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# Evaluation of different rootstocks on the performance of some mandarin cultivars under mid hill conditions of Arunachal Pradesh

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## ABSTRACT

**Four rootstocks, *viz.*, *C. latipes*, Volkamariana, *Tanyum* (*C. medica*) and rough lemon (*C. jambhiri*) were used for budding different genotypes, *viz.*, Hill mandarin, Nagpur mandarin, *Khasi* mandarin and Sikkim mandarin as a scion cultivars. Plant height was observed higher with Nagpur mandarin followed by Hill mandarin. Among the rootstocks, TCSA was noticed higher with *C. latipes* (49.31 ). Sikkim mandarin recorded the highest canopy spread in both the directions with different rootstock combinations. Flower and fruit drop percentage was recorded least in *Khasi* mandarin (25.18 and 6.20, respectively). Fruits/ plant was recorded more in *Khasi* mandarin (399.47) followed by Sikkim mandarin (345.42). Nagpur mandarin and *Tanyum* recorded the higher peel weight (33.46; 32.99) and thickness (5.37; 5.04) among scion and rootstock, respectively. Fruit weight and juice content was recorded more in *Khasi* mandarin (143.09; 76.57, respectively). Highest seed number was recorded with *tanyum* (13.67). *C. volkamariana* positively influenced the TSS content of fruits. Plants of Volkamariana came to early harvesting, *i.e.* in the first week of November, whereas on rough lemon it was late, *i.e.* last week of December to first week of January. Our study showed that *C. volkamariana* was found to be the best rootstock for *Khasi* mandarin in Arunachal Pradesh.**

**Key words:** Citrus, mandarin, rootstock, fruit quality, budding.

## INTRODUCTION

Citrus is one of the world's most important fruit crops, playing vital role in human nutrition and world economy. It is the second most important fruit crop in world trade for fresh fruits and more than 50 countries are growing citrus commercially in different agro-climatic conditions for its diversified use and increasing demand globally (Suresh Kumar *et al.*, 17). These fruits are known to be the native of Southeast Asia but they are now extensively grown almost throughout the world under tropical and sub-tropical conditions, where the soil and climatic regimes are quite favorable for its growth and yield (Ahmed *et al.*, 1). Citrus occupies third place after mango and banana, grown in 0.798 million ha area to the production tune of 7.15 million tonnes per annum in India (Anon, 2). The most commercial citrus cultivars in India are the mandarin, followed by sweet orange and acid lime sharing 41, 23 and 21 per cent of area, respectively (Suresh Kumar *et al.*, 16).

Most of the mandarins in India are raised from nucellar seedlings. They are facing several biotic and abiotic stresses during their growth and thus prematurely die due to citrus decline. There is no controversy over the importance of citrus rootstock for citrus production. More than 20 horticultural characteristics are affected by the rootstock including leaf nutrient status, vigour and size, depth of rooting, low temperature tolerance, adoption to adverse soil conditions, disease resistance and fruit quality (Castle, 5). They are also able to significantly alter the pattern of canopy development and functions such as photosynthesis. The use of rootstock for predominant citrus species has shown revolutionary performance in various other citrus growing countries like Israel, USA and Spain (Levy *et al.*, 14; Perez *et al.*, 15). The effect of rootstocks on citrus tree growth, yield, and fruit quality has been intensively studied in many citrus producing areas of the world (Castle and Phillips, 4; Fallahi *et al.*, 8; Economides and Gregorion, 6; Fallahi and Rodney, 7; Holtzhausen *et al.*, 11; Zekri, 19).

The diverse geographical regions characterized by varying temperature and rainfall have given rise to a wide range of variability in citrus and related genera in India. The North Eastern Himalayan region is endowed with favourable agro-climatic conditions for the growth of different citrus fruits and is considered the natural home of several *Citrus* species. The native mandarin growers all through the Eastern Himalayan Region of India nowadays are showing inclination towards adopting budded orchards as appropriate rootstock offers promising performance than nucellar seedlings with regards to adaptability against biotic and abiotic factors, precocity of bearing, uniform fruit size and higher yield (Suresh Kumar *et al.*, 16). North Eastern Hill region, especially Arunachal Pradesh is known

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for its quality production of *Khasi* mandarin. Among the different fruit crops grown in this state, more than 35% area is under *Khasi* mandarin (Gogoi *et al.*, 10). The environmental conditions and cultural practices are unique and the performance of different rootstocks is found variable under different climatic and edaphic conditions. Therefore, the present study was carried out to determine the horticultural adaptability and performance of four different mandarin cultivars on four commercial rootstocks under mid hills of Arunachal Pradesh.

## MATERIALS AND METHODS

The present study was undertaken at the Experimental Farm of ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, which extends 26°28′ to 29°28′N latitude and 91°35′ to 97°27′E longitude, 631 m above msl for consecutive three fruiting seasons. The soil in the farm is silty loam with slightly acidic pH (5.3). Mean maximum (27.5°C) and minimum (16.7°C) temperature and relative humidity (64.7%), received the average annual rainfall of 1893.43 mm. The soil of the experimental field was silty loam with moisture retention at 0.03 MPa (24.2%), 1.5 MPa (14.5%) and bulk density (1.37 Mg/ $m^3$). The soil of the site was acidic in reaction (pH 5.3), high in soil organic carbon (1.50%), low in available N (205.6 kg/ ha), low in available phosphorus (8.3 kg/ ha) and medium in available K (260 kg/ ha). The experiment was laid out in randomized block design with three replications.

Four rootstocks, *i.e. Citrus latipes*, Volkamariana (*C. volkamariana*), *Tanyum* (*C. medica*) and rough lemon (*C. jambhiri*) were used for budding different mandarin scion varieties, namely, Hill mandarin (HM), Nagpur mandarin (NM), *Khasi* mandarin (KM) and Sikkim mandarin (SM). The treatment details are as follows; $T_1$ = *Khasi* mandarin/ rough lemon; $T_2$ = *Khasi* mandarin/ Tanyum; $T_3$ = *Khasi* mandarin/ *C. volkamariana*; $T_4$ = *Khasi* mandarin/ *C. latipes*; $T_5$ = Sikkim mandarin/ rough lemon; $T_6$ = Sikkim mandarin/ *Tanyum*; $T_7$ = Sikkim mandarin/ *C. volkamariana*; $T_8$ = Sikkim mandarin/ *C. latipes*, $T_9$ = Nagpur mandarin/ rough lemon, $T_{10}$ = Nagpur mandarin/ *Tanyum*; $T_{11}$ = Nagpur mandarin/ *C. volkamariana*; $T_{12}$ = Nagpur mandarin/ *C. latipes*; $T_{13}$ = Hill mandarin/ rough lemon; $T_{14}$ = Hill mandarin/ *Tanyum*; $T_{15}$ = Hill mandarin/ *C. volkamariana*; and $T_{16}$ = Hill mandarin/ *C. latipes*. The trees were planted in March 1999 at a spacing of 4 m × 4 m at a density of 625 trees/ ha. Plants were grown under similar soil and cultural conditions and evaluated during a period of three years to know the stionic effect on various mandarin cultivars. All the treatments were executed in Randomized Block Design (RBD) with four trees as a unit for one replication and replicated thrice. Urea, single super phosphate (SSP) and muriate of potash (MOP) were applied to tree at the constant level of 250, 200, 250 g NPK/ tree/ year. Urea was applied in two splits, *i.e.* immediately after harvesting and pruning (during mid January) and after fruit set (during August). Phosphorus and potassium were applied along with half the dose of nitrogen after harvesting. The package of practices was followed uniformly to all the treatments. The data on growth parameters, *viz.*, tree height (m), canopy coverage (m) were recorded. Trunk circumference (C) was measured and trunk cross- sectional area (TCSA) was calculated (Zekri, 21): TCSA = $C^2 / 4\pi$. Tree height (H) and width in two directions parallel ($W_1$) and perpendicular ($W_2$) to the tree row were measured and tree canopy volume (TCV) was calculated based on the assumption that the tree shape was one half prolate spheroid (Zekri, 21): TCV = $\pi / 6 \times H \times W_1 \times W_2$.

Flower bud initiation period and harvesting period was also recorded to know the variation among cultivars. To observe the effect of rootstocks on sex of flowers, 20 flushes of each tree were marked and data were recorded on total number of flowers and maleness percentage. Ten fruits per replication were taken randomly and analyzed for physico-chemical characteristics. The fruit characteristics like rind thickness (mm), number of segments, fruit length (cm), breadth (cm), fruit weight (g), fruit volume (ml), juice /fruit (ml), and number of seeds, were recorded. At harvesting, total number of fruits per tree were counted to obtain the yield data. Samples of ten fruits per replication from different treatments were collected for fruit quality estimations. Chemical parameters like total soluble solids (TSS), ascorbic acid and acidity were also analyzed (AOAC, 3). The juice was squeezed from the fruit sample and tested for Brix and acid. From these two, the Brix/ acid ratio was calculated. The Brix content was determined using a hand refractrometer and the percent acid was determined by titration using sodium hydroxide and a phenolphthalein indicator.

The average values were recorded for each year and pooled data of three years was subjected to further statistical analysis using the Fisher's test of variance technique. The means were compared using Duncan's multiple range test (DMRT) at 5% probability, using AGRES statistical package.

## RESULTS AND DISCUSSION

Growth and flowering performance of various scion and rootstock is presented in Table 1. It was observed that maximum plant height was observed with Nagpur orange followed by Hill mandarin (4.55), while the minimum plant height (3.82) was observed in Sikkim mandarin. Number of branches did not vary much among scion genotypes and rootstocks. However, number of primary branches was more with Nagpur mandarin (16.14), whereas minimum was recorded in *Khasi* mandarin (12.90). Hill and Sikkim mandarins were at par with each other for their branching pattern. TCSA, which was derived from trunk circumference was higher in Nagpur mandarin followed by Sikkim mandarin. Among the rootstocks, TCSA was noticed higher with *C. latipes* (49.31) followed by rough lemon (47.46). Overall, rootstock has significant influence on tree growth of budded plants. Owing to their vigorous nature *C. latipes* and rough lemon showed more TCSA than others. Canopy spread of the plants followed the similar pattern to that of plant height. Sikkim mandarin recorded the highest canopy spread in both the directions with different rootstock combinations. Hill mandarin and *Khasi* mandarin were similar in their canopy spread with different rootstocks. Among the rootstocks, highest canopy spread was recorded with *C. volkamariana* in both the directions. Rough lemon and *C. latipes* were at par with each other (3.40) on their canopy spread at E-W direction, while *C. latipes* recorded higher spread (3.80) in N-S direction. TCV followed the similar pattern to that of canopy spread for the rootstocks and scion cultivars. Flower and fruit drop were recorded least in *Khasi* mandarin (25.18 and 6.20%, respectively) whereas the highest flower and fruit drop was recorded with Nagpur mandarin (29.86 and 12.43%, respectively). Among the rootstock species, flower drop was recorded more on *C. volkamariana*, whereas the least was recorded with *tanyum* (22.80%). Interestingly, the fruit drop did not follow the any pattern and it was recorded more in rough lemon followed by *C. latipes*. Nonetheless due to higher fruit drop per plant in *C. volkamariana*, it recorded higher number of fruits per plant, which ultimately compensated the fruit drop. Fruits/ plant was recorded more in *Khasi* mandarin (399.47) followed by Sikkim mandarin (345.42). Data on yield per plant revealed significant differences for means various rootstocks. Interestingly, the ultimate tonnage was recorded more in *Khasi* mandarin (33.74) followed by Nagpur mandarin (21.49). Among the rootstocks, *C. volkamariana* recorded higher No. of fruits/ tree and overall yield followed by *tanyum* plants. Yield is the outcome of a number of factors in which rootstock also contributes towards the yield. It is interesting to note that three rootstocks other than rough lemon behaved alike. These results are in accordance with the findings of Castle and Phillips (4) and Fallahi *et al.* (8). It is also confirmed by the information observed that yield in volkamer lemon was least affected by the seasonal variation for the period of study. This suggests that volkamer lemon is a suitable rootstock for prolific bearing in mandarin. Our results are closely related to Georgiou (9) and Jaskani *et al.* (13).

The data profile indicated that Nagpur mandarin recorded comparatively bigger sized fruit than other mandarins (Table 2). Hill and *Khasi* mandarins were similar in length and were medium in size. Sikkim mandarin was comparatively smaller in size. The highest fruit breadth was also recorded with Nagpur mandarin followed by *Khasi* mandarin. Similar observations were recorded by Singh and Singh (16). The results indicated highly significant differences amongst rootstocks over the years; *C. latipes* significantly influenced the fruit size as both fruit length and breadth were recorded

**Table 1.** Growth and yield characteristics of different mandarin cultivars on different rootstock combinations.

| Genotype | Plant height (m) | No. of branches | TCSA ($cm^2$) | Crop canopy (N-S) m | Crop canopy (E-W) m | TCV ($m^3$) | Flower drop (%) | Fruit drop/ plant | Fruit drop (%) | Fruits/ plant | Yield (t/ ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Scion | | | | | | | | | | | |
| KM | 3.93 | 12.90 | 45.37 | 3.68 | 3.45 | 25.85 | 25.18 | 26.13 | 6.20 | 399.48 | 33.74 |
| SM | 3.82 | 14.60 | 46.85 | 4.20 | 3.95 | 32.89 | 26.70 | 28.10 | 7.51 | 345.43 | 21.12 |
| NM | 4.65 | 16.14 | 48.15 | 3.93 | 3.52 | 33.63 | 29.86 | 38.78 | 12.43 | 286.60 | 21.49 |
| HM | 4.55 | 14.65 | 45.09 | 3.67 | 3.45 | 30.42 | 26.35 | 30.40 | 9.12 | 301.15 | 18.34 |
| $CD_{0.05}$ | 0.11 | 0.79 | 1.68 | 0.14 | 0.08 | 1.07 | 0.65 | 1.09 | 0.27 | 11.23 | 3.79 |
| Rootstock | | | | | | | | | | | |
| Rough lemon | 4.40 | 15.23 | 47.46 | 3.53 | 3.40 | 27.53 | 28.37 | 32.85 | 10.63 | 295.95 | 19.79 |
| Tanyum | 3.95 | 13.04 | 42.75 | 3.95 | 3.73 | 30.37 | 22.80 | 26.20 | 7.31 | 344.97 | 25.43 |
| *C. volkamariana* | 3.88 | 14.07 | 45.95 | 4.19 | 3.85 | 32.89 | 30.25 | 34.25 | 8.63 | 366.35 | 25.92 |
| *C. latipes* | 4.72 | 15.95 | 49.31 | 3.80 | 3.40 | 31.98 | 26.68 | 30.10 | 8.70 | 325.37 | 23.56 |
| $CD_{0.05}$ | 0.10 | 0.50 | 1.53 | 0.15 | 0.14 | 1.10 | 1.13 | 1.19 | 0.29 | 13.11 | 1.99 |

KM = *Khasi* mandarin; SM = Sikkim mandarin; NM = Nagpur mandarin; HM = Hill mandarin higher, whereas rough lemon and *C. volkamariana* were at par with each other on their influence on fruit size. Georgiou (9) and Jaskani *et al.* (13) who observed that rootstocks widely affect the fruit size in citrus. Peel weight and thickness are the important criteria for selection of good oranges. Nagpur mandarin on *tanyum* recorded higher peel weight (33.46; 32.99 g) and thickness (5.37; 5.04 mm) among scion and rootstock, respectively. However, the effect of rootstock on peel thickness was statistically not significant. Fruit segment did not had much variation among mandarins. However, *Khasi* mandarin recorded comparatively more segments (11.39) than other mandarins, while the least number was recorded with Nagpur mandarin (9.57). It is clear from data that rootstock species did not show significant effect on segment number and their weight. In spite of segments of their weight was more in *Khasi* mandarin (10.17 g) followed by Nagpur mandarin (9.83 g). Sikkim and Hill mandarins were at *par* with each other with regard to segment weight. Fruit weight was also recorded more with *Khasi* mandarin (143.09 g) followed by Nagpur mandarin (130.87 g). Sikkim and Hill mandarins were at par for fruit weight. Influence of rootstock on fruit weight, was observed to be profound. Highest fruit weight was recorded with *tanyum* followed by *C. latipes*. Seed number was significantly higher in Nagpur mandarin (16.9), while other mandarin cultivars recorded similar seed number. Rootstocks profoundly influenced the seed number in fruits. Highest seed number was recorded with *tanyum* (13.67). Juice content was recorded higher in *Khasi* mandarin (76.57%) followed by Nagpur mandarin (66.08%). Hill and Sikkim mandarins were at par for their juice content. Among rootstocks, *C. volkamariana* recorded the higher juice content followed by *tanyum*.

It could be visualized and compared from Table 3 that *Khasi* mandarin recorded higher TSS among different mandarin cultivars. It was experienced that as the trees got older, there was a noticeable improvement in fruit and juice quality from all the trees (data not shown). The least was recorded in Nagpur mandarin irrespective of rootstocks used. Higher TSS recorded by *Khasi* mandrain might be due to its better adaption and inherent genetic makeup. Among the rootstocks, *C. volkamariana*, positively influenced the fruit TSS content. *Tanyum*, a native plant to *Khasi* hills strongly influenced the TSS content but negatively. The higher the Brix and the Brix: acid ratio, the earlier is the fruit maturity. In this study, it was observed that *C. volkamariana* came to early harvesting, *i.e.* in the first week of November, whereas, rough lemon produced mandarins in the last week of December to first week of January. Ahmed *et al.* (1) also recorded the higher TSS using volkamer lemon as rootstock for Kinnow mandarin. Higher acidity was recorded for Sikkim mandarin. All other mandarin cultivars were similar in their acidity content. Similarly, higher TSS: acid ratio was recorded with *Khasi* mandarin followed by Nagpur mandarin, which was at par with Hill mandarin. Among rootstock species, *C. volkamariana* recorded profound effect on TSS: acid ratio followed by rough lemon (11.64). Ascorbic acid, an important parameter to select rootstock was recorded more with *C. volkamariana* followed by rough lemon. Total sugars content was recorded more for *Khasi* mandarin (8.21) followed by Sikkim mandarin (8.08).

**Table 2.** Influence of scion and rootstock genotypes on fruit characteristics of different mandarin cultivars.

| Genotype | Fruit length (cm) | Fruit breadth (cm) | Peel weight (g) | Peel thickness (mm) | No. of segments/ fruit | Segment weight (g) | Fruit weight (g) | No. of seeds/ fruit | Juice content (ml/ fruit) |
|---|---|---|---|---|---|---|---|---|---|
| Scion | | | | | | | | | |
| KM | 4.89 | 4.92 | 27.17 | 5.56 | 11.39 | 10.17 | 143.09 | 11.55 | 76.57 |
| SM | 4.00 | 3.85 | 29.13 | 4.06 | 10.01 | 8.22 | 102.84 | 11.14 | 54.88 |
| NM | 5.05 | 5.01 | 33.46 | 5.37 | 9.57 | 9.83 | 130.87 | 16.90 | 66.08 |
| HM | 4.60 | 4.69 | 30.83 | 4.66 | 11.26 | 8.38 | 102.50 | 10.07 | 51.55 |
| $CD_{0.05}$ | 0.15 | 0.26 | 1.03 | 0.13 | 0.37 | 0.48 | 5.16 | 1.57 | 4.69 |
| Rootstock | | | | | | | | | |
| Rough lemon | 4.58 | 4.55 | 29.28 | 4.85 | 10.46 | 9.12 | 117.39 | 11.73 | 60.07 |
| *Tanyum* | 4.67 | 4.65 | 32.99 | 5.04 | 10.59 | 9.19 | 123.16 | 13.67 | 61.16 |
| *C. volkamariana* | 4.58 | 4.54 | 27.89 | 4.85 | 10.92 | 9.16 | 118.22 | 11.76 | 65.07 |
| *C. latipes* | 4.71 | 4.71 | 30.42 | 4.91 | 10.25 | 9.12 | 120.55 | 12.49 | 62.76 |
| $CD_{0.05}$ | N.S. | N.S. | 1.09 | N.S. | NS | N.S. | 3.72 | 0.44 | 1.05 |

KM = *Khasi* mandarin; SM = Sikkim mandarin; NM = Nagpur mandarin; HM = Hill mandarin

**Table 3.** Chemical and quality parameters of Mandarin cultivars on different rootstocks.

| Genotype | TSS (Bx) | Acidity (%) | TSS: acid ratio | Ascorbic acid (mg/100 g) | Reducing sugar (%) | Total sugars (%) | Fruit grade | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Extra special (>60 mm) | Special (50-60 mm) | Average (45-55 mm) |
| Scion | | | | | | | | | |
| KM | 12.18 | 0.83 | 14.71 | 49.15 | 4.85 | 8.21 | 270.72 | 78.95 | 50.05 |
| SM | 10.17 | 1.02 | 9.93 | 30.98 | 4.67 | 8.08 | 216.67 | 62.73 | 65.80 |
| NM | 9.05 | 0.86 | 10.58 | 38.15 | 4.20 | 7.38 | 160.36 | 43.87 | 82.39 |
| HM | 9.13 | 0.88 | 10.41 | 44.73 | 4.31 | 7.59 | 172.15 | 48.27 | 70.87 |
| $CD_{0.05}$ | 0.39 | 0.02 | 0.34 | 2.14 | 0.24 | 0.39 | 9.26 | 2.84 | 2.16 |
| Root stock | | | | | | | | | |
| Rough lemon | 10.20 | 0.89 | 11.64 | 41.13 | 4.20 | 7.28 | 169.69 | 48.93 | 75.39 |
| Tanyum | 9.98 | 0.96 | 10.40 | 38.20 | 4.56 | 7.85 | 216.27 | 61.50 | 64.71 |
| *C. volkamariana* | 10.37 | 0.86 | 12.27 | 43.68 | 4.74 | 8.25 | 237.61 | 68.18 | 57.84 |
| *C. latipes* | 10.08 | 0.89 | 11.29 | 40.00 | 4.53 | 7.87 | 196.33 | 55.45 | 71.20 |
| $CD_{0.05}$ | N.S. | 0.04 | 0.49 | 3.22 | 0.26 | 0.64 | 7.87 | 1.92 | 2.16 |

KM = *Khasi* mandarin; SM = Sikkim mandarin; NM = Nagpur mandarin; HM = Hill mandarin

*C. volkamariana* exhibited positive effect on sugar fruit content. Other workers also found that fruit quality of citrus scion cultivars was affected by rootstocks (Economides and Gregorian, 6; Fallahi and Rodney, 7; Zekri, 18,19). Extra special fruit grade fruits were recorded more in *Khasi* mandarin (270.72) followed by Sikkim mandarin (237.61), 68.18 and 57.84 Nos. of extra special and special and graded fruits. Average fruits were recorded more in Nagpur mandarin and *C. latipes*, respectively. Volkamer lemon and *tanyum* produced moderate to good number of fruits with marketable size. Hence, it could be easily inferred that Volkamer lemon could be a suitable rootstocks for *Khasi* mandarin.

Interaction between scion and rootstock revealed that plant height was significantly influenced by both the factors. Rootstock has profound effect on plant height. It is reflected from Table 4 that *Khasi* mandarin scion behaved differently with the rootstocks. The stionic effects on budded plants are statistically significant on plant height. However, among the combinations Nagpur mandarin + *C. latipes* recorded the highest plant height (5.2 m) followed by Hill mandarin + *C. latipes*. The least values were recorded on Sikkim mandarin + *C. volkamariana* combination (3.2 m), which was at par with *Khasi* mandarin + *C. volkamariana* combination. Flower drop was recorded more with Nagpur mandarin + *C. volkamariana* combination, while the least was recorded with *Khasi* mandarin + *tanyum* combination. Nagpur mandarin being the popular mandarin of tropical regions, *i.e.* central India, not growing well under sub-tropical climate with high rainfall areas of Arunachal Pradesh. Further combination with *tanyum* aggravated the higher flower and fruit drop incidence. Overall fruit yield was recorded higher with *Khasi* mandarin + *C. volkamariana* (36.75) followed by *Khasi* mandarin + *tanyum* (36.09). Fruit yield was very low with Hill mandarin + rough lemon followed by Nagpur mandarin + rough lemon combinatos. Peel weight was also varied according to the combinations. Irrespective of bud material peel weight was recorded more when *tanyum* was used as rootstock. Highest peel weight was recorded when Nagpur mandarin was budded on *tanyum* (37.34). Number of segments irrespective of rootstock, was recorded low with Nagpur mandarin. However, the result was statistically not significant. Fruit weight also behaved in the similar fashion that *Khasi* mandarin recorded more fruit weight than other mandarins irrespective of rootstock used. Chemical characteristics of fruits did not vary much among different combinations. Budded plants retain their original inherent characters with little or no change in TSS and ascorbic acid contents on different rootstocks. In other words the stionic effect is very low on chemical characteristics of different mandarin cultivars. However, highest ascorbic acid content was recorded with *Khasi* mandarin + *C. volkamariaiana* followed by *Khasi* mandarin + rough lemon. Similar result was reported by Ahmed *et al.* (1) on Kinnow mandarin. Fruit grade signified that highest extra grade fruits were obtained from *Khasi* mandarin + *C. volkamariana* trees followed by *Khasi* mandarin budded on *tanyum*.

**Table 4.** Effect of scion cultivar and rootstock on growth, yield and quality of mandarin.

| Treatment | Plant ht. (m) | TCV ($m^3$) | Flower drop (%) | Fruit drop (%) | Yield (t/ha) | Peel weight (g) | No. of segments/ fruit | Fruit wt. (g) | No. of seeds/ fruit | TSS: acid ratio | Ascorbic acid (mg/100 g) | Extra grade (> 60 mm) | Special grade (50-60 mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 4.1 | 25.53 | 26.1 | 7.73 | 27.64 | 26.89 | 11.42 | 137.35 | 10.28 | 15.03 | 49.6 | 210.09 | 64.8 |
| $T_2$ | 3.8 | 26.49 | 21.5 | 4.85 | 36.09 | 30.67 | 11.48 | 145.62 | 12.76 | 13.42 | 46.9 | 288.71 | 84.7 |
| $T_3$ | 3.3 | 24.25 | 27.3 | 6.25 | 36.75 | 24.32 | 11.66 | 141.21 | 11.26 | 15.94 | 52.8 | 309.67 | 92.4 |
| $T_4$ | 4.5 | 27.13 | 25.8 | 5.97 | 34.49 | 26.81 | 10.99 | 144.09 | 11.89 | 14.46 | 47.3 | 274.42 | 73.9 |
| $T_5$ | 4.1 | 30.16 | 27.9 | 8.82 | 18.08 | 28.35 | 10.02 | 99.32 | 10.66 | 10.04 | 30.7 | 177.91 | 54.2 |
| $T_6$ | 3.6 | 32.44 | 22.6 | 6.04 | 23.46 | 31.14 | 10.05 | 108.07 | 11.91 | 9.35 | 29.6 | 236.34 | 64.3 |
| $T_7$ | 3.2 | 33.12 | 29.2 | 7.53 | 23.19 | 27.79 | 10.06 | 101.34 | 10.23 | 10.4 | 33.8 | 256.83 | 71.8 |
| $T_8$ | 4.4 | 35.78 | 27.1 | 7.9 | 19.75 | 29.25 | 9.91 | 102.65 | 11.74 | 9.90 | 29.8 | 195.62 | 61.5 |
| $T_9$ | 4.7 | 29.27 | 31.3 | 15.54 | 17.32 | 33.81 | 9.31 | 128.89 | 16.31 | 10.83 | 38.7 | 147.74 | 39.4 |
| $T_{10}$ | 4.1 | 31.67 | 24.9 | 10.53 | 22.63 | 37.34 | 9.64 | 133.61 | 19.28 | 9.56 | 34.4 | 156.85 | 44.7 |
| $T_{11}$ | 4.6 | 38.30 | 34.8 | 11.93 | 24.09 | 30.25 | 10.05 | 129.25 | 15.75 | 11.46 | 41.3 | 185.19 | 49.8 |
| $T_{12}$ | 5.2 | 35.16 | 28.5 | 11.73 | 21.94 | 32.47 | 9.27 | 131.72 | 16.21 | 10.47 | 38.2 | 151.67 | 41.6 |
| $T_{13}$ | 4.7 | 25.16 | 28.2 | 10.42 | 16.12 | 28.15 | 11.07 | 99.87 | 9.67 | 10.7 | 45.5 | 143.06 | 37.3 |
| $T_{14}$ | 4.3 | 30.79 | 22.2 | 7.81 | 19.52 | 32.83 | 11.28 | 105.32 | 10.66 | 9.28 | 41.9 | 183.18 | 52.3 |
| $T_{15}$ | 4.4 | 35.87 | 29.7 | 9.38 | 19.65 | 29.18 | 11.92 | 101.07 | 9.81 | 11.31 | 46.8 | 198.74 | 58.7 |
| $T_{16}$ | 4.8 | 29.84 | 25.3 | 9.19 | 18.07 | 33.16 | 10.86 | 103.75 | 10.14 | 10.34 | 44.7 | 163.61 | 44.8 |
| $CD_{0.05}$ | 0.19 | 2.21 | 1.74 | 0.57 | 1.81 | 2.09 | NS | 3.83 | 0.89 | 1.09 | 1.02 | 14.69 | 4.02 |

Finally, to identify the relation among growth and yield attributes correlation studies were carried out (Table 5). It was noticed that plant height recorded negative correlation with many yield affecting parameters in citrus. Yield and fruit grade were significantly but negatively affected by plant height. Manipulating plant height to certain height through pruning is compulsory for better yield. However, it was observed that flower and fruit drop had negative relationship with the entire yield attributing characters, though the effect was not significant. Therefore, care should be taken to control the flower and fruit drop during critical growth period (Iqbal *et al.*, 12). It was evident that fruit weight had direct highly significant positive correlation with fruit yield. Similarly, fruit weight has highly significant relationship with TSS: acid ratio and seed number/ fruit. Fruit yield directly influenced the fruit grade and physio-chemical characteristics of fruits. However presence of more No. of seed negatively influences the fruit grade and ascorbic acid content. Similar response of rootstock on scion was reported by various other workers (Castle, 5; Ahmed *et al.*, 1).Therefore, the rootstock and scion, which produced less No. of seeds/ fruit should be selected for better quality. TSS: acid ratio significantly influenced the ascorbic acid content and fruit grade.

Based on this study, volkamer lemon was identified as a good rootstock for *Khasi* mandarin in Arunachal Pradesh due to its high fruit and juice quality, yield, yield efficiency, and profit. Dieback is the main problem in this region due to citrus trunk borer and development of hard pan in the soil. Further, rootstocks like *tanyum* and *C. volkamariana* could be exploited to overcome these problems.

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**Table 5.** Correlation matrix of different yield and quality affecting variables of budded mandarin genotypes.

| Parameter | Plant ht. (m) | Flower drop (%) | Fruit drop (%) | Yield (t/ha) | Peel wt. (g) | No. of segments | Fruit wt. (g) | No. of seeds/ fruit | TSS: acid ratio | Ascorbic acid (mg/ 100 g) |
|---|---|---|---|---|---|---|---|---|---|---|
| Flower drop (%) | 0.31 | | | | | | | | | |
| Fruit drop (%) | 0.63 | 0.68* | | | | | | | | |
| Yield (t/ha) | -0.48* | -0.29 | -0.64* | | | | | | | |
| Peel wt. (g) | 0.39 | -0.17 | 0.49 | -0.45 | | | | | | |
| No. of segments/ fruit | -0.26 | -0.33 | -0.57* | 0.42 | -0.52* | | | | | |
| Fruit wt. (g) | -0.03 | -0.07 | -0.08 | 0.77** | -0.04 | 0.06 | | | | |
| No. of seeds/ fruit | 0.27 | 0.22 | 0.55* | 0.04 | 0.66* | -0.66* | 0.51* | | | |
| TSS: acid ratio | -0.26 | 0.02 | -0.37 | 0.82* | -0.66* | 0.57* | 0.70* | -0.18 | | |
| Ascorbic acid (mg/100 g) | 0.06 | -0.02 | -0.17 | 0.51* | -0.39 | 0.77* | 0.48 | -0.27 | 0.78* | |
| Fruit grade | -0.74* | -0.31 | -0.79** | 0.88* | -0.62* | 0.58* | 0.60* | -0.31 | 0.66* | 0.34 |

*, **Significant at 5 & 1% levels, respectively


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