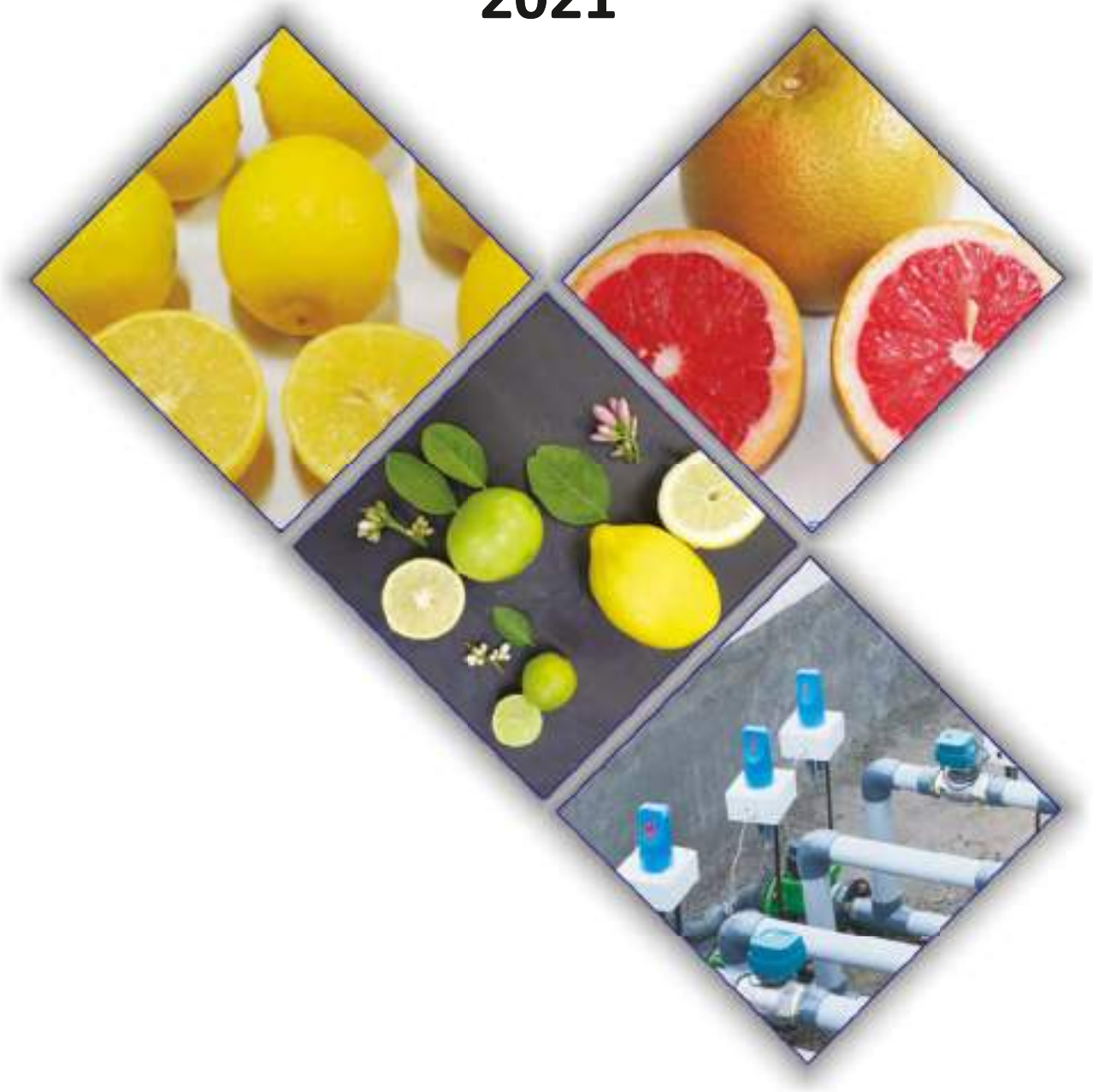
वार्षिक प्रतिवेदन

Annual Report

2021



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(भारतीय कृषि अनुसंधान परिषद)

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ICAR-Central Citrus Research Institute

INDIAN COUNCIL OF AGRICULTURAL RESEARCH

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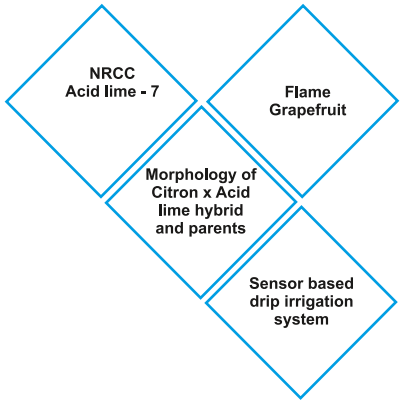

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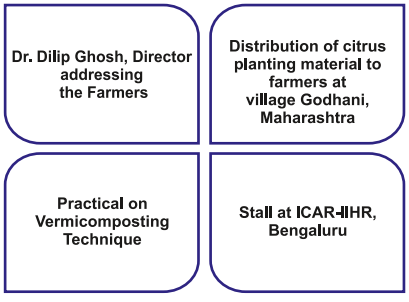

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Preface

I am extremely delighted to present the Annual Report 2021 of ICAR – Central Citrus Research Institute, Nagpur. The past year witnessed the regained enthusiasm and zeal after a couple of years of COVID – 19 containments. Institute delivered to the best of its ability in all spheres of activities i.e. research and development, extension etc. Among significant research achieves, characterization of indigenous lemon varieties and eight exotic lemon varieties *viz.,* Genoa, Frost Lisbon, Limonera Fino, Verna, Frost Eureka, Willafranka Nucellar, Improved Meyer and Bears based on IPGRI descriptors was noteworthy. The clone N-2 was found closely related to the Mudkhed mandarin and clone N-4 was grouped with Darjeeling mandarin utilising 45 InDel markers. Eight citrus rootstock genotypes were investigated for DNA barcoding using rcbL loci. *In vitro* induction of autotetraploids in commercial citrus rootstocks was successful with higher survival (44.98%) in Sweet lime, followed by Alemow (43.10%).

In genetic improvement of citrus through hybridization, one hybrid progeny (NRCC citron x KL 12 Acid lime) had most of the leaf morphological characters as same as parents. Interspecific and intraspecific hybridization during last year resulted in 138 progenies from 1085 different crosses. Studies on evaluation of hybrid rootstocks (NRCC-2, 3, 4 and 5) has revealed that yield of Nagpur mandarin was maximum in NRCC rootstock-3 (14.85 t/ha) followed by NRCC-5 (13.78 t/ha). In raised-bed planting of Nagpur mandarin under high density with Rough lemon as rootstock, the maximum fruit yield (27.68 kg/plant) was recorded in 5×4.5 m spacing. Insect-pest population was higher in general at higher density. Intercropping of vegetables (brinjal, bhindi, tomato) and marigold flowers was successful in the space between the beds.

Under evaluation of exotic citrus cultivars, Blood Red had better canopy volume (30.46 m^3) in 7th year after planting. With respect to the growth of grapefruit, the highest plant height (4.78 m) and canopy volume (40.81 m^3) was recorded in Marsh seedless followed by Star Ruby. Among the sweet orange cultivars, the average maximum fruit yield was recorded in Westin on Swingle (16.53 kg/plant) followed by Pera on Limocrova (16.48 kg/plant). The highest juice content (43.90 %) and Vit.C (45.30 mg/100mg) was recorded in Valencia on Volkameriana.

For the development of INM-module for sustained productivity of citrus, optimum nutrient requirement of Mosambi sweet orange was standardized. 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.

Citrus microbiome was explored in rejuvenating Khasi mandarin plants affected by important citrus diseases at NE regions. Interestingly, soil samples collected from greening positive trees contained maximum diversity of *Bacillus* group while soils from greeing negative trees exhibited dominant and maximum diversity of *Pseudomonas* group of bacteria. Talc based formulation of two promising endophytes CFE -109 and CFE-157 (*Chaetomium globosum*) and CFE 142 (*Aspergillus terreus*) were prepared.

A RT-RPA-LFIC assay was developed for rapid detection of CTV. Further field evalutation of mixture of 2S albumin protein and nano ZnO to control citrus greeing disease has been initiated and its effectiveness in reducing the CLas population has been recorded. Plant parasitic nematode genera *viz*., *Pratylenchus, Meloidogyne, Hoplolaimus* and *Tylenchulus semipenetrans* were identified in Nagpur mandarin growing regions of Amravati district of Maharashtra.

Nagpur mandarin fruits coated with Scholar 230SC (Fludioxonil 23% w/v SC) 3.90 g/L showed significantly better results with respect to post-harvest disease control and other physico-chemical parameters under refrigerated storage conditions. Four post-harvest management technologies were developed *viz*. Osmotically dehydrated segments of Nagpur mandarin and Sweet orange, low calorie Santra Barfi and Ice-cream from Nagpur mandarin. High end value added products like low sugar jelly (*Nutri Jelly*) from Nagpur mandarin and Assam lemon and functional pasta from polyphenol enriched pummelo peel powder were standardized and developed.

The perception of farmers regarding adopted technologies of ICAR-CCRI was assessed where 85% of mandarin farmers reported that they were benefitted in terms of production and income after cultivating CCRI planting materials while 10% reported they experienced no change and 5% suffered loss.

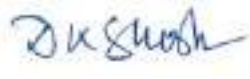
At RRCC, Biswanath Chariali, the evaluation of different commercial *Citrus* spp. on raised bed and flat bed systems was initiated with 17 different citrus species (comprising mandarin, sweet orange, lemon, lime, pummelo and grapefruit varieties) budded on rough lemon rootstock and planted at 5x3 m spacing during August, 2017. All the cultivars displayed excellent growth performance on both the planting systems and results revealed a significant variation among species with respect to plant heights, stock scion girth and canopy spread. New Building of Farm Office and Tractor Shed at RRCC inaugurated on 10th January, 2021. Also, new greenhouse structures were established for nursery related activities during the year.

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. During the year, six field visits in selected orchards of two districts (Nagpur and Wardha) comprising 4 Talukas including 13 Villages covering 23.09 ha area were conducted. Institute organized in all 14 trainings which included 4 on-campus, 3 off-campus trainings, 2 trainings under Tribal Sub-Plan, 4 trainings in NEH region and 1 training under SC Sub-Plan with a total of 1662 beneficiaries. The supply of disease-free plating material programme advanced with the sale of 1.94 lakhs disease-free planting material of citrus and revenue of Rs.104.56 lakhs was generated. Institute generated revenue of Rs.27.48 lakhs through sale of fruit and other products.

Institute licensed the technology of "Containerized Nursery propagation technique to produce disease-free citrus planting material" to M/s Pratima Biotech Pvt. Ltd., Raipur Chhattisgarh. Contract research project on "Evaluation of Scholar 230 SC for Post-harvest Disease management in citrus" signed with Syngenta Pvt. Ltd. Mumbai. Institute awarded its first patent for its invention in developing a process for a product 'Sparkling clear Ready-to-serve beverage for Acid lime'

During 2021, Dr. A.K. Srivastava, Pr. Scientist, Dr. Dinesh Kumar, Pr. Scientist (Hort.), Dr. J.P. Tej Kumar and Dr. Sangeeta Bhattacharyya, Scientist (Extension) were honoured for the R&D activities at different scientific fora.

All these activities could have been successfully completed due to visionary guidance of Dr. T. Mohapatra, Hon'ble Secretary DARE, Govt of India & DG, ICAR. The kind support and constant encouragement of Dr. A.K. Singh, DDG (Hort. Sci.) was the strength of delivery throughout the course. I am thankful to Research Advisory Committee (RAC) and Institute Management Committee (IMC) for their valuable guidance in research and other programmes. I thank all the scintists, technical staff, administrative and supporting staff including contractual staff who contributed to the growth of institute and fulfilling the mandate. Finally, I thank the editorial committee and technical support of Ms. Lily Verghese, CTO and Mr Shailesh Zalke, YP–II for compiling the report.



Nagpur
October, 2022

(Dilip Ghosh)
Director

1 Executive Summary

During the year 2021, ICAR-CCRI further expanded its plantation both at Nagpur as well as Biswanath Chariali, Assam and executed its research programs through different multi-disciplinary projects (in-house and externally funded), disseminated technologies through trainings, visits, demonstrations and commercialized technologies thus making an all round development.

Research Achievements

Citrus genetic resources and improvement

To strengthen the genetic resource base and diversity 36 accessions of different citrus genotypes *viz*., Galgal, citron, sweet lime etc. were regenerated and planted were planted at Block No. 34 of CCRI Farm site, Nagpur. Further 72 accessions were regenerated for NAGS of citrus.

The four indigenous lemon varieties like Pant lemon, Baramasi lemon, Assam lemon and Kagzi Kalan and eight exotic lemon varieties *viz.,* Genoa, Frost Lisbon, Limonera-Fino, Verna, Frost Eureka, Willafranka-Nucellar, Improved Meyer and Bears were morphologically characterized based on IPGRI descriptors. A total of 22 mandarin accessions including exotic collections were characterized using 45 InDel markers. The clone N-2 was found closely related to the Mudkhed mandarin and N-4 is grouped with Darjeeling mandarin.

Among different accessions of galgal the maximum fruit weight was observed in IPS-29 (451 g) along with juice content (32%). Numbers of seeds were lowest in IPS/SKV/199 (5 seeds/ fruit). The highest Vitamin C (29 mg / 100g) was found in IPS-29 followed by IPS-30 (27.96 mg/100g). Among different accessions of Karnakhatta, maximum fruit weigh was observed in IPS/362 (4478 g) and the highest juice content (25.93%) in NRCC-63. Highest content of Vitamin C was observed in NRCC Pummelo-1 (49.87 mg/100g). Maintenance breeding data were recorded as per DUS guidelines for Acid lime cultivars *viz*. Pramalini, Balaji, Sai Sharbati, Vikram, Jaidevi, Phule Sharbati, NRCC Acid Lime - 7, NRCC Acid Lime - 8, Mandarin - Nagpur mandarin, Coorg mandarin Sikkim mandarin, Darjeeling, Mudkhed seedless and Sweet orange cultivars *viz*., Mosambi, Clone TM - 33, Kodur Sathgudi.

In the *in vitro* induction of autotetraploids in commercial Citrus rootstocks with the use of Colchicine, overall seedling survival was higher (44.98%) in Sweet lime, followed by Alemow (43.10%). Higher the concentration, lesser the survival rate. 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 Nagpur mandarin (40.22) and in Kinnow (39.06) in MT+CH+2,4-D (2mg/L)+ BA (5mg/L), whereas in Sweet Orange (44.27) in MT + ME, whereas highest rate of embryogenesis obtained in Nagpur mandarin (53.63%) and in Kinnow (38.81%) with MT+CH+2,4-D (2mg/L) medium, where as in Sweet orange maximum embryogenesis (49.85%) obtained in the medium MT+CH+2,4-D(2mg/L)+BA(5mg/L).Medium supplemented with GA_3 and adenine sulphate enhanced the shoot and root development and complete plantlet regeneration obtained in Nagpur mandarin, Sweet orange and also in Kinnow from endosperm culture.

Under genetic improvement of citrus through hybridization, plant height of US pummelo x NRCC rootstock 5 progenies, ranged from 1.9 to 3.1 m and number of branches ranged from 2 to 6. In case of rough lemon x Rangpur lime progenies the plant height ranged from 1.4 to 1.6 m and number of branches ranged from 1 to 3. During the year 2021, one hybrid progeny (NRCC citron x KL 12 acid lime) out of 258 progenies came for flowering and fruiting. Leaf morphology of hybrid and its parents were characterized based on IPGRI descriptor to study the

inheritance pattern of the characters. Most of the leaf morphological characters of hybrid are as same as parents. Interspecific and intraspecific hybridization during last year resulted in 138 progenies from 1085 different crosses. One hundred and twenty seven progenies were recovered the acid lime x Pant lemon crosses.

Acid lime trees with different gamma irradiation doses (10, 20, 30 and 40 Gy) were screened and evaluated for citrus bacterial canker incidence under natural open field conditions. All the trees under different treatments were found to be susceptible to citrus canker. Disease incidence on leaves ranged from 34.9-67.8% in those acid lime seedlings and percent disease index (PDI) ranged from 6.9-20.0.

Eight citrus rootstock genotypes were investigated for DNA barcoding using rcbL loci. In the phylogenetic tree, Rough lemon grouped with sour orange and Galgal grouped with Trifoliate orange.

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 in NRCC rootstock-3 (14.85 t/ha) followed by NRCC-5 (13.78 t/ha). 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 (18.54 t/ha) and (18.18 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 (43.55 m^3) at 5 x 4 m spacing followed by 4.5×4.5 m (41.38 m^3) after 7 years. The maximum fruit yield (27.68 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 6 x 3 m and 6 x6 m spacing. The plant spaced at 6×3 m spacing showed plant height range from 4.2 – 4.7 m and better canopy volume (29.09 m^3). The fruit yield was 25.34 kg/plant (14.06 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 (4.38 m) while Blood Red had better canopy volume (30.46 m^3) in 7th year after planting. With respect to the growth of grapefruit, the highest plant height (4.78 m) and canopy volume (40.81 m^3) was recorded in Marsh seedless followed by Star Ruby. Among the sweet orange cultivars, the maximum fruit yield was recorded in Blood Red (26.38 kg/plant) followed by Jaffa (23.15 kg/plant). In grapefruit, the average fruit weight was maximum in Marsh Seedless (463.5 g) whereas, the maximum acidity (1.2%) and Vit. C (48.07 mg/100mg) was recorded in Star Ruby.

Among sweet orange varieties introduced from Brazil (planted on raised bed in 2014), plant height (4.3 m) and canopy volume (30.6 m^3) were maximum in Hamlin on Volkameriana rootstock. The average maximum fruit yield was recorded in Westin on Swingle(16.53 kg/plant) followed by Pera on Limocrova (16.48 kg/plant). Maximum fruit weight (272.1 gm) was recorded in Lanelate on rough lemon. The highest juice content (43.90 %) and Vit.C (45.30 mg/100mg) was recorded in Valencia on Volkameriana followed by Pera on Limocrova (42.36% juice content). The maximum average weight loss of fruit was recorded in Rangpur lime rootstock (30.14%) followed by Pera on limocravo (25.11%) while minimum weight loss was recorded in Valencia on Volkameriana (16.70%).

Among 10 acid lime cvs. planted on raised-bed during 2015 for evaluation, maximum plant height (4.12 m) was recorded in Pramalini whereas minimum height was recorded in NRCC-7 (3.54 m). Highest canopy volume (23.69 m3) was noted in Phule Sharbati. 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. Ganganagar lime recorded average fruit weight (40.2 g) and TSS (6.1%), juice content (48.87%) and acidity (5.56%). In lemon cvs. budded on Rough lemon and planted during 2016 on raised-bed, Assam lemon recorded maximum average fruit weight (168.34 g) and highest acidity (6.21%) with minimum TSS, and juice content as (7.62%), and (45.84%) respectively. Whereas, the highest juice content (52.31%) and TSS (7.81%) was noticed in Pant lemon. While maximum fruit yield (33.04 kg/plant) and productivity (18.34 t/ha) was maximum in Assam lemon followed by Pant lemon. Canker incidence was observed only in Assam lemon (with 32.5 % disease incidence on leaves and PDI 6.8). 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 (225.81g) and TSS (9.41%) was recorded maximum in Daisy. Whereas, maximum Vit. C (37.37 mg/100mg) and juice content (52.17%) was recorded maximum in N4. Maximum fruit yield was recorded in Pearl Tangelo i.e. 9.70 t/ha.

In pummelo (planted in the field during July, 2017), maximum average fruit weight (1.36 kg) and TSS (7.8%) was observed in US Pummelo-145 while Vit. C (36.11 mg/100mg), juice content (34.89%) and acidity (1.24%) was recorded maximum in NRCC Pummelo-5 with maximum fruit yield (4.52t/ha).

In high density planting in acid lime in the year 2021 a fruit yield of 20.71 t/ha in 5x5 m, 28.56 t/ha in 5x2.5 m and 40.39 t/ha 2.5x2.5 m was recorded indicating the potential of close planting in increasing yield. However, the downside of the enterprise was the heavy incidence of insects and pests and citrus canker especially during rainy season demanding lot of care and maintenance involving regular plant protection measures and cultural operations with modern equipments, tools and labour.

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. Foliar application of thiourea, GA3 and nitrobenzene at *Ambia* flowering stage enhances the fruits yield in Nagpur mandarin. Among all the concentrations application of nitrobenzene 500 ppm increasing flowering and fruiting intensity as compare to GA3 20 ppm and thiourea 2%.

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 no. of fruits, fruit weight and yield in High production zone was 186.22, 137.58 g and 7.10 t/ha, respectively. The same in Medium and Low production zones was 131.50, 132.12 g, 4.81 t/ha and 110.82, 126.08 g, 3.87 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 25.3 kg/tree (7.03 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 new experiment on

subsurface Micro-irrigation and fertigation schedule for quality production of Nagpur mandarin has been initiated.

The results of the studies on Agrocel-based potassium schoenite (Mahalaabh) in citrus 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 tons/ha).

Citrus microbiome was explored in rejuvenating Khasi mandarin plants affected by important citrus diseases at NE regions. Soil samples were collected from four locations (Khasi mandarin orchards): Motapung, Borgauh, Tinsukia and Khamanpathar in Assam and from 2 locations at Sohkhwai of Meghalaya. Diverse group of *Pseudomonas* and *Bacillus* was appeared on their respective medium in both soil samples. Interestingly, HLB+ soil sample contained maximum diversity of *Bacillus* group while HLB- soil exhibited dominant and maximum diversity of *Pseudomonas* group of bacteria.

Further, demonstration of CCRI technologies for the rejuvenation of old senile Nagpur mandarin and Khasi mandarin orchards were conducted at Nagpur district, Maharashtra and at Umdenlaang basti, Ri-Bhoi district, Meghalaya, respectively.

Plant protection

Under HORTSAP project, bulk SMS and WhatsApp messages 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, six field visits in selected orchards of two districts (Nagpur and Wardha) comprising four Talukas including 13 Villages covering 23.09 ha area were conducted. Pest monitor and pest scout of respective orchards were given training on field identification of insect pest damage on Nagpur mandarin and sweet orange. Additionally virtual training were also given to the scouts and monitors of Nagpur Division and Ahmednagar districts.

Total 39 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 39 isolates, 11 were found promising showing more than 50 % inhibition in the dual culture assay. During the year, 9 numbers of new fungal endophytes (CFE-163–FE-171) were isolated from rhizospheric roots of various citrus varieties including Nagpur mandarin and sweet orange. None of the fungal endophytes were found to have potential against controlling *P. nicotianae*. The inhibition was found below 40% in all the isolates tested. Talc based formulation of two promising endophytes CFE 109 and CFE-157 (*Chaetomium globosum*) and CFE 142 (*Aspergillus terreus*) were prepared.

Another experiment on Nagpur mandarin fruits was conducted with the objective to evaluate Scholar 230SC (Fludioxonil 23% w/v SC) coating in controlling the post-harvest disease in citrus and also in extending the shelf life of Nagpur mandarin fruits. Nagpur mandarin fruits coated with Fludioxonil 23% w/v SC 3.90 g/L shows significantly better results with respect to disease control and other physico-chemical parameters under refrigerated storage conditions.

For the management of citrus greening disease (HLB) microbiome resource was explored under NE conditions. Based on HLB specific PCR, orchards of Khamanpathar, Motapung and Tinsukia (Assam) were identified as HLB positive. Overall, fourteen (4 from Khamanpathar region, 2 samples from Motapung region, 3 from Tinsukia region, 2 from Biswanath Charaili, 2 from Sokhwai and 1 from

Moralgaon) samples have been found positive for HLB. Isolation of microbes was done from both healthy and infected samples, where twelve isolates have been identified as antagonists against *A. tumefaciens* EHA105, a close relative of HLB bacterium, of which two endophytic bacterial isolates, KMME40 and KMME64 found very promising.

A reverse transcription recombinase polymerase based isothermal amplification coupled with lateral flow immunochromatographic assay was standardized for rapid detection of CTV. The CTRPA-F1/R9-Btn primer combination was identified as the most optimally performing primer set consistently amplifying a ~165 bp specific region of the CTV- p25 gene.RT-RPA-LFIC assay was also developed for rapid detection of CTV. The developed assay consistently detected target cDNA of CTV up to 10^{-5} serial dilution synthesized from 141 ng of in vitro-transcribed RNA as the initial template. TaqMan-qPCR based method was also standardized using the CTV specific primer-probe combination.

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). Trunk injection of 2S albumin protein and Nano-ZnO formulation was done on Mosambi Sweet orange trees. However, little significant difference in CLas titer reduction was observed when compared to the control plants. Virtual screening technique was used to identify a potential inhibitor molecules against putative cystine-binding protein from *Candidatus Liberibacter asiaticus*. Two inhibitor molecules *viz.* Pimozide and Clinidium were found very promising.

Based on the morphological characters, different plant parasitic nematode genera *viz*., *Pratylenchus, Hoplolaimus*, *Criconema* and *Tylenchulus semipenetrans* were identified in sweet orange cultivars grown on different citrus rootstocks at CCRI. Plant parasitic nematode genera *viz*., *Pratylenchus, Meloidogyne, Hoplolaimus* and *Tylenchulus semipenetrans* were identified in Nagpur mandarin growing regions in Amravati district of Maharashtra. GC-MS analysis of root exudates collected from healthy citrus rootstocks *viz*., Rough lemon, Rangpur lime, Alemow and Acid lime revealed an array of chemical compounds comprising of hydrocarbons, esters, aldehydes, ketones, alcohols, terpenes and fatty acids.

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 14 days of storage under ambient condition. Nagpur mandarin fruits treated with Sodium caseinate and soy protein @ 2% concentration along with glycerol 2% and cinnamon oil 50 ppm 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 and better PME activity assessed among all the treatments. 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 (11.53, 8.09 and 9.48 ppm) was recorded in *Citrus latipes,* Citrumello and *Citrus pennivesiculata* juice respectively. Total phenol content in juice (13.938 mg GAE L^{-1}) was recorded higher with *Citrus latipes* and in Citrumello juice (13.463 mg GAE L^{-1}) as compared to 9.075 mg GAE L^{-1} in *Citrus pennivesiculata* respectively. Antioxidant potential was found higher value in peel of Citrumello by ABTS (6.44 mmol L^{-1} trolox) and DPPH (9.33 mmol L^{-1} trolox) assays and higher in peel of *Citrus latipes* by FRAP (4.24 mmol L^{-1}trolox) assay. An attempt was made for the first time to assess the flavonoids, ascorbic acid and organic acids in citrus fruits in Northeast Indian region namely *Citrus hystrics*, Chase rough lemon (*Citrus jambhiri*), Elaichi lemon (*Citrus limon*), JoraTenga (*Citrus medica*). The main organic acids found were citric

and malic acids along with tartaric, benzoic, oxalic and succinic acids in trace amounts.

High end value added products like low sugar jelly (*Nutri Jelly*) from Nagpur mandarin and Assam lemon and functional pasta from polyphenol enriched pummelo peel powder were standardized and developed.

Social Science

Attempt was made to map and compare the trend in average annual income of citrus growers of Vidharbha over a period of 5 years between those who purchased planting materials from ICAR-CCRI and from elsewhere (non-CCRI). The farmers who had purchased CCRI planting materials of Nagpur mandarin reported to obtain an average annual income of Rs. 8,22,203.39/ha/yr, 5 years ago which increased to Rs. 10,57,627.1/ha/yr, 3 years ago from the year of study (2021). Those with non-CCRI planting materials reported a lesser average annual income of Rs. 6,21,875/ha/yr, 5 years ago which increased to Rs. 8,11,250/ha/yr, 3 years ago. So an increase of Rs. 2,35,423.71/ha/yr and Rs. 1,89,375/ha/yr was reported among both categories of farmers. Increasing trend was reported in income of sweet orange and acid lime cultivators too but performance of CCRI planting materials was better than non-CCRI planting materials in all 3 citrus crops. CCRI plants due to better quality, lesser cost of cultivation involved in lesser incidence of pest and diseases, gave famrers better remuneration than those having non-CCRI plants.

The perception of farmers regarding adopted technologies of ICAR-CCRI was assessed. The farmers who had purchased CCRI planting materials of Nagpur mandarin, sweet orange and acid lime reported their reviews after planting the materials in their orchards. 85% of mandarin farmers reported that they benefitted in terms of production and income after cultivating CCRI planting materials while 10% reported they experienced no change and 5% suffered loss. There were farmers who were practising CCRI technologies but had established orchards with Non-CCRI plating materials. Attempt was made to record the number of such farmers too. 93% of mandarin farmers reported that they were practising CCRI technologies while 7% did not know about CCRI or had no access to the technological information.

Regional Research Centre for Citrus (RRCC), Biswanath Chariali, Assam

The evaluation of different commercial *Citrus* spp. on raised bed and flatbed systems was initiated with 17 different citrus species (comprising mandarin, sweet orange, lemon, lime, pummelo and grapefruit varieties) budded on rough lemon rootstock and planted at 5x3 m spacing during August, 2017. All the cultivars displayed excellent growth performance on both the planting systems and results revealed a significant variation among species with respect to plant heights stock scion girth and canopy spread. Among mandarins, maximum plant height was recorded in Khasi mandarin seedling in both raised bed (5.17 m) and flat bed (5.13 m) system. Regarding sweet oranges, maximum plant height was noted in Mosambi (4.53 m) on both raised bed and flat bed while maximum canopy spread was noted in Cutter Valencia under flat bed system. Among grapefruit, maximum plant height (4.43 m), stock girth (52.66 cm), scion girth (52.33 cm) and canopy spread was recorded in Flame grapefruit flat bed as compared to the raised bed system. With respect to pummelo, maximum plant height (4.63 m) was noted under flat bed while stock and scion girth (43.67 cm and 43.33 cm) was recorded maximum on raised bed. In Assam Lemon, plant height on raised bed was at par with flat bed system whereas maximum canopy spread was noted on flat bed system. NRCC Acid lime-7 registered the maximum plant height (4.37 m and 4.46 m), stock girth (39.33 cm and 44.66 cm) and scion girth (39.00 cm and 48.66 cm) on raised bed and flat bed respectively as compared to NRCC Acidlime-8. New Building of Farm Office and Tractor Shed at RRCC inaugurated on 10th January, 2021.

Planting material produced

Under Institute nursery programme 1,94,268 lakhs disease-free planting material of citrus were sold and revenue of Rs.104.56 lakhs was generated.

Resource generation

Institute generated revenue of Rs.27.48 lakhs through sale of fruit and other products. Revenue including interests on FDs, fees, sale of publication and other sources was Rs.110.06 lakhs. Therefore, total revenue was Rs.137.54 lakhs during calendar year 2021.

Training /Skill development and Extension

Institute organized in all 14 trainings which included 4 on-campus, 3 off-campus trainings, 2 trainings under Tribal Sub-Plan, 4 trainings in NEH region and one training under SC Sub-Plan with a total of 1662 beneficiaries.

Important events organized by the institute

Republic day (26th January, 2021); Martyrs day (30th January, 2021); International Women's Day (8th March, 2021); World Water Day (22nd March, 2021); 131st Birth Anniversary of Dr. Bhimrao Ambedkar (14th April, 2021) programme organized on 15th April, 2021; Farmers Awareness Campaign on 'Balanced Use of Fertilizers' (18th June, 2021) (Virtual); International Yoga Day (21st June, 2021); 37th Foundation day of CCRI (28th July, 2021); Independence Day (15th August, 2021); Parthenium Awareness (21st August, 2021); Poshan Vatika Maha Abhiyan and Tree Plantation (International Millets Day) (17th September, 2021); Brainstorming workshop on "Citrus fruit drop" (27th September, 2021); Farmers' Scientists Interface on "Climate Resilient varieties, technologies and practices" (28th September, 2021); *Hindi Saptaha* (14-22 September, 2021); 'Mahila Kisan Diwas' (15th October, 2021); 'World Food Day' (16th October, 2021); *Rahstriya Ekta Diwas* (31st October, 2021); Vigilance Awareness Week (26th October, 2021 to 1st November, 2021); National campaign on "Antimicrobial Resistance" (24th November, 2021); "Constitution Day (*Samvidhan Diwas*)" (26th November 2021); "India International Science Festival (IISF) 2021" (27th November, 2021); World Soil Day' (5th December, 2021); Dr. B.R. Ambedkar Maha Parinirvan Diwas (6th December, 2021) andZero Budget Natural Farming (16th December, 2021)

Special lecture

Institute organized first Special Guest lecture under *Azadi ka Amrut Mahotsav* by Dr. Manjul Dutt, Research Scientist, Citrus Research and Education Center (CREC), University of Florida, USA on 30th September, 2021 on the topic "Utilizing Genetic Modification and Genome Editing Strategies for Management of Greening Disease (Huanglongbing) in Citrus".

Welfare Activity

Farm Kit Distribution under Schedule Caste Sub Plan (SCSP) Scheme on 24th February, 2021 and 10th May, 2021. Lecture on"SBI Office Connect" on 23rd November, 2021.

Rajbhasha Activities

The second sub-committee of the Parliamentary Standing Committee for official language under the Chairmanship of Smt. Ranjanaben Bhatt and other members inspected the progress of works related to Rajbhasha of the Institute on 28th December, 2021 in which ICAR officials were also present. For the benefit of institute staff, three workshops of Rajbhasha were organized.

Technologies commercialized

Institute licensed technology of "Containerized Nursery propagation technique to produce disease-free citrus planting material" with M/s Pratima Biotech Pvt. Ltd., Raipur Chhattisgarh.Contract research project on "Evaluation of Scholar 230 SC for Post-harvest Disease management in citrus" signed with Syngenta Pvt. Ltd. Mumbai.

Patent

Institute awarded its first patent for its invention in developing a process for a product 'Sparkling clear Ready-to-serve beverage for Acid lime.

Awards and recognition

During 2021, Dr. A.K. Srivastava, Pr. Scientist Honorary Fellow 2021 for outstanding contribution and recognition in field of "Soil fertility and plant nutrition in Citrus" in the 3rd International Conference on "Global Initiative in Agricultural, Forestry and Applied Sciences for food Security, Environmental Safety and Sustainable Development (GIAFAS-2021)" At Shri Guru Ram Rai University, Dehradun, Uttarakhand, India 17-18th October, 2021; Dr. Dinesh Kumar, Pr. Scientist (Hort.) Awarded CHAI-JISL Fellowship Award 2021, Dr. J. C. Anand Award in Post-harvest management in Horticulture crops- 2021 by "Indian Academy of Horticultural Sciences", New Delhi and CHAI-Dr. Kriti Singh Best Paper Award- 2020; Dr. J.P. Tej Kumar *et.al*. Best Poster award for "Genetic diversity comparison among introduced and indigenous sweet orange cultivars using SSR and InDels" at National Seminar on "Conservation and commercialization of citrus biodiversity in NEH region" at Central Agricultural University, Imphal during 18-19th February, 2021 and Dr. Sangeeta Bhattacharyya, Scientist (Extension) received Best Article Award for the article on "Changes in Migrant Labour Policy of India and Need of a Sustainable Rural Framework: Lessons from the Covid-19 Migrant Exodus" by Agriculture Letters. Besides this the scientists have been recognized at various international and national forums.

कार्यकारी सारांश

वर्ष 2021 के दौरान, भा.कृ.अनु.प.–केन्द्रीय नीबूवर्गीय फल अनुसंधान संस्थान ने नागपुर के साथ–साथ बिश्वनाथ चारीयाली, असम में नीबूवर्गीय पौधरोपण का और विस्तार किया तथा विभिन्न बहु–विषयक परियोजनाओं (संस्थान एंव बाह्य वित्त पोषित) के माध्यम से अपने अनुसंधान कार्यक्रमों को प्रशिक्षण, तकनीकी प्रसार, दौरा, प्रदर्शनी और प्रौद्योगिकियों के 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 विभिन्न नीबूवर्गीय जीनोटाइप के 36 एक्सेसन जैसे, गलगल, नीबू, मोसंबी आदि को पुनर्जीवित किया गया और के.नी.फ.अनु.सं., नागपुर के प्रक्षेत्र में ब्लॉक नंबर 34 में लगाया गया। नीबूवर्गीय एनएजीएस के लिए 72 प्रविष्टियां पुनः उत्पन्न की गईं।

लेमन की चार स्वदेशी किस्में जैसे पंत लेमन, बारामासी लेमन, असम लेमन और कागजी कलान और लेमन की आठ विदेशी किस्में जेनोआ, फ्रॉस्ट लिस्बन, लिमोनेरा–फिनो, वर्ना, फ्रॉस्ट यूरेका, विलाफ्रांका–न्यूसेलर, इम्प्रूव्ड मेयर और बियर की आईपीजीआरआई वर्णन के आधार पर पहचान की गई। 45 ईंडेल मार्करों का उपयोग करते हुए विदेशी संग्रह सहित कुल 22 संतरा प्रजातियों की पहचान की गई। क्लोन एन–2 को मुदखेड संतरा तथा एन–4 को दार्जिलिंग संतरा के निकट संबंधित पाया गया।

गलगल की विभिन्न प्रजातियों में फलभार अधिकतम आईपीएस–29 (451 ग्राम) में रस की मात्रा 32 प्रतिशत के साथ पाया गया। आई पीएस/एफ केवी/199 में बीजों की संख्या सबसे कम(5 बीज/फल) पाई गई। उच्चतम विटामिन सी (29मिग्रा/100ग्रा) आई.पी.एस–29 में पाया गया और इसके बाद आई.पी.एस–30 (27.96 मिग्रा/100ग्रा) में पाया गया। कर्णाखट्टा के विभिन्न प्रजातियों में, आई.पी.एस/362 में अधिकतम फल भार (4478 ग्रा.) और एनआरसीसी–63 में अधिकतम रस मात्रा (25.93%) देखी गई। एनआरसीसी पमेलो–1में विटामिन सी की अधिकतम मात्रा (49.87 मिलीग्राम/100 ग्राम) पाई गई। नीबू की किस्में जैसे प्रमालिनी, बालाजी, साईं शरबती, विक्रम, जयदेवी, फुले शरबती, एनआरसीसी नीबू–7, एनआरसीसी नीबू–8, नागपुरी संतरा, कूर्ग संतरा, सिक्किम संतरा, दार्जिलिंग, मुदखेड बीजरहित और मोसंबी की प्रजातियां जैसे मोसंबी, क्लोन टीएम–33, कोडूर शतगुडी के लिए डीयूएस दिशानिर्देशों के अनुसार अनुरक्षण प्रजनन डेटा दर्ज किया गया।

प्रयोगशाला में कोल्चीसीन के उपयोग से वाणिज्यिक नीबूवर्गीय मूलवृन्त में स्वचतुर्गुणित प्रेरण से मोसंबी में अधिकतम जीवितता (44.98 प्रतिशत) तदोपरांत एलीमो में (43.10 प्रतिशत) पाई गई। अधिकतम सांद्रता में न्यूनतम जीवितता दर पाई गई। *सी. रेटिकुलाटा* (ब्लैंको) सीवी. नागपुर मैंडरिन और *सी. साइनेंसिस* सीवी स्वीट ऑरेंज और किन्नो मैंडरिन (*सी. नोबिलिस* X *सी. डेलिसिओसा*) के कोशिकीय भ्रुणपोष से एंथेसिस के 12 सप्ताह बाद उच्च कैलस प्रेरण दर प्राप्त की गई थी। नागपुरी संतरे (40.22) और किन्नो (39.06) में अधिकतम कैलस प्रेरण एमटी+सीएच+2,4–डी (2ग्राम/ली) + बीए (5ग्राम/ली) माध्यम में हुई। जबकी मोसंबी (44.27) में एमटी + एमई, माध्यम में और भ्रूणजनन की उच्चतम दर नागपुरी संतरे में (53.63 प्रतिशत) और किन्नू (38.81 प्रतिशत) में एमटी+सीएच+2,4–डी (2 ग्राम/ली) माध्यम में जबकि मोसंबी में अधिकतम भ्रुणजनन 49.85 प्रतिशत टी सी एच + 2, 4–डी (2 मिलीग्राम/ली) + बीए (5 मिलीग्राम/ली) में हुई। माध्यम में जीए3 और एडिनाइन सल्फेट के पूरक में सामान्य जड़ और तने के विकास को बढ़ाया तथा नागपुरी संतरे, मोसंबी और किन्नो में पूर्ण पुनर्जनन पौध प्राप्त हुए।

संकरण के माध्यम से नीबूवर्गीय के आनुवंशिक सुधार के तहत, यू. एस. पमेलो X एनआरसीसी मूलवृन्त–5 के पौधे की ऊंचाई 1.9 से 3.मी. और शाखाओं की संख्या 2 से 6 के बीच पाई गई। रफ लेमन X रंगपुर लाईम के मामले में पौधे की ऊंचाई 1.4 से 1.6 मीटर और शाखाओं की संख्या 1 से 3 तक पाई गई। वर्ष 2021 के दौरान, 258 संततियों में से एक संकर संतति (एनआरसीसी सीट्रोन X के एल 12 नीबू) में फूल और फल आया था। आईपीजीआरआई डिस्क्रिप्टर के आधार पर हाइब्रिड और उसके मूल जनक का पत्ती आकारिकी अध्ययन वंशानुक्रम किया गया। पैटर्न के लिए संकरण पौध के पत्तियों की आकारिकी मूल जनक के पत्तियों के समान पाया गया है। पिछले वर्ष के दौरान अंतरजातीय और अंतराजातीय संकरण के परिणामस्वरूप 1085 विभिन्न संकरणों से 138 संततियां हुईं। नीबू X पंत लेमन संकरण से एक सौ सत्ताईस संततियां तैयार की गईं।

विभिन्न गामा किरणन (10,20,30 और 40जी वाय) से उपचारित नीबू के पेड़ों पर लगे हुए फल व पत्तियों की जांच की गई और प्राकृतिक खुले क्षेत्र की स्थितियों के तहत बैक्टीरियल कैंकर की घटना के लिए मूल्यांकन किया गया। सभी पेड़ कैंकर के लिए अतिसंवेदनशील पाये गए। उन नीबू के पौधों में पत्तियों पर रोग प्रकोप 34.9–67.8 प्रतिशत और प्रतिशत रोग सूचकांक (पीडीआई) 6.9–20.0 के बीच पाया गया।

आठ नीबूवर्गीय मूलवृन्त जीनोटाइप का आरसीबीएल स्थान विशेष (लोकाय) का उपयोग कर डीएनए बारकोडिंग के लिए जांच की गई। फाइलोजेनेटिक ट्री में, रफ लेमन को सोर ऑरेज के साथ और गलगल को ट्राइफोलिएट ऑरेंज के साथ समूहीकृत किया गया।

फसल और संसाधन प्रबंधन

संकर मूलवृन्त (एनआरसीसी–2,3,4 और 5) के मूल्यांकन से पता चला है कि एनआरसीसी–3 मूलवृंत में नागपुरी संतरे की उपज अधिकतम (14.85 टन/हेक्टेयर) उसके बाद एनआरसीसी–5 में नागपुरी संतरे की उपज अधिक (13.78 टन/हे.) पाई गई। नागपुरी संतरे पर रंगपुर लाईम और रफ लेमन मूलवृन्त का प्रभाव 6X3 मीटर, 6X4 मीटर, 6X5 मीटर, 6X6 मीटर की दूरी पर मूल्यांकन किया गया। 6x3 मीटर की दूरी पर रफ लेमन और रंगपुर लाईम मूलवृन्त पर क्षेत्रफल के आधार पर अधिकतम उत्पादन क्रमशः (18.54 टन/हेक्टेयर) और (18.18 टन/हैक्टर) दर्ज की गई।

रफ लेमन मूलवृन्त पर उच्च घनत्व के तहत मेढ़ प्रणाली में लगाये गये नागपुरी संतरे में अधिकतम छत्र आयतन 43.55 घन मीटर 5 X 4 मीटर की दूरी पर और 4.5 x 4.5 मीटर दूरी पर 41.38 घन मीटर 7 साल के बाद दर्ज किया गया। अधिकतम फल उपज (27.68 किग्रा/पौधा) 5 x 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 एलिमो (सी.मैक्रोफिलो) मूलवृन्त पर मेढ़ प्रणाली पर 6 x 3 मीटर और 6 x 6 मीटर की दूरी पर लगाये गए पौधों में किया गया। प्रक्षेत्र में 6 X 3 मीटर की दूरी पर पौधे की ऊंचाई 4.2 – 4.7 मीटर और बेहतर छत्र घनत्व (29.09 घन मीटर) प्रदर्शित किया। 6x3 मीटर की दूरी पर लगाये गये पौधों में फलोत्पादन 25.34 किग्रा प्रति पौधा और क्षेत्रफल के आधार पर 14.06 टन/हेक्टेयर देखी गई। मेढ़ के बीच में अंतर–फसल के रूप में सब्जियों (बैंगन, भिंडी, टमाटर) और गेंदा के फूलों को लगाकर सफलता पूर्वक अंतर–फसल ली गई।

पंजाब कृषि विश्वविद्यालय, पंजाब से लाए गए विभिन्न प्रजातियों में पाइनएप्पल मोसंबी में अच्छी ऊंचाई (4.38 मीटर) देखी गई है, जबकि ब्लड रेड में रोपण के बाद 7वें वर्ष में अच्छा छत्र आयतन (30.46 घन मीटर) देखा गया है। ग्रेपफ्रूट प्रजाति मार्स बिजरहित में उच्चतम पौधे की ऊंचाई (4.78 मीटर) और छत्र आयतन (40.81 घन मीटर) तदोपरांत स्टार रूबी में दर्ज की गई। विभिन्न मोसंबी प्रजाती में अधिकतम फलोत्पादन 26.38 किग्रा/पौधा ब्लड रेड में तदोपरांत जाफा में (23.15 किग्रा/पौधा) दर्ज की गई। ग्रेपफ्रूट में मार्स बीजरहित में औसत फल वजन अधिकतम(463.5 ग्राम) था, जबकि अधिकतम अम्लता (1.2%) और विटामिन सी की मात्रा स्टार रूबी में (48.07 मिलीग्राम/100 मिलीग्राम) दर्ज की गई।

ब्राजील से लाये गये मोसंबी किस्म हेमलिन (वोल्कामरीना पर कलमित) जिसे वर्ष 2014 में मेढ़ पर लगाया गया पौधे की अधिकतम ऊंचाई (4.3 मीटर) और छत्र आयतन (30.6 घन मीटर) पाया गया। स्विंगल पर कलमित वेस्टिन में औसत अधिकतम फल उपज (16.53 किग्रा/पौधा) और उसके बाद लिमोक्रोवा पर कलमित पेरा में (16.48 किग्रा/पौधा) दर्ज की गई। रफ लेमन पर कलमित लैनलेट में अधिकतम फल वजन (272.1 ग्राम) दर्ज किया गया। अधिकतम रस मात्रा (43.90%) और विटामिन सी(45.30मि. ग्राम. प्रति 100 मि.ग्रा) वोल्केमेंरियाना पर कलमित वेलेंसिया में दर्ज की गई, इसके बाद लिमोक्रोवा पर कलमित पेरा में रस की मात्रा 42.36 प्रतिशत दर्ज की गई। रंगपुर लाईम मूलवृन्त (30.14%) में फल का अधिकतम औसत फल वजन गिरावट दर्ज की गई, इसके बाद लिमोक्रावो पर कलमित पेरा (25.11%) तथा वोल्केमेरियाना पर कलमित वेलेंसिया में न्यूनतम (16.70%) वजन गिरावट दर्ज की गई।

वर्ष 2015 के दौरान मेढ़ पर लगाए गए नीबू की 10 किस्मों में प्रामालिनी में अधिकतम पौधे की ऊंचाई (4.12 मीटर) दर्ज की गई जबकि न्यूनतम ऊंचाई एनआरसीसी–7 (3.54 मीटर) में तथा फुले शरबती में उच्चतम छत्र आयतन (23.69 घन मीटर) दर्ज की गई। अधिकतम फलोत्पादन पीकेएम–1 यानी 10.37 टन/हेक्टेयर दर्ज की गई जबकि विक्रम में न्यूनतम फलोत्पादन 0.99 टन/हेक्टेयर दर्ज की गई। गंगानगर लाईम में औसत फल वजन 40.2 ग्राम, कुल घुलनशील ठोस 6.1%, रस मात्रा (48.87%) और अम्लता 5.56%

दर्ज की गई। वर्ष 2016 में मेढ़ पर लगाये गये रफ लेमन पर कलमित असम लेमन में अधिकतम औसत फल भार (168.34 ग्राम), अधिकतम अम्लता (6.21प्रतिशत) न्यूनतम कुल घुलनशील ठोस (7. 62 प्रतिशत) के साथ रस की मात्रा 45.84 प्रतिशत पाई गई। जबकि अधिकतम रस की मात्रा (52.31 प्रतिशत) और कुल घुलनशील ठोस (7.81 प्रतिशत) पंत लेमन में दर्ज की गई। असम लेमन में अधिकतम फलोत्पादन (33.04 किग्रा प्रति पौधा और उत्पादन18.34 टन प्रति हेक्टेयर) दर्ज की गई। कैंकर रोग प्रकोप केवल असम लेमन की पत्तियों पर 32.5 प्रतिशत और प्रतिशत रोग सूचकांक 6.8 पाया गया। अन्य किस्मों जिनमें पंत लेमन, कागजी कलाम, बारामासी लेमन को कैंकर रोग से मुक्त पाया गया और 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। डेजी में अधिकतम औसत फलभार (225.81 ग्राम) एंव अधिकतम कुल घुलनशील ठोस 9.41 प्रतिशत तथा एन. 4 में अधिकतम रस की मात्रा (52.17प्रतिशत), अधिकतम विटामिन सी की मात्रा (37.37 मिलीग्राम प्रति 100ग्राम) पाई गई। अधिकतम फलोत्पादन पर्ल टेंजिलो में 9.70 टन प्रति हे. पाया गया।

पमेलो (जुलाई, 2017 के दौरान लगाए गए) में अधिकतम औसत फल वजन (1.36 किग्रा) और कुल घुलनशील ठोस (7.8प्रतिशत) यूएस पमेलो–145 में देखा गया जबकि विटामीन सी (36. 11मिलीग्राम/100 मिलीग्राम), रस मात्रा (34.89 प्रतिशत) और अम्लता (1.24 प्रतिशत) अधिकतम फल उपज (4.52 टन/हेक्टेयर) के साथ एनआरसीसी पमेलो–5 में अधिकतम दर्ज की गई।

वर्ष 2021 में नीबू में उच्च सघन रोपण में 5 X 5 मीटर में 20.71 टन/हेक्टेयर, 5 X 2.5 मीटर में 28.56 टन/हेक्टेयर और 2.5 X 2. 5 मीटर में 40.39 टन/हेक्टेयर की फल उपज दर्ज की गई, जो सघन रोपण में बढ़ती उपज की संभावना को दर्शाता है। हालांकि, इसका नकारात्मक पक्ष कीटों का भारी प्रकोप था और विशेष रूप से बरसात के मौसम में नीबूवर्गीय कैंकर को बहुत अधिक मात्रा में देखा गया। आधुनिक उपकरणों, औजारों और श्रम के साथ नियमित पौध संरक्षण उपायों और तकनीकी कार्यों को शामिल करते हुए देखभाल और रखरखाव की अधिक आवश्यकता थी।

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 एथीलएस्टर 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 2,4–डी 10 पीपीएम ने अच्छे परिणाम दिखाये।अंबिया बहार फूल आने की अवस्था में थायोयूरिया, जीए$_3$ और नाइट्रोबेंजीन का पत्तों पर प्रयोग नागपुरी संतरों में फलों की उपज को बढ़ाता है। सभी सांद्रणों में नाइट्रोबेंजीन 500 पीपीएम के प्रयोग से फूल और फल लगने की तीव्रता जीए3 20 पी.पी.एम और थायोयूरिया 2% की तुलना में बढ़ जाती है।

नागपुरी संतरे की उन्नत बागवानी के लिए पानी और पोषक तत्वों के उपयोग की क्षमता बढ़ाकर, जीपीएस आधारित नमूने (मिट्टी और पत्ती के नमूने) एकत्रित कर जीआईएस आधारित बेरियोग्राम छत्र आयतन (घन मीटर) और फलोत्पादन (किग्रा प्रति पेड़) के लिए विकसित किए गए। पौधों के छत्र आयतन बायोमेट्रिक अवलोकनों पर आधारित उत्पादन प्रबंधन क्षेत्र जैसे न्यूनतम, सामान्य और उच्च निरूपित 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 क्रमशः 186. 22, 137.58 ग्राम और 7.10 टन/हेक्टेयर थी। मध्यम और निम्न उत्पादन क्षेत्रों में समान 131.50, 132.12 ग्राम, 4.81 टन/हेक्टेयर और 110.82, 126.08 ग्राम, 3.87 टन/हेक्टेयर दर्ज की गई।

नीबूवर्गीय फलों के निरंतर उत्पादकता के लिए एकीकृत पोषक प्रबंधन मॉड्यूल को विकसित किया गया और मोसंबी के लिये सर्वोत्तम पोषक तत्वों की आवश्यकता को मानकीकृत किया गया। उपचार टी–5 (800 ग्राम नत्रजन, 200 ग्राम फास्फेट, 400ग्राम पोटाश प्रति पौधा) द्वारा अधिकतम फलोत्पादन 25.3 किग्रा प्रति पेड़ (7.03 टन प्रति हेक्टेयर) देखा गया साथ ही इसी उपचार के साथ अधिकतम रस मात्रा, कुल घुलनशील ठोस और कुल घुलनशील ठोस अम्लता अनुपात की भी जांई। उत्तम नागपुरी संतरे के उत्पादन के लिए अवभूमि सूक्ष्म सिंचाई और उर्वरकीकरण अनुसूची हेतु नये प्रयोग की शुरूआत की गई।

नीबूवर्गीय फलों में एग्रोसेल–आधारित पोटेशियम सोहनाईट (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 सोहनाईट से उपचारित पौधों में पौध ऊंचाई (2.78 मीटर), उत्तर–दक्षिण प्रसार (1.54 मीटर जो उपचार टी3 के बराबर है), पूर्व पश्चिम प्रसार (1.54) के संदर्भ में उच्च फलों की उपज (59.27 किग्रा प्रति पेड़ या 16.53 टन प्रति हेक्टेयर) देखी गयी।

उत्तर पूर्वी क्षेत्रों में महत्वपूर्ण नीबूवर्गीय रोगों से प्रभावित खासी संतरा पौधों के जिर्णोद्धार में नीबूवर्गीय माइक्रोबायोम का पता लगाया गया। मिट्टी के नमूने चार स्थानों (खासी संतरा बागों) असम में मोटापुंग, बोरगौह, तिनसुकिया और खमनपाथर और मेघालय के सोखवाई में 2 स्थानों से एकत्र किए गए। दोनों मिट्टी के नमूनों में *स्यूडोमोनास* और *बेसिलस* के विविध समूह अपने–अपने माध्यम पर दिखाई दिए। दिलचस्प बात यह है कि एचएलबी मिट्टी के नमूने में *बेसिलस* समूह की अधिकतम विविधता थी, जबकि एचएलबी– मिट्टी में जीवाणुओं के *स्यूडोमोनास* समूह की प्रमुख और अधिकतम विविधता प्रदर्शित हुई।

इसके अलावा, नागपुर जिले, महाराष्ट्र और उम्देनलांग बस्ती, री–भोई जिले, मेघालय में क्रमशः पुराने नागपुरी संतरा और खासी संतरा बागों के जीर्णोद्धार के लिए के.नी.फ.अनु.सं. प्रौद्योगिकियों का प्रदर्शन किया गया।

पौध सुरक्षा

उद्यानिकी कीट निगरानी एंव 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 बल्क एसएमएस और व्हाट्सएप मैसेज भेजे गए। स्थानीय समाचार पत्रों और व्हाट्सएप संदेशों, प्रेस नोटों के माध्यम से नीबूवर्गीय फलोत्पादकों के लिए नियमित कीट नियंत्रण सलाह भी जारी की गई। वर्ष के दौरान, 23.09 हेक्टेयर क्षेत्र को कवर करने वाले 13 गांवों, चार तालुकों सहित दो जिलों (नागपुर और वर्धा) के चयनित बागों में छह प्रक्षेत्र दौरे आयोजित किए गये। संबंधित बगीचों के पेस्ट मॉनिटर और पेस्ट स्काउट को नागपुरी संतरा और मोसंबी के कीटों एवं रोगों की पहचान और उनके प्रबंधन पर प्रक्षेत्रों में प्रशिक्षण दिया गया। इसके अतिरिक्त नागपुर मंडल और अहमदनगर जिलों के स्काउट और मॉनिटर को वर्चुअल प्रशिक्षण भी दिया गया।

राइजोबैक्टीरिया के कुल 39 आइसोलेट्स को नीबूवर्गीय जड़ क्षेत्र मृदा से अलग किया गया और फिर *फाइटोफ्थोरा निकोसियाना* के विरूध्द प्रयोगशाला में जांच की गयी। 39 आइसोलेट्स में से 11 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–163–एफई–171) को अलग किया गया था। *फाइटोफ्थोरा निकोसियाना* को नियंत्रित करने में सक्षम पाये गये। पूरी तरह से परीक्षण किए गए आइसोलेट्स में निषेध 40 प्रतिशत से नीचे पाया गया। दो आशाजनक एंडोफाइट्स सीएफई 109 और सीएफई–157 (*चेटोमियम ग्लोबोसम*) और सीएफई–142 (*एस्परजिलस टेरियस*) का टेलकम पावडर आधारित उत्पाद तैयार किया गया।

नागपुर संतरे (*सीट्रस रेटिकुलाटा* ब्लैंको) के फलों पर एक अन्य प्रयोग स्कॉलर 230 एस.सी. (फ्लूडीसोक्वानील 23 प्रतिशत डब्ल्यू/व्ही एससी) कोटिंग का मूल्यांकन करने के उद्देश्य से किया गया था, ताकि नीबूवर्गीय फलों में तुडाई के बाद की बीमारी को नियंत्रित किया जा सके और नागपुर संतरा फलों की शेल्फ लाइफ को बढ़ाया जा सके। नागपुरी संतरा फल फ्लूडीसोक्वानील 23 प्रतिशत डब्ल्यू/व्ही एससी 3.90 जी/ग्रा. ली. एल के साथ लेपित, प्रशीतित भंडारण स्थितियों के तहत रोग नियंत्रण और अन्य भौतिक–रासायनिक मापदंडों के संबंध में काफी बेहतर परिणाम दिखाता है।

सिट्रस ग्रीनिंग रोग (एच एल बी) के प्रबंधन के लिए उत्तर पूर्वी क्षेत्र की उत्तर पूर्वी स्थितियों के तहत माइक्रोबायोम संसाधन का पता लगाया गया। एचएलबी विशिष्ट पीसीआर के आधार पर, खमनपाथर, मोटापुंग और तिनसुकिया (असम) के बागों को एचएलबी पॉजिटिव के रूप में पहचाना गया। कुल मिलाकर, चौदह (खमनपाथर क्षेत्र से 4, मोटापुंग क्षेत्र से 2 नमूने, तिनसुकिया क्षेत्र से 3, बिश्वनाथ चारियाली से 2, सोखवाई से 2 और 1 नमूना मोरालगांव) के सैंपल एचएलबी के लिए पॉजिटिव पाए गए हैं। रोगाणुओं का अलगाव स्वस्थ और संक्रमित दोनों नमूनों से किया गया था, जहां बारह आइसोलेट्स को *ए. ट्यूमेफेशियंस* ईएचए105 एचएलबी जीवाणु के एक संबधित के खिलाफ विरोधी के रूप में

पहचाना गया है, जिनमें से दो एंडोफाइटिक बैक्टीरिया आइसोलेट्स के एमएमई 40 और केएमएमई 64 बहुत ही आशाजनक पाए गए।

पार्श्व प्रवाह इम्युनोक्रोमैटोग्राफिक परख के साथ मिलकर एक रिवर्स ट्रांसक्रिप्शन रिकॉम्बिनेज पॉलीमरेज आधारित आइसोथर्मल प्रवर्धन को सीटीवी का तेजी से पता लगाने के लिए मानकीकृत किया गया था। सीटीआरवीए–एफ1/आर9–बीटीएन प्राईमर संयोजन की पहचान सीटीवी– पी25 जीन के –165 बेस पेयर क्षेत्र को लगातार बढ़ाने वाले सबसे बेहतर प्रदर्शन करने वाले प्राइमर सेट के रूप में की गई थी। सीटीवी की तेजी से पहचान के लिए आरटीआरपीए–एलएफआयसी परख भी विकसित की गई थी। विकसित परख ने प्रारंभिक टेम्पलेट के रूप में इन विट्रो–ट्रांसक्रिब्ड आरएनए के 141 एनजी से संश्लेषित 10^5 क्रमिक मन्दन तक सीटीवी के लक्ष्य सीडीएनए का लगातार पता लगाया। सीटीवी विशिष्ट प्राईमर–जांच संयोजन का उपयोग करके टाकमैन–क्यूपीसीआर आधारित विधि को भी मानकीकृत किया गया था।

2एस एल्ब्यूमिन प्रोटिन को कोहड़ा (*कुकुर्बिटा मैक्सिमा*) के बीजों से पृथक कर शुध्द किया गया और *ई.कोलाई* (डीएच5ए) के विरूध्द इन विट्रो प्रयोगात्मक डेटा के आधार पर प्रभावी रोगाणुरोधी सांद्रता निर्धारित की गई। मोसंबी के पेड़ों पर 2S एल्ब्यूमिन प्रोटीन और नैनो–जेडएनओ सूत्रीकरण का ट्रंक इंजेक्शन किया गया था। हालांकि, नियंत्रण की तुलना में सीएलए टाइटर कमी में थोड़ा महत्वपूर्ण अंतर देखा गया। वर्चुअल स्क्रीनिंग तकनीक का उपयोग *कैंडिडैटस* लाबेरिबैक्टर एशियाटिकस से प्यूटेटिम सिस्टीन–बाइंडिंग प्रोटीन के खिलाफ एक संभावित अवरोधक अणुओं की पहचान करने के लिए किया गया था। दो अवरोधक अणु। पिमोजाइड और क्लिनिडियम बहुत आशाजनक पाए गए।

रूपात्मक गुणों के आधार पर, के.नी.फ.अनु.सं. में विभिन्न नीबूवर्गीय मूलवृन्त पर उगाए जाने वाले मोसंबी की किस्मों में विभिन्न पादप परजीवी निमेटोड जेनेरा जैसे *प्रैटिलेन्चस, होप्लोलाइमस, क्रिकोनेमा* और *टाइलेंचुलस सेमीपेनेट्रांस* की पहचान की गई। महाराष्ट्र के अमरावती जिले में नागपुरी संतरा उगाने वाले क्षेत्रों में पादक परजीवी सूत्रकृमि जेनेरा जैसे *प्रैटिलेन्चस, मेलोइडोगाइन, होप्लोलाइमस* और *टाइलेंचुलस सेमीपेनेट्रांस* की पहचान की गई। स्वस्थ नीबूवर्गीय मूलवृन्त जैसे रफ लेमन, रंगपुर लाइम, एलेमो और नीबू से एकत्र किए गए जड़ रस के जीसी–एमएस विश्लेषण से हाइड्रोकार्बन, एस्टर, एल्डिहाइड, केटोन्स, अल्कोहल, टेरपेन और फैटी एसिड युक्त रासायनिक यौगिकों की एक सारणी का पता चला।

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 14 दिनों के उपरांत नागपुरी संतरे में अधिकतम रस, कम पीएलडब्ल्यू और अच्छी विटामिन सी की मात्रा दर्ज की गई नागपुरी संतरा फलों को सोडियम केसिनेट और सोया प्रोटीन 2 प्रतिशत सांद्रता के साथ ग्लिसरॉल 2 प्रतिशत और दालचीनी के तेल 50 पीपीएम की दर के साथ बेहतर फल की गुणवत्ता बनाए रखी जा सकती है। 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 आइस्क्रीम बनाने की तकनीकों को विकसित किया गया। *सीट्रस लैटिप्स, सीट्रोलो* और *सीट्रस पेनिवेसिकुलता* रस में क्रमशः लिमोनिन की मात्रा (11.53, 8.09 और 9.48 पीपीएम) दर्ज की गई। रस में कुल फिनोल की मात्रा (13.938 मिलीग्राम प्रति गेल) *सीट्रस लैटीपस* के साथ और सीट्रेमेलो में रस की कुल मात्रा (13.463 मिलीग्राम प्रति गेल) के बाद अधिक दर्ज की गई थी। जबकी *सीट्रस वेनिवेसिकुलमा* में केवल क्रमशः 9.075 मिलीग्रॅम प्रति गेल पाया गया। एबीटीएस (6.44 प्रति ली. मोल $^{L-1}$ ट्रोलेक्स) और डीपीपीएच (9.33 मिली मोल प्रति ट्रोलेक्स) पाइ। परख द्वारा सिट्रमेलो के छिलके में एंटीऑक्सीडेंट क्षमता अधिक पाई गई और एफआरएपी (4.24 मोल $^{L-1}$ ट्रोलेक्स) द्वारा *सीट्रस लैटिप्स* के छिलके में उच्च पाया गया। पहली बार भारत में पूर्वोत्तर क्षेत्र में नीबूवर्गीय फलों में फ्लेवोनोइड्स, एस्कॉर्बिक एसिड और कार्बनिक अम्लों का आकलन *सीट्रस हिस्ट्रिक्स,* चेज रफ लेमन (*सीट्रस जंभीरी*), इलाइची नीबू (*सीट्रस लिमोन*), जोराटेंगा (*सीट्रस मेडिक*) सीट्रक एसिड में किया गया। इसमें और ट्रेस मात्रा में टार्टरिक, बेंजोइक, ऑक्सालिक और सक्सिनिक एसिड के साथ मेलिक एसिड पाए गए।

उच्च मूल्य वर्धित उत्पादों जैसे नागपुरी संतरा और असम नीबू से कम चीनी युक्त जेली (न्यूट्री जेली) और पॉलीफेनोल समृद्ध पमेलो छीलके के पाउडर से कार्यात्मक पास्ता बनाने की विधी को मानकीकृत और विकसित किया गया।

सामाजिक विज्ञान

भा.कृ.अनु.प.–के.नी.फ.अनु.सं. और अन्य जगहों से रोपण सामग्री खरीदने वालों के बीच 5 वर्षों की अवधि में विदर्भ के नीबूवर्गीय उत्पादकों की औसत वार्षिक आय में अंतर की जांच करने और तुलना करने का प्रयास किया गया। जिन किसानों ने नागपुरी संतरे की संस्थान की रोपण सामग्री खरीदी थी, उनकी औसत वार्षिक आय 5 वर्ष पहले रु. 8,22,203.39/हे./वर्ष, बढ़कर अध्ययन वर्ष (2021) से 3 वर्ष पहले 10,57,627.1/हेक्टेयर/वर्ष थी। गैर–संस्थान की रोपण सामग्री वाले लोगों ने कम औसत वार्षिक आय जो 5 वर्ष पहले 62,1875/हे./वर्ष थी जो बढ़कर रु. 81,1250 (1/हेक्टेयर/वर्ष अध्ययन वर्ष से 3 वर्ष पहले तक हो गई थी। अतः दोनों श्रेणियों के किसानों में रु. 2,35,423.71/हें/वर्ष और रु. 1,89,375/हे/वर्ष की वृद्धि दर्ज की गई। मोसंबी और नीबू की खेती करने वालों की आय भी संस्थान की रोपण सामग्री, सभी 3 नीबूवर्गीय फसलों में गैर–संस्थान रोपण सामग्री की तुलना में बेहतर थी। बेहतर गुणवत्ता, कीट और रोगों की कम घटनाओं में शामिल खेती की कम लागत के कारण संस्थान के पौधों ने गैर–संस्थान सामग्री वाले किसानों की तुलना में बेहतर परिणाम दिये। भा.कृ.अनु.प.– के.नी.फ.अनु.सं. द्वारा अपनाई गई प्रौद्योगिकियों के बारे में किसानों की धारणा का आकलन किया गया। जिन किसानों ने नागपुरी संतरा, मोसंबी और नीबू की रोपण सामग्री संस्थान ने खरीदी थी, उन्होंने अपने बागों में लगाने के बाद अपनी समीक्षा की सूचना दी। 85% संतरा किसानों ने बताया कि संस्थान की रोपण सामग्री की खेती के बाद उन्हें उत्पादन और आय के मामले में लाभ हुआ, जबकि 10% ने बताया कि कोई बदलाव नहीं हुआ और 5% को नुकसान हुआ। ऐसे किसान जो संस्थान की तकनीकी का उपयोग कर रहे थे लेकिन गैर–संस्थान सामग्री के साथ बागों की स्थापना की थी, ऐसे किसानों की संख्या भी दर्ज करने का प्रयास किया गया। 93% संतरा किसानों ने बताया कि वे संस्थान की प्रौद्योगिकियों को अपना रहे है जबकि 7% लोग तक संस्थान की तकनीकी की जानकारी नहीं पहुंच पाई।

नीबूवर्गीय फलों के लिए क्षेत्रीय अनुसंधान केंद्र (आरआरसीसी), विश्वनाथ चारियाली, आसाम

विभिन्न वाणिज्यिक नीबूवर्गीय प्रजातियों का मेढ़ एवं समतल प्रणाली पर मूल्यांकन हेतु अगस्त, 2017 के दौरान 17 अलग अलग नीबूवर्गीय प्रजातियों संतरा, मोसंबी, लेमन, नीबू, पमेलो और ग्रेपफ्रूट आदि किस्मों का रफ लेमन मूलवृन्त पर 5 X 3 मीटर की दूरी पर रोपण किया गया। सभी किस्मों में उत्कृष्ट प्रदर्शन देखा गया। रोपण प्रणालियों और परिणामों दोनों में विकास प्रदर्शन ने पौधों की ऊंचाई तने की मोटाई और छत्र आयतन के संबंध में प्रजातियों के बीच एक महत्वपूर्ण भिन्नता दिखाई दी। संतरे में दोनों प्रणालीयों मेढ़ एवं समतल दोनों में खासी संतरे के अंकुरण में अधिकतम उंचाई समतल (5.13 मी.) की तुलना में मेढ़ प्रणाली में (5.17 मी) पाई गई । मोसंबी के संबंध में दोनों प्रणालीयों में अधिकतम पौध उंचाई (4.53 मी.) देखी गई और समतल प्रणाली में कटर वेलेंसिया में अधिकतम छत्र आयतन देखा गया। ग्रेपफ्रुट में अधिकतम पौध उंचाई (4.43 मी) , मूलवृन्त तने की मोटाई (52.66 सेमी) तने की मोटाई (52.33 से.मी.) और फ्लेम ग्रेप फ्रुट में समतल प्रणाली में अच्छा छत्र आयतन मेढ़ प्रणाली के तुलना में देखा गया। पमेलो के संबंध में अधिकतम पौध उंचाई (4.63 मी) समतल प्रणाली में और मूलवृन्त तने की अधिकतम मोटाई (43.67 से.मी.) और (43.33 से.मी.) मेढ़ प्रणाली में दर्ज कि गई। असम लेमन में मेढ़ प्रणाली में अच्छी पौध उंचाई जबकि समतल प्रणाली में अच्छा छत्र आयतन देखा गया। एनआरसीसी नीबू–7 में मेढ़ एवं समतल दोनों पद्धती में पौधों की उंचाई (4.37 और 4.46), मूलवृन्त की मोटाई (39.33 और 44.66 से.मी.) पाया गया जो एनआरसीसी नीबू –8 की तुलना में अधिक है।

पौध सामग्री का उत्पादन

संस्थान के पौधशाला कार्यक्रम के तहत नीबूवर्गीय फलों की 1,94,268 लाख रोगमुक्त पौध सामग्री की विक्री कर 104.56 लाख रू. का राजस्व अर्जीत किया गया।

संसाधन निर्माण

संस्थान ने पौध सामग्री, बीज, मूलवृंत जांच कार्य प्रकाशन एंव अन्य उत्पादों की बिक्री के माध्यम से 132.04 लाख रू. एवं अन्य स्त्रोत पर ब्याज सहित राजस्व 35.13 लाख रू. के साथ कुल मिलाकर रू. 167.17 लाख का राजस्व वर्ष 2021 के दौरान प्राप्त किया है।

प्रशिक्षण / कौशल विकास और विस्तार

संस्थान ने 14 प्रशिक्षणों का आयोजन किया जिसमें 4 परिसर में 3 परिसर के बाहर 2 प्रशिक्षण आदिवासी उप–योजना के तहत, 4 प्रशिक्षण उत्तर पूर्वी पर्वतीय क्षेत्र में और एक प्रशिक्षण अनुसूचित जाति उप–योजना के तहत कुल 1662 लाभार्थियों के साथ आयोजित किया गया।

संस्थान द्वारा आयोजित महत्वपूर्ण कार्यक्रम

गणतंत्र दिवस (26 जनवरी, 2021), शहीद दिवस (30 जनवरी, 2021), अंतर्राष्ट्रीय महिला दिवस (8 मार्च, 2021), विश्व जल दिवस (22 मार्च, 2021), डॉ. भीमराव अंबेडकर की 131वीं जयंती (14 अप्रैल, 2021) 15 अप्रैल 2021 को 'उर्वरक के संतुलित उपयोग' पर किसान जागरूकता अभियान कार्यक्रम का आयोजन (18 जून 2021) (आभासी), अंतर्राष्ट्रीय योग दिवस (21 जून, 2021), सीसीआरआई का 37वां स्थापना दिवस (28 जुलाई, 2021), स्वतंत्रता दिवस (15 अगस्त, 2021), पार्थेनियम जागरूकता (21 अगस्त, 2021), पोषण वाटिका महा अभियान और वृक्षारोपण, अंतर्राष्ट्रीय बाजरा दिवस (17 सितंबर, 2021), ''नीबूवर्गीय फल गिरावट'' पर बौद्धिक मंथन कार्यशाला (27 सितंबर, 2021), ''जलवायु अनुकूल किस्मों, प्रौद्योगिकियों और प्रथाओं'' पर किसान वैज्ञानिक इंटरफेस (28 सितंबर, 2021), हिंदी सप्ताह (14–22 सितंबर, 2021), 'महिला किसान दिवस' (15 अक्टूबर, 2021), विश्व खाद्य दिवस' (16 अक्टूबर, 2021) राष्ट्रीय एकता दिवस (31 अक्टूबर, 2021), सतर्कता जागरूकता सप्ताह (26 अक्टूबर, 2021 से 1 नवंबर, 2021), ''रोगाणुरोधी प्रतिरोध'' पर राष्ट्रीय अभियान (24 नवंबर, 2021), ''संविधान दिवस (संविधान दिवस)" (26 नवंबर 2021), "इंडिया इंटरनेशनल साइंस फेस्टिवल (आईआईएसएफ) 2021" (27 नवंबर, 2021), विश्व मृदा दिवस' (5 दिसंबर, 2021), डॉ. बी.आर. अम्बेडकर महा परिनिर्वाण दिवस (6 दिसंबर, 2021) और शून्य बजट प्राकृतिक खेती (16 दिसंबर, 2021) का आयोजन किया गया।

विशेष व्याख्यान

संस्थान द्वारा आजादी का अमृत महोत्सव के तहत पहला विशेष अतिथि व्याख्यान जिसमें डॉ. मंजुल दत्त, अनुसंधान वैज्ञानिक, नीबूवर्गीय फल अनुसंधान एवं शैक्षणीक संस्थान, (सीआरईसी), फ्लोरिडा विश्वविद्यालय, यूएसए ने 30 सितंबर, 2021 को ''सीट्रस में ग्रीनिंग डिजीज (हंगलोंगबीन) के प्रबंधन के लिए जेनेटिक संशोधन और जीनोम एडिटिंग स्ट्रैटेजीज का उपयोग'' विषय पर आयोजित किया गया।

कल्याण गतिविधि

24 फरवरी, 2021 और 10 मई, 2021 को अनुसूचित जाति उप योजना (एससीएसपी) के तहत फार्म किट का वितरण एंव 23 नवंबर, 2021 को ''एसबीआई ऑफिस कनेक्ट'' ने व्याख्यान दिया।

राजभाषा गतिविधियाँ

श्रीमती रंजना भट्ट की अध्यक्षता में संसंदीय राजभाषा समिति की दूसरी उपसमिति के अन्य 8 सदस्यों के साथ 28 दिसंबर 2021 को संस्थान द्वारा राजभाषा संबंधि किये जा रहे कार्यों का निरीक्षण किया। इस निरीक्षण के दौरान संस्थान के संबंधित अधिकारी उपस्थित थे। संस्थान के कर्मचारियों की राजभाषा कार्यों हेतु रूची बढ़ाने हेतु इस वर्ष 3 कार्यशालाओं का आयोजन किया गया।

प्रौद्योगिकियों का व्यावसायीकरण

संस्थान ने अपनी रोगमुक्त पौध सामग्री तैयार करने हेतु लाइसेंस प्राप्त कंटेनरीकृत तकनीकी का मे. प्रतीमा बायोटेक प्रा.लि., रायपुर के साथ हस्ताक्षर किए एवं साथ ही तुड़ाई उपरांत प्रबंधन के लिए इवेल्यूवेशन ऑफ स्कालर 230 एससी के लिए मे. सिजेंटा प्रा. लि., मुंबई के साथ अनुबंध परियोजना पर हस्ताक्षर किये।

पेटेंट

संस्थान ने नीबू के लिए स्पार्कलिंग क्लीयर रेडी–टू–सर्व बेवरेज उत्पाद के लिए एक प्रक्रिया विकसित कर अपना पहला पेटेंट प्राप्त किया।

पुरस्कार और मान्यता

2021 के दौरान, डॉ. ए. के. श्रीवास्तव, प्रधान वैज्ञानिक को प्रा. खाद्य सुरक्षा, पर्यावरण सुरक्षा और सतत विकास के लिए कृषि, वानिकी और अनुप्रयुक्त विज्ञान में वैश्विक पहल (जीआयएएफएएस – 2021) पर तीसरे अंतर्राष्ट्रीय सम्मेलन में ''नीबूवर्गीय फलों में मिट्टी की उर्वरता और पौधों के पोषण'' के क्षेत्र में उत्कृष्ट योगदान और मान्यता के लिए वैज्ञानिक मानद फेलो, 2021)", श्री गुरु राम राय विश्वविद्यालय, देहरादून, उत्तराखंड, भारत में 17–18 अक्टूबर,

2021; डॉ. दिनेश कुमार, प्रा. वैज्ञानिक (बागवानी) को सीएचएआई–जेआईएसएल फेलोशिप अवार्ड 2021, बागवानी फसलों में तुड़ाई उपरांत प्रबंधन के लिए डॉ. जे.सी. आनंद अवार्ड ''इंडियन एकेडमी ऑफ हॉर्टिकल्चरल साइंसेज'', नई दिल्ली और सीएचएआई–डॉ. कृति सिंह उत्कृष्ठ पेपर पुरस्कार– 2020, डॉ. जे. पी. तेज कुमार एवं अन्य, 18–19 फरवरी, 2021 के दौरान केंद्रीय कृषि विश्वविद्यालय, इंफाल में ''उत्तरपूर्व क्षेत्र में नीबूवर्गीय जैव विविधता के संरक्षण और व्यावसायीकरण'' पर राष्ट्रीय संगोष्ठी में ''एसएसआर और इनडेल्स का उपयोग करते हुए स्वदेशी मोसंबी की खेती के बीच आनुवंशिक विविधता की तुलना'' के लिए सर्वश्रेष्ठ पोस्टर पुरस्कार; डॉ. संगीता भट्टाचार्य, वैज्ञानिक (प्रसार) को कृषि पत्रों द्वारा ''भारत की प्रवासी श्रम नीति में परिवर्तन और एक सतत ग्रामीण ढांचे की आवश्यकता कोविड–19 प्रवासी पलायन से सबक'' पर लेख के लिए सर्वश्रेष्ठ लेख पुरस्कार मिला। इसके अलावा वैज्ञानिकों को विभिन्न अंतरराष्ट्रीय और राष्ट्रीय मंचों पर सम्मानित किया गया है।

2 ICAR-CCRI : A PROFILE

Genesis

Citrus crops *viz.,* sweet orange, mandarin, lime, lemon, grapefruit and pummelo are the important fruit crops in nutritional security of the country. Keeping in view 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 37th 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 tonnes/ha to 20 tonnes/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 facility of farmers' Hostel for residential training programmes of farmers and stakeholders.

An excellent library, especially on citrus, with a total collection of 3434 Books and back volumes of research Journals has been established to support research, teaching and extension. Online literature search facility and on-line Journals is also being provided under consortium of e-resources in Agriculture (CeRA) to all scientists in their laboratories. Institute also provides library facility to PG research students on request basis. The library has been fully computerized by using the Koha software, a web-based integrated management system. Documentation unit was further strengthened electronically by subscribing 731 publications in G-Gate e-Journal and science direct for e-journals and e-books for the year 2019-2020.

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 institution 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.

Farm infrastructure : New Building of Farm Office and Tractor Shed at RRCC inaugurated on 10th January, 2021.

Mera Gaon Mera Gaurav

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

Thrust Areas

- Strengthening of Regional Research Centre on 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.
- Trait-based germplasm collection, field evaluation, molecular characterization, induction of triploid / tetraploids and their field evaluation, application of marker aided selection, development of mutant population, application of cis-genics, QTL mapping, CRISPR technologies and RNAi
- Plant multiplication through microbudding, HDP with automated fertigation, citrus under protected system and yield based fertilizer advisory. Dynamics of flowering, inset-pests and diseases, rhizosphere microbiome engineering, sub-surface irrigation, variable rate fertigation, fruit yield and quality assessment system, yield forecasting models.
- Pheromones based citrus pest management, insect vector relation via-a-vis HLB / CTV, MAS for resistance against *Phytophthora*, citrus nematodes, isolation of endophytes against diseases. Host-plant interaction with respect to insect-pests and diseases, identification and multiplication of pest-specific bioagents and citrus greening simulation models.
- Fresh fruit handing for extended shelf life, evaluation of new varieties for processing and automation in post-harvest handling. Electronic nose in fruit maturity, robotics in fruit harvesting, drone farming, nano-formulation in shelf life, smart packaging, market intelligence.
- Linkages and collaboration, technology upscaling, dissemination via PPP mode, feedback mechanism, technology refinement.

Budget (2021-22)

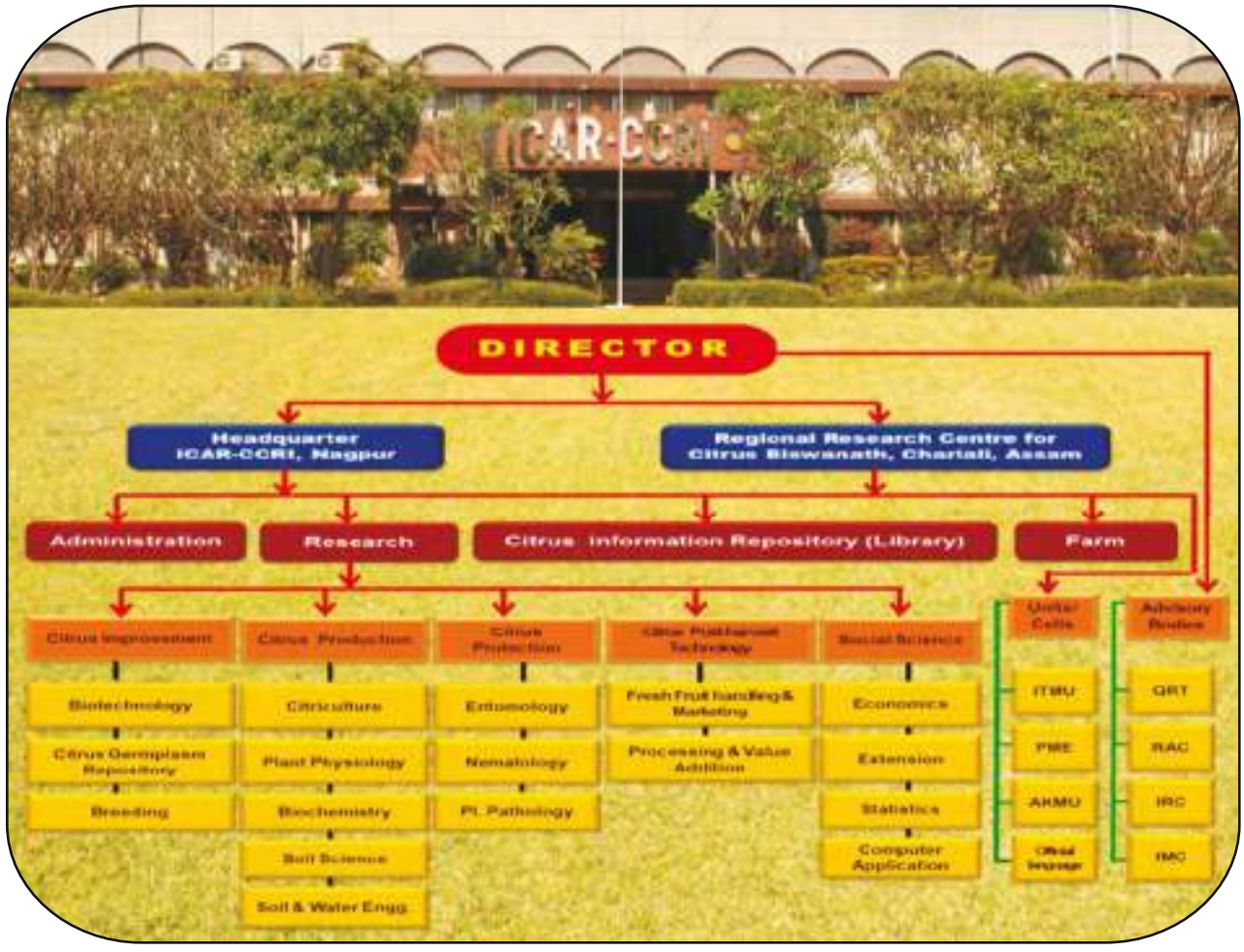
Institute Govt. Grant	Release	Expenditure	Utilization of Funds
1736.23 lakhs	1736.23 lakhs	1678.74 lakhs	96.69 %

Staff Strength (as on 31/12/2021)

Category	CCRI, Nagpur (Hq.)			RRCC, Assam (Regional Centre)			Total Sanctioned posts	Vacant posts
	Sanctioned posts	In Position	Vacant posts	Sanctioned posts	In Position	Vacant posts		
Director (RMP)	01	01	00	00	00	00	**01**	**00**
Scientific	19	15	04	03	01	02	**22**	**06**
Technical	20	18	02	00	00	00	**20**	**02**
Administrative	13	07	06	00	00	00	**13**	**06**
Supporting	20*	19	00	00	00	00	**19**	**00**
Total	72	60	12	03	01	02	**75**	**14**

* One post abolished due to death of CLTS

ORGANOGRAM



3 Research Achievements

3.1 Genetic Resources and Crop Improvement

3.1.1 Collection, conservation and characterization of citrus germplasm

3.1.1.1 Collection of citrus germplasm

New collection of citrus germplasm could not be possible due to COVID - 19 pandemic.

3.1.1.2 Conservation of citrus germplasm

Different citrus germplasm conserved is presented in Table 1. Fourteen galgal (*C. pseudolimon*), seven karna khatta (*C. karna*), nine citron (*C. medica*), four sweet lime (*C. lamettioides*) and two adajamir (*C. assamensis*) were regenerated. The distributed germplasm was pooled in Block no. 34 and planted to evaluate the performance.

Apart from these 36 collections, 72 accessions from other citrus genotypes including hybrids of Trifoliate orange were regenerated. These will be planted in germplasm blocks in a way that accessions from the same group will be pooled at one place.

3.1.1.3 Characterization of citrus germplasm

Lemon

The four indigenous lemon varieties like Pant lemon, Baramasi lemon, Assam lemon and Kagzi Kalan and eight exotic lemon varieties *viz*., Genoa, Frost Lisbon, Limonera Fino, Verna, Frost Eureka, Willafranka Nucellar, Improved Meyer and Bear's were morphologically characterized based on IPGRI descriptors and described in the Table 1.

3.1.1.4 Evaluation of citrus germplasm

Molecular characterization of mandarin accessions

Total DNA was isolated from a total of 22 mandarin accessions including exotic collections. A total 45 InDel 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. Scoring was done based on the presence and absence of the bands and same data was used to construct the dendogram using Darwin software v.6.0 (Fig. 1). The dendrogram has two distinct clades and exotic collections were found in both the clades. Even though kinnow is a

Table 1 : Morphological characterization of lemon varieties

Characters	Pant lemon	Assam lemon	Kagzi Kalan	Baramasi lemon	Genoa	Frost Lisbon	Limonera Fino	Verna	Frost Eureka	Willafranka Nucellar	Improved Meyer	Bears
Plant growth habit	Spreading	Drooping	Spreading	Spreading	Erect	Erect	Erect	Spreading	Erect	Erect	Spreading	Erect
Branch density	Medium	Medium	Medium	Medium	Sparse	Medium	Medium	High	Medium	Medium	High	Medium
Thorn	Absent	Medium	Absent	Absent	Low	Medium	Medium	Low	Low	Low	Low	Low
Shoot tip colour	Green	Purple	Green	Green	Purple	Purple	Purple	Purple	Purple	Purple	Green	Purple
Leaf tip surface	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous	Glabarous
Leaf vegetative cycle	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen	Evergreen
Leaf division	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple	Simple
Intensity of green colour in leaf blade	Dark green	Light green	Medium green	Green	Dark green	Medium green	Medium green	Dark green	Medium green	Dark green	Medium green	Dark green
Leaf colour variegation	No	No	No	No	No	No	No	No	No	No	No	No
Leaf lamina attachment	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile	Sessile

mandarin hybrid, it is closely related to Coorg mandarin. N-2 is closely related to the Mudkhed mandarin and N-4 is grouped with Darjeeling mandarin.

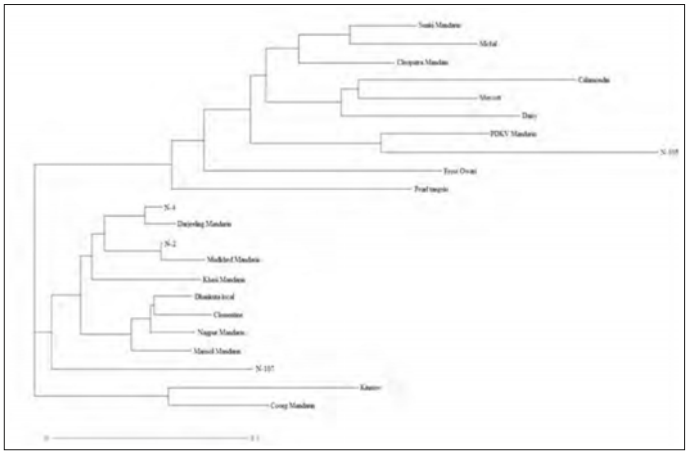


Fig. 1: Dendrogram of 22 mandarin accession using InDel

Molecular characterization of lemon accessions

Total DNA was isolated from a total of 15 lemon accessions including exotic collections. A total 45 InDel 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. Scoring was done based on the presence and absence of the bands and same data was used to construct the dendogram using Darwin software v.6.0 (Fig. 2). The dendrogram has two distinct clades and exotic collections were found in both the clades.

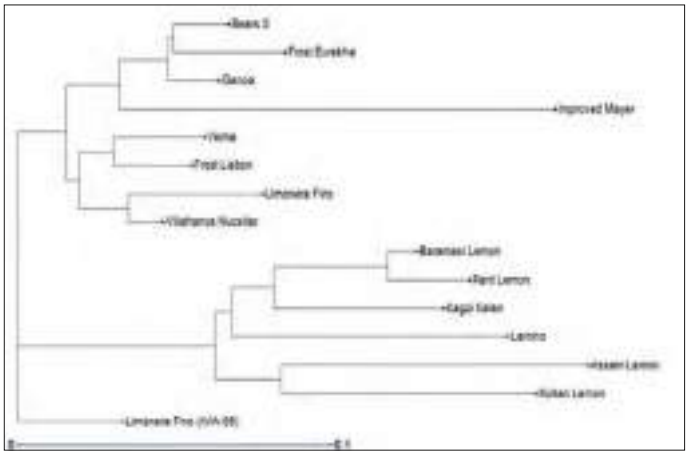


Fig. 2: Dendrogram of 15 lemon accessions using InDel primers.

Physico-chemical evaluation of Galgal

Among different accessions of galgal the maximum fruit weigh was observed in IPS-29 (451 g) along with juice content (32%). Numbers of seeds were lowest in IPS/SKV/199 (5 seeds/ fruit). The highest Vitamin C (29 mg / 100g) was found in IPS-29 followed by IPS-30 (27.96 mg/100g).

Physico-chemical evaluation of Karna khatta

There are seven accessions of karna khatta in the institute. The maximum fruit weigh was observed in IPS/362 (4478 g) and the highest juice content (25.93%) in NRCC-63. Among different accessions Numbers of seeds were at par in all the accessions. Also there was no significant difference observed in number of segments and rind thickness. The highest Vitamin C contents (20 mg/100g) was found in IPS-362 followed by IPS/PNB/322 (19mg/100g).

Evaluation of biomolecules in citrus germplasm

Vitamin C

In an attempt to screen the available germplasm for Vitamin C, different identified clones were evaluated. In acid lime it varied from 21.70 mg/100g to 26.95 mg/100g and in sweet orange the range was 26.03 mg/100g to 44 mg/100g. The highest variation was observed in pummelo with the lowest 20.90 mg/100g to the highest 49.87 mg/100g. Other details are presented in Table 2.

Sub Project : Characterization of citrus germplasm at RRCC

At RRCC, Biswanath Chariali, there are 50 citrus germplasm maintained, of which 39 were characterized morphologically for plant growth and fruit parameters for both quantitative and qualitative traits. Out of the total germplasm, only 36 germplasm fruited during the period. The characterization data of the studied germplasm have been provided (Fig.1 and Table1). Characterization on the basis of qualitative traits revealed the presence of a marked variation among germplasm (Fig.1). The highest variation was noted in fruit shape represented by 5 classes namely spheroid, ellipsoid, pyriform, oblique and obloid shape

Table 2 : Vitamin C contents in different citrus genotypes

Acid lime		Pummelo		Mandarin		Mosambi		Grapefruit	
Cultivar	Vit C (mg/ 100ml)	Cultivar	Vit C (mg/ 100ml)	Cultivar	Vit C (mg/ 100ml)	Cultivar	Vit C (mg/ 100ml)	Cultivar	Vit C (mg/ 100ml)
Phule Sarbati	21.27	NRCC P-1	49.87	N-51	29.88	M8	43.27	Red Blush	26.40
Nag Nimboo	21.63	NRCC P-2	38.23	NRCC-3	22.92	Phule-Mosambi	34.28	Star Ruby	24.51
PDKV Lime	26.22	NRCC P-3	34.47	N-4	26.95	TM 33	26.03		
NRCC-3	21.63	NRCC P-4	33.37	N-34	25.48	M4	44.00		
KL-12	22.37	NRCC P-5	25.34	N-28	23.65	M-155	32.45		
TAL 94/13	24.57	PTF-1	20.90	CRS-4	25.67	Kodur Sathgudi	40.70		
NRCC-2	20.90	PTF-2	21.63	Clone-4	25.30				
NRCC-3	21.63	PTF-3	24.65	M-182	27.50				
NRCC-4	24.93	PTF-4	26.93	NM	24.20				
NRCC-5	26.95			N-2	26.77				
Kagzi Nimboo	21.37								

followed by fruit juice colour characterized by 4 classes namely, white, yellow, orange and pink colour. Spine density, occurrence of petiole wing and fruit surface texture had the least variation which comprised of only 2 classes each. Among all the character states, absence of petiole wing (74.36%), sinuate leaf margin (66.67%) and spheroid fruit shape (64.10%) were dominantly observed among germplasm. Regarding tree growth habit, erect (43.59%) and spreading (51.28%) were predominant among the germplasm whereas only 5.13% of the population possessed drooping growth habit. Likewise, majority of germplasm possessed elliptic (43.59%) and ovate (48.72%) leaf lamina shape with only 7.69% having lanceolate leaf shape. Core diameter among germplasm varies markedly with 41.03%, 46.15 % and 12.82% possessing small, medium and large core size respectively. Fruit surface texture was characterized by only two classes namely smooth (43.59%) and rough (56.41%) texture while the adherence of albedo to pulp were represented by 3 character states which was predominantly observed for medium adherence to pulp (43.59%).

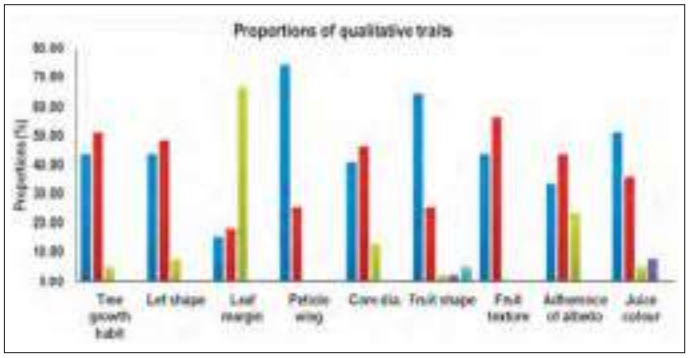


Fig. 3 : Proportion of qualitative traits among germplasm

Regarding quantitative traits, a significant variation among germplasm was noted (Table 3). Leaf lamina length varied significantly from 4.40-15.30 cm and was maximum in Benton followed by Galgal, Kaffir lime and Soh Naring whereas the minimum lamina length was noted in CRH-12, NRC Nimboo-2 and X-639. Likewise leaf lamina width ranges significantly from 1.07 (CRH-12)-7.53 cm (Galgal). Spine length varies greatly among germplasm and highest spine length was noted in *Kaffir lime* (6.47 cm) which was at par with Kinnow (6.33 cm) while spine length less than

1.0 cm was recorded in 6 genotypes namely, Chase Rough Lemon, NRCC Nimboo-1 and 2, Benton, Star Ruby and Marsh Seedless grapefruit. Significant variation in number of fruits per plant was recorded which was highest in Rangpur lime (405.00) followed by Cleopatra mandarin (393.00) while Kachai Lemon, Benton and Tasi had lowest fruits per plant (<25). Fruit weight represented the maximum variation among the studied traits which ranges from 27.67g-1309.33g. Benton followed by Galgal and Pumelo registered the maximum average fruit weight while CRH-12 followed by Calamondin, NRCC Nimboo-1, Cleopatra Mandarin and Phule Sharbati recorded the minimum fruit weight (<55 g). Likewise, a significant variation in fruit length and fruit diameter was also noted

Table 3 : Morphological characterization of citrus germplasm

Treatment	Leaf Lamina Length (cm)	Leaf Lamina Width (cm)	Spine Length (cm)	No of fruits/ plant	Fruit Weight (g)	Fruit Length (mm)	Fruit dia. (mm)	No of segments/ fruit	Peel Thick-ness (mm)	No of seeds/ fruit
Kaffir lime	11.30	4.77	6.47	61.67	133.00	60.33	62.33	12.67	5.33	39.33
Soh Niriang	11.17	6.17	4.17	140.00	158.33	56.67	66.33	11.67	8.00	19.33
Phule Mosambi	10.07	6.43	0.00	183.33	184.00	69.67	66.67	10.00	5.00	20.67
Chase Rough Lemon	9.17	4.97	0.80	158.33	203.33	74.33	69.00	9.33	3.00	14.33
NRCC Nimboo 1	7.57	3.93	0.87	85.67	55.67	42.33	45.67	10.67	1.00	12.33
Kachai Lemon	10.63	5.57	2.77	16.33	332.33	113.67	76.00	12.33	4.00	87.67
NRCC Nimboo 2	5.33	3.17	0.17	135.00	54.67	41.67	43.00	10.67	1.00	15.33
X-639	5.47	3.10	4.70	45.33	50.67	42.33	44.33	8.67	3.00	7.00
Benton	15.37	5.73	0.77	21.00	1309.33	164.67	143.67	11.00	19.67	58.00
Alemow	8.20	3.17	1.40	35.33	556.00	118.00	98.00	14.00	3.67	40.67
Sikkim Mandarin	6.40	2.90	0.00	50.67	126.33	59.00	65.33	9.67	1.33	10.67
Phule Sharbati (Acid Lime)	7.07	3.30	1.03	63.67	51.00	45.33	43.33	9.67	1.00	16.00
Volkameriana	7.80	4.40	1.57	151.33	262.00	92.67	78.33	9.67	2.67	40.33
Rough Lemon (Nagpur)	9.07	5.10	1.90	85.00	327.67	96.00	87.00	10.67	4.67	30.00
Rangpur Lime (Rahuri)	8.73	4.57	2.73	405.00	128.33	64.33	61.67	9.33	1.00	26.33
Jora Tenga	10.23	5.83	4.83	37.33	461.33	100.33	90.33	11.00	9.00	20.67
Calamondin	7.10	3.37	2.83	48.33	28.67	28.00	32.67	5.67	7.67	7.33
NRCC Rootstock 6	9.30	5.40	2.20	131.67	235.00	77.67	79.67	10.33	3.67	29.33
Sohmyndong	8.80	4.83	1.37	110.00	204.67	74.33	69.00	7.33	3.67	15.67
Rough lemon	8.63	4.90	2.00	186.67	173.33	77.33	70.00	10.33	3.00	29.67
Rangpur lime (Nagpur)	9.07	4.07	1.43	69.33	98.00	61.00	49.33	10.00	1.33	13.00
White selliage orange	10.90	5.93	2.53	45.00	241.00	88.33	76.67	10.33	4.33	10.33
NRCC Rootstock-3	9.17	4.57	2.77	105.33	273.00	92.00	67.33	10.33	5.00	23.00
Tasi	9.43	5.17	4.70	25.00	120.33	65.67	68.00	10.33	5.67	11.33
Tangelo (30)	7.57	4.53	2.17	236.67	136.00	62.67	62.67	7.67	3.33	29.00
Cleopatra Mandarin	7.23	3.77	2.23	393.33	43.33	32.00	45.67	12.33	1.00	13.33
Kinnow	8.30	4.10	6.33	123.00	163.33	60.00	68.00	12.00	2.00	19.33
Phillippine Red Lime	8.63	4.27	2.03	270.00	113.33	60.33	59.33	8.67	1.33	20.33
Citron mutant	9.53	5.43	2.40	126.67	266.67	85.00	82.67	9.67	4.00	28.67
Star Ruby grapefruit	9.10	5.33	0.63	86.67	356.33	90.33	91.67	11.67	5.67	2.67
Marsh Seedless grapefruit	9.77	5.80	0.53	83.33	320.00	82.67	87.00	12.67	3.33	2.67
CRH-12	4.40	1.07	2.27	120.00	27.67	32.00	36.67	7.67	1.00	18.67
Galgal	12.83	7.53	2.30	101.67	610.00	134.00	99.33	10.33	4.33	24.67
NRCC rootstock	6.33	3.23	1.00	70.00	61.00	49.00	47.67	9.33	2.67	23.67
Kusaie Rangpur lime	7.67	3.63	2.53	310.00	99.67	56.00	55.00	8.00	1.33	17.67
Norneo Rangpur lime	8.17	3.83	3.43	383.00	95.67	59.67	55.67	9.33	1.00	21.33
C.D.	1.62	0.98	0.64	68.19	90.87	10.03	6.16	1.09	1.04	3.57
SE(m)	0.57	0.35	0.23	24.12	32.15	3.55	2.18	0.39	0.37	1.26
C.V.	11.34	13.20	17.15	32.00	24.87	8.48	5.56	6.59	16.54	9.60

and was maximum in Benton (164.37 mm and 143.67 mm) and Galgal (134.00 mm and 99.33 mm) whereas Calamondin (28.00 mm and 32.67 mm), Cleopatra Mandarin (32.00 mm and 45.67 mm) and CRH-12 (32.00 mm and 36.67 mm) represented the lowest fruit weight. Number of segments per fruit also varies significantly from 5.67 in Calamondin to 14.00 in Alemow. *Kaffir lime*, Kachai Lemon, Cleopatra Mandarin and Marsh Seedless Grapefruit also recorded high number of segment per fruit (>12.00). A highly significant variation in peel thickness was also noted. Benton recorded the highest peel thickness (19.67 mm) followed by Jora Tenga (9.00 mm) while NRCC Nimboo 1 and 2, Phule Sharbati, Cleopatra Mandarin, CRH-12 and Norneo Rangpur Lime registered the lowest peel thickness (1.00 mm). Likewise, number of seeds per fruit also varies greatly among germplasm and maximum seeds per fruit was recorded in Kachaai Lemon (87.67) followed by Benton (58.00). X-639 (7.00) and Calamondin has the lowest seeds per fruit while seedless condition is observed only in Star Ruby and Marsh Seedless grapefruit (<3.00).

3.1.2 On-Site DUS testing for registration of citrus varieties with PPV and FRA

Maintenance breeding data recorded as per DUS guidelines for

- Acid lime - Pramalini, Balaji, Sai Sharbati, Vikram, Jaidevi, Phule harbati, NRCC Acid Lime - 7, NRCC Acid Lime - 8
- Mandarin - Nagpur mandarin, Coorg mandarin Sikkim mandarin, Darjeeling, Mudkhed seedless
- Sweet orange - Mosambi, Clone TM - 33, Kodur Sathgudi

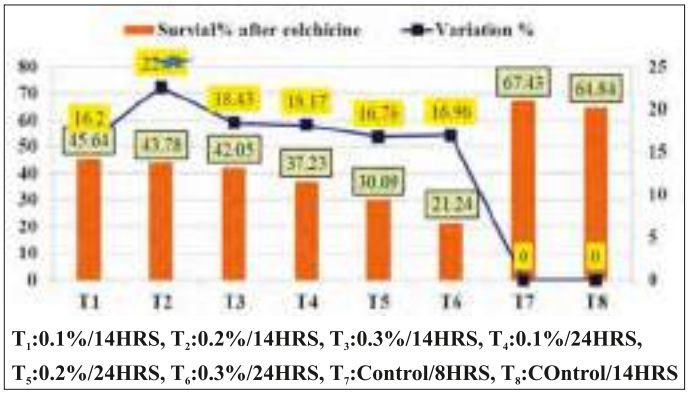
3.1.3 Improvement of important commercial Citrus scions and rootstocks through *in vitro* techniques

3.1.3.1 Production of Polyploids in Citrus

***In vitro* induction of autotetraploids 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 and Sweet lime) were treated with colchicine solutions. The experiment consisted of 8 treatments i.e. T_1 with 0.1% colchicine with 14 hrs exposure, T_2 with 0.1% colchicine with 24 hrs exposure, T_3 with 0.2% colchicine solution and submerged for 14 hrs, T_4 with 0.2% colchicine solution and submerged for 24 hrs, T_5 with 0.3% colchicine solution and submerged for 14 hrs, T_6 with 0.3% colchicine solution and submerged for 24 hrs, T_7 with 0.0% colchicine (Control) for 14 hrs and submerged in liquid MS medium, T_8 with 0.0% colchicine and submerged for 24 hrs. The results showed that colchicine compound severely and significantly affected the germination of Citrus rootstocks. Stunted growth more pronounced with longer submerging time. Across all colchicine treatments overall seedling survival was higher (44.98%) in Sweet lime, followed by Alemow (43.10%). Higher the concentration and lesser the survival rate. The results showed that colchicine affected germination of all rootstock seeds. Germination percentages were highest with T_1 (control 0.1%, 14 hrs exposure) and lowest with T_6 (0.3%, 24 hrs exposure) with mean value of 45.64 and 21.24, respectively. The differences were large and highly significant. The results of colchicine concentration on plant height revealed that highest mean value on plant height was found with T_7 (6.88 cm, control 14 hrs) and lowest with T_6 (0.57 cm with colchicine at 0.3%, 24 hrs exposure). The difference was large and statistically significant. When observed with naked eyes, it was found that stock plants derived from colchicine treated plants gave much larger and thicker leaves than control.

The survival percentage of treated seedlings after transfer to screen house (lab to land transfer) by minigrafting was highest in Sweet lime (8.09 %) followed by Alemow (7.60 %). It appears morphological variation percentage is highest in Alemow (14.46%) followed by Sweet lime (12.84 %) (Fig. 4-7).



T_1:0.1%/14HRS, T_2:0.2%/14HRS, T_3:0.3%/14HRS, T_4:0.1%/24HRS, T_5:0.2%/24HRS, T_6:0.3%/24HRS, T_7:Control/8HRS, T_8:COntrol/14HRS

Fig. 4 : Cumulative effect of *in vitro* colchicine treatment on survival rate and percentage of variation in plant morphology on Citrus rootstocks

Flower of Alemow-4X
Flower dimention-44mm

Flower of Alemow - 2X
Flower dimention-32mm

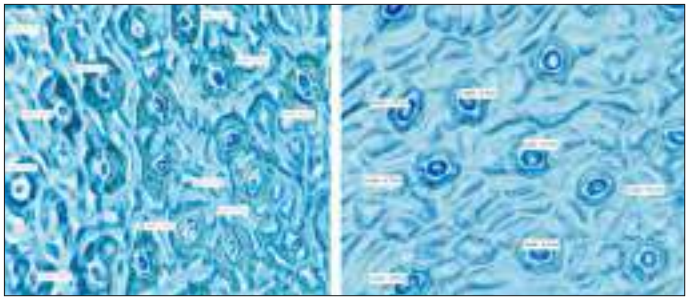
Fig. 5 : Comparison between flower dimension of tetraploid and diploid Alemow

Plant morphology like bi-lobate, round leaves, a dark-green colour, petioles, demonstrating a phenomenon widely known as the gigas effect

Fig. 6 : Morphological characterization of leaves of diploid, tetraploid - Rangpur lime, Rough lemon

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. Experiment was a two way factorial with 3 scions, 4 colchicine concentrations

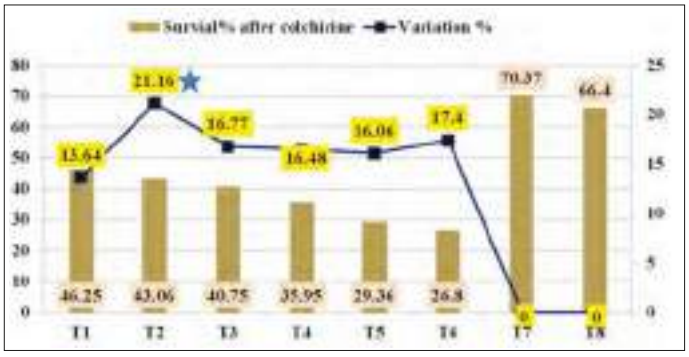


NM - Control on 40X
[Avg. length 39.26µm]

NM - 6X on 40X
[Avg. length 54.89µm]

Fig. 7 : Effect of ploidy level on leaf morphology and stomatal characteristics in Nagpur mandarin hexaploid (2n=6x=54)

(8 treatments) with 2 exposure times and with 4 replications. The germinating seeds meristematically active were treated with colchicine solutions. The results showed that colchicine compound severely and significantly affected the germination of Citrus scions (Fig.8) colchicine 0.1% in solution with 24 hrs exposure was observed to be most efficient for tetraploid induction. Higher colchicine concentration induced higher mortality. Survival rate was more for all genotypes at control and 0.1% concentration with 14 hrs exposure. The germination percentages were highest with T_7 (control) and lowest with T_6 (0.3%, 24 hrs exposure) with the values of 73.67% (USA-145) and 22.94% (Pummelo-5) respectively. The differences were larger and highly significant. In general across all the treatments survival percentage recorded was highest in USA-145 (46.61%) followed by Pummelo-5 (46.08%) and Grapefruit (41.91%). 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 6.50 cm and 0.71 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 Grapefruit-6 (9.253%) followed by Pummelo-5 (8.956 %), and USA-145 (7.047%). Higher levels of colchicine gave no significant effect optimum colchicine for use in treating the Citrus rootstocks and Scions as to attain optimum tetraploids recovering, can be only upto 0.1% with 24hr (T_2) submerging in solution (Fig. 8).



T_1: 0.1%/14 HRS, T_2: 0.2%/14 HRS, T_3 : 0.3%/14 HRS, T_4: 0.1%/24 HRS, T_5: 0.2%/24 HRS, T_6: 0.3%/24 HRS, T_7: Control/8 HRS, T_8:Control/14 HRS

Fig. 8 : Cumulative effect of *in vitro* colchicine treatment on survival rate and percentage of variation in plant morphology on Citrus scions

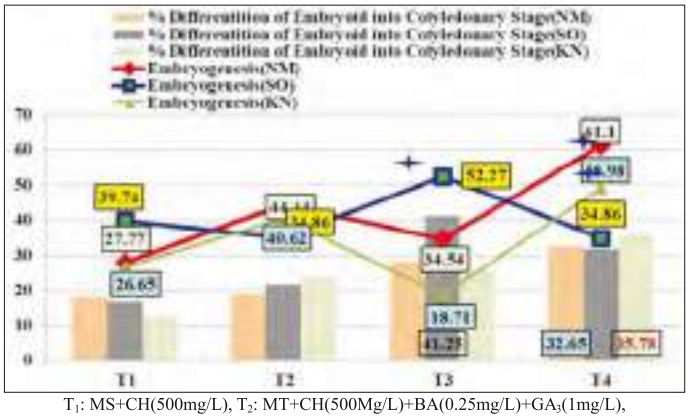
3.1.3.2 Induction of triploids by endosperm rescue, flow Cytometry and cytogenetics in Nagpur mandarin, Sweet orange and Kinnow

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 indicates, that high callus induction rates were obtained in Nagpur mandarin (40.22) and in Kinnow (39.06) in MT+CH+2,4-D (2mg/L)+ BA (5mg/L), whereas in Sweet Orange (44.27) in MT + ME, whereas highest rate of embryogenesis obtained in Nagpur mandarin (53.63%) and in Kinnow (38.81%) with MT+CH+2,4-D (2mg/L) medium, where as in Sweet orange maximum embryogenesis (49.85%) obtained in the medium MT+CH+2,4-D (2mg/L)+BA (5mg/L). In Sweet orange callus induction response varied from 28.41% to 44.27%, and embryogenesis response from 30.88 to 49.85%. In Nagpur mandarin embryogenesis response varied from 26.32% to 53.63%. In Kinnow, embryogenesis response varied from 27.09% to 38.81%. Induction of embryogenesis was lowest in Nagpur mandarin (26.32%) compared to Sweet orange (30.88%) and Kinnow (27.09%).

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



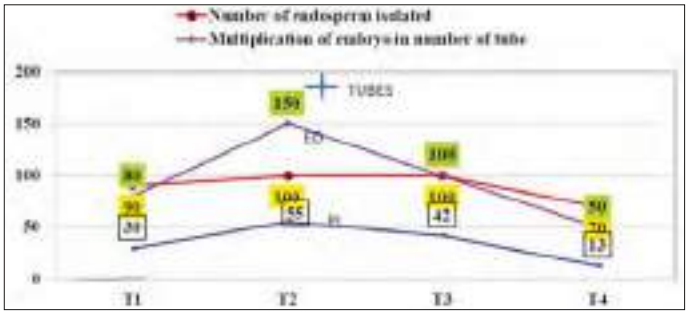
T_1: MS+CH(500mg/L), T_2: MT+CH(500Mg/L)+BA(0.25mg/L)+GA_3(1mg/L), T_3:2MT+CH(500mg/L)+BA(0.25mg/)+GA_3(1mg/L),T_4:2MT+CH(500mg/L)+BA(0.25Mg/L) +GA_3(1mg/L)+Ad.S(2mg/L)

Fig. 9 : Influence of media on morphogenesis of endosperm calli of 3 Citrus scions

increased the development of cotyledonary embryoids significantly. In case of Sweet orange significantly maximum number of cotyledonary embryoids produced in 2MT+ CH(500mg/L)+BA(0.25mg/L)+GA_3(1mg/L) which is devoid of Adenine sulphate. In this study Treatment no. 4 proved better for both Embryogenesis and cotyledonary embryoids production (Fig.9).

Effect of phytohormones *in vitro* root and shoot regeneration

Medium supplemented with GA_3 and adenine sulphate enhanced the shoot and root development in all the 3 scion species. Statistically 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, Sweet orange and also in Kinnow from endosperm culture. In all the 3 scion species studied, efficient regeneration of plants from endosperm rescue and more number of putative triploids obtained T_2-MT+CH (500mg/L)+ 2,4-D (2mg/L) followed by MT+CH+ 2,4-D+BA. 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 (Fig. 10-11).



T_1:MT+ME(500mg/l), T_2:MT+CH(500mg/l)+2,4 D(2mg/l), T_3:MT+CH (500mg/l)+2,4 D(2mg/l)+BA(5mg/l), T_4:MS+ME(500mg/l)

Fig.10 : Efficiency of different media in regeneration of putative polyploids in Nagpur mandarin

Fig. 11: Induction of triploids by endosperm rescue, flow Cytometry of Kinnow

Field evaluation of STG derived planting stock v/s conventional budgraft in farmer's orchards

The distributed STG derived healthy planting stock established in farmers orchards located one at Susundri, Kalmeshwar (Nagpur), at Arvi, Wardha, and another at Ladgaon, Katol 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 par 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 12-14).

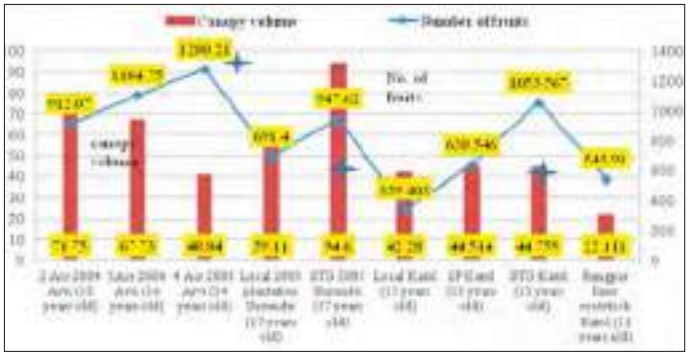


Fig. 12 : Field evaluation of STG conventional budded plants vs STG microbudded plants at Arvi, Wardha, STG plants vs local plants at Susundri, Kalmeshwar and Katol, Nagpur

Around 15 random samples of Nagpur mandarin were collected from farmer's orchard at Arvi, Wardha, for indexing of Virus and Greening bacterium diseases, out of 15 samples, 100 % declared free from virus and virus like diseases.

Table 4 : Analysis of ploidy samples by flow cytometry

Sr. No.	Name of variety	No. of plants tested	3n	4n	5n	6n	Mixoploid
1	NM -Endosperm	16	3	--	--	--	--
2	NM (Seed colchicine)	1	--	--	1	--	--
2	P-5 (Seed colchicine)	3		1	--	--	
3	Kinnow (Seed colchicine)	3	1		--	--	1
4	USA -145 (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	--	--	--	--	--

Fig. 13 : Seventeen (17) years old conventionally budded and 17 years old STG derived Nagpur mandarin plants at Susundri, Kalmeshwar

Fig. 14 : Demonstration of high Yield advantage of STG derived plants at Ladgoan, Katol (15 years old)

Around 17 random samples of Nagpur mandarin were collected from farmer's orchard at Katol, Nagpur, for indexing of Virus and Greening bacterium diseases, out of 17 samples, 100 % declared free from virus and virus like diseases.

Around 14 random samples of Nagpur mandarin were collected from farmer's orchard at Susundri, Kalmeshwar for indexing of Virus and Greening bacterium diseases, out of 14 samples, 92.85% declared free from virus and virus like diseases.

3.1.4 Genetic improvement of citrus through hybridization

Evaluation of progenies : Two hundred and fifty eight progenies developed from different cross combinations for scion improvement established at the field were evaluated for growth characters (Table 5). Significant variations were observed for the plant height and number of branches among the progenies of different cross combinations. The growth traits in progenies of different cross combinations recorded higher CV values indicating that wide variability were observed among the progenies. Eighteen rootstock progenies from US pummelo x NRCC rootstock 5 and four progenies from rough lemon x Rangpur lime were evaluated for growth characters (Table 6). For US pummelo x NRCC rootstock 5 progenies, the plant height ranged from 1.9 to 3.1 m and number of branches ranged from 2 to 6. In case of rough lemon x Rangpur lime progenies the plant height ranged from 1.4 to 1.6 m and number of branches ranged from 1 to 3. The coefficient of variation was high (>41%) for number of branches for both the cross combinations indicating that this trait have wide variability among the progenies.

Table 5 : Descriptive statistics for growth characters of scion hybrid progenies

Parentage	No. of hybrids	Characters	Unit	Min	Max	Mean	Std. Dev.	CV (%)
Adajamir x Citron	14	Plant height	m	1.8	3.4	2.44	0.50	20.48
		No. of branches	No .	2.0	7.0	3.50	1.91	54.61
Acid lime x Adajamir	14	Plant height	m	0.8	2.1	1.36	0.43	31.49
		No. of branches	No .	1.0	3.0	1.79	0.70	39.16
Acid lime x Assam lemon	129	Plant height	m	0.1	1.2	0.28	0.21	73.31
		No. of branches	No .	1.0	5.0	1.32	0.65	49.27
Acid lime x Pant lemon	48	Plant height	m	0.1	1.6	0.50	0.49	99.13
		No. of branches	No .	1.0	3.0	1.31	0.51	39.0
Acid lime x Baramasi lemon	14	Plant height	m	0.1	0.8	0.21	0.18	87.73
US Pummelo 145 x TM -33	20	Plant hei ght	m	0.3	2.2	1.34	0.69	51.51
		No. of branches	No .	1.0	4.0	1.60	0.75	47.12
NRCC pummelo 5 x NRCC grapefruit 6	19	Plant height	m	1.5	4.2	2.44	0.84	34.30
		No. of branches	No .	1.0	3.0	2.05	0.62	30.27

Table 6 : Descriptive statistics for growth characters of rootstock hybrid progenies

Parentage	No. of hybrids	Characters	Unit	Min	Max	Mean	Std. Dev.	CV (%)
US Pummelo 145 x NRCC rootstock 5	18	Plant height	m	1.9	3.1	2.48	0.34	13.53
		No. of branches	No .	2.0	6.0	3.06	1.26	41.20
Rough lemon x Rangpur lime	4	Plant height	m	1.4	2.4	1.95	0.44	22.74
		No. of branches	No .	1.0	3.0	2.25	0.96	42.55

Evaluation of Citron x acid lime hybrid: During the year 2021, one hybrid progeny (NRCC citron x KL 12 acid lime) out of 258 progenies came for flowering and fruiting. Leaf morphology of hybrid and its parents were characterized based on IPGRI descriptor to study the inheritance pattern of the characters. Most of the leaf morphological characters of hybrid are as same as parents (Table 7, Fig.15). The spine length and leaf lamina margin are clearly inherited from citron parent. The leaf lamina attachment is inherited from acid lime parent. The hybrid lacks petiole wing, which is present in both the parents, it is unique to hybrid when compared to parents. The leaf lamina shape is eliptic to ovate, whereas it is orbicular shape in citron ovate shape in acid lime. Some of the characters are intermediate. The leaf lamina length and width are intermediate in nature when compared to the parents. The fruit characters of parents and hybrid were studied. All the fruit parameters studied are intermediate in nature in hybrid (Table 8) except number of segments and seeds/fruit which are higher than the parents.

Fig. 15 : Morphology of citron x acid lime hybrid and parents (a. citron, b. acid lime, c. hybrid)

Table 7 : Expression of leaf morphological characters of Citron x acid lime hybrid and its parents

Characters	Hybrid (Citron x KL-12)	Citron (Female Parent)	KL -12 (Acid Lime) (Male Parent)
Spine Length on Adult Tree	6-15 mm	6-15 mm	≤ 5 mm
Spine Shape	Straight	Straight	Straight
Shoot Tip Colour	Green	Green	Green
Vegetative Life Cycle	Evergreen	Evergreen	Evergreen
Leaf Division	Simple	Simple	Simple
Intensity of green colour of leaf blade	Medium green	Medium green	Medium green
Leaf lamina attachment	Brevipetolate	Sessile	Brevipetiolate
Leaf lamina Length	55.52 mm	70.59 mm	43.70 mm
Leaf lamina width	30.21 mm	49.74 mm	22.28 mm
Leaf lamina shape	Eliptic and Ovate	Orbicular	Ovate
Leaf lamina margin	Acuminate	Acuminate	Acute
Petiole wing shape	No	Obovate	Obovate

Table 8 : Yield and quality parameters of the new Citron x Acid lime hybrid

Sample Name	Fruit weight (g)	Fruit length (mm)	Fruit diameter (mm)	Fruit axis Dia.	Rind thickness (mm)	No. of segments	TSS (°Brix)	Juice %	Acidity (%)	No. of seeds	Vitamin C (mg/100 ml)
NRCC Citron (Female Parent)	143.00	66.79	71.00	5.43	8.80	11	5.9	32.86	6.40	00	17.05
KL-12 acid lime (Male Parent)	50.30	49.10	42.20	3.40	1.20	10	9.4	43.97	6.98	08	26.95
Hybrid (Citron x KL-11)	91.00	50.29	49.00	5.11	4.62	15	7.7	32.96	3.58	10	19.80

Hybridization : Interspecific and intraspecific hybridization during 2021 resulted in 138 progenies (Table 9) from 1085 different crosses. One hundred and twenty seven progenies were recovered the acid lime x Pant lemon crosses. However, acid lime x Assam lemon, acid lime x Kagzi kalan, and acid lime x Baramasi lemon crosses were unsuccessful. Further, the crosses among sweet orange varieties were unsuccessful. Seven progenies from sweet orange var. Mosambi x US pummelo 145 and four progenies from US pummelo 145 x grapefruit were recovered.

3.1.5 Mutation breeding in citrus

In an attempt to raised MV2 generation, budlings were obtained from MV1 and total 221 plants were planted in the field (Table 10). Due to Covid - 19 pandemic the fruit yield was drastically affected in MV1 generation. However, the physio-chemical parameters of fruits in different genotypes showed some symptoms of mutations. In Flame grapefruit the fruit size varied from 270g to 377g (Table 11). Flavedo got thick than control and also in one case it remained green at maturity. In case of NRCC Grapefruit-6 there was no much difference observed over control (Table 12). In sweet some and Kinnow higher acidity in juice was observed (Table 13 and 14).

Table 9 : Details of the hybrids developed by hybridization during 2021 for scion improvement

Cultivar	No. of crosses	No. of fruits harvested	No. of seeds	No. of Plants in nursery
A. Lime x Assam Lemon	163	00	00	00
A. Lime x Kagzi Kalan	105	00	00	00
A. Lime x Baramasi Lemon	177	00	00	00
A. Lime x Pant Lemon	85	19	87	127
Assam Lemon x Baramasi Lemon	32	00	00	00
M-8 x Pera	65	00	00	00
M-8 x Westin	92	00	00	00
TM -33 x Natal	59	00	00	00
Phule Mosambi x Westin	105	00	00	00
Mosambi x US Pummelo 145	45	02	07	07
Mosambi x Blood Red	25	00	00	00
US Pummelo 145 x Grapefruit	37	01	04	04
Phule Mosambi x Blood Red	95	00	00	00
Total	**1085**	**22**	**98**	**138**

Table 10 : MV2 generation

S.N.	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

Table 11 : Effect of irradiation on physico-chemical attributes of Grapefruit cv. Flame

sample name	Fruit weight	Fruit length	Fruit dia	Fruit axis dia	Rind thickness	No. of seg	No. of seeds	Juice%	TSS	Acidity
GF/20Gy B1/R4/P19	270.60	71.52	85.97	12.54	5.85	12.40	4.25	28.95	8.02	1.12
GF/10Gy B1/R4/P2	221.80	76.31	82.24	13.32	4.72	11.80	1.50	28.44	7.98	2.19
GF/10Gy B1/ R4/P26	377.00	84.51	94.03	14.70	9.33	13.00	4.00	31.24	7.95	1.08
Control	359	81.23	88.36	12.26	6.56	12.36	2.36	35.26	8.12	0.98

Table 12 : Effect of irradiation on physico-chemical attributes of Grapefruit cv. NRCC Grapefruit - 6

Sample name	Fruit weight	Fruit length	Fruit dia	Fruit axis dia	Rind thickness	No. of seg	No. of seeds	Juice%	TSS	Acidity
PM - 6/10Gy B1/R3/P9	304.8	76.614	82.54	11.77	8.29	13.60	14.00	31.79	7.54	1.22
PM - 6/10Gy B1/R3/P3	298.00	73.49	83.75	12.77	6.74	12.60	29.80	30.31	8.36	1.41
Control	342.50	82.81	91.60	14.16	8.91	12.23	11.50	33.24	8.80	1.26

Table 13 : Effect of irradiation on physico-chemical attributes of sweet orange fruits

Sample name	Fruit weight	Fruit length	Fruit dia	Fruit axis dia	Rind thickness	No. of seg	No. of seeds	Juice %	TSS	Acidity
TM - 33/15Gy B2/R2/P28	183.17	69.01	73.11	10.06	4.26	10.67	16.17	34.75	10.12	0.73
TM -33/ 5Gy B2/R2/P5	135.17	67.04	65.99	12.11	5.75	11.67	10.00	29.21	10.35	1.72
TM -33/ 10Gy B2/R2/P7	116.67	58.28	60.23	10.26	6.93	11.33	13.00	24.69	8.47	1.30
Control	161.00	65.98	67.72	9.62	3.44	10.75	14.75	32.07	10.43	0.35

Table 14 : Effect of irradiation on physic-chemical attributes of Kinnow fruits

Sample name	Fruit weight	Fruit length	Fruit dia	Fruit axis dia	Rind thickness	No. of seg	No. of seeds	Juice %	TSS	Acidity
Kinnow/20Gy B2/R1/P23	133.00	55.17	66.34	11.05	5.45	11.67	11.67	32.94	8.80	1.54
Control	155.26	58.26	62.15	9.23	3.56	11.56	12.25	35.36	9.56	0.89

Screening of acid lime and rootstock cultivars against citrus canker

Acid lime trees with different gamma irradiation doses (10, 20, 30 and 40 Gy) were screened and evaluated for citrus bacterial canker incidence under natural open field conditions. Results obtained were rated in 3 groups as follows : Resistant : < 10% leaves with lesions, Intermediate or Moderately resistant : 10.1-20% of leaves with lesions, and Susceptible : > 20% of leaves with lesions. All the trees under different treatments were found to be susceptible to citrus canker. Disease incidence on leaves ranged from 34.9-67.8% in those acid lime seedlings and percent disease index (PDI) ranged from 6.9-20.0 (Table 15). Similarly four rootstock cultivars with different gamma irradiation doses were also screened against citrus canker under natural conditions. Canker incidence was observed only in Alemow (*C. macrophylla*) not in Volkamerana, Rangpur lime and rough lemon trees (Table 16).

Table 15 : Incidence of citrus canker in Gamma irradiated acid lime seedlings under natural field conditions [#]

Gamma irradiation	No. of diseased leaves (%)	PDI*
T_1: 10 Gy	34.9 (36.2)[a]	6.9
T_2: 20 Gy	54.5 (47.6)	20.0
T_3: 30 Gy	67.8 (55.4)	13.5
T_4: 40 Gy	52.7 (46.5)	20.0
CD (P = 0.05)	7.6	4.3

[a] Figures in parentheses are angular transformed values

[#] Average of 2 observations taken during Aug- Sept 2021 at monthly interval

* Disease intensity was recorded on 0-5 scale where, 0 = free, 1 = 1-10% leaf area infected, 2 = 11-25% leaf area infected, 3 = 26-50% leaf area infected, 4 = 51-75% leaf area infected and 5 = 76-100% leaf area infected

Table 16 : Incidence of citrus canker in Gamma irradiated Rootstock seedlings under natural field conditions

Sr. No.	Rootstock cultivar	Treatment With Gamma radiation (Gy)	No. of diseased leaves (%)	PDI*
1	Alemow	20	66.2 (54.5)[a]	13.2
		40	37.4 (37.7)	7.5
		60	20.8 (27.1)	4.3
		80	37.5 (37.2)	12.2
2	Volkameriana	20	NIL	NIL
		40	NIL	NIL
		60	NIL	NIL
		80	NIL	NIL
3	Rangpur lime	20	NIL	NIL
		40	NIL	NIL
		60	NIL	NIL
		80	NIL	NIL
4	Rough lemon	20	NIL	NIL
		40	NIL	NIL
		60	NIL	NIL
		80	NIL	NIL

[a]Figures in parentheses are angular transformed values

3.1.6 Collection, characterization and morpho-phenological characterization of Citrus germplasm of North East Region (DBT Funded Project)

DNA barcoding of citrus rootstocks

Eight citrus rootstocks were taken for DNA barcoding using rcbL loci. The rbcL, is a gene noted for its utility as a phylogenetic marker at the rank of family and genus, also demonstrated its utility as a species-level identifier in the comparative data-mining tests. The primers used for polymerase chain reaction amplification of the rbcL-a gene were rbcLa-F (5'-ATGTCACCACAAACAGAGACTAAAGC-3') and rbcLajf634-R (5'-GAAACGGTCTCTCCAACGCAT-3'). In the phylogenetic tree, Rough lemon grouped with sour orange and Galgal grouped with Trifoliate orange.

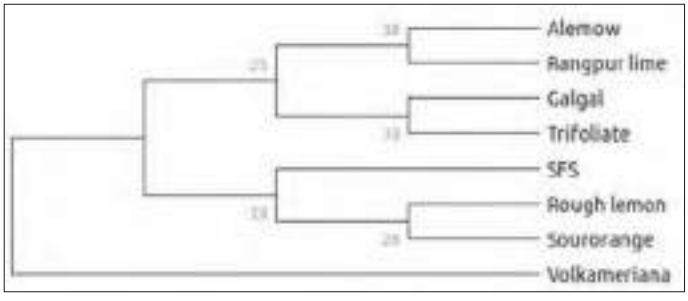


Fig. 16 : Maximum likelihood tree of the *rbcL-a* genes from citrus rootstock accessions. Numbers at the nodes indicate bootstrap values (% over 1,000 replicates).

3.1.7 Genome editing through CRISPR/Cas9 system to improve citrus varieties

In the quest to develop and standardize the protocol of embyogenic cell suspension of citrus cultivars, the present investigation was carried out to determine the response of different concentration and combination of growth regulators on callogenesis, somatic embryogenesis morphogenesis of few commercial citrus species. The results indicates, that high callus induction in Acid lime

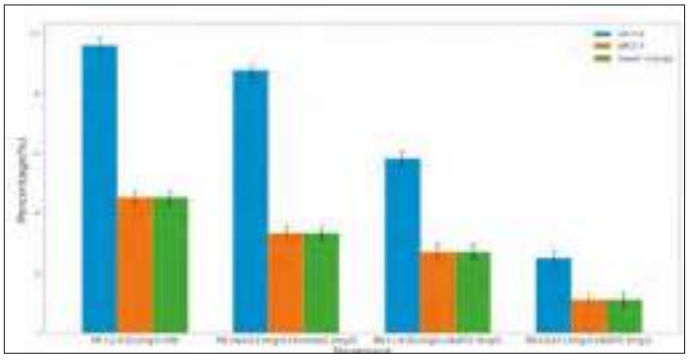


Fig. 17 : Percentage of embryoid/callus primary induction of various citrus cultivars in different media.

(45.5), SO (45.08) and in NRCC-7 (22.00) in MT+2,4-D(2mg/l)+ME and highest embryogenesis rates were obtained Acid lime (95.83), SO (56.33) and in NRCC-7 (45.00) in MT+2,4-D(2mg/l)+ME (Fig.17). For maturation and germination of the somatic embryo further media calibration is needed.

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.

The investigation was carried out at ICAR-CCRI, tissue culture nursery site, under the screen houses. Rootstocks seeds extracted from healthy fruits of rootstock mother trees and after seed treatment with Redomil were sown in polythene bags filled with sterilized soil mixture of sand, soil, FYM starting from first week of July (8/7/2021) till December 2021, at 10 days interval. Germination was significantly higher in Rough lemon (89.4%) when sown in 2nd fortnight of August followed by Rangpur lime (84.5%) and Alemow (83.32%) with August 2nd fortnight sowing directly in polybags. Observations were also recorded on % polyembryony, % of plant survival, days taken for germination, seedling height, seedling diameter and number of leaves. There were 5 replications per treatment, and the data was analyzed in the completely randomized block design. In Rough lemon polyembryony percentage decreased with delayed sowing. Percent plant stand maximum in Rough lemon (83.05%) followed by Rangpur lime (80.62%) and Alemow (78.22%). Maximum plant height obtained in Alemow (5.68 cm) followed by Rough lemon (5.56cm) and Rangpur lime (3.94 cm). Maximum mean central girth of rootstocks obtained in Rough lemon (0.49 cm) and Alemow (0.49 cm) followed by Rangpur lime (0.28 cm). Maximum mean number of leaves obtained in Rough lemon (4.78) followed by Rangpur lime (4.48) and Alemow (4.04). In general superior and distinct growth parameters obtained, when the primary nursery of Rough lemon and Rangpur lime raised directly in polybags in the first and second week of August. Growth can be enhanced, nursery parameters in terms of plant height, girth and number of leaves can be managed and buddable plants can be obtained by January and February itself.

3.2.1.2 Effect of direct sowing on nursery growth parameters before microbudding

The microbudding technique was standardized in citrus to restrict the nursery phase /propagation period from 22 months (conventional way) to 12 months period. Within microbudding propagation period a study was designed to compare the growth of direct sown and transplanted rootstocks at different age *viz.,* 3, 4 and 5 months before microbudding. The seeds of citrus rootstocks *viz.,* rough lemon, Rangpur lime and Alemow were raised in propagation trays and black polythene bag during first week of August. Growth of rootstocks was recorded on transplanted and direct sown seedlings in polythene bags for rootstock height, central girth and number of leaves right from 3 months age to 5 months aged rootstock to demonstrate practically, which category of rootstock attains the required girth and height of rootstock (buddable parameters) at a faster rate / tender age of rootstock to facilitated early budding there by restricting the nursery phase to 1 yrs, unlike the traditional propagation period of 20-22 months. The data revealed maximum mean seedlings height (46 cm), stem girth (1.57 mm), 5 months after sowing obtained in Alemow followed by Rangpur lime (36 cm) and 1.24 cm (girth) and Rough lemon 34.60 cm (height) and 1.42 cm (girth). Whereas in transplanting seedling the maximum seedling height (38.34 cm) and girth (1.24 mm) obtained at the age of 5 months, which is considered unfit / unsuitable for doing the shield budding. In general significantly higher seedling height, stem

diameter, number of leaves obtained in all the 3 citrus rootstocks when sown directly in polybags at both 4 and 5 months age itself, facilitating microbudding propagation at 4 to 5 months age of rootstock. Required nursery parameters height and decimetic obtained between the ages of 4-5 months old direct sown citrus rootstocks, which is not possible to obtain, by raising the seeds in propagation (conventionally).

Minimum values obtained in all the transplanted rootstocks at 3, 4 and 5 months age, making them unsuitable for doing microbudding (Table 17) (Fig. 18).

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 under taken to study the growth of all the 3 rootstocks by raising directly in polybags by bypassing the primary nursery phase in propagation trays. The data revealed that significantly higher microbudding success and early microbuddable seedling obtained when the seeds were sown directly in polybags inside the screen house

Table 17 : Effect of direct sowing on nursery growth parameters 5 months (before microbudding)

Sr. No	Treatments	Total height(cm)	Central girth (cm)	No. of leaves
1	Seed sowing RL directly on polybags	34.600^{bc}	1.420^{a}	20.800^{bc}
2	Seed sowing Rangpur lime directly on polybags	36.000^{bc}	1.240^{b}	24.500^{b}
3	Seed sowing AL directly on polybags	46.000^{a}	1.570^{a}	37.800^{a}
4	Seed sowing of RL in tray	38.342^{b}	1.244^{b}	20.812^{bc}
5	Seed sowing of Rangpur lime in tray	34.176^{c}	1.178^{b}	19.100^{c}
6	Seed sowing of AL in tray	33.698^{c}	1.188^{b}	25.118^{b}
	CD (P=0.05)	**3.941**	**0.158**	**4.460**

Rough lemon

Rangpur lime

Alemow

Fig. 18 : Direct sowing of Rough lemon, Rangpur lime and Alemow in polybags (Four months old seedlings - 2021)

compared to the seeds sown in trays and later transplanted to polybags. Significantly higher percentage of early microbuddable seedlings (68.02%) obtained in Rough lemon followed by Rangpur lime (59.97%) and Alemow (53.74%). Micro budding success whether performed in screen house or net house directly in polybags was found to be (76.35%) in Rough lemon followed by Rangpur lime (65.38%) and Alemow (60.16%). In tray transplanted rootstocks, microbuddable stage delayed by 3 months compared to directly sown seeds (Fig.19).

Fig. 19 : Effect of direct sowing and transplanting citrus rootstocks on percent of microbuddable seedling and microbudding success (one month after microbudding)

3.2.1.4 Effect of different age of direct sowing and transplanting rootstocks on nursery growth parameters before conventional shield budding

The data revealed that maximum mean seedlings height (88.5 cm), girth (2.67 cm) and number of leaves (55.10) were obtained respectively in rough lemon transplanted rootstock (15 months old), followed by tray transplanted 12 months old Rough lemon (70.26 cm), and 12 months old tray transplanted Alemow (70.08 cm). These were significantly higher than the rootstock height, central girth obtained in rest of the treatments. Minimum mean seedlings height, central girth and number of leaves were recorded at 4 months age group of all the 3 rootstocks, making them unfit for doing either microbudding or normal budding except 4 months old rough lemon rootstocks, microbudding stage may be obtained with best management practices. For attempting the conventional shield budding in direct sown category, all the favourable nursery parameters were obtained at 6 months old Rough lemon, Rangpur lime and Alemow within the 6 months old direct sown rootstocks group, maximum mean seedling height (69.65 cm) stem girth (1.94 cm) and number of leaves (37.78) were recorded in Rough lemon followed by Rangpur lime and Alemow. The data depicts, possibility of obtained the favourable nursery parameters for attempting their conventional shield budding just on 6 or 7 months old 3 commercial rootstock in direct sown method. The height in direct sown rootstocks at 6 months age ranged between 63.36 cm (Rangpur lime) to 69.65cm (Rough lemon) and girth ranged between 1.71 cm (Rangpur lime) to 1.94cm (Rough lemon), whereas the required girth of the rootstocks was recorded in 12 months old transplanted Rough lemon (1.71 cm) and Alemow (1.88 cm), Rangpur lime (transplanted) not attanded the girth (1.32 cm) even at 12 months age. The data reveals higher parameters of early buddable seedlings (shield budding) can be obtained at 6 to 7 months age of rootstocks when the seeds were sown directly in polybags. In transplanted rootstocks the favourable height and girth obtained only by beyond 12 months age especially in case of Rangpur lime.

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 (Fig. 20) the higher percentage of early buddable seedling (59.48%) and budding success (64.66%) obtained, when seeds were sown directly in polybags in just 6-7 months old Rough lemon

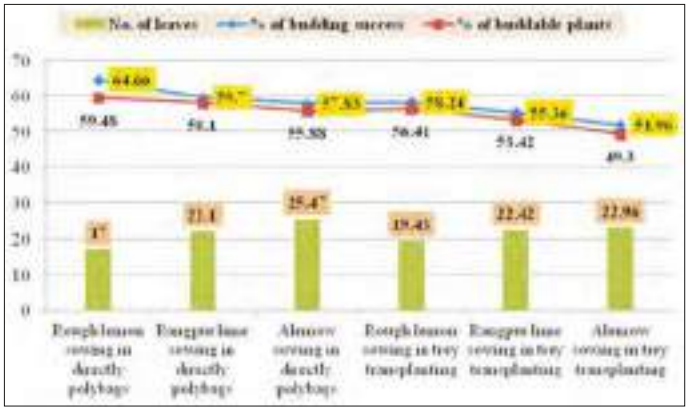


Fig. 20 : Effect of direct sowing and transplanted rootstocks on after commercial budding success (after one month)

rootstocks. Significant differences were found among these treatments for all the studied parameters (for % budding success, % buddable plants and days taken for sprouting). Highest budding success obtained in Rough lemon (64.66%), Rangpur lime (59.70%) and Alemow (57.83%) at 6-7 months age of rootstocks, from sowing of seeds directly in polybags compared to the traditional transplanting method where the budding success ranged from 51.96% to 58.24%. Sprouting observe early in Rough lemon when seeds sown directly in polybags (17 days) and late sprouting in Alemow (25.47) when seeds sown directly in polybags.

Direct sown micro budded on 3 rootstocks (11 months old)

Direct sown commercial budded and conventional on transplanted rootstock

Direct sown micro budded and commercial budded on Rangpur lime

Fig. 21 : Growth of direct sown vs conventional bud grafts (Rough lemon) before release

Fig. 22 : Root coiling while transplanting in traditional propagation method

3.2.1.6 Microbudding of Nagpur mandarin on different Citrus rootstocks

The data indicates maximum mean microbudding success obtained in Nagpur mandarin on SFS (80.58 %) and lowest success in Nagpur mandarin on Alemow (60.28%). Precosity for microbud emergence was observed in Nagpur mandarin on Rough lemon (17.67 days) and delayed sprouting in Nagpur mandarin on SFS (26 day) (Fig. 23).

Fig. 23 : Microbudding of Nagpur mandarin on different Citrus rootstocks

3.2.2 Development of Agrotechniques

3.2.2.1 Rootstocks

Evaluation of hybrid rootstocks for Nagpur mandarin

This project was initiated in 2009-10 to evaluate four hybrid rootstocks (NRCC-2, NRCC-3, NRCC-4, NRCC-5) and rough lemon with Nagpur mandarin as scion. The result of tree growth, fruit yield and quality and disease incidence are mentioned below.

Tree growth : The data on the physical growth parameters was recorded and analysed during the year 2021. The Nagpur mandarin plants have shown the satisfactory growth performance on all the rootstocks and noted significantly higher canopy growth and plant height was recorded The higher canopy growth (387.10 m^3) was recorded in rough lemon and tree height was noted maximum (10.95 m) in NRCC-5. When the In case of stock (85.46 cm) - scion (77.56 cm) growth it was recorded maximum with the rootstock NRCC rootstock-2 showing better growth performance.

Fruit yield and quality : The fruit quality parameter recorded and noted in different rootstocks and maximum average fruit weight (179.23 g) was recorded in NRCC-2 rootstock followed by NRCC-3 (165.78 g). The TSS content was recorded to be higher (10.97%) in NRCC-4 followed by 10.89% in rough lemon as compared to other rootstocks. The acid content was recorded maximum with rough lemon (0.43%) whereas lowest was noted in NRCC-5 (0.29%). Higher juice content was recorded in NRCC-4 (57.45%) followed by NRCC-3 (56.98%) whereas lower acid content (0.29%) with NRCC-5. The fruit yield was recorded maximum 27.86 kg/plant and 14.85 t/ha on NRCC rootstock-3 followed by NRCC-5 (13.78 t/ha). Similar trend was observed in yield on area basis (Table 18).

Disease Incidence : Nagpur mandarin trees on different hybrid rootstocks were observed for *Phytophthora* induced gummosis and foot rot disease. Observations were made with respect to disease incidence, no. of gummosis lesion /

Table 18 : Effect of different hybrid rootstocks on fruit yield and quality of Nagpur mandarin

Rootstocks	Plant height (m)	Canopy spread (m^3)	Fruit weight (g)	Rind thickness (mm)	TSS (%)	Acidity (%)	No. of seed/ fruit	Juice content (%)	Fruit yield (kg/plant)	Fruit yield (t/ha)
NRCC -2	9.12	359.87	179.23	2.46	9.09	0.31	3.45	52.36	26.68	14.45
NRCC -3	9.00	317.98	165.78	2.56	9.53	0.38	3.17	57.98	27.86	14.85
NRCC -4	9.68	340.47	138.45	2.47	10.97	0.32	3.58	56.45	23.03	12.66
NRCC -5	10.95	385.25	149.28	2.59	9.65	0.29	3.00	53.00	25.46	13.78
Rough lemon	10.45	387.10	147.36	2.99	10.89	0.43	2.99	42.68	22.45	12.95
CD (P=0.05)	**0.43**	**9.65**	**2.99**	**0.24**	**0.69**	**0.06**	**0.76**	**0.55**	**0.67**	**0.43**

plant and disease severity. Gummosis incidence was found higher in Nagpur mandarin budded on NRCC-2, NRCC-5 and Rough lemon rootstocks. Maximum propagule density (355/cm^3 soil) of *Phytophthora spp.* was recorded in case of Rough lemon rootstocks.

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

Effect of Rangpur lime and rough lemon rootstocks on performance of Nagpur mandarin at 6×3m, 6×4m, 6×5m, 6×6m spacing was evaluated. This year (2021) was the 10th consecutive period of study and reports are mentioned below.:

Tree growth : Rangpur lime and rough lemon has clearly indicated significant difference in various growth parameters with respect to different spacing. The spacing 6×4 m showed better growth performance with respect to plant height (6.02 m) than other spacing in rough lemon. Maximum canopy spread (84.42 m^3) found in spacing 6×6 m than other spacing. The stock (57.23 m) was found in 6×3 m and scion girth (50.78 m^3) was found maximum in 6×4 m. While in Rangpur lime maximum plant height recorded in 6×3 m i.e. 5.99 m and maximum canopy spread (65.64 m^3) was observed in spacing 6×3 m.The growth of stock (60.89 cm) in 6×3 m spacing and scion (49.03 m) was maximum in 6×5 m.

Fruit yield : The fruit quality data during this year was recorded and heavy fruiting was noted in both the rootstock. In rough lemon, it was noted that the maximum average fruit weight was found in 6×6 m spacing (162.78 g). When sweetness was calculated it was observed that the maximum TSS (9.80%) in spacing 6x6m followed by 6×4 m spacing (9.68%). Whereas the acidity was noted maximum (0.38%) in 6×3 m spacing and minimum (0.30%) was found in 6×6 m spacing. When the plant wise fruit yield was calculated then it was found that the maximum fruit yield i.e. 31.52 kg/plant i.e. 18.54 t/ha was recorded in 6×3 m spacing followed by 11.65 t/ha in 6×4 m spacing. In case of Rangpur lime, maximum (190.23 g) average fruit weight was recorded in 6×5 m spacing. TSS was found to be maximum (9.20%) 6×3 m spacing. While the maximum juice content (52.87%) was noted in 6×3 m spacing. When the fruit yield was calculated it was recorded that, the maximum fruit yield (18.18 t/ha) was found in 6×3 m spacing (Table 19).

Table 19 : Effect of different hybrid rootstocks on fruit yield and quality of Nagpur mandarin on Rough lemon

Spacing (m)	Rough lemon						Rangpur lime					
	Fruit weight (g)	TSS (%)	Acidity (%)	No. of seeds / fruit	Juice content (%)	Fruit yield (kg/plant)	Fruit weight (g)	TSS (%)	Acidity (%)	No. of seeds/ fruit	Juice content (%)	Fruit yield (kg/plant)
6×6	162.78	9.80	0.30	7.21	51.23	37.56	158.79	9.03	0.24	6.89	51.89	38.57
6×5	136.07	9.64	0.33	4.87	50.13	36.99	190.23	8.69	0.31	5.89	46.03	30.23
6×4	147.17	9.68	0.35	6.57	53.87	26.87	182.45	8.10	0.28	6.98	48.74	31.25
6×3	133.89	9.23	0.38	4.01	54.39	31.52	159.30	9.20	0.32	7.00	52.87	35.89
CD (P=0.05)	**3.40**	**0.11**	**0.01**	**0.64**	**NS**	**1.47**	**4.78**	**0.01**	**0.13**	**NS**	**1.03**	**0.15**

3.2.2.2 Evaluation of citrus spp. on raised bed planting system

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

Nagpur mandarin budded on rough lemon rootstock was planted with six different spacing (4.5×4.5, 5×4, 5×4.5, 5×5, 5.4×5.4 and 6×6 m (control)) on raised bed with 2.0 meter width and 0.61m height during July, 2014 and this year was the seventh year of its plantation.

Plant growth : This year growth performance recorded significant variation in all spacing. The plant height was maximum (5.01 m) under 4.5×4.5 m spacing followed by 5×4 m (4.89 m) whereas it was minimum (4.33 m) in 6×6m spacing. The canopy volume recorded significant variation among different spacing and it was maximum under 5×4 m (43.55 m^3) followed by 4.5×4.5 m (41.38 m^3). Different spacing has also influenced the stock and scion girth in all the treatment. The stock-scion growth was noted maximum under 5×4 m spacing as compared to other treatment.

Fruit quality and fruit yield : The fruit quality data pertaining to average fruit weight (165.48 g) was recorded maximum in 5×4.5 m spacing whereas, TSS (8.24%) was noted maximum in 5.4×5.4 m spacing with minimum acidity (0.19%). While, highest juice content (55.17%) was observed in 5×5 m spacing followed by 5.4×5.4 m spacing. The maximum fruit yield (27.68 kg/plant) was recorded in 5×4.5m spacing, whereas the minimum fruit yield (18.64 kg/plant) was recorded in 5×4 m spacing. On area basis, maximum fruit yield of 15.36 t/ha was observed in 5×4.5 m spacing followed by 5×5 m (14.10 t/ha) (Table 20).

Insect pest incidence : Insect pest incidence was monitored on Nagpur mandarin budded on rough lemon rootstocks in raised bed in high density planting system (4.5×4.5 m^2, 5×4 m^2, 5×4.5 m^2, 5×5 m^2, 5.4×5.4 m^2 and 6×6 m^2) during the year 2021(Jan-Dec). Citrus psylla population was significantly higher in 5×4 m^2 spacing (3.39 per 5 cm twig). Per cent leaf miner infestation was maximum in 5×5 m^2 (15.25%) and 4.5×4.5 m^2 (13.54%) spacing. Mites infestation was maximum in 4.5×4.5 m^2, 5×4 m^2 and 5×5 m^2 spacing. Black fly infestation appeared to be more in 4.5×4.5 m^2 (3.04/leaf).

3.2.2.2.2 Evaluation of different sweet orange and grapefruit varieties on raised bed system

Plant growth : Among the sweet orange cultivars, Pineapple has shown maximum plant height (4.38 m) as compared to other cultivars. Canopy volume (30.46 m^3) was highest in Blood Red followed by Pineapple (24.20 m^3). In respect to the growth of grapefruit, the highest plant height (4.78 m) and canopy volume (40.81 m^3) was recorded in Marsh seedless followed by Star Ruby (Table 21 and 22).

Fruit quality and fruit yield : The fruit yield and quality parameters indicated significant variation with all the traits. Maximum average fruit weight (230.78 g) was recorded in Mosambi which was at par with Katol gold (229.57 m). The highest juice content (49.26%) was noted in Blood Red with maximum acidity (0.19%) while minimum juice content was observed in Pineapple (43.41%) with

Table 20 : Effect of different spacing on fruit yield and fruit quality of Nagpur mandarin

Spacing (m)	Plant height (m)	Canopy volume (m^3)	Avg. fruit weight(g)	Juice content (%)	TSS (%)	Acidity (%)	No of seeds/ fruit	Rind thickness (mm)	Vit. C (mg/ 100mg)	Fruit yield (kg/plt)	Fruit yield (t/ha)
4.5 × 4.5	5.01	41.38	148.55	53.47	8.12	0.22	4.12	2.59	37.21	21.68	12.03
5 × 5	4.48	24.06	157.96	55.17	8.2	0.24	5.54	2.63	40.68	25.41	14.10
5 × 4.5	4.67	38.37	165.48	54.45	7.81	0.27	4.38	3.27	41.19	27.68	15.36
5 × 4	4.89	43.55	148.31	53.15	7.96	0.26	3.29	3.17	38.65	18.64	10.35
5.4 × 5.4	4.43	19.88	139.44	54.78	8.24	0.19	4.87	3.24	40.87	20.85	11.57
6×6	4.33	21.02	143.85	52.41	8.04	0.20	4.02	2.76	39.75	19.46	10.80
CD (P=0.05)	**0.059**	**1.533**	**1.509**	**1.401**	**0.147**	**0.073**	**0.351**	**0.102**	**0.507**	**1.245**	**0.587**

maximum vit.C (46.84 mg/100mg) content. The TSS content (9.24%) was found to be maximum in Katol gold followed by Mosambi (9.20%). The maximum fruit yield (26.38 kg/plant) was recorded in Blood red followed by Jaffa (23.15 kg/plant) (Table 21).

In grapefruit, fruit quality data pertaining to average fruit weight (463.49 g) maximum in Marsh seedless whereas, maximum acidity (1.2%) and Vit.C (48.07 mg/100 mg) was recorded in Flame grapefruit and highest juice content (46.41%) was recorded in NRCC grapefruit-6. The maximum fruit yield (25.22 kg/plant) was recorded in Star ruby and non-significant effect was observed in grapefruit w.r.t. yield (Table 22).

Evaluation of exotic sweet orange varieties on raised bed system

Plant growth: The growth data pertaining to plant height (4.30 m) and canopy volume (30.60 m^3) recorded maximum in Hamlin on Volkameriana rootstock, while stock-scion girth was recorded maximum in Valencia on Volkameriana, while rough lemon recorded dwarfing effect on Valencia olinda (16.38 m^3) (Table 23).

Fruit quality and fruit yield : With respect to quality trait, maximum fruit weight (275.14 g) was recorded in Lanlate on rough lemon, whereas Hamlin on Cleopatra recorded minimum (162.36 g) weight. The highest juice content (43.18%) was recorded in Pera on limocravo followed by Westin on limocravo (41.75%). Whereas, maximum TSS content (11.81%) was noted in Mosambi on rough lemon followed by Mosambi on Rangpur lime. The average maximum fruit yield (16.53 kg/plant) was recorded in Westin on swingle followed on Pera on limocravo (16.48 kg/plt). When extrapolated on area basis, Newhall on rough lemon recorded minimum yield of 4.14 t/ha (Table 23).

PLW during storage : The new experiment was conducted on the Sweet orange budded on different rootstocks. The 5 fruits per replication per treatment were kept for the storage for 28 days for observing the weight loss in fruits. The experiment revealed that the loss of weight was noted in the

Table 21 : Plant growth, fruit yield and quality of sweet orange on raised-bed system

Varieties	Plant height (m)	Canopy Volume (m^3)	Average Fruit wt (g)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/100 mg)	No. of seeds/ fruit	Rind thickness (mm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
Blood Red	4.12	30.46	187.67	49.26	8.04	0.19	43.26	4.10	3.32	26.38	14.64
Jaffa	4.09	20.93	198.24	47.38	8.10	0.15	45.69	7.54	3.01	23.15	12.85
Pineapple	4.38	24.20	223.72	43.41	7.91	0.17	46.84	15.21	3.12	16.27	9.03
Mosambi	3.98	19.19	230.78	43.76	9.20	0.13	41.28	12.14	3.31	20.45	11.35
Katol gold	3.74	15.19	229.57	44.59	9.24	0.14	41.82	14.33	3.68	15.89	8.82
CD (P=0.05)	**0.134**	**0.924**	**2.074**	**2.703**	**0.251**	**0.051**	**1.792**	**3.307**	**NS**	**1.813**	**1.150**

Table 22 : Plant growth, fruit yield and quality of grapefruit on raised bed system

Varieties	Plant height (m)	Canopy Vol. (m^3)	Avg. Fruit wt(g)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/100 mg)	No. of seeds/ fruit	Rind thickness (mm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
Star ruby	4.56	34.91	445.28	42.12	6.95	0.39	41.34	4.12	7.03	25.22	14.00
Red blush	4.78	40.81	371.94	41.36	7.2	0.37	39.45	3.56	8.27	24.69	13.59
Marsh seedless	4.52	33.53	463.49	41.56	6.8	0.38	38.57	2.36	7.86	25.13	13.95
NRCC grapefruit-6	3.32	14.75	412.27	46.41	8.1	1.11	34.25	30.14	6.59	6.21 **(4yr age)**	3.45
Flame grapefruit	3.31	12.99	231.41	32.48	6.46	1.2	48.07	9.07	5.51	11.44	6.35
CD (P=0.05)	**NS**	**1.527**	**7.799**	**2.145**	**0.123**	**3.415**	**0.834**	**0.548**	**1.104**	**1.151**	**0.199**

Table 23 : Plant growth, fruit yield and quality of different exotic sweet orange spp. on raised bed system

Varieties	Avg. fruit wt.(g)	Plant height (m)	Canopy volume (m^3)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/100 mg)	No. of seeds/ fruit	Rind thickness (mm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
Hamlin on Volkameriana	210.25	4.30	30.60	35.13	7.13	0.48	40.23	2.46	2.75	11.26	6.25
Hamlin on Cleopatra	162.36	3.65	17.48	38.43	7.43	0.65	41.36	2.84	2.63	8.69	4.82
Pera on Volkameriana	182.48	3.16	18.18	40.76	7.74	0.51	39.15	3.29	2.49	12.36	6.86
Pera on Limocravo	192.46	3.14	17.62	43.18	6.86	0.61	34.16	2.89	2.28	16.48	9.15
Natal on Limocravo	242.48	3.67	17.05	38.21	7.41	0.49	39.22	4.38	3.12	12.74	7.07
Natal on Volkameriana	247.64	3.71	20.50	36.11	7.36	0.54	40.69	4.78	2.87	10.36	5.75
Valencia on Volkameriana	223.26	3.98	26.55	40.79	8.13	0.42	44.18	4.15	2.56	9.68	5.37
Westin on Limocravo	216.46	3.56	18.64	41.75	7.56	0.24	43.86	4.21	3.86	9.71	5.39
Westin on Swingle	225.46	3.67	19.34	35.29	7.85	0.26	43.79	5.37	3.67	16.53	9.17
Mosambi on Rangpurlime	223.11	4.03	28.76	34.37	10.12	0.28	44.86	9.27	2.41	10.69	5.93
Mosambi on rough lemon	231.18	4.12	25.33	34.62	11.81	0.28	38.49	11.36	2.74	11.28	6.26
Washington navel on Roughlemon	248.33	3.54	19.75	34.81	8.21	0.27	40.26	6.03	3.74	7.63	4.23
Lanlate on Rough lemon	275.14	3.52	16.75	30.29	6.61	0.23	38.69	3.71	3.59	8.16	4.53
Newhall on Rough lemon	207.36	3.68	17.98	39.16	8.43	0.66	37.16	2.59	3.36	7.46	4.14
Valencia olinda on Rough lemon	212.41	3.34	16.38	37.34	8.03	0.62	37.94	3.17	2.94	9.38	5.21
CD (P=0.05)	**2.204**	**0.015**	**0.321**	**1.374**	**0.123**	**0.162**	**1.541**	**0.371**	**0.127**	**0.481**	**0.312**

range of 16-30% in all the rootstocks. The maximum average weight loss of fruit was recorded in Rangpur lime rootstock (30.14%) followed by Pera on limocravo (25.11%) while minimum weight loss was recorded in Valencia on Volkameriana (16.70%) (Table 24).

Insect pest incidence : Insect pest and mites incidence were monitored on 12 different Brazilian varieties planted on raised bed. The incidence of citrus psylla was in the range of 9.72 to 14.23 per 5 cm twig. Citrus leaf miner infestation was highest on Mosambi + Rough lemon (36.14%) and it was lowest on Hamlin + Cleopatra (17.94%). Percent fallen fruit due to fruit sucking moth was also recorded during Oct. to Dec., 2021, infestation due to fruit sucking moth was highest in Mosambi + Rough lemon (36.14%) and significantly lowest in Westin + Limocravo (16.64%). There was no significant difference in terms of mites' infestation in between different cultivars.

Table 24 : PLW (%) during storage of different exotic sweet orange

Varieties	1st week	2nd week	3rd week	4th week
Pera on Volkameriana	5.94	13.45	20.05	24.80
Pera on Limocravo	5.51	12.58	18.36	25.11
Natal on Limocravo	3.25	8.03	12.68	18.75
Natal on Volkameriana	5.52	9.89	14.88	18.29
Valencia on Volkameriana	5.48	9.52	13.52	16.70
Westin on Limocravo	6.09	10.57	15.06	17.40
Mosambi on Rangpur lime	8.89	16.65	23.00	30.14
Mosambi on Rough lemon	7.22	12.86	17.55	22.87
Newhall on Rough lemon	7.15	11.51	16.11	24.45
Valencia on Olinda Rough lemon	7.35	13.10	18.00	22.36
CD (P=0.05)	**1.516**	**1.666**	**1.789**	**1.783**

3.2.2.2.4 Evaluation of Acid lime cultivars on raised-bed system

Plant growth : This experiment was initiated with ten different acid lime *cultivars* budded on rough lemon rootstock at 6×3 m spacing planted during 2015. The maximum plant height (4.12 m) was recorded in Pramalini whereas minimum height was recorded in NRCC-7 (3.54 m). Highest canopy volume (23.69 m^3) was noted in Phule Sharbati while, minimum canopy volume (14.75 m^3) was in NRCC-7. In the year 2019, Ganganangar lime variety was planted and it shows good growth performance with 2.2 m plant height.

Fruit quality and yield : The fruit yield was recorded on all the cvs and maximum average fruit weight (61.7 g), TSS (7.7%) was recorded in PKM-1. NRCC-8 recorded maximum juice content (69.09%) followed by PKM-1 (68.10%). 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. Ganganagar lime recorded average fruit weight (40.2 g) and TSS (6.1%), juice content (48.87%) and acidity (5.56%) (Table 25).

Table 25 : Fruit yield and fruit quality of Acid lime cultivars on raised bed system

Variety	Fruit wt.(g)	No. of seeds/ fruit	TSS (%)	Juice content (%)	Acidity (%)	Rind Thickness (mm)	Vit. C (mg/ 100mg)	Fruit yield (kg/plt)	Fruit yield (t/ha)
Pramalini	39.4	7.1	7.8	49.45	3.89	1.34	37.12	13.15	7.29
PKM-1 (Jaidevi)	61.7	5.2	7.7	43.26	3.51	1.32	31.86	24.51	13.60
Phule Sharbati	50.19	11.7	7.2	48.88	4.12	1.38	32.07	16.34	9.07
Sai Sharbati	44.75	5.23	7.6	54.49	3.13	1.24	28.64	19.64	10.90
Vikram	40.46	8.2	7.0	51.14	4.25	1.21	27.21	12.34	6.85
PDKV Bahar lime	49.12	8.86	7.0	52.08	4.4	1.20	28.23	19.67	10.92
Balaji	44.69	7.4	7.2	50.12	3.37	1.28	30.17	20.14	11.18
NRCC-7	40.45	9.1	6.7	50.65	3.14	1.32	31.28	21.36	11.85
NRCC-8	38.57	5.12	7.1	47.89	3.97	0.97	33.69	22.48	12.48
Acid lime seedling	49.80	6.81	7.5	47.79	3.27	1.07	31.24	16.45	9.12
CD (P=0.05)	**1.102**	**0.321**	**0.061**	**1.375**	**0.018**	**0.069**	**1.176**	**1.308**	**0.653**

Insect pest incidence : Among the acid lime cultivars, maximum citrus psylla population was recorded on Pramalini (5.50 per 5 cm twig) and Vikram (5.08 per 5 cm twig) and it was lowest in PDKV bahar lime (3.32 per 5 cm twig) and Sai Sharbati (3.61 per 5 cm twig). Leaf miner infestation was highest on Vikram (24.89%), followed by PDKV bahar lime (24.85%) and Balaji (23.01%), the lowest leaf miner infestation were recorded on Pramalini (17.14%). Thrips infestation was below the ETL on the different cultivar and it was in the range of 2.23 (Chakardhar) to 8.11 (NRCC-7) per stem tapping. There was no significant different with respect to mites infestation among different cultivars. Blackfly population was observed below ETL in the range of 2.40 (in NRCC-8) - 7.12 (in Sai Sharbati). Lemon butterfly infestation was ranging from 1.97-5.02 in NRCC-8 and Sai Sharbati, respectively.

Disease Susceptibility: Disease incidence on leaves ranged from 57.4 - 91.8% in those acid lime clones and percent disease index (PDI) ranged from 12.25 - 35.08. Results obtained were rated in 3 groups as follows : Resistant : < 10 % leaves with lesions, Intermediate or Moderately resistant : 10.1 - 20% of leaves with lesions, and Susceptible : > 20% of leaves with lesions.

All the clones were found to be susceptible to citrus canker under open field conditions. Acid lime seedling, however, was found moderately resistant. This is initial years' observation and will be continued further.

Evaluation of lemon cultivars on raised bed system

This experiment was initiated with four different cultivars budded on rough lemon rootstock during 2017 and planted at 6×3 m spacing.

Plant growth : The Kagzi kalan showed maximum plant height (3.10 m) with maximum canopy spread (23.92 m^3). Whereas, Assam lemon recorded least plant height (2.94 m) and minimum canopy volume (17.86 m^3). Pant lemon was noted highest value with respect to stock-scion girth (Table 26).

Fruit yield and quality : The lemon cultivar Assam lemon recorded maximum average fruit weight (168.34 g) and highest acidity (6.21%) with minimum TSS, and juice content as (7.62%), and (45.84%) respectively. Whereas, the highest juice content (52.31%) and TSS (7.81%) was noticed in Pant lemon. While maximum fruit yield (33.04 kg/plant) and productivity (18.34 t/ha) was maximum in Assam lemon followed by Pant lemon (Table 8). Two more varieties were planted i.e. Lemino (seedless lemon) and Konkan lemon with 6×3 m spacing in the year 2019. Average plant height ranged from 1.8 m - 2.2 m. Average fruit weight (123.6 g), acidity (4.66%), TSS (5.6%), and juice content 43.54% was recorded in Lemino. Lemino recorded 9.27 kg/plant fruit yield. Both the varieties show better growth performance.

Table 26: Plant growth, fruit yield and quality of different lemon cultivars

Varieties	Plant height (m)	Canopy volume (m^3)	Fruit wt.(g)	No. of seeds	TSS (%)	Juice content (%)	Acidity (%)	Rind thickness (mm)	Vit. C (mg/ 100mg)	Fruit yield (kg/plt)	Fruit yield (t/ha)
Pant lemon	3.02	20.20	151.64	14.8	7.81	52.31	6.04	2.65	39.68	30.46	16.91
Assam lemon	2.94	17.86	168.34	22.14	7.62	45.84	6.21	3.01	40.23	33.04	18.34
Kagzikalan	3.10	23.92	159.47	15.75	7.69	49.61	5.41	2.71	42.15	28.11	15.60
Baramasi lemon	2.96	18.58	162.79	18.2	7.76	50.75	5.12	2.59	43.89	29.54	16.39
CD (P=0.05)	**0.814**	**2.121**	**5.681**	**1.34**	**0.22**	**1.183**	**0.051**	**0.042**	**0.442**	**1.512**	**0.875**

Insect pest incidence: The insect pest incidence levels were recorded among the lemon cultivars i.e. Pant lemon, Assam lemon, Kagzi Kalan and Baramasi lemon. Citrus psylla population was observed on Pant lemon cultivar during February to March and September to November in the range of 3.06-6.5 and 3-11 per 5 cm twig, respectively. Leaf miner infestation was below the ETL on Pant lemon (12%), Assam Lemon (22%), Kagzi Kalan (20%) and Baramasi lemon (16%). Thrips population was significantly higher on Pant lemon (5 per stem tapping) as compared to Assam lemon (3 per stem tapping). Mite population recorded below the ETL during March, September to December. Aphids infestation was also below the ETL in all four lemon cultivar and it was in the range of 5 to 7%. Black fly population was also relatively low this year and it was below the ETL for entire year.

Disease Susceptibility: Disease Susceptibility in lemon cultivars were evaluated under field conditions for the presence of bacterial canker infection. Canker incidence was observed only in Assam lemon (with 32.56% disease incidence on leaves and PDI 6.86). Other cultivars (Pant lemon, Kagzi Kalan, Baramasi lemon) were found free from canker.

Evaluation of Nagpur mandarin on Alemow rootstock on raised-bed system

Plant growth : The plant spaced at 6×3 m spacing showed plant height range from 4.2-4.7 m and better canopy volume range from 21-30 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 spacing.

Fruit quality and yield : The fruit quality data was recorded maximum with respect to average fruit weight and acidity in 6×6 m spacing treatment whereas, juice content, vit. C, TSS and fruit yield was recorded better in 6×3 m spacing. The fruit yield was 25.34 kg/plant and 14.06 in terms of t/ha at 6×3 m spacing treatment (Table 27).

Insect pest incidence : Observations on insect pests incidence in raised bed planting system with two spacing's *viz*., 6x3 m^2 and 6x6 m^2 was recorded from January - December 2021. No significant difference was found in terms of pest incidence levels in the two different spacing. Citrus psylla was active during February to March and July to August whenever there was new flush during the year 2021 with a population on an average ranging from 0 - 6.9 per 5 cm twig in 6x3 m^2 spacing while it was ranges from 0 - 5.35 per 5 cm twig in 6x 6m^2 spacing. Leaf miner infestation was recorded during February to March and from July to October in 2021 with 5.14 - 23.4% and 4.94 - 20.14% in 6x 3m^2 and in 6x6 m^2 spacing, respectively. Black fly population was below the ETL in 6x3 m^2 (0-3.57/leaf) and 6x6 m^2 (0-3.70/leaf) spacing. Mites population was observed in Feb-March and Sep-Dec (0.25-3.75/leaf) in 6x6 m^2 spacing. Whitefly and lemon butterfly population were under economic threshold level.

Intercropping of vegetables : The raised bed citrus plantation has potential in intercrop of vegetables in furrow area. During 2021 vegetables such as Tomato (Abhilash), Brinjal (VNR harsh), and marigold flowers were grown. The Tomato, Brinjal, Papaya and marigold flowers too had shown better performance with good productivity in a limited area (5030 sq.m). Plantation of Turmeric (PDKV-

Table 27 : Plant growth, fruit yield and quality of Nagpur mandarin under different spacing on Alemow rootstock

Spacing (m)	Plant height (m)	Canopy volume (m^3)	Average fruit wt. (g)	Juice content (%)	TSS (%)	Acidity (%)	No of seeds/ fruit	Rind thickness (mm)	Vit. C (mg/100)	Fruit yield (kg/plant)	Fruit yield (t/ha)
6 × 3	4.69	29.09	152.17	48.16	7.91	0.51	2.41	2.87	28.22	25.34	14.06
6 × 6	4.25	21.33	172.61	45.81	7.85	0.52	5.48	2.69	27.46	29.46	7.18
CD (P=0.05)	**NS**	**1.025**	**2.261**	**1.008**	**0.365**	**0.001**	**1.278**	**0.547**	**0.896**	**2.274**	**3.353**

Cauliflower

Cabbage

Turmeric

Fig. 24 : Intercropping of vegetables in between raised beds

Waigaon) and ginger has done in the month of June 2021 with the planting distance at 30 cm (plant to plant). Ginger and Turmeric was showing good result and experiment is in progress. In the month of November, 2021 cabbage (var. Ojas), cauliflower (var. Dhawal) and strawberry three varieties i.e. Percinique, sweet sensation, winter dawn were planted as a intercropping at the distance of 45 cm (plant to plant) and experiment is in progress (Fig. 24).

Evaluation of exotic mandarin varieties on raised bed system

The exotic mandarin scion varieties budded on rough lemon rootstock were planted in the field during September, 2015. Nagpur mandarin seedless-4 recorded maximum growth with respect to plant height (4.81 m) with maximum canopy volume (32.45 m3) at par with Daisy. Frost Owari recorded minimum plant height (3.46 m) and Frost Owari recorded minimum canopy volume (12.66). Daisy recorded better stock-scion growth.

Fruit quality and yield : Exotic mandarin varieties showed better fruiting during this year. Average fruit weight (225.81g) and TSS (9.41%) was recorded maximum in Daisy. Whereas, maximum vit. C (37.37mg/100mg) and juice content (52.17%) was recorded maximum in N4. Maximum fruit yield was recorded in Pearl Tangelo i.e. 9.70 t/ha (Table 29 and Fig. 25).

Daisy

Pearl Tangelo

Fig. 25 : Promising performance of exotic Mandarin cultivars

Table 28 : Fruit quality and yield of different exotic mandarin varieties on raised bed

Varieties	Avg. Fruit wt (g)	Fruit length (mm)	Fruit dia. (mm)	Juice content (%)	TSS (%)	Acidity (%)	Vit. C (mg/ 100 mg)	No. of seeds	Rind thickness (mm)	Fruit yield (kg/plant)	Fruit yield (t/ha)
W. Murcott	141.58	56.14	62.47	46.25	8.24	0.31	26.87	7.86	2.11	13.74	7.63
Daisy	225.81	63.71	73.11	39.15	9.41	0.24	28.56	7.24	1.75	11.36	6.30
Pearl Tangelo	186.78	70.24	68.47	44.71	8.46	0.26	32.47	8.41	2.64	17.48	9.70
N4 (Seedless)	111.74	52.91	61.07	52.17	8.12	0.34	37.37	2.16	2.81	9.21	5.11
Frost owari	75.61	51.74	49.22	36.32	6.8	0.98	36.12	22.13	2.14	13.14	7.29
CD (P=0.05)	**2.945**	**7.140**	**3.284**	**2.087**	**0.178**	**0.027**	**2.514**	**1.481**	**0.614**	**0.963**	**0.618**

Table 29 : Insect and mites pests incidence on exotic mandarin varieties

Cultivars	Psylla (popu^{n}/5cm twig)	CLM (% infestation)	Black fly (popu^{n}/leaf)	LBF (Popu^{n}/Plant)	Mites (popu^{n}/leaf)
Clementine	2.18 (1.46)^{d}	14.35 (22.2)^{d}	4.5 (2.11)^{a}	0.87 (0.93)^{bc}	2.25 (1.49)^{a}
Murcot	2.98 (1.72)^{c}	17.12 (24.42)^{bc}	2.84 (1.67)^{cd}	1.13 (1.06)^{ab}	1.19 (1.08)^{c}
Michal	4.52 (2.11)^{b}	24.35 (29.55)^{a}	3.14 (1.75)^{bc}	0.75 (0.86)^{c}	1.65 (1.28)^{bc}
Frost Owari	4.87 (2.2)^{b}	19.03 (25.84)^{b}	3.39 (1.83)^{bc}	1.16 (1.07)^{a}	1.97 (1.39)^{ab}
Daisy	6.48 (2.52)^{a}	14.96 (22.73)^{cd}	2.47 (1.55)^{d}	1.2 (1.09)^{a}	1.91 (1.37)^{ab}
Pearl Tangelo	4.71 (2.16)^{b}	14.37 (22.25)^{d}	3.73 (1.9)^{b}	0.38 (0.6)^{d}	2.11 (1.45)^{ab}
N_4 Seedless	7.04 (2.65)^{a}	24.03 (29.31)^{a}	3.5 (1.8)^{bc}	0.45 (0.66)^{d}	1.65 (1.27)^{bc}
CD (P=0.05)	**0.176**	**1.905**	**0.18**	**0.136**	**0.2**

Figures in parenthesis are arc sine/square root transformed values

Values followed by same letter in a column are not significantly different (P=0.05)

Evaluation of Pummelo cultivars on raised bed system

The plantation of Pummelo varieties was done in the field during July, 2017. The varieties were NRCC Pummelo-5 and US Pummelo-145 at 63 m spacing. Evaluation of plant growth data reveals that US pummelo-145 showed maximum plant height (3.21 m) with canopy volume (10.08 m^3) than NRCC pummelo (Table 30).

Table 30: Plant growth of Pummelo cultivars on raised bed planting system

Variety	Plant height (m)	Stock girth (cm)	Scion girth (cm)	Spread E-W (m)	Spread N-S (m)	Canopy volume (m^3)
NRCC Pummelo-5	3.12	38.16	37.21	2.2	2.3	8.58
US Pummelo-145	3.21	40.21	36.27	2.5	2.31	10.08
CD (P=0.05)	**0.089**	**1.032**	**1.213**	**2.485**	**0.084**	**2.037**

Fruit quality and yield : In pummelo, maximum average fruit weight (1.36 kg) and TSS (7.8%) was observed in US Pummelo-145 while Vit. C (36.11 mg/100mg), juice content (34.89%) and acidity (1.24%) was recorded maximum in NRCC Pummelo-5 with maximum fruit yield (4.52t/ha).

Insect and mite pest incidence : Mites population was high on US Pummelo-145 during September to December and it was in the range 5-12 population/leaf. Leaf miner infestation was below the ETL and it was ranging from 7.72% to a maximum of 25.37%. Thrips population was higher on US Pmmmelo-145 (5-7.25 per stem tapping). Citrus psylla population was more on NRCC Pummelo-5 (3.35-4, 2.66-4). Aphids infestation was below the ETL during February and it was observed in NRCC Pummelo-5 (8.16). Blackfly and whitefly population was observed below the ETL in Pummelo Cultivar.

Evaluation of 3 yrs old Nagpur mandarin plants on raised bed planting system

An experiment was initiated during the month of February 2019. The plants of Nagpur mandarin were maintained in a polythene bag for a period of 3 years in the nursery and then planted in the field. The 3 year old plants (as maintained in nursery) are being compared on raised bed planting system with conventionally planted Nagpur mandarin (as taken from the nursery in normal practice). The plants are also compared with flatbed system in the same block. Plant height varied from 2.21 m (1 year old) to 3.22 m (3 year old) plants. All the plants are showing healthy growth and experiment is in progress.

Monitoring of *Phytophthora* population under raised bed and flatbed field conditions

Phytophthora population was monitored regularly in 5-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 (2.56 / cc soil) compared to the flat bed condition (12.2 / cc soil).

Diversity of plant parasitic nematodes under raised and flatbed field conditions

Soil samples were randomly collected from the feeder roots of 3 year old and 1 year old nursery plants of Nagpur mandarin budded on rough lemon rootstock under both raised bed and flatbed field conditions. Four soil samples collected each from raised and flatbed of 3 year and 1 year old plants were thoroughly mixed to constitute composite samples respectively. In the laboratory, nematodes were extracted from soil samples using Cobb's sieving and decanting technique and modified Baermann funnel technique. Nematode suspensions were taken in beakers and dipped in hot water at 60ºC for 2 minutes. After cooling, the suspensions were concentrated to 25 ml and identified different groups of plant parasitic nematodes (PPN) under stereoscopic microscope. Based on the morphological characters, four PPN genera were identified from 3 year old and 1 year old nursery plants of Nagpur mandarin under both raised bed and flatbed field conditions. The PPN in order of abundance were *Hoplolaimus* >Tylenchinae >*Pratylenchus* >*Tylenchulus*. In addition, different free living nematodes such as rhabditids and mononchids were also identified. However, more number of *Hoplolaimus* sp. (140 no. per 250 cc soil) was observed in 3 year old Nagpur mandarin plants on raised bed system compared to flatbed system (94 no. per 250 cc soil).

3.2.2.3 Evaluation of different citrus species on raised and flatbed planting systems at RRCC, Biswanath Chariali, Assam

The project was approved after establishment of RRCC during the year 2017. This project was arrived to evaluate various citrus spp. under the agro-climatic condition of Biswanath Chariali, Assam which represents the most of the NE region and developed techniques/spp. will be used for this zone.

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

This experiment was conducted on 17 citrus species comprising mandarin, sweet orange, lemon, lime, pomelo and grapefruit budded on rough lemon rootstock. The

evaluation was performed under both raised bed and flatbed system planted at 5x3m spacing during August, 2017.

Plant growth : All the cultivars displayed excellent growth performance on both the planting systems and results revealed a significant variation among species with respect to plant heights stock scion girth and canopy spread. Among mandarins, maximum plant heightwas recorded in Khasi mandarin seedling in both raised bed (5.17 m) and flat bed (5.13 m) system. Regarding sweet oranges, maximum plant height was noted in Mosambi (4.53 m) on both raised bed and flat bed while maximum canopy spread was noted in Cutter Valencia under flat bed system. Among grapefruit, maximum plant height (4.43 m), stock girth (52.66 cm), scion girth (52.33 cm) and canopy spread was recorded in Flame grapefruit flat bed as compared to the raised bed system. With respect to pummelo, maximum plant height (4.63 m) was noted under flat bed while stock and scion girth (43.67 cm and 43.33 cm) was recorded maximum on raised bed. In Assam Lemon, plant height on raised bed was at par with flat bed system whereas maximum canopy spread was noted on flat bed system. NRCC Acid lime-7 registered the maximum plant height (4.37 m and 4.46 m), stock girth (39.33 cm and 44.66 cm) and scion girth (39.00 cm and 48.66 cm) on raised bed and flat bed respectively as compared to NRCC Acidlime-8. Likewise Citron Mutant displayed maximum plant height under flat bed system (3.70 m) while maximum stock and scion girth as well as canopy spread was noted maximum in raised bed system. 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 : Fruit quality and yield among cultivars and between species varied significantly. Among mandarins, the maximum average fruit weight was recorded in grafted Khasi Mandarin (147.33 g) followed by Khasi Mandarin seedling (144.66 g) whereas, Nagpur mandarin budded registered maximum vitamin C content (39.33 mg/100 g pulp) and TSS (10.45°B) on raised bed system. Significantly, the maximum yield was recorded in STG Nagpur Mandarin (58.77 kg/tree) followed by Nagpur Mandarin (Seedless-4) (48.61 kg/tree) on flat bed. Regarding sweet oranges, maximum average fruit weight (236.67 g), fruit diameter (73.33 cm) and TSS (10.60°B) was recorded in Mosambi on both raised bed and flat bed. It is noteworthy to mention that Cutter Valencia (99.02 kg/tree) followed by Mosambi (97.88 kg/tree) recorded the highest yield on raised bed. Among grapefruit varieties, NRCC Grapefruit-6 registered the highest average fruit weight (485.0 g), and acidity (1.96%) while maximum vitamin C (69.33 mg/100 g pulp), juice content (43.01%) and yield (73.52 kg/tree) was noted in Flame Grapefruit. Comparatively, NRCC Pummelo-5 was superior over US Pummelo-145 with respect to fruit quality parameters under raised bed and yield (125.37 kg/tree) on flat bed. Assam lemon recorded maximum fruit quality parameters on flat bed while highest acidity was noted on raised bed (5.33%). Similarly, NRCC Acid lime-7 recorded maximum fruit weight (51.33 g) and vitamin C content (51.33 mg/100 g pulp) while higher acidity (7.68 %) was observed in NRCC Acid lime-8 on raised bed system. In both varieties, the highest yield was noted on raised bed. The maximum fruit weight (242.0 g), acidity (4.63%), juice content (37.52%) and yield (58.23 kg/tree) was also recorded in Citron mutant on raised bed.

Evaluation of different citrus spp. on raised bed and flatbed systems

Plant growth : This experiment was initiated in 2018 on 11 varieties of different citrus species budded on rough lemon rootstock on both raised bed and flat bed systems planted with 53m spacing. Growth data revealed among the sweet orange, cultivars maximum plant height (2.63 m) and stock and scion girth (30.00 and 27.67 cm) was noted in Mosambi followed by Valencia whereas maximum canopy spread was noted in Natal and Valencia on raised bed systems. In case of grapefruit, Red Blush recorded maximum plant height on flat bed, however canopy spread was highest on raised bed compared to other grapefruit cultivars. In Clementine, planting in raised bed system recorded maximum plant height (2.77 m), stock girth (30.00 cm) and canopy spread. In contrast, Petlur Selection showed better growth performance on flat bed as compared to raised bed.

Fruit yield and quality : Data presented in revealed a significant variation among cultivars and species with respect to yield. Among sweet orange, maximum fruit weight (201.00g), rind thickness (2.33 mm) and acidity (1.28%) was observed in Natal while the maximum juice content in Valencia (48.10%) and TSS in Mosambi (9.60°B) was recorded on raised bed. Valencia registered the maximum yield on flat bed (26.95 kg/tree) while Natal recorded highest yield on raised bed (29.54 kg/tree). Similarly, among grapefruit, Marsh Seedless recorded maximum fruit weight (463.33 g), vit.C content (52.00 mg/100 g pulp) and TSS (6.47°B) on flat bed. All cultivars registered maximum yield on flat bed which was highest in Star Ruby (36.25 kg/tree).

Evaluation of exotic citrus varieties on raised bed planting system

The experiment was started in 2019 on two exotic varieties each of sweet orange (Vernia and Fewtrell's Early) and mandarin (Daisy and Western Murcott). Plants were maintained on raised bed at the spacing of 5×3 m. During the period, plants initiated their maiden flowering though erratic. The observations taken on plant growth and yield revealed a significant variation among cultivars.

Diversity of plant parasitic nematodes at RRCC

Soil samples were randomly collected from the experimental blocks of RRCC during the year 2021. The collected soil samples were thoroughly mixed to constitute a composite sample. In the laboratory, nematodes were extracted from the composite soil sample using Cobb's sieving and decanting technique and modified Baermann funnel technique. Nematode suspension was taken in beaker and dipped in hot water at 60ºC for 2 minutes. After cooling, the suspension was concentrated to 25 ml and identified different groups of Plant Parasitic Nematodes (PPN) under stereoscopic microscope. Based on the morphological characters, four PPN genera were identified *viz., Tylenchulus semipenetrans, Hoplolaimus* and *Helicotylenchus* and Tylenchinae. In addition, different free living nematodes such as rhabditids and mononchids were also identified. However, more number of T. semipenetrans were identified (Fig. 27).

Fig. 26 : Commercially important varieties of different citrus species

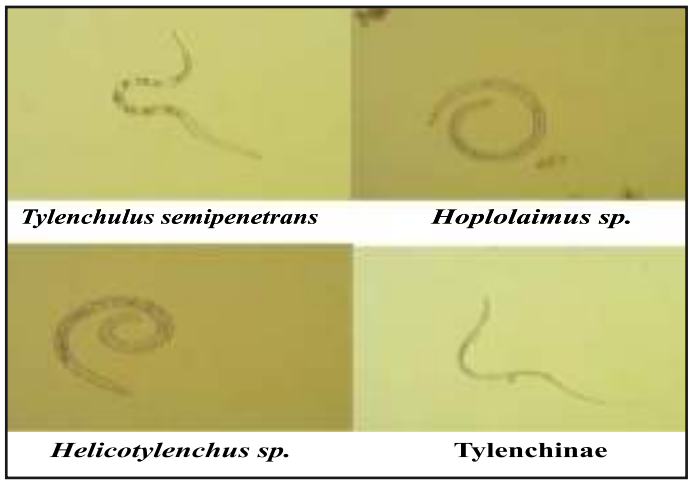


Fig. 27 : Identification of plant parasitic nematode genera

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

A long term experiment carried out during the years 2010-2021 on high density planting in acid lime was concluded. The acid lime seedling progeny plants of cv. Pramalini were planted at spacings of 55 m (400 plants/ha), 52.5 m (800 plants/ha) and 2.52.5 m (1600 plants/ha) at the Institutes experimental orchard. During the initial three years heavy pruning was not required but after third year in 2.52.5 m spacing treatments plants occupied most of the space available between the rows and plants and required pruning.

For the build-up of organic carbon in the soil, farm yard manures and compost prepared from the orchard waste of Institutes farm was applied to the plants. Similarly periodical applications of neem cake and vermi-compost prepared at the Institute farm were made.

Fertigation technique was adopted for supply of all the nutrients. Yearly dose of macro (nitrogen, phosphorus and potash) and micro (iron, zinc, copper, manganese and boron) nutrients was applied through irrigation water in 12 split doses per year.

Plants were managed adopting advanced horticultural practices of training and pruning technique. Pruning was done every year to remove dry twings and unwanted branches. In the fourth year, pruning was required in 2.5x2.5 m as well as in 52.5 m (between the plants). Growth retardant, chlormequat chloride (CCC) was also used to control excessive plant vegetative growth and forcing the plants into flowering and fruiting during *hasta bahar* (October-November flowering).

In high density planting in acid lime in the year 2021 a fruit yield of 20.71 t/ha in 55 m, 28.56 t/ha in 52.5 m and 40.39 t/ha 2.52.5 m was recorded indicating the potential of close planting in increasing yield. However, the downside of the enterprise was the heavy incidence of insects and pests and citrus canker especially during rainy season demanding lot of care and maintenance involving regular plant protection measures and cultural operations with modern equipments, tools and labour.

3.2.2.5 Technology demonstration on canopy architecture management in citrus through training and pruning for higher density and increased productivity

Acid lime : After ten years of experimentation, the ICAR-Central Citrus Research Institute (CCRI) has proved that acid lime can give an yield as high as three times then the conventional cultivation with high density plantation of the trees in the field with spacings of 6x3 meters for acid lime. The institute has also developed a complete agronomic package of practices for the acid lime cv. Pramalini.

Nagpur mandarin : It was possible to manage the canopy of plants planted under close spacing from the fifth year onwards with 6×3 m spacing treatment (555 plants ha^{-1}) which was found economically superior. The management practices helped to retain the quality of fruits and yield which could not be adversely affected by increased insect-pest and disease infestation by virtue of close planting. This study has established practical feasibility and economic superiority of high density planting of Nagpur mandarin over conventional system of plantation. In high density plantation technique, canopy management is equally important in bearing citrus trees to have better interception

of PAR and aeration, strong sap flow for fruiting and supporting branches for convenient harvesting. Last but not the least, an effective alternative to harness available space for increasing net return for first few years of fruiting is high density planting. However, the synchronization of spacings *vis-à-vis* growth pattern needs to be standardized and mechanization for canopy management would be an area for future work to ascertain optimum economic returns.

3.2.2.6 Studies on dynamics of flowering and fruiting in citrus

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 three times on 16th February, 2021, 20th June, 2021 and 20th September, 2021. Observations on fruit retention, yield and quality parameters were recorded in *Ambia* cropping of Nagpur mandarin.

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 liquid formulation at 15 ppm showed desirable results in fruit yield parameters followed by 2,4-D ethyl ester 38% EC at 10 ppm and 2,4-D amine salt 58% SL 15 ppm over other concentration. Foliar application cost of all the 2,4-D concentration is approximate same. 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.

Effect of brassinosteroid on control of fruit growth and quality in Nagpur mandarin

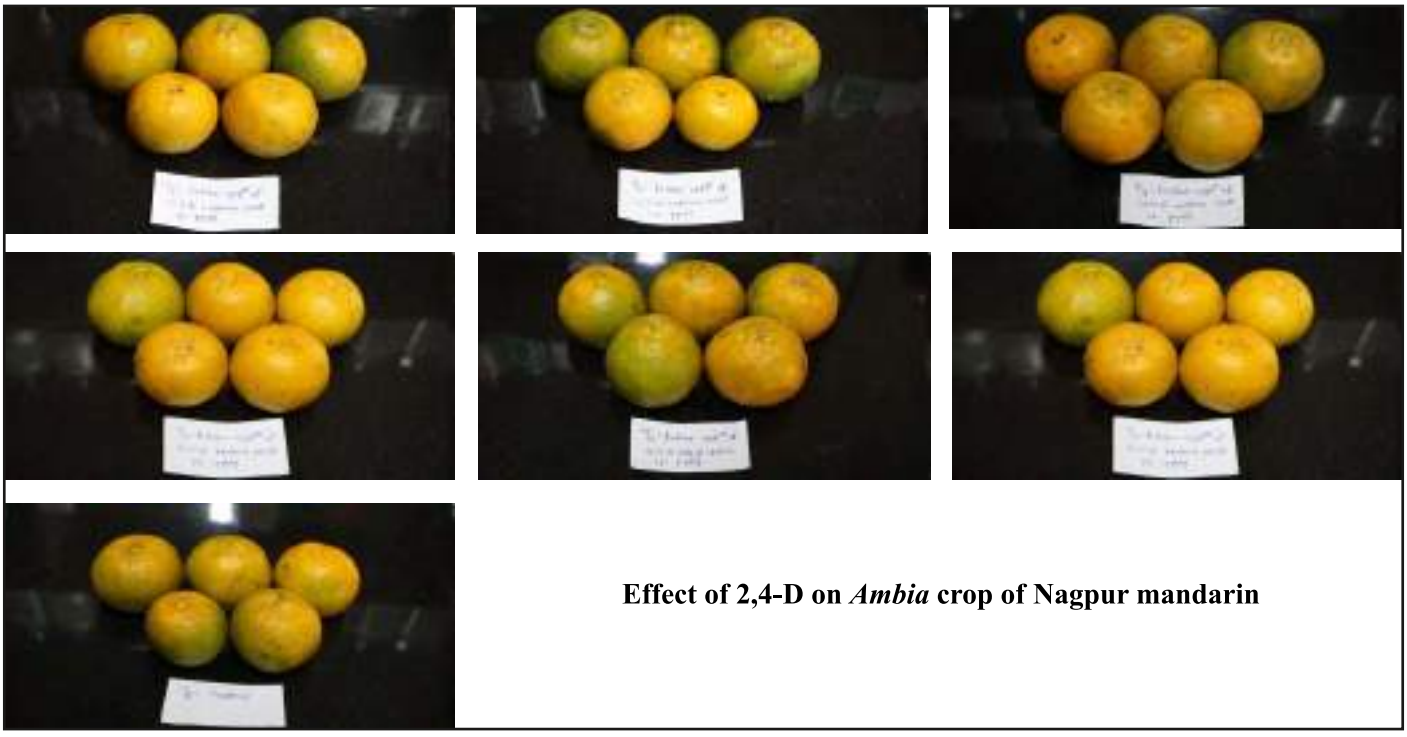
This experiment was conducted on *Ambia* crop of Nagpur mandarin at Hetikundi with available brassinosteroid at 5, 10, 15 and 20 ppm concentrations. A total of 40 trees (2 plants/replication x 4 replications 5 treatments) of Nagpur mandarin budded on rough lemon with 66 m spacing with similar vigour were selected to investigate the effect of brassinosteroid on control of fruit growth and quality of Ambia cropping. The sprays were applied three times on 16th March 2021, 20th June 2021 and 21th September 2021. Observations on fruit retention, yield and quality parameters were recorded in Ambia cropping of Nagpur mandarin.

It was concluded that foliar applications of brassinosteroid at lower concentrations on *Ambia* crop of Nagpur mandarin at fruit set and twice at maturity stages at 10 ppmshowed desirable results in fruit yield parameters followed by brassinosteroid 15 ppmover other concentrations. Also cast of foliar application of brassinosteroid 10 ppm is low as compare to other higher concentration. Therefore, application of brassinosteroid10 and 15 ppmcan be alternatively use forincreasing fruit retention, fruit quality and yieldin Nagpur mandarin.

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

This experiment was conducted in 12-year-old Nagpur mandarin orchard at Hetikundi in Karanja tehsil during the *Ambia* cropping season of 2021. A total of 56 trees (2 plants/replication x 4 replications 7 treatments) of Nagpur mandarin budded on rough lemon with 66 m spacing with similar vigour were selected to investigate the effect of thiourea, GA_3 and nitrobenzene on intensity of *Ambia* cropping in Nagpur mandarin. Foliar applications of thiourea (2 and 3%), GA_3 (20-30 ppm) and nitrobenzene (250 and 500 ppm) were given on 3rd February, 2021 subsequent different yield parameter recorded during *Ambia* cropping of Nagpur mandarin. Irrigation was given to the orchard 10-12 days interval.

It was concluded that foliar application of thiourea, $GA_3$and nitrobenzene at Ambia flowering stage enhances the fruits yield in Nagpur mandarin. Among all the concentrations application of nitrobenzene 500 ppm increasing flowering and fruiting intensity as compare to GA_3 20 ppm and



Effect of 2,4-D on *Ambia* crop of Nagpur mandarin

thiourea 2%. It is also concluded that GA_3 20 ppm and thiourea 2% showed more fruit weight as compare to nitrobenzene. Among all the concentrations, GA_3 20 ppm, nitrobenzene 500 ppm followed by thiourea 2% showed desirable results in all the fruits yield parameters over other concentration. Also, the cast of foliar application of nitrobenzene and GA_3 is low as compare to the thiourea application. Therefore, application of GA_3 20 ppm and nitrobenzene 500 ppm after alleviation of water deficit stress may be recommended for increasing fruits yield in Nagpur mandarin.

3.2.2.7 Precision Citriculture through enhanced water and nutrient use efficiency in Nagpur mandarin

To enhance the fruit production through water and fertilizer use in citrus an experiment in Block (No.28) having 144 eleven years old bearing trees of Nagpur mandarin at 66 m spacing (planted in the year, 2010) was taken up for the studies on precision Citriculture during the year, 2021. These 144 trees have been made as grid points and geo-referenced through the GPS-based observations. Initial status of plant growth, quantified in terms of canopy volume (m^3) on tree-to-tree basis and has been computed as the base map for developing canopy based *variogram* as decision support to delineate three management zones for different treatments of irrigation and nutrients. 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 with fertigation arrangement was done in field. The GIS based *variogram* of initial plant canopy was used to design different treatments for execution. Simultaneously, GPS-based sampling (soil samples and index leaves) was done. GIS-based *variograms* are subsequently developed for canopy volume (m^3) and fruit yield (kg $tree^{-1}$). These two *variograms* developed to judge the uniformity within each management zone and then across different management zones to evaluate the magnitude of changes once variable rates of water and fertilizer application are executed. 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

The soil texture of the experimental site was clay loam with 56 cm depth. Volumetric soil moisture content at field capacity (FC) and the permanent wilting point (PWP), determined using pressure plate method were 31.78% and 20.45%, respectively. The bulk density of the soil was 1.32 g/cc. The available water holding of this soil is 15.94 cm/m depth of soil. The drip irrigation system for water and fertigation unit were installed in the experimental block as per the design having total 144 plants with 48 plants in each unit. The mandarin plants were irrigated with drip system (8 lph/3 plant) and the daily water requirement of the plants was recorded as per the evapotranspiration (ET_{Nm}) based irrigation schedules during the non-rainy months. The fertigation is given using liquid fertilizer injector with the working principle of venturi. The irrigations were scheduled as per the treatment levels and it was given through drip-based on-time duration. The plant growth of individual plants was recorded. The soil sample of each plant was collected and the analysis was done to access the status of nutrients. The changes in soil fertility in terms of availability of nutrients like status of different macro as well as micro-nutrients in soil along with the detail analysis of N, P, K, Fe, Mn, Zn and Cu were analyzed and partitioned across the three working management zones.

Irrigation scheduled and zone wise water requirement:

The water requirement of Nagpur mandarin was estimated based on the daily reference crop evapotranspiration (ET_r). The crop coefficient (K_c) 0.65-0.95 (for Citrus crops) was taken into calculations during different pheneological stages. The Crop Evapotranspiration (ET_{Nm}) of Citrus is estimated as $ET_{Nm} = ET_r \times K_c$. The ET_r varied from 1.65 to 6.48 mm per day. The average Nagpur mandarin tree canopy spread of the plants under study was 2.21 m. The area under the plant canopy was wetted at 100%*WA (wetting factor = 1) as whole area shaded is required to be drip irrigated and canopy area (A_{can}) was 15.34 m^2 during 2021. The mandarin crop ET_{Nm} was estimated as $ET_{Nm} = ET_r \times K_c \times A \times WF/IE$ in litresday^{-1}plant^{-1}. The ET_{Nm} was varied from 1.32 to 6.15 mm per day during the study period. The daily water requirement (ET_{Nm}) of the mandarin plants during the meteorological period I-II (Jan-Feb), III-IV (Mar-Apr), V-VI (May-Jun), VII-VIII (Jul-Aug) and IX-X (Sept-Oct) was estimated (Eq. 1) using the equation as given below:

$$\mathbf{ET_{Nm} = \frac{ET_r \times K_c \times A \times WA}{IE}}$$

Where, ET_{Nm}- Evapotranspiration of Nagpur mandarin in Litersday^{-1}; ET_r- Reference crop evapotranspiration in mmday^{-1}; K_c- Crop coefficient in fraction; A- Plant to plant and row to row area in m^2; WA- Wetted area in fraction and IE-Irrigation efficiency in fraction.

This is the water requirement of the plant at 100% *ET_{Nm} in Low production zone. The WR in High production and Medium production zones are at 80% *ET_{Nm} and 90% *ET_{Nm} levels, respectively. Accordingly, the irrigation were scheduled and given through drip irrigation system to the various zones. The daily quantity of the irrigation is estimated excluding rainy days during the month of crop production period (*i.e.* Jan. to Oct., 2021). The average water requirement of the mandarin plants during peak summer month May (Period V, Week No. 19 to 22) was 176.09 L day^{-1}. The quantity of irrigation scheduled in High production zone was 10,843 L tree^{-1} and the same in Medium and Low production zones were 13,554 and 15,060 Lseason^{-1}tree^{-1} (Table 31).

Table 31 : Monthly water requirement in L tree^{-1} at the various production zones

Months	High Production Zone (80% *ET_c)	Medium Production Zone (90% *ET_c)	Low Production Zone (100% *ET_c)
Jan, 21	858	1073	1192
Feb, 21	703	879	976
Mar, 21	1259	1573	1748
Apr, 21	2172	2715	3017
May, 21	3550	4438	4931
Jun, 21	1311	1638	1820
Jul, 21	-	-	-
Aug, 21	-	-	-
Sept, 21	-	-	-
Oct, 21	991	1239	1376
Total	**10843**	**13554**	**15060**

Fertigation schedule (doses and fertilizers)

The various fertigation levels in three zones are at 60%, 80% and 100% of the RDF (recommended dose of fertilizers) along with irrigation levels of 80% *ET_{Nm}, 90% *ET_{Nm} and 100% *ET_{Nm}. In High production zone @ 60 % RDF of 600:200:300 (N: P: K) the actual fertigation dose is with 360:120:180 (N:P:K). In Medium production zone @ 80% RDF of 600:200:300 (N:P:K) the actual fertigation dose is with 480:160:240 (N:P:K) and in Low production zone @ 100% RDF of 600:200:300 (N:P:K) the actual fertigation dose is with 600:200:300 (N:P:K). The fertilizers used for the fertigation purpose are Urea (46:0:0), DAP (18:46:0) and MOP (0:0:60). The only nitrogen (N) was fertigated from August to October months whereas nitrogen (N), phosphorus (P) and potassium (K) was fertigated during February to April months at monthly intervals. The details of the fertilizers applied through fertigation during the cropping season are further appended.

Growth of the mandarin plant

The individual vegetative growth (plant height, stem girth, N-S and E-W tree spread and canopy volume) of the Nagpur mandarin plants under the study was recorded during Feb-Oct, 2021 as per the production zones Table 32). The mean plant height, stem girth, N-S spread, E-W spread and canopy volume of the plants in High production zone was 3.33 m, 0.50 m, 2.50 m, 2.35 m and 8.53 m^3. The mean plant height, stem girth, N-S spread, E-W spread and canopy volume of the plants in Medium and Low production zones was 3.04 m, 0.46 m, 2.23 m, 2.18 m and 7.17 m^3 and 2.75 m, 0.41 m, 1.96 m, 1.97 m and 5.92 m^3. However the coefficient of variation (CV) of plant height, stem girth, spread and canopy volume was lower within the production management zones compared to across the zones during 2021. The *variograms* of the canopy volume (m^3) of mandarin plants in high, medium and low production management zones during 2021 is shown (Fig. 28).

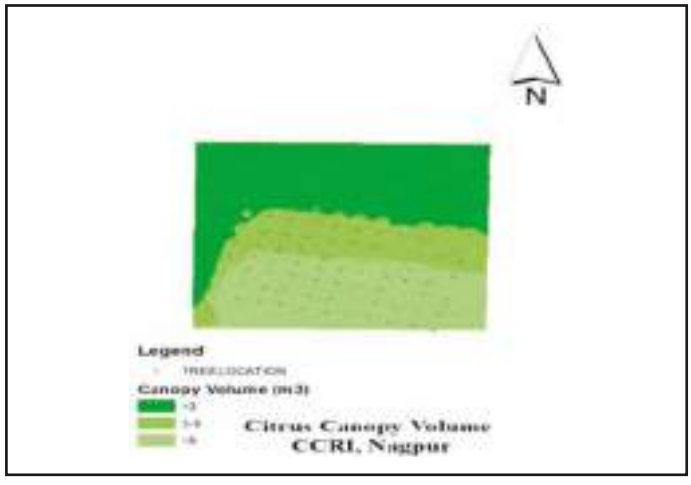


Fig. 28 : *Variogram* of canopy volume of the various zones

Table 32 : Growth of mandarin plants under the various production zones

Production zones	Plant growth parameters				
	Plant height (m)	Stem girth (m)	Spread (m)		Canopy volume (m^3)
			N - S	E - W	
T_1 : HPMZ	4.10 -2.40 (3.33)	0.65 -0.32 (0.50)	3.70 -1.35 (2.50)	4.15 -1.25 (2.35)	15.94 -1.83 (8.53)
T_2: MPMZ	4.00 -1.71 (3.04)	0.58 -0.27 (0.46)	3.65 -0.70 (2.23)	3.65 -0.65 (2.18)	13.95 -1.46 (7.17)
T_3 : LPMZ	3.55 -1.35 (2.75)	0.60 -0.22 (0.41)	3.50 -0.55 (1.96)	3.55 -0.60 (1.97)	12.35 -1.20 (5.92)
CV (%) within zones					
HPMZ	11.8	7.4	11.6	17.2	8.8
MPMZ	14.2	6.5	10.8	17.6	10.4
LP MZ	12.3	8.4	13.4	19.8	13.2
CV (%) across M zone	16.5	9.6	15.6	22.4	18.1

- 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.

Fruit yield and quality parameters across production management zones

The variation in fruit weight, ranging from 145.2-130.6 g in high production management zone to as low as 132.4-120.2 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 33). The mean values of no. of fruits, fruit weight and yield in High production zone was 186.22, 137.58 g and 7.10 t/ha, respectively. The same in Medium and Low production zones was 131.50, 132.12 g, 4.81 t/ha and 110.82, 126.08 g, 3.87 t/ha, respectively. The variation in all the three fruit quality parameters viz., juice content, total soluble solids and acidity are aligned across three production management zones, unless the soil fertility vis-a-vis leaf nutrient composition are rationalized within each management zone to a minimum variation in order to ensure high orchard efficiency. All the three production management zones expressed significantly higher fruit quality parameters (45.1-40.4% juice content with mean value of 43.4% juice content, 10.8-10.0% TSS with mean value of 10.5% TSS and 0.72-0.60% juice acidity with mean value of 0.60% juice acidity) compared to either medium production management zone (43.4-42.5% juice content with mean value of 42.6% juice content, 10.0-9.8% TSS with mean value of 9.6% TSS and 0.78-0.68 % juice acidity with mean value of 0.65% juice acidity) or low production management zone (44.6-42.2% juice content with mean value of 42.2% juice content, 9.6-9.2% TSS with mean value of 9.3% TSS and 0.83-0.70% juice acidity with mean value of 0.80% juice acidity).

However, these responses are indicative of decreasing variation within three production management zones as the nutrient and water use are getting stabilized to optimum. The variogram of the fruit yield (kg/ tree) of mandarin in high, medium and low production management zones during 2021 (Fig. 29). The purpose of the precision cultivation using water and fertilizer inputs is to get good quality uniform fruits of larger diameters. The fruit size

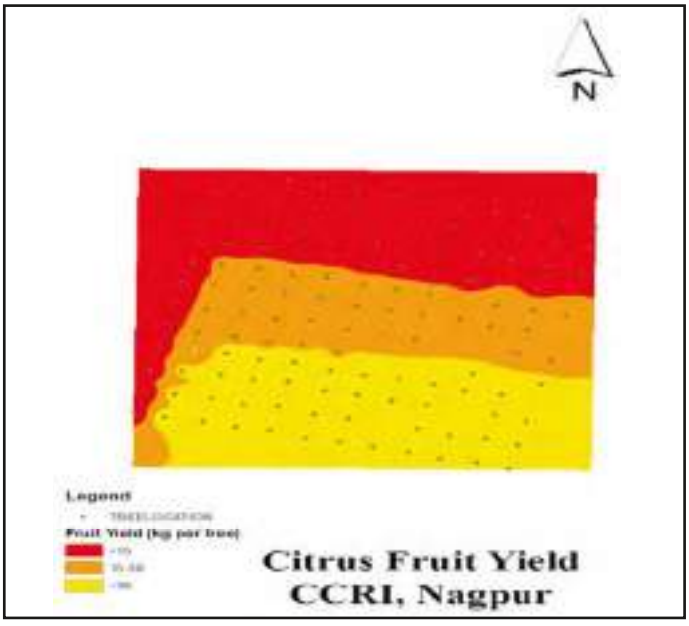


Fig. 29 : *Variogram* of fruit yield (kg/tree) in the various zones

distribution observations were also recorded in all three zones of production. For this 150 fruits diameters were measured using vernier caliper (0.01 mm accuracy) in each zone. The grade size distribution is explained in the graph (Fig.30).

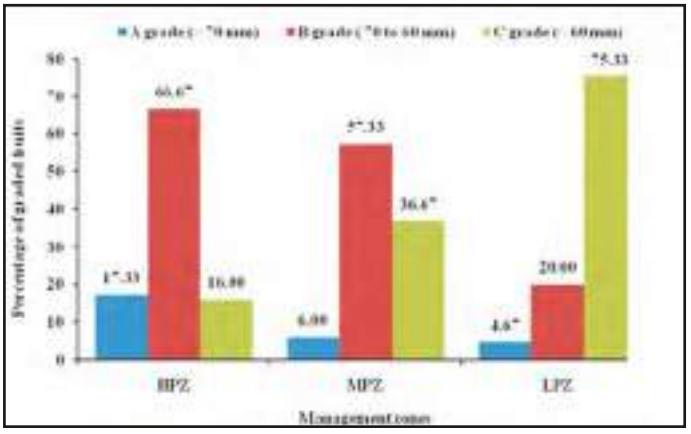


Fig. 30 : Fruit size distribution (%) in the various zones

Table 33 : Fruit yield and quality of Nagpur mandarin in various production zones

Production zones	Fruit yield			Fruit quality parameters		
	No. of fruits	Fruit weight (g)	Yield (t/ha)	Juice (%)	TSS ^{o}Brix	Acidity (%)
T_1 : HPMZ	320 -130 (186.22)	145.2 -130.6 (137.58)	12.87 -4.70 (7.10)	45.1 -40.4 (43.4)	10.8 -10.0 (10.5)	0.72 -0.60 (0.60)
T_2 : MPMZ	280 -100 (131.50)	138.6 -126.4 (132.12)	10.75 -3.50 (4.81)	43.4 -42.5 (42.6)	10.0 -9.8 (9.6)	0.78 -0.68 (0.65)
T_3 : LPMZ	250 -80 (110.82)	132.4 -120.2 (126.08)	9.17 -2.67 (3.87)	44.6 -42.2 (42.2)	9.6 -9.2 (9.3)	0.83 -0.70 (0.80)
CV (%) within M zones						
HPMZ	12.4	14.4	11.1	9.4	8.0	7.5
MPMZ	14.8	13.2	13.5	11.2	8.2	7.9
LPMZ	13.6	12.6	14.6	12.5	9.3	8.0
CV (%) across M zone	15.4	15.5	15.8	12.8	9.6	8.3

- 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.

Changes in soil fertility plant available macro-nutrients across different production management zones

The changes in soil fertility status in terms of $KMnO_4$-N, Olsen-P and NH_4OAc-K across all the three production management zones (HPMZ, MPMZ and LPMZ) were observed significantly varying, with maximum CV of 16.8% observed in case of $KMnO_4$-N followed by 11.2% with Olsen-P and 13.4% with NH_4OAc-K (Table 34). The plant available macronutrients *viz*., $KMnO_4$-N, Olsen-P and NH_4OAc-K were observed invariably higher in HPMZ (162.8-185.6 mg kg^{-1} $KMnO_4$-N, mean 178.1 mg kg^{-1} $KMnO_4$-N; 12.4-16.9 mg kg^{-1} Olsen-P, mean 13.4 mg kg^{-1} Olsen-P and 186.2-248.4 mg kg^{-1} NH_4OAc-K, mean 201.0 mg kg^{-1} NH_4OAc-K) compared to either MPMZ (140.5-169.6 mg kg^{-1} $KMnO_4$-N, mean 160.2 mg kg^{-1} $KMnO_4$-N; 11.4-13.2 mg kg^{-1} Olsen-P, mean 12.1 mg kg^{-1} Olsen-P; 172.1-201.4 mg kg^{-1} NH4OAc-K, mean 182.3 mg kg^{-1} NH4OAc-K) and LPMZ (125.6-148.2 mg kg^{-1} $KMnO_4$-N, mean 146.0 mg kg^{-1} $KMnO_4$-N; 10.1-13.8 mg kg^{-1} Olsen-P, mean 11.2 mg kg^{-1} Olsen-P and 151.6-191.6 mg kg^{-1} NH_4OAc-K, mean 168.2 mg kg^{-1} NH_4OAc-K) with CV of 12.1-14.6%, 9.2-10.1% and 9.1-12.6%, respectively. These observations provided strong clues toward gradual shift in nutrient pool across the three management zones as a function of three nutrient doses.

Changes in soil fertility plant available micro-nutrients across different production management zones

Like plant available macronutrient, the changes in plant available micronutrients followed the same pattern of response across three management zones (HPMZ, MPMZ and LPMZ) (Table 35). The plant available micronutrients *viz*., DTPA-Fe, DTPA-Mn, DTPA-Zn and DTPA-Cu across all the three production management zones (HPMZ, MPMZ and LPMZ) were observed significantly varying, as evident from variation CV values, increasing from 8.2 to 12.1%, 8.4 to 10.1%, 6.4 to 8.9% and from 9.6 to 12.3%, respectively moving from HPMZ to LPMZ. Mean plant available micronutrients *viz*., DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn were observed varying from 14.1-22.6 mg kg^{-1} DTPA-Fe, 11.3-17.5 mg kg^{-1} DTPA-Mn, 1.08-1.42 mg kg^{-1} DTPA-Cu and 1.01-2.01 mg kg^{-1} DTPA Zn in HPMZ; 12.1-17.1 mg kg^{-1} DTPA-Fe, 10.1-14.2 mg kg^{-1}

Table 34 : Response of differential nutrient doses on changes in soil fertility plant available macro-nutrients across different production management zones

Production zones	Plant available macro-nutrients (mg kg^{-1})		
	$KMnO_4$-N	Olsen - P	NH_4OAc -K
T 1: HPMZ	162.8 -185.6 (178.1)	12.4 -16.9 (13.4)	186.2 -248.4 (201.0)
T 2: MPMZ	140.5 -169.6 (160.2)	11.4 -13.2 (12.1)	172.1 -201.4 (182.3)
T 3: LPMZ	125.6 -148.2 (146.0)	10.1 -13.8 (11.2)	151.6 -191.6 (168.2)
CV (%) within zones:			
HPMZ	12.1	10.1	9.1
MPMZ	14 .2	9.8	12.4
LPMZ	14.6	9.2	12.6
CV(%) across M zone	16.8	11.2	13.4

- 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.

DTPA Mn, 0.92-1.10 mg kg^{-1} DTPA-Cu and 0.98-1.46 mg kg^{-1} DTPA Zn in MPMZ; and 10.1-12.2 mg kg^{-1} DTPA-Fe, 9.1-10.4 mg kg^{-1} DTPA Mn, 0.98-1.16 mg kg^{-1} DTPA-Cu and 0.80-1.10 mg kg^{-1} DTPA Zn in LPMZ. These changes suggested that variation within each management zone including all the three management zones is an indication for rationalized nutrient use, thereby, to stabilize the yield performance with time lapse.

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

The response of three nutrient doses as per production management zone was observed producing significant changes in concentration of leaf nutrients (Table 36). The concentration of leaf N, P and K varied from 2.28-2.42%, 0.12-0.16%; 1.42-1.69%, respectively with mean values of 2.38%, 0.14% and 1.58 in HMPZ. These responses in MPMZ were observed of comparatively lower magnitude. The leaf N, P and K content varied from 2.16 to 2.32%, 0.1 1to 0.14% and from 1.40 to 1.52%, respectively with corresponding mean value of 2.22%, 0.12% and 1.42% within MPMZ. While in LPMZ these values were by far lowest with N, P and K varying from 2.08 to 2.20%, 0.10 to 0.12% and from 1.28 to 1.42%, respectively with corresponding mean values of 2.14%, 0.10% and 1.30% within LPMZ. These responses were observed being guided by pool of available nutrients, partitioned across different management zones.

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

The response of three different nutrient doses on leaf micronutrients composition across three different production management zones (HPMZ, MPMZ and LPMZ) exhibited the coefficient of variation from 9.2 to 10.1%, 8.4 to 9.6%, 10.1 to 12.4% and 8.2-9.6%, respectively, with regard to concentration of leaf Fe, leaf Mn, leaf Zn and leaf Cu, respectively (Table 37). The leaf Fe, Mn, Zn and Cu varied from 88.2 to 96.1 ppm, 61.1 to 69.6 ppm, 23.1 to 27.4 ppm and from 12.1 to 14.8 ppm, respectively in HPMZ. The same responses in MPMZ were observed recording the concentration variation of 78.2-84.2 ppm Fe, 53.1-62.4 ppm Mn, 20.1-22.6 ppm Zn

Table 35 : Response of differential nutrient doses on changes in soil fertility plant available micro-nutrients across different production management zones

Production zones	Plant available micro -nutrient (mg kg^{-1})			
	DTPA-Fe	DTPA-Mn	DTPA -Cu	DTPA -Zn
T_1 : HPMZ	14.1 - 22.6 (17.8)	11.3 -17.5 (12.8)	1.08 -1.42 (1.23)	1.01 - 2.01 (1.62)
T_2 : MPMZ	12.1 - 17.1 (1 4.9)	10.1 -14.2 (11.6)	0.92 -1.10 (1.01)	0.98 - 1.46 (1.42)
T_3 : LPMZ	10.1 -12.2 (10.8)	9.1 -10.4 (10.2)	0.98 -1.16 (1.04)	0.80 - 1.10 (0.98)
CV (%) within zones				
HPMZ	8.2	8.4	6.4	9.6
MPMZ	9.2	9.2	8.2	11.2
LPMZ	12.1	10.1	8.9	12.3
CV (%) across				
M zone	13.6	12. 2	9.1	14.6

- 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 36 : Response of different nutrient doses on changes in leaf macro-nutrients composition in different production management zones

Production zones	Leaf macro-nutrients concentration (%)		
	Nitrogen	Phosphorous	Potassium
T_1 : HPMZ	2.28 -2.42 (2.38)	0.12 -0.16 (0.14)	1.42 -1.69 (1.58)
T_2: MPMZ	2.16 -2.32 (2.22)	0.11 -0.14 (0.12)	1.40 -1.52 (1.42)
T_3: LPMZ	2.08 -2.20 (2.14)	0.10 -0.12 (0.10)	1.28 -1.42 (1.30)
CV (%) within M zones			
HPMZ	12.16	8.11	11.12
MPMZ	11.2	9.28	14.12
LPMZ	16.10	9.69	12.12
CV (%) across M zone	18.20	11.42	14.15

- 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 datasets within each management zone were generated based on 48 sampling points.

and 11.1-12.4 ppm Cu. However LPMZ showed a much lower leaf micronutrient composition as 69.1-76.4 ppm Fe, 51.6-59.2 ppm Mn, 20.1-22.6 ppm Zn and 11.4-13.2 ppm Cu. These results again confirmed the reallocation of nutrient response in accordance to soil fertility gradients developed across three production management zones.

Table 37 : Response of differential nutrients doses on changes in leaf micro-nutrients composition across different production management zones

Production zones	Leaf micro- nutrients (ppm)			
	Iron	Manganese	Zinc	Copper
T_1 : HPMZ	88.2 -96.1 (89.1)	61.1 -69.6 (64.2)	23.1 -27.4 (24.1)	12.1 -14.8 (13.2)
T_2: MPMZ	78.2 -84.2 (80.4)	53.1 -62.4 (55.8)	20.1 -22.6 (21.6)	11.1 -12.4 (11.4)
T_3: LPMZ	69.1 -76.4 (69.1)	51.6 -59.2 (52.1)	20.1 -22.6 (20.8)	11.4 -13.2 (12.1)
CV (%) within M zones				
HPMZ	9.2	8.4	10.1	9.6
MPMZ	9.4	9.2	11.4	8.9
LPMZ	10.1	9.6	12.4	8.2
CV (%) across M zone	14.6	10.4	16.4	10.4

- 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 datasets within each management zone were generated based on 48 sampling points.

3.2.2.8 Subsurface Micro-irrigation and fertigation schedule for quality production of Nagpur mandarin

Layout of experiment in black cotton soil at ICAR-CCRI, Nagpur (latitude 21^{0}08$^{"}$, longitude 79^{0}01$^{"}$and 349 m msl) in the Deccan plateau of Vidarbha region to assess the subsurface drip irrigation system for Nagpur mandarin has been completed. Subsurface drip irrigation set purchased, inputs procured (*i.e.* FYM, vermi-compost, etc.) and small equipments procured (*i.e.* pH meter, EC meter, battery operated pump, venturi injector, valve, etc.). Layout of experiments at 6×6 m spacing has been given in Plate Nos. 1 to 6. Based on the experiments, the following treatments were designed.

T_1: SDI with double laterals (30 × 30 cm); T_2: SDI with double laterals (40 × 40 cm); T_3: SDI with double laterals (50 × 50 cm); T_4: SDI with double laterals (60 × 60 cm);T_5: DI with double laterals (4 Drippers); T_6: DI with ring types laterals (6 Drippers) and Main: T_1: SDI double lateral 80%*ET_{Nm}; T_2: SDI double lateral 60%*ET_{Nm}; T_3: DI double lateral 80%*ET_{Nm}; T_4: DI double lateral 60%*ET_{Nm} and Sub-treatments: 80%, 60% and 40% *RDF

For enhancing the fruit production through water and fertilizer use in citrus an experiment in Block No. 03 and 21 having 48 and 96 numbers of Nagpur mandarin trees (planted in the year, 2010) was taken up for the studies on subsurface micro-irrigation during the year, 2021. These 48 and 96 trees have been made as four replication plots based on the micro-irrigation treatments. Initial status of plant growth, quantified in terms of canopy volume (m^3) on tree-to-tree basis has been computed. Based on the biometric observations of plant canopy volume, the micro-irrigation treatments were incorporated and accordingly the micro-irrigation with fertigation arrangement was taken up in field condition.

Plate No. 1
View of plot

Plate No. 2
Layout of main and Sub -main line

Plate No. 3
View of the SDI inline lateral

Plate No. 4 View of wetting area of SDI double lateral on raised bed

Plate No. 5 View of the SDI double lateral on raised bed

Plate No. 6
View of double lateral on flat bed

The soil texture of the experimental site is clay loam with 56 cm depth. Volumetric soil moisture content at field capacity (FC) and the permanent wilting point (PWP), determined using pressure plate method were 31.78% and 20.45%, respectively. The bulk density of the soil is 1.32 g/cc. The available water holding of this soil is 15.94 cm/m depth of soil. The drip irrigation system for water and fertigation unit are installed in the experimental block as per the design having total 48 plants with 8 plants in each unit. The mandarin plants were irrigated with drip system (4 lph/plant) and the daily water requirement of the plants was recorded as per the evapotranspiration (ET_{Nm}) based on irrigation schedules during the non-rainy months. The fertigation is given using liquid fertilizer injector with the working principle of venturi. The irrigations were scheduled as per the treatment levels and it was given through drip-based on-time duration. The plant growth of individual plants was recorded. The soil sample of each plant is collected and the analysis was done to access the status of nutrients. The changes in soil fertility in terms of availability of nutrients like status of different macro as well as micro-nutrients in soil along with the detail analysis of N, P, K, Fe, Mn, Zn and Cu were analyzed and partitioned across the four replications.

Irrigation scheduled and water requirement:

The water requirement of Nagpur mandarin is estimated based on the daily reference crop evapotranspiration (ET_r). The crop coefficient (K_c) 0.65-0.95 (for Citrus crops) is taken during different pheneological stages into calculations. The ET_r varied from 0.81 to 6.47 mm per day. The area under the plant canopy is wetted at 100% *WA (wetting factor =1) as whole area shaded is required to be drip irrigated and canopy area is 8.87 m^2 during 2021. The ET_{Nm} is varied from 2.60 to 5.40 mm per day during the study period. The daily water requirement (ET_{Nm}) of the mandarin plants during the meteorological was estimated using the equation as given below:

$$ET_{Nm} = \frac{ET_r \times K_c \times A \times WA}{IE}$$

Where, ET_{Nm} - Evapotranspiration of Nagpur mandarin in Litersday^{-1}; ET_r - Reference crop evapotranspiration in mmday^{-1}; K_c - Crop coefficient in fraction; A - Plant to plant and row to row area in m^2; WA- Wetted area in fraction and IE - Irrigation efficiency in fraction.

Estimation of reference crop evapotranspiration (ET_r, mm)

Reference crop evapotranspiration (ET_r, mm) is the major component of Nagpur mandarin water requirement. It is the quantity of water transpired by plants during their growth or retained in the plant tissue and the moisture evaporated from the surface of soil and vegetation. It is used to describe the atmospheric "demand" for water. The major factors affecting reference crop evapotranspiration are climatic parameters. Consequently, reference crop evapotranspiration is a climatic parameter and can be computed from weather data. Reference crop evapotranspiration expresses the evaporative power of the atmosphere at a specific location and time of the year and does not consider the crop characteristics and soil factors. Hence, the daily climatic data for the period of Jan, 2021 to Dec, 2021 were used to determine daily, weekly and monthly reference crop evapotranspiration (ET_r) by using Penman-Monteith Method. The weekly E_{pan}, ET_r and rainfall values in mm are presented (Fig. 31). Figure shows that the trend of variation of average E_{pan}, and ET_r values over the year. The yearly reference crop evapotranspiration (ET_r) obtained are 932.96 mm. The ET_r was maximum in May (18-22 SMW) and minimum in Nov-Dec (45-52 SMW). The monthly minimum and maximum E_{pan}, ET_r and rainfall ranged from 62 to 286.75 mm, 25.11 to 201.50 and 0.00 to 151.10 mm.

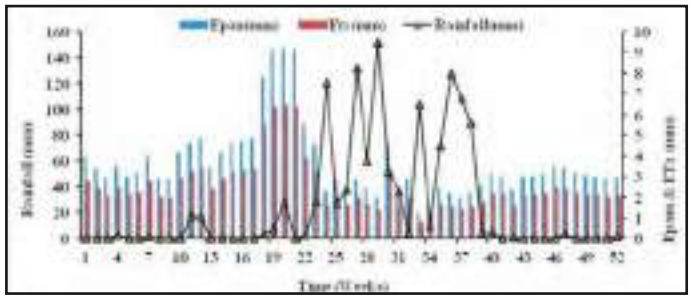


Fig. 31 : Weekly E_{pan}, ET_r and rainfall in mm at experimental site during 2021

Estimation of Nagpur mandarin Evapotranspiration (ET_{Nm}, $Lday^{-1}tree^{-1}$)

The alternate day water to be applied through subsurface drip irrigation system at 90% efficiency from Nov to Dec, 2021 ranged from 32 to 80 $Lday^{-1}tree^{-1}$ for 10th old age of Nagpur mandarin tree at 100% *ET_{Nm} (Eq. 1). It gradually increases or decreases during development of Nagpur mandarin tree due to the variation of reference crop evapotranspiration, pan coefficient, wetted area and crop coefficient values. Lower K_c values represent slower plant growth and lower plant canopy cover, indicating lower ET_{Nm}. The two months average Nagpur mandarin evapotranspiration are 3600.48 $Litrestree^{-1}$ and water to be applied to Nagpur mandarin tree at various treatments ranged from 992.32 to 2400.52 $Literstree^{-1}month^{-1}$.

Growth parameters

Nagpur mandarin was evaluated for their growth parameters (Table 38) according to different micro-irrigation treatments. With respect to different treatments, the plant height, plant spread (N-S & E-W), stem girth and canopy volume (Block No. 03) was ranged from 3.07 to 3.70 m, 2.84 to 3.88 m & 2.96 to 3.80 m, 0.53 to 0.67 m and 14.73 to 29.45 m^3. The same in Block No. 21 was ranged from 2.58 to 2.74 m, 2.12 to 2.84 m & 2.23 to 2.81 m, 0.43 to 0.48 and 6.52 to 11.76 m^3, respectively.

Initial soil fertility status analysis of representative samples across different treatments of block No. 03 and 21

The initial soil fertility analysis of representative samples showed $KMnO_4$-N, Olsen-P and NH_4OAc-K variation from 122.3 to 124.8 mg kg^{-1}, 10.1 to 11.4 mg kg^{-1} and from 218.4 to 226.6 mg kg^{-1}, respectively (Table 39). Likewise, all DTPA extractable micronutrients such as DTPA-Fe, DTPA-Mn, DTPA-Cu and DTPA-Zn showed variation from 11.6 to 14.2 mg kg^{-1}, 10.2 to 12.3 mg kg^{-1} 1.8 to 2.2 mg kg^{-1} and from 0.72 to 0.82 mg kg^{-1}, respectively.

The data developed on initial soil fertility analysis showed variation in $KMnO_4$-N, Olsen -P and NH_4OAc-K from 118.4 to 124.4 mg kg^{-1}, 9.2 to 11.4 mg kg^{-1} and from 204.6 to 222.3 mg kg^{-1}, respectively (Table 40). While DTPA extractable micronutrients such as DTPA-Fe, ATPA-Mn, DTPA-Cu and DTPA-Zn varied from 9.1 to 11.6 mg kg^{-1}, 7.2 to 8.7 mg kg^{-1}, 1.2 to 2.0 mg kg^{-1} and from 0.68 to 0.81 mg kg^{-1}, respectively.

Table 38 : Existing growth performance of experimental plots

Treatments	Plant height (m)	Plant spread (m)		Stem girth (m)	Canopy volume (m^3)
		N-S	E-W		
Block No. 03					
T_1 : SDI (30 x 30 cm)	3.07	3.26	3.36	0.59	17.89
T_2 : SDI (40 x 40 cm)	3.33	2.84	2.96	0.59	14.73
T_3 : SDI (50 x 50 cm)	3.29	3.38	3.75	0.62	22.02
T_4 : SDI (60 x60 cm)	3.22	3.22	3.40	0.53	20.88
T_5 : DI (4 drippers)	3.28	3.28	3.33	0.61	19.31
T_6 : RDI (6 drippers)	3.70	3.88	3.80	0.67	29.45
Block No. 21					
T_1 : SDI 80% *ETNm	2.58	2.12	2.23	0.43	6.52
T_2 : SDI 60% *ETNm	2.65	2.63	2.43	0.46	8.94
T_3 : DI 80% *ETNm	2.62	2.8 0	2.54	0.47	10.14
T_4 : DI 60% *ETNm	2.74	2.84	2.81	0.48	11.76

Table 39 : Initial soil fertility status analysis of representative samples across different treatments (Block No. 03)

Treatment	Macronutrients (mg kg^{-1})			Micronutrients (mg kg^{-1})			
	$KMnO_4$-N	Olsen-P	NH_4OAc-K	DTPA - Fe	DTPA - Mn	DTPA- Cu	DTPA - Zn
T_1	122.6	11.4	218.4	13.1	11.4	1.8	0.72
T_2	124.8	10.8	222.3	12.4	10.2	1.8	0.78
T_3	122.6	10.1	226.6	11.6	11.4	2.2	0.82
T_4	126.4	11.4	224.1	12.3	10.8	2.0	0.78
T_5	122.3	10.9	225.1	14.2	11.6	2.0	0.80
T_6	123.6	10.4	223.8	13.8	12.3	1.8	0.82

Note : T1-SDI with double laterals (30×30 cm); T2 -SD I with double laterals (40×40 cm); T3-SDI with double laterals (50×50 cm); T4-SDI with double laterals (60×60 cm); T5-DI with double laterals (4D) and T6,-DI with ring type lateral (6D)

Table 40 : Initial soil fertility analysis of representative samples across different treatments (Block No. 21)

Treatments	Macronutrients (mg kg^{-1})			Micronutrients (mg kg^{-1})			
	$KMnO_4$ - N	Olsen - P	NH_4OAc - K	DTPA - Fe	DTPA - Mn	DTPA - Cu	DTPA - Zn
A_1B_1*	118.4	11.4	204.6	9.1	7.4	1.8	0.68
A_1B_2	122.3	9.6	218.2	10.4	8.2	1.2	0.72
A_1B_3	121.4	10.5	222.3	11.2	8.6	1.4	0.78
A_2B_1	120.7	9.2	210.3	10.1	8.6	1.4	0.81
A_2B_2	118.4	10.4	214.3	10.4	7.9	1.2	0.72
A_2B_3	119.1	11.2	218.4	11.6	8.1	1.6	0.76
A_3B_1	120.1	11.4	212.3	11.2	8.5	1.8	0.72
A_3B_2	124.4	10.2	217.1	9.8	8.6	2.0	0.74
A_3B_3	120.7	10.6	218.4	10.1	8.7	1.8	0.71
A_4B_1	118.4	9.8	220.1	10.8	8.1	1.8	0.79
A_4B_2	120.2	11.2	222.3	9.8	7.2	1.6	0.76
A_4B_3	122.1	10.6	216.7	11.2	7.6	1.8	0.80

3.2.3 Studies on physiological disorders of citrus fruits

Effect of various methods of controlling *Waywar* (wasteful) fruit disorder in Nagpur mandarin at private orchards near Nagpur in *Mrig bahar* at Bellaharatanda

For this experiment a 12-year-old Nagpur mandarin orchard located at Bellahartanda village of Arvi tehsil in Wardha district was selected based on the incidence of *Waywar* disorder in 2020 cropping season of *Mrig bahar*. The trees were spaced at 66m, grafted on rough lemon rootstock. 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 disordered and normal fruits were collected in the month of January February and March 2021 from Bellaharatanda for *Mrig* crop and subjected to physic-chemical analysis.

Studies on effect of kaolin and calcium sulphate on sunscald of Nagpur mandarin (*Citrus reticulata* Blanco) in *Mrig bahar* at Hetikundi village

For this experiment five different concentrations of kaolin and calcium sulphate are sprayed in the month of September and October (dry spell when temperature rise above 35°c) to control the loss due to sunscald of fruits and to improve yield and quality characteristics of *Mrig* crop of Nagpur mandarin at Hetikundi village.

Studies on effect of foliar application of gibberellic acid with urea on creasing disorder of Nagpur mandarin (*Citrus reticulata* Blanco) in *Mrig bahar* at ICAR-CCRI, Nagpur

For this experiment four different concentrations of GA_3+Urea are sprayed in the month of November, December and January to control the loss due to creasing of fruits and to improve yield and quality characteristics of *Mrig* crop of Nagpur mandarin at Hetikundi village. The significant results noted for the applied treatments in improving yield and yield attributes, and in controlling the creasing disorder.

Studies on effect of plant growth regulators (GA_3 and 2, 4-D) and recommended dose of fertilizers on rough skin disorder of Nagpur mandarin (*Citrus reticulata* Blanco) during *Mrig bahar* at Hetikundi village

For this experiment five different treatments are given through soil (as per the RDF) and foliar application in the month of October, November and December to control the loss due to rough skin of fruits and to improve yield and quality characteristics of *Mrig* crop of Nagpur mandarin at Hetikundi village. The significant results noted for the applied treatments in improving yield and yield attributes, and in controlling the rough skin disorder.

Table 41 : Effect of different soil applications in September, 2020 and foliar applications in September, October, November and December 2020 on control of fruit drop caused due to waywar disorder and yield in *Mrig* crop of Nagpur mandarin at Bellahartanda (2020-21)

Treatment	No. of fruits dropped			No. of fruits harvested per plant	Yield (kg/ plant)	Yield (t/ha)	Graded yield (%) based on fruit diameter		
	Jan - 21	Feb - 21	Mar - 21				40 -49 mm	50 -59 mm	>60 mm
Foliar applications of GA_3 15 ppm + monopotassium phosphate 2%	52	25	10	899	130	36.26	25.01	50.57	24.43
Foliar applications of GA_3 15 ppm + $CaNO_3$ 2 % + Boric acid 0.3 %	52	22	8	1,007	147	40.99	23.95	50.77	25.30
Foliar applications of streptocycline sulphate 200 ppm	48	25	11	828	115	32.12	28.10	48.08	23.84
Soil application of $ZnSO_4$ and Fe SO_4 100g/plant	50	26	12	718	98	27.32	33.11	43.39	23.50
Soil application of single super phosphate 500 kg/plant	51	27	9	783	112	31.20	25.92	49.34	24.73
Control	56	41	16	576	76	21.24	52.75	27.12	20.18
CD (P= 0.05)	4.02	4.59	1.81	32.77	9.40	2.60	2.29	1.78	1.33
SE(m)	1.32	1.51	0.59	10.77	3.09	0.85	0.75	0.58	0.43

Table 42 : Effect of kaolin and calcium sulphate on sunscald fruit disorder and yield attributes in *Mrig bahar* of Nagpur mandarin at Hetikundi

Treatment	No. of fruits harvested per plant	Yield (kg/ pla nt)	Yield (t/ha)	Graded yield (%) based on fruit diameter			No. of fruits sun scalded	Percent of sunscald
				40 -49 mm	50 -59 mm	>60 mm		
Kaolin 2 %	413	56.65	15.69	36.67	42.07	21.25	26	6.38
Kaolin 4 %	415	58.33	16.16	34.60	43.97	21.50	19	4.57
Kaolin 6 %	494	76.12	21.08	29.67	47.49	22.91	16	3.35
Kaolin 8 %	425	63.66	17.63	27.81	49.96	22.21	14	3.49
Kaolin 10 %	438	66.47	18.41	24.83	52.32	22.89	13	3.01
Calsium sulphate 2 %	371	50.57	14.01	36.63	42.50	20.92	32	8.94
Calsium sulphate 4 %	384	53.74	14.88	33.70	44.65	21.69	30	8.18
Calsium sulphate 6 %	386	54.79	15.17	28.28	49.10	22.70	28	7.38
Calsium sulphate 8 %	449	67.13	18.59	25.16	49.71	25.15	23	5.17
Calsium sulphate 10 %	413	61.58	17.05	23.10	53.76	23.21	22	5.59
Control	332	43.44	12.03	48.22	31.88	19.93	52	15.81
C.D.	53.67	7.07	1.96	2.50	3.49	NS	4.99	2.07
SE (m)	18.06	2.38	0.66	0.84	1.17	0.91	1.68	0.69

Table 43 : Effect of different concentrations of GA_3+Urea on creasing fruit disorder and yield attributes in Mrig crop of Nagpur mandarin (CCRI, Nagpur)

Treatment	No. of fruits harvested per plant	Yield (kg/ plant)	Yield (t/ha)	Graded yield (%) based on fruit diameter			No. of creased fruits	Percent of disorder
				40 -49 mm	50 -59 mm	>60 mm		
GA_3 10 ppm + Urea 1.5%	517	71.09	19.69	29.24	57.50	13.29	35	6.84
GA_3 15 ppm + Urea 1.5%	531	75.40	20.88	28.89	56.99	14.15	31	6.00
GA_3 20 ppm + Urea 1.5%	547	78.79	21.82	27.45	57.80	15.21	29	5.47
GA_3 25 ppm + Urea 1.5%	564	82.48	22.84	24.42	59.35	16.27	19	3.41
Control	476	62.55	17.32	48.52	40.77	10.74	45	9.60
CD (P= 0.05)	50 .53	9.83	2.72	2.50	2.49	0.75	6.98	1.08
SE(m)	16.22	3.15	0.87	0.80	0.80	0.24	2.24	0.34

Table 44 : Effect of different cultural treatments on rough skin disorder and yield attributes in *Mrig* bahar of Nagpur mandarin at Hetikundi village

Treatment	No. o f fruits harvested per plant	Yield (kg/ plant)	Yield (t/ha)	Graded yield (%) based on fruit diameter			No. of rough skinned fruits	Percent of disorder
				40 -49 mm	50 -59 mm	>60 mm		
2,4 -D 15 ppm + Urea 1.5%	487	73.21	20.28	37.09	38.46	24.43	51	10.47
GA_3 15 ppm + Urea 1.5 %	519	81.99	22.71	34.77	41.18	24.06	53	10.21
Amrut pani spray	429	60.88	16.86	42.07	35.45	22.47	55	12.86
RDF without potassium	435	61.00	16.89	43.56	37.93	18.56	40	9.22
RDF –600:300:300 g of NPK/ plant	498	76.52	21.19	35.52	40.66	23.89	58	11.71
Control	377	51.15	14.16	55.26	27.67	17.19	70	18.66
CD (P= 0.05)	42.00	7.55	2.09	3.19	3.24	0.91	2.38	0.93
SE(m)	13.81	2.48	0.68	1.05	1.06	0.30	0.78	0.30

Foliar appln of GA_3 15 ppm + monopotassium phosphate 2%

Foliar appln of GA_3 15 ppm + $CaNO_3$ 2 % + Boric acid 0.3 %

Foliar appln of streptocycline sulphate 200 ppm

Soil appln of $ZnSO_4$ and $FeSO_4$ 100g/plant

Soil appln of single super phosphate 500 g/plant

Waywar affected citrus

Fig. 32 : Effect of different treatments on fruit quality and control of *waywar* in Nagpur mandarin fruits (Normal fruits)

Sun scalded Nagpur mandarin fruits

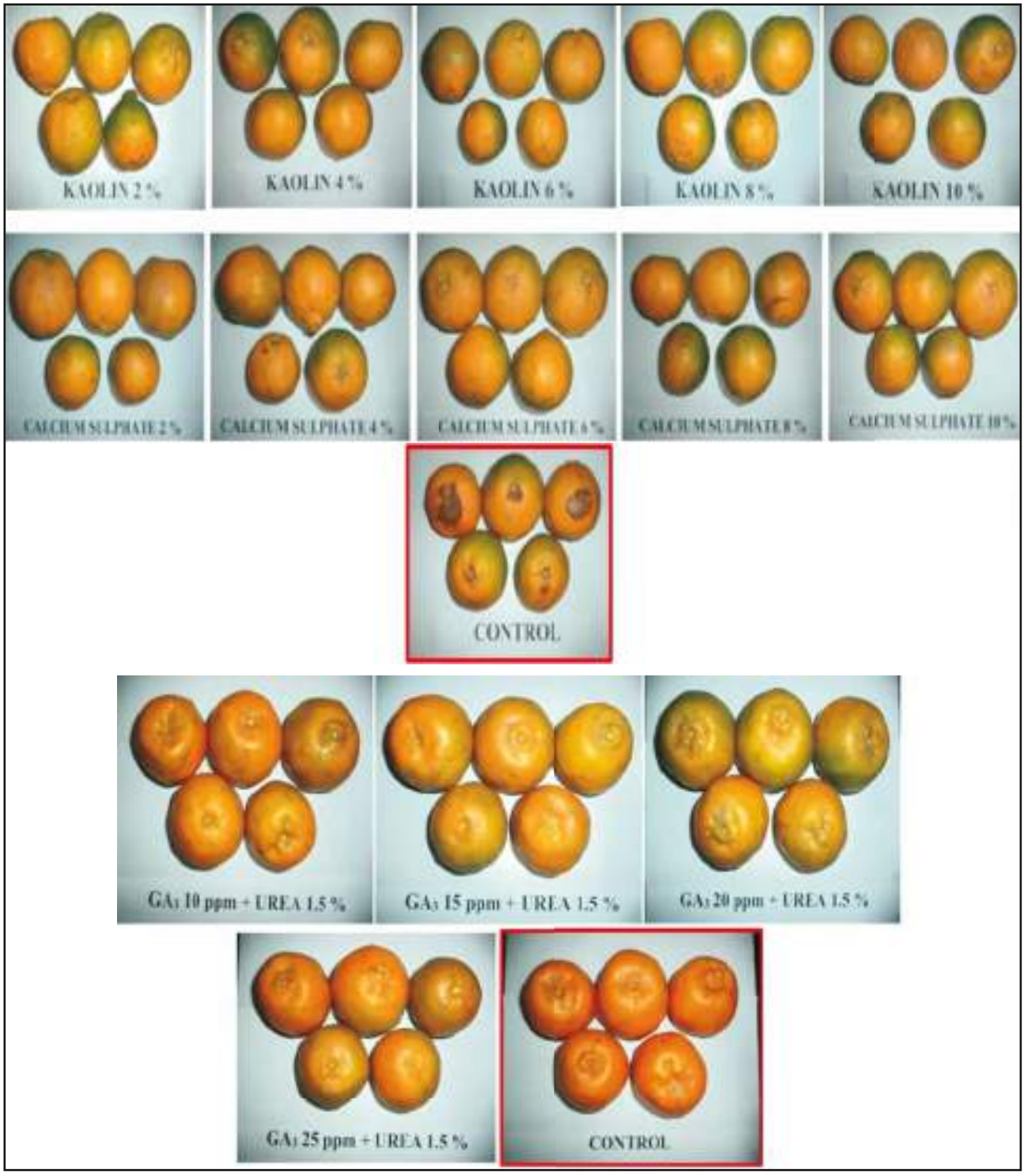


Fig. 33 : Effect of different concentrations of gibberellic acid on fruit quality and control of creasing disorder in Nagpur mandarin fruits with delayed harvesting

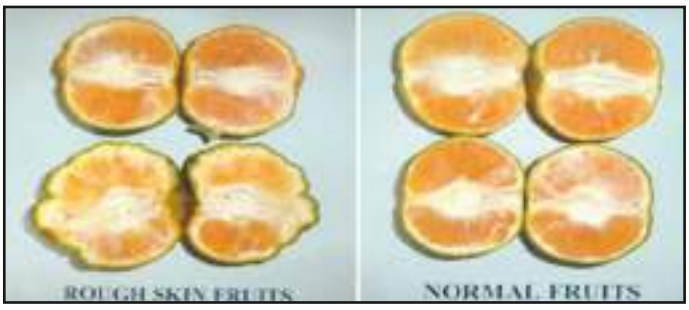


Fig. 34 : Ventral view of rough skinned and normal fruits of Nagpur mandarin

Fig. 35 : Nagpur mandarin fruits treated with various treatments to control rough skin disorder

3.2.4 Development of INM-module for sustained productivity of Citrus

3.2.4.1 Standardization of optimum nutrient requirement of Mosambi sweet orange

This experiment was carried out for fifth year of 2021-22 at Isapur (Katol) in an initial 8-year-old orchard of Mosambi sweet orange (*Citrus sinensis* Osbeck) established on a soil, taxonomically classified of Typic Haplustert. As many nine treatments were tested in a factorial randomized block design.

Response on fruit yield and quality : Considering all the treatments, the net variation in fruit yield was observed are 14.6 kg tree (4.05 t/ha) with treatment T_1 to as high as 25.3 kg tree (7.03 t/ha) with treatment T_5 .The treatment T_5 outstanding rest of other treatments (Table 45). The fruit quality parameters (Juice content, acidity, total solids and TSS/acidity ratio) varied with statistically significant response associated with different treatments (Table 46). The net variation in juice content, acidity, total soluble solids (TSS) and TSS/and ratio was observed as 41.2 to 45.2%, 0.40 to 0.47%, 8.1 to 8.7%, and 17.23 to 20.50%, respectively. Highest juice content, TSS and TSS/acidity ratio were observed with treatment T_5(42.3% juice content, 0.45% acidity, 8.7% total soluble solids and TSS/acidity ratio of 19.33 on par with T_6 registering TSS/acidity ratio of 20.25). The sum response of treatments T_1-T_3 (N_{400}) registered a juice content of 44.3%, significant lower to sum response of treatments T_4-T_6 (N_{800}), but statistically at par with treatments T_7-T_9 involving N_{1200}. Likewise, the sum response of T_4-T_6 (N_{800}) was significantly superior compared to with sum response of T_1-T_3 (N_{400}) or sum response of T_7-T_9 (N_{1200}). However, juice acidity remained unaffected with these fertilizer treatments. These results showed that all the fruit quality parameters were significantly affected by these treatments involving balanced fertilization.

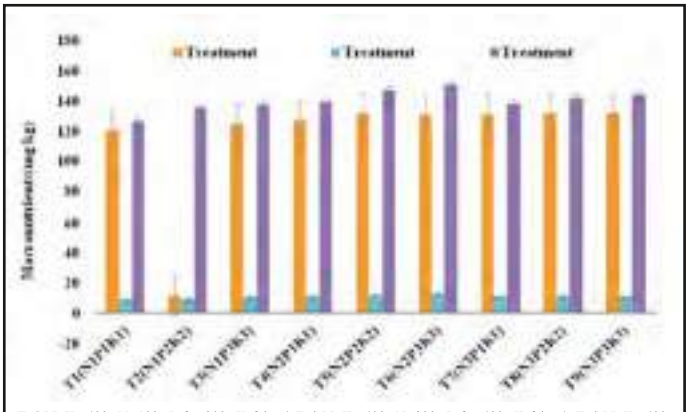
Response on soil fertility changes : Response of different treatments showed a significant changes in soil fertility related parameters. Soil fertility related parameters, the changes in soil pH, soil EC and DTPA-Cu showed no significant response in relation to different treatments. While, $KMnO_4$-N, Olsen-P, NH_4OAc-K, DTPA-Fe, DTPA-Mn and DTPA-Zn displayed significant response (Fig. 36). Plant available $KMnO_4$-N, Olsen-P and NH_4OAc-K varied from 121.1 to 131.2 mg kg^{-1}, 9.1 to 13.2 mg kg^{-1} and from 126.3 to 150.4 mg kg^{-1}, respectively, regardless of treatments. The treatment T_5, however, showed best response. Similarly, all the plant available micronutrients showed a significant response in relation to different treatments. Different plant available DTPA-Fe, DTPA-Mn and DTPA-Zn varied from 9.8 to 13.8 mg kg^{-1}, 8.1 to 11.0 mg kg^{-1} and from 0.81 to 0.98 mg kg^{-1}, respectively. These observations suggested a strong influence macronutrients fertilization on plant available micronutrients supply levels in treated soil, unless applied in combination with micronutrients supply in uniform doses.

Table 45 : Response of different treatment on fruit yield and fruit quality of Mosambi sweet orange

Treatments	Fruit yield		Fruit quality (%)			
	(kg/tree)	(t/ha)	Juice	Acidity	TSS	TSS/Acid ratio
$T_1(N_1P_1K_1)$	14.6	4.05	41.2	0.41	8.1	19.75
$T_2(N_1P_2K_2)$	17.2	4.78	42.6	0.40	8.2	20.5
$T_3(N_1P_3K_3)$	17.8	4.94	43.2	0.43	8.4	19.53
$T_4(N_2P_1K_1)$	20.3	5.64	41.1	0.43	8.5	19.76
$T_5(N_2P_2K_2)$	25.3	7.03	42.3	0.45	8.7	19.33
$T_6(N_2P_3K_3)$	21.3	5.92	43.8	0.42	8.6	20.47
$T_7(N_3P_1K_1)$	22.4	6.22	44.2	0.43	8.7	20.23
$T_8(N_3P_1K_1)$	20.7	5.75	45.2	0.47	8.1	17.23
$T_9(N_3P_3K_3)$	20.4	5.67	45.2	0.47	8.2	17.44
CD (P=0.05)	1.8	0.56	1.01	NS	0.31	1.32

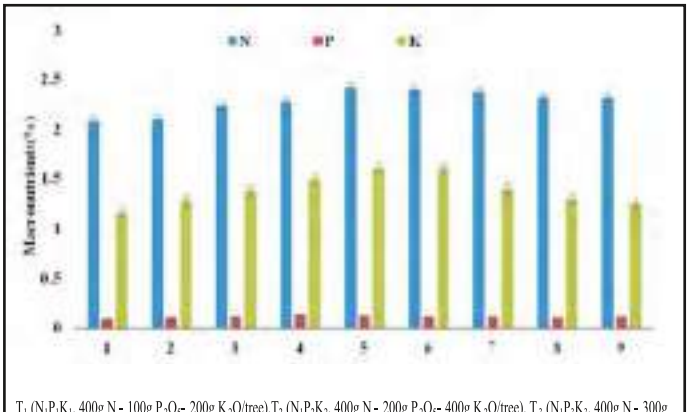
T_1 ($N_1P_1K_1$, 400g N- 100g P_2O_5- 200g K_2O/tree),T_2 ($N_1P_2K_2$, 400g N- 200g P_2O_5- 400g K_2O/tree), T_3 ($N_1P_3K_3$, 400g N- 300g P_2O_5- 600g K_2O/tree), T_4 ($N_2P_1K_1$, 800g N- 100g P_2O_5-200g K_2O/tree), T_5 ($N_2P_2K_2$, 800g N- 200g P_2O_5 - 400g K_2O/tree), T_6 ($N_2P_3K_3$, 800g 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 ($N_3P_3K_3$, 1200g N - 300g P_2O_5- 600g K_2O/tree).These treatments received uniform doses of micronutrients.

Response on leaf nutrient composition: The changes in leaf nutrient composition followed a response as per changes in soil fertility. Different treatments showed a statistically significant variation in leaf N, P, K, Fe, Mn and Zn, with an exception of Cu (Fig.37). Leaf N, P and K showed a variation of 2.08 to 2.42%, 0.09 to 0.12% and from 1.16 to 1.61%, respectively, with treatment T_5 as the most effective treatment registering 2.42% N 0.12% P and 1.61% K, significantly superior to rest of the treatments including treatment T_1. Likewise , the Fe, Mn and Zn content of index leaves varied from 51.2 to 61.2 ppm and from 20.1 to 26.2 ppm, respectively, with treatment T_5 displaying the best response. Incidentally, the treatment T_5 proved to be the best treatment.



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 ($N_3P_3K_3$, 1200g N - 300g P_2O_5- 600g K_2O/tree).These treatments received uniform doses of micronutrients.

Fig. 36 : Response of different treatments on changes in plant available supply of nutrients in soil in Mosambi sweet orange (*Citrus sinensis* Osbeck)



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 ($N_3P_3K_3$, 1200g N - 300g P_2O_5- 600g K_2O/tree).These treatments received uniform doses of micronutrients.

Fig. 37 : Response of different treatments on leaf nutrient composition response to different treatments in Mosambi Sweet orange (*Citrus sinensis* Osbeck)

3.2.4.2 Development of advanced citrus production Systems

The project entitled "Development of Advanced Citrus Production Systems" 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 experiment with five modules of advance citrus production system was implemented during 2021-22.

Plant growth observation: The plant growth observations *viz.* plant height, stock girth, scion girth and number of leaves/plant were taken (Table 46). After one year of treatments response showed statistically no significant response. After one year of growth with these treatments, the plant height, stock girth, and canopy volume varied from 1.19 to 1.51 m, 13.1 to 16.5 mm and 0.26 to 0.51 m^3, respectively. Without any significant difference.

Changes in soil fertility status : Different modules of ACPS showed a significant changes soil fertility status. The pH and EC of the samples varied from 7.2 to 7.6 and 0.21 to 0.32 dS/m, through perlite + cocopeat- based growing media (Module-I, Module-II, Module-III, Module-IV and module-V) registered comparatively higher pH and EC (Table 46). Similarly, $KMnO_4$-N, Olsen-P and NH_4OAc-K were far lower than solarized potting mixture media. The DTPA extractable micronutrients in all the modules involving solarized potting mixture registered a far lower values (6.8-6.9 mg kg^{-1}, 4.8-5.9 mg kg^{-1}, 0.70-0.72 mg kg^{-1} and 0.69-0.70 mg kg^{-1}) in perlite-cocopeat-based growing media than solarized media (11.1-12.4 mg kg^{-1}, 6.8-6.9 mg kg^{-1}, 0.69-0.70 mg kg^{-1} and 0.80-0.90 mg kg^{-1}) (Table 46).

Changes in soil microbial population : The culturable microbes (bacterial count and fungal count) of growing medium were observed significantly affected in response to different modules of treatments (Fig 38). The samples of growing media showed a large variation with respect to bacterial count and fungal count. Soil medium with Module-I (40 x10^3 cfu/g; 5 x10^3 cfu/g) and Module -V with 15 x10^3 cfu/g; 8 x10^3 cfu/g) showed statistically lower range of bacterial and fungal growth. Whereas perlite+Cocopeat based modules displayed an increase in population bacterial growth (23-84 x10^3 cfu/g) and fungal growth (12-41 x10^3 cfu/g).

Table 46 : Initial observations on available supply of nutrients under five different modules of advance citrus production system

Modules	pH (1:2)	EC (dS/m)	Macronutrient (mg kg^{-1})			Micronutrient (mg kg^{-1})			
			$KMnO_4$-N	Olsen-P	NH_4OAc-K	DTPA -Fe	DTPA -Mn	DTPA - Cu	DTPA -Zn
Module-I	7.2	0.25	120.4	10.1	124.3	12.4	6.8	0.86	0.90
Module-II	7.7	0.29	108.2	8.9	94.3	8.1	5.9	0.70	0.70
Module-III	7.6	0.32	109.3	8.8	92.1	8.0	5.2	0.72	0.70
Module-IV	7.4	0.30	110.1	9.2	98.6	7.1	4.8	0.76	0.69
Module-V	7.3	0.21	116.4	10.2	96.4	11.1	6.9	0.80	0.80
CD (P=0.05)	NS	NS	2.10	1.08	3.4	1.16	0.82	NS	0.10

Module-I (Solarized soil mixture + fertigation (NPK) + foliar application (micronutrients)), Module-II (Soilless media + fertigation (NPK) + foliar application (micronutrients)), Module-III (Soilless media + fertigation (NPK) + foliar application (micronutrients - chelated form)), Module- IV (Soilless media + fertigation (NPK) + foliar application (micronutrients- chelated form) + biofertigation (microbial consortium)) and Module-V (Solarized soil mixture + fertigation (NPK) + foliar application (micronutrients) + biofertigation (microbial consortium)); Soilless media (cocopeat: perlite @1:1 ratio)

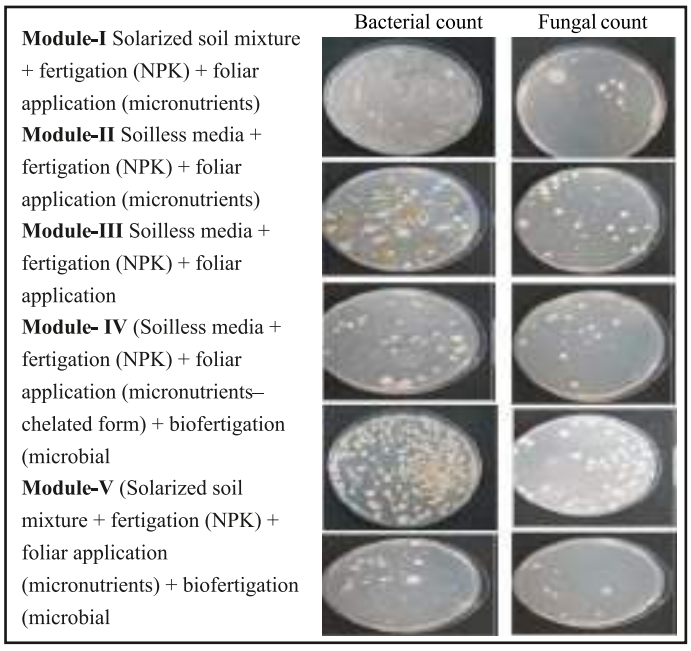


Fig. 38 : Changes in soil microbial population in response to different treatments involving different modules

3.2.4.3 Utilization of citrus microbiome in Rejuvenating Khasi mandarin plants affected by important citrus diseases (DBT funded project)

Survey for Identification of greening Infected khasi mandarin : Soil samples were collected from four locations: Motapung; Borgauh; Tinsukia and Khamanpathar in the vicinity Assam region and from 2 locations: using, Sohkhwai of (Meghalaya-region) Khasi mandarin orchards. All the orchards are seedling based and more than 20-year-old in their age. Health trees and trees with visible signs of disease infections like gummosis and greening were selected from all the locations for culturable bacterial community analysis. All the soil samples were stored at freezing temperature for further experimentation.

Microbial diversity analysis for antagonistic activity against Citrus greening : For the detection of HLB, conventional PCR and qPCR was performed. DNA extraction was done by using commercially available Plant Genomic DNA purification mini kit.

The presence of *Ca*Las was also confirmed by conventional PCR (cPCR) with primer set Las606f/LSSr.

A total of 32 leaf DNA samples from different regions of Meghalaya and Assam were screened for citrus greening by PCR targeting 16SrRNA gene with primers Las F/ Las R. Out of 32, 14 (4 from Khamanpathar region, 2 samples from Motapung region, 3 from Tinsukia region, 2 from Biswanath Charaili, 2 from Sokhwai and 1 from Moralgaon) samples were positive showing an amplification of 500bp (Fig. 39).

Fig. 39 : Detection of HLB by conventional PCR in Leaf DNA

Metagenomics of Root Endophytes: The root samples were designated as healthy and infected based on the both phenotype and molecular analysis. DNA was isolated from the roots using the DNA isolation kit. The presence and quality of DNA was checked on 0.8% agarose gel (Fig.40). Further the concentraion DNA was measured through UV-Spectrophotomer at 260nm. All the samples diluted to the final concentraion of 50 ng/µl. The quality of DNA was also checked by measuring the the ratio of 260 and 280 nm. Only those samples with the ration between 1.8 and 2.0 are taken for further metagenomic analysis.

Conventional PCR of 11 roots DNA and 4 soils DNA was also performed for detection of HLB. PCR was done with primers Las F/R as described above. Even though the leaf samples were positive for HLB, root DNA were negative.

qPCR results : Infection of *Ca*Las was further quantified in the extracted DNA by the quantitative (real time) PCR (qPCR) procedure. TaqMan qPCR amplifications were performed in an ABI 7300 (Applied Biosystems, Foster City, Calif., USA) machine using specific primers HLBas,

HLBr and probe HLBp. Cycle threshold (Ct) values based on fluorescent signals were determined using Applied Biosystems 7300 Real-Time PCR System Software SDS version 1.4.1. Samples were considered qPCR-positive if the Ct (cycle threshold) value was less than 32. The positivity by conventional PCR was further confirmed by qPCR, where the samples showing Ct values ranging between 23- 28 were considered to be positive, whereas Ct values above 32 were considered as negative.

Endophytic and rhizobacterial isolation: Microbial isolation was done from leaves, midribs, roots and soil of healthy citrus plants collected from Meghalaya, Assam and Nagpur. Bacterial endophytes were isolated from roots, leaves and midribs. The samples were surface sterilized using the following protocol. The leaves and roots plants were washed well under running tap water to remove surface soil and other inert particles. The samples were cut into a small pieces and were surface sterilized. The efficacy of sterilization procedure was verified by taking the aliquot (100 µL) of the water from the last rinse and was spread on NA plate. The plates were examined for bacterial growth after incubation at 30°C for 2-3 days.

Additionally, bacterial isolation was also done from soil of healthy plants. A total of 99 bacterial cultures were isolates of which, 62 were endophytes and 37 were rhizobacteria which were purified and screened for antagonistic activity (Fig. 42 and Fig. 43).

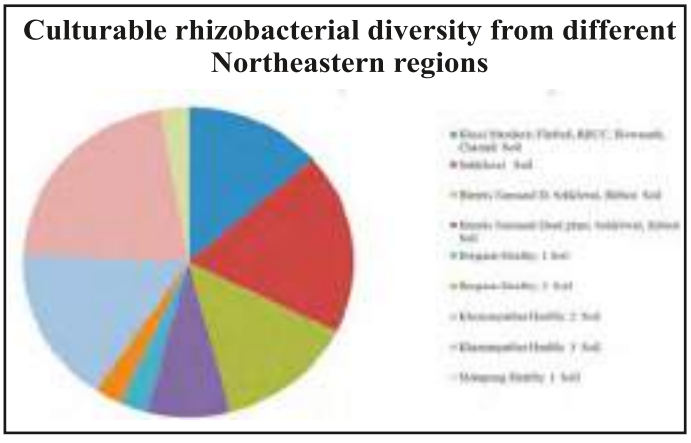


Fig. 42 : Rhizobacterial diversity from different rhizosphere of Khasi mandarin

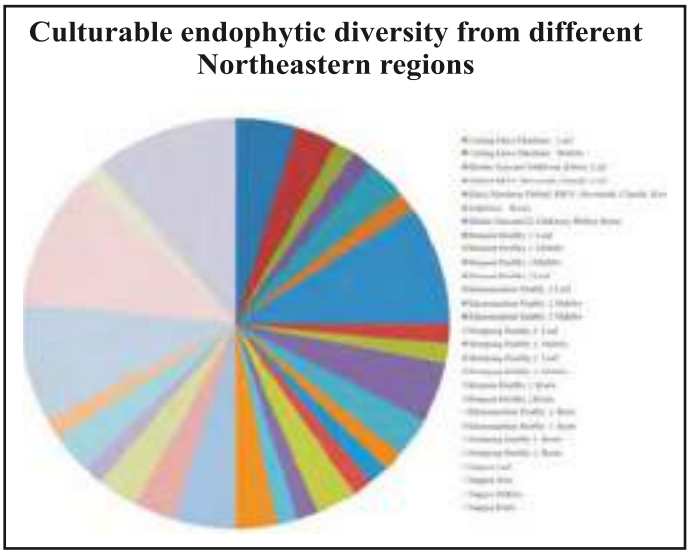


Fig. 43 : Rhizobacterial diversity from different rhizosphere of Khasi mandarin

Antagonism against *Agrobacterium tumefaciens* by dual culture test : Since Las cannot be cultured, we used *Agrobacterium tumefaciens* as a surrogate that is closely related to Las. This species has been used as a surrogate before to test antimicrobial activity against Las due to its close phylogenetic relationship with Las. Antibacterial activity was tested by disc diffusion method.

The disc diffusion method was used to determine the antibacterial activities of the isolates against agrobacterium. Ampicillin (50 µg/ml) was used as positive control. All experiments were performed in triplicate. Eight isolates showed antagonistic activity against *Agrobacterium*, of which 3 were endophytes (1 midrib isolate + 2 root endophytes) and remaining 5 were rhizobacteria (Fig. 44). Among all, the midrib endophyte (KMME40) showed strong antagonism. The diameter of inhibition zone surrounding filter paper disc was measured in mm. The supernatants from fully grown cultures of potential isolates were also extracted and 20µl of it was loaded in each well to check its activity against *Agrobacterium*. Only one isolate supernatant (KMME 40) showed antibacterial activity while others showed negligible activity (Fig. 45). Further work on supernatants is ongoing.

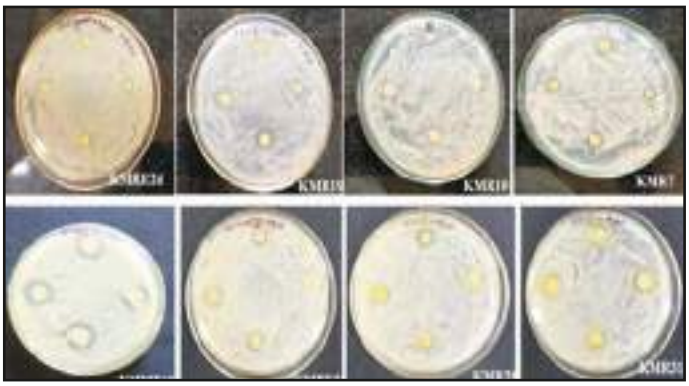


Fig. 44 : Antagonistic activity of potential isolate against *Agrobctaerium tumefaciens*

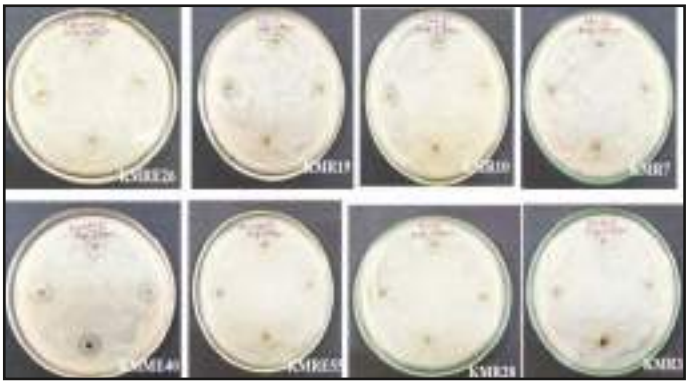


Fig. 45 : Activity of potential isolate supernatant against *Agrobacterium*

Molecular characterization of the potential isolates : The potential isolates were inoculated in Nutrient Broth (NB) and were incubated for 24 hours. DNA isolation was done from bacterial cultures using Genomic DNA purification kit commercially available as per manufacturer's protocol. Conventional PCR was performed by using universal primers FD2, RD1 specific for 16S rRNA gene.

The PCR products were visualized with an ultraviolet transilluminator after agarose gelelectrophoresis stained with ethidium bromide (Fig. 46). Amplicons with a length of~1500bp were sequenced for microbial identity confirmation .

Soil Fertility Appraisal of Rhizosphere Microbes :
Four different rhizospheric soil samples including healthy, dead, HLB^+ and HLB^- of citrus plants were subjected to

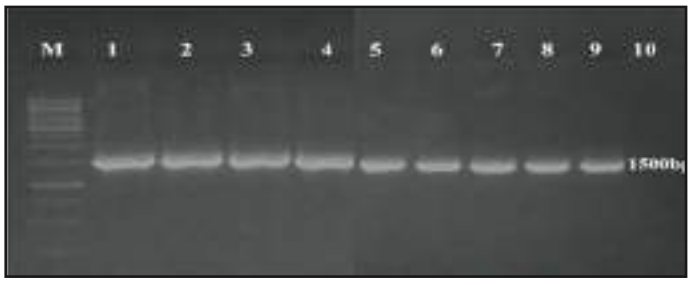


Fig. 46 : Amplification of 16sr RNA gene by conventional PCR

recover morphologically diverse bacterial strains. The soil bacteria were isolated by serial dilution technique on nutrient agar medium (NAM).

All the diluted suspensions (100µl) were spreaded on NAM plate and kept under BOD incubator for 24 to 48 h at 28°C for proper incubation period.

Total forty eight morphologically diverse bacterial strains were recovered from above soil samples of citrus rhizosphere. Among forty eight bacterial isolates, 10 isolates from HLB^+ (SSL1 to SSL10), HLB^- (SSL11 to SSL20) and 24 strains from composite (SSL1 to SSL24) were recovered.

***In vitro* assessment of nutrients solubilizing traits of rhizabacteria :** The bacterial isolates of healthy and dead plants rhizosphere was further subjected for nutrients (phosphate, zinc, iron and potassium) solubilization *in vitro*. The test bacterial isolates were screened for their phosphate, zinc, potassium and iron solubilization activities on their respective agar medium. Freshly grown bacterial cultures were spot inoculated on Pikovskaya's Agar (P-solubilization), Zinc Solubilizing Agar (Z-solubilization), and Aleksandrow Agar (K-solubilization). The spot inoculated plates were incubated at 28 °C for two to three days. The formation of a clear zone of solubilization around the bacterial growth on culture plates was considered positive for nutrient solubilization. Zone of solubilization diameter was measured in mm by using zone measuring scale. Qualitative observation of all the isolates for all the tested nutrient solubilization is pictorially represented (Fig. 47, 48 and 49).

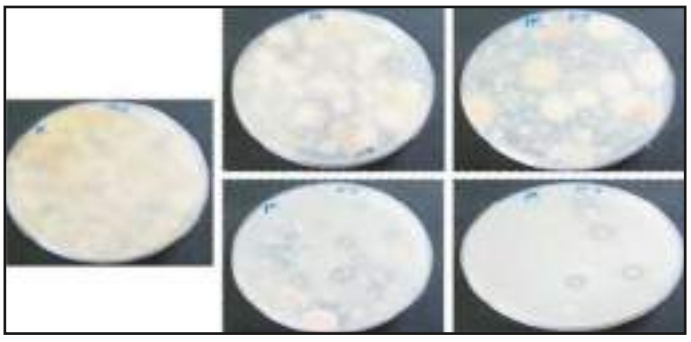


Fig. 47 : Phosphate solubilizing bacterial diversity isolated on Pikovskaya's agar medium

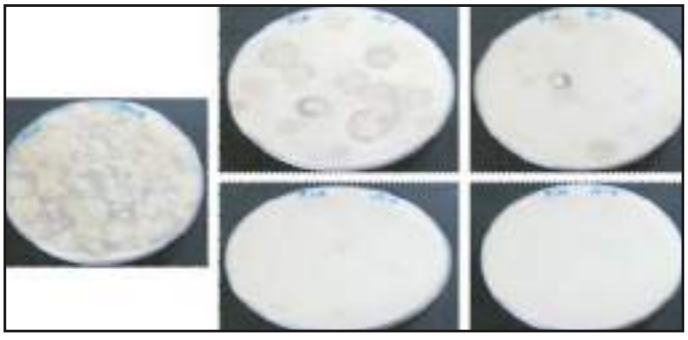


Fig. 48 : Zinc solubilizing bacterial diversity isolated on zinc solubilizing agar medium

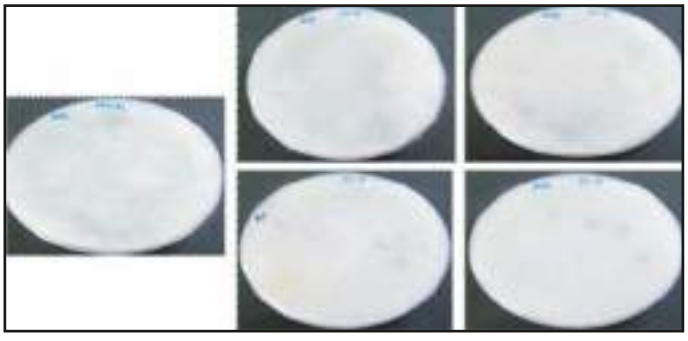


Fig. 49 : Potassium solubilizing bacterial diversity isolated on Aleksandrow agar medium

Comparative solubilization index measurement was carried out on day three of incubation by measuring clear zone and colony diameters in mm. Among twenty isolates, only three isolates well solubilized phosphate, four isolates solubilized zinc, one isolate solubilized potassium and five isolates solubilized iron respectively. These studies generated data on quantitative estimation of nutrients solubilisation.

For nitrogen fixation, overnight freshly grown bacterial cultures were spot inoculated on Jensen's agar plates and incubated at 28°C for 24-48 h or more. The presence and absence of cultural growth was recorded. The ability of bacteria to grow on nitrogen free medium was considered as positive for nitrogen fixation ability. All the 20 isolates grew well on the medium and fix nitrogen (Fig. 50).

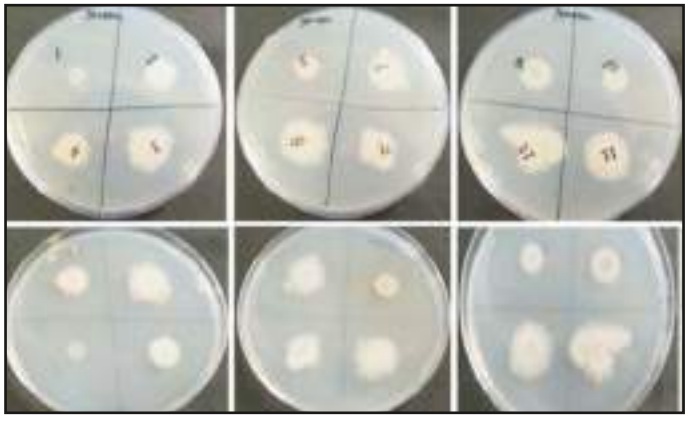


Fig. 50 : Nitrogen fixation by all the isolated rhizobacterial strains on Jensen's medium

Analysis of bacterial diversity of HLB+ and HLB- rhizosphere through culture dependent technique: Rhizospheric soil samples from HLB+ and HLB- citrus plants were collected.

All the twenty four strains was morphologically, culturally diverse and displayed in various appearance. The shape of the bacterial colonies displayed different forms (circular, irregular rhizoid, filamentous concentric, punctiform and spindle) and margins including entire, undulate, lobate, irregular and filamentous. Bacterial colonies also showed various colors like pigmentation (white, red, pink and purple), opaque and transparent. Surface appearance of bacterial colonies was recorded as smooth, rough, glistening, dull, wrinkled, spreading and mucoid on the nutrient agar plates (Fig. 51 and Fig. 52).

Simultaneously, soil samples were subjected for diversity analysis on selective agar medium (Bacillus isolation agar and Pseudomonas isolation agar) to compare the specific bacterial group of Bacillus and Pseudomonas in the respective samples of HLB+ and HLB- rhizosphere. The

study found that diverse group of Pseudomonas and Bacillus was appeared on their respective medium in both soil samples. Interestingly, HLB+ soil sample contained maximum diversity of Bacillus group while HLB- soil exhibited dominant and maximum diversity of Pseudomonas group of bacteria (Fig. 51, Fig. 52).

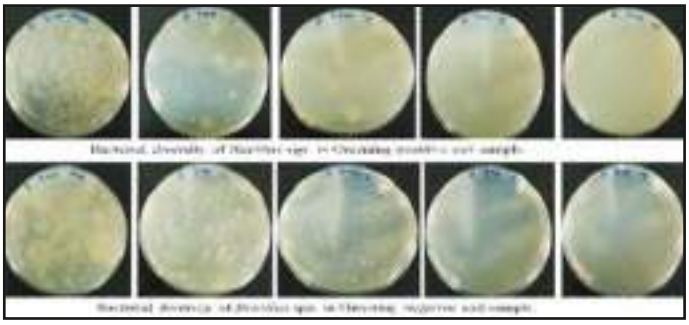


Fig. 51 : Comparative diversity analysis of *Bacillus* spp. in greening positive and negative soil samples

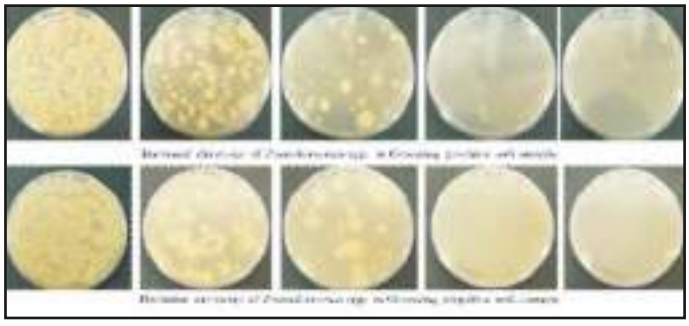


Fig. 52 : Comparative diversity analysis of *Pseudomonas* spp. in greening positive and negative soil samples

3.2.4.4 Studies on Agrocel-based Potassium Schoenite (Mahalaabh) in Citrus (Contract Research Project)

Potassium schoenite is basically a potassic fertilizer, used as a straight fertilizer suitable for fertigation and foliar application. It is nature's unique and perfectly balanced rich source of potassium, magnesium and sulphur in 100% water soluble form in balanced proportion. Hence, this fertilizer is likely to play a vital role in citrus fruit yield and quality.

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.

Response on fruit yield and fruit quality: The differential responses of different treatments of potassium schoenite versus+muriat of potash was observed on fruit yield and different fruit quality-related parameters (Table 48, Fig. 53). Considering all the treatments, the net variation in fruit yield was observed from (33.7 kg/tree or 9.37 t/ha) with treatment T_4 and 47.2 kg tree (13.14 t/ha) treatment T_6 suggesting as the best treatment. 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.

The fruit quality parameters (Juice content, acidity and total solids) varied significantly statistically significant response associated with different treatments (Table 47). The net variation in juice content, acidity and total soluble solids (TSS) were observed as 41.6-44.2%, 0.47-0.61% and 7.2-8.4%, respectively. Highest fruit quality index was observed with treatment T_6 (44.2% juice content, 0.47% acidity and 8.2% total soluble solids), but statistically, significant with treatment T_5 (42.8% juice content, 8.2% total soluble solid and 0.47% acidity).These observations also indicated the superiority of potassium schoenite over muriat of potash applied through fertigation.

Changes in plant available pool of nutrients : Different treatments of Potassium schoenite versus muriat of potash, regardless of mode of application showed a significant

response on 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 when subjected to analysis of plant available nutrients. The nutrients such as $KMnO_4$-N, Olsen-P, NH_4OAc-K, DTPA-Fe, DTPA-Mn and DTPA-Zn produced a marked changes in their concentrations with an exception of DTPA-Cu. The plant available nutrients like $KMnO_4$-N, Olsen-P, NH_4OAc-K in different treatments varied from 126.2 to 136.2 mg kg^{-1}, 11.3 to 14.8 mg kg^{-1} and from 155.2 to 172.3 mg kg^{-1}, respectively, with treatment T_6 observed having maximum plant available nutrients (136.2 mg kg^{-1} $KMnO_4$-N, 14.8 mg kg^{-1} Olsen-P and 172.3 mg kg^{-1} NH_4OAc-K), statistically on par with treatment T_5 (134.1 mg kg^{-1} $KMnO_4$-N, and 14.0 mg kg^{-1} Olsen-P. Hence, T_5 and T_6 treatments expressed better response over rest of the other treatments, including the muriate of potash applied through fertigation. It was interesting to observe that the plant available micronutrients (DTPA-Fe, DTPA-Mn and DTPA-Zn), excluding DTPA-Cu likewise showed a significant response in relation to different treatments of either potassium schoenite or muriat of potash. The changes in DTPA-Fe, DTPA-Mn and DTPA-Zn were observed to vary from 14.2 to 17.2 mg kg^{-1}, 8.6 to 11.2 mg kg^{-1} and from 0.82 to 1.10 mg kg^{-1}, respectively. However, different treatments involving potassium schoenite registered a significantly higher values over muriat of potash through applied through fertigation. Among all the treatments, plants receiving 100% of potassium schoenite through fertigation (T_5 and T_6) showed almost same magnitude of response on plant available micronutrients varying from 16.1-17.2 mg kg^{-1} DTPA-Fe, 10.1- 11.2 mg kg^{-1} DTPA-Mn and 1.00-1.10 mg kg^{-1} 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 plant available nutrients dictated the leaf nutrient composition evident from analysis of 5-7-month-old leaf samples for different nutrients (Table 3). The 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 response of potassium schoenite treatments was invariably better than muriat The leaf N, P and K varied from 2.20 to 2.42%, 0.08 to 0.13% and from 1.60 to 1.79%, respectively, with treatment T_6 and T_5 as the most effective treatments registering 2.31-2.42%

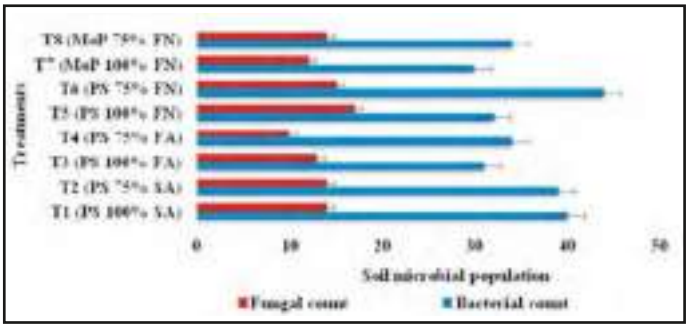
Table 47 : Response of different doses of potassium schoenite versus muriate of potash on fruit yield and fruit quality parameters of Nagpur mandarin

Treatments	Fruit yield parameter				Fruit quality parameters		
	Fruit weight (g)	No. of fruits/tree	Fruit yield (kg/tree)	Yield (t/ha)	Juice (%)	TSS (%)	Acidity (%)
T_1 (PS $_{100\% SA}$)	170.5	237.5	40.1	11.27	42.2	7.6	0.61
T_2 (PS $_{75\% SA}$)	164.5	208.3	34.9	9.70	41.6	7.2	0.60
T_3 (PS $_{100\% FA}$)	180.5	188.9	34.2	9.50	41.6	8.0	0.54
T_4 (PS $_{75\% FA}$)	155.5	215.8	33.7	9.37	42.2	8.0	0.48
T_5 (PS $_{100\% FN}$)	153.7	254.2	39.7	11.05	42.8	8.4	0.48
T_6 (PS $_{75\% FN}$)	157.3	300.0	47.2	13.14	44.2	8.2	0.47
T_7 ($MoP_{100\% FN}$)	153.8	245.8	38.1	10.60	41.6	7.6	0.52
T_8 ($MoP_{75\% FN}$)	165.5	211.1	34.5	9.60	42.2	7.8	0.50
CD (P=0.05)	5.1	30.1	4.2	0.90	1.4	0.51	0.11

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.

N, 0.12-0.13% P and 1.69-1.79% K, significantly superior to rest of the other treatments (2.20-2.42%N, 0.08-0.12%P and 1.52-1.71%) irrespective of mode of application. Similarly, the Fe, Mn and Zn content varied from 76.5 to 81.5 ppm, 44.1 to 49.2 ppm and from 23.8 to 27.8 ppm, respectively, with treatment T_5 and T_6 both displaying the best response (79.6-81.5 ppm Fe, 48.1-49.2 ppm Mn and 26.4-27.8 ppm Zn). It was interesting to observe this T_6 producing better response than T_6. These observations suggested for better superiority of potassium schoenite fertigation with 75% of its requirement, however, T_5 and T_6 displayed on par response, treatment T_6 using 75% RDF equivalent K could be considered as most effective treatment.

Changes in soil microbial population: The soil microbial population in terms of culturable bacterial count and fungal count was observed significantly affected by both, different modes of application of potassium schoenite as well as fertigation of conventional ± muriat of potash (Fig. 53). The treatments involving potassium schoenite registered a significantly higher bacterial count and fungal count (31-44×10^{-3} cfu/g and 10-17×10^{-3} cfu/g, respectively) than bacterial count and fungal count (30-34×10^{-3} cfu/g and 12.14×10^{-3} cfu/g) with treatments involving muriat of potash. However the best treatment, T_6 registered a bacterial count of 44×10^{-3} cfu/g and fungal count 15×10^{-3} cfu/g with treatment T5 on par (17×10^{-3} cfu/g).



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.

Fig. 53 : Effect of different doses of potassium schoenite versus muriate of potash on changes in soil microbial population

3.2.5 Demonstration of rejuvenation technology of Citrus orchards

3.2.5.1 Demonstration of rejuvenation rechnology of Nagpur mandarin

This project was initiated in 2020 to rejuvenate the declined and semi declined mandarin plants. This is second year of the project. There were around 45 trees which were either in declined or near-decline stage with no to minimal fruiting of *Ambia* noticed. The selected 7 years decline and 18 years semi decline plant are treated with treatments suggested by the institute. FYM and micronutrients are given to the plants. Bordeaux paste also applied to the plants before and after the rainy season. Observations are taken throughout the year.

Fruit yield and quality : The fruit quality parameter recorded and noted in selected seven years controlled and decline plants. The maximum average fruit weight was found in 7 years controlled plants (163.6g) which was minimum in 7 years decline plants (141.0g). The TSS content noted to be slightly higher (7.3%) with 7 years controlled plants than the decline plants (7.2%). The maximum acidity was recorded with 7 years controlled plants (0.7%) with higher juice content (40.8%) whereas lower acid content (0.6%) with 7 years decline plants. The fruit yield was recorded maximum (12.2 kg/plant) on 7 years controlled plants and minimum in decline plants i.e. (7.5 kg/plant).

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 (164.26g) which was slightly low in 18 years decline plants (151.13g). The TSS content noted to be slightly higher (7.85%) with 18 years controlled plants than the decline plants (7.78 %). The maximum acidity was recorded with 18 years controlled plants (0.82%) with higher juice content (43.84%) whereas acid content (0.77%) with 18 years decline plants. The fruit yield was recorded (11.34

kg/plant) on 18 years controlled plants and in decline plants it i.e, (12.35 kg/plant) (Table 48).

Incidence of insect pest : Incidences of insect pests were recorded in seven and eighteen year's old Nagpur mandarin orchards at village Nimji, Taluka. Kalmeshwar, District. Nagpur. In seven years old orchard, the average incidence of citrus psylla ranges from 1.5-5.75 population per 5 cm twig and leaf miner infestation was in the range of 10.41-26.54% per 5-10 cm twig during August to December, 2021. In eighteen years old declined mandarin orchard, the incidence of citrus psylla ranges from 1.25-6.70 population per 5 cm twig and the leaf miner infestation ranges from 7.28-20.46% per 10-15 cm twig. The infestation due to fruit sucking moth and fruits fly was above the ETL in seven year old orchards and it was in the range of 10-16.55% and 7.56-25.47% of fallen fruits, respectively. Comparatively less infestation was observed in eighteen year old orchards, where infestation caused by fruit sucking moth and fruit fly was 4.0-5.47% and 3.55-4.46%, respectively.

Diversity of plant parasitic nematodes in Nagpur mandarin, Nimji Collection of soil samples

Soil samples were collected from the rhizosphere of Nagpur mandarin orchard, Nimji. Samples were collected from 15-30 cm depth around the feeder roots of Nagpur mandarin.

Isolation of plant parasitic nematodes from soil

250 cc of composite soil sample was processed by Cobb's sieving and decanting technique and modified Bergmann funnel technique. Temporary mounts were prepared to identify the nematode species under compound microscope.

Identification of plant parasitic nematode genera

Based on the morphological characters, higher abundance of citrus nematode, *Tylenchulus semipenetrans* was found in collected soil samples. Whereas, *Pratylenchus* and *Hoplolaimus* were least abundant. In addition, free living nematodes such as rhabditids were also identified (Fig.54).

Soil samples collected from the type of t rees	Citrus nematode, *Tylenchulus semipenetrans* (No.)
18 years semi declined (control)	833
18 years semi declined (treated)	765
7 years semi declined (treated)	165

Table 48 : Plant growth, fruit yield and quality of Nagpur mandarin

Plants	Plant ht. (mt)	Stock and Scion ratio	Canopy volm (m^3)	Fruit weight (gm)	Fruit length and Dia. ratio	No. of seeds/ fruit	Tss (%)	Juice cont. (%)	Acidity (%)	Rind thickness (mm)	Vit. C (mg/ 100 mg)	Fruit yield (Kg/Plant)	Fruit yield (t/ha.)
7 years decline plants	4.14	1.06	18.52	141.0	1.0	5.4	7.2	36.5	0.6	2.4	42.6	7.5	3.0
7 years controlled plants	4.25	1.20	22.40	163.6	1.0	6.8	7.3	40.8	0.7	2.7	43.6	12.2	4.9
18 years Semi decline plants	5.16	1.30	62.30	151.1	0.99	6.0	7.78	42.4	0.77	2.54	42.20	12.35	4.99
18 years controlled plants	5.92	1.22	88.86	164.2	0.99	6.29	7.85	43.8	0.82	3.08	45.00	11.34	4.58
CD (P=0.05)	**0.138**	**0.067**	**6.976**	**3.052**	**NS**	**NS**	**0.19**	**4.935**	**0.079**	**NS**	**NS**	**1.435**	**0.581**

Fig. 54: Citrus nematode, *Tylenchulus semipenetrans*

Fig. 55: Application of Bordeaux paste

Fig. 56 : Taking observations and application of mixture of DAP and MOP to the selected Nagpur mandarin trees

3.2.5.2 : Demonstration of rejuvenation technology of Khasi mandarin

Survey conducted during 2020 at Sohkhowai area of Ri Bhoi district, an orchard with bearing plants in the Nongtrylaw (Site-A) and Umdenla-ang (Site-B) village was selected to conduct demonstration of rejuvenation technologies. In the orchard 50 numbers of Khasi mandarin plants were selected which were applied with the recommended doses of FYM and fertilizers. Although no apparent significant disease and pest infestation was observed during the study period, prophylactic spray with neem oil and Trichoderma application was done on these plants. In adjust cent to these plants another 50 plants were marked/tagged as control with prevailing farmers practice (no FYM or fertilizers or plant protection materials).

Soil fertility and plant nutrient status : Analysis of soil samples collected from the two-demonstration site (A and B) in Sohkhowai area of Ri-Bhoi district revealed (Table 49) that soil is strongly acidic (4.0-4.5) in reaction at site-A and highly acidic (4.5-5.0) in reaction at site-B. The soil at both site A and B, recorded high content of organic carbon, medium level of available nitrogen (280-560 kg ha^{-1}), low level of available (Bray P1-extractant) phosphorus (<34 kg ha^{-1}), medium level of available potassium (120-180 kg ha^{-1}) and low in Ca + Mg. Available sulphur content of 46.7 and 42.4 kg ha^{-1} is recorded in site-A and site-B, respectively.

The average plant height in site-A is 4.64, 4.68 m, respectively in treated and untreated plants (Table No.51). In site-B, it was 5.07 and 4.67 m, respectively for treated and untreated plants. In site-A individual plant recorded 288.4 no. of fruits with average weight of 96.2g, 45.3% juice, 13.5% TSS content and 1.46% acidity (Fig. 57).

Table 49 : Soil fertility status in demonstration site

Parameters/ Location details	Sample location	pH	SOC (%)	Available nutrients (Kg ha^{-1})				Ca+Mg (meq/100g)
				N	P	K	S	
Site -A	Top	4.36	1.53	276	13.7	175	41.0	0.90
	Middle	4.48	1.11	301	14.2	151	52.7	0.60
	Bottom	4.34	1.14	301	13.4	164	46.4	0.40
	Mean	**4.39**	**1.26**	**293**	**13.8**	**163**	**46.7**	**0.63**
Site -B	Top	4.33	1.50	314	14.2	152	41.5	0.40
	Middle	4.51	1.71	301	13.2	155	44.1	0.30
	Bottom	4.86	1.68	314	17.0	158	41.6	0.50
	Mean	**4.67**	**1.63**	**310**	**14.8**	**155**	**42.4**	**0.40**

Table 50 : Leaf nutrient content in citrus plants

S. N.	Sample location/ orchard No	Total nutrients (in %)			Total nutrients (in ppm)			
		N	P	K	Fe	Zn	Cu	Mn
1	Site -A	1.95	1.56	0.98	295	90.5	61.3	25.3
2	Site -B	1.70	0.86	1.06	262	73.0	53.6	26.6

Table 51 : Plant growth and fruit quality parameters at demonstration site

Parameter	Site - A		Site -B	
	Treated	Untreated	Treated	Un treated
Plant height (m)	4.64	4.68	5.07	4.67
Collar diameter (cm)	45.2	37.8	43.8	26.7
Fruit quality parameters at site - A				
Parameters	Mean of 15 observations		STD DEV	
Plant height (m)	4.64		0.71	
Collar diameter (cm)	45.2		9.68	
Fruit weight (g)	96.2		25.2	
No. of seeds/fruit	10.6		4.21	
TSS (%)	13.5		1.12	
Acidity (%)	1.46		0.25	
Rind thickness (mm)	2.73		0.60	
Fruit length and diameter ratio	0.93		0.09	
Juice %	45.3		6.53	
No. of fruits/ tree	288.4		54.1	
Average fruit weight/tree (Kg)	27.7		5.20	

Ring method of fertilizer application

Fertilizer application

Fig. 57 : Different activities carried out regarding the project

Field day on intercultural operation in citrus orchards organized

Sohkhowai, Umdenla-ang and Tyrlaw village of Ri-Bhoi District are known for production of tasty *Khasi* mandarin which is popularly branded as "Sohkhwai Mandarin". A Field Day was organized at the Umdenla-ang basti, Sohkhwai village of Ri-Bhoi district on 2nd November 2021. The programme was attended by 50 farmers from different *basti* under Sohkhowai. In the day long programme, the farmers were appraised about the calendar of intercultural operations to be followed for rejuvenation as well as maintaining a healthy orchard. Further, demonstrations on various intercultural operations for citrus orchard management were made during the prograame. Critical inputs such as FYM, mustard oil cake, organic fertilisers and micronutrients were distributed among the farmers. The programme was co-ordinated by scientists Dr. Tasvina R. Borah, Dr. A. Balusamy and Dr. H. Rymbai of ICAR Research Complex for NEH Region, Umiam. The programme was organized under the collaborative project *"Demonstration of rejuvenation technology of citrus orchards"* of ICAR Central Citrus Research Institute, Nagpur, Maharashtra (Fig. 58).

Fig. 58: Activities carried out during the field day on 2nd November, 2021

3.3 Integrated Pest and Disease Management

3.3.1 Integrated Insect Pest Management

3.3.1.1 Horticulture Pest Surveillance and Advisory Project (HORTSAP)

During 2021, six field visits in selected orchards of two districts (Nagpur and Wardha) comprising 4 Talukas including 13 Villages covering 23.09 ha area were conducted. Pest monitor and pest scout of respective orchards were given training on field identification of insect pest damage on Nagpur mandarin and sweet orange. Additionally virtual training were also given to the scouts and monitors of Nagpur Division and Ahmednagar districts on 24th June 2021. 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 June 2021 to December 2021 was compiled on Nagpur mandarin for 6 districts *viz.,* Nagpur, Amravati, Wardha, Buldhana, Washim and Ahmednagar. The locations were insect pest incidence reaches above ETL level in different months were monitored as well as documented and advisories have been uploaded as a caution. A multidisciplinary team of ICAR-CCRI and office of Divisional Joint Director of Agriculture, Nagpur Division, visited the Nagpur mandarin and sweet orange growing areas of Katol (Dhalwalpur, Paradsinga, Jamgaon, Naigaon, Khapri and Pardi - Narkhed (Umtha) to ascertain the problem of fruit drop and issued spot advisories. ICAR-CCRI Scientists delivered lectures in virtual mode on 'Care and management of citrus orchards' for RAMETI, Amravati and Nagpur. In-Person, Farmer scientist interaction on management of *Ambia* and *Mrig* bahar of Nagpur mandarin and Sweet orange were arranged at ICAR-CCRI. Regular pest advisories were issued through WhatsApp messages, mobile SMS and press notes in daily newspapers to concerned citrus growers under HORTSAP project. Provided regular guidelines and method of observation to pest scout and pest monitor if any anomaly observed in uploaded pest data.

3.3.2 Integrated Disease Management

3.3.2.1 Consortia Research Platform (CRP) on Vaccines and Diagnostics: Developing diagnostics for Citrus viruses and greening bacterium

A) Development of a reverse transcription recombinase polymerase based isothermal amplification coupled with lateral flow immunochromatographic assay for rapid detection of CTV

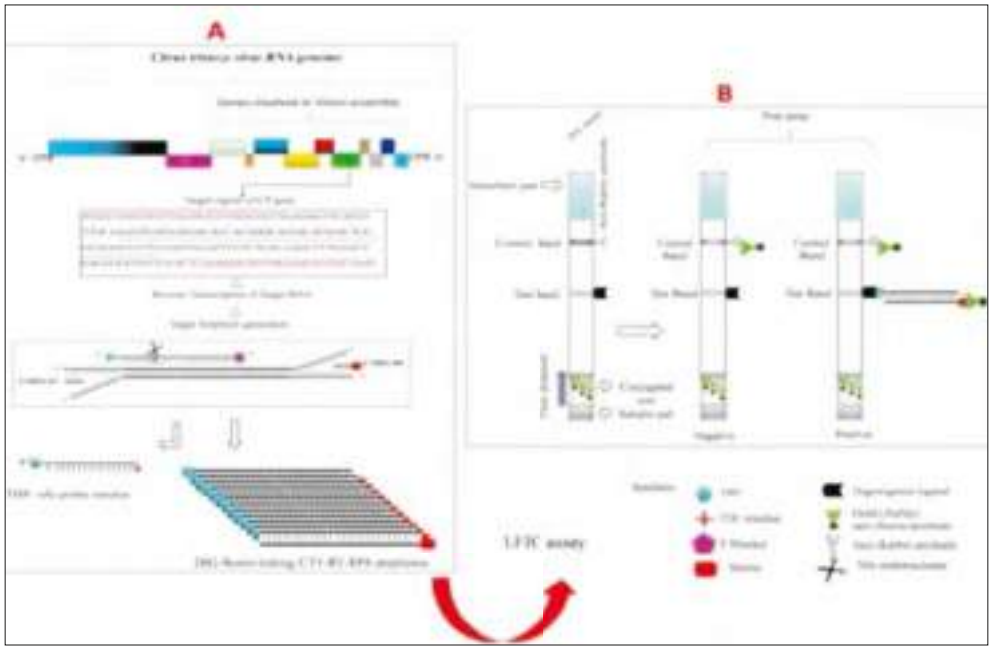


Fig. 59 : Schematic representation of the CTV-RT-RPA-LFICA principle for the detection of CTV

Tristeza is a highly destructive disease of citrus caused by the phloem-limited, flexuous filamentous Citrus tristeza virus (CTV) in the genus Closterovirus and the family Closteroviridae. Here, we have developed a rapid, sensitive, robust, reliable, and highly specific reverse transcription-RPA technique coupled with a lateral flow immunochromatographic assay for CTV detection (Fig. 59).

Screening of RT-RPA-LFICA primers: Forty different combinations of forward and reverse primers (4 forward and 15 reverse) targeting a portion of the coat protein gene of CTV (CTV-p25) were analyzed for specificity and cross reactivity using different strains of CTV and other citrus pathogens with primer-BLAST software. The CTRPA-F1/R9-Btn combination was identified as the most optimally performing primer set consistently amplifying a ~165 bp specific region of the CTV- p25 gene and was used for further optimization.

Development of RT-RPA-LFIC assay : The assay was optimized using synthesized cDNA and the RNA obtained from CTV positive citrus plants maintained in the screen house. To develop a rapid lateral flow immunochromatographic assay, a PCRD nucleic acid detector was used to capture and detect CTV specific amplified double labelled products generated by RT-RPA. The end point detection was analyzed by loading diluted (0.5:100) amplified product of RT-RPA on the sample port of the PCRD detector. Upon application of the amplified product on the sample port, the carbon conjugated anti-biotin antibodies react with the Dig/biotin labelled amplicons. The complex of carbon conjugated antibody-Dig/biotin amplicons gets captured at the test line (T-lines) and control line (C-line) by production of a coloured visible line. The appearance of both lines occurring simultaneously within 2 min after application of the amplified product of RT-RPA on the sample port of the PCRD detector was considered as a positive result for CTV whereas development of only the control line indicated negative results (Fig. 60).

Fig. 60 : RT-RPA-LFICA using RNA as a template with three reaction lines: Line C is the control line; Line1 for detection of digoxigenin/biotin-labelled CTV amplicons. A1, A2, M1, M2, N1, N2, and H represent experimental samples, H: Healthy control, -Ve: negative control and +Ve positive control.

Optimization of the assay : Samples having more CTV titer required a minimum time (60 sec) to develop a more intense-visible T line. The RNA templates required more incubation time (20-25 min) than cDNA as initial template. The optimal results of the assay were observed at 40- 42°C (Fig. 61) in 20-25 min from RNA as initial template and 15 min for cDNA as template (Fig. 61B). No result was observed at < 36°C and at > 42°C.

Sensitivity and specificity evaluation of the assay : The developed assay consistently detected target cDNA of CTV up to 10-5 serial dilution synthesized from 141 ng of

Sr. No	Primer /Probe Code	Sequence (5′ - 3′)	Amplicon Size
1	CTRPA-F1	ATAGCTATGATGTTATATCGTTTAGCGGT	~ 165 bp
2	CTRPA-R9 -Btn	[Btn] ATTACTACAGCTACCAATAGCATTAGAG	
3	CTRPA-Probe	dT[DIG] - AAGTGATGATGACACCACGGGCATAACATA dSpacer - ACTCGGGAGGGTGTT - Spacer C3 (Blocker)	

Fig. 61 : Determination of optimum reaction temperature and time: A, RT-RPA-LFICA was performed at different temperatures. B, times represented in the figure.

invitro - transcribed RNA as the initial template. The sensitivity analysis based on RNA showed a detection limit up to 0.23 ng/µl with RNA as an initial template. The detection limit of the assay was 1.41 pg of RNA when converted into cDNA and used as a template (Fig. 62). However, the assay detected 0.23 ng/µl when RNA was used directly as template. The detection limit for RT-PCR was observed up to 10-5 serial dilution of target cDNA (Fig. 62B). Specificity analysis showed that the developed assay was highly specific to CTV and failed to detect any other non-target citrus pathogens.

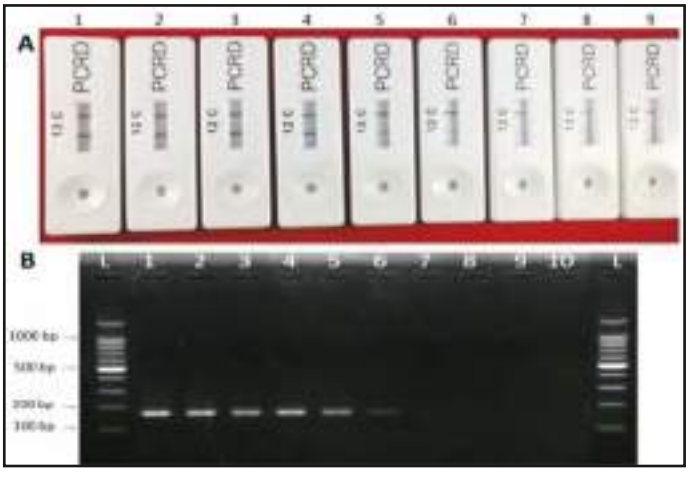


Fig. 62: Detection limit analysis of RT-RPA versus RT-PCR using 10 fold serially diluted cDNA as template

B) Standardization of TaqMan Real-time PCR assay for CTV

TaqMan-qPCR was standardized using the CTV specific primer-probe combination. The assay was performed using a StepOne Real Time PCR System in a total of 20 µl reaction volume containing 300 nM each of forward and reverse primers, 250 nM probe (CTV-FAM) with CXR reference dye containing 1x GoTaq qPCR master mix. The reaction protocol of 95°C for 2 min, followed by 40 cycles at 95°C for 15s, annealing and primer extension simultaneously for 1 min at 60°C was used. All experimental reactions were conducted in triplicate along with non-template controls and the data was analyzed using StepOne Software v2.1 (Fig. 63).

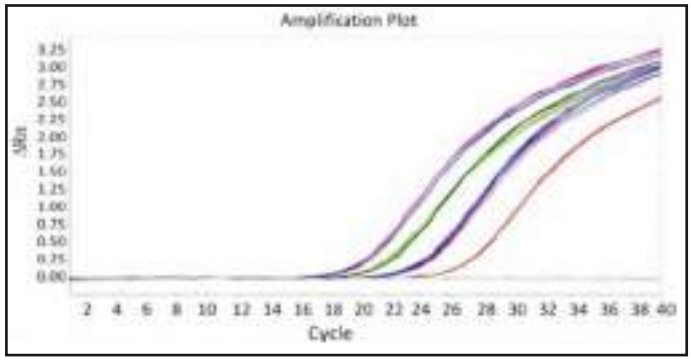


Fig. 63 : qPCR Amplification plot for CTV positive samples

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

Preparation of 2S albumin protein and Nano-ZnO formulation: The purity/quality of 2S albumin was confirmed by a single band on a non-reducing 12% SDS-PAGE. The purified protein was concentrated to 1 mg/ml. The concentration of protein was determined by BCA protein assay kit. The 1000 ppm solution (38 mg of Nano-ZnO dissolved in 20 ml of PBS buffer (pH 7.4)) of Nano-ZnO was used for the trunk injection. Before use, the Nano-ZnO solution was vortexed for 2 min and sonicated for 5 minutes to obtain the homogenized solution. Then, the Nano-ZnO and 2S albumin protein were mixed in 1:1 ratio and sonicated for 1 hour. The each experimental plant was injected with 25 mL of 2S Albumin-Nano ZnO formulation (1000:1000 ppm) in two consecutive days. The each experimental Mosambi plant was injected with Nano-ZnO formulation in both sides (12.5 mL in each side) of the stem.

Trunk injection of 2S albumin protein and Nano-ZnO formulation: In order to inject the Mosambi trees with 2S albumin protein and Nano-ZnO formulation, the trees having stem diameter of ~15 to 20 cm were drilled using a Bosch Professional GSSR 120-LI with 5 mm bit to create 5-6 cm depth hole of 5 mm diameter. The injected volume of 2S albumin protein and Nano-ZnO formulation was 12.5 ml each day for two consecutive days of every month during morning hours (25 ml/tree). The formulation was injected using a Chemjet tree injector (www.chemjet.com.au), which took around 2-3 hours to inject the complete formulation.

Fig. 65: Trunk injection of 2S albumin protein and Nano-ZnO formulation: A- Drilling of mosambi trunk using a Bosch Professional GSSR 120-LI machine B- Chemjet tree injector C- View of trunk injected plant with Chemjet injector.

The effectiveness of 2S albumin protein plus Nano-ZnO formulation against CLas : The impact of 2S albumin protein and Nano-ZnO against CLas was assessed by measuring CLas titer using qPCR with TaqMan chemistry on 0, 30, 60, 90, and 120 days after treatment. Negative and positive controls were included in the treatment. The results revealed that at 30 DAT, the CLas titer significantly suppressed, average Ct value increased from 22.10 to 27.63. The reduction in the CLas titer also observed in case of positive non treated control plants, the average Ct value increased from 22.38 to 25.79. However, the data shows that the treated CLas infected plants had more decrease in CLas titer than the positive control plants at 30 DAT (Fig. 66). The CLas titer increased in both control and treated plants at 60 days than the titer of 30 DAT (average Ct value decreased from 27.63 to 23.68 for treated plants and average Ct value decreased from 25.79 to 21.99 for positive non treated control plants), with the increase in CLas titer being somewhat high in positive controls plants. However, even at 60 DAT, the CLas titer was lower than the 0 DAT titer for treated plants (average Ct value increased from 22.10 to 23.68), but the CLas titer was higher in positive non-treated plants (average Ct value decreased from 22.10 to 21.99). Overall, the reduction in the CLas titer was observed in treated plants as compared to the positive control (Fig. 66). In conclusion, the results showed that the CLas titer was reduced after the administration of 2S albumin protein and Nano-ZnO formulation to HLB-infected Mosambi plants. However, the significant difference in CLas titer reduction was quite little when compared to the control plants. This could be attributed to factors such as lower concentrations of 2S albumin protein and Nano-ZnO formulation, as well as the huge tree canopy of the citrus plant.

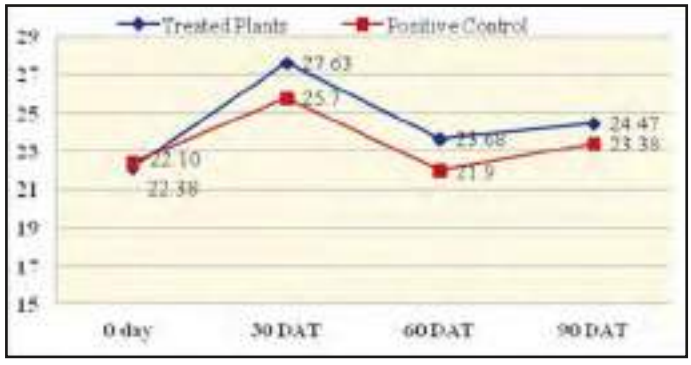


Fig. 66 : The effect of 2S albumin protein and Nano-ZnO formulation on CLas titer at 0, 30, 60, and 90 DAT, compared with positive control plants (Blue color line represents for treated plants and maroon color line represents for positive control plants).

3.3.2.3 To develop potential inhibitor molecules against putative cystine-binding protein from *Candidatus* Liberibacter asiaticus

Raising of rough lemon plants and production of HLB infected citrus plants by grafting: Rough lemon rootstocks were grafted by wedge grafting and micro-grafting techniques in which the bud of infected HLB plant was

placed on rough lemon plant. The HLB grafted-inoculated plants were then maintained in an insect-proof screen house (Fig. 67). The grafted inoculated HLB plants were monitored continuously for typical HLB symptoms like blotchy mottle and vein corking on leaves and also tested for *C*Las using conventional PCR and RT- PCR.

Fig. 67 : Production of HLB infected plants: A-Rough lemon seedlings; B-Micrografting techniques used for HLB graft inoculation; C-Wedge grafted plants; D-Plants after successful grafting.

Confirmation of HLB graft inoculated plants by PCR and qPCR : The successfully graft inoculated plants were tested for CLas by conventional PCR using CLas specific primers. Petioles and midribs were excised and grounded in liquid nitrogen.100 mg of the liquid nitrogen grounded sample was used for the DNA extraction using the DNeasy Plant mini kit or cetyltrimethylammonium bromide (CTAB) method. Isolated DNA further used to carry out PCR and RT-PCR tests. These PCR positive plants were selected for further investigations (Fig. 68).

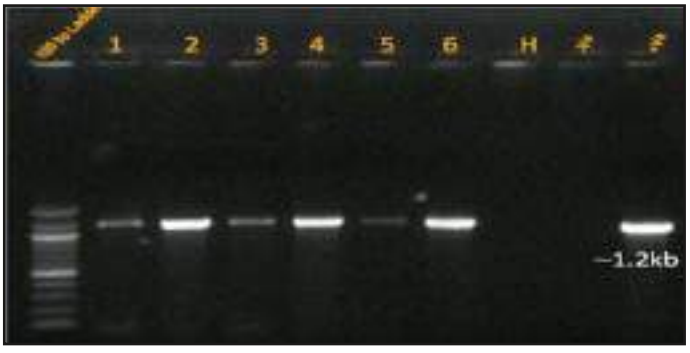


Fig. 68: Agarose gel electrophoresis of PCR amplified productobtained using the 16S rRNA specific primer set OI1 and OI2cof HLB graft inoculated plants

LaneM, 100 bp DNA Ladder; lane 1 to 6 amplified product of representative isolates; lane H, healthy plant control, -Ve, non-template control and lane +Ve, positive control.

The qPCR was performed for each of the experimental plants to determine the CLas load. The real-time PCR assay was carried out in a total of 20 µl reaction volume using an Applied Biosystems Real Time PCR System with the following reagents at optimized concentrations:300 nM (each) target primers (HLBas-F/HLBas-Rn), 200 nM target probe (HLBp), 300 nM (each) internal control primers (COXf and COXr), 200 nM internal control probe (COXp) with 1x TaqMan Universal Master Mix II (Applied Biosystems). The protocol was 95°C for 10 min, followed by 40 cycles at 95°C for 20s, 58°C for 30 s and 60°C for 30s. The HLB positive plants showing optimum Ct value were selected for further experiment (Fig. 69). The copy number of the pathogen in individual plant will be calculated using real time PCR.

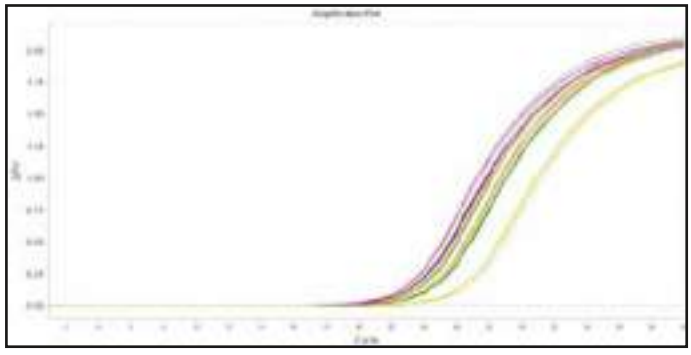


Fig. 69: Amplification plot for representative HLB graft inoculated plants inoculated plants showing average Ct (cycle threshold) values ranging from 22 to 27.12, no fluorescence signal was observed with Healthy plant and non-template controls (NTC).

Identification of potential inhibitor molecules against CLasTcyA: In the earlier study, we identified molecules with higher binding affinity compared to the CYS for CLasTcyA in the range of -9.4 to -10.7 kcal/mol compared to the substrate (-7.2 kcal/mol), as shown in the following table. All the four molecules fulfilled the Lipinski rule of five (molecular weight < 500 Da, H-bond donor < 10, and cLogP< 5).

Among these inhibitor molecules Pimozide and Clinidium was selected for further analysis (Fig. 70).

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

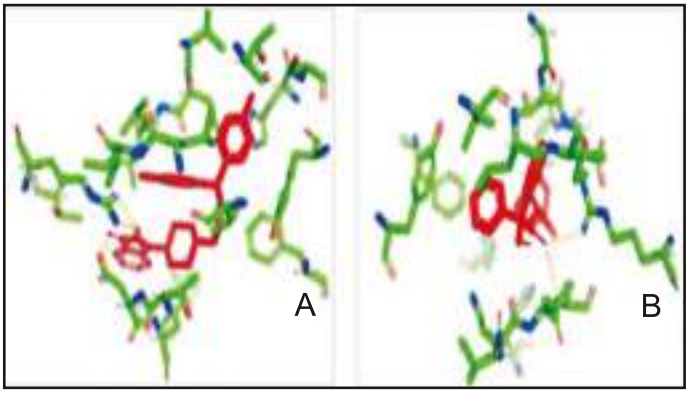


Fig. 70 : Molecules identified in the present study A), Clinidium bromide, B) Pimozide.

3.3.2.4 Endophytic bacteria and fungi as bioagents for management of Phytophthora diseases in citrus

3.3.2.4.1 Isolation and diversity of fungal endophytes inhabiting citrus

New sets of samples consisting of leaf, bark and rhizospheric roots from healthy plants of Nagpur mandarin and Sweet orange were collected from ICAR-CCRI farm site. Samples were individually placed in plastic bags and immediately taken to the laboratory and processed further. Leaf, bark and roots from each plant were surface sterilized following the already standardized procedure. Individual fungal hyphal tips were picked as they appeared from the margins of leaf, bark, and root tissues and transferred to fresh PDA plates to obtain pure cultures of the isolates. Nine fungal endophytes (CFE-163 – FE-171) isolated rhizospheric roots from healthy plant of citrus cultivars were used for performing confrontation assay against *P. nicotianae*.

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. 71.

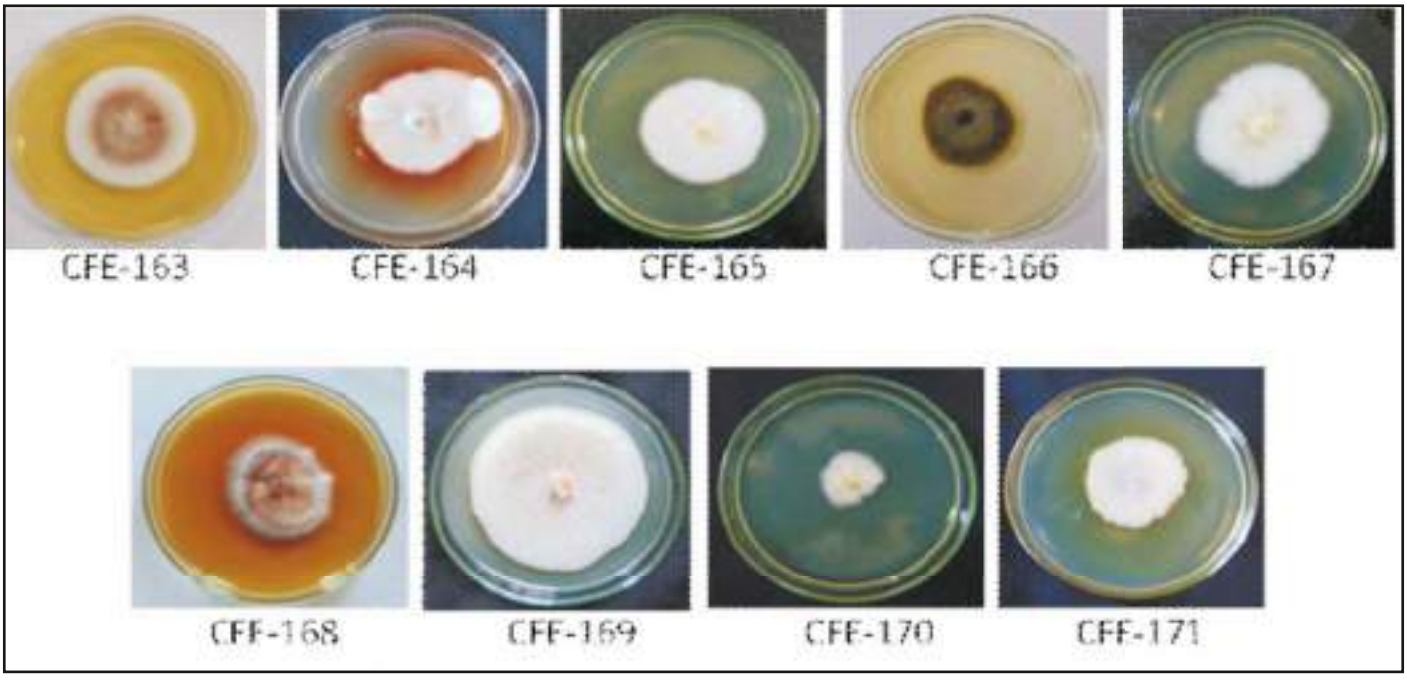


Fig. 71 : Colony morphology of fungal endophytes

3.3.2.4.1 *In vitro* dual culture assay

The above nine fungal endophytes were tested against *Phytophthora nicotianae* in Dual culture technique. Experiment was set up in 90 mm petri plate containing Corn Meal Agar (CMA). Plates were labeled for two points equidistant from the centre - one for *Phytophthora* and another for fungal endophyte inoculation. First *Phytophthora* culture was inoculated and plates were incubated at 25ºC for 48 hrs (2 days). After 2 days, fungal endophyte was inoculated in the same plate at other point. Control plates each for *Phytophthora* and fungal endophyte tested were also included in the experiment. Plates were observed daily for contact, once there was contact between *Phytophthora* and fungal endophyte their growth (along with growth in control plates) were measured and recorded. None of the fungal endophytes were found to have potential against controlling *P. nicotianae.* The inhibition was found below 40% in all the isolates tested.

3.3.2.4.2 Mass production of promising endophytes CFE 109, CFE 142 and CFE-157

Talc based formulation of two promising endophytes CFE 109 & CFE-157 (*Chaetomium globosum*) and CFE 142 (*Aspergillus terreus*) were prepared after growing the respective cultures in potato dextrose broth (PDB).

CFU from talcum based CFE culture:

CFE 109 - $1.48x10^6$ cfu/ g of talc formulation

CFE 142 - $2.43x10^6$ cfu/ g of talc formulation

CFE-157 - $2.76x10^6$ cfu/ g of talc formulation

3.3.2.4.3 *In vivo* efficacy studies of fungal endophytes (Pot Culture experiment)

The *in vivo* efficacy studies of promising fungal endophytes on growth of rough lemon seedlings were carried out at the Glasshouse. In this experiment 3 talc-based formulation endophytic fungal isolates (CFE-109, CFE-142 and CFE-157) were used. Results indicated that isolates had a moderate effect in controlling root rot.

3.3.2.4.4 Isolation, characterizationand 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 CCRI farm site. Samples were individually placed in plastic bags and immediately taken to the laboratory and processed further.

Total 39 isolates of rhizobacteria were isolated and purified from citrus rhizospheric soil, rhizoplane and endorhizosphere using standard serial dilution technique. The rhizobacterial isolates were screened by *in vitro* confrontation assay against *Phytophthora nicotianae.* Out of 39 isolatess, 11 were found promising showing more than 50% inhibition in the dual culture assay. All these isolates were characterized by morphological, biochemical and molecular means.

3.3.2.5 Evaluation of Scholar 230SC (Fludioxonil 23% w/v SC) for Post-Harvest Disease Management in Nagpur mandarin (Contract Research Project)

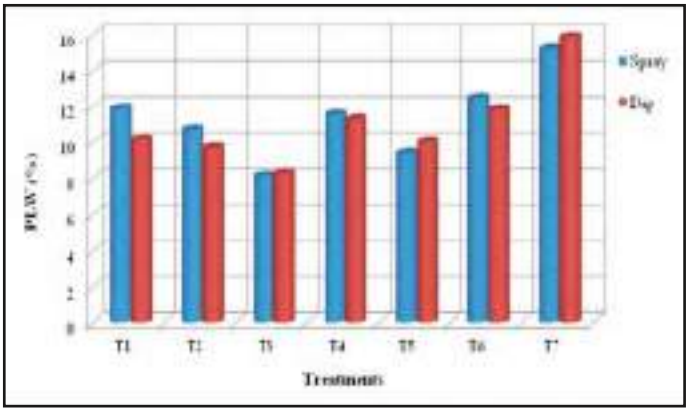
SCHOLAR is a new non-systemic phenylpyrrole fungicide in which the active ingredient is fludioxonil. According to the Fungicide Action Resistance Committee (FRAC), fludioxonil (Group 12 fungicide) has a low and reduced risk of developing resistance against plant pathogens. MOA is to inhibit transport-associated phosphorylation of glucose, which reduces mycelial growth rate. Experiments were conducted with the objectives : Bio-efficacy of Scholar 230SC (Fludioxonil w/v 23% SC) against post-harvest diseases of Nagpur mandarin and effect of Scholar 230SC on the shelf-life, physico-chemical and bio-chemical parameters of Nagpur mandarin.

Both Fruit Dip and Spray Mist methods were deployed for post-harvest treatments. Fruits were passed through a manual dip and spray mist (in mechanical packing line) containing the fungicide for 30 - 45 seconds and kept at ambient temperature and refrigerated conditions.

3.3.2.5.1 Evaluation of Scholar 230SC (Fludioxonil 23% w/v SC) for Post-Harvest disease management in Nagpur mandarin during ambient and refrigerated temperature conditions

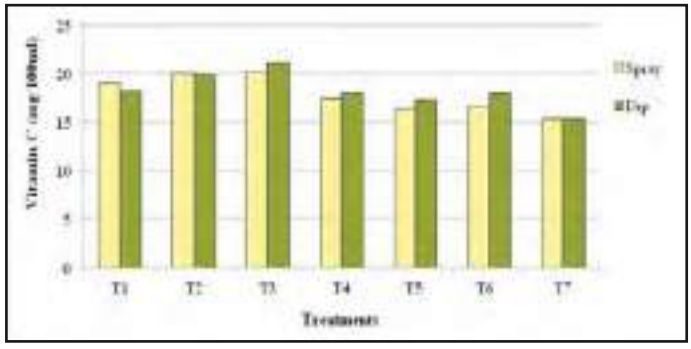
A preliminary experiment on Nagpur mandarin (*Citrus reticulata* Blanco) fruits was conducted with the objective to evaluate Scholar 230SC (Fludioxonil 23% w/v SC) coating in controlling the post-harvest disease in citrus and also in extending the shelf life of Nagpur mandarin fruits. Nagpur mandarin fruits were collected from the nearby farmer orchard. Fruits of uniform shape and size sorted, washed and air dried. The collected fruits were coated with Fludioxonil 23% w/v SC, Zineb 75% WP and Copper oxychloride 50% WP in varying concentration in 7 treatments. A set of 7 treatments, fruits were spray mist in respective coating solution on mechanized packaging line of ICAR-CCRI, Nagpur and another set of same 7 treatment was dipped with same set of solutions, air dried, packed in CFB boxes and stored in Ambient condition upto 14 days and refrigerated condition upto 45 days.

The physiological parameters including the fruit firmness, colour, TSS, PLW, acidity, vitamin C, juice recovery, spoilage percentage, flavor, quality and organoleptic profile was recorded at interval of 7 days in ambient condition and 15 days upto 45 days under refrigerated storage condition. The fruits in ambient condition recorded higher spoilage within 7 days and almost after 14 days. Nagpur mandarin fruits coated with Fludioxonil 23% w/v SC 3.90 g/L (T_3 treatment) and 7.80 g/L (T_4 treatment) shows significantly better results and maintained the physico-chemical parameters considerably under refrigerated storage conditions.



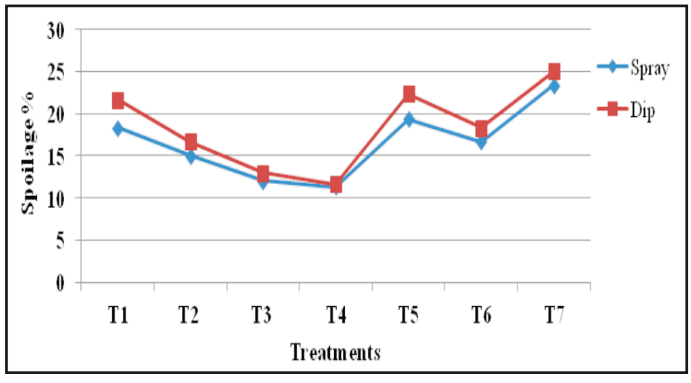
Where, T_1 -Fludioxonil 23% w/v SC 2.60 ml/L; T_2-Fludioxonil 23% w/v SC 3.25 ml/L; T_3-Fludioxonil 23% w/v SC 3.90 ml/L; T_4-Fludioxonil 23% w/v SC 7.80 ml/L; T_5-Zineb 75% WP 2.67 g/L; T_6-Copper oxy Chloride 50% WP 3.33g/L and T_7-Control

Fig. 72 : Effect of Scholar 230SC (Fludioxonil 23% w/v SC) on PLW of Nagpur mandarin fruits stored in refrigerated conditions after 45 days



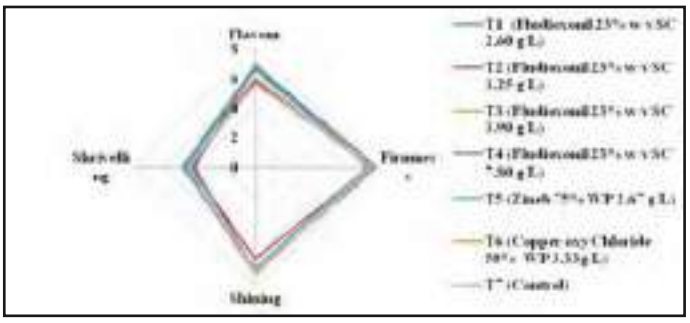
Where, T_1-Fludioxonil 23% w/v SC 2.60 ml/L; T_2-Fludioxonil 23% w/v SC 3.25 ml/L; T_3-Fludioxonil 23% w/v SC 3.90 ml/L; T_4-Fludioxonil 23% w/v SC 7.80 ml/L; T_5-Zineb 75% WP 2.67 g/L; T_6-Copper oxy Chloride 50% WP 3.33g/L; T_7-Control

Fig. 73 : Effect of Scholar 230SC (Fludioxonil 23% w/v SC) on Vitamin C of Nagpur mandarin fruits stored in refrigerated conditions after 45 days



Where, T_1-Fludioxonil 23% w/v SC 2.60 ml/L; T_2-Fludioxonil 23% w/v SC 3.25 ml/L; T_3-Fludioxonil 23% w/v SC 3.90 ml/L; T_4-Fludioxonil 23% w/v SC 7.80 ml/L; T_5-Zineb 75% WP 2.67 g/L; T_6-Copper oxy Chloride 50% WP 3.33g/L; T_7-Control

Fig. 74 : Effect of Scholar 230SC (Fludioxonil 23% w/v SC) on Spoilage % of Nagpur mandarin fruits stored in refrigerated conditions after 45 days



Where, T_1-Fludioxonil 23% w/v SC 2.60 ml/L; T_2-Fludioxonil 23% w/v SC 3.25 ml/L; T_3-Fludioxonil 23% w/v SC 3.90 ml/L; T_4-Fludioxonil 23% w/v SC 7.80 ml/L; T_5-Zineb 75% WP 2.67 g/L; T_6-Copper oxy Chloride 50% WP 3.33g/L; T_7-Control

Fig. 75 : Spider graph of sensory evaluation of spray mist coated Nagpur mandarin fruits after 30 days in refrigerated storage condition

It was observed that among the treatments, T_3 treatment was found best due to lower PLW and higher vitamin C content (as shown in Fig. 72 and 73). As depicted in Fig.74, the spoilage was found minimum (11.33%) with T_4 treatment and highest in control fruits (23.33%) after 45 days of storage in refrigerated conditions. Acidity and total soluble solids did not respond to the treatments. Sensory evaluation of coated fruits was performed by trained panelists (Fig. 75). They assessed in terms of Flavour, Firmness, Shining and Shrivelling properties. Overall acceptability score was calculated as average of the whole sensory attributes. Fruits spray mist in mechanized packing line showed better results in comparison to the fruits treated by dip method.

Incidence of different post-harvest pathogens (Fig. 77) responsible for microbial spoilage/ decay of Nagpur mandarin fruits under different treatments were monitored at different time intervals both under ambient conditions and refrigerated conditions. Maximum incidence of Botryodiplodia stem end rot was found under ambient temperature conditions (Fig. 76) whereas Penicillium (green mould) incidence was noticed higher under refrigerated conditions. Spoilage of fruits was found least in treatment T_3: Fludioxonil 23% w/v SC 3.90 g/L and treatment T_4: Fludioxonil 23% w/v SC 7.80 g/L as indicated previously under refrigerated conditions. Incidence of Diplodia stem end rot was found lowest in treatment T_3.

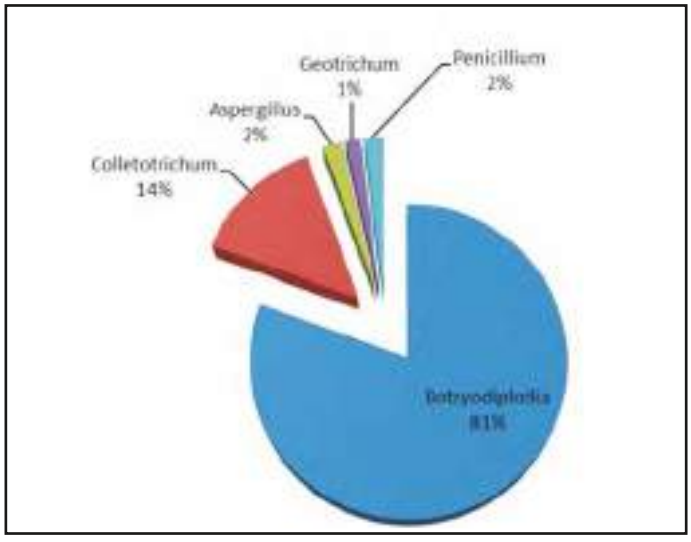


Fig. 76 : Incidence of post -harvest pathogens under ambient conditions

In-vitro evaluation of fungicides against post-harvest pathogens :

The potential of fungicides in controlling different post-harvest pathogens was done using the *in vitro* poisoned

Fig. 77 : Colony morphology of different post-harvest fungal pathogens in potato dextrose agar (PDA) media. (From left) *Botryodiplodia, Penicillium, Colletotrichum,* and *Aspergillus* sp.

food technique. Results of *in vitro* efficacy tests revealed that Fludioxonil was very effective in inhibiting the growth of *Botryodiplodia* and *Penicillium*.

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 exotic sweet orange cultivars on raised bed system

A study was undertaken to understand the diversity and distribution of plant parasitic nematodes in exotic sweet orange cultivars on raised bed system at CCRI in the year 2021. Composite samples were collected from various sweet orange cultivars *viz*., Hamlin on Volkameriana, Hamlin on Cleopatra, Pera on Limocravo, Pera on Volkameriana, Natal on Limocravo, Natal on Volkameriana, Valencia on Cleopatra, Valencia on Vokameriana, Westin on Limocravo, Westin on Swingle. 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*., *Pratylenchus*, *Hoplolaimus*, *Criconema*, *Tylenchulus semipenetrans* and Tylenchinae were identified (Fig. 78). Among these, *Pratylenchus* was prominently recorded compared to other genera. In addition, different free living nematodes such as rhabditids and mononchids were also identified.

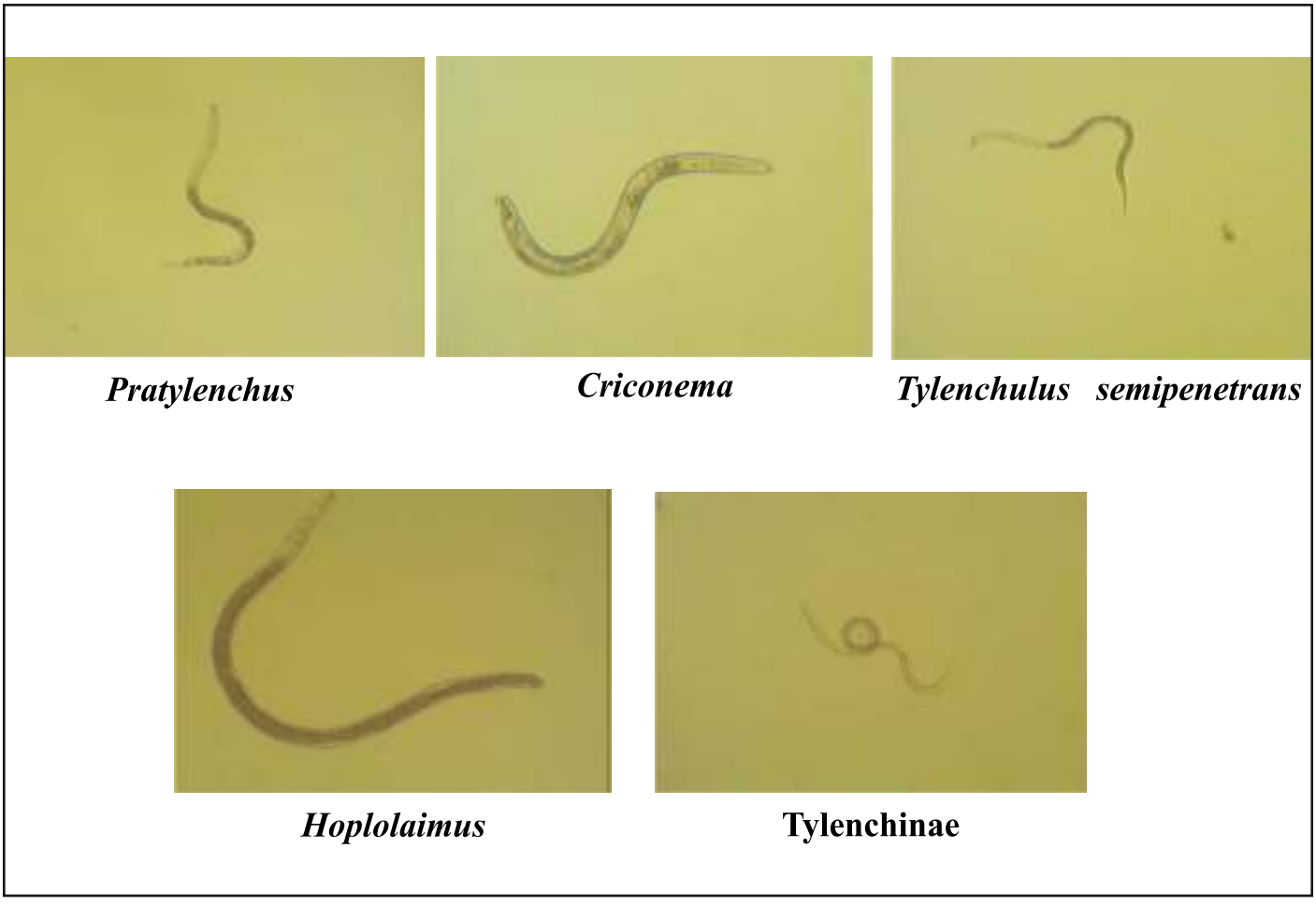


Fig. 78 : Nematode genera identified in exotic sweet orange cultivars

Diversity of plant parasitic nematodes in Nagpur mandarin in Maharashtra

An extensive survey was undertaken in Nanori, Wani, Madhan, Kazali and Jasapur villages in Amravati District in the year 2021 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*., *Pratylenchus*, *Meloidogyne*, *Hoplolaimus* and *Tylenchulus semipenetrans* were identified (Fig. 79). Among these, *T. semipenetrans* was prominently recorded compared to other genera. In addition, different free living nematodes such as rhabditids and mononchids were also identified.

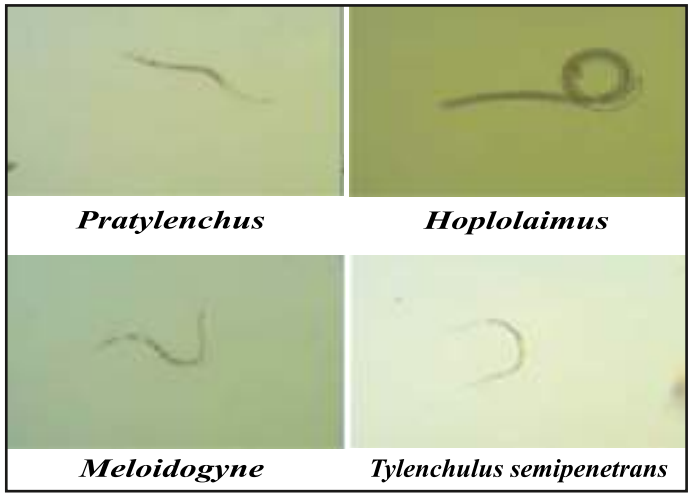


Fig. 79 : Nematode genera identified in Nagpur mandarin

Diversity of plant parasitic nematodes in Kinnow in Rajasthan

Based on the morphological characters, abundance of plant parasitic nematodes belonging to the genus *Tylenchorhynchus* with an average of 208 no. per 250 cc soil was identified in the soil sample. In addition, different free living nematodes such as rhabditids were also identified (Fig. 80).

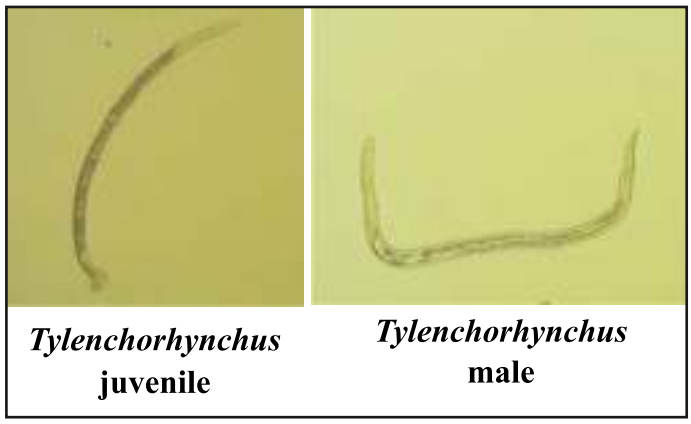


Fig. 80 : Nematode genera identified in Kinnow

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

Isolation and characterization of root exudates from healthy (non-infested) citrus rootstocks

Collection and preparation of root exudates extract for GC-MS analysis

Different citrus rootstocks *viz*., Rough lemon, Rangpur lime, Alemow and Acid lime seedlings were grown in plastic trays under controlled conditions. One year old seedlings of these rootstocks were uprooted and washed gently. They were transferred to 1 litre conical flask separately with 500 ml of sterile distilled root ecudated and kept at 23-25ºC. After every 12 hours the root exudates was collected and stored at 4ºC. This was repeated four times and finally the collected exudated was filtered and used for GC-MS analysis for profiling of the root exudates of each root stock after partitioning with hexane.

GC-MS analysis

GC-MS analysis was carried out using 8890 GC equipped with an automatic liquid injector model 7693A and tandem mass spectrometer model 7000D GC/TQ (Agilent Technologies, United States). The samples were analyzed on a non polar HP-5MS column (30 m × 0.25 mm; 0.25 µm, Agilent Co., United States). The injection volume was 1 µL with flow mode in split control, while the carrier gas flow was set at 1 mL min^{-1} helium. Helium was used as carrier gas at a head pressure of 10 psi. For the analysis, oven temperature was initially held at 40°C for 1 min, thereafter, raised with a gradient of 3°C min^{-1} until it reached 60°C,

and held for 10 min. The temperature was again raised with a gradient of 2°C min^{-1} up to 220°C and held for 1 min. Finally temperature was raised up to 280°C with an increment of 5 °C min^{-1} with total runtime of 111 min. The MS acquisition parameters were as follows: ion source 180°C, electron ionization 70 eV, full scan mode (50-550 mass units), transfer line temperature 280°C, solvent delay 3 min, and EM voltage 1376. The ionization energy was 70 eV with a scan time of 1 s and mass range of 50-550 AMU. Compounds were identified by matching their mass spectra. NIST (National Institute of Standards and Technologies) Mass Spectra Library was used as a reference for identifying each component.

Identification of probable compounds from citrus root exudates

GC/MS analysis of root exudates collected from healthy Rough lemon, rangpur lime, alemow and acid lime revealed an array of chemical compounds comprised of hydro carbons, esters, aldehydes and ketones, alcohols, terpenes and fatty acids (Fig. 81).

In acid lime root exudates, the prevailing compounds identified were Decanedioic acid, bis (2-ethylhexyl) ester (21.76%), Mono (2-ethylhexyl) phthalate, phthalic acid, hept-4yl isobutyl ester (10.60%) and ethanol,2-[2-(4-nonylphenoxy) ethoxy] (9.23%).

In Alemow root exudates, the prevailing compounds identified were Seselin (37.89), dibutyl phthalate (18.42%), phthalic acid, hept-4yl isobutyl ester (8.93%).

In Rough lemon root exudates, prevailing compounds identified were Seselin (20.26%), xanthyletin (17.82%), Cyclopentyl-methyl-phosphinic acid, 2-isopropyl-5-methyl-cyclohexyl ester (8.43%) and 1,3-Bis(1-isocyanato-1-methylethyl)benzene (7.83%).

In Rangpur lime root exudates, the prevailing compounds identified were Methyl 4-azido-4-deoxy-beta-L-xylopyranoside (13.78%), niacinamide (8.28%), propylamine, N,N,2,2 teteramethyl-,N-oxide (6.51%) and n-hexadecanoic acid (5.8%).

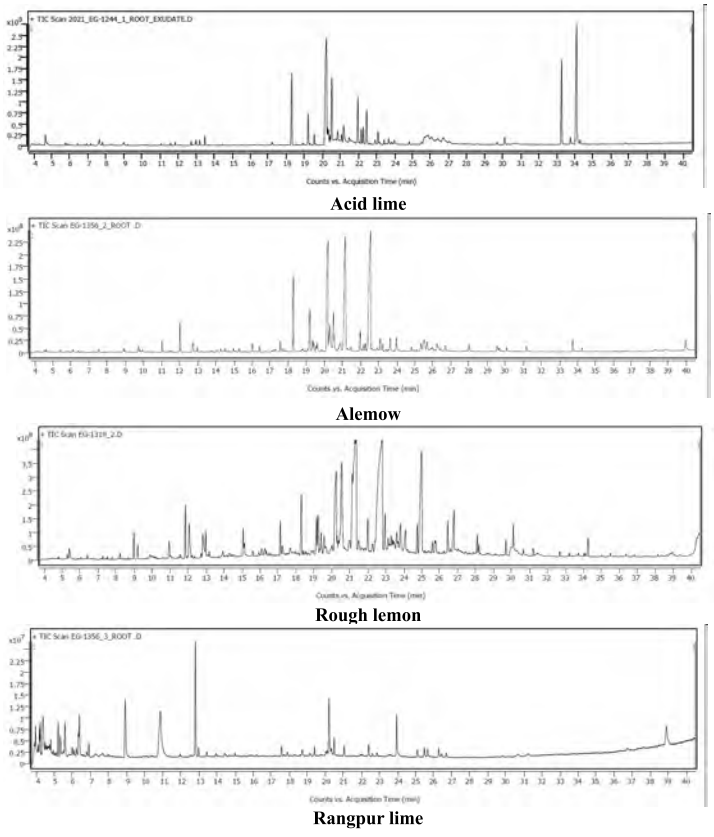


Fig. 81 : Chromatograms of GC/MS profiles obtainted from root exudates of various citrus rootstocks

Histology of citrus roots

Healthy (non-infested) feeder roots were collected from 1-1.5 year old rootstocks *viz*., Rough lemon, Rangpur lime, Alemow and seedlings of Acid lime and fixed in FAA (Formalin Acetic acid). Then the root portions were dehydrated in graded series of ethanol (70-100%), followed by infiltration with xylene with specified time intervals and embedding in paraffin wax. The processed root portions were embedded in the paper boat (made using glossy paper) using paraffin wax to form blocks. These blocks are kept at room temperature for 24h and then subjected to serial transverse sectioning using a rotary microtome at 10 µm to form paraffin wax ribbon (series of sections). These ribbons were affixed on glass slides using adhesive Mayer's albumin. Immediately after this, the glass slides with sections are spread on hot plate at 60ºC for 30 sec and kept for drying at room temperature (25-29ºC) for 4-5 days. After complete drying, the slides were transferred to xylene which aids complete removal of paraffin and put in graded alcohol series (100-30%). The sections are then stained using 1% safranin and 0.5% fast green combination method. Stained slides were cleared in xylene and mounted in DPX mountant and dried overnight at room temperature. Finally, the slides were observed under compound microscope and images were captured (Fig. 82).

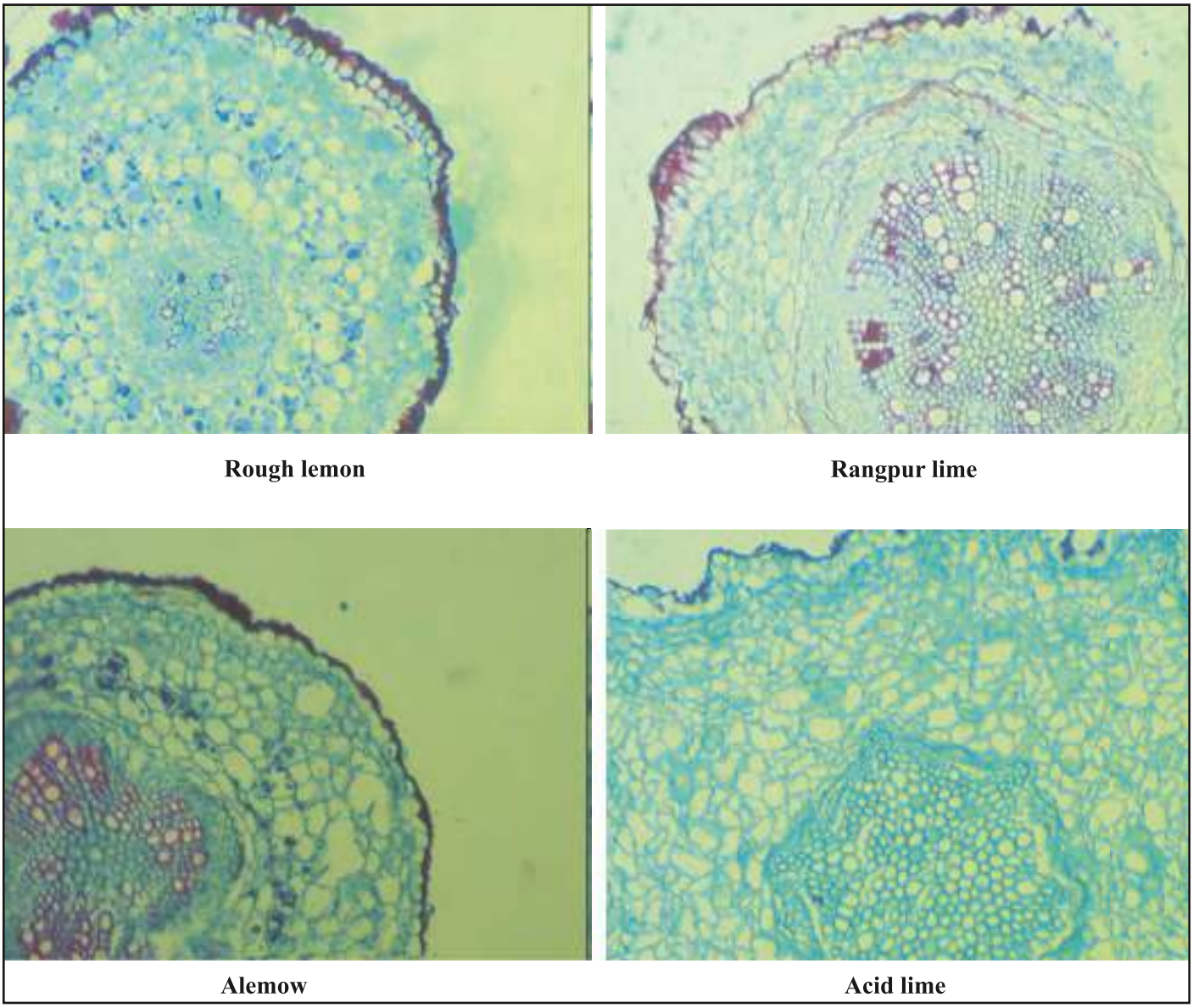


Fig. 82 : Transverse sections of healty roots of various citrus rootstocks

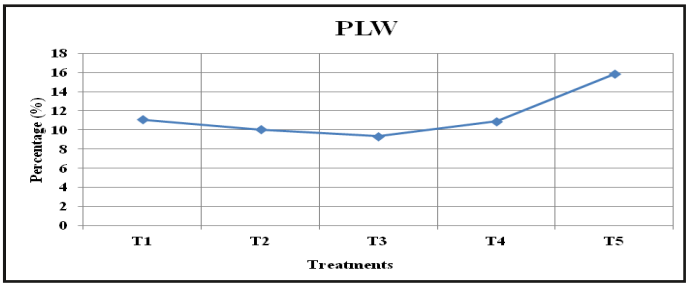
3.4 Post-harvest management and value addition

3.4.1 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

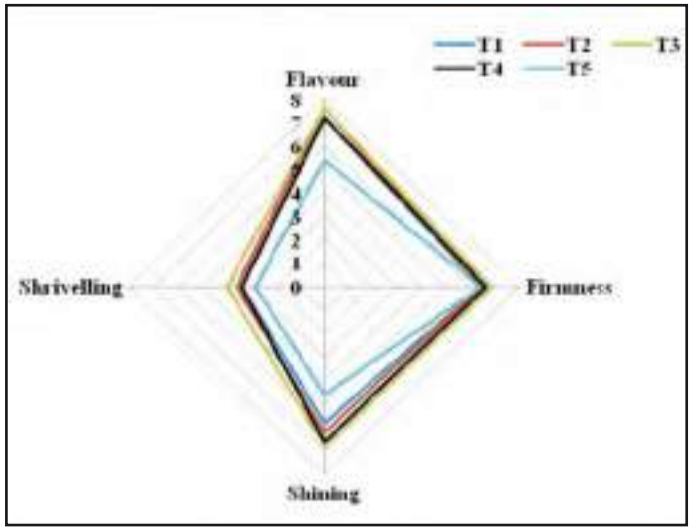
Nagpur mandarin fruits of uniform shape and size sorted, washed and air dried and treated with polysaccharides - Maltodextrin (2%), Methyl cellulose (2%), Carboxymethyl cellulose (2%) and Hydroxypropyl cellulose (2%) concentration with Glycerol as plasticizer (2%) and Cinnamon oil (50 ppm) in distilled water and control. Effects of different polysaccharides on storage ability of Nagpur mandarin were tested. Among the treatments, T_1 and T_2 fruits were coated with maltodextrin and methyl cellulose together with glycerol and cinnamon oil, T_3 and T_4 fruits were treated with polysaccharides carboxymethyl cellulose and hydroxypropyl cellulose together with glycerol and cinnamon oil and T_5 was control. Further, these treated fruits were packed in CFB boxes and stored at ambient condition for 14 days. The physico-chemical response of fruits with respect to different disinfectants was studied.

Among the polysaccharides, Carboxymethyl cellulose had maximum juice recovery (33.54%); lower PLW (9.34%) (Fig.83) and also retained Vitamin C content (20.62 mg/100ml) during the storage.



Where, T_1: Maltodextrin (2%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_2: Methyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_3: Carboxymethyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_4: Hydroxypropyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_5: Control

Fig. 83 : Percent PLW of Nagpur mandarin fruits stored in ambient conditions after 14 days



Where, T_1 : Maltodextrin (2%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_2: Methyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_3: Carboxymethyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_4: Hydroxypropyl cellulose (0.5%) + Glycerol (5%) + Cinnamon oil (50mg/lit); T_5: Control

Fig. 84 : Spider graph of sensory evaluation for Nagpur Mandarin fruits after ambient storage conditions after 14 days

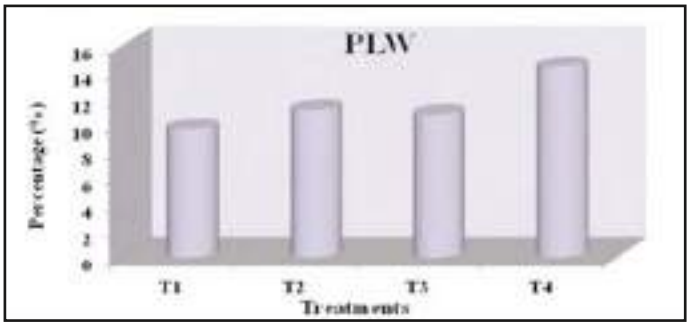
Fig. 84 : Sensory evaluation by panel of judges

3.4.1.2 Effect of protein based edible coating and essential oil on storage ability of Nagpur mandarin fruits

Effects of different proteins based edible coating with essential oil on storage ability of Nagpur mandarin were tested. Nagpur mandarin fruits of uniform shape and size sorted, washed and air dried and treated with proteins with 2% concentration along with glycerol 2% and cinnamon oil

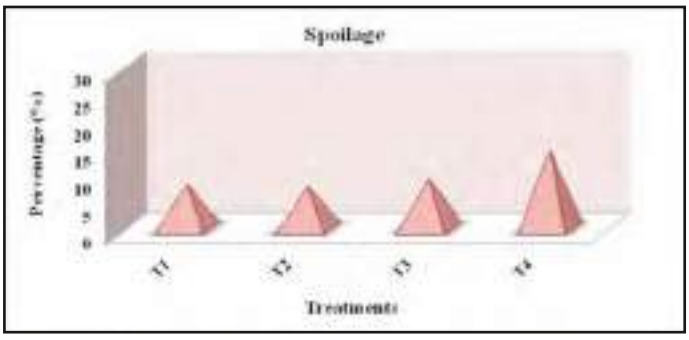
50 ppm in distilled water. Among the treatments, T_1, T_2 and T_3 fruits were coated with sodium caseinate, soy protein and zein protein and T_4 was control. Further, these treated fruits were packed in CFB boxes and stored in ambient condition for 14 days. The physico-chemical response of fruits with respect to different proteins was studied.

Among the proteins tested, fruits coated with sodium caseinate (T_1 treatment) had lower PLW (9.65%) (as shown in Fig. 86), retained Vitamin C content (22.70 mg/100ml) and TSS content (11.46°Brix) during the storage (Table 52). Acidity did not respond to the treatments. As depicted in Fig. 87, the spoilage was found minimum (7.60%) with soy protein treated fruits (T_2 treatment) and highest in control fruits (14.40%) after 14 days of storage in ambient conditions. The respiration rate of fruits in response to various treatments is depicted in Fig. 88.



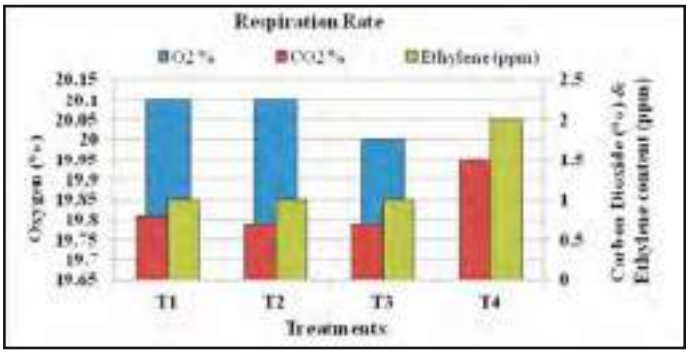
Where, T_1:Sodium Caseinate (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_2:Soy Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_3:Zein Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_4:Control

Fig. 86 : Effect of protein based edible coating and essential oil on PLW of Nagpur mandarin fruits stored in ambient conditions after 14 days



Where, T_1 : Sodium Caseinate (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_2 : Soy Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_3 : Zein Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_4 : Control

Fig. 87 : Effect of protein based edible coating and essential oil on spoilage % of Nagpur mandarin fruits stored in ambient conditions after 14 days



Where, T_1:Sodium Caseinate (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_2:Soy Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_3:Zein Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit); T_4:Control

Fig. 88 : Effect of protein based edible coating and essential oil on respiration rate of Nagpur mandarin fruits stored in ambient conditions after 14 days

Table 52 : Effect of protein based edible coating and essential oil on storage ability of Nagpur mandarin fruits in ambient condition after 14 days

Treatments	TSS (° B)	Acidity (%)	Vit. C (mg/100ml)
T_1= Sodium Caseinate (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit)	11.46	0.47	22.70
T_2= Soy Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit)	11.02	0.50	21.60
T_3= Zein Protein (2%) + Glycerol (2%) + Cinnamon oil (50mg/lit)	11.12	0.45	20.00
T_4= Control	10.00	0.60	19.10
CD (P=0.05)	**1.16**	**0.12**	**2.52**

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

3.4.2.1 Study the impact of heat pasteurization and thermo-sonication on biochemical parameters of Nagpur mandarin juice

Orange juice is the predominant juice processed by the beverage industry worldwide. Although thermal processing remains the most widely employed pasteurization technique, there is growing interest in the development of alternative preservation techniques that result in minimal changes in organoleptical and nutritional properties. Sonication is considered to be an emerging Non-thermal processing technology 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 have desirable physical and mechanical effects on samples and prevent them from microbial spoilage.

The experiment is carried out to study the effect of heat pasteurization and thermo-sonication at the various temperatures ranges on physico-chemical as well as biochemical parameters. Among them, limonin content and Pectin Methylesterase (PME) activity in Nagpur mandarin juice were studied.

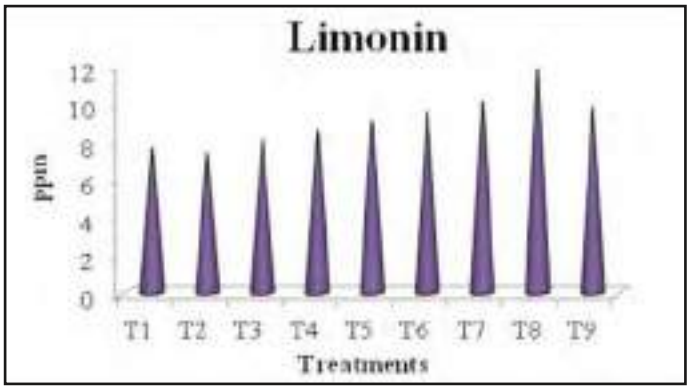
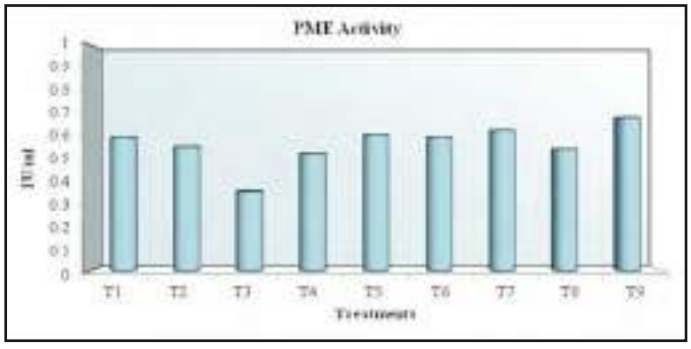


Fig. 89 : Limonin content of thermo-sonicated and pasteurized Nagpur mandarin juice after 7 days of storage

Nagpur mandarin juice thermo-sonicated at 55°C for 20 min *viz.*, T_2 treatment showed better results in terms of limonin and T_3 treatment *viz.,* juice thermo-sonicated at 60°C for 15 min showed better PME activity among all treatments. The physico-chemical and biochemical parameters are also get influenced with the treatment during the experimentation.

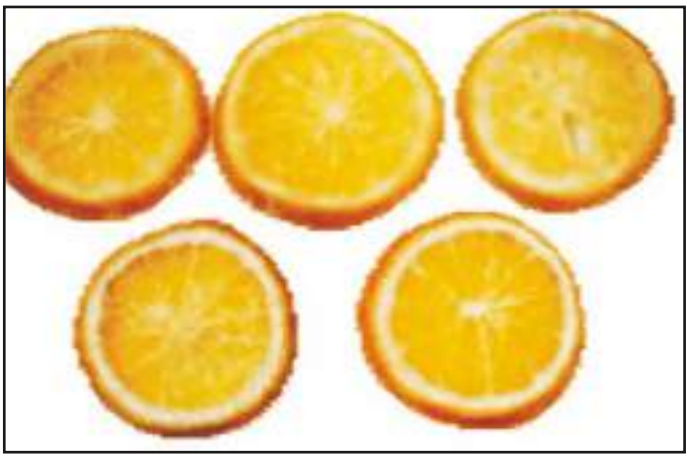


Where, T_1 : Sonication at 50°C for 25 min; T_2 : Sonication at 55°C for 20 min; T_3 : Sonication at 60°C for 15 min; T_4 : Sonication at 63°C for 10 min; T_5 : Pasteurization at 65°C for 80 sec; T_6 : Pasteurization at 75°C for 60 sec; T_7 : Pasteurization at 85°C for 40 sec; T_8 : Pasteurization at 95°C for 20 secand T_9 : Control

Fig. 90 : Pectin Methylesterase (PME) activity of thermo-sonicated and pasteurized Nagpur mandarin juice after 7 days of storage

3.4.2.2 Osmotically dehydrated candy from sweet orange

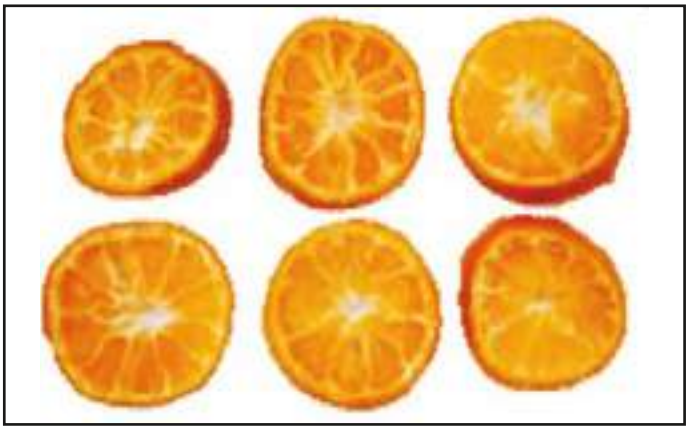
Sweet orange was collected from the orchard and taken to processing laboratory of ICAR-CCRI. Sweet orange cv. Mosambi fruits were thoroughly washed to remove dirt and pesticides residues and allowed them to dry completely. Blanched the fruit at 54^0C and let them dry. Fruit was cut in slices about 3mm to 5mm thick and dipped in the sugar syrup of 70^0B with continuous agitation for 2 days and then the brix was maintained at 70^0B for 12 days, candy was removed from syrup and washed it. Candy was dried in tray oven at room temperature and vacuum packed. Physico-chemical analysis and micro-flora count in sweet orange candy was analysed. The microbiological evaluation of sweet orange candy was done by serial dilution method and expressed in CFU/g. No microbial growth was observed up to 90 days storage. The physico-chemical properties of sweet orange candy remained unchanged indicating the entrepreneurship potentiality of the product.



Sweet Orange Candy (Osmotically Dehydrated)

3.4.2.3 Osmotically dehydrated candy from Nagpur mandarin

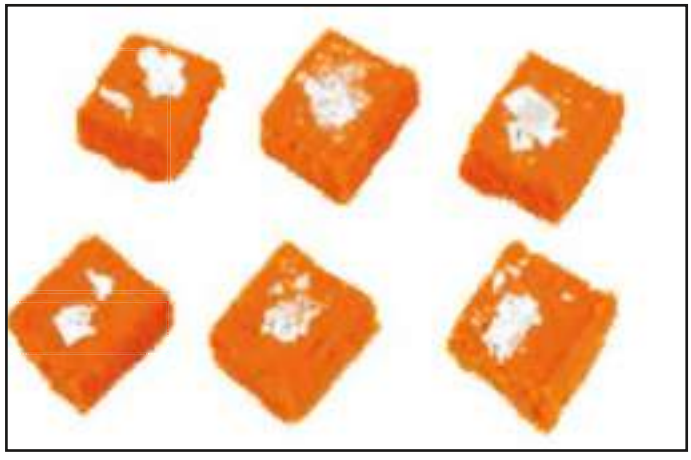
Nagpur mandarin was collected from the orchard was taken to processing laboratory of ICAR-CCRI. Nagpur mandarin fruit were thoroughly washed to remove dirt and pesticides residues and allowed them to dry completely. Blanched the fruit at 54^{0}C and let them dry. Fruit was cut in slices about 3 mm to 5 mm thick and dipped in the sugar syrup of 70^{0}B with continuous agitation for 2 days and then the brix was maintained at 70^{0}B for 12 days, candy was removed from syrup and washed it. Candy was dried in tray oven at room temperature and vacuum packed. Physico-chemical analysis and micro-flora count was analysed. The microbiological evaluation was conducted after preparation of osmotically dehydrated Nagpur mandarin candy. Total aerobic count was recorded and expressed in CFU/g. No microbial growth was observed after evaluation of 90 days.



Nagpur mandarin candy (Osmotically Dehydrated)

3.4.2.4 Low calories Santra Barfi from Nagpur Mandarin

The product is prepared from the Nagpur mandarin juice. Filtered milk is pasteurized at 90^0 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, keep in cool and dry place. The microbiological evaluation was done by serial dilution method and expressed in CFU/g. No microbial growth was observed up to 90 days storage.



Low calorie Santra Barfi

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

Bio-active compounds of citrus varieties

In the present work, a comparative study among the different accessions grown under diverse climate conditions was carried out. 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 Citrus latipes, Citrumello and Citrus pennivesiculata etc have been screened this year have been screened in successive years and this year also. 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.

3.4.3.1 Phytochemical analysis of *Citrus latipes*, Citrumello and *Citrus pennivesiculata*

The limonin content in *Citrus latipes* was found to be 11.53 ppm which was highest among the varieties assessed while Citrumello and *Citrus pennivesiculata* contained 8.09 ppm and 9.48 ppm respectively as depicted (Fig. 91). In varieties analyzed, total phenol content in juice was higher in *Citrus latipes* (13.938 mg GAE L^{-1}) and Citrumello (13.463 mg GAE L^{-1}) as compared to *Citrus pennivesiculata* 9.075 mg GAE L^{-1}) which can be correlated with higher antioxidants potential (Fig. 92). However carotenoid content in juice of *Citrus latipes*, Citrumello and *Citrus pennivesiculata* contain 0.585 mg/100ml, 0.141 mg/100ml and 0.200 mg/100ml respectively.

In juice, total phenol content was higher in Khasi Papeda (15.413 mg GAE L^{-1}), Sathgudi (13.910 mg GAE L^{-1}), Kichili (12.030 mg GAE L^{-1}) and Early Valencia (11.060

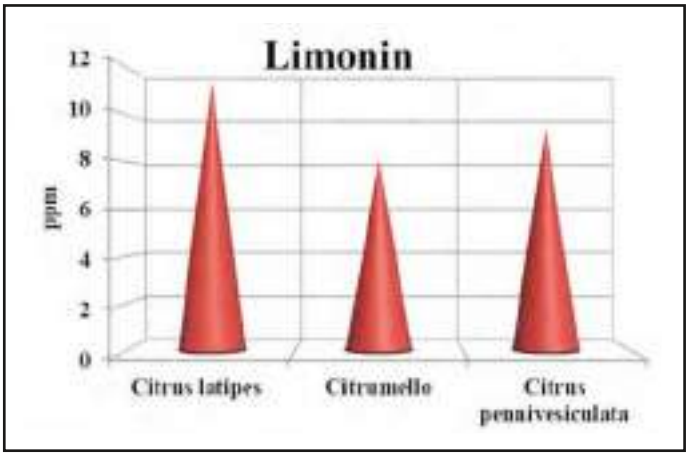


Fig. 91 : Comparison of Biochemical parameters of *Citrus latipes*, Citrumello and *Citrus pennivesiculata*

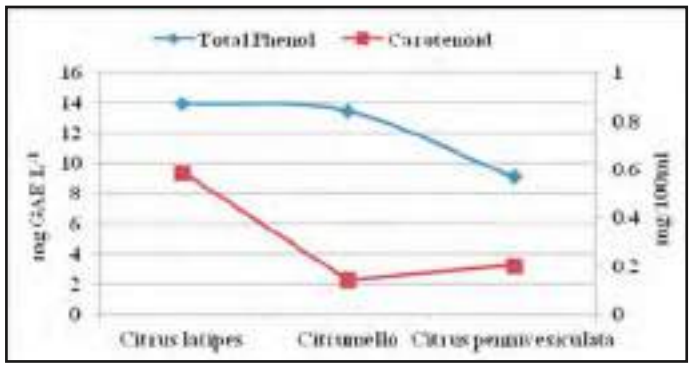


Fig. 92 : Phytochemical analysis of *Citrus latipes*, Citrumello and *Citrus pennivesiculata* collected from West Garo Hills, Nokrek, Tura, Meghalaya

mg GAE L^{-1}) respectively which can be correlated with higher antioxidants potential. However, Early Valencia, Sathgudi, Khasi Papeda and Assam lemon contain more carotenoid (0.262 mg/100ml), (0.163 mg/100ml), (0.116 mg/100ml) and (0.100 mg/100ml) respectively in juice.

Bioactive compounds present in Mandarin, Sweet orange, Lemon, Gajanimma and Khasi papeda

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 *Citrus latipes,* Citrumello and *Citrus pennivesiculata* 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.

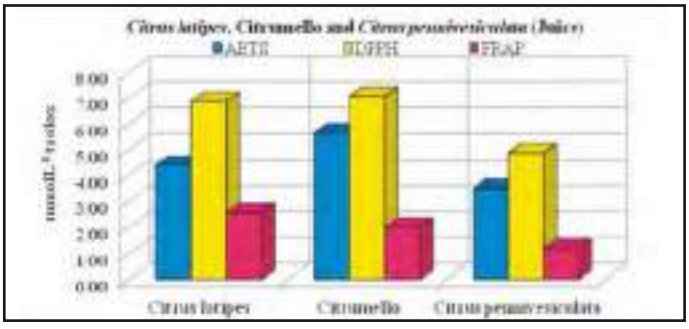


Fig. 93 : Antioxidant capacity of *Citrus latipes*, Citrumello and *Citrus pennivesiculata* juice

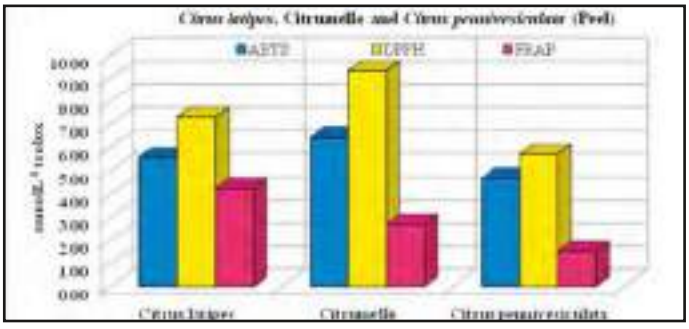


Fig. 94 : Antioxidant capacity of *Citrus latipes*, Citrumello and *Citrus pennivesiculata* peel

In case of antioxidants potential, radical scavenging capacity was found highest in peels of varieties in comparison with its respective juice as depicted in Fig. 87 and 88. Citrumello show highest ABTS assay 5.66 mmol L^{-1}trolox, DPPH assay 7.07 mmol L^{-1}trolox, in juice and ABTS and DPPH values of 6.44 mmol L^{-1}trolox and 9.33 mmol L^{-1}trolox in peels while *Citrus latipes* show highest FRAP assays values of 2.56 mmol L^{-1}trolox and 4.24 mmol L^{-1}trolox in juice and peel analyzed respectively (Fig. 93, 94).

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, etc. Hesperidin bioflavonoid is the most active bioflavonoid in citrus fruits and shows 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 Natural hybrid and *Citrus macroptera*. Fruits juice was injected in HPLC (Agilent 1260 Infinity model) and quantified. The hesperidin content in fruits of Natural hybrid and *Citrus macroptera* was found to be 20.23 ppm, and 64.44 ppm respectively (Fig. 95 and 96). Naringin content in range Natural hybrid was 20.21 ppm.

Fig. 95 : Chromatogram of Hesperidin and other flavonoids of Natural hybrid

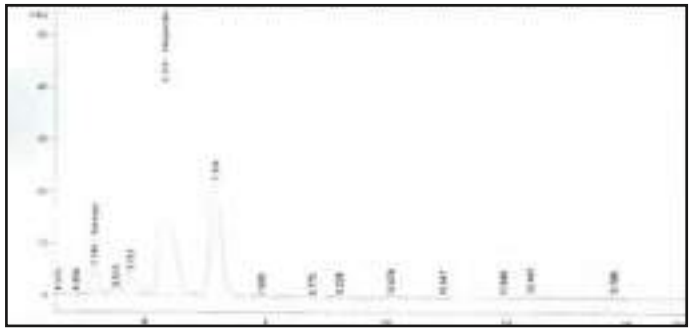


Fig. 96 : Chromatogram of Hesperidin and other flavonoids of *Citrus macroptera*

Quantification of amino acids by High Performance Liquid Chromatography

Amino acid content of fruit and fruit derived foods is studied intensely because of the contribution to nutritional value, aroma, taste and health-promoting effects and their possible use as markers of origin and authenticity. Amino acid profile can provide alternative sources of feeds of citrus varieties offering high quality nutrients and also energy.

An attempt was made to do the profiling of Amino acid in different citrus varieties. For this, different varieties namely *viz.* include; Citrumelo and *Citrus pennivesiculata* fruit were collected and analyzed for amino acids (aspartic acid, glutamic acid, serine, histidine, glycine, threonine, alanine, arginine, tyrosine, cystine, valine, methionine, phenylalanine, isoleucine, leucine, lysine and proline) content by high performance liquid chromatography. The

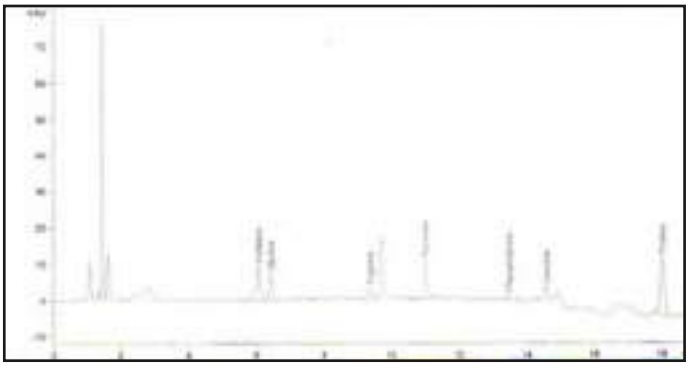


Fig. 97 : Chromatogram of amino acids of Citrumelo juice in high performance liquid chromatography

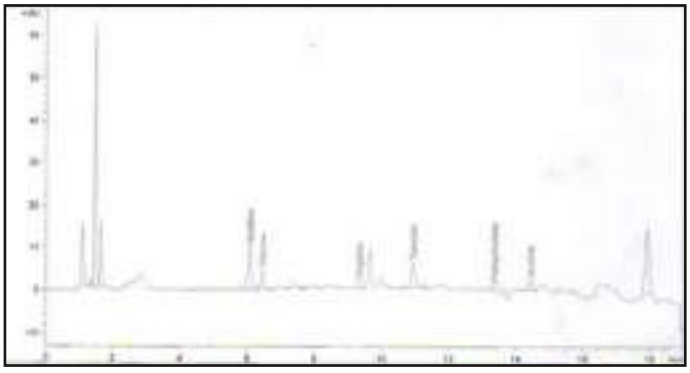


Fig. 98 : Chromatogram of amino acids of *Citrus pennivesiculata* juice in high performance liquid chromatography

amino acids which were predominantly present in higher concentration are Histidine, Glycine, Phenylalanine, Arginine, Isoleucine, Proline and Tyrosine. The remaining amino acids were found in low concentration (Fig. 97 and 98). The results obtained were approximately in the same trend.

3.4.4 Phytochemical characterisation and nutritional profiling of germplasm diversity of citrus species existing in North East region (DBT Project)

Estimation of polyphenols; organic acids; flavonoids; carotenoids; limonoids of citrus fruits in Northeast Indian region are to be exploited and also other potent phytoconstituents for diversified commercial uses. As it is start of the project, varieties namely *Citrus hystrics*, Chase rough lemon (*Citrus jambhiri*), Elaichi lemon (*Citrus limon*), Jora Tenga (*Citrus medica*) were collected from North east hill region for the analysis of flavonoids, ascorbic acid and organic acids.

3.4.4.1 Identification and quantification of flavonoids of germplasm diversity of citrus spp. existing in NE India

Flavonoids are a group of pigments contained in plants and they are responsible for colouration and therefore are an important part of the human diet. All the flavonoids obtained in citrus sp. can be classified as flavonones, flavones and flavonols. Flavonoids are a widely distributed group of polyphenolic compounds with many health-related properties like anti-cancer, anti-viral, anti-inflammatory activities, which are based in their antioxidant activity. The flavonoids have strong inherent ability to modify the body's reaction to allergens, viruses and carcinogens. Flavanone chemical structures are specific for every species, which renders them markers of adulteration in commercial juices. The north-eastern citrus varieties namely *Citrus hystrics*, Chase rough lemon (*Citrus jambhiri*), Elaichi lemon (*Citrus limon*) and Jora Tenga (*Citrus medica*) were assessed for flavonoid glycosides mainly naringin and hesperidin and found that hesperidin (11.45-43.50 ppm) is the predominant flavonoid

than naringin (4.77-18.05 ppm) and are present in varying concentration (Fig. 99-102).

Fig. 99 : Chromatogram of Flavonoids of *Citrus hystrics* juice in high performance liquid chromatography

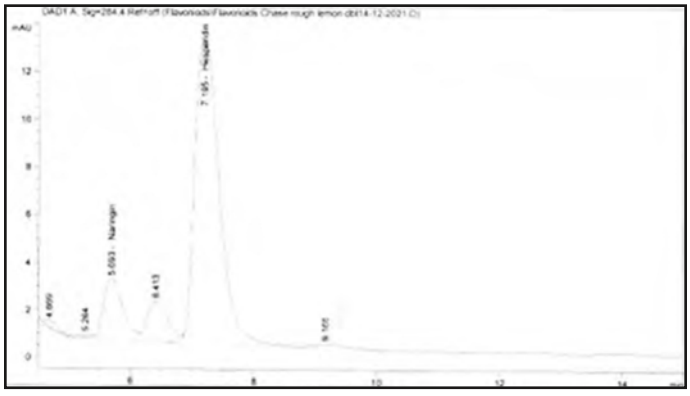


Fig. 100 : Chromatogram of Flavonoids of Chase rough lemon (*Citrus jambhiri*) juice in high performance liquid chromatography

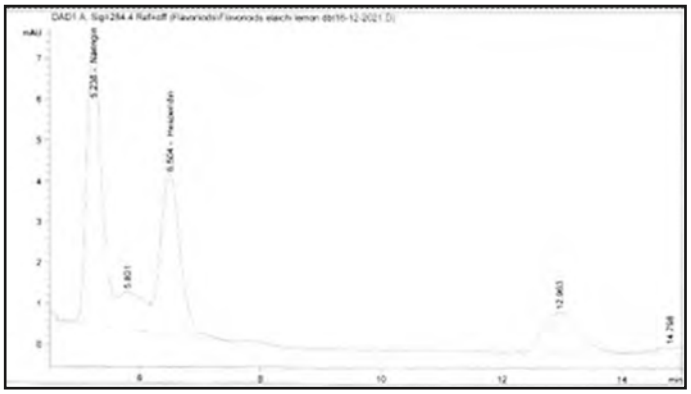


Fig. 101 : Chromatogram of Flavonoids of Elaichi lemon (*Citrus limon*) juice in high performance liquid chromatography

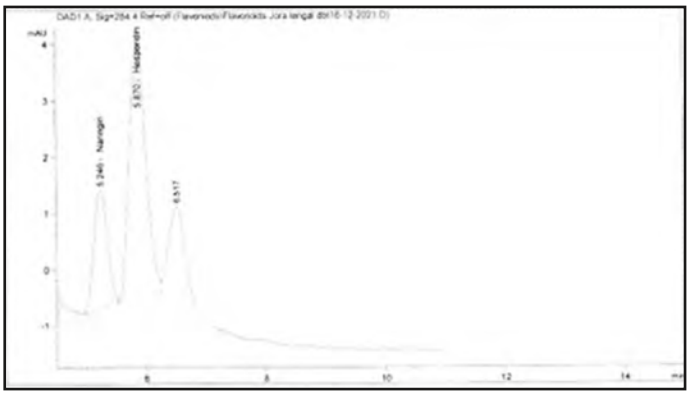


Fig. 102 : Chromatogram of Flavonoids of Jora Tenga (*Citrus medica*) juice in high performance liquid chromatography

3.4.4.3 Ascorbic acid of germplasm diversity of citrus sp. collected from in NE India

Citrus fruits and juices are rich in several types of bioactive compounds such as ascorbic acid, antioxidants, carotenoids, etc. that are important to human nutrition. These constituents are also known as secondary metabolites. These are essentially required for the existence of life confers extra health benefits against pathogens. The consumption of Citrus fruits or juice is inversely associated with several diseases because of its abundant secondary metabolites. Their antioxidant activity and related benefits derive not only from flavonoids, carotnoids and other phytochemicals but also from vitamin C i.e. ascorbic acid. The north-eastern citrus varieties assessed were found to be good source of ascorbic acid content. Presence of ascorbic acid was assessed by High Performance Liquid Chromatography (HPLC) which varies with the different

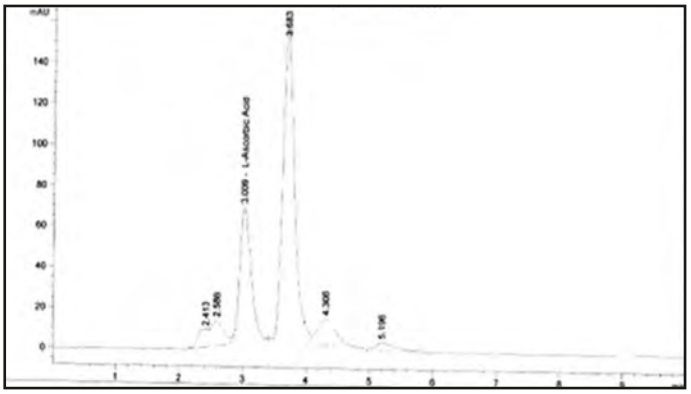


Fig. 103 : Chromatogram of Ascorbic acid of *Citrus Hystrics* juice in high performance liquid chromatography

varieties of citrus. Ascorbic acid content in fresh juice of Citrus hystrics and Chase rough lemon (*Citrus jambhiri*) was 39.90 mg/100ml and 36.67 mg/100ml whereas in Elaichi lemon (*Citrus limon*) and Jora Tenga (*Citrus medica*) juice; ascorbic acid content was 32.76 mg/100 ml and 32.31 mg/100ml respectively (Fig. 103-106).

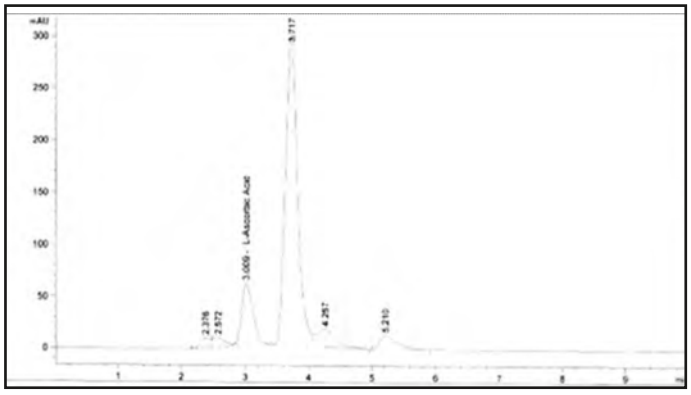


Fig. 104 : Chromatogram of Ascorbic acid of Chase rough lemon (*Citrus jambhiri*) juice in high performance liquid chromatography

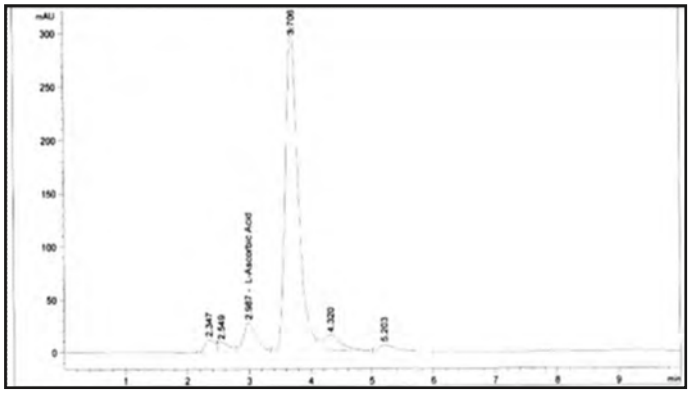


Fig. 105 : Chromatogram of Ascorbic acid of Elaichi lemon (*Citrus limon*) juice in high performance liquid chromatography

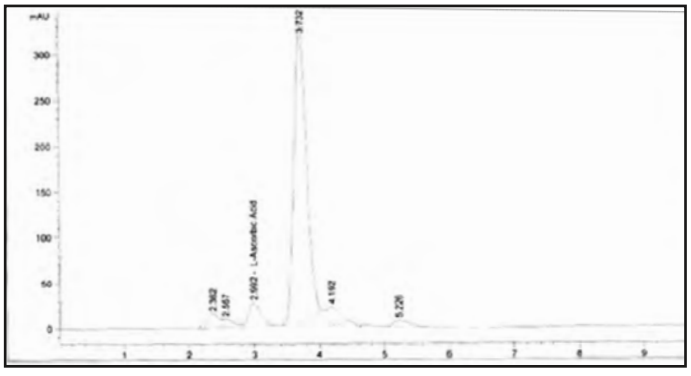


Fig. 106: Chromatogram of Ascorbic acid of Jora Tenga (*Citrus medica*) juice in high performance liquid chromatography

3.4.4.5 Estimation of Organic acids of germplasm diversity of citrus varieties collected from North-eastern hill region

Citrus fruits 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. 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

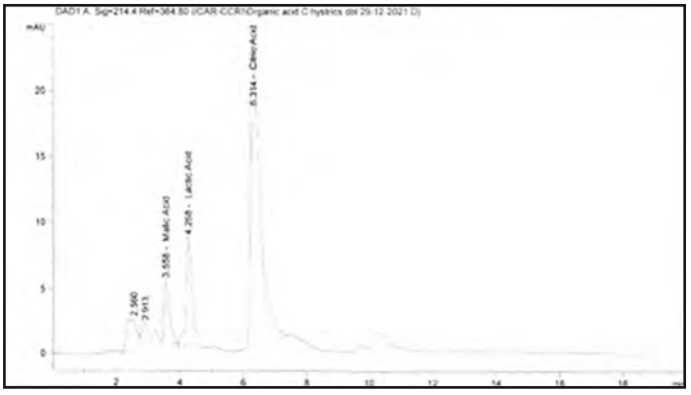


Fig. 107: Chromatogram of Organic acids of *Citrus hystrics* juice in high performance liquid chromatography

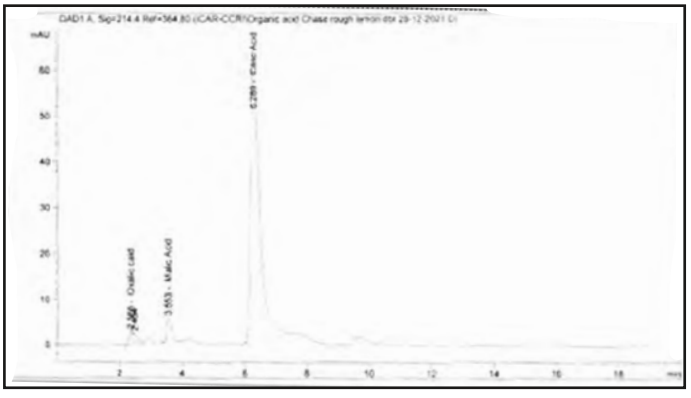


Fig. 108 : Chromatogram of Organic acids of Chase rough lemon (*Citrus jambhiri*) juice in high performance liquid chromatography

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 agro climate (Fig. 107- 110).

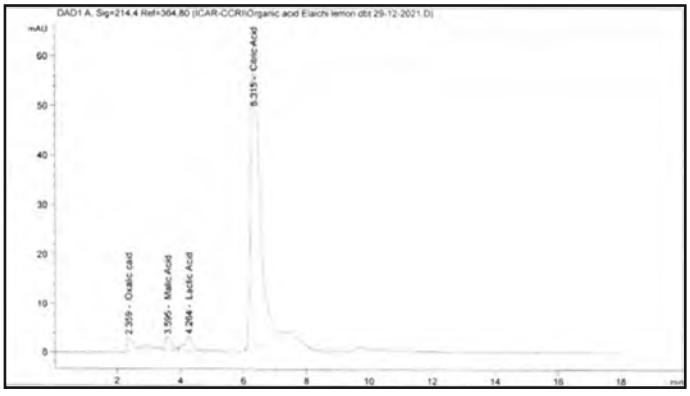


Fig. 109 : Chromatogram of Organic acids of Elaichi lemon (*Citrus limon*) juice in high performance liquid chromatography

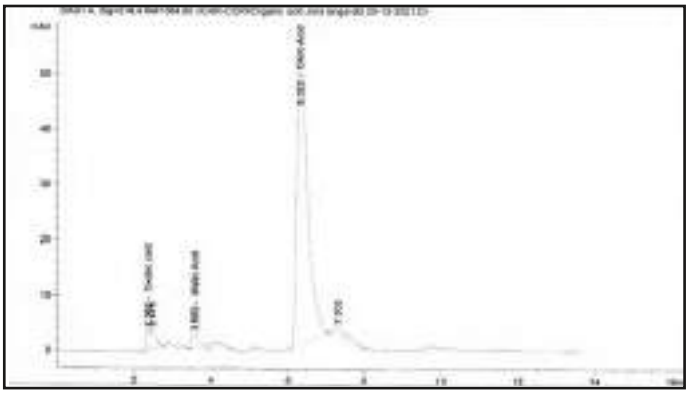


Fig. 110 : Chromatogram of Organic acids of Jora Tenga (*Citrus medica*) juice in high performance liquid chromatography

3.4.5 Development of high end value added products from underutilized/commercial citrus fruits and its by-products

3.4.5.1 Standardization and development of low sugar jelly from Nagpur mandarin and Assam lemon

Reducing the sugar level in jelly products creates texture problems in the final products. So replacing the sugar level in the jelly is tricky one to perform. Fructose oligosaccharide (FOS) is one of the low calorie sweetener used for sugar replacement in food products. Low sugar products are gaining popularity because of its low calorific value and its nutritional health benefits.

The low sugar jelly from Nagpur mandarin and underutilized Assam lemon was prepared. The low sugar jelly from both fruits was prepared with different treatments and different combinations. The 50% juice was taken for preparation of low sugar jelly for both the fruits. Nagpur mandarin low sugar jelly was prepared with addition of Fructose oligosaccharide (FOS), sugar, food grade pectin and 25 ppm sodium benzoate as preservative. The TSS of low sugar Nagpur mandarin jelly was maintained to 54.3°brix and pectin content 0.9%. In treatments, T_1 to T_6 the Fructose oligosaccharide content varies from (0, 2, 4, 6, 8 & 10%) and sugar content (0, 5, 10, 15, 20 & 25%). The treatment T_4 (6% Fructose oligosaccharide + 15% Sugar) responded well and shows highest overall acceptability (8.13) in sensory evaluation. On the basis of highest sensory score the sample T_4 further used for evaluation of physic-chemical characteristics which includes pH (3.45), Acidity (1.98%), Vitamin C (18.7 mg/100g), colour values (L- 4.18, a- 3.84, b- 5.60).

Assam lemon low sugar jelly was prepared with addition of Fructose oligosaccharide (FOS), sugar, food grade pectin and 25 ppm sodium benzoate as preservative. The TSS of

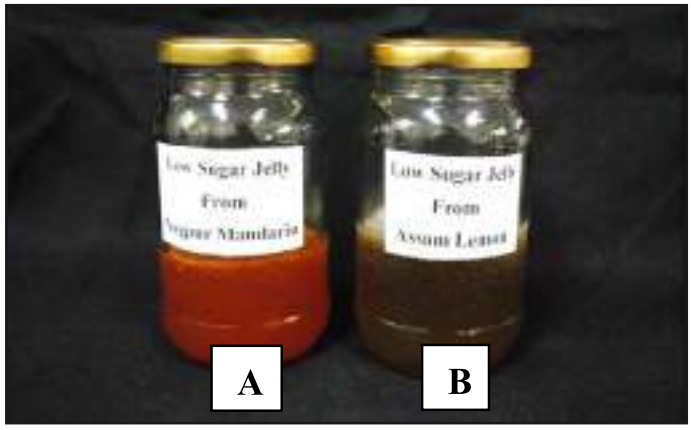


Fig. 111 : Low Sugar Jelly
A) Nagpur mandarin B) Assam lemon

low sugar Assam lemon jelly was maintained to 53.7°brix and pectin content 0.7%. In treatments, T_1 to T6 the Fructose oligosaccharide content varies from (0, 3, 6, 9, 12 & 15%) and sugar content (0, 7, 14, 21, 28 & 35%). The treatment T_5 (12% Fructose oligosaccharide + 28% Sugar) responded well and shows highest overall acceptability (7.91) in sensory evaluation. On the basis of highest sensory score the sample T5 further used for evaluation of physico-chemical characteristics which includes pH (2.82), Acidity (3.90%), Vitamin C (12.5 mg/100g), colour values (L- 1.29, a- (-0.29), b- (-0.61).

3.4.5.2 Standardization and development of nutri-jelly with natural sugars from Assam Lemon (*Citrus limon*)

The Assam lemon (*Citrus limon*) is one of the most important crops of Assam and other parts of North East region of India. It is proud beholder of number of useful characteristics like aroma, flavor and medicinal value. The nutri-jelly was prepared by replacing sucrose with natural sugars like jaggery and honey. The nutri jelly from Assam Lemon was prepared with different treatments and different combinations. The 45% juice was taken for preparation of nutri-jelly. The Assam lemon nutri-jelly was prepared with addition of jaggery, food grade pectin and 25 ppm sodium benzoate as preservative. In treatments, T_1 to T_6 the jaggery content varies from (0, 15, 30, 45, 60 & 75%). The pectin content was maintained as 0.8% in all the treatments. The treatment T_4 (45% jaggery) responded well and shows highest overall acceptability (8.35) in sensory evaluation. On the basis of highest sensory score the sample T_4 further used for evaluation of physic-chemical characteristics which includes pH (3.10), Acidity (3.84%), Vitamin C (11.7 mg/100g), TSS (51.3obrix), Total phenol content (1.53 mg GAE/g), colour values (L- 1.11, a- (-0.05), b- (-0.97).

Fig. 112 : Assam Lemon nutri-jelly with natural sugars A) Jaggery B) Honey

The nutri-jelly with addition of honey was also standardized. In treatments, T_1 to T_6 the honey content varies from (0, 15, 30, 45, 60 & 75%). The pectin content was maintained as 0.8% in all the treatments. The treatment T_4 (45% honey) responded well and shows highest overall acceptability (8.24) in sensory evaluation. On the basis of highest sensory score the sample T_5 further used for evaluation of physico-chemical characteristics which includes pH (2.65), Acidity (3.12%), Vitamin C (10.9 mg/100g), TSS (52.5°brix), Total phenol content (1.22 mg GAE/g), colour values (L- 1.7, a- (-0.09), b- (-1.27).

3.4.5.3 Standardization and development of nutri-jelly with blends of multi citrus fruits

The multi citrus fruits nutri-jelly was prepared in different combinations. In treatments, T_1 to T_5, the concentration of pummel juice (30%), pectin (0.8%) and TSS (66.5°brix) was kept constant. The juice of other citrus fruits varies as per combinations; T_1 (Pummelo + galgal 15%), T_2 (Pummelo + TM33 15%), T_3 (Pummelo + Valencia late 15%), T_4 (Pummelo + sweet lime 15%), T_5 (Pummelo +

Fig. 113 : Nutri-jelly with multi citrus fruit blend; a) Pummelo+TM33 b) Pummelo+ Galgal c) Pummelo + Valencia late d) Pummelo + Citron-2 e) Pummelo + Sweet lime

citron-2 15%). The Physico-chemical characteristics and sensory evaluation of prepared samples were carried out and depicted in Table 53.

3.4.5.1 Standardization and development of Herbal lemon jelly and Acid lime jelly

The herbal lemon jelly was prepared from Assam lemon. The prepared herbal jelly includes lemon juice (40%), extract of Ginger (0.5%), Lemongrass (0.3%), Basil leaves (0.3%) and mint leaves (0.3%). The pectin concentration was 0.8% and TSS maintained about 66.3°brix.

The Acid lime jelly was prepared from Sai Sarbati variety of acid lime. The prepared acid lime jelly includes lime juice (40%) and extract of Ginger (0.5%). The pectin concentration was 0.8% and TSS maintained about 67.3°brix. The physico-chemical characteristics and sensory evaluation was carried out and depicted in Table 54.

Standardization and development of functional pasta from polyphenol enriched pummelo peel powder

A pasta product from semolina durum or common wheat flour is one of the most popular cereal products and can be suitable food matrix for enrichment with functional ingredients. The functional pasta prepared from polyphenol enriched pummelo peel powder in different combinations (0, 3, 6, 9 and 12%) along with semolina, water and starch. Among all the samples T_2 (3% addition of pummelo peel powder) responded well in sensory parameters. The cooking qualities (cooking time, cooking loss, weight increase) and sensory evaluation of functional pasta was carried out and depicted in Table 55.

Fig. 114 : A) Herbal Lemon Jelly B) Acid Lime Jelly

Fig. 115 : A) Pummelo Peel Powder B) Functional pasta fortified with Pummelo peel powder

Table 53 : Physico-chemical characteristics and sensory evaluation of nutri-jelly with blends of multi citrus fruits

Treatments	Acidity (%)	pH	Vitamin C (mg/100g)	Colour			Overall acceptability
				L	a	b	
T_1	1.76	3.46	20.9	0.84	-0.06	-0.28	7.76
T_2	0.98	3.88	21.3	0.19	-0.08	-0.22	7.45
T_3	1.34	3.85	28.0	1.33	-0.19	-0.80	7.50
T_4	1.60	3.40	24.7	0.67	0.08	0.21	8.10
T_5	2.62	2.98	18.9	0.90	0.01	0.36	7.92

Table 54 : Physico-chemical characteristics and sensory evaluation of Herbal lemon jelly and Acid lime jelly

Products	Acidity (%)	pH	Vitamin C (mg/100g)	Colour			Overall acceptability
				L	a	b	
Herbal lemon jelly	2.68	2.83	11.9	1.7	-0.09	-1.27	8.10
Acid lime jelly	2.81	2.90	12.5	1.01	-0.18	-0.23	7.85

Table 55 : Cooking qualities and sensory evaluation of functional pasta

Treatments	Cooking qualities and sensory evaluation of functional pasta			
	Cooking time (min)	Cooking loss (%)	Weight increase (%)	Overall acceptability
T_1	5.9	6.30	105.28	7.82
T_2	6.2	6.30	108.11	8.15
T_3	6.3	6.50	103.41	7.66
T_4	6.4	7.02	107.22	7.02
T_5	6.4	7.16	104.92	6.47

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 third year of the project (2021), impact of planting materials purchased from CCRI and also the impact of advisories, technologies and package of practices on the production and income of farmers of Vidarbha were assessed.

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. But in 2021 only Wardha district could be covered in the study. So randomly selected, 100 citrus growers of Wardha district were the respondents for 2021 year.

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 due to the second wave and prevailing conditions of global pandemic Covid-19. Trends in citrus production and income generated from citrus cultivation were compared of farmers who had purchased planting materials from CCRI with those who had purchased from local nurseries. The change in production and income of farmers who purchased planting materials from CCRI and used CCRI technology were also reported.

3.5.1.1 Trend in annual income based on source of planting materials

The farmers who had purchased CCRI planting materials of Nagpur mandarin reported to obtain an average annual income of Rs.8,22,203.39/ha/yr, 5 years ago which increased to Rs.10,57,627.1/ha/yr, 3 years ago from the year of study. Those with non-CCRI planting materials reported a lesser average annual income of Rs.62,1875/ha/yr, 5 years ago which increased to Rs.81,1250/ha/yr, 3 years ago. So an increase of

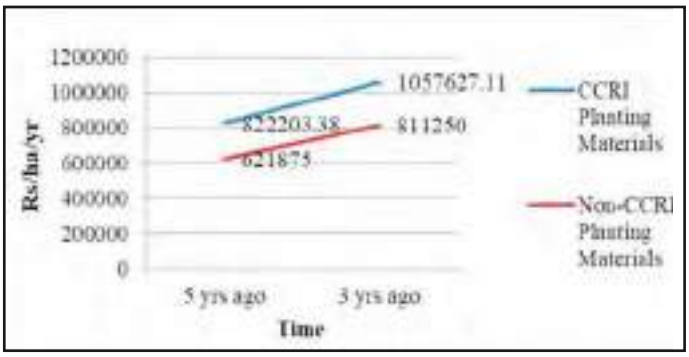


Fig. 116 : Comparative trend in annual income generated from Nagpur mandarin orchards having CCRI and Non-CCRI planting materials in Wardha over the past 5 years

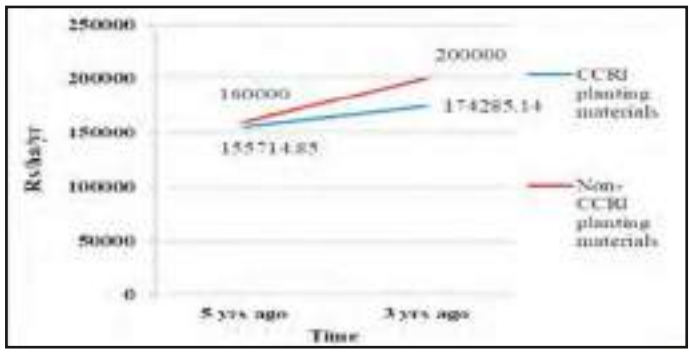


Fig. 117: Comparative trend in annual income generated from sweet orange orchards having CCRI and Non-CCRI planting materials in Wardha over the past 5 years

Rs.2,35,423.71/ha/yr and Rs.1,89,375 / ha /yr was reported among both categories of farmers (Fig. 116).

The farmers who had purchased CCRI planting materials of sweet orange reported to obtain an average annual income of Rs.1,60,000/ha/yr, 5 years ago which increased to Rs.2,00,000/ha/yr, 3 years ago from the year of study. Though there was a decrease in production but due to rise in market prices of sweet orange, farmers had an increase in income. Those with non-CCRI planting materials reported a lesser average annual income of Rs.1,55,714.85/ha/yr, 5 years ago which increased to Rs.1,74,285.14/ha/yr, 3 years ago. So an increase of Rs.40,000/ha/yr and Rs.18,570.29 / ha/yr was reported among both categories of farmers (Fig. 117). Hence it was revealed that CCRI sweet oranges due to better quality, lesser cost of cultivation involved in lesser incidence of pest and diseases gave farmer's better remuneration than those having non-CCRI plants.

The farmers who had purchased CCRI planting materials of acid lime reported to obtain an average annual income of Rs. 1,62,500/ha/yr, 5 years ago which increased to Rs. 2,07,500/ha/yr, 3 years ago from the year of study. Those with non-CCRI planting materials reported a lesser average annual income of Rs. 1,60,000/ha/yr, 5 years ago which increased to Rs. 1,90,000/ha/yr, 3 years ago. So an increase of Rs. 45,000/ha/yr and Rs. 3,00,000/ha/yr was reported among both categories of farmers (Fig. 118).

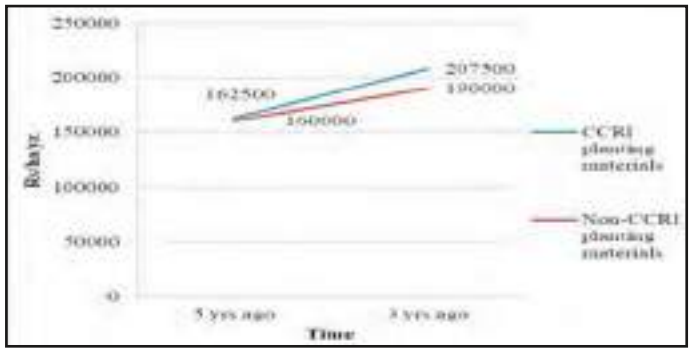


Fig. 118: Comparative trend in annual income generated from acid lime orchards having CCRI and Non-CCRI planting materials in Wardha over the past 5 years

3.5.1.2 Review of farmers after using CCRI planting materials of various citrus cultivars

The farmers who had purchased CCRI planting materials of Nagpur mandarin, sweet orange and acid lime reported their reviews after planting the materials in their orchards. 85% of mandarin farmers reported that they benefitted in terms of production and income after cultivating CCRI planting materials while 10% reported they experienced no change and 5% suffered loss. In case of sweet orange, 64% reported increase in production and income after cultivating CCRI plants but 4% experienced no change and 32% had suffered losses. In case of acid lime the beneficiaries were 75%, 5% with no change and 20% had reported losses (Fig. 119).

3.5.1.3 Farmers practising technologies of CCRI other than planting materials

There were farmers who were practising CCRI technologies but had established orchards with Non-CCRI plating materials. We attempted to record the number of such farmers too. 93% of mandarin farmers reported that they were practising CCRI technologies while 7% were not knowing about CCRI or had no access to the technological information. In case of sweet orange, 45% farmers reported that they were practising CCRI technologies while 55% were not knowing about CCRI or had no access to the technological information. In acid lime, the beneficiaries were 32% of acid lime cultivator respondents of the study (Fig. 120).

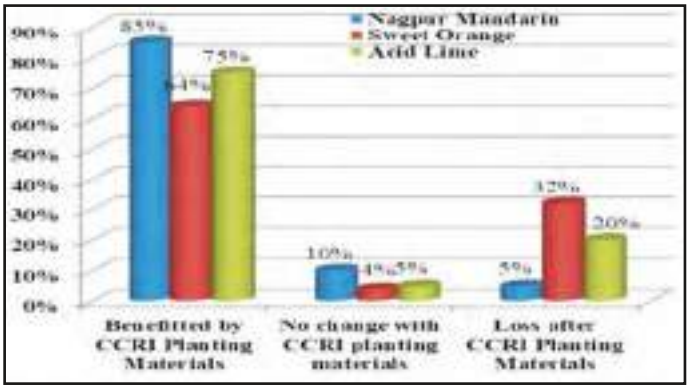


Fig. 119 : Review of farmers after using CCRI planting materials of various citrus cultivars

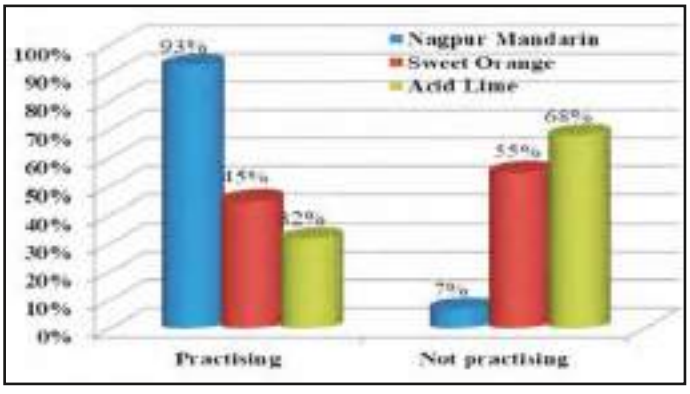


Fig. 120 : Percentage of farmers practising technologies of CCRI other than planting materials

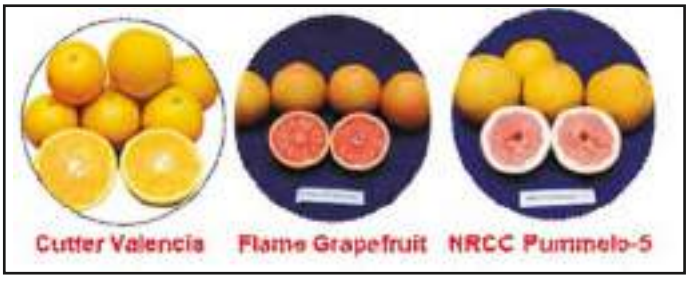
Fig. 121 : Glimpses of data collection

4 Technology Assessed and Transferred

4.1 Technologies Developed

Varietal Improvement

- Three varieties *viz*., Grapefruit cv. Flame, Sweet orange cv. Cutter Valencia and Pummelo cv. NRCC Pummelo - 5 were approved by the State Variety Release Committee (SVRC), Maharashtra for cultivation in Maharashtra.
  - ➢ Cutter Valencia : Processing variety of sweet orange with high juice content (45-50%), fruit weight 200-230g, yield 21-30 t/ha.
  - ➢ Flame Grapefruit : Fruit colour very attractive with pink blush on surface, red flesh coloured, fruit weight 350-400g, yield 25 t/ha.
  - ➢ NRCC Pummelo-5 : Yellow coloured fruit with tasty red coloured segments, fruit weight 600-800g, yield 32 t/ha.



4.2 Services Offered

4.2.1. M/s. Sahyadri Agro Farm, Nashik

- Dr. A. K. Das, Pr. Scientist (Plant Pathology) and Dr. A. A. Murkute, Principal Scientist (Hort.) visited and inspected the Nursery and Post-entry Quarantine (PEQ) facility of M/s. Sahyadri Agro Farm, Post Adagaon, Nashik on 24th July, 2021.

4.2.2. Helpline, SMS Services and Advisories

- Advisories issued on following aspects.
  - ➢ Management of Fungal disease- *Phytophthora* Gummosis, Foot rot, Root rot, Brown rot, on 24th March, 2021 (Marathi).
  - ➢ Management of Blackfly and Whitefly, on 24th March, 2021 (Marathi).
  - ➢ Management of *Phytophthora* disease, on 5th July, 2021 (Marathi and English).

4.2.3. Survey / Field day / Visit to Citrus Growers' orchard

- Dr. A. K. Srivasatava, Pr. Scientist (Soil Science) and Dr. A. K. Das, Pr. Scientist (Plant Path.) visited Zilpa village, Katol tehsil, Nagpur district in response to the report/ problem of severe decline and incidence of fungal infection in the Nagpur mandarin orchard of Mr. Dadasaheb Kale on 8th January, 2021.
- A field visit to citrus growers orchard at Sahur, Ashti taluka, Wardha was conducted on 10th August, 2021 by Dr. R. K. Sonkar, Pr. Scientist and Dr. D. T. Meshram, Pr. Scientist for collecting information about citrus cultivation and guiding the farmers for successful cultivation of citrus.
- A multidisciplinary team of ICAR-CCRI scientists along with State Government officials evaluated the causes of fruit drop in Nagpur mandarin growing areas of Chandur bazar (Nanori, Wani, Madhan, Kazali, Jasapur and Pimbri) and Paratwada (Sawali Datura, Ekalaspur and Tondgaon) taluk of Amravati district on 23rd August, 2021. Prior to that, there was a meeting of entire scientific staff of ICAR-CCRI and delegation of citrus growers of Chandur bazar and Paratwada under the Chairmanship of Dr. Dilip Ghosh, Director of the

Field visit at Sahur,
Ta- Ashti, Dist- Wardha

Scientists and officials interacting with citrus growers at Chandur bazar

Scientists and officials interacting with citrus growers at Katol

institute. This visit was the follow-up of the same meeting.

- On 26th August, 2021 Dr. A. D. Huchche, (Horticulture) Dr. A. K. Das, (Plant Pathology) and Dr. Naresh Meshram, (Entomology), along with experts from College of Agriculture, Nagpur (Dr. PDKV, Akola) and State Government Officials visited the Nagpur mandarin and sweet orange growing areas of Katol (Dhalwalpur, Paradsinga, Jamgaon, Naigaon, Khapri and Pardi) - Narkhed (Umtha) to ascertain the problem of fruit drop and issued on the spot advisories.
- A field visit was undertaken at Zilpa village of Katol taluka, Dist-Nagpur on 4th September, 2021 to assess the issues related to sub-surface micro-irrigation, nutrient management and fruit drop in Nagpur mandarin/ Mosambi orchards by a team of Scientists comprising Dr. D. T. Meshram, Pr. Scientist (L&WME), Dr. U. R. Sangle, Pr. Scientist (Plant Pathology) and Dr. V. Bansode, Scientist (Food Technology). The team visited/ surveyed orchard of Shri. Dadasaheb Kale (Progressive farmer) and other orchards from Zilpa village.
- Dr. A. D. Huchche, Pr. Scientist and Dr. A. K. Das, Pr. Scientist surveyed the Katol tehsil on 5th September, 2021 for observing the sweet orange orchards for unprecedented fruit drop of *Ambia* crop and advised the farmers to undertake suitable control measures.
- Dr. (Mrs.) N. Vijayakumari, Pr. Scientist (Hort.) visited Green Valley Nursery of Mrs. Lalita Junghare at Hatla, Katol, Nagpur on 2nd November, 2021, in relation to the MoUs signed for transfer of technology, expertise on "Production of disease free planting material of Citrus".

Dr. N. Vijayakumari visiting Green Valley Nursery, Hatla

CCRI stall at ICAR-IIHR, Bengaluru

4.2.4. 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 :

- "National Horticulture Fair - 2021" at ICAR-IIHR, Bengaluru during 8-12th February, 2021 wherein Institute disseminated its technologies to more than 90 visiting farmers/ stakeholders/ students etc.
- Institute participated and put up its stall in the Agrovision-2021 during 24-27 December, 2021 at

CCRI stall in Agrovision at Nagpur

4.2.5. Farmers visit to CCRI

State	District	No. of Farmers	Date
Madhya Pradesh	Khargon	5	8th January, 2021
	Harda	8	14th January, 2021
	Chhindwara	13	15th February, 2021
Maharashtra	Mugala, Washim	4	25th January, 2021
	Gadchiroli	52 (SHG female farmers)	2nd February, 2021
	Hoshangabad	13	17th February, 2021
	Bhamragad, Gadchiroli	40	19th September, 2021
Karnataka	Vijayapur	12	1st December, 2021
	Total	**147**	

5 Training and Capacity building

5.1 Capacity building of Institute Staff

The Staff of the Institute participated in various training programmes during 2021 for capacity building and details of which are as follows :

5.2 HRD Fund Allocation and Utilization

During 2021-22, Rs. 2.18 lakhs were allocated and Rs. 2.18 lakhs were spent with 100 % utilization.

5.3 Visit of Students to the Institute

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

5.4 Visit of Trainees /Officers

- Officials and trainees undergoing training at different organizations in the country visited ICAR-CCRI, Nagpur during 2021. They were appraised of activities and research programmes of the institute.
  - Dr. Devinder S. Thakur Project Director and Dr. Rajeshwar Parmar, Nodal Officer, Himachal Pradesh Sub-tropical Horticulture, Irrigation and Value Addition Project (HP-SHIVA Project), Directorate of Horticulture, Himachal Pradesh on 4th January, 2021.
  - Seven Agri./Horti. Officers from Collector Office (Hort.), Chhindwara, M.P., under Aatmanirbhar, Madhya Pradesh on 15th January, 2021.
  - Two officers from Karnataka organized by Karnataka State Lime Development Board, Vijayapur on 1st December, 2021.

Table 5.1 : Training programmes attended by the Institute's Staff

Name of the Personnel	Title of the Course	Place and Duration
Dr. D.T. Meshram Pr. Scientist (L&WME)	Enhanced Research Skills and Refinement of Technology by a Scientist	IIHR, Bengaluru, 18-20 January, 2021 (Virtual)
Dr. J. P. Tej Kumar Scientist (Biotechnology)	Hands on laboratory course on CRISPR-Cas Gene Editing	SGT University, New Delhi, 23-27 March, 2021 (Virtual)
Dr. J. P. Tej Kumar Scientist (Biotechnology)	Training for Nodal Officers on Implementation and Use of Agricultural Research Management System (ARMS)	ICAR-IASRI, New Delhi, 8th June, 2021 (Virtual)
Sh. V. Bansode, Scientist (Food Technology); Dr. K.K. Kommu, Scientist (Nematology) and Mrs. Usha Dhanvijay, Assistant	Workshop on MS-Excel	ISTM, New Delhi, 12-14 July, 2021 (Virtual)
Dr. J. P. Tej Kumar Scientist (Biotechnology)	Introduction to Genomics and Bioinformatics	C-CAMP, Bengaluru Genomics Centre, 22-24 September, 2021 (Virtual)
Sh. V. Bansode Scientist (Food Technology)	Advances in Sustainable Disruptive Technology in Food Processing	Department of Food Process Engineering, National Institute of Technology, Rourkela, Odisha, 27-31 December, 2021 (Virtual)

Sr. No.	Name of College and place	No. of Students and Staff	Date
1.	Sh. Shivaji College of Agricultural Biotechnology, Amravati	4 students of 7th Semester B. Sc (Biotechnology)	13th August, 2021
2.	P.R. Pote Patil College of Agriculture, Amravati, Maharashtra	2	3rd September, 2021
3.	Dr. PDKV, Akola, Maharashtra	8	9th September, 2021
4.	College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra	170 students IInd Semester (21) and IVth semester (149) of B. Sc (Agriculture)	29th October, 2021
5.	College of Agriculture, Nagpur, Maharashtra	60 students 1st year students of B.Sc (Hons.)	24th November, 2021
	Total	**251**	

5.5 Training Programmes Organized by the Institute

On-Campus

- Citrus cultivation in Telangana State : Webinar on "Citrus cultivation in Telangana State" organized by CCRI, Nagpur in collaboration with Department of Horticulture, Govt. of Telangana State on 3rd June, 2021.

- Nagpur Mandarin Production Technology: A Profitable Horticulture Enterprise : A Webinar on "Nagpur Mandarin Production Technology: A Profitable Horticulture Enterprise" organized on July 22, 2021 under *Azadi ka Amrit Mahotsav* to commemorate the 75 years of India's Independence in which more than 200 citrus growers participated. In the welcome address Dr. Dilip Ghosh, Director, CCRI elaborated the dimensions of citrus R&D and successful intervention by the institute. He also highlighted the success stories attributed to exclusive endeavours of the institute in past 30 years. In the presidential remarks, Dr. B.K. Pandey, ADG (HS-II), ICAR, emphasized the need for modernization in citrus cultivation and other scientists of CCRI delivered lectures.

Dr. Dilip Ghosh, Director along with Scientists in the Webinar

- Modern trends in Citrus Production Technology : Training on 'Modern trends in Citrus Production Technology' held during 16-19th August, 2021 under

VNR Nursery staff and farmers with ICAR - CCRI scientists

Azadi ka Amrit Mahotsav in which 10 VNR Nursery staff (Raipur) and 2 farmers associated with them participated.

Dr. Dilip Ghosh, Director highlighted the gaps between demand and supply of quality planting material of citrus in India. Chief Guest Dr. B. K. Pandey, ADG (HS-II), ICAR (Online) emphasized need for modernization in planting material production. Dr. A.A. Murkute, Pr. Scientist coordinated the training.

- Management of fruit drop in Nagpur mandarin and Mosambi during rainy season : Training on "Management of fruit drop in Nagpur mandarin and Mosambi during rainy season" organized virtually on 28th August, 2021 under *Azadi Ka Amrit Mahotsav* in collaboration with Agriculture Department, Nagpur. About 200 citrus growers from Nagpur Division including State Govt. officials attended.

Off-Campus

- Sweet Orange Technology : A virtual training programme on "Sweet Orange Technology" jointly organized by ICAR-CCRI, Nagpur, VNMKV, Parbhani and KVK, Badnapur (Jalna) during 6-8 May, 2021. A total of 80 scientists, officers, extension workers, students and farmers participated.

- Food and Nutrition for farmers : A training programme on "Food and Nutrition for farmers" was organized at Hetikundi village, Dist. Wardha at the orchard of Mr. Sadashiv Bhakte, Progressive citrus grower on 26th August, 2021 in which 35 citrus grower participated. Dr. A. Thirugnanavel, Scientist 'SS', Sh. V. Bansode, Scientist, Dr. K.K. Kommu, Scientist, delivered lectures.

Training at Hetikundi, Wardha

- Rejuvenation Technologies for Citrus decline in North eastern Region of India: Virtual Workshop cum Training programme on "Rejuvenation Technologies for Citrus decline in North eastern Region of India" organized in collaboration with ICAR-ATARI, Guwahati, Assam and ICAR RC for NEH Region, Umiam, Meghalaya on 6th December, 2021. The major focus of this training programme was to train and strengthen the KVK staff based in entire North-eastern region. Nearly two hundred participants that includes KVKs staff and citrus farmers attended this training program. The scientists of CCRI delivered lectures.

Training on Rejuvenation technologies in NEH

Training under Tribal Sub-Plan (TSP)

- Citrus Cultivation Practices : On the occasion of International Women's Day a training programme under TSP on "Citrus Cultivation Practices" was organized at KVK, Dhar, M.P. on 8th March, 2021 in which a total of 160 tribal women were benefited.

- Cultivation of modern horticulture fruits and vegetables : Under TSP imparted training on "Cultivation of modern horticulture fruits and

vegetables" for tribal farmers in the Naxalite area village Chatgaon, Tq. Dhanora, Dist. Gadchiroli (MS) on 10th October, 2021. About 300 participants (140 male and 160 female) attended the training. The inputs of vegetable seed for kitchen gardening and literature were distributed. Dr. A. D. Huchche, Pr. Scientist, Dr. A. A. Murkute, Pr. Scientist and Sh. V. Bansode, Scientist were experts from Institute.

Training at Gadchiroli

Training under SC Sub-Plan (SCSP)

- Training program under Scheduled Caste Sub Plan at Sonoli, Taq. - Kalmeshwar, Dist-Nagpur organized on 20th August, 2021. During the technical session CCRI scientists delivered the lectures on various topics. Under this scheme distributed farm implements which include Hand Hoe and Acid lime plants (50 each) alongwith a kit comprising of Copper oxychloride, Carbendazim, Ridomil gold, Magnifying glass, Literatures on citrus were distributed to the 20 farmers. In addition, two power weeder (one to the KVK, Dudhburdi, Nagpur-II and one to the Grampanchayat, Sonoli) was given. Dr. R. K. Sonkar (Pr. Scientist) coordinated the training.

Dr. Dilip Ghosh, Director addressing the farmers

Dr. R. K. Sonkar, Pr. Scientist distributing kits to farmers

6 Honours, Awards and Recognition

6.1 Patent

ICAR-CCRI bags first patent for ready-to-serve-beverage : Institute awarded its first patent for its invention in developing a process for a product 'Sparkling clear Ready-to-serve beverage for Acid lime'. A team of researchers consisting of Dr. M.S. Ladaniya, Dr. Dinesh Kumar and Dr. Sunil Kumar UT contributed for developing the process for this product which high-end value which is nutritionally composite. Several technologies of value-added products, namely Ready to Serve (RTS) beverage from acid lime fruits and carbonated drinks from Nagpur mandarin and acid lime fruits have been developed, commercialized and given to the industry for developing the products. Similar technologies were also developed for Assam lemon, Kachai lemon and Khasi mandarin, three important citrus fruits grown in the North Eastern Hill (NEH) region.

6.2 Awards

- Tej Kumar, J. P, Thirugnanavel, A. and Murkute, A. A. (2021). Best poster award for “Genetic diversity comparison among introduced and indigenous sweet orange cultivars using SSR and InDels” at National Seminar on “Conservation and commercialization of citrus biodiversity in NEH region” at Central Agricultural University, Imphal during 18-19th February, 2021.

- Dr. Dinesh Kumar, Pr. Scientist (Hort.) Awarded CHAI-JISL Fellowship Award 2021 and CHAI-Dr. Kriti Singh Best Paper Award- 2020 for the research paper entitled "Integrated Membrane Process for the Production of Nagpur Mandarin (*Citrus reticulata Blanco*) Juice Concentrate: Impact on Nutritional Content and Antioxidant Activity" by Kumar, D., Ladaniya, M. S., Gurjar, M., Mendke, S. and Kumar, S. in the AGCM of CHAI, New Delhi held on 16th September, 2021 in the Global Conference on "Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture" organized by ASM Foundation, New Delhi and PJTSAU, Hyderabad.

Dr. Dinesh Kumar, Pr. Scientist receiving CHAI Awards

- Dr. Dinesh Kumar, Pr. Scientist (Hort.) Conferred with Dr. J. C. Anand Award in Post-harvest management in Horticulture crops- 2021 in recognition for outstanding contributions in Post-Harvest Technology conferred by "Indian Academy of Horticultural Sciences", New Delhi.

- Dr. A.K. Srivastava, Pr. Scientist (Soil Science) Awarded Honorary Fellow 2021 for outstanding contribution and recognition in field of "Soil fertility and plant nutrition in Citrus" in the 3rd International Conference on "Global Initiative in Agricultural, Forestry and Applied Sciences for food Security, Environmental Safety and Sustainable Development (GIAFAS-2021)" At Shri Guru Ram Rai University, Dehradun, Uttarakhand, India 17-18th October, 2021.

- Dr. Sangeeta Bhattacharyya, Scientist (Extension) received Best Article Award for the article on "Changes in Migrant Labour Policy of India and Need of a Sustainable Rural Framework: Lessons from the Covid-19 Migrant Exodus" by Agriculture Letters.

6.3 Honours and Recognition

- **Dr. Dilip Ghosh, Director**
  - ➢ Member of the Research Council of University of Horticultural Sciences, Bagalkot for the period of two years w.e.f. 16th June, 2021.
  - ➢ Chief Guest in the Hindi Diwas Programme on 14th September, 2021 at GTC, Nagpur
  - ➢ Special Invitee in the 45th Foundation Day Celebrations at ICAR-NBSS&LUP on 23rd August, 2021
  - ➢ Member of Task Force Committee for Agro Climatic Zone - IX
  - ➢ Member of Study Group for citrus fruit drop in Vidarbha region under the Chairmanship of Vice Chancellor, Dr. PDKV, Akola
  - ➢ Chief Guest in the Citrus-Graduate Readiness Programme organized by Dr. Y. S. R. Horticultural University, Andhra Pradesh during 8-12-2021 to 14-02-2022 (virtual).

- **Dr. A.K. Srivastava, Pr. Scientist (Soil Science)**
  - ➢ Member, Organizing Committee, International Agriculture and Horticulture Conference organized by Madridge Journal of Agriculture and Environmental Sciences at Madridge, USA on 3rd March, 2021(Virtual).
  - ➢ Chairman of the session under theme: Production and Rejuvenation technology in the National seminar "Conservation and Commercialization of Citrus Biodiversity in NEH Region" Organized by Central Agricultural University Imphal, Manipur during 18-19 February, 2021
  - ➢ Guest editor of Special Issue (PLANTS by MDPI) on "Factor-specific Nutrient Modeling and Management of Agricultural and Forest Crops". MDPI Academic Open Access Publishing, Basel, Switzerland (NAAS: 8.76).
  - ➢ Guest Editor of Special Issue: Mycorrhizal fungi and sustainable Development of Agriculture. Qiang-sheng, Wu; Yue-Jun, He; Srivastava, A.K.; Ortas, I and Bo Shu (2021). Phyton-International Journal of Botany Vol.90
  - ➢ Associate-Editor-in-Chief in International Journal of Agricultural and Applied Sciences. Agricultural & Environmental Technology Development Society, Uttarakhand, India.
  - ➢ Member, Re-constitution of Technical Advisory Committee at Central Institute of Horticulture, Nagaland, 18-19 February, 2021.
  - ➢ Member of assessment committee for promotion of Category-III (Workshop and Engineering) at ICAR-NBSS&LUP, Nagpur on 19th July, 2021 and 28th August, 2021
  - ➢ Member of assessment committee of Technical Personnel Category-III at ICAR-Indian Institute of Soil Science, Bhopal, Madhya Pradesh on 9th September, 2021
  - ➢ Member of Advisory Board in an All India Life Sciences Article writing competition: Write for life Sciences 2021, organized by Centre of Excellence in Life Sciences (CELS) on 25th September, 2021.
  - ➢ Chairman Technical Session under the theme "Life science Biomedical Sciences and Biotechnological Aspects in the 3rd International Conference on "Global Initiative in Agricultural, Forestry and Applied Sciences for food Security,

Environmental Safety and Sustainable Development (GIAFAS-2021)" at Shri Guru Ram Rai University, Dehradun, Uttarakhand, India 17-18th October, 2021.

➢ Associate Editor in Frontiers in Plant Science, Frontier Publishers, Switzerland

➢ Guest Editor of Special Issue on "Mycorrhizal Roles in Horticultural Plants". Horticulturae (ISSN 2311-7524). Editors: Wu, Qiang-Sheng, Srivastava, A.K., Ortas, I., Shu, B., Zhou, N., MDPI Publiser

- **Dr. A. K. Das**, Pr. Scientist (Plant Patho.) and Dr G. T. Behere, Pr. Scientist (Ento.) nominated as an Experts for National Network of Plant Health Management of National Institute of Plant Health Management, GOI, Hyderabad, Telangana, India w.e.f. 16th February, 2021.

- **Dr. A. K. Das**, Pr. Scientist (Pl. Pathology) nominated as DBT representative for the Institutional Biosafety Committee (IBSC) constituted at CSIR-National Environmental Engineering Research Institute, Nagpur

- **Dr. Dinesh Kumar**, Pr. Scientist (Hort.) Convenor of the Technical Session-6 "Varietal improvement for enhancing water productivity" on 17th September, 2021 in the Global Conference on "Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture" organized by ASM Foundation, New Delhi and PJTSAU, Hyderabad.

- **Dr. A.A. Murkute, Pr. Scientist (Hort.)**
  - ➢ Technical guidance for implementation of ADB funded Himachal Pradesh Sub-tropical Horticulture, Irrigation and Value Addition (HPSHIVA) Project w.e.f January, 2021 for 3 years.
  - ➢ Member, Board of Studies, faculty of Horticulture and Forestry, CAU, Imphal.
  - ➢ Member (DDG's nominee) for the DPC of ARS Scientists at ICAR - NBSS & LUP, Nagpur during 6-7 August, 2021.
  - ➢ Fellowship of Society for Advanced Research on Pomegranate - 2021.

- **Dr. G.T. Behere, Pr. Scientist (Ento.)**
  - ➢ Convenor of National Symposium on "Probing Beneficial Microorganism for Next generation Green Revolution" jointly organized by Association of Plant Pathologists, Dr. PDKV, Akola and Indian Phytopathological Society (West Zone), New Delhi during 25-26th February, 2021 (Virtual).
  - ➢ Country Expert (For India) by CABI for the collaborative project on "Coordinative surveillance and early warning for sustainable management of transboundary plant pests in Asia"
  - ➢ Member (DDG nominee) for the DPC for Promotion of ARS Scientists under CAS at ICAR- Research Centre for Pomegranate, Solapur on 8th October, 2021.
  - ➢ Member Assessment Committee of Technical Personnel Category I & II (Field/Farm Group) of ICAR-CICR, Nagpur on 12th October, 2021.
  - ➢ Member (DG nominee) for the DPC for Promotion of ARS Scientists under CAS at ICAR-CICR, Nagpur on 26th November, 2021.

➢ Fellow of National Academy Environmental Sciences (NESA), New Delhi

- **Dr. D.T. Meshram, Pr. Scientist (L&WME):** Best oral paper "Deficit irrigation in Pomegranate (*Punica granatum* L.) improves water use efficiency." Meshram, D.T., Babu, Dhinesh, Nair A.K., and Wadne, S.S. in 30th National Web Conference on Soil and water Management Technologies for Climate Resilience, Agricultural and Environmental Sustainability, (SCSI, New Dehli) at OU&AT, Bhubaneswar during 14-16 December,2021.

- **Dr. Naresh Meshram, Sr. Scientist (Ento.)**
  - ➢ Member, Selection Committee, YP - I at ICAR-NBSS&LUP, Nagpur on 12th August, 2021.
  - ➢ Reviewer for International journal: Scientific Reports.

- **Dr. A. Thirugnanavel, Scientist 'SS' (Hort.)**
  - ➢ Co-Chairman for Exhibition Stall evaluation in the National Seminar on "Conservation and Commercialization of Citrus Biodiversity in NEH Region" organized by Central Agricultural University, Imphal in collaboration with ICAR-Central Citrus Research Institute, Nagpur, Maharashtra from 18th to 19th February, 2021.
  - ➢ Member of Nursery Accreditation committee for evaluating the nurseries at Nagpur, Gondia, Wardha and Akola for NHB accreditation certificate during 25-28th October, 2021.

- **Dr. Kiran Kumar Kommu** was awarded "Certificate of Reviewing" in recognition of the review contributed to the Journal- "Biological Control Journal"

- **Dr. Sangeeta Bhattacharyya, Scientist (Extension)** Awarded "Certificate of Excellence in reviewing" in recognition of an outstanding contribution to the quality of the Journal- 'Asian Journal of Agricultural Extension, Economics and Sociology' and 'Asian Journal of Research in Animal and Veterinary Sciences', in year 2021.

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 2021 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
Protection of Plant Varieties &Farmer's Right Authority, New Delhi	"DUS centre for Acid lime, Mandarin and Sweet orange".	July, 2015 ongoing project
Science and Engineering Research Board (SERB), Department of Science and Technology (DST), New Delhi	Effect of citrus root exudates on survival, penetration and development of *Tylenchulus semipenetrans* and *Meloidogyne indica*	November, 2019 ongoing project
	Evaluation of antimicrobial Nano -zinc oxide-2S albumin protein formulation on HLB infected plants -	17th December, 2019 ongoing project
	To develop potential inhibitor molecules against putative cystine - binding protein from *Candidatus* Liberibacter asiaticus	14th January, 2020 ongoing project
Department of Biotechnology (DBT), GoI, New Delhi	Phytochemical characterization and nutritional profiling of germplasm diversity of citrus species existing in North East Region	15th February, 2021 ongoing project
	Collection, Conservation and Morpho - Phenological Characterization of citrus germplasm of North East Region	16th February, 2021 ongoing project
	Utilization of citrus by Microbiome in rejuvenating khasi mandarin plants affected by important citrus diseases	8th March, 2021 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.

- A Contract Research Project entitled "Evaluation of scholar 230SC (Fludioxonil w/v 23% SC) for post-harvest disease management in Nagpur mandarin" signed with M/s Syngenta India Pvt. Ltd. Pune on 16th January, 2021 for a period of 2 years. Dr. A.K. Das, Pr. Scientist (Plant Patho.) as PI and Dr. Dinesh Kumar, Pr. Scientist (Hort.) as Co-PI of the project.

MoU with Syngenta India Pvt. Ltd.

MOU with Cropdata Technology Pvt. Ltd.

- Signed a MoU with Cropdata Technology Private Limited, Nagpur for consultancy project on "Development of questionnaire and template for technical data collection and validation to assess productivity potential in citrus production area of the Country" on 1st August, 2021 for one year. Dr. A.A. Murkute, Pr. Scientist (Hort.) as PI and Dr. G.T. Behere, Pr. Scientist (Ento.) as Co-PI of the project.

7.3 Linkage with AICRP (Fruits)

ICAR-Central Citrus Research Institute, Nagpur is providing co-ordination on technical aspects of citrus crops under AICRP fruits and Dr. Dilip Ghosh, Director, CCRI is a citrus crop co-ordinator. There were 13 centres *viz*., Ludhiana (PAU), Abohar (PAU), Sriganganagar (RAU), Akola (Dr. PDKV), Rahuri (MPKV), Tirupathi (Dr. YSR Hort. Univ.), Periyakulam (TNAU), Chettali (IIHR), Pasighat (CAU), New Delhi (IARI), Darjeeling (UBKV), Arabhavi and Nagpur (CCRI). Following activities were undertaken during 2021 under the All India Coordinated Research Project (Fruits) at ICAR-CCRI, Nagpur.

- Institute scientists involved in AICRP activities participated in the 8th Group Discussion on All India Coordinated Research Project (Fruits), organised by ICAR-HHR, Bangalore during 3-6 March, 2021 (Virtual) .

7.4 Collaboration with Academic Institutions /SAU's

- In order to promote collaborative research on citriculture, develop linkages and openness CCRI signed MoU with following Universitites and Colleges for long term collaboration for promotion of students training and quality research in cutting edge areas.
  - ➢ Dr. YSR Horticultural University, Andhra Pradesh on 18th May, 2021. Dr. T. Janakiram, Vice-Chancellor Dr. YSR Horticultural University and Dr. Dilip Ghosh, Director, ICAR-CCRI signed the MoU alongwith other staff of respective University and Institute.

Virtual MoU with Dr. YSR Horticultural University

MoU with Hislop College

MoU with Assam Agricultural University

- Hislop College, Nagpur on 29th September, 2021. Dr. Dilip Ghosh, Director, ICAR-CCRI and Dr. Prashant S. Shelke, Principal, Hislop College, Nagpur signed the MoU on behalf of their respective organizations.
- Assam Agricultural University, Jorhat, Assam on 9th November, 2021. The MoU was signed by Dr. Dilip Ghosh, Director, ICAR-CCRI, Nagpur and Dr. Ashok Bhattacharyya, Director of Research (Agri.), AAU, Assam in the presence of Dr. B. C. Deka, Vice-Chancellor, AAU, Assam.

7.5 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. Vikram Dadasaheb Kapse	Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	Effect of seaweed extract on yield, Quality, Nutrient uptake, soil properties and growth performance of chilli (*Capsicum annum* L.) in Alfisols of Konkan	College of Agriculture, Dapoli, Ratnagiri, Maharashtra	• Evaluated Ph.D thesis (21st January, 2021) • External Examiner for Viva-Voce Examination of Ph.D Student on 6th August, 2021 (Online)
Mr. Abhik Patra	Dr. A.K. Srivastava, Pr. Scientist (Soil Science)	--	Banaras Hindu University	External Examiner for oral comprehensive examination of Ph.D Scholar (3rd Feb., 2021)
Ms. Vrunda Shrihari Thakare	Dr. G.T. Behere, Pr. Scientist (Ento.)	Exploration of resistance sources in brinjal to *Leucinodes orbonalis* Guenne	Dr. PDKV, Akola	External Examiner for Final thesis viva voce examination of Ph.D (Ento.) student online (23rd Feb., 2021)
Ms. Ruchira Chilbule and Ms. Gunjan Mahajan	Dr. J.P. Tej Kumar, Scientist (Biotech.)	Genetic diversity Analysis of Acid Lime (*Citrus aurantifolia*) using SSR &InDel markers	Rajiv Gandhi Institute of Information Technology and Biotechnology, Pune	M.Sc Dissertation Research at ICAR - CCRI, Nagpur (Feb - Jun, 2021)

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. Diksha Manaware	Dr. A.A. Murkute, Pr. Scientist (Hort.)	Investigations on impact of various plant growth regulatory micro nutrients and Phytothermal regions and morpho-phygical traits and productivity of brinjal	JNKVV, Jabalpur	Evaluated Ph.D. thesis conducted online viva on July 29, 2021
Shri Shivam Mishra	Dr. A.D. Huchche, Pr. Scientist (Hort.)	Variability studies in the Tamarind Genotypes	College of Agriculture, VNMKV, Parbhani, Maharashtra	Evaluated the M.Sc thesis on 24th August, 2021
Mr. Rajnish Kumar Sahu	Dr. Dinesh Kumar, Pr. Scientist (Hort.)	Impact of Thermo-sonication on Pectin methylesterase (PME) inactivation and physico-chemical parameters of Nagpur mandarin juice	College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh	Co-Major advisor, thesis viva-voce examination of M. Sc (Hort.) student on 27th August, 2021 (Virtual)
Mr. Anand Kaltippi	Dr. A.D. Huchche, Pr. Scientist (Hort.)	Studies on effect of plant growth regulators and nutrients on yield, quality and fruit physiological disorders of Nagpur mandarin (*Citrus reticulata* Blanco.) in central India conditions	Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, (Madhya Pradesh)	Guided Ph. D. student
Mr. P. Saravana Kumar	Dr. G.T. Behere, Pr. Scientist (Ento.)	Studies on Whitefly-virus relationship and their Management in Okra	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	External Examiner for evaluation of Ph.D thesis on 30th September, 2021
Ms. Dewashree S. Takalkar	Dr. N.M. Meshram, Sr. Scientist (Ento.)	Ultrastructure of the Various Sensilla in the Predatory Ants *Myrmicaria* and *Leptogenys*'	RTM Nagpur University	External Examiner for open viva-voce test online of Ph.D thesis on 8th Sept. 2021
Ms. J. Komal	Dr. N.M. Meshram, Sr. Scientist (Ento.)	Taxonomic studies on microlepidoptera	IARI, New Delhi	Co-Chairman on 16th September, 2021
Ms. Arpitha B.V.	Dr. G.T. Behere, Pr. Scientist (Ento.)	Studies on the Biology and Management of Rust Red Flour Beetle	JNKVV, Jabalpur, Madhya Pradesh	External Examiner for evaluating M.Sc (Agri. Ento) thesis on 20th November, 2021
Ms. Sanhita Malvi	Dr. A.K. Das, Pr. Scientist (Plant Pathol.)	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

8 AICRP / Coordination Unit / National Centres

ICAR-Central Citrus Research Institute, Nagpur is co-ordinating citrus research under All India Co-ordinated Research Project on Fruits and there were thirteen centres were working during 2021 *viz*., Ludhiana (PAU), Abohar (PAU), Sriganganagar (RAU), Akola (Dr. PDKV), Rahuri (MPKV), Tirupati (Dr. YSR Hort. Univ.), Periyakulam (TNAU), Chettali (IIHR), Pasighat (CAU), New Delhi (IARI), Darjeeling (UBKV), Arabhavi and Nagpur (CCRI).

8.1 Genetic Resources and Crop improvement

8.1.1. Evaluation of Mandarin cultivars

Eight mandarin cultivars *viz.,* Mudkhed mandarin, Nagpur mandarin, Kinnow, mandarin, Coorg mandarin, Khasi mandarin, Darjeeling mandarin, N-2 and N-4 (Seedless mandarin) were evaluated for growth and yield to select superior promising clones. The analysis of the data revealed that the significant variation was observed for plant height, canopy volume, rootstock girth and scion girth among the different mandarin clones. The highest plant height of 4.31 m was recorded in Darjeeling mandarin followed by N-2 (3.87 m). The maximum plant spread of 81.33 m was recorded in N-2, whereas the maximum canopy volume was recorded in Darjeeling mandarin (51.14 m^3)

8.1.2. Evaluation of promising clones of Sweet orange

Eight sweet orange clones *viz.,* Phule Mosambi, Kodur Sathgudi, M3, M4, M8, Mosambi, Shamouti Orange and TM-33 were evaluated for growth and yield to select superior promising clones. The maximum plant height was recoreded by Shamouti (3.47 m), closely followed by TM-33 (3.45 m). The maximum canopy volume was recorded by TM-33 (37.02 m^3). The analysis of the fruit data revealed that all the parameters except fruit axis diameter and number of segments per fruit were differed significantly among the clones evaluated. Among the eight clones evaluated, the highest plant height was found in TM-33 (3.30 m) along with highest canopy volume (37.02 m^3). The highest fruit weight was found in M-4 (243.89 g) followed by Phule Mosambi (241.78 g) and TM-33 (239.78 g). The highest TSS was in M-4 (10.00 ^{0} Brix) along with highest juice content M-4 (43.76 %). Mosambi recorded the maximum number of fruits (201.6) whereas TM-33 recorded the maximum yield (41.57 kg/tree).

8.1.3. Evaluation of promising clones of Acid lime

Seven Acid lime clones *viz.,* TAL 94/13 (Tirupati), Phule Sharbati (Rahuri), Akola lime (Akola), NRCC Niboo –2 (Nagpur), NRCC Niboo –3 (Nagpur), NRCC Niboo – 4 (Nagpur), KL –12 (Nagpur) and Kagzi nimboo were evaluated for growth and yield to select superior promising clones. The analysis of data revealed that the data differ significantly for growth characters (for yield and quality characters and it did not differ significantly for growth characters. The highest fruit weight was found in Phule Sharbati (52.52 g) along with the highest fruit length (48.75 mm), fruit diameter (47.43 mm), and Acidity (8%). The lowest fruit weight was observed in TAL 94/13 (43.36 g) and the lowest fruit juice (39.23%). The lowest rind thickness (1.33 mm) and number of segments was observed in NRCC Niboo-4 (11.44). The highest number of fruits per tree was observed in PDKV lime (446.67 fruits/tree) and however, the data did not differ significantly with other clones.

8.1.4. Evaluation of promising clones of Pummelo

Nine pummelo clones *viz.,* PTF-1 (IIHR), PTF-2 (IIHR), PTF-3, (IIHR), PTF-4, (IIHR), NRCC Pummelo-1, (Nagpur), NRCC Pummelo-2, (Nagpur), NRCC Pummelo-3, (Nagpur), NRCC Pummelo-4, (Nagpur), NRCC Pummelo-5, (Nagpur), Check (local) were evaluated for growth and yield to select superior promising clones. All the parameters studied among the clones differed significantly, except scion girth and rootstock girth. The highest plant height was observed in NRCC-P– 2 (4.20 m),

whereas, lowest plant height was recorded in PTF-3 (2.80 m). The maximum canopy volume of 39.32 m^3 was recorded in NRCC-P-5 which was closely followed by NRCC-P– 2 (39.12 m^3). The lowest canopy volume of 20.76 m^3 was recorded in NRCC-P– 3. The highest fruit weight (1494.00 g) was found in NRCC-P-5. The highest fruit weight (1494.0 g), fruit length (139.48 mm), fruit diameter (143.61 mm), and yield (197.34 kg/tree) was found in NRCC-P-5. TheNRCC-P-3 recorded maximum number of segments (18.67). The highest TSS was recorded in PTF-4 (12.40 ^{0}Brix) whereas PTF-1 recorded highest vitamin C (49.87 mg/100g). PTF-2 recorded maximum number of fruits per tree (265.33).

8.1.5. Evaluation of promising clones/ varieties of grapefruit

Seven grapefruit clones *viz.,* Flame Grapefruit (Nagpur), NRCC Grapefruit-6 (Nagpur), Star Ruby (Ludhiana), Red Blush (Ludhiana), Imperial (New Delhi), Foster (New Delhi) and Marsh Seedless (New Delhi) were evaluated for growth and yield to select superior promising clones. The highest plant height was found in Red Blush (1.71 m) followed by Marsh Seedless (1.60 m). However, the highest canopy volume was found Red Blush (4.84 m^3) followed by Marsh Seedless (3.51 m^3), which were at par. Among seven cultivars the highest fruit weight was found in NRCC Grapefruit 6 (470.67 g) followed by Red Blush (370.00 g) and Flame Grapefruit (319.33 g). The highest TSS was found in Foster (8.60 ^{0}Brix) and NRCC Grapefruit-6 (8.60 ^{0}Brix). The highest juice content was in NRCC Grapefruit-6 (37.79^A%). However, the lowest TSS (7.52 ^{0}Brix) in Marsh Seedless and lowest juice content (23.25 %) was observed in Foster.

8.1.6. Evaluation of promising clones of Citrus II (a) Mandarin (MLT-II)

PDKV mandarin was evaluated for its performance along with local check Nagpur mandarin. Plant growth characters were recorded on plant height, scion girth, rootstock girth, plant spread and canopy volume. The analysis of the data revealed that the data did not significantly varied for plant height, plant spread and canopy volume.

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

Nine acid lime clones *viz.,* PDKV Bahar, NRCC AL – 7, NRCC AL – 8, Pusa Udit, Pusa Abhinav, SGNR- AL -1, Petlur Sel-1 were evaluated for growth and yield to assess the performance of new clone. The highest plant height was found in SGNR- AL -1 (2.07 m), highest canopy volume in NRCC AL – 7 (4.67 m^3) and highest plant spread in NRCC-AL-7 (2.09 m). The lowest plant height was observed in PUSA ABHINAV (1.33m), lowest canopy volume was found in PDKV BAHAR (1.12m^3) and lowest plant spread in PUSAABHINAV (1.03 m).

8.2 Crop and Natural Resource Management and Environment

8.2.1. Evaluation of promising rootstocks for sweet orange

Sweet orange var. Mosambi was budded on eight different rootstocks viz., T_1- NRCC rootstock-2 (CCRI, Nagpur), T_2- NRCC rootstock-4 (CCRI, Nagpur), T_3- NRCC rootstock-5 (CCRI, Nagpur), T_4- NRCC rootstock-6 (CCRI, Nagpur), T_5 - CRH-12 (IIHR, Bengaluru), T_6 - Alemow (CCRI, Nagpur), T_7- Rangpur lime, and T_8- Rough lemon to study the effect of rootstocks on growth, yield and quality of Mosambi.

8.2.1.1. Evaluation for growth, yield and quality

The Mosambi recorded maximum plant height on NRCC-5 rootstock (3.46m) as compared to all the other rootstocks. The stock (43.33 cm) –scion (50.60cm) growth was recorded maximum in NRCC -6. The canopy spread was recorded maximum (21.37 m^3) in Rangpur lime than other rootstocks. The fruit quality of sweet orange on different rootstock were recorded and maximum average fruit weight (256.20 g) was noted in NRCC -5 whereas CRH-12 recorded minimum (176.54 g) average weight. The highest TSS (10.29 %) and juice content (45.94 %) was observed on rough lemon whereas TSS was minimum (9.39 %) in CRH-12. NRCC-5 noted maximum Vitamin C (40.29 mg/100mg). The fruit juice acidity was recorded maximum (0.36%) in CRH-12 while minimum acidity (0.25%) was noted in NRCC rootstock-4. In the year 2021 fruiting was

recorded in all the treatments and maximum fruit yield (11.44 t/ha) was recorded in NRCC-2 followed by NRCC-4 whereas minimum (8.66 t/ha) in NRCC-6.

8.2.1.2. Disease Incidence

During the year 2021, rhizospheric soil samples were collected from experimental block. Mosambi (sweet orange) grown on eight different rootstocks (including hybrid rootstocks) were monitored for *Phytophthora* population using the selective media. Maximum *Phytophthora* propagule was observed in case of Rangpur lime rootstock while least population density was observed in NRCC-2 hybrid rootstock. This is initial years' observation and will be continued further.

8.2.2 Studies on Residual and Cumulative Effect of Nutrients in Citrus

The experiment was conducted with two objectives:

i. residual effect of fertilizers as a function of RDF applied annually. ii. cumulative effect of residual fertilizers available to the crop from preceding years. This experiment started in 2017 and results of the 16 th year of experimentation are briefly summarized: The response on canopy volume showed an increased magnitude of response of fertilization from 0.46 m^3 with A_1B_1 to as much as 1.01 m^3 with A_3B_3 indicating the response of residual effect complementing with cumulative effect on plant growth, increasingly higher magnitude of response over 2020-21. The fruit yield varied from 14.11kg/tree (3.92 t/ha) to 26.16 kg/tree (7.27 t/ha) with mean effect varying from 15.54 kg/tree (4.32 t/ha) to 22.81 kg/tree (6.34 t/ha) from $A_1 - A_3$ treatments. While, mean effect of response from B_1-B_3 varied from 17.48 kg/tree (4.86 t/ha) to 19.55 kg/tree (5.43 t/ha). The maximum yield of 26.18 kg/tree (7.27 t/ha) was observed with treatments A_3B_3. The mean juice acidity increased from 0.67% with A_1 to 0.72% with A_3 corresponding increase from 0.67% to as low as 0.72% from B_1 to B_3. While, TSS under A_1-A_3 and B_1-B_3 varied from 8.03 to 8.64% and from 8.14 to 8.46 %, respectively, with maximum of 8.46% with A_3B_3 treatment. Similarly, juice content displayed a non-significant variation in response to different treatments. Plant available nutrients and 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 were observed 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 produced residual effects, which can later display their cumulative crop response. The studies provided continuously strong clues towards readjusting the fertilizer doses based on such residual and cumulative response of nutrients.

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 17 samples tested, 14 samples were found positive for greening bacterium infection .

9 Publications

9.1 Research Papers (in Peer Reviewed Journals)

- Meng L.L., Liu, R.Ch., Yang, L., Zou, Y.N., Srivastava, A.K., Kuca, K., Abeer Hashem, Elsayed Fathi Abd_Allah, Bhoopander Giri and Wu, Q.S. (2021). The change in fatty acids and sugars reveals the association between Trifoliate Orange and endophytic fungi. *Journal of Fungi* 7 (9), 716. (NAAS rating : 10.62)
- Liu, R.C., Gao, W.Q., Srivastava, A.K., Zou, Y.N., Kuča K, Abeer Hashem, Elsayed Fathi Abd Allah and Wu, Q.S. (2021). Differential effects of exogenous glomalin-related soil proteins on plant growth of trifoliate orange through regulating auxin changes. *Frontiers in Plant Science* 12: 745402. (NAAS rating : 10.40)
- Zou, Y.N., Zhang, F., Srivastava, A.K., Wu, Q.S. and Kuča, K. (2021). Arbuscular mycorrhizal fungi regulate polyamine homeostasis in roots of trifoliate orange for improved adaptation to soil moisture deficit stress. *Frontiers in Plant Science* 11: 2046. (NAAS rating : 10.40).
- Panigrahi P, Srivastava, A.K. and Pradhan, S. (2021). Runoff and soil conservation effects in Nagpur mandarin orchard under a sub-humid tropical climate of central India. *Agricultural Water Management* 258 : 107185. (NAAS rating : 10.02)
- Ladaniya, M.S., Marathe, R.A., Murkute, A.A., Huchche, A.D., Das, A.K., Alexander, A. and Kolwadkar, J. (2021). Response of Nagpur mandarin (*Citrus reticulata* Blanco) to high density planting systems. *Scientific Reports* 11:10845. doi.org/10.1038/s41598-021-89221-4 (NAAS rating : 10.00).
- Kumar, D., Ladaniya, M.S., Gurjar, M., Kumar, S. and Mendke, S. (2021). Quantification of flavonoids, phenols and antioxidant potential from dropped *Citrus reticulata* Blanco fruits influenced by drying techniques. *Molecules* 26 (14): 4159. Doi:10.3390/molecules 26144159 (NAAS rating : 9.27)
- Ghosh, D.K., Kokane, A., Kokane, S., Tenzin, J., Gubyad, M., Wangdi, P., Murkute, A.A., Sharma, A.K. and Gowda, S. (2021). Detection and molecular characterization of '*Candidatus* Liberibacter asiaticus' and Citrus tristeza virus associated with citrus decline in Bhutan. *Phytopathology* https://doi.org/10.1094/PHYTO-07-20-2266-R (NAAS rating : 9.23).
- Wu, H.H., Srivastava, A.K., Li, Y., Zou, Y.N., Hashem, A., Elsayed, Fathi Abd_Allah and Wu, Q.S. (2021): Transcriptomic analysis of late-ripening sweet orange fruits (*Citrus sinensis*) after foliar application of Glomalin-related soil proteins. *Agriculture* 11 (11): 1171. (NAAS rating : 8.92)
- Kumar, K. K. and Dara, S. K. (2021). Fungal and bacterial endophytes as microbial control agents for plant-parasitic nematodes. *International Journal of Environmental Research and Public Health* 18: 4269. https://doi.org/10.3390/ijerph 18084269 (NAAS rating: 8.85).
- Dong, Z.H., Srivastava, A.K., Liu, X.D., Riaz, M., Gao, Y., Liang, X.M., Tan, Q.L., Sun, X.C., Wu, S.W. and Hu, C.X. (2021). Interactions between nutrient and Huanglongbing pathogen in citrus: An overview and implications. *Scientia Horticulturae* 290 : 110511 (NAAS rating : 8.77)
- Kumar, K. K. and Arthurs, S. (2021). Recent advances in the biological control of citrus nematodes: a review. *Biological Control* 157:104593 (NAAS rating : 8.75).
- Das, A. K., Chichghare, S., Sharma, S. K. and S. Singh., Kumar, A. Nerkar, S., Baranwal, V. K. (2021). Genetic diversity and population structure of '*Candidatus* Liberibacter asiaticus' associated with citrus Huanglongbing in India based on the prophage types. *World Journal of Microbiology and*

Biotechnology 37(6):95. doi: 10.1007/s11274-021-03057-8 (NAAS rating : 8.48).

- Meng, L.L., Liang, S.M., Srivastava, A.K., Li, Y., Liu, C.Y., Zou, Y.N., Kuča, K., Abeer Hashem, Elsayed Fathi Abd_Allah and Wu, Q.S. (2021). Easily extractable glomalin-related soil protein as foliar spray improves nutritional qualities of late ripening sweet oranges. *Horticulturae* 7:228 (NAAS rating : 8.33).
- Dong, Z.H., Low, W., Srivastava, A.K., LIU, X.D., Riaz, M., Tan, Q.L., Sun, X.C. and Hu, C.X. (2021). Association between plant nutrients, the development of Huanglongbing and abnormal growth symptoms in navel orange. *Plant biology* 23(6):1167-1176 (NAAS: 8.17).
- Chatterjee, D., Kuotsu, R., Ray S.K., Patra M. K., Thirugnanavel, A., Kumar, R., Borah, T. R., Chowdhury, P., Pongen I., Satapathy, B.S. and Deka, B. C. (2021). Preventing soil degradation in shifting cultivation using integrated farming system models. *Archives of Agronomy and Soil Science* DOI: 10.1080/03650340.2021.1937139 (NAAS rating : 8.14).
- Kokane, A.D., Lawrence, K., Kokane, S.B., Gubyad, M.G., Misra, P., Reddy, M.K. and Ghosh, D.K. (2021). Development of a SYBR Green-based RT-qPCR assay for the detection of Indian citrus ringspot virus. *3 Biotech* 11:359 (NAAS rating : 7.80).
- Kokane, S.B., Misra, P., Kokane, A.D., Gubyad, M.G., Warghane, A.J., Surwase, D., Reddy, M.K. and Ghosh, D.K. (2021). Development of a real-time RT-PCR method for the detection of Citrus tristeza virus (CTV) and its implication in studying virus distribution in planta. *3 Biotech* 11:431 (NAAS rating : 7.80).
- Huang, G.M., Srivastava, A.K., Zou, Y.N., Wu, Q.S. and Kuča, K. (2021). Exploring arbuscular mycorrhizal symbiosis in wetland plants with a focus on human impacts. *Symbiosis* 1-10 (NAAS: 7.78).
- Srivastava, A.K., Wu, Q.S., Mousavi, S.M. and Hota, D. (2021). Integrated soil fertility management in fruit crops: An Overview. *International Journal of Fruit Science* 21 (1): 413-439 (NAAS rating : 7.35).
- Komal, C., Shashank, P.R., Meshram, N.M., et al., (2021). Moths (Insecta: Lepidoptera) of Delhi, India: An illustrated checklist based on museum specimens and surveys. *Biodiversity* doi:10.3897/BDJ.9.e73997 (NAAS rating : 7.22)
- Firake, D. M. Sankarganesh, E., Yeshwant, H. M. and Behere, G. T. (2021). Mirid bug, *Helopeltis cinchonae* Mann: a new pes of economically important horticultural crops in Northeast India. *Phytoparasitica* 49 : 317-326. doi:10.1016/ j.biocontrol.2020.104303(NAAS rating : 7.14).
- Meng, Lu., Lu, Srivastava, A.K., Kuča K., Giri, B., Rahman, M. M. and Wu, Q.S. (2021). Interaction between earthworms and arbuscular mycorrhizal fungi in plants: A review. *Phyton-International Journal of Experimental Botany* 90 (3): 687-699 (NAAS rating : 7.03).
- Meshram, N.M. and Rai, S. (2021). A new species of the genus *Igerna* (Hemiptera: Cicadellidae: Megophthalminae) from India. *Biologia* 1-5 (NAAS rating: 6.81).
- Roy, A., Som, S., Bhattacharyya, S., Das, B.K., Pandit, A. and Yadav, A.K. (2021). Impact of trainings in increasing farmers income: Evidence from Bihar, India. *Journal of Environmental Biology* 42: 499-504 (NAAS rating: 6.78).
- Kumar, K.K. and Mohan, S. (2021) Evaluation of primary and mutant forms of *Photorhabdus luminescens* on *in vitro* growth and multiplication of their nematode symbiont *Heterorhabditis indica*. *Russian Journal of Nematology* 29(1): 59-64 (NAAS rating : 6.39).
- Marathe, R.A., Murkute, A.A., Sonkar, R.K., Ladaniya, M.S., Kolwadkar, J. and Deshpande, C. (2021). Scheduling of nutrient doses for rough lemon

rootstock under containerized primary and secondary nursery. *Indian Journal of Agricultural Sciences* 91 (10): 1457–1460 (NAAS rating : 6.21).

- Bhattacharyya, S., Burman, R.R., Padaria, R.N., Sharma, J.P., Paul, S. and Roy, P. (2021). Model Villages as a Pathway towards Inclusive Development. *Indian Journal of Agricultural Sciences* 91(3): 486-489 (NAAS rating: 6.21).
- Bhattacharyya, S., Burman, R.R., Sharma, J.P., Padaria, R.N., Paul, S., Datta, A., Venkatesh, P., Singh, L., Prasad, Y.G., Nalkar, S., Kumari, A.S., Rao, N.V., Kumar, N.K. and Roy, P. (2021). Measuring Stakeholders' Perception of SansadAdarsh Gram Yojana. *Indian Journal of Agricultural Sciences* 91(10): 1476-81. (NAAS rating: 6.21)
- Roy, P., Hansra, B.S., Burman, R.R., Roy, T.N., Bhattacharyya, S. and Kumar, P. (2021): Impact of improved varieties on farmers income: Insight from lower Shivalik hills. *Indian Journal of Agricultural Sciences*, 91(11): 64-68. (NAAS rating: 6.21)
- Kumar, D., Ladaniya, M. S., Gurjar, M., Mendke, S. and Kumar, S. (2021). Efficacy of fungicides with edible coatings on quality of Nagpur mandarin fruits. *Indian Journal of Horticulture* 78(3): 319-324. doi: 10.5958/0974-0112.2021.00046.3 (NAAS rating : 6.16) .
- Gupta, D. N., Dalal, V., Savita, B. K., Dhankhar, P., Ghosh, D. K., Kumar, P., and Sharma, A. K. (2021). In-silico screening and identification of potential inhibitors against 2Cys peroxiredoxin of *Candidatus* Liberibacter asiaticus. *Journal of Biomolecular Structure and Dynamics* 1-15 (NASS rating: 9.39).
- Meshram, N.M., Ramaiah, M. and Shashank, P.R. (2021). New record of the genus *Baseprocessa* (Hemiptera: Cicadellidae: Coelidiinae) from India with description of a new species. *Zootaxa* 4999 (5): 479-483 (NAAS rating : 6.00).
- Bhattacharyya, S., Huchche, A. D., Ladaniya, M. S., and Pakhmode, P. (2021). Analysis of constraints faced by citrus growers of central India amidst covid-19 lockdown and delineation of post-pandemic marketing strategies. *Journal of Community Mobilization and Sustainable Development* 16 (2): 327-332 (NAAS rating : 5.67).
- Firake D. M. and Behere, G.T. (2021). Molecular approaches in insect pest management: relevance and reality. *Indian Journal of Entomology* 83: e201805 (NAAS rating : 5.08).
- Yamini, Huchche, A.D., Dhongade, A., Thirugnanavel A. and Kumar, V. (2021). Effect of foliar application of growth regulators and nutrients on fruit retention and yield of acid lime (*Citrus aurantifolia* Swingle). *Biological Forum* 13 (3a): 348-354 (2021) (NAAS rating: 5.1).
- Jeyabaskaran, K.J., Shirgure, P.S., Pandey V., Srivastava, A.K. and Uma, S. (2021). Fertigation in Horticulture: A guarantee to economized quality production. *Indian Journal of Fertilisers* 17 (4): 364-383 (NAAS rating: 4.76).

9.2 Oral Papers Presented in Seminar/ Symposia / Conferences etc.

- National seminar on "Conservation and Commercialization of Citrus Biodiversity in NEH Region" organized by Central Agricultural University Imphal, Manipur during 18-19 February, 2021
  - ➢ Srivastava A.K. (2021). Soil Health Care of Citrus: Concept to Commerce
  - ➢ Huchche, A.D. (2021). Climate change and Citrus
  - ➢ Murkute, A.A., Tej Kumar, J.P. and Thirugnanavel, A. (2021). Citrus germplasm and improvement paradigms in India.
  - ➢ Thirugnanavel, A., Tej Kumar, J.P. and Murkute, A.A. (2021). Citrus rootstock breeding for biotic and abiotic stress tolerance in India
  - ➢ Tej Kumar, J.P., Thirugnanavel, A. and Murkute, A.A. (2021). CRISPR as a tool for citrus crop improvement

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- Srivastava A.K. (2021). Decision support for soil test based fertilizers recommendation in citrus, International Agriculture and Horticulture Conference organised by Madridge Journal of Agriculture and Environmental Sciences on 3rd March, 2021(Virtual).
- Bhattacharyya, S., Burman, R.R., Padaria, R., Paul, S., Sharma, J.P. and Roy, P. (2021). Comparative analysis of status of rural health and sanitation in model villages of Maharashtra and Telangana in National Conference on Techno-Scientific Challenges and Sustainable Solutions for Living beings during Changing Environment (TCSE-2021) held during 29-30, January, 2021, organized by National Environmental Science Academy and ICAR-Indian Agricultural Statistics Research Institute, New Delhi pp-40 (Virtual).
- Kumar, D. (2021). Value Chain Management in Fruits and Vegetables for Enhancing the Availability and Consumption of Fruit and Vegetables in Webinar on New Paradigms in Production and Utilisation of Fruits and Vegetables for Health and Livelihood organized by Confederation of Horticulture Association of India, New Delhi in collaboration with Tamil Nadu Agricultural University, Coimbatore and Horticulture Department, Directorate of Horticulture, Haryana on 11th February, 2021.
- Kumar, D. (2021). Role of Value Addition in Citrus on Secondary Agriculture during National Webinar on Novel Product Development Opportunities from Horticultural Crops during COVID Era under NAHEP-CAAST sub project to PG students organized by Navsari Agricultural University, Gujarat on 20th February, 2021.
- Ghosh, D. (2021). Citrus Industry in India Webinar on World Environment Day with theme Restore and Recreate Earth's Ecosystems : Act before it is too late organized by Vanrai Foundation, Nagpur on 5th June, 2021.
- Srivastava A. K. (2021). Diagnosis and management of nutrient constraints in citrus on 29th June, 2021 during IX international Symposium on Mineral Nutrition of Fruit Crops organized by International Society of Horticultural Sciences at Tel Avin, Israel during 28-30 June, 2021
- Srivastava, A. K. (2021). Microbes mediated soil fertility management in fruit crops on 10th July, 2021 during 8th International Horticulture Research Conference (10-12th July, 2021) organised jointly by Nanjing Agricultural University, China and Michigan State University, USA at Nanjing, China (Keynote lecture)
- Global Conference on Innovative Approaches for Enhancing Water Productivity in Agriculture including Horticulture held at PJTSAU, Rajendranagar, Hyderabad, Telangana during 16-17 September, 2021.
  - ➢ Srivastava, A.K. (2021) Soil Fertility Mediated Water Productivity in Fruit Crops (Keynote lecture).
  - ➢ Kumar, D. (2021). Underutilized Citrus sp. Pummelo (*Citrus grandis*) and Grapefruit (*Citrus paradisi*): Rich source of Nutraceuticals.
- Kumar, D. (2021). Prospects of Post-Harvest Management, Value-addition and Waste Utilization of Citrus Fruits during International e-Conference on Postharvest disease management and value addition of horticultural crops organized on 20th August, 2021 by ICAR- Indian Agricultural Research Institute, New Delhi.
- 9th Indian Horticultural Congress - 2021 on Horticulture for Health, Livelihoods and Economy organized by Chadra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during 18-21 November, 2021.

- ➢ Ghosh, D. (2021). New Development in Citrus rootstocks.
- ➢ Srivastava, A.K. (2021). Addressing soil fertility and plant nutrition in horticultural crops : Paradigm shifts.
- ➢ Kumar, D. (2021). Nutraceutical: Present status and prospects of underutilized citrus fruits.

- Ghosh, D. (2021). Present status on molecular diagnosis, characterization and management of citrus greening disease (Huanglongbing) in India in the National Symposium on Sustainable Plant Health Management amidst Covid pandemic : Challenges and strategies organized by Indian Phytopathological Society (South Zone) and ICAR-CPCRI, Kasaragod, Kerala during 1-3 December, 2021 (virtual).

9.3 Abstracts / Poster Paper presented in Proceedings / Souvenir of Seminar/ Symposia/conferences etc.

- Meshram, D.T., Babu, D., Sharma J. and Wadane, S. S. (2021). Efficacy of water harvesting structures and its utilization for optimum pomegranate production in micro-watershed 2nd Asian Web-Conference at CAU, Imphal during 12-13 February, 2021.
- Tej Kumar, J.P., Thirugnanavel, A. and Murkute, A. A. (2021). Genetic diversity comparison among introduced and indigenous sweet orange cultivars using SSR and InDels In: Souvenir cum abstract book, National Seminar on Conservation and commercialization of citrus biodiversity in NEH region organized by Central Agricultural University, Imphal, Manipur during 18-19th February, 2021.
- 9th Indian Horticultural Congress-2021 on Horticultural for Health, Livelihoods and Economy organized by Chadra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during 18-21 November, 2021.
- ➢ Huchche A.D. (2021). Climate change risks and resilience strategies in citrus
- ➢ Sonkar, R.K., Ladaniya, M.S., Das, A.K., Thirugnanavel, A., George, A., Behere, G.T., Zade, P., Bhaladhare, V.P., Kumar A. and Kolwadkar J. (2021). Performance of exotic sweet orange on raised bed in Central India
- ➢ Sonkar, R.K., Ladaniya, M.S., Kommu, K. K., Das. T., Zade, P., Thakare, P., Khaire, S., Bhaladhare, V.P. and Khanikar, H. (2021). Performance of different citrus species in Assam
- ➢ Sonkar, R.K., Ladaniya, M.S., Das, A.K., Thirugnanavel, A., George, A., Behere, G.T., Thakre, P. and Khaire, S. (2021). Raised bed Planting system in Citrus-A new concept.
- ➢ Murkute, A., Tej Kumar, J.P. and Thirugnanavel, A. (2021). Citrus rootstock identification by DNA fingerprinting with Indels.
- ➢ Meshram, D.T., Srivastava, A.K., Shirgure, P.S., Huchche, A.D. and Pangul, C.S. (2021). Precision Citriculture through variable fertigation rate in Nagpur mandarin (*Citrus reticulata* Blanco).
- ➢ Ramajayam, D., Jeyabaskaran, K.J., Sivasankari, R., Suresh Kumar, P.S., Thirugnanavel, A., Pitchai M., R., Kalpana, S., Ranjani, M., Singh, A., Saraswathi M.S. and Uma, S. (2021). Can the bananas (Banana and Plantain) be the panacea for India's hidden hunger
- ➢ Bansode, V. (2021). Development of Nutri-Jelly from underutilized Assam Lemon (*Citrus limon*) fruit.

- Meshram D.T., Babu, D., Nair A.K. and Wadne, S.S. (2021). Deficit irrigation in Pomegranate (*Punica granatum* L.) improves water use efficiency in 30th National Web Conference on Soil and water Management Technologies for Climate Resilience, Agricultural and Environmental Sustainability at OUA&T, Bubaneswar, Odisha, during 14-16 December, 2021 (virtual).

9.4 Books / Book Chapters :

- Bhattacharyya, S. and Ponnusamy, K. (2021). Gender and Agricultural Extension- Imperatives for Transformational Interventions. In book: Gender Mainstreaming for Egalitarianism, Equity and Sustainability Karthikeyan, C., Venkata Pirabu J. and Sivakumar, S.D. editors. Publisher: NAHEP, Directorate of Planning and Monitoring, TNAU, Coimbatore, pp. 135-143.
- Jagannadham, P. T. K., Siddanna Savadi, and Senthil kumar, K. M. (2021). Plant Genome Editing in Basic Research to Understand Molecular Functions In: *Genome Editing in Plants* CRC Press pp.187-202.
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- Roy, P. and Bhattacharyya, S. (2021). Market Information System: Applications and Prospects in Indian Agriculture. In book: Agri-Entrepreneurship: Challenges and Opportunities. Publisher: Jaya Publishing House, New Delhi, India, pp: 103-126.
- Sharma, S. D., Sharma, V. K., Murkute, A. A., Chandrabhan (2021)., Nimbu Vargiya Phallo Ki Kheti (Hindi) ISBN No. 978-8-19-360810-4 pp. 87.
- Sharma, S.D., Sharma, V.K., Murkute, A.A., Yadav, A.K., Thakur, M.K. (2021)., Phaldhar Paudhoki Sadhan Kheti ISBN No. 978-8-19-456640-3, pp. 114.
- Sharma, S. D., Sharma, V. K., Murkute, A. A. (2021). Krishi me aatmanirbhar gram swalaban evam satat vikas, ISBN No. 978-8-19-456642-7, pp.137.

9.5 Extension Bulletins/Folders :

- Ladaniya, M.S., Sonkar, R.K., Das, A.K., Murkute, A.A., Behere, G.T., Thirugnanavel, A., George, A. and Kommu, K.K. (2021). Management of Khasi Mandarin in Assam and other North-Eastern States. Extension Bulletin No. 66, pp-29. ICAR-Central Citrus Research Institute, Nagpur 440033, Maharashtra.
- Ladaniya, M.S., Huchche, A.D., Das, A.K., Marathe, R.A., Behere G.T., Rao C.N. and George, A. (2021). High density cultivation of Nagpur mandarin. Extension Bulletin No. 67, pp-32. ICAR-Central Citrus Research Institute, Nagpur 440033, Maharashtra.
- Ladaniya, M.S., Sonkar, R.K., Das, A.K., Murkute, A.A., Behere, G.T., Thirugnanavel, A., George A. and Kommu, K.K. (2021). Management Practices of Assam Lemon. Extension Folder No. 29. ICAR-Central Citrus Research Institute, Nagpur 440033, Maharashtra.
- Srivastava, A.K., Vijayakumari, N., Huchche, A.D., Sonkar, R.K., Das, A.K., Dinesh, Murkute, A.A., Behere, G.T., Meshram, D.T., Meshram, N.M., Kommu, K.K. and Ghosh, D. (2021). Improved Cultivation Practices for Nagpur mandarin. Extension Bulletin No. 68, pp 1-38, ICAR-Central Citrus Research Institute, Nagpur 440033, Maharashtra.

9.6 Popular articles

- Bansode, V. (2021). By-product valorization of citrus fruits *Readers Shelf*, 17(12) : 51-53.
- Bhattacharyya, S., Burman, R.R., Padaria, R.N., Paul, S. and Roy, P. (2021). Changes in Migrant Labour Policy of India and Need of a Sustainable Rural Framework: Lessons from the Covid-19 Migrant Exodus. *Agriculture Letters*, 2(12): 48-59.
- Tej Kumar, J.P., Thirugnanavel, A., George A., and Kumar, K.K. (2021). Citrus Genomes: Enigma Code Breaker. *Agro Science Today* 2(3): 101-103.
- Thirugnanavel, A., Jagannadham, P. T. K., George A. and Kumar, K.K., (2021). A snapshot of citrus in India. *Agro Science Today* 2(2): 77-80.

9.7 Review article

- Kumar J.P.T., and Thirugnanavel A. (2021). CRISPR-based genome editing: Catching impossibles for citrus improvements. *International Journal of Agricultural and Applied Sciences*, 2(1): 24-29.

9.8 Training manual

- Murkute, A.A. and Ghosh D.K. (2021). Training manual for the training on "Modern trends in citrus production technology" for VNR Nursery, Raipur held during 16-19th August, 2021 at ICAR-CCRI, Nagpur.

9.9 Publications of the CCRI

· Annual Report (2020), ICAR-Central Citrus Research Institute. Nagpur, p. 148

9.10 e-Publications / Coverage in Electronic media: videos / Documentaries

- ICAR-CCRI, Newsletter July to September, 2020
- ICAR-CCRI, Newsletter October to December, 2020
- A documentary on "Progress of Regional Research Centre for Citrus, Biswanath Chariali, Assam".

10 Regional Research Centre for Citrus (RRCC), Biswanath Chariali, Assam

Training programme organized

- Training programme on "Production Technology of Citrus" organized at RRCC, Biswanath Chariali, Assam on 10th January, 2021 under NEH Plan in which around 100 farmers from Biswanath, Sonitpur, Tezpur, Lakhimpur, Dhemaji and Tinsukia districts alongwith KVK officials attended. Dr. B.K. Pandey, ADG, Hort. (II), ICAR was the Chief Guest. Shri. Pranav Kumar Sharma, District Commissioner, Biswanath, Dr R.N. Barman, Associate Dean and Dr. A.C. Barbora, Ex Head, Citrus Research Centre, Tinsukia, Assam were the guests of honour. Dr. M. S. Ladaniya, Director, presided over the function. Dr. A.K. Singh, DDG (Hort), ICAR inaugurated the programme and addressed the farmers virtually from New Delhi. Experts and CCRI Scientists *viz*., Dr. R.K. Sonkar, Pr. Scientist (Hort.); Dr. A.A. Murkute, Pr. Scientist (Hort.); Dr. G.T. Behere, Pr. Scientist (Ento.); Dr. Thirugnanavel, Scientist 'SS' (Hort.) and Dr. Kiran Kumar Kommu, Scientist (Nematology) delivered lectures with presentation of other issues during training included.
  - ➢ A documentary on "Progress of Regional Research Centre for Citrus, Biswanath Chariali" was released.
  - ➢ Publications (1) Management of Khasi Mandarin in Assam and other North-Eastern States (2) High density cultivation of Nagpur mandarin (3) Management Practices of Assam Lemon were released.
  - ➢ Two progressive citrus growers namely Sh. Bhaben Saikia, Narayanpur (Lakhimpur) and Sh. Jyoti Das, Maralgaon, dist. Biswanath, were felicitated on the occasion.
  - ➢ Citrus Expert Dr. A.C. Barbora, Head- Citrus Res. Station, Tinsukia has been felicitated for his long service to citrus industry.

- ICAR-CCRI and RRCC organized a training programme under NEH plan on "Production technology of citrus" in collaboration with HRS, Kahikuchi and KVK, Kamrup, Assam on 12th January, 2021. Member of Parliament from Guwahati Mrs. Queen Oja joined virtually and guided the farmers. The training programme was conducted at KVK, Kamrup which was attended by 25 citrus growers. Later during technical sessions, Dr. M. S. Ladaniya, Director Dr. R. K. Sonkar, Pr. Scientist (Hort.); Dr. A. A. Murkute, Pr. Scientist (Hort.); Dr. G. T. Behere, Pr. Scientist (Ento.); Dr. A. Thirugnanavel, Scientist 'SS' (Hort.) and Dr. Kiran Kumar Kommu, Scientist (Nematology) from ICAR-CCRI, Nagpur delivered technical presentations on Overview of Citrus Cultivation and its management practices.

- Training under NEH plan on Production technology of citrus organized by ICAR-CCRI, Nagpur, in collaboration with ICAR Research complex for NEH

Dignitaries releasing Citrus Publication

Dignitaries during the training programme

Region, Umiam, Meghalaya at Sohkhowai village, Umsiling Block, RiBhoi, Meghalaya on 5th October 2021 in which 65 citrus growers of Sohkhowai and Umdelang village along with the village headmen, participated. Mr. Mawjam Makdoh, Horticulture Development Officer, Nongpoh in his remarks, expressed hope that the past glory of Sohkhowai oranges will be restored with the initiative of the ICAR-CCRI and ICAR RC for NEHR. ICAR-CCRI in collaboration with ICAR RC for NEHR is also undertaking a project "Demonstration of rejuvenation technology of citrus orchards" at these villages. The training programme was co-ordinated by Principal Scientists Dr. R. K. Sonkar, Dr. A. K. Das and Dr. G.T. Behere of ICAR-CCRI, Nagpur, Scientist Dr. Evening Stone Marboh of Research Station, ICAR-CCRI Biswanath Charaili, Assam and Scientists Dr. Tasvina R. Borah and Dr. A. Balusamy of ICAR RC for NEHR, Umiam, Meghalaya.

- ICAR-Central Citrus Research Institute, Nagpur in collaboration with Krishi Vigyan Kendra, Lakhimpur, Assam organized Training on Production Technology of Citrus under Tribal Sub Plan on 10th November, 2021. A total of 65 tribal citrus growers from different villages of Lakhimpur participated. The programme was graced by Dr. Dilip Ghosh, Director, ICAR-CCRI, Nagpur as Chief Guest. Other dignitaries present include Dr. Prasanta Pathak, Head, KVK, Lakhimpur; Dr. Dhiren Choudhury, Principal Scientist, RARS, Assam Agricultural University, North Lakhimpur; and

Chief Guest Dr Dilip Ghosh addressing citrus growers at Lakhimpur

Mr. Amlan Tamuli, DDM, NABARD, Lakhimpur. Dr. Pathak, shared the significant role and contributions made by the KVK in Lakhimpur, Assam. The participants were also provided with starter kits in knapsack bags comprising of different agricultural inputs along with distribution of lemon planting materials.

Infrastructure

- New Building of Farm Office and Tractor Shed at RRCC was inaugurated by Dr. A.K. Singh, DDG (Hort. Science) ICAR in the presence of Dr. B.K. Pandey, ADG, Hort. Science (I), ICAR, Dr. B.C. Deka, Vice-Chancellor, AAU, Jorhat, Dr. R.N. Barman, Associate Dean, BNCA, Biswanath Chariali, Assam and Dr. M.S. Ladaniya, Director, ICAR-CCRI, Nagpur on 10th January, 2021.

Training at RiBhoi, Meghalaya

Dignitaries Inaugurating Farm House Building

11 On-going research programmes and projects

S.N.	Project Title	Project Leader	Co-Investigators
In – House projects			
1.	Collection, conservation and characterization of citrus germplasm	A.A. Murkute	N. Vijayakumari, A.K. Das, G.T. Behere, A. Thirugnanavel, Dinesh Kumar and J.P. Tej Kumar
2.	Sub Project : Citrus repository at RRCC, Biswanath Chariali, Assam	A.A. Murkute	Kiran Kumar Kommu, Evening Stone Marboh, G.T. Behere, 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	A.K. Das, G.T. Behere A. Thirugnanavel and J. P. Tej Kumar
5.	Genetic improvement of citrus through hybridization	A. A. Murkute	G.T. Behere, J. P. Tej Kumar and A. Thirugnanavel,
6.	Genome editing through CRISPR/Cas9 system to improve citrus varieties	J.P. Tej Kumar	A. A. Murkute, A. Thirugnanavel , A.K. Das and N. Vijayakumari
7.	Improvement of citrus rootstocks through hybridization	A.Thirugnanavel	A. A. Murkute, J.P. Tej Kumar, N. Vijayakumari, N.M. Meshram and U.R. Sangle
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	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	A.D. Huchche	A.K. Das and A. Thirugnanavel
12.	Studies on dynamics of flowering and fruiting in citrus	A.D. Huchche	---

S.N.	Project Title	Project Leader	Co-Investigators
13.	Evaluation of citrus spp. on raised bed planting system	R.K. Sonkar	A.K. Das, A.A. Murkute, A. Thirugnanavel and G.T. Behere
14.	Studies on physiological disorders of citrus fruits	A. D. Huchche	R.K. Sonkar, D.T. Meshram and A. K. Das
15.	Technology Demonstration on Canopy architecture management in citrus through training and pruning for higher density and increased productivity	A. D. Huchche	A.K. Das and A. Thirugnanavel
16.	Precision citriculture through enhanced water and nutrient use efficiency in Nagpur mandarin	D.T. Meshram	A.K. Srivastava and A.D. Huchche
17.	Subsurface Micro-Irrigation and fertigation schedule for quality production of Nagpur mandarin	D.T. Meshram	A.K. Srivastava, A.D. Huchche and N. Meshram
18.	Development of advanced citrus production system	A.K. Srivastava	G.T. Behere, D.T. Meshram, A. Thirugnanavel, and A.K. Das
19.	Adoption and Impact Assessment of ICAR – CCRI Technologies. In Vidarbha region of Maharashtra	S. Bhattacharyya	R.K. Sonkar, U.R. Sangle and N. Meshram
20.	Molecular characterization of citrus trunk borer (*Pseudonemophas versteegii*): a major pest of Khasi mandarin in North eastern India	G.T. Behere	N. Meshram, J.P. Tej Kumar and Evening Stone Marboh
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 fruits	Dinesh Kumar	V. Bansode
24.	Screening of citrus germplasm across India for bio-active compounds at maturity and during storage	Dinesh Kumar	V. Bansode, A.A. Murkute and A. Thirugnanavel

S.N.	Project Title	Project Leader	Co-Investigators
25.	Functional food, value added products and beverages from citrus fruits.	Dinesh Kumar	V. Bansode
26.	Development of high end value added products from commercial/ underutilized citrus fruits and its byproducts	V. Bansode	Dinesh Kumar
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, Evening Stone Marboh, Tasvian Rahman Borah and A. Balusamy
RRCC ,Biswanath Chariali, Assam			
1.	Evaluation of different citrus species on raised and flat bed planting system at RRCC, Biswanath Chariali, Assam	R. K. Sonkar	Evening Stone Marboh, Kiran Kumar Kommu, and A. Thirugnanavel
Network Project			
1.	Consortium Research Platform on Vaccines and diagnostics (Citrus viruses)	D.K. Ghosh	**----**
Other 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 G.T. Behere
2.	Effect of citrus root exudates on survival, penetration and development of *Tylenchulus semipenetrans* and *Meloidogyne indica* - (SERB-DST Funded)	Kiran Kumar Kommu	----
3.	Evaluation of antimicrobial Nano-zinc oxide-2S albumin protein formulation on HLB infected plants - SERB (DST funded).	D.K. Ghosh	

S.N.	Project Title	Project Leader	Co-Investigators
4.	To develop potential inhibitor molecules against putative cystine-binding protein from *Candidatus* Liberibacter asiaticus - SERB (DST funded).	D.K. Ghosh	
5.	Collection, Conservation and Morpho-Phenological Characterization of citrus germplasm of North East Region – DBT Funded	A.A. Murkute	J.P. Tej Kumar and A. Thirugnanavel
6.	Utilization of citrus microbiome in rejuvenating khasi mandarin plants affected by important citrus diseases – DBT Funded	A.K. Srivastava	J.P. Tej Kumar and A.K. Das
7.	Phytochemical characterization and nutritional profiling of germplasm diversity of citrus species existing in North East Region – DBT Funded	Dinesh Kumar	
Contract Research project			
1.	Studies on Agrocel-based Potassium Schoenite (Mahalaabh) in Citrus	A.K. Srivastava	D.T. Meshram
2.	Evaluation of scholar 230SC (Fludioxonil w/v 23% SC) for post-harvest disease management in Nagpur mandarin	A.K. Das	Dinesh Kumar
All India Coordinated Research Project			
1	Citrus Germplasm	A.A. Murkute	A. Thirugnanavel and Evening Stone Marboh
2	Citrus rootstocks	R.K. Sonkar	
3	Citrus Nutrition	A.K. Srivastava	A.D. Huchche
4	Citrus diseases – greening	A.K. Das	

12 Consultancy and commercialization of technology

Establishment of Agri-Business Incubation (ABI) Centre (Under Component II of NAIF Scheme)

Activities undertaken

1. Annual Progress Report of the project from October-2020 to October-2021 has been submitted to Dr. Vikram Singh, Scientist, Intellectual Property and Technology Management, ICAR HQ, New Delhi on October 18, 2020.
2. Enriched the ABI centre by procurement of Fruit Juice Pasteurizer for pasteurizing the citrus juice during product preparation
3. Sensitized and given information of the developed technologies of ICAR-Central Citrus Research Institute, Nagpur to the interested Entrepreneurs

Fruit Juice Pasteurizer

Agri -Business Incubatee Room

Intellectual Property Management and Transfer Commercialization of Agriculture Technology (NAIF Project)

Activities undertaken

- Submitted monthly, quarterly and annual reports of project, time-to-time giving details of plant varieties released, technologies commercialized, contract research service provided, training programme organized, planting material sale by the institute ICAR-Central Citrus Research Institute (ICAR-CCRI), Nagpur to ZTMC, South Zone.
- Annual Progress Report of the project from October-2020 to September-2021 has been submitted to Dr. Vikram Singh, Scientist, Intellectual Property and Technology Management, ICAR HQ, New Delhi on October 18, 2020.
- Information regarding the list of Food processing technologies commercialized by ICAR-Central Citrus Research Institute, Nagpur, Maharashtra was submitted to office on 5th June, 2021 for forwardal to Dr. Vikram Singh, Scientist (IP & TM) ICAR HQ, New Delhi.

ITMU and ITMC meetings for commercialization of developed technologies

- Following five technologies were approved for commercialization by the ITMU and ITMC.
  - Nagpur mandarin Ice-cream
  - Nagpur mandarin Santra Burfi
  - Nagpur mandarin Candy
  - Sweet orange Candy
  - Retrofitting nursery phase for optimizing production cost of citrus planting stock.

- **MoU for Licensee Nursery :** ICAR- Central Citrus Research Institute, Nagpur signed license agreement / MoU for Containerized Nursery Propagation

Technique to Produce Disease-Free Citrus Planting Material with M/s. Pratima Biotech Ltd., Raipur, Chhattisgarh on 24th November, 2021. There is demand of about 20 million plants of various commercial Citrus cultivars in India for new plantation as well as for replanting of gaps within an existing orchard. Institute has standardized the protocol for containerized nursery production system for Citrus and is promoting the nursery production through PPP mode by signing MoU with nursery owners.

- **MoU with APEDA :** ICAR-Central Citrus Research Institute signed a Memorandum of Understanding with Agricultural and Processed Food Products Export Development Authority (APEDA) under the Ministry of Commerce and Industry, New Delhi for boosting exports of citrus fruits and its value added products. MoU was signed by Director of ICAR-CCRI, Dr. Dilip Ghosh and Director of APEDA, Dr. Tarun Bajaj. Hon'ble Union Minister for Road Transport and Highways, Nitin Gadkari Ji and Chairman of APEDA, Dr. M. Angamuthu were also present on this occasion. The MoU envisages export promotion of citrus fruits and its products by focussing on creation of product specific clusters along with the development of technologies by ICAR-CCRI and APEDA with a focus on efficient and precision farming, expanding and diversifying export basket and destinations through global market linkages.

MoU with Agricultural and Processed Food Products Export Development Authority (APEDA)

MoU with M/s. Pratima Biotech Ltd.

13 IRC, IBSC, Major Recommendation/ Decision

13.1 Institute Research Committee (IRC) meeting

The thirty third Institute Research Committee (IRC) meeting of ICAR-CCRI, Nagpur was held during 19-20 July, 2021 under the Chairmanship of Dr. Dilip Ghosh, Director of the Institute in which all the scientists participated. Experts Dr. Awtar Singh, Pr. Scientist, IARI, New Delhi and Dr. S.R. Bhat, Ex-Professor (Biotech), NRCPB, New Delhi attended the meeting virtually.

IRC Meeting in progress

13.2 Institutional Biosafety Committee (IBSC) :

The constitution of Institutional Biosafety Committee is mandatory in R&D Centres which intends to carry out or engaged in research activities involving genetic manipulation of genetic material, microorganisms plants or animals. In accordance with the above the IBSC was constituted at ICAR-CCRI for a period of 3 years w.e.f. 3rd December, 2021 with the following composition :

- ➢ Dr. Dilip Ghosh, Director, ICAR-CCRI - Chairman
- ➢ Dr. Amudha Jagannathan, Pr. Sci. (Biotech.), ICAR - CICR, Nagpur - DBT Nominee
- ➢ Dr. J.P. Tej Kumar, Scientist (Biotech.), ICAR - CCRI, Nagpur -Member Secretary
- ➢ Dr. G. Balasubramani, Pr. Sci. (Biotech.), ICAR - CICR, Nagpur -Outside Expert)
- ➢ Dr. Vijay Upadhyaya, Doctor, Nagpur - Biosafety Officer
- ➢ Dr. A.K. Das, Pr. Sci. (Plant Patho.); Dr. G. T Behere, Pr. Sci. (Ento.) and Dr. N. M Meshram, Sr. Sci. (Ento.) of ICAR - CCRI, Nagpur - Internal Experts

IBSC meeting in progress

13.3 Rajbhasha meeting

- The Rajbhasha meeting were held on 9th March, 2021, 29th June, 2021, 6th September, 2021 and 12th December, 2021.

13.4 Other Meetings

- A virtual meeting was organized with IIM, Nagpur on 1st June, 2021 for mutual collaboration towards the promotion of entrepreneurship in the region. In the meeting Prof. Bhaimaraya Metri, Director, IIM, Nagpur and Chairman, InFED and Dr. Shivaji Dhawad, Chief Operating Officer, IIM, Nagpur, Dr. D.K. Ghosh, Director and Dr. Dinesh Kumar, Pr. Scientist were present. It was discussed to have a collaborative programme for Entrepreneurship Development InFED the business incubator for promotion of entrepreneurship in the region of Food and Agriculture for the thrust areas of IIM, Nagpur.

- Institute organized virtual meeting with licensees of the CCRI nursery technology of Containerized Citrus

Virtual meeting with IIM, Nagpur

Nursery Production on 21st August 2021. The meeting was chaired by Dr. Dilip Ghosh, Director, ICAR-CCRI. Nursery owners Mr. Akhil Junghare (Green valley), Mr. Anil Rajkarne, Dr. Chaporkar and Dr. Renganathan (Seven Star Fruits Pvt. Ltd.), Mr. Ravindra Kadlik, (Karunamaya Agro tech.) and Mr. Yogesh Bangade, (Shivam Nursery) participated.

14 Participation of Scientist in conferences/ workshop/ symposia/meeting etc.

14.1 Participation

Name and Designation	Programme	Place and date/duration
Dr. G.T. Behere Pr. Scientist (Ento.)	National webinar on ESI Young Entomologist Award Lectures 2020	The Entomological Society of India on 9th January, 2021 (Virtual)
Dr. A.D. Huchche, Pr. Scientist (Hort.)	Annual Review Meeting of CHAMAN and FASAL Project	15th January, 2021 (Virtual)
Dr. Dinesh Kumar Pr. Scientist (Hort.)	2nd meeting of National Steering Committee under NetSCoFAN (Network of Scientific Co-operation for Food Safety and Applied Nutrition)	Food Safety and Standards Authority of India, New Delhi on 20th January, 2021
Sh. V. Bansode Scientist (Food Tech.)	International Workshop on "Root Architecture Imaging and Analysis for Tropical Tuber Crops"	ICAR-CTCRI, Trivandrum in collaboration with Sweet Potato Research Station, Louisiana Research Station, Louisiana State University Agcentre, LSU, USA during 20-22 January, 2021 (Virtual).
Dr. G.T. Behere Pr. Scientist (Ento.)	International webinar on "Insect Systematic: Importance, Challenges and Way Forward"	ICAR-National Bureau of Agricultural Insect Resources, Bengaluru on 29th January, 2021 (Virtual)
Dr. A.K. Das Pr. Scientist (Plant Pathology)	Annual Review Meeting of the CGIAR Centres	3rd February, 2021 (Virtual)
Dr. Dinesh Kumar Pr. Scientist (Hort.)	22nd meeting of Scientific Panel on Fruits & Vegetables and their Products (Including dried fruits and nuts),	FSSAI, New Delhi on 3rd February, 2021 (Virtual)
Dr. A.K. Srivastava, Pr. Scientist (Soil Science), Dr. A.D. Huchche Pr. Scientist (Hort.), Dr. A.A. Murkute, Pr. Scientist (Hort.); Dr. A. Thirugnanvel, Scientist 'SS' and Dr. J. P. Tej Kumar, Scientist (Biotechnology)	National seminar on "Conservation and commercialization of citrus biodiversity in NEH region"	Central Agricultural University, Imphal during 18-19th February, 2021.

Name and Designation	Programme	Place and date/duration
Dr. A.D. Huchche Pr. Scientist (Hort.)	National level Technical Committee meeting for standardization of term sheet weather triggers etc under RWBCIS, MAFW, GoI	22nd February, 2021
Dr. A.K. Das Pr.Scientist (Plant Pathology)	Mid-term Review meeting of ICAR Regional Committee No. VII	25th March, 2021 (Virtual)
Dr. Dinesh Kumar Pr. Scientist (Hort.)	Meeting for "Mandarin juice processing and pulp production"	Warud, Amravati on 25th March, 2021 (Virtual)
Dr. A.A. Murkute Pr. Scientist (Hort.)	Workshop on herbal gardens	NCERT, New Delhi during 15-17 February, 2021
Dr. A. D. Huchche Pr. Scientist (Hort.)	Standardization of term sheet under restructured weather-based crop insurance scheme	Credit Division, DAC, MoA, GoI, New Delhi on 9th April, 2021 (Virtual)
Dr. A. D. Huchche Pr. Scientist (Hort.)	Mid-term review meeting of ICAR Regional Committee-III (Virtual)	ICAR-RC, Umiam, Meghalaya on 10th April, 2021 (Virtual)
Dr. Dilip Ghosh, Director and Dr. A. A. Murkute, Pr. Scientist (Hort.)	Meeting for importing planting material from abroad under Atma Nirbhar Bharat	MIDH, Min. of Agri & Farmers Welfare on 29thApril, 2021
Dr A. D. Huchche, Pr. Scientist (Hort.) and Dr. G. T. Behere, Pr. Scientist (Ento.)	Members of Crop Specific Technical Sub-Committees (CSTSCs) for specific crops to discuss progress made on analysis of proposed weather triggers and term sheets for Kharif 2021 and Rabi 2021-22 seasons for Maharashtra	5th and 19th May, 2021 (Virtual).
Dr. Dilip Ghosh, Director alongwith AO, AF&AO and PME Incharge	EFC/SFC (2021-26) meeting	7th May, 2021 (Virtual)
Dr. A. D. Huchche Pr. Scientist (Hort.)	Restructured Weather Based Crop Insurance Scheme (RWBCIS) meeting with members of Crop Specific Technical Sub- Committee on Citrus fruits	28th May, 2021
Dr. A. D. Huchche Pr. Scientist (Hort.)	XXVI Scientific Advisory Committee meeting	KVK, CICR, Nagpur on 4th June, 2021 (Virtual)
Dr. Dinesh Kumar, Pr. Scientist (Hort.) and Sh. V. Bansode, Scientist (Food Technology)	National Dialogue on Innovative Food for Hospitality Industry"	22nd June, 2021 (Virtual)

Name and Designation	Programme	Place and date/duration
Dr. A. Thirugnanavel Scientist 'SS' (Hort.)	National Webinar on "Emerging Trends in Plant Physiology"	Department of Plant Physiology, Sri Karan Narendra Agriculture University, Jobner, Rajasthan on 28th June, 2021
Dr. Dilip Ghosh, Director	Directors Conference	ICAR, New Delhi on 2nd July, 2021 (Virtual)
Dr. A. D. Huchche, Pr. Scientist (Hort.) and Dr. G.T. Behere, Pr. Scientist (Ento.)	'One district, one crop' meeting under the Self-reliant India initiative of the Govt. of India	Collectorate, Chhindwara during 2-3 July, 2021
Dr. A.A. Murkute Pr. Scientist (Hort.)	Board meeting	RVSKVV, Gwalior on 9th July, 2021
Dr. Dilip Ghosh, Director	12th Research Council Meeting	University of Horticultural Sciences, Bagalkot on 14th July, 2021 (Virtual)
Dr. A. D. Huchche, Pr. Scientist (Hort.) and Dr. Naresh Meshram, Pr. Scientist (Ento.)	20th Scientific Advisory Committee meeting	Krishi Vigyan Kendra, Yavatmal on 26th July, 2021
Dr. Dinesh Kumar Pr. Scientist (Hort.)	ABI project review meeting for reviewing the Agri-Business Incubation (ABI) Centres of Horticulture Division.	27th and 28th July, 2021(virtual)
Dr. Dinesh Kumar Pr. Scientist (Hort.)	23rd and 24th meeting of Scientific Panel	FSSAI, New Delhi on 28th July, 2021 and 27th September, 2021(Virtual)
Dr. A. D. Huchche, Pr. Scientist (Hort.) and Dr. G.T. Behere, Pr. Scientist (Ento.)	Crop specific technical sub-committee meeting for citrus crops chaired by Dr. A. K. Singh, DDG (Hort.), ICAR, New Delhi to take status / update about standardization of Term-sheets, Weather Triggers and Risk Periods for the crops notified under (RWBCIS)	6th August, 2021(Virtual)
Dr. Dinesh Kumar, Pr. Scientist (Hort.)	Orientation workshop for ICAR labs	Federation of Indian Export Organisations, Ministry of Commerce, Govt. of India on 12th and 13th August, 2021 (Virtual)

Name and Designation	Programme	Place and date/duration
Dr. Dilip Ghosh, Director and Dr. A.D. Huchche, Pr. Scientist (Hort.)	26th meeting of ICAR Regional Committee No. VII	25th August, 2021 (virtual)
Dr. Dilip Ghosh, Director and Dr. A.A. Murkute, Pr. Scientist (Hort.)	State Variety Release Committee meeting	2nd September, 2021 (Virtual)
Dr. Dilip Ghosh Director	Strategy workshop – Certification of quality planting material of clonally Propagated Fruit Crop for Promoting Diversification	20th September, 2021.
Dr. A. D. Huchche Pr. Scientist (Hort.)	Vigilance enquiry	NBPGR Regional Station, Akola during 23-24th September 2021
Dr. A. Thirugnanavel Scientist 'SS' (Hort.)	Workshop on Germplasm registration in Horticultural crops	IIHR, Bengaluru on 1st October, 2021 (Virtual)
Dr. A. Thirugnanavel, Scientist 'SS' (Hort.) and Dr. J.P. Tej Kumar, Scientist (Biotech.)	Inception workshop on citrus germplsam under DBT project "Collection, Conservation and Morpho-Phenological Characterization of Citrus Germplasm of North East Region"	AAU, Khanapara during 5-6th October, 2021
Dr. Dilip Ghosh, Director and Dr. Dinesh Kumar, Pr. Scientist (Hort.)	Workshop of ZTMUs/ ITMUs/ PMEs under NAIF Scheme	5-11 October, 2021
Dr. A.D. Huchche Pr. Scientist, (Hort.)	Vigilance enquiry at NBPGR headquarters at New Delhi	6-7th October, 2021
Dr. A.A. Murkute Pr. Scientist (Hort.)	Board meeting of RVSKVV, Gwalior	26th October, 2021
Dr. Dilip Ghosh, Director; Dr. A. Thirugnanavel, Scientist'SS'(Hort.); Admn. Officer and AF&AO	Review meeting on special campaign on Swachhta and Pending matters organized by ICAR	27th October, 2021 (Virtual)
Dr. Dilip Ghosh, Director alongwith 13 Scientists	Interaction with Secretary, DARE and Director General, ICAR	28th October, 2021 (Virtual)
Dr. Dilip Ghosh, Director; Dr. A.K. Das, Pr. Scientist (Plant Pathology) and Dr. A.A. Murkute, Pr. Scientist (Hort.)	National Conference on "International Year on Fruits and Vegetables" as a part of "Azadi ka Amrut Mahotsav" under MIDH	29th October, 2021 (Virtual)

Name and Designation	Programme	Place and date/duration
Dr. A.A. Murkute Pr. Scientist (Hort.)	Meeting of Board of Studies	CAU, Imphal on 8th November, 2021 (Virtual)
Dr. A.A. Murkute Pr. Scientist (Hort.)	University Convocation	RVSKVV, Gwalior on 20th November, 2021 (Virtual)
Dr. A.D. Huchche, Pr. Scientist (Hort.); Dr. R.K. Sonkar, Pr. Scientist (Hort.); Dr. Dinesh Kumar, Pr. Scientist (Hort.); Dr. D.T. Meshram, Pr. Scientist (L&WME); Dr. U.R. Sangle, Pr. Scientist (Plant Pathology) and Sh. Venkatraman Bansode, Scientist (Food Technology)	9th Indian Horticulture Congress 2021	Kanpur, Uttar Pradesh during 18-21 November, 2021
Dr. U.R. Sangle Pr. Scientist (Plant Pathology)	National Workshop on "Farmers' Income and Research Impact Assessment"	ICAR-NIAP, New Delhi on 29th November, 2021 (Virtual)
Dr. A. Thirugnanavel, Scientist 'SS' (Hort.); Dr. Evening Stone Marboh, Scientist 'SS' (Hort.); Dr. J.P. Tej Kumar, Scientist (Biotechnology); Mr. Venkatraman Bansode, Scientist (Food Technology) and Dr. Kiran Kumar Kommu, Scientist (Nematology)	Interaction of Young Scientists with Director General, ICAR	8th December, 2021 (Virtual)
Dr. Dilip Ghosh, Director; Dr. R.K. Sonkar, Pr. Scientist (Hort.); Dr. A.K. Das, Pr. Scientist (Plant Patho.) and Dr. Evening Stone Marboh, Scientist 'SS' (Hort.)	25th Regional Committee Meeting (Zone – III)	11th December, 2021 (Virtual)
Dr. D. T. Meshram Pr. Scientist (L&WME)	30th National Webinar, (SCSI), OU&AT, Bhubaneswar	OUA&T, Bhubaneswar, Odisha on 14-16 December, 2021 (Virtual)

Name and Designation	Programme	Place and date/duration
Dr. A.D. Huchche, Pr. Scientist (Hort.), Dr. D.T. Meshram, Pr. Scientist (L&WME), Dr. Naresh Meshram, Sr. Scientist (Ento.), Dr. A. Thirugnanavel, Scientist 'SS' (Hort.), Sh. V. Bansode, Scientist (Food Technology) and Dr. Kiran Kumar Kommu, Scientist (Nematology)	Agrovision Foundation-2021	Reshimbagh Ground, Nagpur during 24-27 December, 2021
Dr. A. Thirugnanavel Scientist 'SS' (Hort.)	Workshop on science communication	Indian Institute of Horticultural Research, Bengaluru on 29th December, 2021 (Virtual)

14.2. Lectures delivered by CCRI Scientists in training / skill development / other programmes of other organizations

- **Dr. Dilip Ghosh, Director**
  - "Citrus status in India" in the virtual programme of "Dr. YSRHU year of Citrus" (2021-22) which was declared by Hon'ble Minister for Agriculture & Co-operation, Marketing, Food Processing, Govt. of Andhra Pradesh on 8th June, 2021.
  - National webinar on "Pest Management in Organic Farming : Options and Challenges" held on 30th July, 2021 organized by Krishi Vigyan Kendra, Sepahijala, CAU (I), Tripura.
  - BEST TALKS on "Advances in Citriculture" organized by Bharatiya Engineering Science and Technology Innovation University (BESTIU), Andhra Pradesh on 23rd October, 2021 (Virtual).

- **Dr. A. K. Srivastava, Pr. Scientist (Soil Science)**
  - Soil Health Management in Fruit Crops in Digital Training program 'Fruit Science Research : Progress and Prospects' organized by Department of Horticulture, PG College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar during 1-8 September, 2021.
  - Soil, a service provider to mankind organised by Indian Society of Soil Survey and Land Use Planning, Nagpur, Maharashtra on the occasion of World Soil Day on 8th December, 2021

- **Dr. A. D. Huchche, Pr. Scientist (Hort.)**
  - Citrus Production Technology in the farmers' training programme at Rajgarh, MP on 16th January, 2021 organized by Madhya Pradesh Agriculture Department.
  - Export Potential for Agri Crops/Fruits and Vegetables in Vidarbha' organized by Agrovision at Hotel Centre Point, Nagpur on 9th October, 2021.
  - Importance of citrus fruits in human life' to students of Vidya Krushi Vikas High School, Bhuyar, Taluka-Pauni, District-Bhandara in the DST programme "Indradhanush : A Science Exhibition – Cum - Demonstration programme, a Scientific Inspirational Programme sponsored by

DST New-Delhi for the School Children from rural areas during 20 - 22, October 2021.

- Citrus production technology and post-harvest management' to the Agricultural Assistants orientation programme at RAMETI, Nagpur on 10th November, 2021.

- **Dr. G. T. Behere, Pr. Scientist (Ento.)**
  - Identification and Management of Major Insect Pests of Citrus on 24th February, 2021 in Five Days Orientation Training Programme organized by Regional Central Integrated Pest Management Centre, Nagpur.
  - Management of fruit drop in Nagpur mandarin and sweet orange caused by insect pests to the farmers of Nagpur Division, Department of Agriculture, Govt of Maharashtra organized by RAMETI, Nagpur on 1st September, 2021.

- **Dr. D. T. Meshram, Pr. Scientist (L&WME)**
  - Drip Irrigation and Fertilizer Management in Citrus orchards webinar organized by VANAMATI, Nagpur (Farmer Ghosti) during 18th June, 2021 (Virtual).
  - Drip irrigation and fertilizer management in Citrus orchards training programme at VANAMATI on 22nd September, 2021.

- **Dr. Naresh Meshram, Sr. Scientist (Ento.)**
  - "Management of Insect pest of Citrus "in Virtual training programme on "Management of Citrus Orchard" organised by RAMETI, Amravati on 14th October, 2021.
  - "Integration of classical and molecular Taxonomy for spp. delineation" for brain storming session organised by ICAR-NBAIR, Bengaluru. 18th November, 2021.

- **Dr. A. Thirugnanavel, Scientist 'SS' (Hort.)**
  - How does ICAR-CCRI help and guide farmers organized by Agriculture Information, Bengaluru on 16th February, 2021 (Virtual).
  - Citrus breeding in India to the M.Sc (Horticulture) and Ph.D (Horticulture) students, IIHR, Bengaluru on 22nd April, 2021.
  - "Role of ICAR-CCRI Indian Citrus Industry" to Students of Horticulture, Hiriyur on 23rd July, 2021.
  - "ICAR-CCRI technologies" Students of final year B.Sc. (Hons) Horticulture, College of Horticulture – Bidar, Arabhavi, Bagalkot and Sirsi, University of Horticultural Sciences, Bagalkot on 10th August, 2021.

- **Sh. V. Bansode, Scientist (Food Technology):** "Processing and Value addition of Citrus fruits and its by-products" to B.Sc (Agri) students of College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli during Virtual Education Tour on 29th October, 2021.

- **Ms. Sangeeta Bhattacharyya, Scienitst (Extension) :** Scientist Resource person for Preparation of Agricultural Extension Subject in Social Science Group of ICAR-JRF Examination to the students of college of Horticulture & Forestry, CAU, Pasighat in the programme of JRF Coaching for JRF Aspirants under IDP-NAHEP on 26th March, 2021 (Virtual).

- "Orange Fruit Production-Management and Marketing" organized by VANAMATI, Nagpur during 20-21 May, 2021 (virtual).
  - **Dr. A. K. Srivastava (2021):** Nagpur Orange-Overview, INM in Orange Fruit Crops.
  - **Dr. A. D. Huchche (2021):** *Mrig and Ambia Bahar* Management in Orange Fruit Crop.

- Training programme to the HORTSAP trainees on 24th June, 2021.
  - **Dr. A.D. Huchche (2021):** "*Limboovargiya phal pikache bahar niyantran ani phalgal samasya"*
  - **Dr. A. K. Das (2021)**: "Surveillance, Identification and Management of Diseases in Citrus".

- **Dr. G. T. Behere (2021)** : "*Limboovargiya pikateel keed vyavasthapan*"

- Dr. A. D. Huchche, Pr. Scientist (Hort.), Dr. G. T. Behere, Pr. Scientist (Ento.) and Dr. A. K. Das, Pr. Scientist (Plant Patho) : 'Care and management of citrus orchards' in the RAMETI, Amravati sponsored citrus growers training programme on 7th September and 20-21 September, 2021(virtual).
- Agrovision Foundation -2021, at Reshimbagh Ground, Nagpur from 24-27 December, 2021
  - Dr. A. D. Huchche (2021) : Management of cropping in mandarin and sweet orange on 26th December, 2021.
  - Dr. Naresh Meshram (2021) : Major Insect pest of Citrus on 26th Dec. 2021
  - Dr. A. Thirugnanavel (2021) : "Production technology of banana" on 26th December, 2021
- Citrus-Graduate Readiness Programme organized by Dr. Y. S. R. Horticultural University, Andhra Pradesh during 8-12-2021 to 14-02-2022 (virtual).
  - **Dr. J. P. Tej Kumar (2021) :** Role of Biotechnology in citrus improvement on 17th December, 2021.
  - **Dr. A. D. Huchche (2021) :** 'Climate change and climate-resilient Citriculture' on 27th December 2021.
  - **Dr. Dinesh Kumar (2021) :** "Value addition in Citrus" on 29th December, 2021.
  - **Dr. N. Vijayakumari (2021) :** Innovative propagation techniques to conserve citrus germplasm on 31st December, 2021.

15 Institutional Activities / Celebrations

15.1 International Women's Day

International Women's Day on the theme "Women Leadership in Agriculture : Entrepreneurship, Equity & Empowerment (3 E's)" celebrated on 8th March, 2021 in which 74 staff participated (54 staff and 20 students). Chief Guest Dr. Meena Patil, Obstetrician & Gynecologist of Nagpur, emphasized the importance of the day and contribution of women in the society. Dr. Meena Patil delivered a lecture on Women's health issues and over all health issues of mankind where she deliberated on proper nutrition, exercise and mental health which are fundamental to the well being of the people and society. Dr. (Mrs.) N. Vijayakumari, Pr. Scientist (Hort.) conducted the programme and highlighted the significant contributions of women in various fields. Dr. B. S. Dwivedi, Director, also spoke on the occasion and Dr. J. P. Tej Kumar, Scientist proposed vote of thanks.

15.2 World Water Day

World Water Day on the theme "Valuing Water" celebrated on 22nd March, 2021 in hybrid mode in whcih 74 participants (24 farmers, 41 staff and 9 students) attended. Dr. D. T. Meshram, Pr. Scientist highlighted the importance of water in agriculture. Dr. B. S. Dwivedi, Director emphasized the importance of the day and availability and role of water in agriculture. Chief Guest Dr. S. N. Das, Former Director, MRSAC, Nagpur, delivered a lecture on technologies for assessment of water resources and focused

Dr. Meena Patil addressing the staff and students

Dr. S. N. Das, Ex-Director, MRSAC, Nagpur

A view of the participants

Dr. D. T. Meshram, Pr. Scientist welcoming the Guest on the occassion of world water day

on water management related technologies, importance and role of RS and GIS in agriculture. Progressive farmers Shri. Shyam Agrawal from Paratwada and Shri. Dadasheb Kale, from Katol spoke on importance of drip irrigation system and importance of surface and subsurface drip irrigation system in citrus crops. Dr. D. T. Meshram, Pr. Scientist (L&WME) co-ordinated the programme and also proposed vote of thanks.

15.3 *Azadi ka Amrit Mahotsav*

- Farmers Awareness Campaign on 'Balanced Use of Fertilizers' in the form of "Farmers Goshti" (virtual) organized on 18th June, 2021 which was attended by 148 farmers. The programme was inaugurated by Dr. Madhavi Khode Chaware, IAS, Director, VANAMATI, Nagpur and Dr. Dilip Ghosh, Director, CCRI, Nagpur was the Guest of Honour. The technical session comprised lectures on 'Soil Health Card for citrus' (Dr. A. K. Srivastava, Pr. Scientist, ICAR-CCRI), 'Drip / fertigation in citrus' (Dr. D. T. Meshram, Pr. Scientist, ICAR-CCRI,) and Soil Health Card Mission' (Smt. Archana Raut Kochare TO, SAO Office Nagpur). Programme was coordinated by Dr. A. K. Srivastava, Pr. Scientist. and vote of thanks by Dr. D.T. Meshram, Pr. Scientist.

- Institute organized first Special Guest lecture under Azadi ka Amrit Mahotsav by Dr. Manjul Dutt,

A view of Farmers Goshti

Dr. Manjul Dutt, Chief Guest in the Webinar

Research Scientist, Citrus Research and Education Center (CREC), University of Florida, USA on 30th September, 2021 on the topic "Utilizing Genetic Modification and Genome Editing Strategies for Management of Greening Disease (Huanglongbing) in Citrus". The lecture highlighted various means to improve disease resistance in the citrus crops like sweet orange and mandarin against the citrus greening disease that has threatened the global citrus industry. Nearly two hundred participants involving researcher's and students from different research organization and universities from India and abroad joined through online mode. Dr. Dilip Ghosh, Director, ICAR-CCRI, Nagpur, chaired the session and in his introductory remarks highlighted the importance of genome editing techniques in citrus improvement program. The program was coordinated by Dr. G. T. Behere, Principal Scientist, ICAR-CCRI.

- Sh. V. Bansode, Scientist (Food Technology) delivered a lecture on "Citrus fruits and its byproducts: As a source of functional food" on 21st May, 2021 which was attended by CCRI scientists.

15.4 International Yoga Day

- "International Yoga Day" on the theme "Yoga for Well-being" celebrated on 21st June, 2021. The programme was chaired by Dr. Dilip Ghosh, Director of the Institute. He appealed to all the staff to practice

different Yoga postures and Pranayam consistently to build up positive energy and immunity during the difficult times of the highly infectious COVID-19 pandemic. Yoga experts from Shri Janardan Swami Yogabhyasi Mandal, Nagpur, conducted the yoga exercises, demonstrations and narrated the importance of various postures and benefit of yoga on human health in a lucid language before the participants. Dr. A. D. Huchche, Pr. Scientist, Dr. Naresh Meshram, Sr. Scientist and Dr. Ashok Kumar, ACTO organized the event.

Yoga expert instructing Asanas on International Yoga Day

15.5 Foundation Day Celebration

Institute celebrated its "37th Foundation Day" on 28th July, 2021. At the outset Dr. Dilip Ghosh, Director, welcomed the Chief Guest Dr. C.D. Mayee, Ex-Chairman, ASRB; and Guests of Honour, Dr. Y.G. Prasad, Director, ICAR-CICR and Dr. B.S. Dwivedi, Director, ICAR-NBSS&LUP and all others physically present as well as those attending the event from different parts of the country through virtual mode. In his introductory remarks he explained in detail about the remarkable contributions made by the institute during its more than three decades of journey that has enabled the institute to become a symbol of trust for farmers, industry, academia and other stakeholders in terms of research and development, extension and farm advisory services.

Sh. Prashant Khursange, being felicitated by the Chief Guest

Dr. Y. G. Prasad and Dr. B. S. Dwivedi, in their special address touched upon the present requirements of the citrus industry in general and emphasized the role of ICAR-CCRI in contributing to bring the prosperity of citrus growers. Progressive citrus farmers, Sh. Prashant Khursange from Narkhed, Dist. Nagpur and Sh. Sandeep Padalwar from Mahur, Dist. Nanded were felicitated for establishing excellent citrus orchards of Nagpur mandarin and Sweet orange crop with the technical guidance of the institute.

Awards in different categories *viz*., 'Employee of the year', 'Top Five Research Publications', 'Three Best Collaborative Publications', 'Externally Funded Project' and 'Licensed / Commercialized Technology' were distributed. Essay competition on the topic '75 years of Citrus Industry in India: A Conspectus' organized for the staff. Dr. C. D. Mayee, Chief Guest, highlighted the constraints presently faced by the citrus growers. He further elaborated and appreciated the research work of the institute scientists and their scientific way of dealing with the farmers' problems. He suggested that taking up collaborative assignments with different stakeholders will be helpful in dealing with the problems of planting material supply. The programme was moderated by Dr. Dinesh Kumar, Pr. Scientist and vote of thanks by Sh. Venkatraman Bansode, Scientist.

15.6 Brainstorming workshop on "Citrus fruit drop"

One-day Brainstorming workshop on "Citrus fruit drop" organized under the Bharat ka Amrit Mahotsav on 27th September, 2021. Scientists from ICAR-CCRI, State Agricultural Universities viz., Dr. PDKV, Akola; VNMKV, Parbhani; and MPKV, Rahuri, as well as officers from State Agriculture Department and progressive citrus growers participated.

Chief Guest Hon'ble Shri Sunil Kedar, Minister of Animal Husbandry Dairy Development, Sports and Youth Welfare, Govt. of Maharashtra, stressed that an integrated strategy to deal with citrus fruit drop problem should be devised early. An Extension Bulletin entitled "Improved Cultivation Practices for Nagpur mandarin" was released. Earlier Dr. Dilip Ghosh, Director, welcomed the dignitaries and gave brief account on the research achievements of the institute in different areas and also briefed technologies to control citrus fruit drop available with the institute which has been successfully disseminated among the farmers. In his address, Dr. B.K. Pandey, ADG (HS-II), ICAR, clarified that there are many fold problems in the perennial fruit crop like citrus due to climate change in different parts of the country. He emphasized about proper nutrient management in citrus orchard and assured farmers that CCRI will certainly deliver solutions to different problems of citrus growers. Dr. B.S. Dwivedi, Director, ICAR- NBSS & LUP and Dr. Vilas Kharche, Director of Research, Dr. PDKV, Akola also spoke on the occasion.

Dignitaries releasing CCRI Extension publication

During the technical sessions Dr. A. K. Das, Pr. Scientist, presented in detail about different causes of fruit drop menace and suggested integrated management strategies. Dr. D. M. Panchbhai, Associate Dean, College of Agriculture, Nagpur, Dr. Dinesh Paithankar, AICRP, Akola, Dr. Sanjay Patil, VNMKV, Parbhani. Shri Ravindra Bhosale, JDA, Nagpur etc shared their experiences and expressed the need of training for extension workers and farmers and establishment of demonstration blocks at taluka level. The programme was attended by invited farmers from Katol, Narkhed, Karanja, Morshi, Achalpur, Amravati, Chandurbazar, talukas of Nagpur, Amravati and Wardha districts. Dr. Ashutosh Murkute, Pr. Scientist conducted the proceedings and Dr. R. K. Sonkar, Pr. Scientist proposed the vote of thanks.

15.7 Farmers' Scientists Interface on "Climate Resilient varieties, technologies and practices"

The live telecast programme of Hon'ble Prime Minister Shri. Narendra Modi ji was organized at the institute on 28th September, 2021 in which around 80 people including farmers from Hingna, Katol and Kalmeshwar regions attended. Hon'ble Prime Minister virtually released / dedicated 35 crop varieties to the nation developed by ICAR. During a ceremony Prime Minster inaugurated the newly constructed campus of National Institute of Biotic Stress Management, Raipur, Chhattisgarh and also interacted with five farmers across the country. Later Prime Minister distributed Green campus award to the Agricultural Universities. Dr. Dilip Ghosh, Director addressed the audience on Climate resilient varieties, technologies and practices. The programme was coordinated by Dr. A. D. Huchche, Pr. Scientist (Hort.).

Chief Guest distributing prizes to the winner

Glimpses of Farmers' Scientists Interface

15.8 Hindi Saptah

Hindi Saptah was celebrated during 14-20 September, 2021 during which Essay competition entitled "Azadi ka Amrit Mahotsav - Aapke Vichar", translations and questionary competitions were organized in which the staff participated enthusiastically and received awards. The valedictory programme of Hindi Saptaha was celebrated on 21st September, 2021 in which Dr. S.K. Shukhla, Pr. Scientist, GTC, ICAR-CIRCOT, Nagpur was the Chief Guest. Prizes to the awardees were given. Earlier Dr. Dilip Ghosh, Director stressed the use of Hindi in day to day work. Programme was conducted by Dr. Dinesh Kumar, Pr. Scientist and Dr. V. Bansode, Scientist proposed vote of thanks.

15.9 Other Programmes

- 'Mahila Kisan Diwas' was organized on 15th October, 2021 at ICAR-CCRI research farm in which 11 women and 39 men from Wadi, Hingna, Pardi area of Nagpur district participated. Training on vermicomposting techniques, farm residue management and practical's was conducted by Sh. V. P. Bhaladhre, Sh. Ajay Gadge, and Sh. Santosh Khaire, Technical Officers, ICAR-CCRI, Nagpur.

- Organized 'World Food Day' on 16th October, 2021 in which CCRI staff (60) participated. The programme was inaugurated by Dr. Dilip Ghosh, Director, ICAR-CCRI. Sh. Venkatramam Bansode, Scientist delivered lecture on "Food Nutrition: Source to alleviate hunger and malnutrition in India". Dr. A. Thirugnanavel, Scientist proposed vote of thanks.

- A National campaign on "Antimicrobial Resistance" under Azadi ka Amrit Mahotsav was organized at Hatla village, Katol Taluka, Nagpur on 24th November, 2021 which was attended by fifteen farmers. Dr. A. K. Das, Pr. Scientist, Dr. Dinesh Kumar, Pr. Scientist and Dr. Sunil Kumar, U.T. (ACTO) were the experts. The focus was given to create awareness on the antibiotic uses and consequences of the over and under use of antibiotics towards developing antibacterial resistance. The farmers also asked their queries on the

aspects related to antimicrobial resistance. Dr. Kiran Kumar Kommu, Scientist co-ordinated the training programme.

- "India International Science Festival (IISF) 2021" organized under Azadi Ka Amrit Mahotsav on 27th November, 2021 with the theme "Celebrating Creativity in Science". Twenty Post Graduate students from Biochemistry department and four lecturers from Hislop College, Nagpur attended the programme. Dr. U. R. Sangle, Pr. Scientist and Dr. Kiran Kumar Kommu, Scientist explained an overview of the IISF, importance of citrus industry in India and the achievements of the Institute. They were shown Biotechnology and Post-harvest & processing laboratories where the scientists explained the molecular approaches for improving citrus, post-harvest technologies, value-added products in citrus respectively.

- Institute celebrated 'World Soil Day' on the theme "Halt Soil Salinization, Boost Soil Productivity" on 5th December, 2021 at Gram Panchayat of Mohgaon Zilpi village of Hingana taluka in Nagpur district in which 17 farmers and students attended. Dr. D. T. Meshram, Pr. Scietnsit explained importance of maintaining healthy ecosystems and human well-being by addressing the growing challenges in soil management, fighting soil salinization and encouraging societies to improve soil health. Progressive farmers discussed the issues related to use of organic & inorganic fertilizer and how excessive use of chemical fertilizers deteriorates the

Practical on vermicomposting

A view of the experts and participants on Antimicrobial Resistance

Dr. Dilip Ghosh addressing the participants on World Food Day

A view of the participants of IISF

Dr. D.T. Meshram addressing the farmers on World Soil Day

A view of participants

productivity of soil. Shri. Bipin Mahalle, YP-II proposed vote of thanks.

- The live telecast address of Hon'ble Prime Minister, Shri Narendra Modi ji in the conference on "Natural Farming (Zero Budget Natural Farming)" organised by the Govt. of Gujarat as a part of "Pre-Vibrant Gujarat Summit 2021" on 16th December, 2021 was attended by 99 CCRI staff and farmers. The event was coordinated by Dr. D. T. Meshram, Pr. Scientist, Dr. Naresh Meshram, Sr. Scientist and Dr. Kiran Kumar Kommu, Scientist.

Director and staff attending Pre Vibrant Gujarat Summit

15.10 Welfare Activity

- Farm Kit Distribution under Schedule Caste Sub Plan (SCSP) Scheme : Institute organized kit distribution programme at two villages under Ta. Katol, Dist. Nagpur on 24th February, 2021 at Metpanjara, in presence of Mrs. P. D. Zode, Sarpanch of Metpanjra Grampanchayat and at Wadhvihira in presence of Mrs. S. N. Kharbate, Sarpanch of Wadhvihira

Kit distribution at Metpanjara and Wadhvihira villages under SCSP

Grampanchayat. The farm related Kit comprising of "Nagpur Santryachi Sudharit Lagwad" (CCRI Extension Bulletin), Carbendazim (500 gm), COC (500 gm), Metalaxyl (500 gm), Secateur, Magnifying Glass, Mask, Sanitizer Bottle, Notepad and Pen were distributed to more than 30 farmers in each villages. The programme was co-ordinated by Dr. R. K. Sonkar, Pr. Scientist and Nodal Officer, SCSP.

- Looking to the health problems in human life due to COVID-19, Health and Educational kits were distributed to Scheduled Cast Labourers of ICAR-CCRI on 10th May, 2021. The kit that included oximeter, thermometer, sanitizer, vaporizer, mask, etc. were distributed by the Chief Guest, Dr. Dilip Ghosh, Director. He guided the laborers on COVID-19 and on awareness about vaccination to protect oneself from this pandemic. Dr. R. K. Sonkar Pr. Scientist and Nodal Officer, SCSP coordinated the programme.

Dr. Dilip Ghosh, Director distributing kit at CCRI under SCSP

- Institute organized "Parthenium Awareness" on 21st August, 2021 to make farmers and the general public aware about the menace of Parthenium. Organized a plethora of activities for Parthenium uprooting in the campus under the Swachh Bharat Abhiyan, in which 43 staff were participated.

- ICAR-CCRI, Nagpur celebrated Poshan Vatika Maha Abhiyan and Tree Plantation (International Millets Day) on 17th September, 2021 at Village Godhani, Dist. Nagpur in which 40 farmers were present. On this occasion tree plantation was undertaken by Chief Guest Mr. Dipak Raut, Sarpanch, Godhani, Nagpur and Mr. Mahendra Gajbhiye, Agriculture Officer. A lecture on 'Nutritional and health importance of Millets and their value addition in day to day life was delivered for the benefit of the farmers. Packets of finger millet and pearl millet and 570 citrus planting materials were distributed to the farmers. Dr. R.K. Sonkar, Pr. Scientist (Hort.), Dr. A. Thirugnanavel, Scientist (Hort.) and Sh. V. Bansode, Scientist (Food Technology) coordinated the programme.

Parthenium uprooting in campus

Distribution of citrus planting material to farmers at Village Godhoni

- Scientists, Technical and Administration staff attended the Interactive Session with State Bank of India (SBI) Officials on "SBI Office Connect" on 23rd November, 2021 which was coordinated by Dr. Kiran Kumar Kommu, Scientist (Nematology).

15.11 *Mera Gaon Mera Gaurav* (My Village My Pride) programme

Training, demonstration and technology dessimination activities continued in the two villages *viz.*, Pachgaon, taluka Umred, dist. Nagpur and Hetikundi, taluka Karanja, dist. Wardha

15.12 Celebration of other events / days

Following events were celebrated :

- Republic day on 26th January, 2021 and Martyrs day on 30th January, 2021, 131st Birth Anniversary of Dr. Bhimrao Ambedkar on 14th April, 2021. A programme was organized on 15th April, 2021; Independence Day on 15th August, 2021; and Dr. B.R. Ambedkar Maha Parinirvan Diwas on 6th December, 2021

- *Rahstriya Ekta Diwas* was celebrated on 31st October, 2021 on the occasion of Birthday of first Deputy Prime Minister of India Sh. Vallabhbhai Patel. Programmes like debate and wall painting for the staff and students were conducted to increase awareness of the day. Dr. Dilip Ghosh, Director, ICAR-CCRI administered the pledge on 31st October, 2021. Dr. Dilip Ghosh enlightened with the events that transpired after the independence and the role played by the Sh. Vallabhbhai Patel. The programme culminated with the visit to the wall painting (Prizes were distributed for the winners). The event was coordinated by Dr. J. P. Tej Kumar, Scientist (Biotechnology), Mr. Venkatraman Bansode, Scientist (Food Technology) and Dr. Kiran Kumar Kommu, Scientist (Nematology).

***Rahstriya Ekta Diwas* Celebration**

- Vigilance Awareness Week observed from 26th October, 2021 to 1st November, 2021 (Theme: Independent India @ 75: Self Reliance with Integrity) during which all staff administered pledge on 26th October, 2021.

- Observed "Constitution Day (Samvidhan Diwas)" on 26th November 2021. All the scientists and staff read the preamble to the constitution on https://readpreamnble, nic.in and also attended online event of the live celebrations of Constitution Day graced by Hon'ble President, Hon'ble Vice President and Hon'ble Prime Minister. The institute staff were enlightened with the information regarding our constitution framework and its principles by Dr. Dilip Ghosh, Director.

15.13 Rajbhasha Activities

Institute organized following online Hindi Workshops for the benefit of staff

- ➢ "Sarkari Karyalayon me Hindi ko protsahan" in which Dr. Renu Bali, Director, Hindi Department, Vasantrao Naik Government Institute of Arts College, Nagpur, delivered a lecture on 24th March, 2021.
- ➢ "Karyalay me upyog Hindi ka vyavharik paksh" Dr. Brajesh Kumar Yadav, Hindi Translator,

National Green Tribunal, New Delhi on 13th December, 2021.

- "Rajbhasha Hindi samasya aur samadhan" by Dr. Veena Dadhe, Prof. Hindi Department, Nagpur University on 14th December, 2021.

15.14 Visit of Parliamentary Rajbhasha Standing Committee

The second sub-committee of the Parliamentary Standing Committee for official language under the Chairmanship of Smt. Ranjanaben Bhatt and other members inspected the progress of works related to Rajbhasha of the Institute on 28th December, 2021 at Hotel Radisson Blue, Nagpur. Officials from ICAR, New Delhi viz., Dr. B.K. Pandey, ADG (HS), Sh. Jagdishan A.K., Deputy Director (Rajbhasha) and Sh. Manoj Kumar, CTO (Rajbhasha) alongwith Dr. Dilip Ghosh, Director, Dr. A.K. Srivastava, Pr. Scientist; Dr. Dinesh Kumar, Pr. Scientist; Sh. V. Bansode, Scientist; Sh. Yogesh Pathare, Admn. Officer; Sh. R.K. Mandalekar, ACTO, ICAR-CCRI, Nagpur were present during the inspection.

Officials seen during Parliamentary Standing Committee

15.15 Special National *Swachhta* Campaign

- The Special *Swachhata* Campaign during 2nd to 31st October, 2021 was inaugurated by Dr. D.K. Ghosh, Director, ICAR-CCRI, Nagpur and all the staff members of the Institute attended the inaugural programme. He highlighted the importance of the cleanliness and its positive impact in the society. The staff members took a Swachhta Pledge. The cleanliness drive was organized after the pledge. The staff members cleaned the office building laboratories, corridors, porch, farm office, etc.

Special *Swachhata* Campaign

- The special *swachhta* campaign was organized at Dr. D.V. Durugkar Aadarsh Bharat Vidyalaya and Juniour College, Mohpa Zilpi, Hingna Taluk, Nagpur district under the theme 'Waste to Wealth' on 12th October, 2021. Sh. Yawalkar, Principal of the College was the Chief Guest. Sarpanch of the village and Sh. Sanjay Aande Progressive farmer were the guest of honour in which the ICAR-CCRI staffs, school teachers, farmers, and students participated. Lecture on

Students cleaning school campus

importance of cleanliness in human life and waste to wealth were delivered by the ICAR-CCRI staffs. After the lecture, cleanliness drive was organized to clean the school premises, and village council office premises.

- *Swachhata* campaign was organized during 16-31 December, 2021. The drive commenced from 16th December, 2021 with pledge by all staff. During this campaign organized cleanliness drive around water harvesting structure, drainage lines in the residential quarters, office and farm building, children's, park, collecting the scrap material for its disposal and demonstrated Vermicompost preparation using kitchen waste to families residing in quarters.

16 Distinguished Visitors

- Mr. Rajbir Singh, Joint Secretary, MIDH visited on 27th December, 2021.

Dr. Dilip Ghosh, Director welcoming Mr. Rajbir Singh

- Dr. Dilip Ghosh, Director had an interaction / meeting with Hon'ble Agriculture Minister, Shri Narendra Singh Tomar and Hon'ble Minister for Road Transport & Highways, Shri Nitin Gadkari-ji, Government of India during their visit to Agrovision, Nagpur on 24th December, 2021.

Dr. Dilip Ghosh, Director interacting with Hon'ble Ministers

17 Personnel

17.1 Appointment

Permanent Staff

- Sh. Venkatraman Vishwanath Bansode, Scientist (Food Technology) joined on 27th January, 2021 on transfer from ICAR- Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala.
- Dr. B.S. Dwivedi, Acting Director of ICAR-CCRI, Nagpur w.e.f. 30th January, 2021 (afternoon) till 28th April, 2021.
- Dr. Dilip Ghosh, Director, ICAR-Central Citrus Research Institute, Nagpur on 28th April, 2021.
- Dr. Naresh Meshram Sr. Scientist (Agril. Ento.) joined CCRI on 31st May, 2021 consequent upon transfer from ICAR-IARI, New Delhi.
- Dr. U.R. Sangle, Pr. Scientist (Plant Pathology) joined the institute on 2nd July, 2021 upon his transfer from ICAR-IGFRI, Jhansi.
- Dr. Evening Stone Marboh, Scientist 'SS' (Fruit Science) joined the institute on 2nd July, 2021 upon his transfer from ICAR-NRC on Litchi, Muzaffarpur, Bihar.
- Sh. Yogesh R. Pathare, Administrative Officer joined the Institute on 15th November, 2021 on transfer from ICAR-CIRCOT, Mumbai.

Contractual Staff

- Sh. Shailesh M. Zalke, Young Professional - II w.e.f. 3rd March, 2021.
- Mr. Chiatanya P. Deshpande, Junior Research Fellow w.e.f. 1st July, 2021
- Mr. Firoj Ahmad Ansari, Senior Research Fellow w.e.f. 26th July, 2021.
- Ms. Ruchi Bhate, Senior Research Fellow w.e.f. 3rd August, 2021
- Mr. Lochan Jyoti Dutta, Young Professional (YP-I) w.e.f 1st September, 2021 at RRCC, Biswanath Chariali, Assam.
- Mr. Sahinur Ahmed, Young Professional (YP-I) w.e.f 1st September, 2021 at RRCC, Biswanath Chariali, Assam.
- Sh. Shubham A. Chichghare, Young Professional (YP-I) w.e.f 29th September, 2021
- Sh. Tulshidas V. Baraskar, Young Professional (YP-I) w.e.f 29th September, 2021
- Ms. Priyanka A. Tandulkar, Young Professional (YP-II) w.e.f 1st October, 2021.
- Ms. Vaishnavi B. Berad, Young Professional (YP-I) w.e.f 5th October, 2021.
- Ms. Darshna C. Admane, Young Professional (YP-I) w.e.f 21st October, 2021.
- Mr. Sachin A. Mendke, Junior Research Fellow (JRF) w.e.f. 25th October, 2021.
- Sh. Prafulla R. Jalamkar, Young Professional (YP-I) w.e.f 1st November, 2021.
- Ms. Shraddha Dahat, Young Professional (YP-I) w.e.f 1st November, 2021.
- Sh. Datta R. Surwase, Young Professional (YP-I) w.e.f 17th November, 2021
- Sh. Mrugendar G. Gubyad, SRF w.e.f. 31st December, 2021

17.2 Retirement

- Dr. M.S. Ladaniya, Director relieved on 30th January, 2021 on superannuation.
- Sh. V.N. Dhengre, ACTO superannuated on 30th June, 2021.

17.3 Promotion

- Sh. Vinayak Khuspure and Sh. Suresh Kamble, Temporary Status Labourers promoted as Skilled Supporting Staff w.e.f. 10th February, 2021.
- Nine staff from Temporary Status Labourers Sh. Rajkumar Dhongade, Sh. Vilas Khawale, Sh. Suresh Choudhari, Sh. Dhanraj Bante, Sh. Suresh Shinde, Sh.

Ramprasad Bihare, Sh. Dinkar Asutkar, Sh. Bhimrao Pande and Sh. Raju Rohankar promoted as Skilled Support Staff w.e.f. 1st September, 2021

17.4 Resignation/relieving

- Sh. Dinesh S. Rathod, Young Professional-II under "ICAR-All India Coordinated Research Project on Fruits (AICRP)" relieved w.e.f. 31st August, 2021.

17.5 Transfer

- Dr. Anjitha George, Scientist 'SS' (Ento.) relieved on 25th March, 2021 consequent upon her transfer to Regional Station, ICAR-Indian Institute of Seed Science, Bengaluru.

17.6 Education / Study Leave

- Ms. Sangeeta Bhattacharyya, Scientist (Extension) relieved on 20th January, 2021 for Split Ph.D programme at IARI, New Delhi for one year. Submitted Ph.D thesis titled "Socio-economic Impact of Sansad Adarsh Gram Yojana in Maharashtra and Telangana" in December 2021

17.7 Staff Position (as on 31.12.2021)

Research Management Position

Dr. Dilip Ghosh, 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. R. K. Sonkar
   Principal Scientist (Horticulture)
5. Dr. A. K. Das
   Principal Scientist (Plant Pathology)
6. Dr. Dinesh Kumar
   Principal Scientist (Horticulture)
7. Dr. U. R. Sangle
   Principal Scientist (Plant Pathology)
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. Naresh Meshram
    Senior Scientist (Entomology)
12. Dr. A. Thirugnanavel
    Senior Scientist (Horticulture)
13. Dr. Evening Stone Marboh
    Scientist (Horticulture)
14. Sh. V. Bansode
    Scientist (Food Technology)
15. Dr. Prasanth Tej Kumar, J.
    Scientist (Ag. Biotechnology)
16. Dr. Kiran Kumar Kommu
    Scientist (Nematology)
17. Ms. Sangeeta Bhattacharyya
    Scientist (Agril. Extension)

Technical Staff

1. Miss. Lily Varghese
   Chief Technical Officer
2. Dr. U. T. Sunil Kumar
   Chief Technical Officer
3. Sh. S. L. Shirkhedkar
   Asstt. Chief Technical Officer
4. Sh. Ravikiran Mandlekar
   Asstt. Chief Technical Officer
5. Dr. Ashok Kumar
   Asstt. Chief Technical Officer
6. Sh. D. D. Banerjee
   Asstt. Chief Technical Officer
7. Mrs. Jayshree Kolwadkar
   Sr. Tech. Officer

8.	Sh. M. P. Gorle	Tech. Officer
9.	Sh. C. H. Chauhan	Tech. Officer.
10.	Sh. V. P. Bhaladhare	Tech. Officer.
11.	Sh. R. D. Dhone	Tech. Officer.
12.	Sh. A. B. Gadge	Tech. Officer.
13.	Sh. B. G. Awari	Tech. Officer.
14.	Sh. S. K. Khaire	Tech. Asstt.
15.	Sh. M. B. Sayam	Sr. Tech. Asstt.
16.	Sh. K. K. Ghaiwat	Sr. Tech. Asstt.
17.	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. Yogesh Pathare	Administrative Officer
4.	Sh. S. W. Ambekar	Assistant, I/c. AAO
5.	Sh. N. F. Suryavanshi	Assistant
6.	Smt. Usha Dhanvijay	Assistant
7.	Sh. P. M. Khobragade	Jr. Clerk
8.	Sh. M. S. Utane	Jr. Clerk

Skilled Support Staff

1.	Sh. A. N. Mahanande	Skilled Support Staff
2.	Sh. D. S. Sardar	Skilled Support Staff
3.	Sh. Anil Shaneshwar	Skilled Support Staff
4.	Sh. D. N. Sambhare	Skilled Support Staff
5.	Sh. N. K. Mohariya	Skilled Support Staff
6.	Sh. Namdeo Thakre	Skilled Support Staff
7.	Smt. Manisara Gurung	Skilled Support Staff
8.	Sh. Sunil Kharche	Skilled Support Staff
9.	Sh. Vinayak Khuspure	Skilled Support Staff
10.	Sh. Suresh Kamble	Skilled Support Staff
11.	Sh. Rajkumar Dhongade	Skilled Support Staff
12.	Sh. Vilas Khawale	Skilled Support Staff
13.	Sh. Suresh Choudhari	Skilled Support Staff
14.	Sh. Dhanraj Bante	Skilled Support Staff
15.	Sh. Suresh Shinde	Skilled Support Staff
16.	Sh. Ramprasad Bihare	Skilled Support Staff
17.	Sh. Dinkar Asutkar	Skilled Support Staff
18.	Sh. Bhimrao Pande	Skilled Support Staff
19.	Sh. Raju Rohankar	Skilled Support Staff

Annexure –I

The weather parameters recorded at ICAR-CCRI, Nagpur agro-meteorology observatory during 2021

MW	T_{db} (°C)	T_{wb} (°C)	T_{max} (°C)	T_{min} (°C)	WS (kmph)	RH (%)	V. Pre (mmHg)	Rainfall (mm)	E_{pan} (mm)
1	21.0	19.4	29.3	16.9	4.02	72.1	24.2	0.00	3.98
2	25.5	21.7	31.1	16.4	6.13	63.1	25.6	0.00	3.45
3	29.9	18.6	30.7	14.1	1.74	52.9	15.5	0.00	2.98
4	31.7	18.2	31.4	15.2	2.70	64.0	16.1	2.60	3.55
5	25.5	17.9	29.2	12.4	4.45	48.7	17.2	0.00	3.05
6	19.4	17.1	30.8	12.8	3.61	41.9	17.7	0.00	3.22
7	21.9	16.8	31.0	15.5	3.43	69.9	14.9	1.90	3.98
8	22.0	16.0	32.9	15.2	2.65	48.7	13.7	0.00	2.89
9	25.4	21.8	37.7	17.1	3.26	32.7	27.3	0.00	2.85
10	22.6	19.2	37.8	18.8	1.09	51.6	25.7	0.00	4.15
11	23.4	19.2	35.6	20.1	2.44	72.6	18.6	17.10	4.65
12	25.7	21.8	33.0	19.4	1.41	74.6	21.6	16.40	4.88
13	30.3	22.6	40.2	21.8	0.90	30.0	21.3	0.00	3.47
14	30.3	20.2	41.0	21.9	1.33	31.1	14.4	0.00	4.15
15	29.5	22.0	37.6	21.9	1.60	37.2	22.6	0.40	4.65
16	29.1	23.0	40.1	22.9	1.04	30.7	22.9	0.00	4.78
17	32.8	21.3	41.7	22.6	1.13	28.4	17.1	0.00	4.88
18	30.5	22.8	40.1	24.5	1.42	49.1	21.8	4.00	7.85
19	32.3	23.4	39.8	24.7	2.11	54.9	25.1	7.70	9.15
20	31.2	26.1	38.3	25.9	2.23	69.3	24.1	27.90	9.25
21	33.6	24.9	40.7	26.3	2.68	48.6	23.0	0.00	9.14
22	31.7	24.7	40.1	26.8	3.71	76.3	25.0	2.70	5.56
23	29.2	24.8	37.0	24.9	2.98	76.8	27.4	28.60	4.58
24	29.8	23.4	34.3	23.5	3.16	83.1	23.3	120.90	2.35
25	32.6	23.5	33.2	24.0	3.21	84.0	23.8	27.20	2.84
26	27.7	24.2	34.5	24.8	1.52	90.3	27.3	37.70	2.45
27	26.6	20.2	34.9	25.2	1.78	84.7	28.4	131.30	2.88
28	28.7	22.4	33.0	24.7	2.59	88.9	30.9	60.40	2.45
29	28.5	21.6	32.1	24.4	2.20	89.9	31.7	151.10	2.01
30	26.4	23.2	30.3	23.9	3.65	90.7	29.4	51.50	4.65
31	27.6	20.8	29.2	23.7	3.28	91.1	27.3	36.60	2.18
32	28.1	24.7	33.1	24.2	1.40	80.6	28.1	4.70	2.87
33	26.8	16.2	31.9	23.9	3.08	87.7	28.5	103.80	1.16
34	27.9	24.9	31.4	24.1	1.40	87.1	28.1	10.00	1.94
35	28.1	24.2	31.3	24.1	1.67	89.9	26.4	71.40	2.52
36	26.8	23.4	31.7	23.7	2.46	90.4	29.7	127.40	2.26
37	23.3	21.8	30.8	23.9	1.69	92.9	29.8	108.30	1.98
38	25.4	22.5	30.7	23.5	1.81	89.3	26.5	89.40	2.25
39	25.0	24.1	32.2	24.3	2.77	83.0	31.7	4.50	2.57
40	27.9	25.1	33.0	23.8	1.45	79.9	28.2	5.00	3.14
41	27.7	23.4	34.6	22.2	1.95	67.1	25.1	0.00	3.06
42	26.0	23.4	32.9	21.3	1.67	73.3	26.7	1.30	2.36
43	24.1	20.1	32.8	17.9	1.90	66.0	19.3	0.00	3.03
44	22.4	15.7	31.3	16.6	2.61	59.1	12.0	0.00	3.04
45	21.6	16.3	30.9	15.1	1.80	60.0	14.0	0.00	3.12
46	22.5	21.0	31.9	21.1	2.10	64.3	18.1	0.00	3.55
47	24.0	21.6	31.7	20.8	2.90	72.1	22.4	3.90	3.45
48	21.6	15.8	29.9	14.2	6.73	55.3	13.5	0.00	3.20
49	20.6	15.6	29.4	16.7	1.22	70.0	14.7	0.00	3.10
50	17.0	11.8	28.9	13.6	1.49	67.7	11.0	0.00	3.00
51	17.6	12.6	28.0	9.9	2.02	57.5	10.6	0.00	2.90
52	17.1	13.5	27.0	14.5	2.14	73.1	13.5	1.80	3.00
Max.	**33.6**	**26.1**	**41.7**	**26.8**	**6.7**	**92.9**	**31.7**	**151.1**	**9.3**
Min.	**17.0**	**11.8**	**27.0**	**9.9**	**0.9**	**28.4**	**10.6**	**0.0**	**1.2**

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
- Water management in citrus
- Fungal disease of citrus diagnosis and management
- Exploration, Collection and mapping of citrus genetic diversity in India
- Nutrient Diagnostics and Management in citrus
- Intercropping in Nagpur Mandarin
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- Citrus entomology a decade at NRCC
- Processing and value addition of citrus
- Micronutrients in Citrus
- Soil and water conservation in citrus
- Post harvest Technology for Sweet Orange for fresh fruit market
- Fertilization in Citrus
- Citrus Greening (HLB) : Diagnostics

EXTENSION BULLETINS

- Nagpur mandarin cultivation
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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
- Flowering problems in Nagpur mandarin
- Evaporative cool chamber for storage of Nagpur mandarin fruits
- Phytophthora disease of citrus and their management
- Management of Post-harvest disease of Nagpur mandarin
- Insect pests of Nagpur mandarin and their management
- संत्रा फळांची तोडणी व हाताळणी
- Multiplication of chrysopid predator (Mallada boninensis)
- संतरे एवं नींबू में पोषण प्रबंधन की समस्याऐं और समाधान
- लिंबू वर्गीय फळझाडांवरील फायटोफ्थोरामुळे होणारे रोग आणि त्यांचे व्यवस्थापन
- संत्रा तोडणीनंतर उद्‌भवणाऱ्या रोगांचे व्यवस्थापन
- संत्रा फळांच्या साठवणुकीसाठी पाण्याच्या बाष्पीभवनावर आधारित शीतगृह
- संत्रा व लिंबू बागांमध्ये खतांचे व्यवस्थापन
- नागपूर संत्र्यावरील कीड व त्यांचे व्यवस्थापन
- Export of Nagpur Mandarin
- Weed management in citrus orchards
- Production of disease free planting material of citrus
- Drainage problems and management in Nagpur mandarin orchards
- Virus and virus- like diseases of citrus and their management
- Citrus Genetic Resources
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- लिंबूवर्गीय फळझाडांच्या रोगरहित कलमांचे उत्पादन
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- Improved Cultivation Practices for Khasi Mandarin in Mizoram

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- Nagpuri santrae ke keede makhode aur unka prabandan
- High density cultivation in acid lime

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