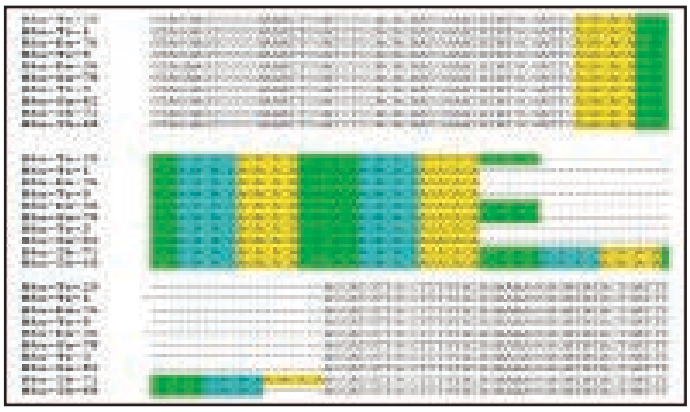


Fig. 63 : Nucleotide sequence alignment of the CLIBASIA_01645 loci of Bhutanese *C*Las isolates with variable tandem repeats.

thirty six samples were found positive for CTV, and the representative amplicons of eight isolates for each gene were separated on 1% gel (Fig. 63 A, B and C).

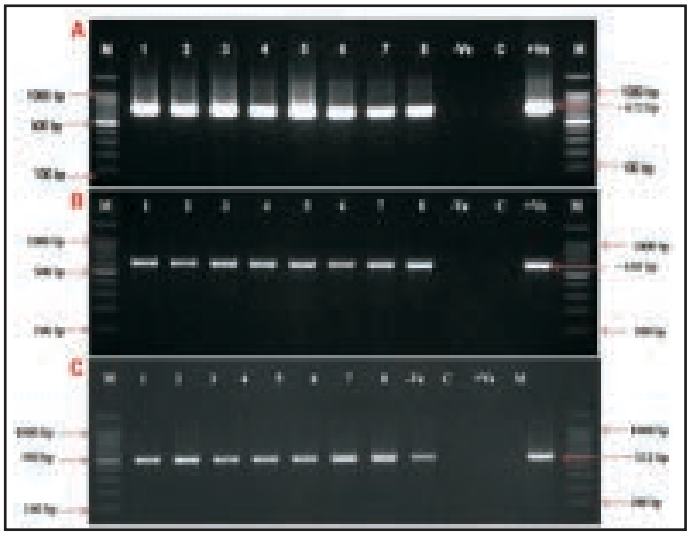


Fig. 63 : Agarose gel electrophoresis of PCR amplified product of Bhutanese CTV isolates: A, p25 gene of Bhutanese CTV isolates with primer set CN150/CN151. B, p23 gene of Bhutanese CTV isolates with primer set RBP23F/R. C, p18 gene of Bhutanese CTV isolates with primer set AR18F/R. Lane M, 100 bp DNA Ladder; lane 1 to 8 representative Bhutanese isolates; lane -ve, reaction control; lane C, healthy plant control, and lane +ve, positive control.

Molecular characterization of CTV : Bhutanese CTV isolates were further characterized based on sequences of p25 gene. The constructed phylogenetic tree with 1000 bootstrap value based on coat protein gene of 12 Bhutanese CTV isolates along with 23 other reported

isolates represented that nine Bhutanese isolates belonged to Genogroup III along with isolates from Meghalaya and Andhra Pradesh state of India i.e., KC590492, KC590495, and KC590501. Whereas, the single Bhutanese isolate Bhu-Da-76 was segregated to Genogroup I with Indian isolates and two Bhutanese CTV isolates (Bhu-Ts-18 and Bhu-Ts-20) belong to Genogroup IV with other isolates from Jamaica i.e., HM160503, HM160511 (Fig. 64). The sequence similarities of the coat protein gene of all Bhutanese CTV isolates with other reported CTV isolates available in the GenBank database were 96% to 99%.

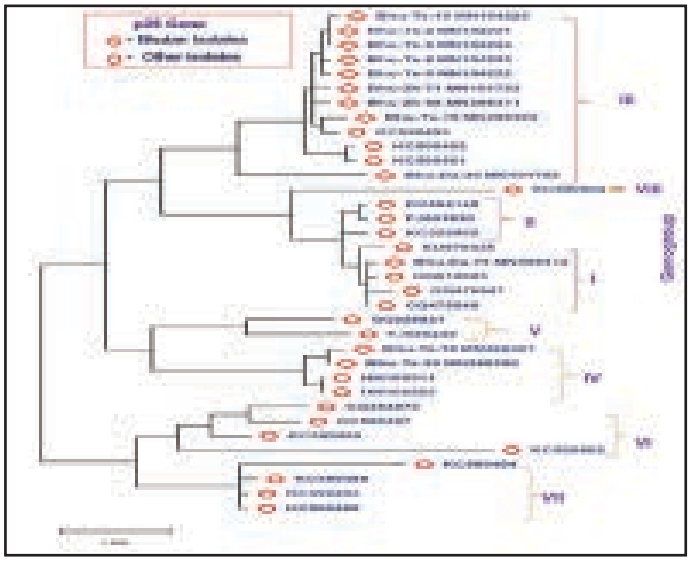


Fig. 64 : Phylogenetic tree constructed based on coat protein gene (p25) of Bhutanese CTV isolates with other reported coat protein gene sequences using a maximum likelihood method in MEGA X and significance of the node was estimated with 1000 bootstrap value.

Evaluation of antimicrobial Nano-zinc oxide-2S albumin protein formulation on HLB infected plants

Purification of 2S albumin protein

2S albumin protein has been isolated and purified from the seeds of pumpkin (*Cucurbita maxima*) and the effective antimicrobial concentration determined based on in vitro experimental data against E. coli (DH5α). The hard seed coat of mature seeds (25 g) was removed before grounding them. Soft part of the pumpkin seeds crushed with the help of pestle and mortar and soaking overnight in Tris buffer (Tris 50mM) pH 7.4. Filtered and centrifuged the

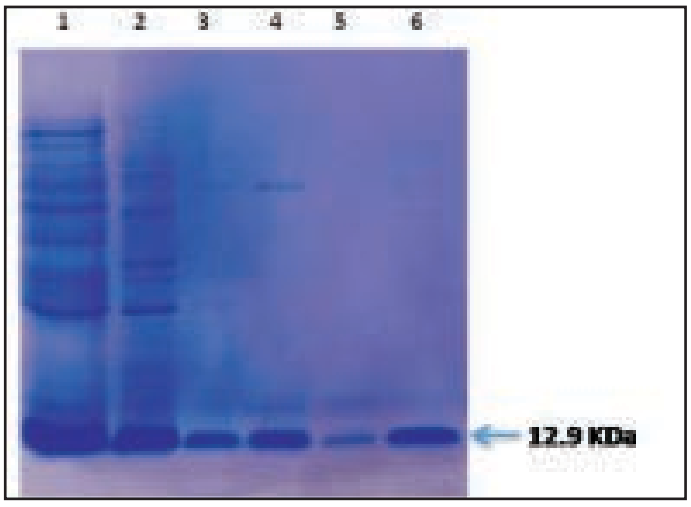


Fig. 65 : Purification of 2S albumin protein from pumpkin seeds: SDS-PAGE analysis of the protein. L1, pumpkin seed crude; L2, DEAE flow through; L3, CM-sepharose 100 mM NaCl elute, L4, CM-sepharose 300 mM NaCl elute; L5, Cibacrone blue bound fraction; L6, Concentrate protein after gel filtration.

seed extract at 18000 rpm for 45 min.The supernatant was loaded onto the pre-equilibrated DEAE column. The flow-through after DEAE column containing 2S albumin protein was applied on to a pre-equilibrated (50 mM Tris buffer, pH 7.4) CM column. 2S albumin protein eluted from CM column with NaCl gradient (50, 100, 300 and 500 mM) in 50mM TrismM buffer. Eluted protein was dialyzed to remove NaCl and concentrated with 3kDA cut off Centricon concentrator. Again, the impurity with the protein was removed with the help of affinity chromatography. For this chromatography, Cibacron Blue 3GA column (1.5×5 cm, Bio-Rad) was used in the same tris buffer pH 7.4. Interested protein was eluted in buffer containing 50mM Tris and 500mM NaCl, after substantial washing. We got purified 2S albumin protein after gel filtration with the help of superdex 75, 10/300 GL in 50mM Tris buffere pH 7.4. The purity of the eluted protein was confirmed by a single band on a non-reducing 12% SDS-PAGE (Fig. 65). The purified protein was concentrated and used in further experiments.

Identification and raising of HLB infected experimental citrus plants

The raised rough lemon rootstocks and mosambi plants were graft-inoculated with in planta live cultures of CLas.

The confirmed inoculums stem pieces approximately 5-10 cm long matched with the diameter of rootstock plant were cut from the source plant. Wedge cuts were slice on the both sides at the end of stem piece. A slicing cut was then made into the receptor plant. Each plant was inoculated with two side grafts and one bark graft. The inoculated plants and healthy controls subsequently maintained in the screen house at temperatures ranging from 32±5^{0}C (day time) to 22±5^{0}C(night) for further experiment. The successfully graft inoculated plants as well as field plants were tested for CLas by conventional PCR using CLas specific primers (OI1/OI2c). It was observed that total 16 plants were inoculated successfully and found positive for CLas. These PCR positive plants were selected for further investigations.

The qPCR was performed for each of the experimental plants to determine the Ct values before the treatments. The CLas specific primer pair (HLBas-F/-Rn) and probe (HLBp) based on sequences of 16S rDNA with an expected amplicons length of 76 bp (GenBank accession number L22532) were used. The HLB positive plants showing optimum Ct value were selected for further experiment (Fig. 66). The copy number of the pathogen in individual plant will be calculated using real time PCR. The selected CLas positive and healthy mosambi plants will be used for evaluation of efficacy of 2S albumin, Nano-ZnO and their combination by trunk injection. The formulation will be injected in HLB infected test plants at regular interval of three months for one/two years. The uninfected plants are being taken as controls. The CLas titer will be monitored during the experimental period using highly sensitive, specific and robust TaqMan- qPCR assay. The quantification of CLas copy number will be carried out using the standard curve method to determine the effectiveness of treatment using RT PCR. All treatments will be performed in triplicate with negative control (template from untreated healthy plant), positive control (template from untreated HLB infected plant) and non-template control.

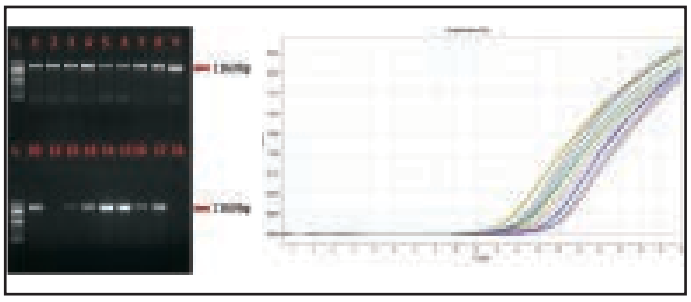


Fig. 66 : A Gel electrophoresis of the PCR products obtained using the 16S rRNA specific primer set OI1 and OI2c. Lane: 100 bp ladder, Lane 1-17 are the representative graft inoculated plants. Lane 18: Healthy control. B, Amplification plot for HLB positive samples showing average Ct value between 21 - 28 whereas undetermined Ct observed for non template control and H: Healthy control.

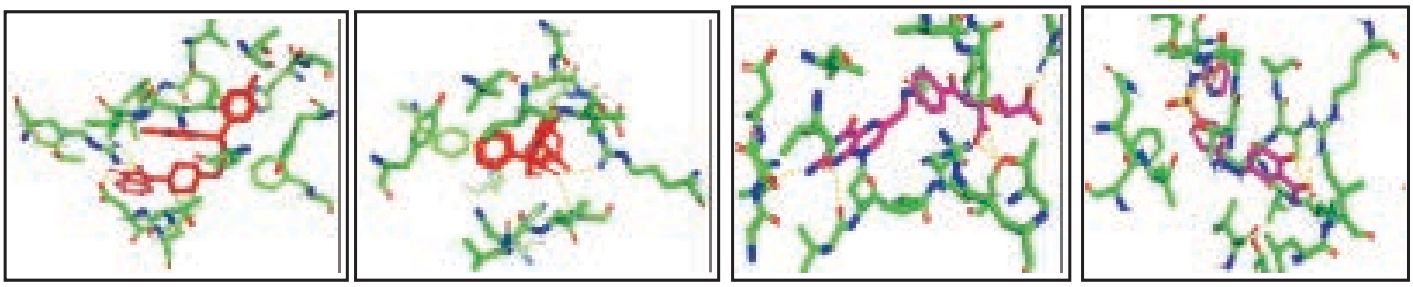
3.3.2.2 Development of potential inhibitor molecules against putative cystine-binding protein from *Candidatus* Liberibacter asiaticus

Identification of potential inhibitor molecules against CLasTcyA through virtual screening

Virtual screening is a powerful technique to identify the potential lead molecules in the field of drug discovery. Drug-like compounds of Drugbank databases were screened against CLasTcyA using AutoDock Vina in PyRx. Top 4 molecules showed the higher binding affinity as compared to the CYS for CLasTcyA in range of -9.4 to -10.7 kcal/mol as compared to the substrate (-7.2 kcal/mol) as shown in following Table 38 and all the 4 molecules fulfilled the Lipinski rule of five (molecular weight < 500 Da, H-bond donor < 10, and cLogP < 5).

Table 38 : Potential inhibitor molecuales against CLsTcyA

Molecules	Autodock Vina (kcal/mol)
Cystine	-7.2
Pimozide	-10.6
Sulfasalazine	-10
Clinidium	-9.9
Folic acid	-9.2



(A) (B) (C) (D)

Fig. 67 : Docking interaction of analysis of CLasTcyA with (A) Pimozide (B) Clinidium bromide (C) Folic acid (D) Sulfasalazine complex, interacting residues of CLasTcyA are shown in stick. The interactions are shown as yellow dash line.

Further, molecular docking was performed to study the interactions of the above compounds with protein using AutoDock Tools. All the molecules exhibit higher binding energy as compared to CYS. All the molecules exhibit intermolecular hydrogen bonding interactions with Arg82 of CLasTcyA. Virtual screening and molecular docking results infer that identified molecules possess higher affinity than CYS at the active site of CLasTcyA. Molecular docking and dynamics studies were performed to predict the stability of protein-inhibitor complexes. The overall RMSD results show that CLasTcyA-inhibitor(s) complexes have lesser RMSD as compared to the CLasTcyA-CYS. RMSF which indicate that all the identified molecules were well fitted at the active site of CLasTcyA without causing much fluctuation in the protein-inhibitor complex. The lesser Rg of CLasTcyA-inhibitor(s) complexes to CLasTcyA-CYS complex suggested that protein is compactly packed and maintained the rigidity of CLasTcyA-inhibitor(s) complexes. SASA analysis also revealed that binding of these compounds to CLasTcyA results in formation of compact complex as compared to CLasTcyA-CYS complex. Intra-molecular hydrogen bonding results also show that the binding of identified molecules results in the formation of stable complexes as compared to CLasTcyA-CYS complex. Further, MMPBSA results confirm that all these compounds bind efficiently to CLasTcyA. Overall molecular dynamics simulations result conclude that all the identified compounds are potent molecules to prevent the binding of CYS to CLasTcyA.

3.3.2.3 Molecular diagnostics, transcriptomics and cisgenic approaches to combat Citrus greening (Huanglongbing) disease of citrus

(DBT Funded Twining Project: Collaborating Institutes: Assam Agricultural University, Jorhat (Coordinating centre), ICAR-Research Complex for NEH, Manipur Centre, Manipur and ICAR-Indian Agricultural Research Institute, New Delhi)

Prophage diversity of *Candidatus* Liberibacter asiaticus (CLas) strains

A total number of 441 CLas positive DNA samples (isolates) were obtained from 18 citrus growing states of India (Assam-57, Gujarat-10, Nagaland-12, Manipur-9, Mizoram-15, Arunachal Pradesh-11, West Bengal-23, Rajasthan-16, Madhya Pradesh-68, Andhra Pradesh-19, Telangana-15, Karnataka-24, Maharashtra-69, Punjab-39, Tamil Nadu-14, Meghalaya-17, Sikkim-12 and Tripura-11) and were used in the study for screening of prophage types and assessing CLas population diversity where each sample typically represents a single tree.

DNA was extracted from each sample using DNeasy ^{R} Plant Mini Kit (QIAGEN) as per the manufacturer's protocol. The Presence of CLas was confirmed by PCR with primer set of Las-F, Las-R and OI1-F, OI2c-R. PCR products were sequenced by outsourcing and sequences obtained were analyzed and further the sequences were BLAST (http://blast.ncbi.nlm.nih.gov/ Blast.cgi?) analyzed to identify the species.

Amplification and identification of prophage region : All CLas isolates were subjected to prophage-typing using six primer sets described previously Primer sets T1-2F/T1-2R and T1-3F/T1-3R specific to prophage Type 1, T2-2F/T2-2R and T2-3F/T2-3R specific to prophage Type 2 and 891-1F/891-1R and 891-2F/891-2R specific for prophage Type 3 were used for PCR amplification of the prophage region. All primers used in this study are detailed in Table 39. All the CLas isolates were then classified into eight possible prophage-based groups: Type 1, Type 1 + Type 2, Type 1 + Type 3, Type 1 + Type 2 + Type 3, Type 2, Type 2 + Type 3, Type 3 and no prophage.

All possible eight combinations of the three known prophage types (Type 1, Type 2 and Type 3) were detected using different prophage-specific PCR markers (Table 40). The highest 117 samples (26.50%) harboured only Type 1 prophage, followed by 90 samples (20.4%) of the combination Type 1 + Type 2 prophage and then 83 samples (18.8%) showed only Type 2 prophage. The combinations of all the 3 prophages i. e. Type 1 + Type 2 + Type 3 were noticed in 50 samples (11.3%). The number of CLas isolate lacking all three prophages was found to be 19 (4.3%). All the probable eight combinations were found in the states of Karnataka, Telangana, Maharashtra and Madhya Pradesh. The combination Type 1 + Type 3 prophage accounted for 55 samples (12.5%) whereas Type 2 + Type 3 combination accounted for 21 samples (4.8%). Presence of Type 3 alone accounted lowest 6 samples (1.4%). In the Western part of India, in the state of Gujarat, only Type 2 prophage was found. Fig. 68 illustrates the representative amplicons obtained by using two each of

Table 39 : General information of prophage type specific primer sets and 16S rDNA specific primer sets used in diversity study

Primer	Size (bp)	Specificity	Targeted region
891-1F	950	Type 3 prophage	*hsdS*
891-1R			
891-2F	884	Type 3 prophage	*hsdR*
891-2R			
T1-2F	975	Type 1 prophage	Endolysin
T1-2R			
T1-3F	866	Type 1 prophage	Hypothetical protein gene
T1-3R			
T2-2F	813	Type 2 prophage	Phage structural protein gene
T2-2R			
T2-3F	918	Type 2 prophage	Hypothetical protein gene
T2-3R			
Las-F	500	CLas chromosomal region	16 S rRNA gene
Las-R			
OI1-F	1167	CLas chromosomal region	16S rRNA gene
OI2-R			

Type-1, Type-2 and Type-3 prophage specific primer sets. In addition, among eight different types of prophage combination groups of CLas isolates, no particular citrus cultivar preference was found, e.g., three different types of prophage combination were identified from 20 HLB-affected Nagpur mandarin trees in the same orchard located in Maharashtra and Type 1 CLas strains were confirmed from the 15 DNA samples extracted from three different citrus species (*C. reticulata*, *C. grandis*, *C. jambhiri*) in the same orchard located in Assam.

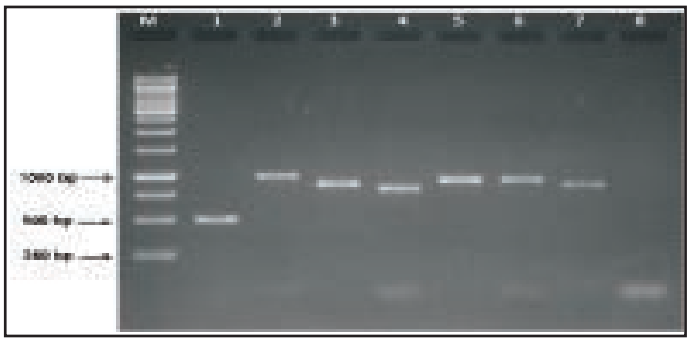


Fig. 68 : Conventional PCR-based detection of prophage associated genes in CLas strains. Lane 1, "*Ca.* L. asiaticus" detection with primer set Las606/LSS. Prophage detection with primer T1-2F/T1-2R (lane 2) and T1-3F/T1-3R (lane 3) for Type 1; T2-2F/T2-2R (lane 4) and T2-3F/T2-3R (lane 5) for Type 2; 891-1F/891-1R (lane 6) and 891-2F/891-2R (lane 7) for Type 3 prophage. Lane 8, Healthy citrus DNA amplified with either of the above primers. Lane M, 1 Kb Gene Ruler Ladder

Table 40 : Frequencies of different prophage combinations in "*Candidatus* Liberibacter asiaticus"-infected citrus DNA samples in 18 different states of India as determined by Type specific primer sets

State	No. of isolates[a]	# CLas samples with prophage combination[b] (frequency, %)							
		Type 1	Type 2	Type 1 + Type 2	Type 2 + Type 3	Type 1 + Type 3	Type 1 + Type 2 + Type 3	Type 3	Neither Type 1 + Type 2 + Type 3
Andhra Pradesh	19	5 (26.3)[c]	1 (5.3)	2 (10.5)	4 (21.1)	3 (15.8)	2 (10.5)	-	2 (10.5)
Arunachal Pradesh	11	3 (27.3)	2 (18.2)	3 (27.3)	-	1 (9.1)	2 (17.2)	-	-
Assam	57	20 (35.1)	1 (1.8)	30 (52.6)	-	3 (5.3)	3 (5.3)	-	-
Gujarat	10	-	10 (100.0)	-	-	-	-	-	-
Karnataka	24	4 (16.7)	6 (25.0)	1 (4.2)	2 (8.3)	2 (8.3)	7 (29.2)	1 (4.2)	1 (4.2)
Madhya Pradesh	68	8 (11.8)	10 (14.7)	4 (5.9)	4 (5.9)	23 (33.8)	15 (22.1)	1 (1.5)	3 (4.4)
Maharashtra	69	22 (31.9)	11 (15.9)	10 (14.5)	8 (11.6)	8 (11.6)	7 (10.1)	1 (1.4)	2 (2.9)
Manipur	9	3 (33.3)	2 (22.2)	2 (22.2)	-	1 (11.1)	1 (11.1)	-	-
Meghalaya	17	2 (11.8)	2 (11.8)	11 (64.7)	-	1 (5.9)	1 (5.9)	-	-
Mizoram	15	5 (33.3)	4 (23.5)	4 (23.5)	-	1 (6.7)	1 (6.7)	-	-
Nagaland	12	6 (50.0)	2 (16.7)	1(8.3)	-	1 (8.3)	2 (16.7)	-	-
Punjab	39	8 (20.5)	19 (48.7)	6 (15.4)	-	-	-	-	6 (15.4)
Rajasthan	16	3 (18.8)	7 (43.8)	3 (18.8)	-	-	-	-	3 (18.8)
Sikkim	12	3 (25.0)	2 (16.7)	3 (25.0)	-	2 (16.7)	2 (16.7)		
Tamil Nadu	14	9 (64.3)	-	-	-	2 (14.3)	-	2 (14.3)	1 (7.1)
Telangana	15	4 (26.7)	1 (6.7)	2 (13.3)	3 (20.00)	2 (13.3)	1 (6.7)	1 (6.7)	1 (6.7)
Tripura	11	2 (18.2)	1 (9.1)	3 (27.3)	-	2 (18.2)	3 (27.3)	-	-
West Bengal	23	10 (43.5)	2 (8.7)	5 (21.7)	-	3 (13.0)	3 (13.0)	-	-
Total	**441**	**117 (26.5)**	**83 (18.8)**	**90 (20.4)**	**21 (4.8)**	**55 (12.5)**	**50 (11.3)**	**6 (1.4)**	**19 (4.3)**

[a]All *Ca*Las strains are positive for *Ca*Las infection using qRT-PCR method of Li et al. (2006) and cPCR using LasF/ LasR primers

[b]Distribution of different prophage combinations in "*Candidatus* Liberibacter asiaticus"-infected citrus DNA samples determined by Type specific primer sets described in Table 1

[c]Figures in parentheses are percentage frequency

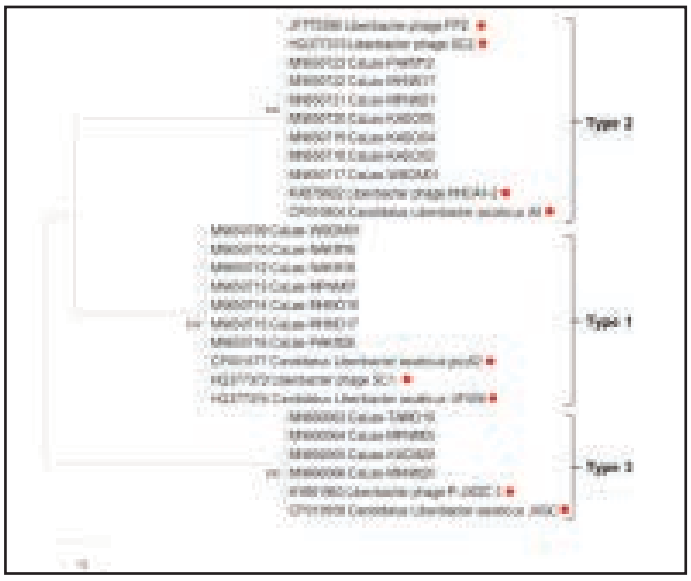


Fig. 69 : An unrooted phylogenetic tree of "*Candidatus* Liberibacter asiaticus" isolates based on propahge sequences obtained by using type-specific primers. Downloaded sequences from published prophages are identified in red circle. Numbers at each branch are bootstrap values supported in 1,000 replication by neighbour-joining method.

Diversity of CLas populations

A pairwise population matrix of genetic distance and genetic identity was generated for CLas populations from individual states using the POPGENE v. 1.32 software. By detection of Type 1, Type 2 and Type 3 prophages CLas populations from eighteen citrus growing states were separated into two major Prophage Typing Groups (PTG1 and PTG2), and five subgroups (PTG1-A, PTG1-B, PTG2-A, PTG2-B and PTG2-C) (Fig. 70)

The prophage typing group 1 (PTG1) formed from North-West India and prophage typing group 2 (PTG2) classified from rest of the country (North-East, Central and South India), and both major groups were further divided into two (PTG1-A, PTG1-B) and three (PTG2-A, PTG2-B and PTG2-C) subgroups respectively. The subgroup PTG1-A comprised of CLas isolates from Punjab and Rajasthan and PTG1-B from Gujarat, the North-West sates of India. The PTG2-A comprised of CLas isolates from North Eastern states of India, although this subgroup further showed significant genetic heterogeneity within the CLas isolates from Assam, Arunachal Pradesh, Meghalaya, Manipur and Mizoram were together. Whereas, the CLas isolates from Nagaland, Hilly terrains of West Bengal, Sikkim and Tripura clustered together. The subgroup PTG-2 B comprised of CLas isolates from South and Central states of India (Andhra Pradesh, Maharshtra, Telangana, Karnataka and Madhya Pradesh). Interestingly, the CLas isolates from Tamil Nadu segregated into a distinct subcluster PTG-2 c (Fig. 70).

The H-values of genetic diversity for CLas populations from central India and adjoining Southern states were found relatively higher whereas the H-values of genetic diversity for CLas populations from North-West and North-East Indian states (except Arunachal Pradesh and Sikkim) were relatively low. The overall average estimated H-value was 0.3512.

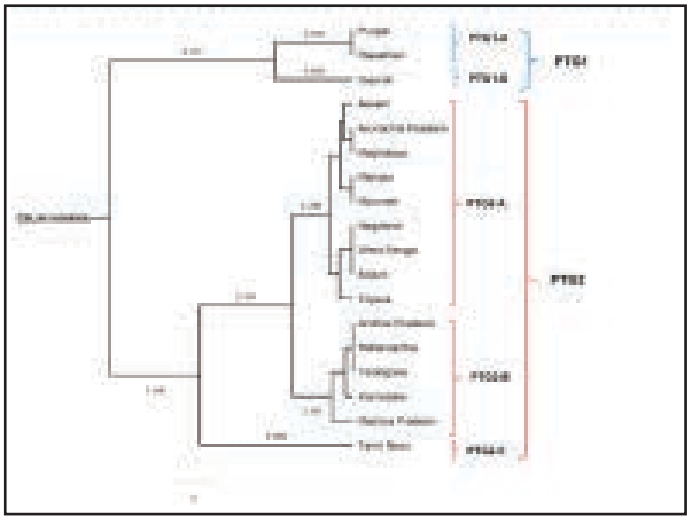


Fig. 70 : The grouping of '*Candidatus* Liberibacter asiaticus' populations from eighteen citrus growing states of India by detection of the presence of prophages. The dendrogam was built using the unweighted paired group method with arithmetic mean (UPGMA) and figures represent genetic distance between isolates. PTG, prophage typing group.

CRISPR/cas analyses

In this study we also tried to find the presence of CRISPR/cas system in CLas isolates. The CRISPR repeats array in the prophage region of different CLas isolate were identified by PCR amplification with primer set CRIF/CRIR. Amplicons were directly sequenced bi-directionally by

standard Sanger's sequencing method. Multiple sequence alignment was performed using the BioEdit software.

PCR-based detection method using the primer pair CRIF/CRIR identified a CRISPR (clustered regularly interspaced short palindromic repeats) region in all the 3 types of prophages (Type1/2/3). Thirteen CLas field isolates sampled from 6 states were found to have a CRISPR element based on the PCR assays and subsequent sequence analysis. The CRISPR array contained four highly similar 22 bp repeats with three heterologous spacers of 23 bp (Fig. 71). Repeat sequences were much more homogeneous (82%, 18/22) than spacers (39%, 9/23). No similar CRISPR array was found in GenBank sequence database except for the already published CLas prophages suggesting the CRISPR/cas system was shared by these prophages.

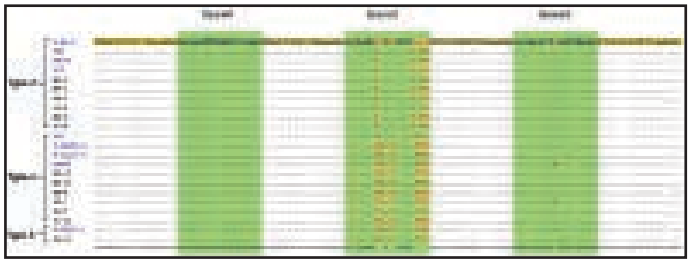


Fig. 71 : Sequence alignment of clustered regularly interspaced short palindromic repeats (CRISPR) arrays among 22 isolates / prophage sequences of "*Candidatus* Liberibacter asiaticus". Already published 9 prophage sequences (obtained from GenBank) are identified in blue. MP, MS, KA, AS, MZ and PJ represent the *Ca*Las isolates from Madhyapradesh, Maharshtra, Karnataka, Assam, Mizoram and Punjab states. Strain P-A4-2 was used as a reference. CRISPR repeats are highlighted in yellow. Dots represent nucleotide identity to those of Strain P-A4-2. A * at the bottom of alignment indicates identical nucleotides. Nucleotide variations are marked in red.

Characterization of Indian *Candidatus* Liberibacter asiaticus (CLas) populations by double-locus analyses

Reliable genotyping that provides an accurate description of diversity in the context of pathogen emergence is required for the establishment of strategies to improve disease management. Taxonomically, CLas is defined by a signature sequence in the 16S rRNA gene (rrs). Strain variation of CLas in this rrs genomic locus, however, is very limited and the locus is not suitable for strain differentiation. In this study, we focused on double loci: (i) prophage gene locus (*snp*1) and (ii) variable tandem repeat numbers locus (*trn*1) and analyzed its variation in '*Ca*. L. asiaticus' populations from different parts of India.

Both sequencing-based and PCR-based procedures were used to identify bacterial variations in *snp*1 locus. PCR-based genotype grouping of CLas isolates was determined using the primer set CT3f/CT3r specific for Term-A and primer set FC3f/FC3r for Term-G (Fig. 72).

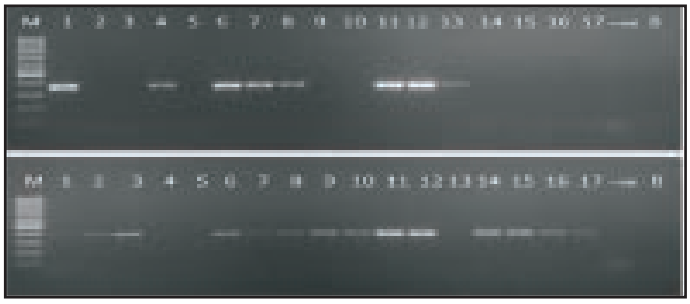


Fig. 72 : PCR-based agarose gel electrophoresis for genotyping of representative fourteen (lane 1-14) ''*Candidatus* Liberibacter asiaticus'' isolates at *snp*1 locus using primer sets CT3f/CT3r (top) and FC3f/FC3r (bottom). M, 100 bp ladder.

Grouping of CLas isolates by SNP term determination was also verified by sequencing the cPCR amplified products. Primer set 766f/766r amplified a 766 bp fragment from prophase terminase gene. The derived sequences and CLas strain YN-840-China (GenBank accession HM105498), 3 strains from Florida and California, USA and another strain from Iran were used as reference sequences for identification of single nucleotide polymorphisms (SNPs). Sequence alignment detected SNP at position 392. On the basis of this SNP, all CLas isolates were divided into two groups (as mentioned previously): Term-A (for adenine), and Term-G (for guanine).

Variation among CLas isolates : HLB CLas genomic variation was tested by double-locus (DL) analysis, representing a tandem repeat number (TRN) locus (*trn*1)

and the above single nucleotide polymorphism (SNP) locus (*snp*1). The methods included one cPCR for TRN and two cPCRs for SNP locus, and if cPCR positive, the corresponding PCR product was directly sequenced through commercial service. Specific primers (LAPGP1f/LAPGP1r) were used to amplify for phage-related bacteriophage repressor protein C1 genes (at CLIBASIA 01645 genomic region/ locus) of CLas and subsequently TRN repeat numbers were counted from TRN-cPCR product direct sequencing results. To analyze the variations in the trn1 locus, the binary grouping system (TRN<10/TRN>10) was used. Identification of the two groups was simplified using agarose gel electrophoresis with reference to product of 592 bp, the calculated TRN = 10 amplicon from primer set LapGP-1f/LapGP-1r (Fig. 72). Forty five no. of LapGP-1f/LapGP-1r sequences were submitted to NCBI GenBank and TRN numbers were evaluated / verified by manual counting. Results were found in consonance with the PCR-based binary grouping.

Table 41 : A double-locus (DL; *trn*1 and *snp*1) analysis of "*Candidatus* Liberibacter asiaticus" 259 isolates from different citrus growing states of India.

	trn1		
snp1	TRN<10	TRN>10	Total
Term -A	187 **DL genotype 1**	5 **DL genotype 2**	**192**
Term -G	96 **DL genotype 3**	5 **DL genotype 4**	**101**
Total	283	10	**293**

A total of 293 CLas isolates (from 16 citrus growing states; Assam-47, Andhra Pradesh-06, Arunachal Pradesh-10, Gujarat-04, Karnataka-18, Maharashtra-48, Madhya Pradesh-61, Manipur-02, Meghalaya-06, Mizoram-13, Nagaland-07, Punjab-36, Rajasthan-06, Tamil Nadu-08, Tripura-07 and West Bengal-14) were analyzed through DL genotyping (Table 41). Results showed that 187 isolates belonged to the DL genotype 1, 5 isolates to DL genotype 2, 96 isolates DL genotype 3 and 5 isolates belonged to DL genotype 4. Analysis revealed the maximum existence of DL genotype 1 followed by DL genotype 3 in India.

Characterization of highly mosaic genomic loci of *Candidatus* Liberibacter asiaticus

Identification and characterization of unique genomic loci in *Ca*. L. asiaticus is currently a critical and most practical means to evaluate this unculturable bacterium. A genomic region (CLIBASIA_05640 to CLIBASIA_05650) of '*Ca*. L. asiaticus' show hyper-sequence variation (Wang *et al*, 2012). Locus mosaicism in the CLas isolates from different states of India was done by studying the electrophoretic profiles (E-type).

In the present study Locus mosaicism of 101 CLas isolates were studied from 16 different states of India. Five different patterns of E-type were observed. Out of 101 isolates, 20 isolates were of 'E-type A', 26 isolates were of E-type C, 10 isolates were of 'E-type D', 5 isolates were of 'E-type E' and 25 isolates showed new electrophoretic profile which was not reported by earlier. This new electrophoretic profile was designated as 'E-type I' to differentiate it from the previously reported E-type A-H. Remaining 15 isolates showed absence of any definitive pattern. Primer set Lap5640f/Lap5650r yielded one to three amplicons for a given HLB samples. A total of five amplicons with different sizes were identified. They are related by insertion/deletion events, demonstrating the mosaicism in the population genome of '*Ca*. L. asiaticus'.

3.3.2.4 Endophytic bacteria, fungi and free-living rhizobacteria as bioagents for management of *Phytophthora* diseases in citrus

Isolation, characterization and antagonistic effect of citrus rhizobacteria

Samples of soil and rhizospheric roots of healthy citrus plants (cultivars Nagpur mandarin, sweet orange and Pummelo) were collected from different citrus blocks situated at ICAR-CCRI farm site. Total 25 isolates of rhizobacteria were isolated and purified from citrus rhizospheric soil, rhizoplane and endorhizosphere using standard serial dilution technique. The rhizobacterial isolates were screened for their ability to inhibit the growth of the root rot pathogen *P. nicotianae* by dual culture technique. Out of 25 isolatess, 10 were found

Table 42 : Source and characterization data of promising rhizobacteria

Isolate #	Citrus variety	Tissue source	Molecular identification*	Gram Staining	% inhibition against *P. nicotianae*
P1	Sweet orange	Rhizospheric soil	*Pseudomonas* sp.	Gram negative	73.21
P4	Sweet orange	Rhizoplane	*Pseudomonas* sp.	Gram negative	77.98
P6	Sweet orange	Rhizospheric soil	*Pseudomonas* sp.	Gram negative	57.74
P7	Sweet orange	Rhizospheric soil	*Pseudomonas* sp.	Gram negative	57.74
P11	Nagpur mandarin	Rhizoplane	*Pseudomonas* sp.	Gram negative	73.21
P14	Nagpur mandarin	Rhizospheric soil	*Pseudomonas* sp.	Gram negative	59.52
P15	Nagpur mandarin	Rhizoplane	*Pseudomonas* sp.	Gram negative	64.28
P16	Nagpur mandarin	Rhizoplane	*Pseudomonas* sp.	Gram negative	52.38
P21	Nagpur mandarin	Rhizoplane	*Pseudomonas* sp.	Gram negative	58.93
P22	Nagpur mandarin	Rhizospheric soil	*Pseudomonas* sp.	Gram negative	54.17

*Based on 16S rRNA gene sequencing

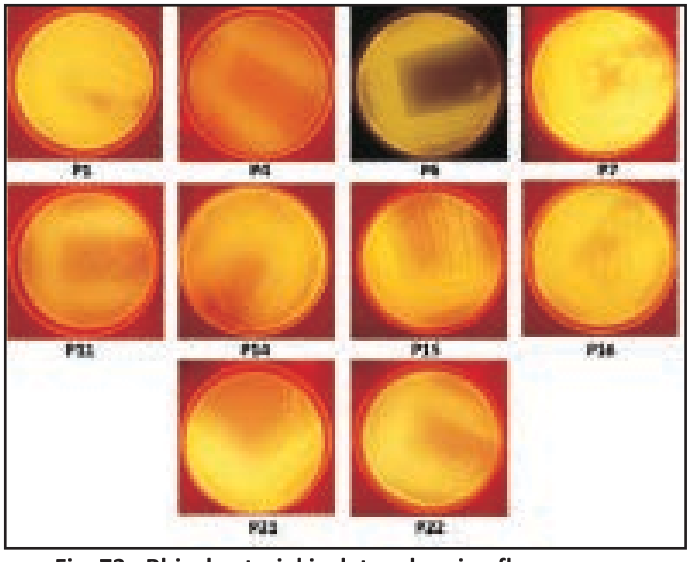


Fig. 73 : Rhizobacterial isolates showing fluorescence under UV light

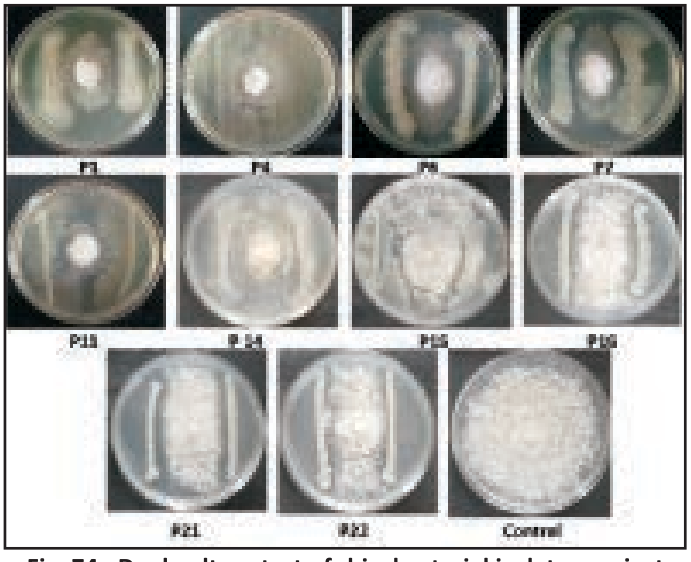


Fig. 74 : Dual-culture test of rhizobacterial isolates against *Phytophthora nicotianae*

promising showing more than 50% inhibition in the dual culture assay (Table 42 ; Fig. 73 and 74).

All these isolates were characterized by morphological, biochemical and molecular means (Table 42). All the isolates were identified belonging to the fluorescent Pseudomonad group.

Fungal endophytes

Nine fungal endophytes (CFE-154 – FE-162) isolated rhizospheric roots from healthy plant of sweet orange. Morphological characterization of all isolates was done with respect to colony morphology, growth pattern, mycelium colour, colony appearance, surface texture, margin characters and pigmentation. Colony morphology

of the fungal endophytes was illustrated in Fig. 75. The molecular analysis (ITS sequence) using online BLAST tool confirmed the identity of the respective fungi. The purified isolates generated were used for performing confrontation assay against *P. nicotianae*. Evaluation of antagonistic activity of these fungal isolates against *Phytophthora* was carried out.

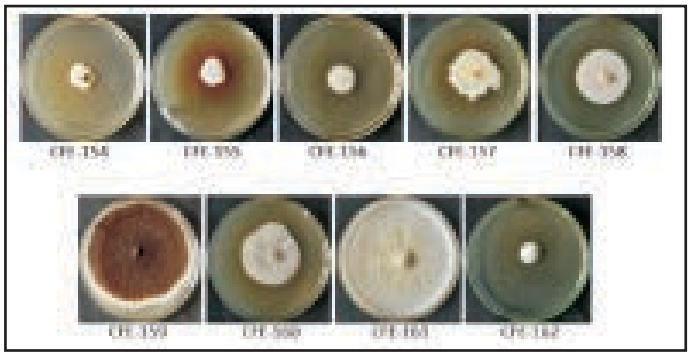


Fig. 75 : Colony morphology of promising fungal endophytes

The fungal endophytes which were found to have potential against controlling *P. nicotianae* were CFE-154, CFE-157 and CFE-162. Maximum inhibition was found in case of CFE-154 (*Rhytidhysteron rufulum*) followed by CFE-157 (*Chaetomium globosum*) and CFE-162 (*Penicillium parvum*) (Fig. 76).

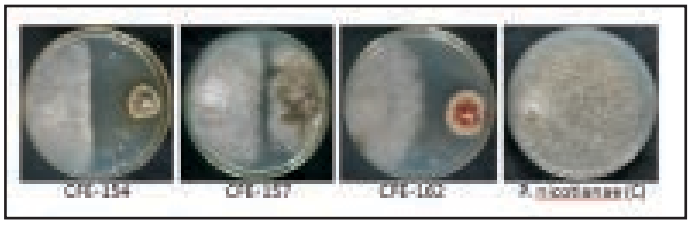


Fig. 76 : Inhibition of *Phytophthora nicotianae* by various fungal endophytes on CMA media in dual cultures at 8 days post inoculation

Mass production and efficacy of promising endophytes CFE 109 and CFE 142

Talc based formulation of two promising endophytes CFE 109 *(Chaetomium globosum)* and CFE 142 *(Aspergillus terreus)* were prepared after growing the respective cultures in potato dextrose broth (PDB). The propagule count recorded was $1.48x10^6$ cfu/ g of formulation for CFE 109 and $2.43x10^6$ cfu/ g of talc formulation was for CFE 142. Both the formulation was found effective in reducing the root rot of rough lemon seedlings in pot culture studies under glasshouse conditions.

3.3.2.5 Studies on the prevalence and distribution of plant parasitic nematodes associated with citrus in India

Diversity of plant parasitic nematodes in Nagpur mandarin in Maharashtra

An extensive survey was undertaken in Susundri, Pipla, Mohpa and Nimji in Nagpur district in the year 2020 to understand the diversity and distribution of plant parasitic nematodes in Nagpur mandarin. Composite samples were collected from different orchards in the above mentioned locations. Samples were collected from 15-30 cm depth around the feeder roots. Plant parasitic nematodes were isolated from soil by Cobb's sieving and decanting technique and modified Baermann funnel technique.

Identification of plant parasitic nematode genera

Based on the morphological characters, different plant parasitic nematode genera *viz.*, *Tylenchulus semipenetrans*, *Pratylenchus*, *Helicotylenchus* and *Hoplolaimus* were identified. Among these, *T. semipenetrans* was prominently recorded compared to other genera (Table 43). In addition, different free living nematodes such as rhabditids and mononchids were also identified (Fig. 77).

Community analysis of plant parasitic nematodes

In order to study poly specific nematode community with reference to relative frequencies, relative densities, prominence values, the population of nematodes were analyzed (Table 43).

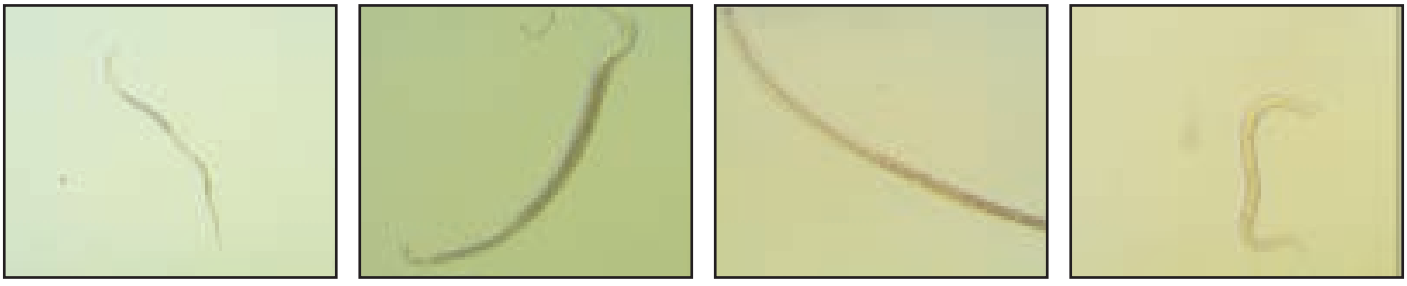
3.3.2.6 Effect of citrus root exudates on survival, penetration and development of *Tylenchulus semipenetrans* and *Meloidogyne indica*

Soil samples were collected from the rhizosphere of rough lemon blocks. The collected soil samples were processed

Table 43: Community analysis of plant parasitic nematodes (250 cc soil) infecting Nagpur mandarin in Nagpur district, Maharashtra

Parameter	*Tylenchulus semipenetrans*	*Pratylenchus* sp.	*Helicotylenchus* sp.	*Hoplolaimus* sp.
AF	100	100	75	50
RF	30.7	30.7	23.07	15.38
AD	169.6	24	1.8	0.7
RD	86.44	12.28	0.91	0.35
PV	478.94	68.04	4.37	1.37

AF- Absolute frequency; RF-Relative frequency; AD-Absolute density; RD-Relative density; PV-Prominence value



Tylenchulus semipenetrans ***Pratylenchus sp.*** **Predatory nematode** **Rhabditid**

Fig. 77 : Nematode genera identified in Nagpur mandarin

by cobb's sieving and decanting technique and modified Baermann funnel technique. The isolated second stage juveniles of *Tylenchulus semipenetrans* were inoculated on rough lemon seedlings for the maintenance of pure culture and for bioassay studies. The root exudates extracts collected from *T. semipenetrans* infested and non-infested (control) rootstocks such as rough lemon, rangpur lime, alemow and acid lime seedlings were sent for chemical profiling using GC-MS.

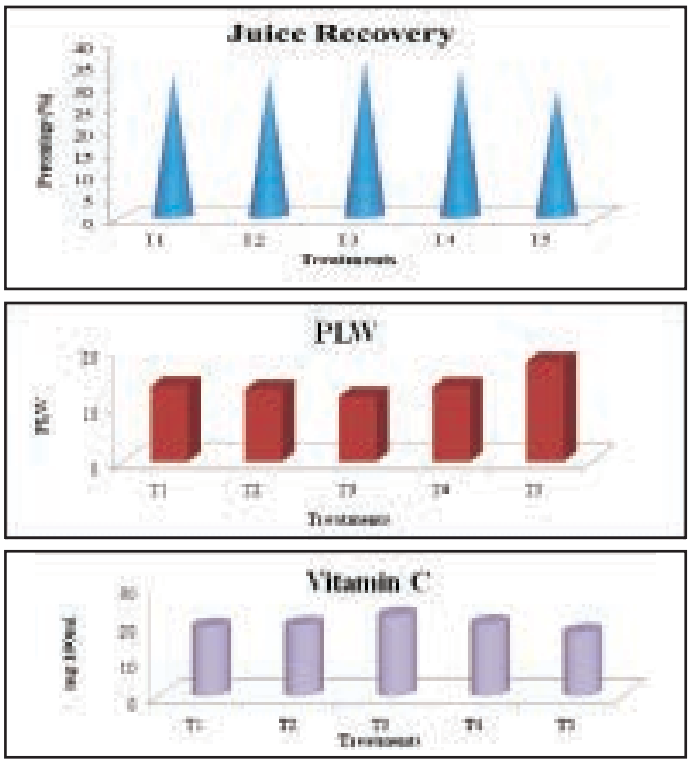
3.4 Post-harvest management and value addition

3.4.1 Studies on extending the storage life of citrus fruits

3.4.1.1 Effect of polysaccharide based edible coating and essential oil on storage ability of Nagpur mandarin fruits

Effects of different polysaccharides on storage ability of Nagpur mandarin were tested. Nagpur mandarin fruits were collected from the farmer orchard. Fruits of uniform shape and size sorted, washed and air dried and treated with polysaccharides - Maltodextrin (2%), Methyl cellulose (0.5%), Carboxymethyl cellulose (0.5%) and Hydroxypropyl cellulose (0.5%) concentration with Glycerol as plasticizer (5%) and Cinnamon oil (50 ppm) in distilled water. Among the treatments, T_1 and T_2 fruits were coated with maltodextrin and methyl cellulose together with glycerol and cinnamon oil and were wrapped in polyethylene liner (0.5%). In the treatments T_3 and T_4 fruits were treated with polysaccharides carboxymethyl cellulose and hydroxypropyl cellulose together with glycerol and cinnamon oil and were wrapped in polyethylene liner (0.5%) and T_5 was control. Further, these treated fruits were packed in CFB boxes and stored at ambient condition for 21 days. The physico-chemical response of fruits with respect to different polysaccharides was studied.

It was observed that among the polysaccharides, Carboxymethyl cellulose had maximum juice recovery (35.43%) (Fig.78), lower PLW (11.52%) (Fig. 78), retained Vitamin C content (21.70 mg/100ml) during the storage.



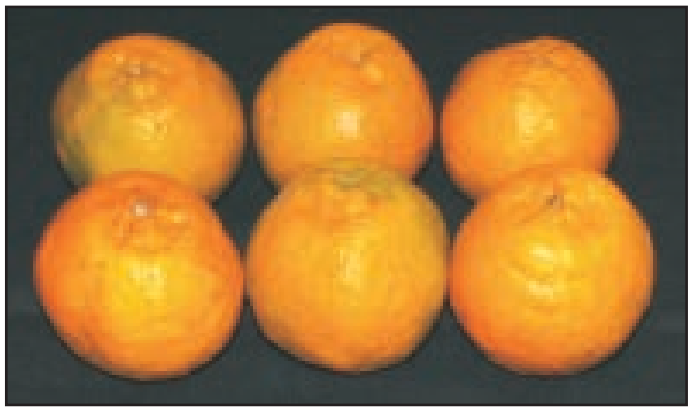
Where,
T1 : Maltodextrin (2%) + Glycerol (5%) + Cinnamon oil (50mg/lit)
T2 : Methyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit)
T3 : Carboxymethyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit)
T4 : Hydroxypropyl cellulose (0.5%) + Glycerol (5%) + Cinna mon oil (50mg/lit)
T5 : Control

Fig. 78 : Effect of polysaccharides on Juice recovery, PLW and Vitamin C of Nagpur mandarin fruits stored in ambient condition after 21 days

Polysaccharide coated Nagpur mandarin fruits

Fig. 79 : Effect of polysaccharides on of Nagpur mandarin fruits stored in ambient conditions after 21 days

Acidity and total soluble solids did not respond to the treatments. Fig. 79 and 80 depicts the treated and control of Nagpur mandarin fruits.



Uncoated Nagpur mandarin fruits

Fig. 80 : Polysaccharide coated and uncoated Nagpur mandarin fruits stored in ambient conditions

3.4.2 Value Addition

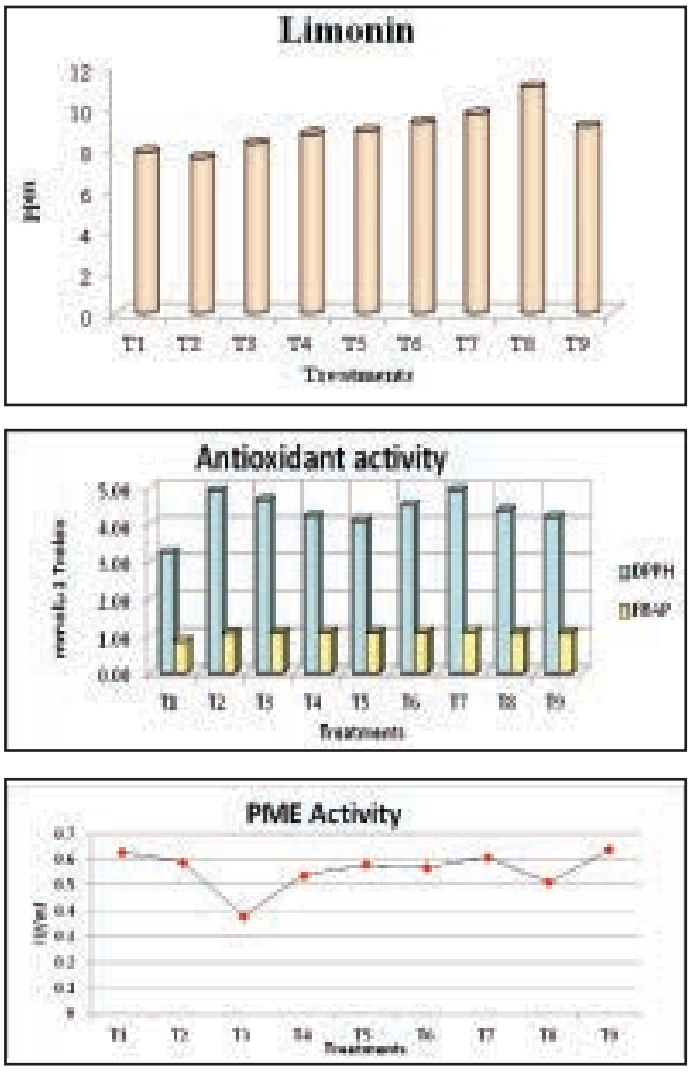
3.4.2.1 Functional food, value-added products and beverages from citrus fruits

Impact of heat pasteurization and thermo-sonication on biochemical parameters of Nagpur mandarin juice

Sonication is considered to be an emerging technology and becomes an excellent option to the thermal processing in food processing industry and valuable source in less energy input, minimal processing and reduced processing time. Thermosonication (TS) is a combined treatment of ultrasound and heat in which the product is subjected to moderate heat for microbial inactivation. Thermosonication (TS) is an emerging nonthermal processing technique used for the liquid food preservation and is employed to improve the quality and acceptability of Orange juices.

The experiment is carried out to study the effect of Thermo-Sonication at the various temperatures ranges on physico-chemical and biochemical parameters. Among them, inactivation of Pectin Methylesterase (PME), limonin content and antioxidant potential in Nagpur Mandarin juice were studied.

Nagpur mandarin juice thermo-sonicated at 55°C for 20 min viz. T_2 treatment showed better results in terms of limonin and antioxidant activity and T_3 treatment *viz*. juice thermo-sonicated at 60°C for 15 min showed better PME



Where,

T1 : Sonication at 50°C for 25 min
T2 : Sonication at 55°C for 20 min
T3 : Sonication at 60°C for 15 min
T4 : Sonication at 63°C for 10 min
T5 : Pasteurization at 65°C for 80 sec
T6 : Pasteurization at 75°C for 60 sec
T7 : Pasteurization at 85°C for 40 sec
T8 : Pasteurization at 95°C for 20 sec
T9 : Control

Fig. 81 : Limonin content, Antioxidant and PME activity of thermo-sonicated and pasteurized Nagpur mandarin juice after 7 days of storage

activity among all treatments. The physico-chemical and biochemical parameters are also get influenced with the treatment during the experimentation (Fig. 81).

Technologies developed and ready for commercialization

The four technologies developed under the project viz. Osmotically dehydrated sweet orange candy, Osmotically dehydrated Nagpur mandarin candy, Nagpur mandarin Ice-cream and Low calorie santra barfi from Nagpur mandarin and technologies were presented in ITMU and ITMC committees for commercialisation.

a. Osmotically dehydrated Sweet orange candy

Sweet orange was collected from the orchard which was taken to processing laboratory of ICAR-CCRI. Sweet orange cv. Mosambi fruits were thoroughly washed to remove dirt and pesticides residues and allowed them to dry completely. Blanched the fruit at 54°C and let them dry. Fruit was cut in slices about 3mm to 5mm thick and dipped in the sugar syrup of 70°B with continuous agitation for 2 days and then the brix was maintained at 70°B for 12 days, candy was removed from syrup and washed it. Candy was dried in tray oven at room temperature and vacuum packed (Fig. 82).

b. Osmotically dehydrated Nagpur mandarin Candy

Nagpur mandarin was collected from the orchard which was taken to processing laboratory of ICAR-CCRI. Nagpur mandarin fruits were thoroughly washed to remove dirt and pesticides residues and allowed them to dry completely. Blanched the fruit at 54°C and let them dry. Fruit was cut in slices about 3 mm to 5 mm thick and dipped in the sugar syrup of 70°B with 2 days and then the brix was maintained at 70°B for 12 days, candy was removed from syrup and washed it. Candy was dried in tray oven at room temperature and vacuum packed (Fig. 82).

c. Nagpur mandarin ice-cream

The product is prepared by incorporating the Nagpur mandarin juice. Milk was pasteurized at 90°C for 10 seconds and homogenized. Added cream (30%), skimmed milk powder (SMP) (10%), sugar (14%), Glyceryl Mono Stearate (GMS) (0.25%) and in hot milk, blended it well and kept it for aging. Aging should not be below 4°C for minimum of four hours. There should be continuous

Fig. 82 : Osmotically dehydrated Sweet orange Candy (Left) Nagpur mandarin Candy (Right)

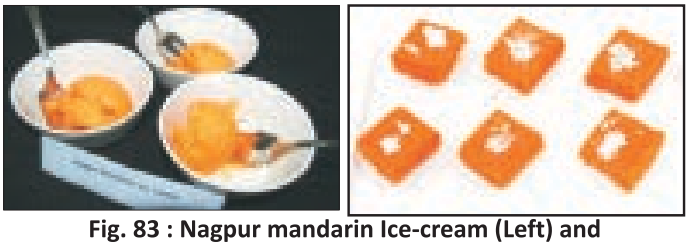


Fig. 83 : Nagpur mandarin Ice-cream (Left) and Low calorie Santra barfi (Right)

agitation. Flavor essence and natural fruit juice (2.5%) should be added during aging and then aerated at 5000 rpm. Poured it in cups, cooled and stored it (Fig. 83).

d. Low calories *santra barfi* from Nagpur mandarin

The product is prepared from the Nagpur mandarin juice. Filtered milk is pasteurized at 90°C for 10 seconds and homogenized at 3500 psi. Heated the milk till semi solid consistency is achieved. Mandarins juice vesicles (15%), khoa (31%), rawa (9.5%), sugar (9.5%) and sweetener (750 ppm) is added and the mixture was further mixed for 10 min till it get homogenous. Poured the hot mixture on tray containing the butter paper greased with ghee. Cooled at room temperature and cut it. This *barfi* should keep in cool and dry place (Fig. 83).

The above mentioned products are ready for commercialization.

3.4.3 Screening of citrus germplasm across India for bio-active compounds at maturity and during storage

3.4.3.1 Phytochemical analysis of elite citrus wild varieties collected from sites across India

The positive health benefits of juices have been ascribed in part to vitamin C (ascorbic acid), the major vitamin found in fruits and vegetables. Citrus juices are consumed majorly because of their nutritional value and special flavour. Fruit juice consumption is beneficial for the maintenance of good health and prevention of diseases. Citrus fruits are also known to contain bioactive compounds such as phenolics, flavonoids, vitamins, and essential oils which are believed to be responsible for a range of protective health benefits including anti-oxidative, anti inflammatory, anti-tumor, and anti-microbial activities. Phytochemicals are certain non-nutritive plant chemicals which have some disease preventive properties. They are not required by the human body for life sustenance, but they offer protection against pathogens. They can act as an antioxidant and protect cells against free radical damage, eg. polyphenols, carotenoids etc. Phytochemicals that possess many ecological and physiological roles are widely distributed as plant constituents. Citrus plants synthesize and accumulate in their cells a great variety of phytochemicals including low molecular phenolic (hydroxy benzoic and hydroxycinnamic acids), acetophenones, terpenoids, flavonoids, stilbenes and condensed tannins.

The present study was conducted for screening of existing elite germplasm for suitability to release as variety rich in phytochemical composition and antioxidant potential from fruits and its residue utilisation. Various elite species like Probable hybrid, *Citrus indica* and Gandharaj lemon have been screened this year. These newly identified citrus varieties were collected from West Garo Hills, Nokrek, Tura, Meghalaya and brought to the processing laboratory and were analyzed for their bio-active compounds, mainly total phenols, carotenoids, limonoids content, ascorbic acid (vitamin C) content, etc. Similarly antioxidant potentialby DPPH, ABTS and FRAP assays of citrus fruits were evaluated.

Phytochemical analysis of Probable hybrid, *Citrus indica* and Gandharaj lemon

The limonin content was 11.38 ppm in *Citrus indica* which was found highest among the assessed varieties while Probable hybrid and Gandharaj lemon contained 9.19 ppm and 9.55 ppm respectively.

In varieties analyzed, total phenol content in juice was higher in Probable hybrid (17.288 mg GAE L^{-1}) as compared to *Citrus indica* (6.071 mg GAE L^{-1}) and Gandharaj lemon (6.201 mg GAE L^{-1}) respectively which can be correlated with higher antioxidants potential. However, *Citrus indica* and Probable hybrid contain more carotenoid (0.865 mg/100ml) and (0.202 mg/100ml) content respectively in juice.

Antioxidant analysis of probable hybrid, Citrus indica and Gandharaj Lemon

The increasing interest gained by antioxidants is due to the health benefits provided mainly by natural sourced (exogenous) low molecular weight antioxidants. This consists in preventing the occurrence of oxidative-stress related diseases, caused by the attack of free radicals on key biocomponents like lipids or nucleic acids. Various methods have been developed to determine the antioxidant potential of food products. The trolox equivalent antioxidant capacity (TEAC) using ABTS (2, 2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid) as an oxidant, the ferric reducing antioxidant power (FRAP), 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) assays are some of the most commonly used.

The objective of the study is to determine antioxidant properties in Probable hybrid, *Citrus indica* and Gandharaj lemon by most appropriate method. To study antioxidant capacity in fruit extracts, we chose three methods (ABTS, FRAP, DPPH) that utilize the same single electron transfer mechanism. The three methods can be used with antioxidants in an aqueous and alcoholic media, are relatively simple to conduct, and are cost-effective. First, each of the methods provides only an estimate of the capacity that is dependent upon time of reaction, method used, and the complexity of the reaction kinetics. Second, the potential for interaction polymerization of phenolic compounds may cause antioxidant capacity to be underestimated in fruit samples and with individual compounds. Therefore, no single antioxidant assay method can provide a complete picture of the antioxidant capacity of compounds that show complex kinetics.

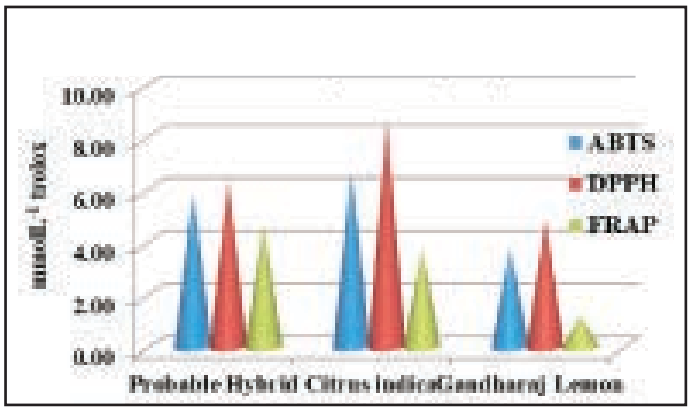


Fig. 84 : Antioxidant capacity of probable hybrid, *Citrus indica* and Gandharaj Lemon peel

In case of antioxidants potential, radical scavenging capacity is highest in peels of varieties in comparison with its respective juice as depicted in fig. 84. Probable hybrid show highest ABTS assay 4.47 $mmolL^{-1}$ trolox, DPPH assay 6.41 $mmolL^{-1}$ trolox and FRAP assays 2.86 $mmolL^{-1}$trolox in juices analyzed. Among peels of varieties, Citrus indica show highest value of ABTS 6.65 $mmolL^{-1}$trolox, DPPH assay 8.60 $mmolL^{-1}$trolox while Probable hybrid show highest value of FRAP assays 4.65 $mmolL^{-1}$ trolox (Fig. 84).

Quantification of hesperidin and other flavonoid content in the citrus fruits

Citrus fruits are the main fruit trees grown throughout the world and are well-appreciated for their refreshing juice and health benefits. Health benefits of citrus fruits are linked to the high amounts of phytochemical and bioactive compounds such as flavonoids, carotenoids, vitamins and minerals available in citrus fruits. Among these, the hesperidin bioflavonoid is the most active bioflavonoid in citrus fruits and is mainly responsible for the promising effects. The experiment was conducted with the objective that citrus fruits can act as potential source of bioflavonoids for pharmaceutical as well as neutraceutical industry.

In this experiment, hesperidin and other flavonoids viz. naringin, hesperidin, neoponcirin, diosmin, hesperitin and isonaringin were quantified in *Citrus jambhiri* and Probable hybrid. Fruits juice was injected in HPLC (Agilent

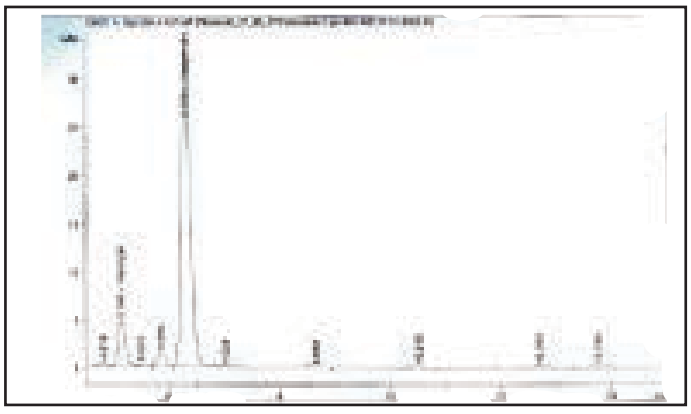


Fig. 85 : Chromatogram of Hesperidin and other flavonoids of *Citrus jambhiri*

1260 Infinity model) and quantified. The hesperidin content in fruits of Citrus jambhiri and Probable hybrid was found to be 34.75 ppm and 160.38 ppm respectively (Fig. 85). Naringin content was 159.25 ppm in Probable hybrid.

Estimation of organic acids of elite citrus wild varieties collected from sites across India

Citrus fruits, one of the important fruit crop groups, are consumed mostly as fresh or as juice because of their nutritional value and special flavor. Citrus fruits are classified as acid fruits, since their soluble solids are composed mainly of organic acids and sugars, which are used as the main index of maturity and one of the major analytical measures of flavor quality. The organic acid composition of fruits is also of interest because of its important influence on the sensory properties of fruits and fruit juices. Organic acids are a useful index of authenticity in fruit products, since they have lower susceptibility to change during processing and storage than other components of fruits. Accurate knowledge of organic acid levels (and ratios) might be useful for determining the percentage juice and also for detecting misbranding and/or adulteration in fruit juices, since each fruit has a unique pattern of organic acids. The main acids of citrus fruits are citric and malic acids with trace amounts of tartaric, benzoic, oxalic and succinic acids. Moreover, organic acids are also widely used as preservatives, antioxidants, acidulants, and drug absorption modifiers. At the same time, some organic acids may be used as indicators of ripeness, bacterial activity and adulteration. Organic acid accumulation in the vacuole of cells of citrus fruits is a developmentally regulated process, the degree and timing of which varies greatly among species and varieties and is highly susceptible to agroclimate.

The elite varieties of citrus i. e. *Citrus jambhiri* and Citron were assessed for organic acids mainly Oxalic acid, Tartaric acid, Malic acid, Lactic acid, Citric acid and Succinic acid and results indicated that Citric acid is the predominant organic acid present in assessed varieties as compared to other organic acids (Fig. 86, 87).

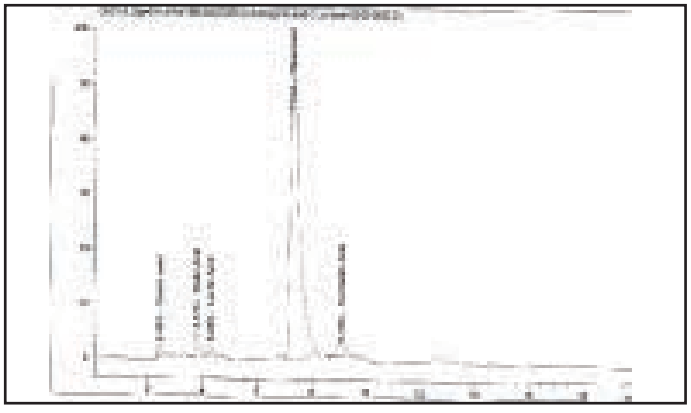


Fig. 86 : Chromatogram of organic acids of *Citrus jambhiri* juice in high performance liquid chromatography

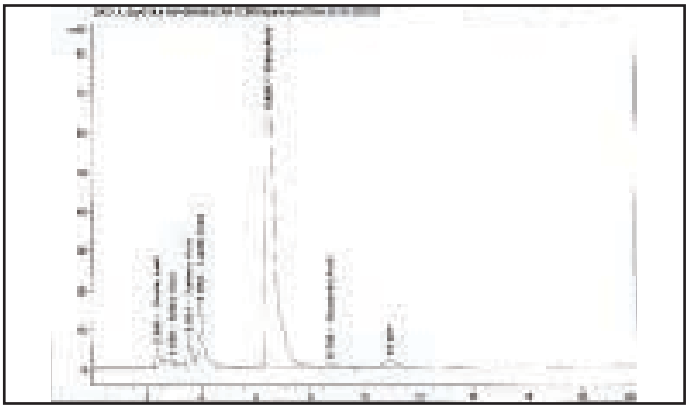


Fig. 87 : Chromatogram of organic acids of Citron juice in high performance liquid chromatography

3.5 Social Science

3.5.1 Adoption and impact assessment of ICAR-CCRI technologies in Vidarbha Region of Maharashtra

The project was taken up to study the extent of adoption and impact of various technologies of ICAR-CCRI among the citrus growers of Vidarbha Region of Maharashtra. In the first year of the project (2019), study on extent of adoption of CCRI technologies by citrus growers of Vidharbha and factors affecting adoption were studied. In the second year of the project (2020) the perception of farmers regarding adopted technologies of CCRI was measured using a Likert type perception scale developed for the purpose. Also the relative relationship between different income levels of farmers and their age of orchard and also contact with CCRI was explored using Correspondence Analysis (CA). The technique of Classification and Regression Tree (CART) was used to classify respondents into mutually exclusive and exhaustive sub-groups based on the dependent variable of income generated from citrus cultivation.

Locale of study and sampling

Nagpur, Amravati and Wardha districts which are the popular citrus belts of Maharashtra were purposively selected for the project. A sample of 100 citrus growers was selected as respondents for the study through stratified random sampling method from each of the 3 districts thus making a total sample size of 300 farmers. Citrus growers with orchards aged 6-10 years, 11-15 years and 16-25 years (6 to 25 years is productive age of citrus plants) were selected for study and analysed separately because analysis involved income variable and income generated from different age groups of citrus trees varies. Farmers growing Nagpur mandarin were selected because majority farmers of these districts cultivate mandarin. Sampled farmers may or may not have orchards of other citrus fruits like sweet orange, acid lime, pummelo, grape fruit. The analysis was done with respect to mandarin cultivation only except for the perception analysis where farmers who were cultivating CCRI varieties of mandarin (NRCC Mandarin Seedless-4), sweet orange (Cutter Valencia), pummelo (NRCC Pummelo-5), grape fruit (Flame Grape Fruit), acid lime (NRCC Acid Lime-7&8) were also selected from amongst the 300 farmers. Such farmers were 78 in number comprising of all districts.

Research design and methodology

The research design followed was *ex post facto*. Semi structured interview schedule was developed and data was collected through personal interview method, telephone calls and online Google forms circulated in Farmers' Whatsapp groups as there were movement restrictions resulting from global pandemic Covid-19 in the year 2020. Likert type scale was used to measure perception of respondents. CART was used to classify farmers into strictly mutually exclusive and exhaustive subgroups of independent variables against the dependent variable of net income generated per hectare from citrus cultivation. CA was used to show the extent of association between levels of net income (rows) and age of orchard and contact with CCRI (columns). Both CA and CART was run in R software. For CA, two packages were used viz., *FactoMineR* (Data analysis) *factoextra* and ggplot2 (data visualization)

3.5.1.1 Socio-Economic Profile

The socio-economic characteristics of respondents often play the role of determinants in defining their adoption behaviour. Hence the profiling of socioeconomic characteristics is essential for any study.

Classification of farmers on the basis of age

Majority farmers of all 3 districts- Nagpur (55%), Amravati (59%), Wardha (67%) were middle aged (30-50 years). Next in number was more than 50 years category followed by the age group of less than 30 years (Table 44).

Classification of farmers on the basis of orchard size

It is evident that in Nagpur, majority famers (52%) had mandarin orchards of size 2-4 hectares while Amravati (61%) and Wardha (62%) had dominance of farmers having orchards less than 2 hectares in area. Nagpur had 32% farmers with less than 2 hectare (Table 44). In all 3 districts,

Table 44 : Socio economic profile of respondents (N=300)

Category (%)	Age of farmer (years)			Orchard Size (hectares)			Net Income from citrus per hectare (Rs/ha)				
	<30	30 -50	>50	<2	2-4	>4	<50k	50k - 1lakh	1 lakh - 1.5lakh	1.5lakh -2lakh	>2lakh
Nagpur (n=100)	15	55	30	32	52	16	3	8	43	14	32
Amravati (n=100)	18	59	23	61	23	16	0	18	44	20	18
Wardha (n=100)	13	67	20	62	23	15	2	17	46	12	25

farmers with orchard size more than 4 hectares was less in number.

Classification of farmers on the basis of net income per hectare

In all 3 districts, majority farmers (Nagpur-43%, Amravati-44%, Wardha-46%) had average annual income between Rs.1 lakh to Rs.1.5 lakh per hectare obtained from citrus cultivation (Table 44). Nagpur with 32% farmers and Wardha with 25% farmers having average annual income going beyond Rs. 2 lakh, were next in majority in those districts, while in Amravati (20%) average annual income per hectare ranging from 1.5 lakh to 2 lakh was next major category.

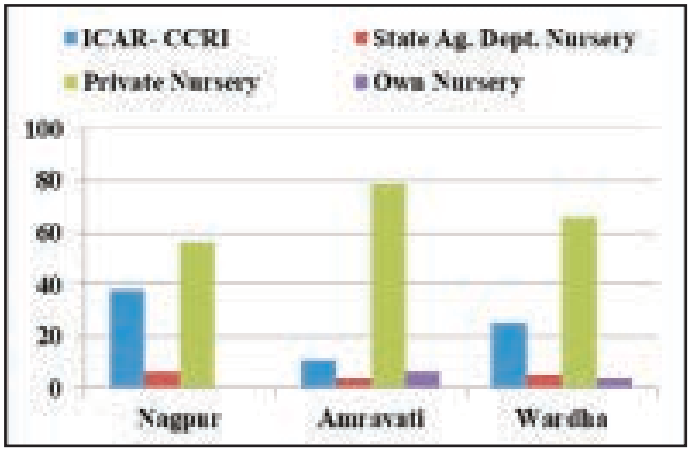


Fig. 88 : District wise source of planting materials for farmers of Vidarbha region of Maharashtra

Source of planting materials

In all 3 districts (Fig. 88), majority farmers purchased the planting materials from private nurseries due to various reasons like affordability, availability, peer group effect and nearness to their residence etc. Amongst them, only Nagpur (38%) had highest number of farmers who purchased planting material from CCRI, followed by Wardha (25%). Amravati had least number of (11%) farmers in this category. Those farmers who had purchased planting materials from CCRI, cited trustworthiness, brand value, longevity of orchards, less disease attacks as reasons behind their decision.

3.5.1.2 Perception of CCRI varieties amongst farmers

Farmers' perception of a technology is crucial for the adoption of the technology. A positive or favourable perception can give rise to a positive attitude leading to adoption. Hence farmers cultivating the varieties of CCRI of mandarin (Nagpur mandarin Seedless-4), sweet orange (Cutter Valencia), pummelo (NRCC Pummelo-5), grape fruit (Flame grapefruit), acid lime (NRCC Acid Lime-7&8) were selected from amongst the total sample of 300 farmers to measure their perception of CCRI varieties. Such farmers were 78 in number comprising of all districts.

For measuring perception a 4 point Likert type scale was developed. Items analysis was done. The data collected were subjected to descriptive statistical analysis such as

frequency counts, percentage and mean derived from four-point Likert's type scale as the following: 4 =strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree. The Likert's scale was done by asking some positive questions like CCRI technologies are affordable? To which the responses were rated according to their perceptions and the cut-off mean score was determined by adding the ratings up (4 + 3 + 2 + 1 = 10) and dividing the sum by 4 to give 2.5 as the cut-off mean score. For each statement, the total score was divided by the number of respondents, for instance a statement like "CCRI technologies are affordable" may have responses of strongly agree (*f*= 165); agree (*f* = 56); disagree (*f* = 48) and strongly disagree (*f* = 31). It will now be worked as 165 x 4 = 660, 56 x 3 = 168, 48 x 2 = 96 and 31 x 1 = 31. Then 660 + 168 + 96 + 31 = 955. The sum was divided by the total *f* thus, 955 / 300 = 3.18. In this case, 3.18 is the mean score which is greater than the cut-off mean score of 2.50. The ranking was done according to the mean values, with the one with the highest mean ranking '1'.

It is evident that farmers perceive CCRI varieties to be relatively advantageous (Mean=3.6) in terms of better yield, high quality and less recurring cost involved in controlling disease pest attack because these varieties are lesser prone to diseases. Similar mean perception score was received by the statement on affordability which states that CCRI varieties though initially costly, are scientific and of high quality (Mean=3.6). The next highest perception score (Mean=3.1) was obtained by the predictable and trustworthy nature of CCRI developed varieties. 38.46% farmers strongly agree that CCRI has brand value hence its varieties can be predicted to be of high quality and it for adoption. Compatibility, trialability, complexity of CCRI varieties ranked 4th, 5th and 6th in perception score. The farmers perceived that planting materials for CCRI varieties were not easily available in market or difficult to purchase from CCRI due to scarcity because of which 67.95% farmers strongly disagreed with ease of availability criteria and ranked it least (Mean=1.5) which was much lesser than mean cut-off score of 2.5. Next least favoured perception score was cost-effectiveness of cultivation and management (Mean=1.9). The perception regarding affordability (Mean=2.1) and observability of visible results (Mean=2.1) wre next in number in lesser perception scores and ranked below cut-off. It can be concluded that there exists a problem of availability of CCRI planting materials to farmers who highly regard the institute's excellence in producing disease free materials. They also want to pay lesser amount for it as they consider materials to be slightly high priced. Yield wise visible results may appear in long run due to lesser disease incidence but farmers who have lack of scientific knowledge perceive short term bumper yield as a measure of better variety. Disease free character is not a visible or tangible quality hence it is difficult for farmers to perceive and report it.

3.5.1.3. Association between average annual income, orchard age and contact with CCRI

As income obtained from citrus cultivation varies with age of the orchard, an effort was made to explore this association along with contact with CCRI scientists for professional guidance. The age of orchard was grouped into 6-10 years (Yrsoforc1), 11-15 years (Yrsoforc2) and 16-25 years (Yrsoforc3) considering the average productive age of citrus plants.

Contingency table was prepared (Table 45) for conducting the correspondence analysis (CA) of 3 districts. The CA map (Fig. 89) can be interpreted that chi-square of independence was found to be significant and first 2 eigenvalues account for 91.6% variance thus suggesting the 2D CA map to be satisfactory. Farmers with income more than 2 lakhs were more associated with yrsoforc2 (11-15 years of orchard age). It is very interesting to find that in overall sample comprising of 3 districts, farmers with orchards of less than 10 years (6-10 years) who had contacted CCRI, also earned an income of 1.5 lakhs to 2 lakhs which is a commendable achievement of CCRI scientists who reach out to farmers and make effort for better productivity of their orchards.

Hence overall it was established that the most productive age of citrus plants on an average was 11-15 years and

higher income was associated with contact with CCRI for guidance on citrus cultivation techniques.

3.5.1.4. Classification of farmers using CART

CART analysis is a tree-building technique which is different from traditional data analysis methods. In CART, the observations are successively separated into two subsets based on associated variables significantly related to the response variable. CART can be applied either as a classification tree or as a regressive tree depending on whether the response variable is categorical or continuous. In our study, response variable (Average annual income per hectare) is continuous, so CART can be applied as regression tree.

These rules are produced by repeatedly splitting the predictor variables, starting with the variable (For e.g. Contact CCRI) that is most effective in classifying the sample into subgroups against the common response variable (Net Income). The process continues until some predetermined stopping criteria are met. The tree grows from the top (root), at each node the algorithm decides the best split cutoff that results to the greatest purity (or homogeneity) in each subpartition (Fig. 90).

CART analysis was done for Nagpur, Amravati, Wardha (n=300) and in all 3 districts, highest average income group was having income Rs. 218000 (3%) who use both CCRI mobile app and CCRI website (Appweb<3) for professional guidance on citrus cultivation techniques (Fig. 90). They had contacted CCRI also and had orchards of age 6-10 years. The most effective predictor variable was age of orchard in classifying the total sample.

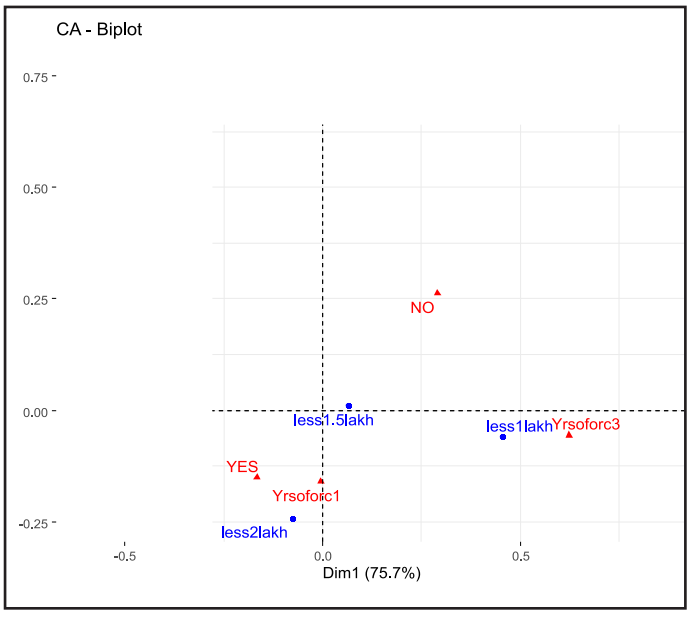


Fig. 89 : Correspondence analysis (CA) Map of 3 districts of Vidarbha region of Maharashtra

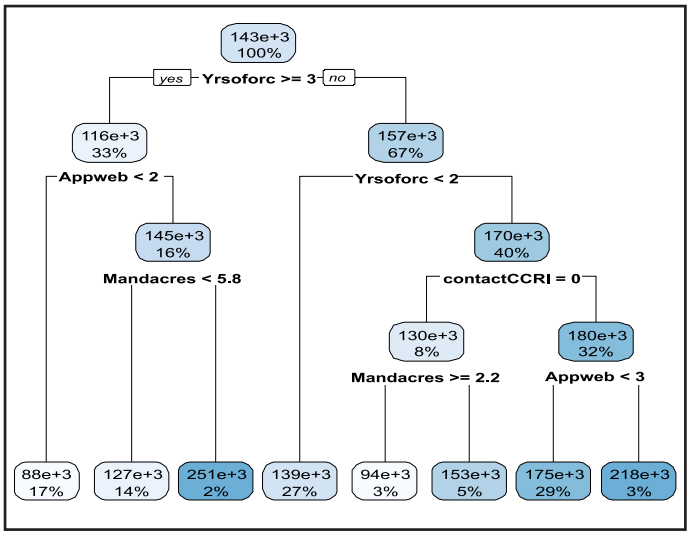


Fig. 90: Classification and Regression tree (CART) of 3 districts (n= 300) of vidarbha region of Maharashtra

Table 45: Contingency table of 3 districts (n=300)

Annual Income (coding)	Contact with CCRI		Age of orchard (coding)		
	YES	6-10 yrs (Yrsoforc1)	6-10 yrs (Yrsoforc1)	6-10 yrs (Yrsoforc1)	(Yrsoforc 3)
Less than 50k (less50)	0	8	0	2	6
50k to 1lakh (less1lakh)	34	25	13	9	37
1lakh to 1.5lakh (less1.5lakh)	70	52	45	40	37
1.5lakh to less2lakh (less2lakh)	39	9	15	17	16
More than 2lakh (more2lakh)	48	15	13	49	1

4 Technology Assessed and Transferred

4.1 Technologies Developed

New Production Technology Developed : Package of practices for high density planting and ultra high density planting developed for acid lime and Nagpur mandarin to increase yields by 2 to 3 times compared to conventional method.

Management of fruit drop due to fruit sucking moth :

- ✓ Foliar application of Horticultural Mineral Oil @ 2% or Neem oil @ 1% alternatively coinciding with colour breaking stage till harvest at 10 days interval would significantly reduce the fruit drop (up to 48.0-70.0%) due to fruit sucking moths during Ambia season in Nagpur mandarin.
- ✓ Integrated module with hanging of sachets with acephate/phorate (10g) @ 2 per tree and foliar spray with Horticultural Mineral Oil @ 2%, Neem oil @ 1% and pongamia soap @ 2% at 10 days interval during colour breaking stage(mid September/early October to second fortnight of November during ambia season fruiting would effectively reduce fruit drop up to 60-70%. Need based replacement of sachets is required at 10-15 days interval.

4.2 Technology Transfer

4.2.1 Demonstration on raised–bed planting system

A demonstration started by planting mandarin and sweet orange at the farm of progressive farmer at Masod, taluka-Chandur bazar, dist. Amravati. Planting material given in July, 2020 so that technology of planting on raised-bed with drip and fertigation is further propagated.

4.3 Services offered

4.3.1 M/S. Sahyadri Agro Farms

This company wanted to import Mandarin variety LB 8 – 9 (Sugar Belle) from Spain. Permission / approval was given keeping in view post-entry quarantine facilities available with them. M/S. Sahyadri Agro farm, a Farmers Producer Co. (Shri. Vilas Vishnu Shinde) of Nasik, Maharashtra to import "Sugar Belle" LB 8-9, a mandarin variety, claimed to be tolerant to greening, through Directorate of Plant protection, quarantine and storage, (Quarantine sub-station at Mumbai), as per plant quarantine order 2003. This company also imported other citrus varieties (budwood) from Spain like Fino, Eureka and Verna lemons, Oronules, Nova, Murcott, Owari, Iwasaki mandarins and Navelina, Lane Late, Valencia and Midknight Valencia sweet oranges during December 2020. Plants are maintained in post-entry quarantine facility (closed structure) at Post Adgaon, dist. Nasik.

4.3.2 Helpline, SMS Services and Advisories

- Books and publications on Citrus Orchard Management shared with KVKs of citrus belts of Maharashtra in April, 2020
- Farm advisories in English, Hindi and Marathi published in newspapers and also for All India Radio (Advisory for Nagpur Mandarin Cultivation) during the period of national lockdown.
- Advisory on hailstorm management published in Hitavada on 21st May, 2020. Bulk SMS through mobile sent to 1000 farmers on hailstorm management on 22nd May, 2020
- Advisory on lemon butterfly management published in Marathi newspapers. Bulk SMS through mobile sent to 1000 farmers on 24th July, 2020
- Advisory on Snails and Slug management communicated to SDO of Morshi taluka and also for press release on 24th July, 2020.
- Bulk SMS through mobile sent to 500 farmers on fruit fly management on 4th August, 2020
- Advisory issued on 18th August, 2020 in English and Marathi language on Management of Citrus Leaf Miner and Bark Eating Caterpillar in Citrus orchards.
- Advisory on fruit sucking moth management in sweet orange sent as Bulk SMS to farmers and also shared in whatsapp groups of citrus growers on 27th August, 2020.
- Advisory issued on 18th September, 2020 in Marathi language on Management of Fruit Flies, Mites and Fruit Sucking Moth in Citrus orchards.

- Advisory on *Phytophthora* brown rot disease in Mosambi Sweet orange and Nagpur Santra/Mandarin with its control measures issued for citrus growers of Vidarbha region of Maharashtra through various social media/ website, newspaper on 29th August, 2020.

4.3.3 Survey / Field day / Visit to Citrus Growers' orchard

- Dr. G.T. Behere, Pr. Scientist (Ento.), Dr. Anjitha George, Scientist 'SS' (Ento.) and Sh. V.N. Dhengre, Sr. Tech. Officer visited the orchard of Mr Gajanan Futane at village Chicholi Gawali, Taluka Morshi District Amravati to examine the insect pests problem on 22nd February, 2020 and 6th March, 2020.
- A team of ICAR-CCRI scientists comprising of Dr. A. D. Huchche, Principal Scientist (Horticulture), Dr. A. K. Das, Principal Scientist (Plant Pathology) and Dr G. T. Behere, Principal Scientist (Agril Entomology) alongwith Sh. Vijay Nimje, Subdivisional Agriculture Officer (SDAO) visited Katol & adjoining areas of Nagpur district in response to the report/ problem of severe fruit drop by the Sweet orange growers of those areas on 4th September, 2020 to assess the issues related to fruit drops in Sweet orange orchards. All the affected Sweet orange orchards were found severely infected with *Phytophthora*-induced brown rot disease. Meeting was organized at Gram panchayat which was attended by around 250-300 farmers. Besides farmers, the meeting was also attended by members of Zilla Parishad, Shri Salil Deshmukh and Shri Shekar Zade, Shri Vijay Nimje (SADO, Katol), Shri Suresh Kannake (TAO, Katol). The advisories and alerts issued by ICAR-CCRI, Nagpur on brown rot disease was shared with the farmers.
- A tour was undertaken by Dr. Ashok Kumar (ACTO), Sh.V.N. Denghre (ACTO) and Sh. Anup Tatewar (YP-II) to Jarud, Warud, Bargoan and Gadegoan area of Amravati district to assess fruit drop problems of Sweet orange on 5th September 2020. Sh. Ramesh Jichkar, Sh. Santosh Satdive, Mandal Krisihi Adhikari Warud and Aagriculture Officers of State Agriculture Department, Warud and 7-8 farmers from nearby area were also present during the visit and the staff of CCRI imparted Pathological and Entomologist recommendations.

Visit of CCRI Scientists to citrus orchards at Warud (Amravati) on 5th Sepetmber, 2020

- Dr. A. D. Huchche, Pr. Scientist (Hort.) and Dr. G. T. Behere, Pr. Scientist (Ento.) and Miss. Aparna Sontakke (RA) visited farmers fields to assess the issues related to fruit drop in sweet orange orchards at different villages of Narkhed Tehsil of Nagpur district on 5th September, 2020.

4.3.4 Participation in Krishi Exhibitions

ICAR-CCRI participated in Agricultural/Krishi exhibitions and disseminated technologies through the sale of publications, display of exhibits and guidance to farmers during the following events :

- Exhibition and Fruit Show during National Citrus Meet held at Regional Research Centre for Citrus, Biswanath Chariali, Assam from 10th to 12th January, 2020.
- 9th Science Expo - 2020 at Raman Science Centre & Planetarium, Nagpur from 16-20th January, 2020.
- National Horticultural Fair-2020 under the theme 'Horticulture Making Farming An Enterprise' at ICAR-IIHR, Bengaluru during 5-8th February, 2020.

Visit of dignitaries to Fruit show at National Citrus Meet-2020 at RRCC, Biswanath Chariali, Assam

CCRI Stall at 9th Science Expo-2020 at Raman Science Centre, Nagpur

CCRI Stall at IIHR, Bengaluru

4.3.5 Farmers visit to CCRI

States	District	No. of Famers	Date
Odisha	Nabarangpur	30	27-28 January, 2020
Madhya Pradesh	Seoni	108	5th February, 2020
	Mandala	15	29th February, 2020
	Kareli, Dist. Narsinhapur	40	28th February, 2020
	Badwani	30	29th February, 2020
	Baghpat	4	3rd March, 2020
	Balaghat	11	3rd March, 2020
	Turkikhapa, Dist. Chhindwara	4	5th March, 2020
	Kasarawad, Khargaon	7	17th November, 2020
Maharashtra	CARD, Nagpur (John Deere CSR Samrudhi Sponsored)	60	17th and 22nd February, 2020
	Chandrapur	3	20th February, 2020
	KVK, Baramati, Pune	3 Experts & 2 farmers	6th& 7th December, 2020
	Metaumari, Nildoh, Mangrul, Girola, Khairi Pannase in Hingna Block (John Deere CSR Samrudhi Sponsored)	60 farmers 60 farmers	18th December, 2020 19th December, 2020
	Krishi Vigyan Kendra, Baramati, Pune	27 farmers with 3 officers	18th December, 2020
Chattisgarh	Sukama, Chattisgarh	53	24th February, 2020
	Total	**520**	

5 Training and Capacity Building

5.1 Capacity Building of Institute Staff

The Staff of the Institute participated in various training programmes during 2020 for capacity building and details of which are as follows :

Name of the Personnel	Sponsoring agency/Project	Title of the Course	Place and Duration
Scientific			
Dr. A. Thirugnanavel, Scientist 'SS' (Hort.)	IARI, New Delhi	Non-conventional Approaches For Genetic Improvement of Perennial Horticultural Crops	IARI, New Delhi 17th January, 2020 to 6th February, 2020 (21 days)
Dr. J.P. Tej Kumar, Scientist (Biotechnology)	ICAR-IASRI, New Delhi	Management Information system (TMIS) for HRD Nodal Officers of ICAR (Virtual)	IASRI, New Delhi 8th May, 2020 (1 day)
Dr. G.T. Behere, Pr. Scientist (Ento.), Dr. J.P. Tej Kumar, Scientist (Biotech.), Ms. Sangeeta Bhattacharyya, Scientist (Extn.) and Sh. D.D. Banerjee, ACTO	ICAR-IASRI, New Delhi	Implementation of e-Office Modules in ICAR Institutes (Virtual)	IASRI, New Delhi 22-25th June, 2020 (4 days)
Dr. Dinesh Kumar, Pr. Scientist (Hort.)	ABI, Project	Orientation workshop and training programme for ABI units (Virtual)	ICAR-NAARM, Hyderabad 17-19th August, 2020 (3 days)
Ms. Sangeeta Bhattacharyya, Scientist (Extn.)	AAU Anand	Research Methodology in Social Sciences (Virtual)	NAHEP -CAAST and Centre for Agricultural Market Intelligence, AAU, Anand 1-11th September, 2020 (11 days)
Dr. Dinesh Kumar, Pr. Scientist (Hort.)	NAIF, Project	Intellectual Property Rights in Agricultural Research & Education in India (Virtual)	NAHEP & IP&TM Unit, ICAR, New Delhi 12-28th September, 2020 (17 days)
Dr. A.K. Das, Pr. Scientist (Plant Patho.)	ICAR-NAARM, Hyderabad	MDP on PME in Agricultural Research Project (Virtual)	ICAR-NAARM, Hyderabad 12-17th October, 2020 (6 days)

Name of the Personnel	Sponsoring agency/Project	Title of the Course	Place and Duration
Dr. G.T. Behere, Pr. Scientist (Ento.)	ICAR-NAARM, Hyderabad	Management Development Programme on Leadership Development (Virtual)	ICAR-NAARM 8-19th December, 2020 (12 days)
Technical			
Sh. D.D. Banerjee, ACTO	ICAR-NBSS&LUP, Nagpur	Training/Workshop on ICAR Krishi Geoportal – Challenges and Way Forward	ICAR-NBSSLUP, Nagpur 9-10th January, 2020 (2 days)
Sh. V. Bhaladhare, Tech. Officer	ICAR-NAARM, Hyderabad	Capacity Building Programme for CJSC Member of ICAR	ICAR-NAARM, Hyderabad 27-31 January, 2020 (5 days)
Administration			
Sh. Sunil Ambekar, Assistant and I/c AAO and Sh. B.T. Dhongade, PS cum Cashier	ICAR-CCRI, Nagpur	FMS Training cum workshop	ICAR-CIRCOT, Mumbai 4th January, 2020 (1 days)

5.2 HRD Fund Allocation and Utilization

During 2020, Rs. 15.55 lakhs were allocated and Rs. 15.53 lakhs were spent with 100 % utilization.

5.3 Visit of Students to the Institute

- Students and Staff of different school/colleges visited the institute as a study tour. They were given information about various activities and research programmes of the institute in field and nurseries.

Sr. No.	Name of School/College and place	No. of Students and Staff	Date
1.	Sh. Lemdeo Patil Mahavidyala, Mandhal, Tal. Kuhi, Dist. Nagpur	40	18th January, 2020
2.	College of Agriculture, Golegaon, Parbhani	60	4th February, 2020
3	Shri Shivaji Agriculture College, Amravati	60	12th February, 2020
4.	School of Agricultural Sciences, G.H Raisoni University, Chhindwara	142	13th February, 2020
5.	Mahatma Gandhi English Medium High School, Nagpur	141	27th February, 2020
6.	Cathedral Vidya School, Lonavala, Pune	42	4th March, 2020
7.	Pt. S.K.S College of Agriculture and Research Station, Rajnandgaon, Chattisgarh	58	5th March, 2020
8.	Shri Sant Shankar Maharaj College of Agriculture, Pimpalkhuta, Dhamangaon, Amravati	54	12th March, 2020
9.	RAWE students from Shivaji Agri. College, Amravati	2	18th August, 2020
10.	Shri Sant Shankar Maharaj Krishi Mahavidyalaya, Pimpalkhuda, Tah. Dhamangaon, Distt. Amravati	4	24th August, 2020
	Total	**603**	

Students of School of Agricultural Sciences, G.H. Raisoni University, Chhindwara (M.P.) visited CCRI

Group photo of CCRI staff and Trainee participants (20-21 Feb., 2020)

5.4 Visit of Trainees /Officers

- Officials and trainees undergoing training at different organizations visited ICAR-CCRI, Nagpur during 2020. They were appraised of activities and research programmes of the institute.

5.5 Training Programmes Organized by the Institute

On-Campus

- Training cum Exposure visit of 30 progressive farmers of Odisha during 20-21st February, 2020 by Development Foundation (Gurgaon based NGO). The training included management of citrus orchards, water and nutrient management, insect-pest and disease management, nursery and value addition besides visit to nursery, field and market.

  Dr. D. K. Ghosh, Pr. Scientist and Ms. Sangeeta Bhattacharyya, Scientist were the training coordinators.

- **Training programme on nursery management :** ICAR-CCRI, Nagpur in collaboration with Directorate of Horticulture, Govt. of Maharashtra, Pune and Divisional Joint Director of Agriculture, Nagpur organized training programme on Nursery for heads and their Controlling officer of Agric. Deptt., Govt. of Maharashtra on 26th February, 2020. Total 90 officers of two divisions (Amravati and Nagpur) were present. Training was inaugurated by Dr. M. S. Ladaniya, Director in presence Smt. Pradnya Golghate, Divisional SAO, Nagpur and Mr. Milind Shende, District SAO, Nagpur. Dr. M. S. Ladaniya stated that citrus area and production is increasing but modern citrus nursery techniques are not being followed by Agriculture department/fruit plant nurseries. There is urgent need to revise nursery act in Maharashtra which is 35 years old and there are

Dr. M. S. Ladaniya, Director addressing the trainees 26 February, 2020

Sr. No.	Organization	Number of Officials / Trainees	Date
1.	61st batch of "Diploma in Agricultural Marketing" at Directorate of Marketing and Inspection, Civil Lines, Nagpur	14	16th January, 2020
2.	Ramkrishna Bajaj College of Agriculture, Pipri, Wardha	40	22nd January, 2020

many advancements since 1976. Dr. I. P. Singh, Pr. Scientist was training Coordinator.

- Training on "Citrus Nursery Management, Production and Post-harvest Technology" under Skill Development programme (200 hrs. training) during 3-30th March, 2020 in which 12 citrus growers participated. Dr. J. P. Tej Kumar, Scientist was Coordinator and Ms. Sangeeta Bhattacharyya, Scientist was Associate Co-coordinator.

Practical training under skill development

- Agrovision Foundation, Nagpur and ICAR-CCRI, Nagpur organized Orange cultivation Webinar for farmers on 25th June, 2020. Dr. M. S. Ladaniya, Director, Dr. A. K. Srivastava, Pr. Scientist, Dr. A. D. Huchche, Pr. Scientist, Dr. A. K. Das, Pr. Scientist, Dr. Dinesh Kumar, Pr. Scientist, Dr. A. A. Murkute, Pr. Scientist and Dr. Anjitha George, Scientist 'SS' delivered the lectures.
- ICAR-CCRI organised training on e-office implementation for scientists, technical and administrative staff on 2, 4 and 6th July, 2020.
- National Webinar on "Management of Ambia & Mrig crops of Nagpur mandarin" for the citrus growers of Maharashtra, Madhya Pradesh and Rajasthan through webex was organized on 31st August, 2020 which was attended by 100 farmers. The speakers were Dr. M. S. Ladaniya, Director, Dr. A. K. Srivastava, Pr. Scientist, Dr. A. D. Huchche, Pr. Scientist, Dr. A. K. Das, Pr. Scientist and Dr. G.T. Behere, Pr. Scientist. Dr. Prashant Tej Kumar, Scientist coordinated and compared the programme while Ms. Sangeeta Bhattacharyya, Scientist proposed vote of thanks.
- A webinar on "Citrus Production Technology" was organized for farmers on Kisan App during 12-14th October, 2020 in which CCRI scientists delivered the lectures and answered the queries of the farmers. About 200 farmers from more than 10 major State of India were benefitted through the webinar.

Off-Campus

- Dr. A. D. Huchche, Pr. Scientist, Dr. A. K. Das, Pr. Scientist and Dr. G. T. Behere, Pr. Scientist provided training on Horticultural aspects and Integrated management of insect-pests and diseases during Farmers Melava organized jointly by SDAO, Nagpur and CCRI Nagpur under HORTSAP project at Village-Raanmangalee Taluka-Bhivapaur District-Nagpur on 28th February, 2020.

Training under Tribal Sub-Plan (TSP)

- Under TSP, 3000 acid lime seedlings were distributed among tribal farmers of KVK, Nandurbar; KVK Dhar, KVK Gadchiroli, KVK-IGKV, Raipur and all farmers were sensitized on production of disease- free planting material.

Training under SC Sub-Plan (SCSP)

- Training programme on "Production Technology on citrus" during 2-7th March, 2020 at ICAR-CCRI, Nagpur in which 26 citrus growers were benefited. In the technical sessions the scientists guided the farmers. Dr. R.K. Sonkar, Pr. Scientist was Coordinator and Dr. Kiran Kumar Kommu, Scientist was Co-Coordinator.
- Training on "Production Technology of Citrus" on 11-12th November, 2020 through Webex platform and You Tube Livestream. Scientists from CCRI Dr. M. S. Ladaniya, Director, Dr. A. K. Srivastava, Pr. Scientist, Dr. N. Vijayakumari, Pr. Scientist, Dr. Dinesh Kumar

Pr. Scientist, Dr. A. D. Huchche, Pr. Scientist, Dr. R. K. Sonkar, Pr. Scientist, Dr. A. K. Das, Pr. Scientist, Dr. A. A. Murkute, Pr. Scientist, Dr. G. T. Behere, Pr. Scientist, Dr. Kiran Kumar Kommu, Scientist and Ms. Sangeeta Bhattacharyya, Scientist and Dr. D. M. Panchbhai, Associate Dean from College of Agriculture, Nagpur delivered the lectures and answered the queries of the farmers which was attended by 82 (61 male and 21 female) farmers.

Group photo of CCRI staff and trainee participants (2-7 March, 2020)

6 Honours, Awards and Recognition

6.1 Awards

- Dr. A. K. Srivastava, Pr. Scientist (Soil. Sci.)
  - ✓ Honorary Fellow of Society for Biotic and Environmental Research, Tripura, for outstanding contribution in the field of soil fertility and nutrient management during 18th May, 2020.
  - ✓ "Outstanding Scientist Award" in 9th International Scientist Awards on Engineering, Science and Medicine, organised by VDGOOD Association at Trichy, during 12-13th September , 2020.
  - ✓ Honorary Fellow of SHRD-2018 for significant contribution in Horticultural Research and Development presented during Indian Horticulture Summit-2020, 14-16th February, 2020 at Mahatma Gandhi Chitrakoot Gramodya Vishwavidyalaya, Chitrakoot, Madhya Pardesh.
  - ✓ First Poster prize in Session-III Climate Change and Horticulture, paper entitled "Rhizosphere crosstalk transcends qualitative response of acid lime" authored by Debashish Hota, Vijay Kumar, I. P. Singh, A. K. Srivastava and Shraddha Dahat and 3rd Poster Prize for "Studies on rhizosphere hybridization and nutrient dynamics in sweet orange (Citrus sinensis)" authored by A.S. Cheke, V. D. Patil and A. K. Srivastava at Indian Horticulture Summit-2020 during 14-16th February 2020 at Mahatma Gandhi Chitrakoot Gramodya Vishwavidyalaya, Chitrkoot, Madhya Pardesh.
- Dr. G. T. Behere, Pr. Scientist (Ento.) and Dr. Anjitha George, Scientist 'SS' (Ento.) received Scientist Award - 2020 and Young Scientists Award - 2020 respectively by Dr. B. Vasantharaj David Foundation, Chennai on 5th December, 2020.
- Dr. Anjitha George, Scientist 'SS' (Ento.) Young Scientist Award by Society for Biotic and Environmental Research, Tripura on 15th October, 2020

Dr. A.K. Srivastava, Pr. Scientist (Soil Science) receiving award

- Dr. Kiran Kommu, Scientist (Nematology) received International Best Scientist award in Crop Protection (Agriculture) by RULA on 26th January, 2020 at Trichy, Tamil Nadu.

Dr. Kiran Kumar Kommu, Scientist (Nematology) receiving award

- Dr. A. Thirugnanavel, Scientist 'SS' (Hort.) received Best Poster Award for the poster entitled "DUS characterization of farmer's variety Kamal Vikas A1" during International Conference on Banana-2020 held at ICAR National Research Centre for Banana, Trichy, Tamil Nadu during 22-25th February, 2020.
- Ms. Sangeeta Bhattachharyya, Scientist (Agri. Extn.)
  - ✓ Second Best Oral Presentation award for research paper 'Constraints faced by citrus growers of central India amidst the nationwide lockdown due to COVID-19 (Bhattachharyya, S. and Sonkar, R. K.) at National

WEBCON-2020 on Agricultural Production andSupport system managing COVID-19 pandemic : Experience sharing and Strategies on 6-8th May, 2020 organized by Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.

- ✓ Hindi Article awarded first prize in Hindi Saptaha at ICAR-CCRI, Nagpur from 14th-21st September, 2020.
- ✓ Second Best Oral Presentation Award : "Online Assessment Tools for E-Teaching and Learning : Making ICT more Handy" (Bardhan, T., Dey, A., Bhattacharyya, S., Mohanty, S. Bhardwaj, N.). In Global Conference on "Emerging Agricultural Research to Endure the Predicament of COVID - 19 Pandemic", 12-13th December, 2020 at Triveni Devi Bhalotia College, Kazi Nazrul University, West Bengal.
- ✓ Best Article Award : "Gandhiji and his life : Gandhian Principles in Indian Agriculture." on the occasion of Gandhi Jayanti celebrations at ICAR-CCRI, Nagpur from 01st to 02nd October, 2020.
- ✓ Awarded Certificate of Excellence in reviewing in recognition of an outstanding contribution to the quality of the Journal- 'Journal of Social Sciences', 'Journal of Public Affairs', 'Journal of Education, Society and Behavioural Science', 'Asian Journal of Research in Animal and Veterinary Sciences', 'Asian Journal of Agricultural and Horticultural Research' in year 2020.

- National Citrus Meet at Biswanath College of Agriculture, Biswanath Chariali, Assam, 10-12th January, 2020.
  - ✓ Best Poster Award "Awareness and Adoption of ICAR-CCRI Technologies amongst Citrus Growers of Nagpur and Amravati districts of Maharashtra" author by Bhattacharyya, S., Sonkar, R. K., Pakhmode, P. and Thakre, P.
  - ✓ Best Poster Award "Diversity and Biocontrol potential of fungal endophytes against the citrus root rot pathogens" *Phytophthora nicotianae* authored by P. Pali, A. K. Das, Ashok Kumar and S. Chichghare.

6.2 Honours and Recognition

- Dr. A. K. Srivastava, Pr. Scientist (Soil Science) :
  - ✓ Panelist for session III A (Nutrition) and III B (Water Management) during the 7th Group Discussion meeting of ICAR-AICRP on Fruits held during 16-19 January, 2020 at PAU, Ludhiana.
  - ✓ Convener, of plenary lectures and Co-Chairman of technical session VIII: Climate change and Horticulture in Indian Horticulture Summit-2020 organized by Society for Horticultural Research and Development, Ghaziabad and ICAR, New Delhi at MGCGV, Chitrakoot, M.P. during 14-16th February, 2020.
  - ✓ Member, Editorial Board, Notulae Scientia Biologica, Romanian Academy of Science, Romania on February, 2020.
  - ✓ Member of Assessment Committee of technical personnel in administration of ICAR- IISS, Bhopal held on 18th March 2020.
  - ✓ Recognized as visiting scientist at Agricultural Research, Education and Extension Organization, Ministry of Agriculture (AREEO), Tehran, Iran in May, 2020.
  - ✓ Chairman of technical session VII (Theme III: Life Sciences, Biomedical Sciences and Biotechnological aspect) in "International Web Conference on Perspective on Agricultural and Applied Sciences in COVID-19 Scenario (PAAS-2020)" jointly organized by Agricultural & Environmental Technology Development Society Uttarakhand, India; Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh; Shobhit

Institute of Engineering & Technology Meerut, India; Soils, Water and Environmental Res. Inst, (SWERI), Agriculture Research Center, (ARC) Giza, Egypt, Rajiv Gandhi Central University, Itanagar and Corteva agriscience during 4-6th October, 2020.

- ✓ Member, Board of Studies at Banaras Hindu University, Varanasi, UP for two years w.e.f. 2nd November, 2020.
- ✓ Member, Organizing committee, 14th International Citrus Congress-2020 in Mersin, Turkey during 8-13th November, 2020.
- ✓ Member, DPC career advancement of ARS scientist of soil science at ICAR-NBSS & LUP, Nagpur.
- ✓ Member, Internal Review Committee, project entitled: Genetic Improvement of Kinnow mandarin for Fruit quality, Biotic and Abiotic stress Tolerance at Dr. J. C. Bakshi Regional Research Station, Abohar, Punjab Agricultural University, Ludhiana, Punjab during 2020-21.
- ✓ Member, Editorial Board, Progressive Horticulture Uttarakhand.

- Dr. A. K. Das, Pr. Scientist (Pl. Pathology) nominated as a DBT representative for the Institutional Biosafety Committee (IBSC) constituted at CSIR-National Environmental Engineering Research Institute, Nagpur and also for ICAR- Central Institute for Cotton Research, Nagpur.
- Dr. A. A. Murkute, Pr. Scientist (Hort.)
  - ✓ Member, Technical Committee for Himachal Pradesh Subtropical Irrigation and Value Addition project funded by ADB.
  - ✓ Chairman of Committee to decide the qualification criteria for M.Sc and PhD advisors for RVSKVV, Gwalior.
- Dr. A. Thirugnanavel, Scientist 'SS' (Hort.) :
  - ✓ Co-Chairman, Technical Session III - Organic Citrus Cultivation during National Citrus Meet-2020 held at Biswanath College of Agriculture, Biswanath Chariali, Assam during January 10-12, 2020
  - ✓ External examiner for evaluating the Experiential learning programme for final year B.Sc. Agri. students of Kalasilingam Academy of Research and Education, Tamil Nadu on 18th December, 2020
- Dr. R. K. Sonkar, Pr. Scientist; Dr. A. A. Murkute, Pr. Scientist; Dr. A. Thirugnanavel, Scientist; Dr. Anjitha George, Scientist; Dr, J.P. Tej Kumar, Scientist and Dr. Kiran Kumar Kommu, Scientist; Co-organizing Secretary, National Citrus Meet-2020 on "Development of Citrus in NEH region", 10-12th January, 2020, organized by ICAR-CCRI, Nagpur and RRCC at BNCA, Biswanath Chariali, Assam.

7 Linkages and Collaborations

7.1 National

ICAR - CCRI established linkages with many organizations in the country and several externally funded projects were operational at the institute during 2020 in collaboration with organization as given below :

Collaborating organization	Project Title	Date of Start and present status
ICAR – Indian Institute of Horticultural Research, Bengaluru	Consortium Research Platform (CRP) on Vaccines and diagnostics. (ICAR)	October, 2015 ongoing project
Govt. of Maharashtra Agriculture Department, Pune	Horticultural Crop Pest Surveillance, Advisory and Management Project (HORTSAP).	October, 2014 ongoing project
Department of Biotechnology (DBT), GoI, New Delhi	Molecular diagnostics, transcriptomics and cisgenic approaches to combat citrus greening (Huanglongbing) disease of citrus.	January, 2017 completed project
Protection of Plant Varieties & Farmer's Right Authority, New Delhi	"DUS centre for Acid lime, Mandarin and Sweet orange".	July, 2015 ongoing project
Mahalanobis National Crop Forecast Centre (MNCFC), Ministry of Agriculture, New Delhi	Coordinated Horticulture Assessment and Management using Geo -informatics (CHAMAN) phase -II.	November, 2018 completed project
Science and Engineering Research Board (SERB), Department of Science and Technology (DST), New Delhi	Effect of citrus root exudates on survival, penetration and developmentof *Tylenchulus semipenetrans* and *Meloidogyne indica*	November, 2019 ongoing project
Science and Engineering Research Board (SERB), Department of Science and Technology (DST), New Delhi	Evaluation of antimicrobial Nano -zinc oxide-2S albumin protein formulation on HLB infected plants -	February, 2020 ongoing project
Science and Engineering Research Board (SERB), Department of Science and Technology (DST), New Delhi	To develop potential inhibitor molecules against putative cystine -binding protein from *Candidatus* Liberibacter asiaticus	January, 2020 ongoing project

7.2 Linkage with Private Sector

Memorandum of Understanding (MoU) for contract research, licensing of technology

Strong linkages have been established with the private sector particularly pesticide, fertilizers and agro-chemical manufacturing companies. Contract research projects are regularly being signed with private companies for testing their new molecules/products as paid up trials.

7.3 Linkage with AICRP (Fruits)

CCRI, Nagpur is providing co-ordination on technical aspects of citrus crops under AICRP fruits and Dr. M.S. Ladaniya, Director, CCRI is a citrus crop Co-ordinator. There were 12 centres *viz*., Ludhiana (PAU), Abohar (PAU), Sriganganagar (RAU), Akola (Dr. PDKV), Rahuri (MPKV), Tirupati (Dr. YSR Hort. Univ.), Periyakulam (TNAU), Chethalli (IIHR), Tinsukia (AAU), Pasighat (CAU), Delhi (IARI) and Darjeeling (UBKV). Following activities were undertaken during 2020 under the All India Coordinated Research Project (Fruits) at ICAR-CCRI, Nagpur.

- ✓ Dr. A. K. Das, Pr. Scientist (Plant Pathology) & Nodal Officer and Concerned Scientists participated in the meeting conducted by AICRP (Fruits), IIHR, Bengaluru held on 29th May, 2020, 09th July, 2020, 25th July, 2020, 05th August, 2020, 23rd September, 2020, 29th September, 2020, 03rd November, 2020, 04th November, 2020 and 18th December, 2020.

7.4 Academic /Educational collaboration of CCRI, Nagpur with other organisations

Student Name	Examiner/ Co-guide from CCRI, Nagpur	Title of the thesis, dissertation	Collaborating organization/SAUs/ College	Type of collaboration Viva-voce examiner/ Research at CCRI
Mr. Abhik Patra	Dr. A. K. Srivastava, Pr. Scientist (Soil Science)	-	Department of Soil Science and Agricultural Chemistry, Banaras Hindu University	External Examiner for oral comprehensive examination of Ph.D Scholar on 3rd February, 2020
Mr. Nripen Kumar Gogoi	Dr. A. K. Srivastava, Pr. Scientist (Soil Science)	Bioprospecting actinobacteria of Assam for some rice disease management and growth promotion	Department of Plant Pathology, AAU, Jorhat	External Examiner for evaluation of M.Sc. thesis on 19th February, 2020
Miss Rokozeno Chalie-u	Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Influence of carbon and nitrogen source on enzyme activities and population dynamics of *Trichoderma viride* and its performance or impact on chickpea	Department of Soil Science and Agricultural Chemistry, JNKVV, M.P., Jabalpur	External Examiner for evaluation and conducted viva-voce of Ph.D. thesis on 8th October, 2020
Mr. Debashish Hota	Dr. A. K. Srivastava, Pr. Scientist (Soil Science)	Response of biofertilizer in acid lime	Department of Fruit Science, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh	Co-Major Advisor, Advisory Committee Ph.D. student

Student Name	Examiner/ Co-guide from CCRI, Nagpur	Title of the thesis, dissertation	Collaborating organization/SAUs/ College	Type of collaboration Viva-voce examiner/ Research at CCRI
Ms. Bhoyar Kajal Damodharrao	Dr. A. K. Srivastava, Pr. Scientist (Soil Science)	Response of nutrients on yield, soil nutrient status and carbon fractions under Nagpur mandarin in vertisol	Department of Soil Science & Agricultural Chemistry, College of Agriculture, Dr PDKV, Akola	Co-Guide, Advisory Committee Ph.D. student
Mr. Tushar Nakade	Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Integrated nutrient management in relation to sustainable quality production of Nagpur mandarin	Dr PDKV, Akola	Co-Guide, Advisory Committee, M.Sc. student
Sh. Debashish Hota, Sh. Ravishankar Lanjiyana and Sh. Saket Dubey	Dr. Dinesh Kumar, Pr. Scientist (Hort.)	-	IGKV, Raipur	Oral Comprehensive Examination of Ph.D. students through Skype on 27th May, 2020
Ms. Sanhita Malvi,	Dr. A.K. Das, Pr. Scientist (Plant Pathology)	'Studies on *Phytophthora* diseases of citrus: Identification, genetic characterization of the causal agent and its management'	JNKVV, Jabalpur (MP)	Co-guide, Advisory Committee, Ph.D. student

7.5 Linkage with Farmers' organization, State Agriculture or Horticulture Deptt.

- **Farm advisories disseminated to farmers :** There are 13 WhatsApp groups operated by scientists in coordination with progressive citrus farmers who actively discuss problems and related solutions of citrus cultivation. The advisories prepared in the wake of the pandemic and lockdown due to COVID-19 were circulated in these 13 Whatsapp groups. The advisories were received by 2055 members which include citrus farmers from citrus belts of Central and Northern India and also ICAR scientists and professors of SAUs along with State Agriculture department officials.
- CCRI scientists were experts in various horticulture farmers' groups across India where they are consistently addressing the problems of citrus growers and reached out to 1419 farmers.
- Scientist answered more than 8-10 calls daily of farmers.
- **Advisories/Technologies updated through YouTube channels :** CCRI contributed videos of technologies to the YouTube on Ambia and Mrig bahar advisories for Nagpur mandarin and have right now 4300 views and 3400 views respectively.
- **Advisories/Technologies to farmers to save their crops during lockdown :** On request of Telangana State Agriculture Department, an advisory on Sathgudi Orange - how farmers can delay harvest of their crop during lockdown to avoid the harvesting address and storage problems due to unavailability of labour, machines, transportation. The advisory was translated in to Telugu and circulated in local newspapers by the State agric. Deptt, Telangana.

Sr. No.	WhatsApp Group Name	No. of members in the group
1.	Precision Agriculture	200
2.	Smart Farming Horticulture	215
3.	Shetkari foundation	256
4.	Precision Hitech Kisan	217
5.	Kinnow Ganganagar	128
6.	Kinnow Farmers	220
7.	Horticulture Uttarakhand	183

ICAR-Central Citrus Research Institute, Nagpur has started co-ordinating citrus research under All India Co-ordinated Research Project on Fruits since 2014-15. The Co-ordinating Cell has been established at CCRI for citrus research. There are thirteen centres working on citrus under AICRP (Fruits) for Citrus and these are as follows: Ludhiana (PAU), Abohar (PAU), Sriganganagar (RAU), Akola (Dr. PDKV), Rahuri (MPKV), Tirupati (Dr. YSR Hort. Univ.), Periyakulam (TNAU), Chethalli (IIHR), Tinsukia (AAU), Pasighat (CAU), Delhi (IARI) and Darjeeling (UBKV). CCRI, Nagpur is co-ordinating centre and functions in collaboration with Project Co-ordinator, AICRP (F), IIHR, Bengaluru. Under this restructuring of AICRP (F), CCRI, Nagpur shall have decisive role in technical matters while its role is advisory in case of administrative and financial matters.

8.1 Genetic Resources and Crop Improvement

8.1.1 Characterization of germplasm

8.1.1.1 Evaluation of citrus germplasm /varieties

Evaluation of mandarin varieties and clones

To evaluate the performance of seven mandarin cultivars cv. Darjeeling mandarin, Mudkhed seedless, Khasi mandarin, Coorg mandarin and Kinnow, N-4 the physical plant parameters and physico-chemical parameters of fruits were assessed. The highest plant height was observed in Mudkhed seedless (4.99 m), whereas lowest height was found in Kinnow (3.51m). The canopy volume was highest in Darjeeling mandarin (46.77 m^3) and the lowest was in Khasi mandarin (26.90 m^3). Except juice contents in fruits, all other parameters were significantly different. The highest fruit weight was found in Kinnow (177.73 g) followed by Coorg mandarin (160.34 g). However, number of segments was highest in Kinnow (11.83) and the lowest were in Coorg mandarin (10). The number of seeds were lowest in Nagpur seedless mandarin (2.17) and highest in Kinnow (22.33). The TSS was highest in Khansi mandarin (10.53) and lowest was in Mudkhed seedless (9.3). The highest acidity was found in Kinnow (1.09%) and the lowest was in Coorg mandarin (0.6%).

Ten elite mandarin clones *viz*., N-51, N-4, N-34, N-38, N-43, Mandarin-182, N-28, NM, Clone-11, and CRS-4 were evaluated for growth and quality traits. The experiment was laid out in RBD with three replications. To evaluate the performance of nine mandarin cultivars cv. N-51, N-4, N-34, N-38, N-28, N-43, M-182, Clone – 11 and CRS – 4 along with check Nagpur mandarin were analyzed for the physical plant parameters and physico-chemical parameters of fruits. The highest plant height was observed in N- 4 (3.58 m) and CRS4 (3.53m), and the highest canopy volume was found in Nagpur Mandarin (32.76 m^3) and N-4 (31.16 m^3). The highest fruit weight was found in N-34 (184.22 g) followed by N-28 (174.44g). Lowest seeds were found in N-4 (1.00) and highest juice contents in clone-11 (44.59%).

Evaluation of promising clones of Sweet orange

Among seven sweet orange clones *viz.*, Phule Mosambi, M-3, M-4, M-8, Kodur Sathgudi, Shamouti and Mosambi, the highest plant height was found in Phule mosambi (3.02 m) and at par with Mosambi (3.00 m). However, the highest canopy volume was found in Shamouti (23.72 m^3) followed by Mosambi (20.38 m^3), which were at par. Among seven sweet orange cultivars the highest fruit weight was found in Shamouti (225 g) followed by Mosambi (213 g) and clone M4 (210 g). However, the lowest TSS (7.62) and juice content (26.11%) was observed in Shamouti. The highest TSS was in Kodur Sathgudi (10.32^{0}Brix) and the highest juice content was in Phule Mosambi (39.71%).

Evaluation of promising clones of Acid lime

Nine acid lime clones have been evaluated for growth, yield and quality under RBD with three replications. All clone like KL-12, NRCC Niboo-2, NRCC Niboo-3, NRCC Niboo- 4, NRCC, Niboo-5, Phule Sharbati, TAC 94/13, PDKV Lime, Nag Niboo were performing well under Nagpur conditions. The highest plant height was found in Phule

Sharbati (3.07 m) along with the highest canopy volume (25.18 m^3). The lowest plant height was observed in NRCC Niboo-4 (2.6 m) and the lowest canopy volume was found in Tal94/14 (14.01 m^3). The highest fruit weight was in NRCC Niboo-3 (53.56 g) and highest fruit juice was in (46.96%).

Evaluation of promising clones of pummelo

Nine pummelo (*C. grandis*) clones were evaluated for physical parameters of the tree and physico-chemical parameters of the fruits. There was significant different in all the parameters recorded. The highest height was observed in P-1 (4.60 m), whereas, PTF-4 has the lowest (2.65 m). Obviously the highest canopy volume (32.53 m^3) was observed in P-1. The highest fruit weight (1478.67 g) was found in P-5 and highest rind thickness (39.97 mm) was found in PTF-2 followed by in PTF-1 (1065.67 g and 24.78 mm in PTF-4, respectively). On the contrary, in PTF-3 the lowest fruit weight i.e. 418.67 g was recorded and PTF2 had highest number fruits per tree (256.67). TSS ranged between 6.27^{0}Brix to 12.43^{0}Brix and acidity ranged between 0.98 % to 1.34%.

Evaluation of promising clones/ varieties of grapefruit

Seven grapefruit varieties *viz*., NRCC Grapefruit - 6, Flame, Star Ruby, Red Blush, Marsh Seedless, Foster and Imperial were plated in June - July 2017. The highest plant height was found in NRCC Grapefruit-6 (1.39) followed by Marsh Seedless (1.35 m). However, the highest canopy volume was found Marsh Seedless (2.54 m^3) followed by Star Ruby (2.27 m^3), which were at par. Among seven cultivars the highest fruit weight was found in NRCC Grapefruit-6 (477.67 g) followed by Red Blush (389.17 g) and Imperial (309.67 g). However, the lowest TSS (7.35) in Star Ruby and lowest juice content (21.52%) was observed in Imperial. The highest TSS was in Foster (8.52) and the highest juice content was in Flame Grapefruit (38.01%).

Evaluation of promising clones of Mandarin (MLT-II)

This experiment started in 2018 under MLT-II to assess the performance of new clones (PDKV Mandarin-5) for its characters (Yield) compared to released variety (Nagpur mandarin). Plant growth characters were recorded not much variation was observed in respect to plant growth.

Evaluation of promising clones of Acid lime (MLT - II)

This experiment started during with 9 acid lime varieties. Planting was done in the year 2017 in RBD with three replications. Plant growth characters were recorded not much variation was observed in respect to plant growth. However the highest plant height was found in SGNR- AL -1 (1.82 m) and highest canopy volume in NRCC AL – 7 (2.99 m^3). The lowest plant height was observed in Pusa Udit (1.17 m) and the lowest canopy volume was found in Pusa Abhinav (0.5 m^3) was recorded in NRCC Acid lime.

8.2 Crop and Natural Resource Management and Environment

8.2.1 Evaluation of promising rootstocks in citrus

8.2.1.1 Evaluation of different rootstocks for optimum growth and productivity of Sweet orange cv Mosambi

Plant growth : The 2020-21 is the seventh year of its plantation and plant growth was recorded in terms of plant height, stock-scion and spread east-west and north-south growth. The maximum plant height was recorded on rough lemon rootstock (2.98 m) and the stock-scion growth was recorded maximum in NRCC rootstock-6. The canopy spread was recorded maximum (16.09 m^3) in Rangpur lime than other rootstocks. Sweet orange on Alemow followed by NRCC rootstock -2 noted to be significantly minimum canopy spread than other treatments (Table 8.1 and Fig. 8.1).

Fruit yield and fruit quality: The highest fruit yield (7.95 t/ha) was recorded in NRCC rootstock-4 followed by Rangpur lime (7.91 t/ha) whereas lowest fruit yield was recorded (4.38 t/ha) in CRH-12. The fruit quality of Mosambi budded on different rootstocks were recorded. The maximum average fruit weight of 188.12g was recorded in Alemow rootstock whereas the minimum weight of 128.33 g was recorded in rough lemon. The highest TSS (11.5%) and juice content (46.10%) was observed in Rangpur lime rootstock followed by NRCC

rootstock-6, whereas the minimum TSS (9.23%) was recorded in NRCC rootstock-5. The maximum Vitamin C (52.2 mg/100 ml) was recorded in rough lemon rootstock followed by CRH-12 (51.1 mg/100 ml). The fruit acidity was maximum (0.32%) in NRCC rootstock-6 while minimum acidity (0.10%) was noted in NRCC rootstock-4 (Table 8.1).

different rootstocks (including hybrid rootstocks) for monitoring *Phytophthora* population using the selective media. Data revealed that maximum *Phytophthora* incidence (31.6 cfu/cc) was recorded on CRH-12 rootstock while minimum incidence (4.6 cfu/cc) was noted on NRCC rootstock-6.

Table 8.1 : Fruit quality and yield of sweet orange on different promising rootstocks

Varieties and R/S	Average fruit weight (g)	Fruit length (mm)	Fruit dia. (mm)	Rind thickness (mm)	No. of seeds / fruit	Juice content (%)	TSS (%)	Vit. C (mg/ 100 ml)	Acidity (%)	Fruit yield (kg/plant)	Fruit yield (t/ha)
T_1: NRCC rootstock -2	179.19	67.72	71.08	3.67	18.33	36.24	9.77	35.5	0.22	10.35	5.74
T_2: NRCC rootstock –4	167.40	67.54	67.99	3.65	28.50	43.67	10.47	42.2	0.10	14.34	7.95
T_3 : NRCC rootstock - 5	174.77	68.38	69.19	3.58	28.47	43.75	9.23	43.10	0.19	13.86	7.69
T_4 :NRCC rootstock –6	141.33	65.57	66.93	4.02	26.67	45.57	11.43	51.0	0.32	11.15	6.18
T_5: CRH-12	148.22	64.37	66.01	4.17	16.68	38.76	11.20	51.1	0.19	7.88	4.38
T_6 :Alemow	188.12	67.16	68.59	3.81	18.03	44.95	9.27	46.2	0.22	12.36	6.85
T_7: Rangpur lime	179.78	68.49	70.57	3.92	27.40	46.10	11.50	41.5	0.13	14.26	7.91
T_8: Rough lemon	128.37	61.09	61.96	4.08	15.77	42.40	11.17	52.2	0.31	11.18	6.21
CD (P=0.05)	1.145	1.479	0.986	0.023	0.211	1.034	0.109	1.075	0.005	0.111	0.062

Soil macronutrients : The different rootstocks *viz*., NRCC rootstock-2, NRCC rootstock-4, NRCC rootstock-5, NRCC rootstock-6, CRH-12, Alemow, Rangpur lime and Rough lemon were tested for soil macronutrients uptake. The analysis of data revealed that significant variation was noted for nutrient uptake among the different rootstocks. The soil nutrient uptake indicated that highest N uptake (269.25 kg/ha) was found in NRCC rootstock-4 while maximum P uptake (38.83 kg/ha) was found in rough lemon. The maximum uptake of K (638.4 kg/ha) was found in NRCC rootstock-2. Overall study indicated significant difference in sweet orange budded on different rootstocks with respect to nutrient status.

Disease Incidence : Rhizospheric soil samples were also collected from the field of Mosambi grown on nine

PLW during storage : The storage data recorded for all the treatments. The 25 fruits per replication in all the treatment were kept under ambient condition for the storage for 28 days for observing the weight loss indifferent treatments. The data revealed that the loss of weight was noted in the range of 5-10% per week in all the rootstocks. After 28 days of storage minimum PLW was noted in NRCC rootstock-2 (22.30%) followed by rangpur lime rootstock whereas, maximum average weight loss of fruit was recorded in Rough lemon rootstock (34.87%) followed by CRH-12 (31.40%). Storage data reveled that TSS of sweet orange increase during the storage. Maximum TSS was recorded in NRCC-6 rootstock (12.2%) followed by rough lemon rootstock and NRCC-4 rootstock. The first year study suggested that rootstock plays meaningful role in controlling PLW which is associated with fruit quality.

Fig. 8.1 : Sweet orange cv. Mosambi budded on different rootstocks

8.2.2 Studies on Residual and Cumulative Effect of Nutrients in Citrus

The experiment was initially laid out in 2006-07 in a 4-year-old Nagpur mandarin orchard established on Calciustert soil type at Bihadi village of Karanja with a total of 9 treatments (A_1B_1 - A_1B_2 - A_1B_3 - A_2B_1 - A_2B_2 - A_2B_3 - A_3B_1 - A_3B_2 - A_3B_3) comprising of three levels of nutrient age-wise: i. application of 1/10 of RDF for 10 years (A_1), ii. application of 1/8 of RDF for 8 years (A_2) and iii. application of 1/6 of RDF for 6 year (A_3) and three doses of nutrients agewise *viz.,* 100% RDF after 10 years (B_1), 80% of RDF after 8 years (B_2) and 60% RDF after 6 years (B_3) in a factorial randomized block design with five replications with each treatment carrying 2 plants. The data was generated with respect to canopy volume, fruit yield, changes in fruit quality, leaf nutrient composition (N, P, K, Fe, Mn, Cu, and Zn) and available pool of nutrients in soil (N, P, K, Fe, Mn, Cu and Zn). This is the fifteenth year of experimentation.

The canopy volume through two way data showed an increased response of fertilization from 0.40 m^3 with A_1B_1 to as much as 0.81 m^3 with A_3B_3, justifying the definitive role of fertilization in plant growth. These increases in canopy volume over canopy volumes of 2019-20, were statistically significant. The fruit yield varied from 40.10 kg/tree (11.14 t/ha) to 56.40 kg/tree (15.68 t/ha) with mean effect varying from 42.41 kg/tree (11.70 t/ha) to 51.87 kg/tree (14.41 t/ ha) from $A_1 – A_3$ treatments. While, mean effect of response from B_1-B_3 varied from 43.97 kg/tree (12.22 t/ha) to 50.61 kg/tree (14.07 t/ha). The maximum yield of 56.40 kg/tree (15.68 t/ha) was observed with treatments A_3B_3. The mean juice acidity reduced from 0.68% with A_1 to 0.61% with A_3 with corresponding reduction from 0.69 % to as low as 0.59 % from B_1 to B_3. While, TSS under A_1-A_3 and B_1-B_3 varied from 9.54 to 9.72% and from 9.66 to 9.92 %, respectively, with maximum of 10.10% with A_3B_3 treatment. Similarly, juice content displayed a significant variation from 44.4 to 46.1 % (A_1-A_3) and from 44.1 to 46.7 % (B_1-B_3), with a maximum of 47.2% with A_3B_3 treatment. Response of individual and cumulative effect of fertilizers as well, were observed significantly affecting the leaf nutrient composition in terms of macronutrients and micronutrients. Response on changes in all the macro- (N, P, K) and micronutrients (Fe, Mn, Cu and Zn) in index leaves as well as rhizosphere soil was observed to be significantly affected by different treatments, irrespective of either individual treatment or in combination compared to preceding years. Studies so far revealed that application of even 60% RDF could produce residual effects which can later display their cumulative crop response

8.3 Crop Protection

8.3.1 Studies on citrus greening disease [Service-oriented Trial]

Indexing and confirmation of greening isolates by standardized PCR-based methods

Twenty two no. of citrus leaf samples were obtained from AICRP centre, Tinsukia, Assam, MPKV Rahuri and Dr. PDKV, Akola and the samples were indexed thro' standardized PCR-based technique. Out of 22 samples tested, 17 samples were found positive for greening bacterium infection.

9 Publications

9.1 Research Papers (in Peer Reviewed Journals)

- Kumar, P., Dalal, V., Kokane, A., Ghosh, D.K. and Kumar, A.S. (2020). Mutation studies and structure-based identification of potential inhibitor molecules against periplasmic amino acid binding protein of *Candidatus* Liberibacter asiaticus (CLasTcyA). *International Journal of Biological Macromolecules* 147, 1228-1238. (NAAS rating : 11.16)
- Mohan, S., Kumar, K.K., Sutar, V., Saha, S., Rowe, J. and Davies, K.G. (2020) Plant root-exudates recruit hyperparasitic bacteria of phytonematodes by altered cuticle aging: implications for biological control strategies. *Frontiers in Plant Science* 11:763. DOI: 10.3389/fpls.2020.00763. (NAAS rating : 10.11)
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- Das A.K., A. Kumar, S. Nerkar, S.A. Chichghare and P.G. Pali (2020): First Report of *Pantoea ananatis* causing fruitlet blight of Nagpur Mandarin (*Citrus reticulata*) In India. *New Disease Re*ports (2020) 41, 5. http://dx.doi.org/10.5197/j.2044-0588.2020. 041 .005]
- George Anjitha (2020). Arthropod Biodiversity of Citrus Ecosystem with Special Reference to Citrus Leaf Miner. *Journal of Plant Health Issues* 1(2): 033-038.

9.2 Oral Papers Presented in Seminar / Symposia / Conferences etc.

- National Citrus Meet-2020 organised by ICAR-CCRI, Nagpur at Biswanath College of Agriculture (AAU), Biswanath, Chariali, Assam from 10-12 January, 2020
  - ✓ Das A. K., (2020). Fungal and bacterial diseases of citrus: Recent progresses in diagnostic approaches and management tactics. 172-181(Lead Paper)
  - ✓ Ghosh D.K. (2020). Recent advances in molecular diagnosis, characterization and management of virus and greening disease of citrus. Pp 163-171 (Lead Paper)
  - ✓ George Anjitha (2020). New Integrated Pest Management Paradigm for the Modern Age in citrus. Pp 184-191(Lead Paper)
  - ✓ Huchche A.D., (2020) : Flowering & fruiting in citrus: A physiological perspective. pp 109-119 (Lead Paper)

- ✓ Singh I. P., Murkute A. A., Thirugnanavel A. and Tej Kumar P. (2020). Citrus Biodiversity in North Eastern Region, pp : 33-43 (Lead Paper).
- ✓ Kumar Dinesh and Ladaniya M.S. (2020). Prospects of Citrus Post Harvest Management and Processing in North Eastern Region. Pp 223-232 (Lead Paper)
- ✓ Kumar Dinesh, Ladaniya M.S., Gurjar Manju, Mendke S. and Kumar Sunil (2020). Citrus Phytochemical : "Boon of Nature" for NEH Region of India. pp 234 (Oral)
- ✓ Kommu K. K. (2020). Nematode problems in citrus in North Eastern India. pp 192-193 (Oral)
- ✓ Ladaniya M.S., Overview of Citrus Industry with special reference to North -East region of India. (Keynote address).
- ✓ Murkute A. A., Singh I.P., Tejkumar J. P., Thirugnanavel A. and Ladaniya M.S. (2020). Citrus improvement endeavours and way forward with special reference to North – Eastern regions. Pp. 55-66 (Lead Paper)
- ✓ Sonkar R.K., Ladaniya M.S. Das A.K., George Anjitha and Thirugnanavel A. (2020). Performance of citrus varieties on raised bed system of planting in Central India. pp 120-124 (Lead Paper)
- ✓ Sonkar R.K., Kommu K. K., Singh I.P., Ladaniya M.S., and Khanikar H. (2020). Performance of citrus varieties on raised and flat (plain land) bed planting system. Pp 130-131 (Oral)
- ✓ Thirugnanavel A., Singh I.P., Murkute A.A., and Tej Kumar J.P. (2020). Performance of Sikkim and Darjeeling mandarin clones under sub-humid tropical zone. Pp 74 (Oral).
- ✓ Tej Kumar J. P., Murkute A.A., Thirugnanavel A. and Singh I.P. (2020). Biotechnological interventions in citrus Current status and future prospects. Pp. 67-69 (Lead Paper).

- Srivastava A. K. (2020). Climate Smart Integrated Soil Fertility Management in Fruit Crops in Indian Horticulture Summit-2020 during 14-16th February 2020 at Mahatma Gandhi Chitrakoot Gramodya Vishwavidyalaya, Chitrkoot, Madhya Pardesh.
- Meshram D. T. (2020). "Response of inorganic mulches in Pomegranate (*Punica granatum L.*) cv. Bhagwa" 29th National Web Conference during 29-30th December, 2020.
- Bhattacharyya, S. and Sonkar, R. K. (2020). "Constraints faced by citrus growers of Central India amidst the nationwide lockdown due to Covid-19" in National Webcon on Agricultural Production & Support System Managing Covid 19 Pandemic: Experience Sharing and Strategies, 6-8 May, 2020, organised by Chandra Sekhar Azad University of Agriculture and Technology, Uttar Pradesh, India.
- Behere G.T. (2020). "*Insect pests management in organic agriculture: opportunities and challenges*" in the National Webinar on "Sustaining Organic Farming During and Post COVID-19" organized by Multi-Technology Testing Centre and Vocational Training Centre, College of Agricultural Engineering and Post-Harvest Technology, Central Agricultural University (Imphal), Ranipool, Sikkim, India, during 3-5 August, 2020.

9.3 Abstracts / Poster Paper presented in Proceedings/ Souvenir of Seminar/ Symposia/Conferences etc.

- National Citrus Meet – 2020, January 10-12, Biswanath Chariali, Assam.
  - ✓ Bhattacharyya S., Sonkar R.K. and Pakhmode P. (2020). Advanced citriculture leading to doubling of farmers' income : A case study of successful adoption of ICAR-CCRI technologies. Pp 286-287
  - ✓ Bhattacharyya S., Sonkar R.K., Pakhmode P. and Thakare P. (2020). Awareness and adoption of ICAR-CCRI technologies amongst citrus growers of Nagpur and Amravati districts of Maharashtra. Pp 287-288

- ✓ Christy B. K., Sangma A., Thirugnanavel A., Rajesh, James Z., Kikon H., Romen Sharma and Raj Khowa D.J. Effect of Soil health and orch and age on khasi mandarin fruit quality with respect to fruit yield and quality Pp. 125
- ✓ Das A.K., Chichghare S., Sharma S. K. and Singh S. (2020). Prophage diversity of '*Candidatus* Liberibacter asiaticus' strains causing citrus greening disease (Huanglongbing) in India. p. 198
- ✓ Hota Debashish, Singh I. P., Srivastava A.K., Kumar Vijay and Dahat Shraddha (2020). Deciphering the consequences of rhizosphere hybridization on pre-evaluation of acid lime. Pp 137-138
- ✓ Jhade R.K., Huchche A.D., Ladaniya M.S. and Jain P.K. (2020). Impact of changing climate on phenology of Nagpur mandarin *(Citrus reticulata* Blanco). Pp 209
- ✓ Kumar D., Ladaniya M.S., Gurjar M., Mendke, S. and Kumar, S. (2020). Citrus Peel: "Waste to Wealth" for NEH region. Pp 242
- ✓ Kommu, K. K. and Das, A. K. (2020). Diversity of plant parasitic nematodes associated with Assam lemon in Assam. p. 197
- ✓ Lahane Y., Vijayakumari N., Kawale K., Fiske K. and Uge P. (2020). Standardization of leaf chromosome preparation protocol by enzyme digestion for citrus cytogenetic studies. Pp 81
- ✓ Malvi S., Singh S.N., Kumar A., Das A.K. (2020). Diversity and characterization of oomycete species in the citrus agroecosystem of Vidharbha region of Maharashtra. p. 197
- ✓ Pali P., Das A.K., Kumar Ashok, and Chichghare S. (2020). Diversity and biocontrol potential of fungal endophytes against the citrus root rot pathogen, *Phytophthora nicotianae*. p. 199
- ✓ Singh, I.P., Murkute A.A., Thirugnanavel A. and Tejkumar J. P. (2020). Evaluation of promising clones of Sweet orange. Pp 82
- ✓ Singh I.P., Murkute A.A., Thirugnanavel A. and Tejkumar J. P. (2020). Evaluation of promising clones of pummelo. Pp 83
- ✓ Singh I.P., Murkute A.A., Thirugnanavel A. and Tejkumar J. P. (2020). Evaluation of promising clones of mandarin. Pp 83
- ✓ Singh I.P., Kommu K. K., Sonkar R. K. and Gadge A.B. (2020). Performance of Citrus germplasm accessions at RRCC, Assam. Pp 85
- ✓ Sonkar R.K., Ladaniya M.S., Das A.K., George A., Thirugnanavel A., Thakare P., Bhaladhare V.P. and Kolwadkar J. (2020). Bearing performance of different lemon cultivars on Raised bed planting system. Pp 143
- ✓ Sonkar R.K., Kommu K. K., Singh I.P., Ladaniya M.S., Bhaladhare V.P., Kumar A., Khanikar H. and Dhengre V.N. (2020). Raised bed planting system for citrus at RRCC, Assam. Pp 142
- ✓ Sonkar R.K. and Singh I.P. (2020). On Site Distinctness, Uniformity and Stability testing of citrus spp. pp 144
- ✓ Tej Kumar J. P., Murkute A.A., Thirugnanavel A. and Singh I.P. (2020). Analysis of Genetic diversity in sweet orange using InDels. Pp 82
- ✓ Thakare P., Kumar A. and Sonkar R.K. (2020). Space utilization in Nagpur mandarin through vegetable intercropping for doubling farmers' income. Pp 144

- Indian Horticulture Summit – 2020: at Chitrakoot, Madhya Pradesh during 14-16 February, 2020
  - ✓ Cheke A. S., Patil V. D. and Srivastava A. K. (2020). Effect of application of value added consortium on physico-chemical properties of sweet orange orchard from field experiment. pp.102
  - ✓ Cheke A. S., Patil V. D. and Srivastava A. K. (2020). Studies on isolation of bacterial strains in rhizosphere soil of umber tree (*Ficus racemosa*) in (16s rRNA) sequencing by culture independent method. pp.103

- ✓ Cheke A. S., Patil V. D. and Srivastava A. K., (2020). Effect of various ficus species rhizosphere soil on germination of seeds of sweet orange. pp.103
- ✓ Cheke A. S., Patil V. D. and Srivastava A. K. (2020). Studies on rhizosphere hybridization and nutrient dynamics in sweet orange (*Citrus sinensis*). pp.102
- ✓ Debashish Hota, Vijay Kumar, Singh, I. P., Srivastava, A. K. and Dahat Shraddha (2020). Rhizosphere crosstalk transcends qualitative response of acid lime. pp.104
- ✓ Prakash Om, Srivastava A. K. and Nhakur N. (2020). Doubling farmers income through dragon fruit based crop diversification model in bundelkhand region. pp.116
- ✓ Thirugnanavel A. and Deka B.C. (2020) "Characterization and evaluation of indigenous colocasia (*Colocasia esculenta*) germplasm of NEH region of India".
- ✓ Tej Kumar J. P., Murkute A. A., Thirugnanavel A., Singh I. P. (2020) "*In silico* identification and sequence analysis of RNase T2 genes in citron (*Citron medica*)"
- ✓ Wei-Qin Gao, Li-Hui Lu, Srivastava, A.K. and Qiang-Sheng Wu. (2020) Mycorrizal effects on physiological responses and relevant gene expression of peach suffering from replant disease. pp.121
- ✓ Ya-Dong Shao, De-Jian Zhang, Qiang-Sheng Wu, Tian-Yuan Yang and Srivastava A. K. (2020). Mycorrhizas promote P acquisition of tea plants through changes in root morphology, phosphatise activity and P transporter gene expression. pp.43

- Saraswati, M.S., Durai P., Satish S., Mahalakshmi, B. Thirugnanavel A., Backiyarani, S. and Uma S. (2020) DUS Characterization of farmers variety Kamal Vikas A at ICAR-NRCB Trichy. International Conference on Banana 2020 held at NRC Banana, Trichy, Tamil Nadu during 22-25 February, 2020.

9.4 Books / Book chapters

- Cheke S., Patil V. D. and Srivastava A. K. (2020). Rhizosphere hybridization and Nutrient dynamics. Lambert Academic Publishing. ISBN:978-620-0-43134-9, https://www.lap.publishing.com
- Srivastava A. K. and Chengxaio Hu (2020). Fruit crops: Diagnosis and Management of Nutrient Constraints. Elsevier Publications ISBN: 978-0-12-818732-6, pp . 1-776.
- Sridhar J., Kumar, K.K., Baskaran Murali, Senthil-Nathan R.K., Sharma S., Nagesh S., Kaushal M., P.and Kumar, J. (2020). Impact of Climate Change on Communities, Response and Migration of Insects, Nematodes, Vectors and Natural Enemies in Diverse Ecosystems. In: Venkatramanan V., Shah S., Prasad R. (eds) Global Climate Change: Resilient and Smart Agriculture. Springer, Singapore. pp. 69-93. https://doi.org/10.1007/978-981-32-9856-9_4
- Kumar, K.K. (2020). Fungi: A Bio-resource for the Control of Plant Parasitic Nematodes. In: Yadav, A., Mishra, S., Kour, D., Yadav, N. and Kumar, A. (eds) Agriculturally Important Fungi for Sustainable Agriculture. Fungal Biology. Springer, Cham. https://doi.org/10.1007/978-3-030-48474-3_10
- Singh Sandeep, Sandhu R. K., Haldhar S. M., Reddy P. V. R., Reddy D. S., Irulandi S., Sheti M.H., George Anjitha, Singh V., Siraj M.and Patil P. Integrated pest management in citrus crops (2021). In: Pest management in dryland horticultural crops, Biotech Books, Ansari Road, Darya Ganj, New Delhi 110002.243-267pp.

9.5 Extension Bulletins/Folders

- George Anjitha and Rao C.N. 2020. *Nagpuri santrae ke keede makhode aur unka prabandan*. Revised Extension Bulletin No.32, ICAR-CCRI, Nagpur. 26 p.

- Ladaniya, M. S., Huchche, A. D., Das, A. K., Marathe, R. A., Shirgure, P. S. Rao, C. N. and George A. (2020). High density cultivation in acid lime. Extension bulletin No. 65. ICAR- CCRI, Nagpur, Maharashtra. 46p.

9.6 Popular articles

- Bhattacharyya, S., Sonkar, R.K. and Pakhmode, P. (2020). *Santrachya Shetine Shetkaryanchya Utpannat Jhali Vadh: Vacha Amravatitil Yashogatha*. Online issue of *Krishi Jagran*, September, 2020.
- Choudhary, A.G., Roy, P. and Bhattacharyya, S. (2020). Studies on Innovative Fruit Growers to Draw Attention of Marginal Farmers. *Agriallis,* 2(3): 07-17.
- George Anjitha and Dhengre V.N. (2020). *Santra bagaom mein keednashako ke chidkav, parivahan evam bhandaran ke dhoran barthi jane wali saavdhaniyan*. *Rashtriya Krishi* 15(2):71-73.
- Kumar, K.K. (2020). Nematode survival strategies. *Readers Shelf* 16(8):22-24.
- Kumar, K.K. (2020). Impact of climate change on nematodes. *Readers Shelf* 16(9):30-32.
- Meshram, D. T., Babu, K.D., Wadne, S. S. and More, B. A. (2020). Water management in Pomegranate (*Punica granatum* L.) during *Hasta bahar*. *Agricultural Observer*. *ISSN 2582-6611*.1(4):26-31.
- Meshram D. T. and Babu, K. D. (2020). Innovation of micro-irrigation systems for sustainable production of pomegranate (*Punica granatum* L.). *Agricultural Observer*. 1(7):34-39.
- Som, S., Bhattacharyya, S. and Roy, P. (2020). Crime and Pandemic: Hidden Face of Covid-19. *Food and Scientific Reports*, 1(10): 31-36.

9.7 Publications of the CCRI

- Annual Report (2019), ICAR-Central Citrus Research Institute. Nagpur, p. 184
- ICAR-CCRI, Citrus Newsletter, Jan-March., 2019, ICAR-CCRI, Nagpur p. 8.
- ICAR-CCRI, Citrus Newsletter, April-June, 2019, ICAR-CCRI, Nagpur p. 8
- ICAR-CCRI, Citrus Newsletter, July- Sept, 2019, ICAR-CCRI, Nagpur p. 8.
- ICAR-CCRI, Citrus Newsletter, Oct.- Dec., 2019, ICAR-CCRI, Nagpur p. 8.
- ICAR-CCRI, Citrus Newsletter, Jan-March., 2020, ICAR-CCRI, Nagpur p. 8.
- ICAR-CCRI, Citrus Newsletter, April-June, 2020, ICAR-CCRI, Nagpur p. 8

9.8 Compilation and Documentation

Souvenir and Abstracts

- Ladaniya M.S., Huchche A.D., Ghosh D.K., Das A.K., Kumar Dinesh, Murkute A.A., Thirugnanavel A., George A., Tej Kumar J.P., Kommu K.K. and Singh I.P. (2020): Souvenir & Abstracts-National Citrus Meet-2020. Theme Development of Citrus in North-Eastern Region published by ICAR-CCRI, Nagpur Pp 1-288.
- Singh B., Dutt S., Tomar B.S., Srivastava A.K. Rajan J.K, Singh P.K, Jat G. S., Singh J., Lata S., Lyngdoh Y. A., Jain R., Rajan P. and Singh A. K. (2020) Souvenir and Book of Abstracts. Indian Horticulture Summit-2020 on Mitigating Climate Change and Doubling Farmers Income though Diversification, 14-16 February, 2020 at MGCGV, Chitrakoot (M.P.) organized by SHRD, Ghazibad (Uttar Pradesh), India.

10 Regional Research Centre for Citrus (RRCC), Biswanath Chariali, Assam

10.1 New plantation

At RRCC, Biswanath Chariali, on raised-bed planting system new introduced varieties of sweet orange *viz*., Trovita, Delta, Saluatiana, Diller were planted as a new block during November, 2020.

10.2 Training programme organized

Training programme on "Advance production technology of Citrus" under TSP at KVK, Lakhimpur, Assam on 17th March, 2020 in which 35 citrus growers participated. Dr. M. S. Ladaniya, Dr. A. K. Das, Dr. A. A. Murkute, and Dr. A. Thirugnanavel, delivered lectures on citrus cultivation. After the program, two farmers' orchards were also inspected and necessary guidelines and recommendations were suggested.

10.3 Establishment of demonstration blocks

A field demonstration of Mosambi and Nagpur mandarin was done during June 2020 under NEH plan in farmer's field at village Narayanpur, Lakhimpur District, Assam under CCRI-RRCC, Biswanath Chariali. Planting material of Mosambi and mandarin was given to progressive farmer Sh Bhaben Saikia The plantation was completed as per the instructions of Dr. M. S. Ladaniya, Director and Scientists of ICAR-CCRI, Nagpur.

10.4 Infrastructure development

Construction work of farm building and tractors inplement shed completed in the year, 2020.

Dr. M. S. Ladaniya, Director; Dr. G. T. Behere and Dr. R. K. Sonkar inspecting demonstration plot in farmer's field

10.5 Disposal of fruits produced at RRCC, Biswanath Chariali, Biswanath, Assam

Considerable quantity of fruit was produced in 2nd year of bearing (2020-21) at RRCC and arrangements were made for sale of this fruit (Mosambi, Cutter Valencia and other sweet orange, grapefruit, acid lime and other citrus fruit) through Biswanath college of Agriculture.

New farm building under construction at RRCC, Assam

New Tractor Shed built at RRCC, Assam

New Mosambi plantation in demonstration plot

11 On- Going Research Programmes and Projects

S.N.	Project Title	Project Leader	Co-Investigators
In – House projects			
1.	National citrus repository at CCRI	I.P. Singh (upto March, 2020) A.A. Murkute (wef 1st April, 2020)	N. Vijayakumari, D.K. Ghosh, A.K. Das, A. A. Murkute (upto March, 2020), Anjitha George, A. Thirugnanavel, Dinesh Kumar and J. P. Tej Kumar
2.	Sub Project : Citrus repository at RRCC, Biswanath Chariali, Assam	I.P. Singh (upto March, 2020) A.A. Murkute (wef 1st April, 2020)	Kiran Kumar Kommu, A. A. Murkute (upto March, 2020), Anjitha George, D. K. Ghosh and A. Thirugnanavel
3.	Improvement of important commercial citrus scions and rootstocks through *in vitro* techniques	N. Vijayakumari	J. P. Tej Kumar and A. Thirugnanavel
4.	Mutation breeding in citrus	A. A. Murkute	I. P. Singh (upto March, 2020), A. K. Das, G.T . Behere A. Thirugnanavel and J. P. Tej Kumar
5.	Genetic improvement of citrus through hybridization	A. A. Murkute	I. P. Singh (upto March, 2020), J. P. Tej Kumar, A. Thirugnanavel, D. K. Ghosh and G. T. Behere
6.	Molecular characterization of citrus germplasm	J. P. Tej Kumar	A. A. Murkute, I. P. Singh (upto March, 2020) and A. Thirugnanavel
7.	Improvement of citrus rootstocks through hybridization	A. Thirugnanavel	I. P. Singh (upto March, 2020), A. A. Murkute, J. P. Tej Kumar, D. K. Ghosh and N. Vijayakumari
8.	Retrofitting of citrus nursery phase for optimizing the production costs of planting stock	N. Vijayakumari	A. Thirugnanavel
9.	Evaluation of citrus rootstocks for improving productivity and quality of citrus	R. K. Sonkar	I. P. Singh (upto March, 2020), A. K. Das, A. A. Murkute and A. Thirugnanavel
10.	Development of INM Module for Sustained Productivity of Citrus	A. K. Srivastava	A. D. Huchche
11.	Response of citrus trees to training, pruning and plant growth retardants with respect to management of canopy architecture, plant density and productivity	M. S. Ladaniya	A. D. Huchche, A. K. Das, P. S. Shirgure, Anjitha George and A. Thirugnanavel

S.N.	Project Title	Project Leader	Co-Investigators
12.	Studies on dynamics of flowering and fruiting in citrus	A.D. Huchche	P. S. Shirgure
13.	Abiotic stress management in citrus	A. D. Huchche	P. S. Shirgure and A. A. Murkute
14.	Evaluation of citrus spp. on raised bed planting system	M. S. Ladaniya	R. K. Sonkar, A. K. Das, Anjitha George and A. Thirugnanavel
15.	Studies on physiological disorders of citrus fruits	A. D. Huchche	P. S. Shirgure and A. K. Das
16.	Technology Demonstration on Canopy architecture management in citrus through training and pruning for higher density and increased productivity	M. S. Ladaniya	A. D. Huchche, A. K. Das, Anjitha George and A. Thirugnanavel
17.	Precision citriculture through enhanced water and nutrient use efficiency in Nagpur mandarin	P. S. Shirgure (upto 10th November, 2020)	A. K. Srivastava and A. D. Huchche
18.	Development of advanced citrus production system	A. K. Srivastava	P. S. Shirgure (upto 10th November, 2020) , A. K. Das A. Thirugnanavel, and Anjitha George
19.	Adoption and Impact Assessment of ICAR – CCRI Technologies. In Vidarbha region of Maharashtra	S. Bhattacharyya	R. K. Sonkar
20.	Studies on multiplication and management of fruit piercing moths *Eudocima* sp	Anjitha George	Kiran Kumar Kommu and G. T. Behere
21.	Endophytic bacteria and fungi as bioagents for management of *Phytophthora* diseases in citrus	A. K. Das	Kiran Kumar Kommu
22.	Studies on the prevalence and distribution of plant parasitic nematodes associated with citrus in India	Kiran Kumar Kommu	A. K. Das
23.	Studies on extending the storage life of citrus furits	Dinesh Kumar	M. S. Ladaniya
24.	Screening of citrus germplasm across India for bio-active compounds at maturity and during storage	Dinesh Kumar	M. S. Ladaniya, I. P. Singh (upto March, 2020), A. A. Murkute and A. Thirugnanavel
25.	Functional food, value added products and beverages from citrus fruits.	Dinesh Kumar	M. S. Ladaniya
Collaborative Project with ICAR-RC for NEH, Umiam			
1.	Demonstration of rejuvenation technology of citrus orchards	R. K. Sonkar	Sangeeta Bhattacharyya, G. T. Behere, Kiran Kumar Kommu, D. M. Firake, Tasvian Rahman Borah and A. Balusamy

S. N.	Project Title	Project Leader	Co-Investigators
RRCC, Biswanath Chariali, Assam			
1.	Evaluation of different citrus varieties on raised and flat bed planting system ar RRCC, Biswanath Chariali, Assam	R. K. Sonkar	M. S. Ladaniya, I. P. Singh (upto March, 2020), Kiran Kumar Kommu, and A. Thirugnanavel
Network Project			
1.	Consortium Research Platform on Vaccines and diagnostics (Citrus viruses)	D. K. Ghosh	----
Externally Funded Projects			
1.	Horticultural pest surveillance, advisory and management project (HORTSAP) for Nagpur mandarin in Maharashtra – Funded by Maharashtra State Government	A. D. Huchche	A. K. Das and Anjitha George
2.	Molecular diagnostics, transcriptomics and cisgenic approaches to combat Greening (Huanglongbing) disease of citrus [DBT funded]	A. K. Das	---
3.	CHAMAN (Coordinated Horticulture Assessment and Management using Geo - informatics) - MNCFC, New Delhi Funded	A. D. Huchche	
4.	Effect of citrus root exudates on survival, penetration and development of *Tylenchulus semipenetrans* and *Meloidogyne indica* - (SERB-DST Funded)	Kiran Kumar Kommu	----
5.	Evaluation of antimicrobial Nano-zinc oxide-2S albumin protein formulation on HLB infected plants - SERB (DST funded).	D. K. Ghosh	
6.	To develop potential inhibitor molecules against putative cystine-binding protein from *Candidatus* Liberibacter asiaticus SERB (DST funded).	D. K. Ghosh	
Contract Research projects			
1.	"Evaluation of membrane assisted controlled atmosphere storage for enhancing shelf life of Nagpur mandarin fruits" - Funded by M/s. Yashasvi Enterprises, Airoli, Mumbai.	Dinesh Kumar	M. S. Ladaniya
2.	Studies on Agrocel-based Potassium Schoenite (Mahalaabh) in Citrus Funded by Agrocel Industries Pvt. Ltd,.Mumbai	A. K. Srivastava	P. S. Shirgure (upto 10 th November, 2020)
All India Coordinated Research Projects			
1	Citrus Germplasm	I.P. Singh (upto March, 2020) A. A. Murkute (from 1st April, 2020)	
2	Citrus rootstocks	R. K. Sonkar	
3	Citrus Nutrition	A. K. Srivastava	A. D. Huchche
4	Citrus diseases – greening	A. K. Das	

ITMU and ITMC meetings for Commercialization of Developed Technologies

- Organized ITMU meeting for Commercialization of Following Technologies :
  - ✓ LAMP based diagnostic kit for citrus greening disease (HLB) on 26th June, 2020 Institute, Nagpur.
  - ✓ RT-LAMP based diagnostic kit for citrus Tristeza virus (CTV) on 26th June, 2020.
- Organized ITMC meeting for Commercialization of Following Technology :
  - ✓ Release of Alemow (*Citrus macrophylla*) as a rootstock on 21st July, 2020.
  - ✓ Pheromone trap: A cost effective monitoring tool against citrus leaf miner on 21st July, 2020.

Agri-Business Incubation (ABI) Centre (Under Component II of NAIF Scheme)

1. Signed MoU between ICAR-CCRI, Nagpur and M/s. Karunamaya Agrotech, Nagpur. (As incubatee under 'ABI' Project) for "High-tech nursery management for production of disease- free planting material in citrus" on 15th September, 2020.
2. Enriched the Value Added Product Development Lab by procurement of Fruit Juice Pasteurizer for pasteurizing the citrus juice during product preparation.

Signing of agreement between ICAR-Central Citrus Research Institute and M/s Karunamaya Agrotech, Nagpur

Business Planning & Development Unit

13 RAC, IRC and IMC meetings Recommendation / Decision

13.1 Institute Research Committee (IRC)

The Thirty Second Institute Research Committee (IRC) meeting was held during 20-21 May, 2020 under the Chairmanship of Dr. M. S. Ladaniya, Director. The meeting was conducted by Dr. A. K. Das, Member Secretary, IRC. The two days meeting was conducted according to the MHA, GoI guidelines on COVID-19, by wearing face covers, observing social distancing norms and all other directives.

IRC meeting in progress

13.2 Research Advisory Committee (RAC)

The Twenty-fourth (XXIV) Research Advisory Committee (RAC) meeting was held under the Chairmanship of Dr. D. P. Ray, Former VC, OUAT, Bhubaneshwar on 4th December, 2020 at CCRI, Nagpur in virtual mode due to COVID - 19 Pandemic. Other members present were Dr. M. S. Ladaniya, Director, CCRI; Dr. P. P. S. Pannu; Dr. D. V. K. Samuel; Dr. R. K. Rattan and Dr. D. K. Ghosh, Member Secretary. Sh. A. M. Raut, farmer representative was also present.

Virtual RAC meeting in progress

13.3 Institute Management Committee (IMC) meeting

The virtual XXXVII meeting of the IMC was held on 11th December, 2020 under the Chairmanship of Dr. M. S. Ladaniya, Director, CCRI, Nagpur. Members present were Dr. B. K. Pandey, Assistant Director General (HS-II), ICAR, New Delhi, Dr. D. V. Sudhkar Rao, Pr. Scientist, IIHR, Bengaluru, Dr. Anuradha Upadhyay, Pr. Scientist, NRC Grapes, Pune, Dr. Govindrao Hande, Technical Consultant for export to the Agri. Dept, Representative of Director of Horticulture Pune (MS), Dr. V. K. Kharche, Director of Research, Dr. PDKV, Akola, Shri Anand Motiram Raut, Progressive farmers, Nagpur, Shri. Y. V. Sorte, AF&AO, ICAR-CCRI, Nagpur and Dr. A. K. Das, Pr. Scientist and I/c AO, was the Member Secretary.

13.4 Journalists meet

A team of sixteen (16) eminent journalists, editors and photographers from PIB, Ministry of Information and Broadcasting GoI, Bhopal, Madhya Pradesh visited institute on 18th February, 2020. Dr. M. S. Ladaniya, Director briefed about the citrus scenario of the Country and also achievement and progress of TMC for Chhindwara was presented. Later, they were shown the various research activities and visited citrus experimental blocks and nurseries of the institute.

Journalists and editors of PIB, Min. of I & B, GoI, Bhopal

14 Participation of Scientist in Conferences/Workshop/Symposia/Meeting etc.

14.1 Participation

Name and Designation	Programme	Place and date/duration
Dr. M.S. Ladaniya; Dr. N. Vijayakumari, Dr. A.D. Huchche; Dr. I.P. Singh; Dr. D.K. Ghosh; Dr. R.K. Sonkar; Dr. A.K. Das; Dr. Dinesh Kumar; Dr. A.A. Murkute; Dr. A. Thirugnanavel; Dr. Anjitha George; Dr. J.P. Tej Kumar; Dr. Kiran Kumar Kommu and Ms. Sangeeta Bhattacharyya	National Citrus Meet – 2020	Biswanath College of Agriculture, Biswanath Chariali, Assam on 10-12th January, 2020
Dr. A.D. Huchche, Pr. Scientist (Hort.)	National Conference on Agriculture and Horticulture – 2020	NASC, New Delhi on 17th January, 2020
Dr. A.A. Murkute, Pr. Scientist (Hort.)	International Convention on "Perspectives to face contemporary challenges of Agricultural Development"	NASC, New Delhi on 18-19th February, 2020.
Dr. A.D. Huchche, Pr. Scientist (Hort.)	Technical Committee and Crop Specific Technical Sub-Committee for standardization of Term Sheet, Weather Trigger & Risk periods for crop notified under RWBCIS	Krishi Bhavan, New Delhi on 22nd February, 2020
Dr. M.S. Ladaniya, Director, Dr. A.K. Das, Pr. Scientist (Plant Pathology) and Dr. A. A. Murkute, Pr. Scientist (Hort.)	Meeting with Hon'ble VC, Scientists and professors w.r.t. Formulation of DBT project on Citrus in North-Eastern region.	Assam Agril. University, Jorhat, 18-19 March, 2020
Dr. A.D. Huchche, Pr. Scientist (Hort.)	CHAMAN project Review Meeting	9th April, 2020
Ms. Sangeeta Bhattacharyya, Scientist (Extension)	National Webcon on Agricultural Production & Support System Managing Covid 19 Pandemic: Experience Sharing & Strategies	Chandra Sekhar Azad University of Agriculture and Technology, Uttar Pradesh, 6-8th May, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Horticulture technologies for increasing farmers income" organised by Progressive Horticulture Journal through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand, 10th May, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar Cosmic farming in horticulture organised by Progressive Horticulture Journal through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand, 17th May 2020
Ms. Sangeeta Bhattacharyya, Scientist (Extension)	Webinar Series on Quantitative Methods for Social Sciences	ICAR-NIAEPR, New Delhi on 1-18 June, 2020
Dr. J.P. Tej Kumar, Scientist (Biotechnology)	Meeting on "ICAR Krishi Geoportal Spatial Data Infrastructure and Application – A Way forward"	NBSS&LUP, Nagpur on 2nd June, 2020
Dr. A.D. Huchche, Pr. Scientist (Hort.) and Dr. A.K. Das, Pr. Scientist (Plant Pathology)	Online workshop "Citrus Production Technology and Perspective"	KVK, AgarMalava, M.P. on 4th June, 2020
Ms. Sangeeta Bhattacharyya, Scientist (Agril. Extension)	Twenty-fifth Scientific Advisory Committee Meeting	KVK, ICAR-CICR, Nagpur on 10th June, 2020

Name and Designation	Programme	Place and date/duration
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Horticulture in northeast India: challenges and opportunities" Progressive Horticulture Journal through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand on 14th June, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Mango improvement: status and challenges" Progressive Horticulture Journal through Facebook Live as Horticulture conclave.	Indian Society of Horticultural Research and Development, Uttarakhand on 17th June, 2020
Dr. G.T. Behere, Pr. Scientist (Ento.)	"National Webinar on "Presentations of Newly Elected NAAS Fellow"	National academy of Agricultural Sciences (NAAS), New Delhi on 22nd and 24th June, 2020.
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Pomegranate-the ancient fruit in modern horticulture" and "Future vegetable research needs: directions and opportunities" organised by Progressive Horticulture through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand on 28th June, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Innovations in horticulture for employment and prosperity" organised by Progressive Horticulture Journal through Facebook Live as Horticulture conclave,	Indian Society of Horticultural Research and Development, Uttarakhand on 3rd July, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	"Temperate fruits challenges and opportunities" by Progressive Horticulture Journal through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand on 8th July, 2020
Dr. Dinesh Kumar, Pr. Scientist (Hort.)	20th Virtual meeting of Scientific Panel	FSSAI, New Delhi on 11th July, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Lecture on "Vegetable grafting" by Progressive Horticulture Journal through Facebook Live as Horticulture conclave	Indian Society of Horticultural Research and Development, Uttarakhand on 15th July, 2020
Dr. M.S. Ladaniya, Director and Scientists	92nd Foundation Day and Award Ceremony of the ICAR	ICAR, New Delhi on 16th July, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	ICAR-NRCB webinar Organic Banana production and certification the status and way forward	National Research Centre for Banana, Tamil Nadu on 18th July, 2020
Dr. G.T. Behere, Pr. Scientist (Ento.)	"National Webinar on Biodiversity and Biological Diversity Act, 2002''	National Biodiversity Authority (NBA) and UNDP India on 22nd July, 2020.
Dr. M.S. Ladaniya, Director	Agrovision Advisory Council Meeting	MAFSU, University, Nagpur on 23rd July, 2020

Name and Designation	Programme	Place and date/duration
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Precision farming in Banana''	ICAR- National Research Centre for Banana, Tamil Nadu on 25th July, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar "Bio-enhancers for organic production" organised by Progressive Horticulture Journal through Facebook Live	Indian Society of Horticultural Research and Development, Uttarakhand on 26th July, 2020
Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Webinar on "Integrated Disease management in Banana"	ICAR- National Research Centre for Banana, Tamil Nadu on 29th July, 2020
Dr. G.T. Behere, Pr. Scientist (Ento.)	Online "National Stakeholders Dialogue on Current Challenges and Way Forward for Pesticides Management"	TAAS, New Delhi, Indian Society of Phytopathology, New Delhi, and Entomological Society of India on 24th July, 2020
Dr. M.S. Ladaniya, Director and Scientists	"Launching of Integration of ICAR-IIHR seed portal with SBI, YONO Krishi" by Hon'ble Shri Narendra Singh Tomar, Union Minister of Agriculture and Farmers Welfare, Government of India	ICAR-IIHR, Bengaluru on 26th August, 2020
Dr. Anjitha George, Scientist 'SS' (Ento.)	AGRIOTA CROP DATA for connecting farmers	DMCC on 26th August, 2020
Dr. Kiran Kumar Kommu, Scientist (Nematology)	National Webinar on "Boosting immunity through Horticulture"	Society for Horticulture Research and Development, Ghaziabad, UP on 1-9th September, 2020
Dr. M.S. Ladaniya, Director and Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	7th Dr. B. P. Ghildyal, Soil Physicist memorial lecture through a virtual platform	Society of Agrophysics and hosted by the Division of Agricultural Physics, ICAR-IARI, New Delhi on 10th September, 2020
Dr. M.S. Ladaniya, Director	Meeting on review of research achievements for last five years	SMD (Hort. Sci.), ICAR, New Delhi on 23rd September, 2020
Dr. A. K. Srivastava, Pr. Scientist (Soil Science) and Dr. P. S. Shirgure, Pr. Scientist (L&WME)	Webinar on Water soluble Fertilizers in India-status and way forward	FAI, IPI New Delhi on 23rd September, 2020
Dr. Kiran Kumar Kommu, Scientist (Nematology)	Webinar on "Sustainable food production: Myths and Realities"	NMIMS on 26th September, 2020
Dr. A. A. Murkute, Pr. Scientist (Hort.)	Management Board meeting	RVSKVV, Gwalior on 22nd August, 2020
Dr. M.S. Ladaniya, Director and Dr. A.K. Das, Pr. Scientist (Plant Pathology)	Inauguration of College and Administration Buildings by Hon'ble Prime Minister, Shri Narendra Modi-ji	Rani Lakshmi Bai Central Agricultural University, Jhansi, UP on 29th August, 2020
Dr. M.S. Ladaniya, Director along with Scientists	Global Summit on Responsible AI for Social Empowerment (RAISE 2020)	5-9 October, 2020

Name and Designation	Programme	Place and date/duration
Dr. M.S. Ladaniya, Director	Preliminary meeting of EFC/SFC schemes	Horticultural Science Division, ICAR, New Delhi on 22nd October, 2020
Dr. M.S. Ladaniya, Director	48th Joint Agricultural Research and Development Committee	27th October, 2020
Dr. A.A. Murkute, Pr. Scientist (Hort.)	Nursery Accreditation at Varhokar Nursery	Shedurjana Ghat Amravati on 10th November, 2020
Dr. A.D. Huchche, Pr. Scientist (Hort.)	Steering Committee meeting through video conferencing of Crop surveillance and advisory project 2020-21,	Commissionerate of Agriculture, Pune on 11th November, 2020
Ms. Sangeeta Bhattacharyya, Scientist (Extension)	Dialogue 2020 on "Future of Agricultural Extension and Advisory services"	MANAGE, Hydrabad on 18-20 November, 2020
Dr. A.D. Huchche, Pr. Scientist (Hort.)	Interface meeting between Goa state department of agriculture and ICAR institutes for drawing a road map of agriculture development in the state of Goa.	Panji, Goa on 25th November, 2020
Ms. Sangeeta Bhattacharyya, Scientist (Extension)	Workshop on "Psychometric scale construction techniques : Basic to advances"	ICAR-NDRI, Karnal on 24-28th November, 2020
Dr. M.S. Ladaniya, Director	Director Conference, ICAR, New Delhi	5th December, 2020
Ms. Sangeeta Bhattacharyya, Scientist (Extension)	"Emerging Agricultural Research to Endure the Predicament of COVID-19 Pandemic"	Triveni Devi Bhalotia College, Kazi Nazrul University, West Bengal on 12-13th December, 2020
Dr. D. T. Meshram, Pr. Scientist (L&WME)	29th National Web Conference, SCSI	NASC Complex, New Dehli on 29-30th December, 2020

14.2. Lectures delivered by CCRI Scientists in training / skill development / other programmes

- Training programme on Orange Cluster for Exports at VANAMATI, Nagpur 7th January, 2020.
  - Dr. A. K. Srivastava : Soil Fertility & Nutrient Management for Nagpur mandarin.
  - Dr. A. D. Huchche : '*Mrig & Ambia bahar* Management in Nagpur mandarin.
- Dr. I. P. Singh (2020) : Citrus Biodiversity, Its Conservation and Utilization during ICAR sponsored winter school on Non-conventional Approaches for Genetic Improvement of Perennial Horticultural crops from 17th January to 6th February, 2020 at IARI, New Delhi
- Dr. M. S. Ladaniya (2020) : Exportable Santra production and export promotion at Karanja (Ghadge), Wardha on 29th January, 2020.
- Dr. G. T. Behere (2020): Integrated management of insect pests in Nursery in Training Programme organized by TAO, GoM at Susundri, Taluka-Kalmeshwar, District- Nagpur on 11th March, 2020.
- Dr. A. Thirugnanavel (2020) : "Eco-friendly farming practices in citrus crops" during the Faculty development programme on "Climatic changes adaptation and Alterations in farming practices" organized by Kalasilingam Academy of Research and Education during 25th May to 31st May, 2020.
- Dr. A. K. Srivastava (2020): Soil health care of fruit crops-Breakthroughs and challenges on Hortalk-10 series on 27th May, 2020.

- Dr. A. D. Huchche (2020): "Advanced Production Technology of Kagzi lime" KVK, Baramati on 28th May, 2020
- Dr. A. K. Das (2020) : "Disease management in Mandarin crop", in Farmers' training on Mandarin Production post COVID-19 organized by KVK Agar Malwa (MP) on 4th June, 2020
- Dr. A. K. Srivastava (2020) : Soil fertility and nutrition management in citrus organised by Krishibodh (Kisan samwad) on 2nd July, 2020
- Dr. Dinesh Kumar (2020) : Citrus fruits processing and value addition in the webinar on Processing of Acid Fruits at College of Horticulture, SDAU, Mehsana, Gujarat, September, 2020
- Dr. A. K. Srivastava (2020) : "Nimbu Vargiya phalo me mrida swasthya ebam poshan prabandhan" organized by Krishibodh, Pune on 2nd July, 2020
- Dr. A. D. Huchche (2020) : Management of Ambia Bahar at RAMETI on 4th July, 2020.
- Dr. Anjitha George (2020) : "Integrated Insect Pests and Nematodes Management in Banana" NRC for Banana, Trichy on 4th July 2020.
- Dr. Anjitha George(2020) : "Monitoring of insects pests and their management for HORTSAP Scouts', supervisors' and master trainers (online) on 9th July, 2020
- Dr. A. K. Das, (2020) : Integrated disease Management in Citrus training on Nagpur mandarin Bahar Management Organized by Agri. Dept. GoM on 16th December, 2020
- Online training on Citrus for farmers at RAMEI, Amravati.
  - ✓ Dr. A. D. Huchche (2020) : Management of Ambia bahar on 16th July and 4th August, 2020
  - ✓ Dr. G. T. Behere (2020): "Integrated Management of Citrus Pests" on 17th July, 2020
  - ✓ Dr. Anjitha George (2020) : Insect pest management in citrus on 7th August, 2020.
- Online training for farmers through webinar (on Citrus) at RAMETI, Nagpur Govt of Maharashtra 12, 13 & 27 August, 2020
  - ✓ Dr. G. T. Behere : Integrated Management of Insect Pests of Citrus on 12th August, 2020
  - ✓ Dr. A. K. Das : संत्रा पिकावरील प्रमुख रोग on 13th and 27th August, 2020
- Online training on "Management of Fruit Drop" organized by RAMETI, Amravati, GoM for the farmers of Warud, Morshi and Tivsa Taluka on 17th August, 2020
  - ✓ Dr. A. K. Das : "Disease Management in Nagpur mandarin"
  - ✓ Dr. G. T. Behere : "Integrated Management of Citrus Pests"
- Online training program on "Management of Fruit Drops" organized by RAMETI, Amravati, GoM for the farmers of Achalpur and Anjangaon Surjee of Amravati District on 19th August, 2020
  - ✓ Dr. A. D. Huchche : Santra Bahar Vevasthapan
  - ✓ Dr. A. K. Das : Santra Rog Vevasthapan
  - ✓ Dr. G. T. Behere : Santra Kid Vevasthapan
- Online training program on "Management of Fruit Drops" organized by RAMETI, Amravati, GoM for the farmers of Naandgaon, Dhamnagaon Railway, Chandur Bazar Taluka on 20th August, 2020
  - ✓ Dr. A. K. Das : "Disease Management in Nagpur mandarin.
  - ✓ Dr. G. T. Behere : Integrated Management of Citrus Pests
- Dr. A. K. Srivastava (2020) : Guest Speaker : "Post pandemic management in fruit crops" National Webinar organised by Confederation of Horticulture Association of India, Pusa, Bihar; ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar, Lt Amit Singh Memorial Foundation, Mahamada, Samastipur during 3rd September, 2020.
- Dr. A. K. Srivastava (2020) : "Integrated nutrient management" in an online training programme at RAMETI, Nagpur on 11th September, 2020
- Dr. A. K. Srivastava (2020) : Keynote Presentation: "Climate - Smart Soil Fertility Management in Perennial Fruits", International Web Conference on Perspective on Agricultural and Applied Sciences in COVID-19 Scenario (PAAS-2020) Jointly Organized by

Agricultural & Environmental Technology Development Society (AETDS), U.S. Nagar, Uttarakhand, India; Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh; Shobhit Institute of Engineering & Technology (A NAAC Accredited, Deemed to be University), Meerut, India; Soils, Water and Environmental Res. Inst, (SWERI), Agriculture Research Center, (ARC) Giza, Egypt, Rajiv Gandhi Central University, Itanagar, and Corteva agriscience during 4-6 October, 2020.

- Dr. A. K. Srivastava (2020) : Keynote Lecture: "Climate-smart soil fertility management in perennial fruits", Webinar on Plant Science and Biosecurity organised by Innovinc group, Great America PKWY, United State during 12-13 October, 2020.
- Dr. A. K. Srivastava (2020) : Keynote Speaker: "Climate smart soil fertility management in fruit crops and its impact on nutritional value", International Virtual Conference on "Plant based food: Potential for food security and pandemic management" organised by Department of Food Science and Technology, MNS University of Agriculture, Multan (Pakistan) on 15-16 October, 2020.
- Dr. A. K. Srivastava and Dr. P. S. Shirgure : "Water and Nutrient Management" Dr. A. D. Huchche : "Pre-harvest fruit drop management", "Management for growth in fruit size" and "Weed Management and Dr. A.K. Das and Dr. G.T. Behere : "Disease and Insect Pest Management" delivered lecture in HORTSAP Farm School Training on 21st October, 2020 at Savangi Village under the jurisdiction of Hingna Taluka Krishi Adhikari Officer
- Dr. A. K. Srivastava (2020) : "Integrated Nutrient Management in orange fruit crop" in the online training of "Orange fruit crop management" organized by Vasantrao Naik State Agriculture Extension Management training Institute, Dharampeth, Nagpur during 9-10th November, 2020
- Dr. A. Thirugnanavel (2020) : "Preharvest operations to improve post harvest shelf life of fruits and vegetables" for III year B.Sc students of Imayam Institute of Agriculture and Technology, Tamil Nadu on 24th November, 2020
- Dr. A. K. Srivastava, (2020) : "Research opportunities in citrus" through virtual mode to students of Shri Mathuradas Mohota College of Science, Nagpur on 3rd December, 2020
- Dr. A. K. Srivastava (2020) : "What is research? Plan and process of research and its importance", Online workshop on Research Methodology and Scientific Writing organised by Department of Biotechnology and Biochemistry, Dr. Ambedkar College, Deekshabhoomi, Nagpur, during December 14-16, 2020.
- Dr. A. K. Srivastava (2020) : Keynote Presentation: "Integrated nutrient management in different tropical fruits crops", National webinar on Integrated Nutrients Management in Horticulture Crops organised by College of Horticulture, Maharana Pratap Horticulture University, Karnal, Haryana during December 16-17, 2020.

14.3. TV Telecast / Social media

- Provided video on "Management of Ambia bahar of Nagpur Mandarin and Mosambi" prepared by Dr. A. D. Huchche to VANAMATI on 26th September, 2020 for uploading in their YouTube channel "Vanamati Orange" for disseminating CCRI technology to citrus growers all over India.
- Video documentation of success stories of two citrus growers of Telkamtee village, Kalmeshwar taluka in Nagpur district of Maharashtra was done and uploaded in CCRI YouTube channel on 6th November, 2020.

15.1 National Citrus Meet 2020

ICAR-Central Citrus Research Institute Nagpur, completed 35 years of its service to the nation in 2020. After upgradation, the institute established a Regional Research Centre for Citrus (RRCC) at Biswanath Chariali, Assam to address the issues regarding the citrus crops in the North-Eastern region. "National Citrus Meet-2020" was organized during 10-12, January 2020 in collaboration with Assam Agricultural University, Assam; Central Agricultural University, Imphal; ICAR - Research Complex for North-Eastern Hill Region, Umiam, Meghalaya. The theme was - "Development of Citrus in North- Eastern Region". Total 150 delegates including citrus experts, horticulturists, State Agric. department officials, KVK Subject matter specialists & Programme Coordinators, development agencies, University faculties, scientists, students and farmers participated. During Inaugural Session on 10th January, Dr. K. V. Prabhu, Chairperson, PPV&FRA was the Chief Guest, while Dr. A. K. Singh, DDG (Hort. Sci.), ICAR; Dr. Ashok Bhattacharya, Vice Chancellor (I/C), AAU; Dr. B. K. Kandpal, Director (I/C), ICAR RC for NEH Region and Dr. R. N. Barman, Associate Dean, BNCA, Biswanath Chariali were Guests of Honour.

Dr. K. V. Prabhu stressed the need for registration of the citrus varieties. He appealed to scientists to develop techniques to identify the duplicates in germplasm and focus on germplasm collection and cataloging. Dr. A. K. Singh stressed on improving productivity value addition and economics. He emphasized on green but low cost technologies for doubling farmers' income.

Dr. M. S. Ladaniya, in his welcome address highlighted the activities of ICAR-CCRI and RRCC in the recent years. He stated that Institute will provide first-hand information and all details about cultivation, marketing and post-harvest management of citrus fruits in North-Eastern region. The three day meet included 7 technical sessions comprising nursery management to post harvest management and socio economic issues with oral and poster presentations.

The 'Souvenir and Abstracts' and Extension bulletin on 'Improved cultivation practices for Khasi mandarin in Mizoram' were released. The 'Citrus diversity show' was also organized in which wide varieties of citrus fruits from eight North Eastern States were displayed. Farmers interaction with scientists was also held during which issues raised by them were addressed. During the valedictory programme on 12th January, Mr. Dhrubajyoti Das, Deputy Commissioner, Biswanath was the Chief Guest, while Mr. Abdul Jalil, Director, Horti. & Food Processing, Assam Mr. Mangthiana, Joint Director (Hort.), Mizoram were Guests of Honour. Dr. R. N. Barman, Associate Dean, BNCA proposed Vote of thanks. The three day meet organized at RRCC was a grand success.

Dignitaries releasing Abstract and Souvenir of National Citrus Meet on 10th January, 2020

Dr. A. K. Singh, DDG (HS), ICAR laying foundation stone of Farm House Building and Tractor shed of RRCC at Biswanath Chariali, Assam

DDG (Hort. Sci.) laid the two foundation stones i.e. 1) Farm House Building and Tractor Shed. 2) Foundation stone of the Regional Research Centre for Citrus at Biswanath Chariali, Assam. This is the land mark activity of the CCRI on its 35th anniversary year in 2020.

Dr. A. K. Singh, DDG (HS), ICAR laying foundation stone of RRCC at Biswanath Chariali, Assam

15.2 Visit of Parliamentary Standing Committee

Parliamentary Standing Committee on Agriculture visited ICAR-CCRI, Nagpur as a study tour on 24th January, 2020. The committee consisting of parliament members (Lok Sabha and Rajya Sabha) viz. Sh. Parvathagouda Chananagouda Gaddigowder, Chairman, Sh. Afzal Ansari, Sh. A. Ganeshamurthi, Sh. Kanakmal Katara, Sh. Ram Kripal Yadav, Sh. Kailash Soni, Sh. Devji Mansingram Patel, Sh. Shiv Kumar (JS, Parliament), Mrs. Navneet Ravi Rana and Mrs. Shardaben Anilbhai Patel apart from officials such as Sh . Nirantar Kumar Singh (Reporting Officer), Sh. Rajeev Kumar Sharma, Sh. Rajesh Singh Solanki, and Sh. Sumesh Kumar. From ICAR side, Dr. R. K. Singh, ADG (Commercial Crops) and Dr. W. S. Dhillon ADG-I (Hort. Sci.) were present apart from all the scientists of the institute and invited progressive farmers. All the committee members were given the documents such as Highlights/ achievements of the CCRI and detailed response of the institute on 32 points for discussion given by the committee before their arrival apart from CCRI publications. Dr. M. S. Ladaniya, Director, CCRI welcomed the visitors and gave the detailed power point presentation of the institutes achievements, technologies developed, outreach programmes for the

Visit of parliamentary standing committee to post harvest technology lab

Parliamentary Standing Committee meeting in progress at CCRI, Nagpur

stakeholders and commercialization of technologies. The constraints and future requirements were also discussed. Hon'ble members of parliamentary committee also enquired about manpower and new regional Centre of the institute in Assam. The committee was happy to know that Institute is having citrus nursery with "5-Star" rating in India and supplying disease-free planting material all over the country.

The new varieties and products were displayed in which Hon'ble members took lot of interest. Thereafter, Committee visited Post-harvest technology laboratory. The committee appreciated the progress and programmes of the institute.

15.3 International Women's Day

ICAR-CCRI, Nagpur celebrated International Women's Day - (Theme "I am generation equality: Realizing Women's

rights") on 8th March, 2020. The Institute organized programmes especially for women wherein Dr. (Mrs.) Sushila Takbhoure, Rtd. Professor of Seth Kesarimal Porwal College, Nagpur was the Chief Guest in which 25 students of College of Agriculture and Institute staff participated.

Dr. (Mrs.) Sushila Takbhoure, Rtd. Professor addressing the staff

15.4 Foundation Day Celebration

ICAR - Central Citrus Research Institute completed a glorious 35 years of service to the citrus industry of the country on 28th July, 2020 and celebrated its 36th Foundation Day. The institute marked its 36th Foundation Day through a Tree Plantation Drive conducted on 27th July, 2020 in the campus where all staff took part in plantation of trees like custard apple, aonla, neem, kadamb etc.

On 28th July, 2020 the Foundation Day programme was held by strictly following all precautions of COVID-19. The programme was conducted in video conference mode where dignitaries and participants joined the program virtually from all over India. Dr. C. D. Mayee (Ex-Chairman, ASRB, ICAR, New Delhi) graced the occasion as Chief Guest. Director congratulated the staff and all farmers connected virtually for successful completion of 35 years of the institute. It was followed by the virtual inaugural address of Dr. A. K. Singh, DDG, Horti. Sci., ICAR which was conveyed to the gathering through Dr. Vikramaditya Pandey. He applauded the institute's research activities and also highlighted how citrus has now become an essential food in the wake of the pandemic for its inherent immunity boosting capabilities.

Group of CCRI staff honoured along with Chief Guest Dr. C.D. Mayee and Dr. M.S. Ladaniya, Director

CCRI Annual Report 2019 and an Extension Bulletin in Hindi were relcesed on the ocassion. 'Nagpuri santre ke kire makode aur unka prabandhan'. The prize distribution ceremony followed where 12 staff Dr. Kiran Kumar Kommu, Scientist (Nematology), Ms. Lily Varghese, CTO, Sh. V. N. Dhengre, ACTO, Sh. V. P. Bhaladhare, TO, Sh. A. B. Gadge, TO, Sh. B. G. Awari, TO, Sh. S. W. Ambekar, AAO, Sh. P.M. Khobragade, Jr. Clerk, Sh. Namdeo Thakare, SSS, Sh. Sunil Kharche, SSS, Sh. Vinayak Khuspure, TSL and Sh. Dinkar Asatkar, TSL were honoured for their significant contribution towards the development of the institute. The institute also honoured five progressive citrus growers for contributing significantly to citrus industry of Central India through their scientific farming techniques, innovations and dissemination of knowledge to fellow farmers. Shri. Amol Tote (Hiwarkhed, Amravati), Shri. Sagar Chikte (Dawargaon, Warud, Amravati), Shri. Keshav Bhakte (Hetikundi, Wardha), Shri. Raju Vaidya (Mohgaon, Saunsar, Chhindwara) and Shri. Dadasaheb Keshawrao Kale (Katol, Nagpur) were recipients of the felicitation that included shawl, shreephal, certificate of honour and a cash prize.

While addressing the participants Chief Guest, Dr. C.D Mayee appreciated the institute for its concerted efforts in research and also in development of disease free planting materials which has proved as a milestone in the history of CCRI's achievements. Dr. K. B. Patil (President, Jain Irrigation Systems, Jalgaon) emphasized on the need for

research on citrus varieties for juice processing and how it can boost the nutritional security of Indian population. Mr. Amol Tote, Executive Secretary of Orange Growers Associations of India and also the awardee farmer who highlighted how CCRI technologies had brought a revolution to citrus industry by boosting farmers' production multiple times. Dr. Prashant Tej Kumar (Scientist, Biotechnology) delivered vote of thanks and Ms. Sangeeta Bhattacharyya (Scientist, Agricultural Extension) was the moderator of the programme.

15.5 Hindi Saptah

Hindi Saptaha was celebrated during 14-21st September, 2020 during which various Hindi competitions like translation, word knowledge and essay competition were organized in which the staff participated enthusiastically and received awards. All the competitions was conducted by various committee under the guidance of Dr. Dinesh Kumar, Pr. Scientist and in-charge Rajbhasha. Social distancing was followed due to the Corona pandemic. The Hindi saptaha closing ceremony was celebrated on 21st September, 2020. Dr. Veena Dadhe, Prof. Hindi department at Nagpur University, was the Chief Guest. She discussed on the development of Hindi bhasha and emphasized on the need of Hindi in the office. Programme was conducted by Dr. Dinesh Kumar, Pr. Sci. and Dr. Ashok Kumar, ACTO proposed vote of thanks.

15.6 Krishi Samwad

Dr. Veena Dadhe, Prof. addressing the CCRI staff during Hindi Rajbhasha Programme

Programme "Krishi Samwad" organized on 7th October, 2020 to create awareness among farmers about recently passed three historical bills on farm sector in the Parliament. The Chief Guest Padmashri Dr. Vikas Mahatme, Hon'ble Member of Parliament (Rajya Sabha) highlighted various benefits that farmers will get from the recently passed farm bills. These bills will give more freedom and opportunities to farmers in selling their farm produce. Other dignitaries present were Dr. M. S. Ladaniya, Director, Dr. M. S. S. Nagaraju, HOD, Division of Remote Sensing, NBSS & LUP, Nagpur, Shri. Prakash Gajbhiye, Member of Maharashtra Legislative Council & BJP President, Nagpur District, Shri. Sagar Sarode, District President of Kisan Morcha and Shri. Anandrao Raut, progressive farmer. There were around 100 farmers from Nagpur District.

Dr. Vikas Mahatme, addressing the farmers and staff during Krishi Samvad programme

15.7 Good Governance / Swachh Bharat Mission

- Institute celebrated 150th Birth Anniversary of Mahatma Gandhi on 1st October, 2020. Eminent personalities well conversant in Gandhian Philosophy Shri Girishji Gandhi Trustee, President, Vanrai Foundation, Nagpur and Shri Aprup Adawadkar visiting Faculty Gandhian Thoughts Nagpur University, Nagpur were the Chief Guest and Guest of Honour. They spoke on the life, society and other application of his ideas Principles, practices, and beliefs Followers and international influence of

Shri Girishji Gandhi, addressing the CCRI staff

Live telecast of Hon'able Prime Minister Shri Narandra Modi

Mahatma Gandhi. On 2nd October Dr. M. S. Ladaniya, Director administered the 'Swacchta Pledge' alongwith all the staff members. Undertaken intensive cleaning campaign in the Institute premises, administrative building, cleaning of road side grass and unwanted plants, children's park, Farmers' Hostel and institute lawn.

- ICAR-CCRI, Nagpur observed "Swachhata Pakhwada" from 16-31 December, 2020 as part of Swachh Bharat Mission. Various activities were identified and staff were motivated to take personal interest to make this campaign a grand success. Dr. M. S. Ladaniya, Director administered the pledge 'Swachhta Shapth' alongwith all the staff members and instructed to devote some time for Swachh Bharat Abhiyan.

15.8 Pradhan Mantri Kisan Samman Nidhi

The live telecast programme of Hon'ble Prime Minister Shri. Narendra Modi was organized at ICAR - CCRI, Nagpur on 25th December, 2020. Hon'ble Prime Minister virtually interacted with farmers from six states along the country. Dr. M. S. Ladaniya, Director, Scientist and other officials of the institute were present. On the occasion, PM digitally deposited a total of Rs. 18,000 crore in the bank accounts of nine crore farmers under the "Pradhan Mantri Kisan Samman Nidhi" scheme. The programme was attended by around 80 people some of them had present virtually. Later Dr. M. S. Ladaniya, Director briefed the audience regarding the scheme. The programme was coordinated by Miss. Sangeeta Bhattacharyya following all the safety protocols instructed by Government of India.

15.9 Other Programmes

Welfare Activities

- Institute provided about one quintal (100 kg) Nagpur mandarin fruit to the Police Department free of cost during April 2020 keeping in view their dedicated services in maintaining law and order during curfew and lockdown during that period.
- Collector, Nagpur requested ICAR-CCRI for providing RT-PCR machine for testing of COVID patients at Mahatma Gandhi Institute of Medical Sci., Sevagram (Dist. Wardha). The machine was given to district administration on 11th May, 2020 and it was returned back on 6th November, 2020.
- The staff of the institute including contractual staff and labour were given masks and sanitizers free of cost. Guidelines were issued in local languages to maintain safe distance and wash/disinfect the hands. Building and other premises were dis-infected/sanitized. As per the guidelines received from the Council time-to-time, staff was asked to work from home and attendance was regulated so that there is no crowding in the office in view of COVID-19.

15.10 *Mera Gaon Mera Gaurav* (My Village My Pride) programme

The training, demonstration and technology dissemination activities continued in the two villages viz., Pachgaon, Tah. Umred, Dist. Nagpur and Hetikundi, Tah. Karnja, Dist. Wardha.

15.11 Celebration of other events / days

Following events were celebrated : Republic Day on 26th January, 2020; Martyrs' day (Shahid Diwas) on 30th January, 2020; 130th Birth Anniversary of Dr. Bhimrao Ambedkar on 14th April, 2020. A programme was organized on 15th April, 2020; Independence Day on 15th August, 2020; Constitution Day on 26th November, 2020 Vigilance awareness week (October 2020) and Dr. B. R. Ambedkar Maha Parinirvan Diwas on 6th December, 2020.

Dr. M. S. Ladaniya, Director administering Vigilance Awareness Oath to the staff of CCRI

16 Distinguished Visitors

- Dr. Satender Singh Arya, Chief Executive Officer, ASCI visited the institute on 27th February, 2020.
- Sh. Eknath Dawale, Secretary, Agriculture, Govt. of Maharashtra visited the nursery and farm and also had interaction meeting with the scientists on 11th September, 2020.

Sh. Eknath Dawale, Secretary, Agriculture, Govt. of Maharashtra interacting with CCRI scientists

17 Personnel

17.1 Appointment

Permanent Staff

- Dr. G. T. Behere, Pr. Scientist (Entomology) joined on 14th January, 2020 on transfer from ICAR- RC for NEH Region, Umiam, Meghalaya.
- Dr. D. T. Meshram, Sr. Scientist (L&WME) joined on 12th November, 2020 on transfer from ICAR-NRCP, Solapur

Contractual Staff

- Ms. Aparna S. Sontakke, RA w.e.f. 11th February, 2020
- Sh. Dinesh S. Rathod, Young Professional - II w.e.f. 20th February, 2020.
- Sh. Datta R. Surwase, Young Professional-II w.e.f. 20th May, 2020
- Sh. Chetan S. Pangul, Young Professional-II w.e.f. 8th June, 2020
- Sh. Sunil B. Kokane, Research Associate w.e.f. 17th June, 2020
- Sh. Sachin A. Mendke, Young Professional-II w.e.f. 1st July, 2020
- Ms. Shraddha D. Dahat, Young Professional-II w.e.f. 4th July, 2020
- Sh. Prafulla R. Jalamkar, Young Professional-II w.e.f. 6th July, 2020
- Sh. Amol D. Kokane, Senior Research Fellow w.e.f. 7th July, 2020
- Sh. Mrugendra G. Gubyad, Senior Research Fellow w.e.f. 27th July, 2020
- Sh. Datta M. Ingle, Young Professional-II w.e.f. 27th July, 2020
- Sh. Shailesh M. Zalke, Young Professional-I w.e.f. 25th September, 2020
- Sh. B. P. Mahalle, Young Professional-II w.e.f. 25th September, 2020
- Sh. Ashish S. Bambal, Young Professional-I w.e.f. 25th September, 2020
- Sh. Vaibhav U. Bhose, Young Professional-I w.e.f. 26th September, 2020
- Sh. Sachin S. Wadhai, Young Professional-I w.e.f. 26th September, 2020
- Sh. Jitendra U. Kuthe, Young Professional-I w.e.f. 26th September, 2020.
- Sh. Rajkumar P. Bhure, Young Professional-I w.e.f. 1st October, 2020
- Ms. Krutika P. Fiske, Young Professional-I w.e.f. 1st October, 2020
- Ms. Dhanshree P. Deshmukh, Young Professional-II w.e.f. 24th October, 2020
- Sh. Dharmendra P. Sinh, Junior Research Fellow w.e.f. 2nd November, 2020
- Ms. Priya A. Zade, Young Professional-II w.e.f. 17th November, 2020
- Ms. Priya R. Uge, Young Professional-I w.e.f. 23rd November, 2020
- Sh. Nikhil Dhole, Young Professional-I w.e.f. 1st December, 2020.
- Sh. Trailukya Das, yp-II w.e.f. 2nd December, 2020 at RRCC, Biswanath Chariali, Assam.

17.2 Retirement

1. Dr. I. P. Singh, Pr. Scientist (Hort.) superannuated on 31st March, 2020.
2. Dr. C. V. Bankar, CTO superannuated on 30th April, 2020

17.3 Promotion

- Sh. V. N. Dhengre, Sr. Tech. Officer to Asstt. Chief Technical Officer w.e.f. 1st July, 2018
- Dr. Ashok Kumar, Sr. Tech. Officer to Asstt. Chief Technical Officer w.e.f. 30th April, 2018

- Sh. B. B. Banerjee, Sr. Tech. Officer to Asstt. Chief Technical Officer w.e.f. 28th September, 2018

17.4 Resignation/relieving

- Sh. Bhakta Khanikar, Young Professional-I relieved on 28th October, 2020.
- Sh. Sachin A. Mendke, Young Professional-I relieved on 2nd December, 2020.

17.5 Transfer

- Dr. P. S. Shirgure, Pr. Scientist (L&WME) transferred to ICAR-NRCP, Solapur on 10th November, 2020.

17.6 MACP

- Shri, D. S. Sardar, SSS w.e.f. 10th Janaury 2020 and 17th July 2021.

17.7 Education

- Ms. Sangeeta Bhattacharyya, Scientist (Agril. Extension) received Provisional Degree Certificate in December, 2020 for one year correspondence course on Post Graduate Diploma in Educational Technology Management from ICAR-NAARM in collaboration with University of Hyderabad.

17.8 Staff Position (as on 31.12.2020)

Research Management Position

Dr. M. S. Ladaniya
Director

Scientific Staff

1. Dr. A. K. Srivastava
   Principal Scientist (Soil Science-Pedology)
2. Dr. (Mrs.) N. Vijayakumari
   Principal Scientist (Horticulture)
3. Dr. A. D. Huchche
   Principal Scientist (Horticulture)
4. Dr. D. K. Ghosh
   Principal Scientist (Plant Pathology)
5. Dr. R. K. Sonkar
   Principal Scientist (Horticulture)
6. Dr. A. K. Das
   Principal Scientist (Plant Pathology)
7. Dr. Dinesh Kumar
   Principal Scientist (Horticulture)
8. Dr. A. A. Murkute
   Principal Scientist (Horticulture)
9. Dr. G. T. Behere
   Principal Scientist (Entomology)
10. Dr. D. T. Meshram
    Principal Scientist (L&WME)
11. Dr. A. Thirugnanavel
    Scientist 'SS' (Horticulture)
12. Dr. (Mrs.) Anjitha George
    Scientist 'SS' (Entomology)
13. Dr. Prasanth Tej Kumar, J.
    Scientist (Ag. Biotechnology)
14. Dr. Kiran Kumar Kommu
    Scientist (Nematology)
15. Ms. Sangeeta Bhattacharyya
    Scientist (Agril. Extension)

Technical Staff

1. Miss. Lily Varghese
   Chief Technical Officer
2. Dr. U. T. Sunil Kumar
   Asstt. Chief Technical Officer
3. Sh. S. L. Shirkhedkar,
   Sr. Tech. Officer
4. Sh. Ravikiran Mandlekar
   Sr. Tech. Officer
5. Dr. Ashok Kumar
   Asstt. Chief Technical Officer
6. Sh. V. N. Dhengre
   Asstt. Chief Technical Officer
7. Sh. D. D. Banerjee
   Asstt. Chief Technical Officer
8. Mrs. Jayshree Kolwadkar
   Tech. Officer

9. Sh. M. P. Gorle
   Tech. Officer
10. Sh. C. H. Chauhan
    Tech. Officer.
11. Sh. V. P. Bhaladhare
    Tech. Officer.
12. Sh. R. D. Dhone
    Tech. Officer.
13. Sh. A. B. Gadge
    Tech. Officer.
14. Sh. B. G. Awari
    Tech. Officer.
15. Sh. S. K. Khaire
    Sr. Tech. Asstt.
16. Sh. M. B. Sayam
    Sr. Tech. Asstt.
17. Sh. K. K. Ghaiwat
    Sr. Tech. Asstt.
18. Sh. P. R. Bagde
    Sr. Technician

Administrative Staff

1. Sh. Y. V. Sorte
   Asstt. Fin. & Accts. Officer
2. Sh. B. T. Dhongade
   Personal Secretary
3. Sh. S. W. Ambekar
   Assistant, I/c. AAO
4. Sh. N. F. Suryavanshi
   Assistant
5. Smt. Usha Dhanvijay
   Assistant
6. Sh. P. M. Khobragade
   Jr. Clerk
7. Sh. M. S. Utane
   Jr. Clerk

Supporting Staff

1. Sh. A. N. Mahanande
   Skilled Support Staff
2. Sh. D. N. Sambhare
   Skilled Support Staff
3. Sh. D. S. Sardar
   Skilled Support Staff
4. Sh. N. K. Mohariya
   Skilled Support Staff
5. Sh. Anil Shaneshwar
   Skilled Support Staff
6. Sh. Namdeo Thakre
   Skilled Support Staff
7. Smt. Manisara Gurung
   Skilled Support Staff
8. Sh. Sunil Kharche
   Skilled Support Staff

Annexure - I

The weather parameters recorded at ICAR-CCRI, Nagpur agro-meteorology observatory during 2020

MW	T_{db} (^{0}C)	T_{wb} (^{0}C)	T_{max} (^{0}C)	T_{min} (^{0}C)	WS (Kmph)	RH (%)	V. Pre (mmHg)	Rainfall (mm)	E_{pan} (mm)
1	15.6	14.6	24.0	12.5	4.02	75.0	15.2	50.20	2.69
2	15.5	16.8	16.8	11.2	6.13	32.8	12.3	7.30	2.52
3	17.1	15.1	28.7	12.8	1.74	79.8	16.0	0.00	5.29
4	18.9	14.9	30.0	14.8	2.70	75.0	16.9	0.30	2.31
5	17.1	13.0	27.8	12.5	4.45	59.6	12.0	0.60	3.17
6	15.5	11.9	27.7	11.6	3.61	58.4	10.4	13.70	3.62
7	19.0	14.2	31.7	11.8	3.43	55.5	13.8	0.00	4.03
8	19.1	15.2	35.5	13.5	2.65	63.3	14.1	0.00	6.41
9	21.5	16.8	32.2	13.9	3.26	54.6	15.8	0.00	4.46
10	22.5	17.1	34.3	16.4	3.90	55.0	14.9	0.00	3.99
11	23.8	18.0	33.9	16.9	3.79	62.0	14.3	6.20	4.94
12	24.7	21.1	30.7	19.7	3.25	71.4	20.1	2.00	5.62
13	25.7	21.5	33.7	19.6	15.29	69.5	21.2	4.80	5.80
14	26.8	22.7	36.3	18.1	4.45	69.8	21.5	0.00	6.29
15	28.7	24.7	36.4	21.0	8.36	61.0	21.9	0.00	6.43
16	30.4	26.3	37.2	21.4	9.75	54.1	22.3	0.00	5.93
17	35.1	30.4	40.7	22.0	7.71	48.4	22.4	7.70	7.79
18	35.3	31.8	41.1	23.5	18.82	44.4	22.7	1.50	7.60
19	35.5	31.6	40.6	22.3	8.66	51.2	22.9	15.10	8.22
20	35.7	24.9	40.4	24.3	1.42	38.6	22.7	1.80	9.41
21	36.3	29.9	41.5	27.6	1.50	43.5	27.3	0.00	10.07
22	32.8	21.9	38.5	23.9	1.79	54.1	27.8	33.20	9.91
23	31.2	24.3	35.8	24.2	2.42	30.4	26.0	16.80	8.38
24	27.0	25.7	35.6	24.8	1.50	26.8	31.8	89.30	7.18
25	27.1	24.7	33.2	23.5	2.06	83.0	29.4	87.60	4.81
26	28.0	23.6	33.0	21.0	1.38	67.0	26.1	51.60	4.49
27	27.6	25.0	32.2	23.6	5.81	88.5	29.7	28.90	3.07
28	26.3	24.1	31.3	25.0	6.21	84.6	28.3	113.40	2.86
29	26.9	25.6	30.5	23.6	5.39	87.6	31.1	61.30	2.38
30	26.3	25.3	30.4	24.1	5.86	89.1	31.4	74.80	8.30
31	26.5	23.9	31.8	21.2	5.57	78.6	28.7	201.00	3.84
32	26.4	23.4	31.5	21.9	11.67	75.4	26.7	43.30	4.55
33	26.8	23.1	31.6	21.7	8.46	65.4	24.7	38.20	2.77
34	25.2	23.3	31.4	21.8	8.55	68.6	25.9	49.00	5.12
35	26.0	21.7	32.1	19.9	9.39	89.3	22.4	79.20	3.90
36	27.3	25.3	32.3	23.3	5.02	83.6	36.4	49.10	2.62
37	28.3	25.6	33.2	23.8	4.69	83.2	28.4	0.70	2.58
38	27.0	24.5	33.0	23.0	4.14	81.8	28.8	75.10	2.99
39	26.4	23.6	32.8	23.1	4.34	77.6	27.5	47.20	3.35
40	27.2	23.8	33.0	22.2	4.36	26.8	26.9	0.00	4.00

MW	T_{db} (^{0}C)	T_{wb} (^{0}C)	T_{max} (^{0}C)	T_{min} (^{0}C)	WS (Kmph)	RH (%)	V. Pre (mmHg)	Rainfall (mm)	E_{pan} (mm)
41	27.3	23.3	32.1	23.6	4.03	85.0	30.2	0.50	3.51
42	30.9	25.0	31.2	23.9	3.97	64.6	26.9	20.70	3.99
43	33.0	24.8	33.5	20.1	3.73	31.7	25.2	0.00	4.39
44	27.5	20.3	32.7	17.5	4.01	55.4	18.6	0.00	2.97
45	20.5	16.3	31.2	14.7	7.69	60.6	15.3	0.00	8.07
46	26.3	24.2	31.6	19.2	6.20	82.0	24.4	0.00	4.12
47	38.1	19.3	32.5	15.3	7.09	22.8	11.2	11.50	6.30
48	26.6	17.4	28.5	14.5	8.85	44.0	11.9	0.00	3.14
49	20.3	18.8	31.5	13.0	4.38	82.6	18.7	0.00	2.54
50	24.3	19.8	30.5	16.6	4.67	66.0	19.5	1.00	2.60
51	27.8	18.3	30.2	14.0	4.24	40.0	13.4	1.00	3.79
52	21.6	16.1	29.7	12.7	4.09	56.5	15.4	0.00	2.67
Max.	**38.10**	**31.80**	**41.50**	**27.60**	**18.82**	**89.30**	**36.40**	**201.00**	**10.07**
Min.	**15.50**	**11.90**	**16.80**	**11.20**	**1.38**	**22.80**	**10.40**	**0.00**	**2.31**

CCRI PUBLICATIONS

BOOKS

- Citrus decline and management in NEH Region
- Potassium nutrition in citrus
- Post-harvest technology and processing of citrus fruits in India
- Citrus insect pests
- Citrus in NEH Region

CATALOUGE

- Catalogue of Citrus Germplasm

STATUS PAPER

- Organic Citrus Status

MONOGRAPH

- Citrus Monograph

HANDBOOK

- Handbook of Citrus (Hindi)

MANUAL

- Manual on citrus insect pest management
- Diagnosis of Nutrient Constraints in citrus

INTERACTIVE C.D.

- Integrated pest management in citrus

TECHNICAL BULLETINS

- Fertilizer use efficiency in citrus
- Post-harvest technology of Nagpur mandarin (Citrus reticulate Blanco)
- Management of insect pests in citrus
- Citrus flowering
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- Exploration, Collection and mapping of citrus genetic diversity in India
- Nutrient Diagnostics and Management in citrus
- Intercropping in Nagpur Mandarin
- Site Specific Nutrient Management in Citrus
- Citrus entomology a decade at NRCC
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- Fertilization in Citrus
- Citrus Greening (HLB) : Diagnostics

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- Handling of Nagpur mandarin
- नागपूरी-संतरे की बागवानी
- Nutrient management in Nagpur mandarin and acid lime
- Propagation of Nagpur mandarin
- Germplasm of citrus
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- Phytophthora disease of citrus and their management
- Management of Post-harvest disease of Nagpur mandarin
- Insect pests of Nagpur mandarin and their management
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- संत्रा व लिंबू बागांमध्ये खतांचे व्यवस्थापन
- नागपूर संत्र्यावरील कीड व त्यांचे व्यवस्थापन
- Export of Nagpur Mandarin
- Weed management in citrus orchards
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- Citrus Genetic Resources
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- High density cultivation in acid lime

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