TREE MORPHOLOGY, YIELD EFFICIENCY AND FRUIT QUALITY OF KINNOW MANDARIN (*CITRUS NOBILIS* LOUREIRO × *CITRUS DELICIOSA* TENORA) BUDDED ON DIFFERENT ROOTSTOCKS IN THE NORTH-WESTERN REGION OF INDIA

PANDEY, K.[1*] – RATTANPAL, H. S.[2] – SIDHU, G. S.[3] – SINGH, J.[2]

[1]*Division of Fruits & Horticultural Technology, ICAR-Indian Agricultural Research Institute, New Delhi, India*

[2]*Department of Fruit Science, Punjab Agricultural University, Ludhiana, India*

[3]*School of Agricultural Biotechnology, Punjab Agricultural University, Ludhiana, India*

[*]*Corresponding author*
e-mail: pandeykuldeephort@gmail.com

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Abstract. This experiment aimed to evaluate the horticultural performance viz, tree morphology, yield efficiency and fruit quality of Kinnow mandarin budded on ten rootstocks in the north-western region of India. Results revealed, rootstocks had a significant effect on several variables. Differences among the rootstock girth were recorded during the sixth year after planting (YAP) where the significantly highest values were found in Rough lemon and NRCC-6 however, the lowest value was present in NRCC-5. In the seventh year after planting, trees of Kinnow mandarin on all rootstocks produced similar yield efficiency. Trees on Carrizo citrange showed the highest fruit yield whereas, minimum fruit yield was observed on NRCC-4 during the sixth YAP. During seventh YAP, maximum influence on total soluble solids (TSS) content of Kinnow mandarin was recorded from the fruits obtained from trees on NRCC-1 and CRH-12, whereas fruits from trees on NRCC-3 had minimum soluble solids content. In both seasons, the maximum ascorbic acid content was recorded in fruits on CRH-12, whereas the minimum was observed from the fruits harvested from Carrizo citrange.
Keywords: *fruit yield, ascorbic acid, total soluble solids (TSS), Carrizo*

Introduction

Citrus is one of the most important fruit crops, grown throughout the tropical and sub-tropical regions of the world. India ranks fifth in global citrus production with an annual production of more than 13.2 million mt, which contributes 8.72% of the world’s citrus production. In India, citrus cultivation is dominated by mandarins (*Citrus reticulata* Blanco), which contribute 40.76% of total citrus production. A North-western state of India, Punjab is the largest mandarin growing region, with a total production of 13.98 million tonnes from 1.1 million ha area (Anonymous, 2019). Kinnow mandarin (*C. nobilis* Lourerio × *C. deliciosa* Tenora) is the ruling citrus cultivar of Punjab and because of its better adaptability and high returns, Kinnow has replaced most of sweet oranges (Mosambi, Jaffa and Blood Red). With the popularization of Kinnow cultivation, it has now acquired the status of an independent citrus industry in Punjab (Aulakh et al., 2016).

Rough lemon (*C. jambhiri* Lush) rootstock has been commercially used for Kinnow mandarin in north-western region of India. Kinnow budded onto Rough lemon is generally vigorous in growth, produce higher yield, and having large fruit size with

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thicker peel and poor fruit quality (Nasir et al., 2011). However, it is susceptible to *Phytophthora* (Lacey, 2012) and salinity (Dubey and Sharma, 2016), which has decreased the productive age of the orchards and is not suitable for wet and poorly drained soils. These drawbacks of Rough lemon are proving to be a limiting factor in preventing the progress of citrus industry of the region. The choice of rootstock is an important and permanent part of orchard, however soil and local climatic conditions are important factors in the selection of rootstocks too. Although any citrus variety can be used as rootstock but some of them are better suited to particular conditions than others (Davies and Albirgo, 1994). Rootstocks have ability to manipulate tree performance and longevity, since they typically regulate the level of tolerance to diseases like Tristeza and gummosis, roots penetration, adoption to soil pH, high salinity and alkalinity, excess soil moisture, nutrient uptake, tree stature, fruit yield, fruit quality and maturity (Soost and Cameron, 1975; Wutscher, 1979). Many researchers have reported that rootstocks impart more than twenty horticultural characteristics including leaf nutrient status, vigour and size, depth of rooting, low temperature tolerance, adoption to adverse soil conditions, disease resistance and fruit quality (Castel, 1987; Josan and Thatai, 2008; Singh et al., 2019). Although it has already been understood that stock and scion have a mutual effect upon one another, for the healthy development of a composite plant, there has to be a congenial relationship between them.

No rootstock is found suitable in all circumstances (Saini et al., 2020). There is a growing need to found a suitable rootstock for Kinnow mandarin to replace the Rough lemon. However, only limited information is available about concerned rootstocks effects on Kinnow mandarin performance. Therefore, this study aimed to evaluate the performance of Kinnow mandarin budded onto ten rootstocks in the north-western Indian region, in terms of tree characters, productivity and fruit characteristics.

Materials and Methods

Experimental site and planting material

The experiment was carried out in College Orchard of Department of Fruit Science, Punjab Agricultural University (PAU), Ludhiana, India (latitude 30° 53’ N, longitude 75° 48’ E; elevation 244 m). The soil was well drained and deep alluvial. Ludhiana features a humid subtropical under the Köppen climate classification, with average maximum and minimum temperatures of 35.8 °C and 2.7 °C, respectively, and an average annual rainfall of 630 mm and out of which 90% was received during rainy season (July to September) (Singh et al., 2020). The monthly mean temperature and, mean precipitation and mean relative humidity are presented from 2015 to 2017 period in *Fig. 1*.

Ten rootstocks *i.e.*, Rough lemon (*C. jambhiri* Lush.), Carrizo citrange, CRH-12 [*C. sinensis* (L.) Osbeck × *Poncirus trifoliata* (L.) Raf], Volkamer lemon (*C. volkameriana* L.) NRCC-1, NRCC-2, NRCC-5 {*C. jambhiri* Lush × [*C. sinensis* (L.) Osbeck × *P. trifoliata* (L.) Raf]} and NRCC-3, NRCC-4, NRCC-6 [*C. jambhiri* Lush × *P. trifoliata* (L.) Raf] were evaluated when budded with Kinnow mandarin (*Fig. 2*).

The seeds of the rootstocks were sown (during September 2009) in polybags of size 7" × 12". To fill the polybags, potting material used was composed of one part of healthy soil, one-part sand, one-part cow dung manure and one-part coco peat. When the seedling attained pencil thickness, spring budding was performed during

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February-March. Budded Kinnow plants were transplanted in field during September 2010 in rectangular system of planting spaced at 3 m × 6 m, following a randomized block design with three replications *i.e.*, tree on each rootstock. The plants were fertilized with 440-770 g nitrogen, 220-385 g phosphorus, and 40-80 kg farm yard manure per plant, as per package and practices of PAU, Ludhiana. Entire FYM was applied during the month of December, while nitrogen was applied in two split doses *i.e.*, February/March (before flowering) and April/May (after fruit set). However, phosphorus was applied along with first dose of nitrogen. Weed, pest and disease management were performed as per standard commercial practices. Other cultural operations were undertaken routinely. The study was carried out in two consecutive years *i.e.*, 2016-17 (sixth year after planting) and 2017-18 (seventh year after planting). All the recommended practices for Kinnow mandarin cultivation were given as per PAU recommendations.

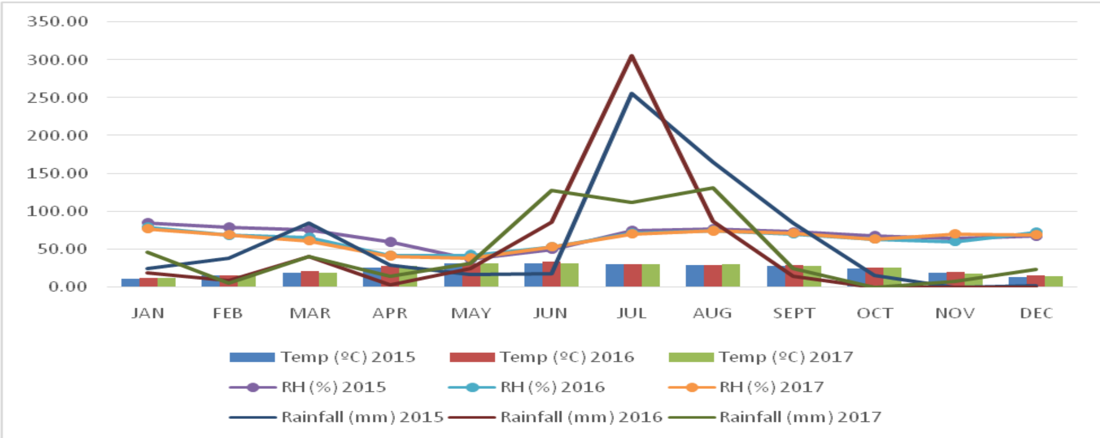

Figure 1. *Monthly mean temperature (°C), relative humidity (%) and precipitation (mm) of experimental site during 2015-2017*

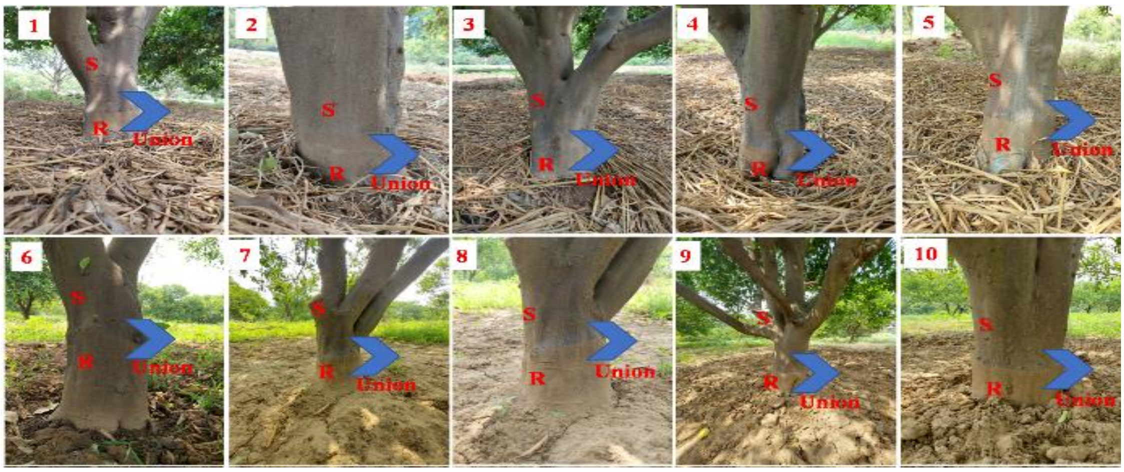

Figure 2. *S: Scion (Kinnow mandarin, R: Rootstock 1: Rough lemon, 2: Carrizo citrange, 3: CRH-12, 4: Volkamer lemon, 5: NRCC-1, 6: NRCC-2, 7: NRCC-5, 8: NRCC-3, 9: NRCC-4, 10: NRCC-6*

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Growth parameters

All the growth factors were recoded once per year before flowering began. The circumference of scion and rootstock (10 cm above/below the bud union) was measured annually with the help of digital Vernier's Callipers (Mitutoyo Inc. Japan). Tree shape was assumed to be one - half of the prolate spheroid and the tree volume was calculated by following (Morse and Robertson, 1987) *Equation 1*:

$$\text{Tree Volume} = 0.524 \times \text{height} \times \text{width}^2 \qquad \text{(Eq.1)}$$

Weight of harvested fruits per tree was recorded at harvest time and yield efficiency was calculated by the ratio of yield to tree volume.

Fruit quality parameters

Ten representative fruits per replication were randomly selected from all the directions for determining the vegetative physio-chemical characteristics. Fruits were harvested from 10^{th} to 20^{th} January 2016-17 at the same time for same rootstock. Average fruit weight (g) of 20 mature fruits was determined by individual fruit weight. The fruit yield was determined by multiplying the average weight of the fruit to number of fruits per plant. Fruit height (cm), width (cm), rind thickness (mm) and pedicel thickness (mm) were measured with the help of digital Vernier's Callipers (Mitutoyo Inc. Japan). Fruit rind and flesh colour was assessed by using Color Flex meter (Hunter Lab Color Flex, Hunter Associates Inc., Reston, VA, USA) (Hunter and Harold, 1987) for estimation of 'L' 'a' 'b' values and results were expressed as a citrus color index using *Equation 2*:

$$\text{Citrus color index (CCI} = \text{a} \times 1000/\text{L} \times \text{b)} \qquad \text{(Eq.2)}$$

where a* indicates chromaticity on a green (−) to red (+) axis and b* indicates chromaticity on a blue (−) to yellow (+) axis; this index is widely used in the citrus industry as a maturation index (DOGV, 2006). CCI gives four types of values: negative value means dark green color, value around zero means green-yellow color, small positive value means yellow color and high positive value means red-orange color. The juice was extracted by rotatory extractor and the juice, peel and pulp were weighed and expressed as a percentage of the total fruit weight. The total soluble solid content (TSS) was measured using a digital refractometer (Hanna Instruments, Woonsocket, Rohde Island, USA) and expressed as °Brix. The titratable acidity was estimated by titrating 2.0 ml of fruit juice against N/10 sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and then TSS/acid ratio was estimated. Ascorbic acid was determined by 2, 6-dichlorophenol indophenol method (AOAC, 2000) and results were expressed as mg ascorbic acid per 100 ml juice.

Statistical analysis

The data rootstock girth, scion girth, tree height, spread of the tree, tree volume, number of fruits per tree, fruit yield, yield efficiency, fruit weight, fruit length, fruit width, pedicel thickness, rind thickness, juice %, rind %, pulp %, total soluble solids, titratable acidity, TSS: acid ratio, ascorbic acid, rind Citrus Colour Index and flesh Citrus Colour Index were analyzed statistically with three replications via two-way analysis of variance (ANOVA) using the SAS software (version 9.3 SAS institute Inc., Cary, NC USA) and differences among the means assessed by LSD test with a P value 0.05. Furthermore, the standardized traits mean values were pooled and used to investigate correlation.

Results and Discussions

Rootstock girth

Differences among the rootstock trunk girth are evident from *Table 1*, that in the sixth year after planting (YAP) Rough lemon (38.3 cm) and NRCC-6 (38.3 cm) were significantly the highest, while NRCC-5 (25.3 cm) was the lowest one. Carrizo citrange (36.3 cm) and CRH-12 (33.5 cm) were statistically at par. In the seventh YAP, maximum stock trunk girth was achieved by Carrizo citrange (41.7 cm) which was statistically at par with Volkamer lemon (41.4 cm), Rough lemon (41.3 cm) and NRCC-6 (41.1 cm) while minimum was recorded in NRCC-1 (31.5 cm). Similar findings have also been found on Marisol mandarin, where rootstock girth was maximum in Carrizo citrange and minimum in Cleoptara mandarin after fifth year of planting. Whereas, during sixth YAP all studied rootstocks were statistically at par, showing no significant differences among them (Bassal, 2009). Also, Chahal and Gill (2015) while evaluating six exotic sweet orange varieties, found that plants on Volkameriana rootstock yielded significantly higher stock girth than C-35 and Benton.

Table 1. *Effect of different rootstocks on tree growth parameters of Kinnow mandarin*

Rootstocks	Rootstock (cm)		Scion (cm)		Tree height (m)		Spread of the tree (m)		Canopy volume (m^3)	
	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Carrizo	36.3^{abc}	41.7^{a}	30.9^{abc}	35.0^{a}	3.0^{a}	3.2^{bc}	2.9^{ab}	3.1^{abc}	11.8^{ab}	16.1^{ab}
CRH-12	33.5^{abc}	33.5^{bc}	28.1^{dbc}	28.1^{cd}	2.7^{a}	3.0^{bc}	2.6^{b}	2.9^{cd}	9.9^{b}	13.2^{bc}
NRCC-1	27.1^{de}	31.5^{c}	24.5^{d}	26.6^{d}	2.1^{b}	2.4^{d}	2.3^{c}	2.6^{e}	5.9^{c}	8.5^{d}
NRCC-2	31.8^{cd}	40.5^{a}	25.9^{cd}	34.7^{ab}	2.8^{a}	2.9^{bc}	2.9^{ab}	3.1^{abc}	12.5^{a}	14.6^{ab}
NRCC-3	31.7^{cd}	38.9^{ab}	25.2^{d}	32.1^{abc}	2.8^{a}	2.9^{bc}	2.8^{ab}	3.2^{ab}	11.6^{ab}	14.9^{ab}
NRCC-4	33.1^{bc}	38.9^{ab}	25.1^{d}	32.1^{abc}	3.0^{a}	3.0^{bc}	2.9^{ab}	3.1^{abc}	13.0^{a}	15.1^{ab}
NRCC-5	25.3^{e}	35.2^{abc}	19.3^{e}	30.0^{bcd}	2.7^{a}	2.7^{bc}	2.6^{b}	2.8^{de}	9.7^{b}	11.1^{cd}
NRCC-6	38.3^{a}	41.1^{a}	34.0^{a}	35.4^{a}	2.9^{a}	3.1^{bc}	2.9^{ab}	3.2^{ab}	12.4^{a}	16.6^{a}
Rough lemon	38.3^{a}	41.3^{a}	33.8^{a}	33.9^{ab}	2.8^{a}	2.9^{bc}	2.8^{ab}	3.3^{a}	11.4^{ab}	16.5^{a}
Volkamer lemon	37.3^{ab}	41.4^{a}	32.5^{ab}	33.5^{ab}	2.8^{a}	3.5^{a}	3.0^{a}	3.0^{bcd}	12.6^{a}	16.5^{a}
LSD (P≤ 0.05)	5.16	6.81	5.18	4.78	0.46	0.48	0.27	0.21	2.37	2.94

Note: In small letters the superscript shows significant difference at P<0.0

Scion girth

A significant variation in scion trunk girth was observed among different rootstocks (*Table 1*). In sixth YAP, maximum scion trunk girth was recorded on NRCC-6 (34.0 cm) rootstock followed by those on Rough lemon (33.8 cm) and it was minimum on NRCC-5 (19.3 cm). In the seventh YAP, trees budded on NRCC-6 (35.4 cm) and Carrizo (35.0 cm) had significant, maximum scion girth while trees on NRCC-1 (26.6 cm) showed minimum in this respect. Similar results were also obtained by De

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Assis Alves Mourao Filho et al. (2007) who found that scion girth of Fallglo mandarin trees on Cleopatra mandarin was wider than that of trees on Swingle citrumelo. Contrarily, Chahal and Gill (2015) revealed that scion trunk girth of sweet oranges was not affected by rootstocks.

Tree height

Rootstocks had a significant effect on tree height, tree spread and canopy volume (*Table 1*). During sixth YAP, trees on NRCC-1 (2.1 m) had minimum height whereas, trees on NRCC-4 (3.0 m), Carrizo citrange (3.0 m), Rough lemon (2.8 m), NRCC-2 (2.8 m), NRCC-6 (2.8 m) Volkamer lemon (2.8 m), CRH-12 (2.7) and NRCC-5 (2.7 m) were statistically at par with each other. In the seventh YAP, trees budded on Volkamer lemon (3.5 m) and NRCC-1 (2.4 m) had maximum and minimum tree heights respectively. However, those budded on to Carrizo (3.2 m), NRCC-6 (3.1 m), CRH-12 (3.0 m), NRCC-4 (3.0 m), Rough lemon (2.9 m), NRCC-2 (2.9 m), NRCC-3 (2.9 m) were statistically similar to each other. According to studies of Georgiou (2000) trees budded on Estes rough lemon had lowest value of plant height whereas, highest canopy height was induced by Rough lemon although it was not significantly different from those induced by *C. taiwanica*, Swingle citrumelo, Yuma citrange and Carrizzo citrange. Furthermore, Tahiti lime budded on Catania 2 Volkamer lemon, Orlando tangelo, Morton citrange and Swingle citrumelo rootstock had maximum plant height in both experiments (irrigated & non-irrigated condition) (Espinoza-Nunez et al., 2011). Similar outcomes have been found in some of the earlier experiments (Hearn and Hutchison, 1997; Figueiredo et al., 2001; Stenzel et al., 2003; Garcia-Sanchez et al., 2006; de Assis Alves Mourao Filho et al., 2007). On the other hand, Sau et al. (2018) while working on Nagpur mandarin, disclosed that plant height was not affected by the different rootstocks.

Spread of the tree

In the sixth YAP, the trees budded onto Volkamer lemon (3.0 m) showed the highest values of spread of the tree, whereas, lowest value was recorded on NRCC-1 (2.3). Trees of Kinnow mandarin budded on Rough lemon (3.3 m) were significantly higher than those on NRCC-3 (3.2 m), Carrizo citrange (3.1), NRCC-2 (3.1 m) and NRCC-4 (3.1 m) whereas, trees on NRCC-1 (2.6 m) showed lowest value of spread of the tree during seventh YAP (*Table 1*). In similar studies, of Nova mandarin (Georgiou, 2000) and Clementine mandarin (Georgiou, 2002), was found that trees on Sour orange showed highest values of tree spread.

Canopy volume

The trees budded onto NRCC-4 (13.0 m^3), Volkamer lemon (12.6 m^3), NRCC-2 (12.5 m^3) and NRCC-6 (12.4 m^3) had the highest tree volume and did not significantly differ from each other whereas, trees on NRCC-1(5.9 m^3) had the lowest in this respect during the 6^{th} YAP (*Table 1*). In the 7^{th} YAP, highest canopy volume was recorded on NRCC-6 (16.6 m^3) and it was not significantly different from those budded on Rough lemon (16.5 m^3) and Volkamer lemon (16.5 m^3), while lowest tree volume was found on NRCC-1 (8.5 m^3) (*Table 1*).

In this aspect, Forner-Giner et al. (2003) disclosed that, canopy volume of Navelina orange trees was maximum on the 03017rootstock selection, without any substantial

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differences especially in comparison to the Volkamer lemon, 030123 and 030146. In addition, Okitsu Satsuma mandarin on Sunki mandarin and Swingle citumelo rootstock produced maximum tree size and canopy volume (Tazima et al., 2013). While, smallest canopy of Valencia orange was measured on Cleopatra mandarin than other rootstocks (Zekri, 2000).

Number of fruits per tree

Number of fruits per tree were significantly affected by rootstocks (*Table 2*). Trees on NRCC-6, NRCC-4, Carrizo, NRCC-2, Rough lemon and Volkamer lemon had statistically similar number of fruits (496.1, 489.9, 489.3, 457.8, 455.3 and 405.8, respectively). However, lowest numbers were recorded on NRCC-5 (278.9) and CRH-12 (245.7) during first year of experiment. In the 7^{th} YAP, highest numbers of fruits per tree were recorded on NRCC-6 (491.8), Carrizo citrange (491.6) and Rough lemon (483.4) whereas trees on NRCC-4 (211.3) had lowest number of fruits (*Table 2*). Results have similarity with the experiments of Sharma et al. (2000a) who reported that cumulative yield (number of fruits per tree) of seven seasons of Kinnow mandarin was found maximum on Jatti Khatti, followed by Karun Jamir and Estes rough lemon while, it was minimum on Cleopatra mandrain. Similar findings were also reported by Aulakh (1999) and Sharma et al. (2002a).

Table 2. *Effect of different rootstocks on fruit trait yield parameters of Kinnow mandarin*

Rootstocks	Number of fruits per tree		Fruit yield (kg/tree)		Yield efficiency (kg/m^3)		Fruit weight (g)		Fruit height (cm)		Fruit width (cm)	
	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Carrizo	489.3^{a}	491.6^{a}	103.53^{a}	104.34^{a}	8.94^{a}	6.44^{a}	212.3^{abc}	211.1^{ab}	6.04^{bc}	6.00^{b}	7.40^{b}	7.33^{bc}
CRH-12	245.7^{c}	375.7^{cd}	53.56^{c}	80.67^{abc}	5.51^{e}	6.19^{a}	216.0^{ab}	217.0^{a}	6.13^{b}	6.09^{b}	7.25^{b}	7.21^{bc}
NRCC-1	293.5^{bc}	293.5^{de}	52.67^{c}	59.57^{cd}	8.87^{a}	7.15^{a}	179.2^{d}	202.2^{ab}	7.28^{a}	7.36^{a}	8.01^{a}	7.99^{a}
NRCC-2	457.8^{a}	477.4^{ab}	85.17^{ab}	83.57^{abc}	6.83^{cd}	5.77^{a}	185.8^{cd}	176.9^{c}	6.00^{bc}	5.96^{b}	7.20^{b}	7.26^{bc}
NRCC-3	390.8^{ab}	390.8^{bc}	83.83^{ab}	78.52^{abc}	7.30^{bcd}	5.30^{ab}	214.0^{ab}	201.2^{ab}	6.27^{b}	6.27^{b}	7.11^{b}	7.14^{bc}
NRCC-4	489.9^{a}	211.3^{e}	100.57^{a}	45.14^{d}	7.82^{bc}	3.09^{b}	206.5^{abc}	211.3^{ab}	5.87^{bc}	5.89^{b}	7.20^{b}	7.16^{bc}
NRCC-5	278.9^{c}	377.2^{cd}	63.68^{bc}	74.47^{bc}	6.69^{d}	6.8^{a}	229.8^{a}	196.4^{b}	5.15^{d}	6.08^{b}	7.24^{b}	7.33^{bc}
NRCC-6	496.1^{a}	491.8^{a}	103.25^{a}	98.55^{ab}	8.27^{ab}	6.04^{a}	206.8^{abc}	201.6^{ab}	5.61^{cd}	5.67^{b}	7.50^{b}	7.41^{b}
Rough lemon	455.3^{a}	483.4^{a}	90.69^{a}	96.96^{ab}	8.16^{ab}	5.94^{a}	201.3^{bcd}	198.6^{b}	5.95^{bc}	5.90^{b}	7.21^{b}	7.26^{bc}
Volkamer lemon	405.8^{a}	431.3^{abc}	83.11^{ab}	91.21^{ab}	6.63^{d}	5.56^{ab}	206.5^{abc}	210.2^{ab}	5.63^{cd}	5.67^{b}	7.10^{b}	7.05^{c}
LSD ($P \leq 0.05$)	108.27	91.75	23.66	28.60	1.04	2.54	27.23	16.89	0.49	0.64	0.50	0.33

Note: In small letters the superscript shows significant difference at P<0.

Fruit yield

Data in *Table 2* shows that rootstocks had significant effect on fruit yield (kg/tree) in both seasons, although trees on Carrizo citrange (103.53 kg) had maximum average fruit yield followed by NRCC-6 (103.25 kg), NRCC-4 (100.57 kg) and Rough lemon (90.69 kg) which were statistically at par with each other. Whereas, minimum fruit yield was recorded on NRCC-1 (52.67 kg) during the sixth YAP. On Carrizo citrange (104.34 kg), similar to the previous year, maximum fruit yield was produced in the

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seventh YAP, and NRCC-4 (45.14 kg) reported minimum. The trees on NRCC-2 (83.57 kg), CRH-12 (80.67 kg) and NRCC-3 (78.52 kg) had similar yield and were in between. Present results show similarities where, common clementine trees on Carrizo citrange were most productive (Hussain et al., 2013).

Furthermore, Citrange rootstocks were found to have significant effect on fruit yield (Georgiou, 2000, 2002; Stenzel et al., 2003). On the contrary, fruit yield of Fallglo and Sunburst mandarin were not significantly affected by different rootstocks, from 2000 through 2006 (de Assis Alves Mourao Filho et al., 2007).

Yield efficiency

In the sixth YAP, yield efficiency was affected by different rootstocks (*Table 2*). Trees on Carrizo citrange (8.94 kg/m^3) produced highest yield efficiency followed by NRCC-1 (8.87 kg/m^3) which was significantly different from trees budded on NRCC-6 (8.27 kg/m^3) and Rough lemon (8.16 kg/m^3), whereas, lowest was produced on CRH-12 (5.51 kg/m^3) in this respect. In the seventh YAP, trees of Kinnow mandarin on all rootstocks produced similar yield efficiency, where the highest was produced on NRCC-1 (7.15 kg/m^3) while the lowest was on NRCC-4 (3.09 kg/m^3) (*Table 2*). Similar kind of findings reported by several researchers, worked on different mandarin varieties and reported that yield of these varieties was significantly affected by rootstocks (Georgiou, 2002; de Assis Alves Mourao Filho et al., 2007; Cantuarias-Aviles et al., 2010). In addition, Forner-Giner et al. (2003) reported that trees of Navelina orange on Cleoptara mandarin and Carrizo citrange had similar yield efficiency. In contrast, Georgiou and Gregoriou (1999) revealed that rootstocks did not bring significant variation in yield efficiency.

Fruit weight

During both the years of study, fruit weight was significantly affected by rootstocks (*Table 2*). Trees budded on NRCC-5 (229.8 gm) gave fruits with highest weight followed by CRH-12 (216.0 gm) and NRCC-3 (214.0 gm), which were significantly different from NRCC-1 (179.2 gm) that produced fruits with lowest weight during sixth YAP. In the seventh YAP, Kinnow fruit with maximum weight of 217.0 gm were produced on CRH-12, which was significantly higher than those on NRCC-4 (211.3 gm), Carrizo citrange (211.1 gm), Volkamer lemon (210.2 gm), NRCC-6 (201.6 gm) and NRCC-3 (201.2 gm). Lowest fruit weight was obtained from the fruits on NRCC-2 (176.9 gm). Sharma et al. (2002b) found that fruit weight of Campabell Valencia was significantly affected by rootstocks, where average fruit weight was maximum on Troyer closely followed by Carrizo citrange while the minimum was recorded on Jatti Khatti. Besides, heaviest fruits of Nagpur mandarin were harvested on Rough lemon rootstock (Sau et al., 2018). In contrast to this, fruits of Fallglo mandarin produced similar fruit weight on different rootstocks (de Assis Alves Mourao Filho et al., 2007).

Fruit height

Fruits of Kinnow mandarin produced on NRCC-1 (7.28 cm) rootstock, had significantly highest fruit height and fruits from the Carrizo citrange (6.04 cm), NRCC-2 (6.00 cm), Rough lemon (5.95 cm) and NRCC-4 (5.87 cm) were significantly at par. Fruits produced on NRCC-5 (5.15 cm) had lowest fruit height during first season

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(*Table 2*). In the second season, rootstocks had no significant effect on the fruit height of Kinnow mandarin except on NRCC-1 rootstock.

Fruit width

In the 6th YAP, fruit width was not affected by rootstocks, whereas trees on NRCC-1 (8.01 cm) produced fruits with maximum fruit width. During second season, fruits of Kinnow mandarin with maximum fruit width were produced on NRCC-1 (7.99 cm) while, minimum fruit width (7.05 cm) was found on Volakmer lemon (*Table 2*). The above findings are in agreement with those recorded by Continella et al. (2018) who observed that Tarocco Scire sweet orange on Carpenter, Furr and F6P12 had largest fruit width and lowest was recorded on Swingle Citrumelo. Bassal (2009) reported that there was no significant effect of rootstocks on fruit width of Marisol clementine during both the season.

Pedicel thickness

The Kinnow fruits from the trees budded on different rootstocks showed significant variation with respect to pedicel thickness (*Table 3*). Fruits from the trees budded on NRCC-6 (3.75 mm) and NRCC-2 (3.69 mm) had highest pedicel thickness, whereas, fruits from the Volkamer lemon rootstock had lowest pedicel thickness, in both seasons.

Table 3. *Effect of different rootstocks on quality parameters of Kinnow mandarin*

Rootstocks	Pedicel thickness (mm)		Rind thickness (mm)		Juice (%)		Peel (%)		Pulp (%)	
	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP	6th YAP	7th YAP
Carrizo	3.14^{cd}	3.20^{bcd}	3.14^{d}	3.28^{cd}	57.75^{a}	57.69^{a}	22.82^{d}	22.75^{f}	15.98^{bcd}	16.13^{bc}
CRH-12	3.45^{abc}	3.39^{abc}	3.39^{bcd}	3.48^{bcd}	48.45^{d}	48.31^{e}	24.03^{bc}	24.19^{ef}	15.01^{cde}	14.85^{cde}
NRCC-1	3.25^{bcd}	3.18^{bc}	3.61^{ab}	3.59^{abcd}	54.38^{ab}	54.78^{ab}	25.28^{bcd}	25.36	14.19^{efg}	14.34^{def}
NRCC-2	3.67^{a}	3.54^{a}	3.85^{a}	3.91^{a}	54.12^{abc}	54.04^{bc}	29.00^{a}	28.78^{a}	16.00^{bc}	15.91^{bc}
NRCC-3	3.13^{cd}	3.26^{abc}	3.34^{bcd}	3.40^{bcd}	54.49^{ab}	54.51^{ab}	24.95^{bcd}	25.00^{cde}	14.69^{def}	14.78^{cde}
NRCC-4	3.55^{ab}	3.47^{ab}	3.58^{abc}	3.62^{abc}	50.65^{bcd}	50.70^{cde}	26.51^{abc}	26.42^{bc}	13.58^{fg}	13.47^{ef}
NRCC-5	3.48^{abc}	3.35^{abc}	3.19^{cd}	3.27^{d}	52.69^{bcd}	52.54^{bcd}	25.69^{bcd}	25.79^{cde}	15.89^{bcd}	15.67^{bcd}
NRCC-6	3.75^{a}	3.52^{a}	3.75^{ab}	3.68^{ab}	53.00^{bc}	52.71^{bcd}	26.27^{abc}	26.19^{bcd}	13.11^{g}	13.06^{f}
Rough lemon	3.24^{bcd}	3.17^{dc}	3.66^{ab}	3.59^{abcd}	50.02^{cd}	49.37^{de}	27.79^{ab}	27.64^{ab}	17.45^{a}	17.97^{a}
Volkamer lemon	3.00^{d}	2.96^{d}	3.54^{abcd}	3.47^{bcd}	51.98^{bcd}	52.04^{bcd}	25.01^{bcd}	24.69^{de}	16.90^{ab}	16.83^{ab}
LSD (P≤ 0.05)	0.39	0.29	0.41	0.34	4.26	3.53	3.13	1.61	1.30	1.49

Note: In small letters the superscript shows significant difference at P<0.0

Rind thickness

It is an important factor responsible for the freshness of citrus fruits. Fruits with thick rind are low in juice whereas thin rind fruits are not suitable for storage and shipping Sharma et al. (2016). Data revealed that the rind thickness was significantly affected by the rootstocks (*Table 3*). Fruits obtained from the tree budded on NRCC-2 had highest rind thickness in both years, whereas, in 6th YAP, it was lowest on Carrizo citrange (3.14 mm). During next season, lowest rind thickness was recorded on NRCC-5 (3.27 mm) while, fruits on CRH-12 (3.48 mm), Volakamer lemon (3.47 mm) and

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NRCC-3 (3.40 mm) were significantly to each other. Similarly, fruits of Allen Eureka showed the highest rind thickness on Macrophylla, Volkamer lemon and Rough lemon whereas, lowest rind thickness was observed on Cleoptara, Amblycarpa, Sour orange and Taiwanica rootstocks (Al-Jaleel et al., 2005). Rind thickness of Valencia and Navel orange, on Tawanica, Macrophylla and Rough lemon was recorded highest while, fruits with thinnest rind were collected from Cleoptara, Amblycarpa and sour orange rootstock (Zekri and Al-Jaleel, 2004). Likewise, Sharma et al. (2002c) found that fruits of Kinnow mandarin were thick peeled on Jatti Khatti (4.9 mm) and Karna Khatta (4.9 mm) rootstocks whereas, those on Troyer and Carrizo ctrange were thin peeled (4.6 mm).

Juice, peel and pulp content

Rootstocks significantly affect juice, rind and pulp content in the fruits (*Table 3*). Juice content varied from 57.75% to 48.45%. Fruits from trees on Carrizo citrange had maximum juice content whereas it was lowest from trees on CRH-12. Same trend was observed in both the years. Juice content of Tarocco Scire pigmented sweet orange was recorded maximum (52 %) on Bitters rootstock while it was recorded minimum (46%) on F6P12 (Continella et al., 2018). In another similar experiment, Folha Murcha mandarin budded on Cravo Limeira, FCAV trifoliate and Sunki mandarin had highest juice content whereas, it was lowest on Flying Dragon rootstock (Cantuarias-Aviles et al., 2010). In this context, Georgiou (2002) reported that fruits of Clementine mandarin on Swingle citrumelo rootstock, had significantly higher juice content and it significantly reduced on Volkamer lemon and Palestine sweet lime.

Regarding peel content, Kinnow mandarin fruits on Carrizo citrange (22.82% & 22.75%) had minimum peel percentage compared to those on Rough lemon (27.79% & 27.64%), NRCC-6 (26.27% & 26.19%) and NRCC-4 (26.51% & 26.42%). Fruits with maximum peel percentage were obtained from trees on NRCC-2 (29.00% & 28.78%) in both the years. Results showed concordance with a study conducted by Romero et al. (2006) who found that fruits of Clemenules mandarin on Cleoptara mandarin had lower peel percentage. Inverse to this, Bassal (2009) reported no significant differences in peel percentage due to rootstocks. Pulp content was recorded minimum in Kinnow fruits on NRCC-6 (13.11% & 13.06) and maximum content was recorded on Rough lemon (17.45% & 17.97%) rootstock in both seasons.

Total soluble solids

A perusal of the data in the *Table 4* reveals that TSS was significantly affected by different rootstocks. Kinnow fruits from trees on NRCC-1 (11.29) rootstock showed maximum soluble solids content, and it significantly differed from CRH-12 (11.21), NRCC-5 (10.88), Carrizo citrange (10.58) and NRCC-3 (9.58) and NRCC-6 (9.28) which showed the minimum value in the sixth YAP. Similarly, during seventh YAP, maximum soluble solid content was recorded from the fruits obtained from trees on NRCC-1 (11.30) and CRH-12 (10.93) whereas fruits from trees on NRCC-3 (9.07) had minimum total soluble solids content. AA118 Trifoliate orange and Holansis Trifoliate orange rootstocks induced high TSS in Clementine fruits whereas, Gou Tou sour orange and Da Hong Pao mandarin induced low TSS (Hussain et al., 2013). Likewise, fruits of Kinnow mandarin on Troyer citrange had maximum TSS while it was minimum on Jatti Khatti (Sharma et al., 2002c). Fruits of ‘Fremont’ tangerine and ‘Washington Navel’

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recorded highest TSS on Carrizo citrange rootstock reported by Ali (2002) and Tuzcu et al. (2004), respectively.

Table 4. *Effect of different rootstocks on quality parameters of Kinnow mandarin*

Rootstocks	**Total soluble solids (°Brix)**		**Titratable Acidity (%)**		**TSS: acid ratio**		**Ascorbic acid (mg/100ml juice)**		**Rind CCI (Citrus Color Index)**		**Flesh CCI (Citrus Color Index)**	
	6th YAP	**7th YAP**	**6th YAP**	**7th YAP**	**6th YAP**	**7th YAP**	**6th YAP**	**7th YAP**	**6th YAP**	**7th YAP**	**6th YAP**	**7th YAP**
Carrizo	10.58^{abcd}	10.13^{bc}	0.98^{a}	0.91^{b}	10.80^{e}	11.46^{e}	20.85^{e}	20.64^{d}	10.38^{ab}	7.94^{ab}	5.08^{abc}	5.65^{a}
CRH-12	11.21^{ab}	10.93^{a}	1.00^{a}	1.09^{a}	11.23^{e}	9.96^{f}	25.01^{a}	24.86^{a}	8.83^{b}	8.38^{a}	5.95^{abc}	5.26^{a}
NRCC-1	11.29^{a}	11.30^{a}	1.01^{a}	0.92^{b}	11.17^{e}	12.38^{de}	20.88^{e}	20.64^{d}	9.10^{b}	8.01^{ab}	6.46^{abc}	5.92^{a}
NRCC-2	10.26^{cde}	10.07^{bc}	0.81^{b}	0.74^{cd}	12.68^{d}	13.29^{cd}	22.44^{bcde}	22.12^{bcd}	11.09^{a}	7.65^{abc}	5.87^{abc}	4.89^{a}
NRCC-3	9.58^{ef}	9.07^{d}	0.66^{c}	0.61^{e}	14.51^{ab}	14.97^{ab}	21.41^{de}	21.50^{cd}	10.04^{ab}	7.65^{abc}	5.74^{abc}	5.63^{a}
NRCC-4	10.29^{cde}	9.60^{cd}	0.79^{b}	0.78^{c}	13.02^{cd}	12.25^{e}	21.09^{e}	21.34^{cd}	10.07^{ab}	7.77^{abc}	5.65^{abc}	5.21^{a}
NRCC-5	10.88^{abc}	10.60^{ab}	0.79^{b}	0.75^{c}	13.78^{bc}	14.20^{bc}	23.69^{abc}	23.55^{ab}	10.64^{ab}	8.01^{ab}	4.32^{bc}	5.00^{a}
NRCC-6	9.28^{f}	9.67^{cd}	0.68^{c}	0.67^{de}	13.62^{c}	14.39^{b}	21.99^{dce}	22.09^{bcd}	9.85^{ab}	7.20^{bc}	4.11^{c}	4.59^{a}
Rough lemon	10.48^{bcd}	10.03^{bc}	0.71^{c}	0.67^{de}	14.76^{a}	15.07^{ab}	23.02^{bcd}	22.20^{bc}	9.76^{ab}	6.72^{c}	7.11^{a}	5.01^{a}
Volkamer lemon	10.02^{def}	9.73^{cd}	0.66^{c}	0.62^{e}	15.19^{a}	15.63^{a}	24.00^{ab}	23.78^{a}	9.30^{ab}	7.79^{abc}	5.22^{abc}	5.67^{a}
LSD (P≤ 0.05)	0.77	0.76	0.05	0.69	0.87	1.02	1.83	1.53	1.83	1.18	2.27	1.88

Note: In small letters the superscript shows significant difference at P<0.0

Titratable acidity

Titratable acidity (TA) of mandarins plays an important role in determining maturity and juice attributes. In this experiment, the accumulation of TA in fruits was significantly affected by rootstocks. In the first season, juice of fruits from tress on NRCC-1 (1.01), CRH-12 (1.00) and Carrizo citrange (0.98) had the highest TA and it was significantly different from those on NRCC-2 (0.81), Rough lemon (0.71), NRCC-3 (0.66) and Volkamer lemon (0.66). Acidity of the fruit juice from Kinnow trees on NRCC-3 (0.61) and Volkamer lemon (0.62) were significantly lower than those on NRCC-6 (0.67), Rough lemon (0.67) and NRCC-2 (0.74). The highest juice acidity was recorded for Kinnow fruits budded on CRH-12 (1.09) in the second season (*Table 4*). Continella et al. (2018) also found that fruits of Tarocco Scire pigmented sweet orange on Citrumelo produced highest titratable acidity. Fruits of Common clementine on Holansis Trifoliate orange and AA18 Trifoliate orange were more acidic whereas, on Carrizo citrange were comparatively less acidic (Hussain et al., 2013). Likewise, titratable acidity of Oneco mandarin was maximum on Flying Dragon Trifoliate orange while it was minimum on Volkamer lemon rootstock (Gonzatto et al., 2011).

TSS: acid ratio

TSS: acid ratio was significantly affected by rootstocks. Kinnow fruits produced from the trees on Volkamer lemon (15.19) and Rough lemon (14.76) gave highest value of TSS: acid ratio whereas it was recorded lowest on Carrizo citrange (10.80), CRH-12 (11.23) and NRCC-1 (11.17) during first year. In the second year, highest TSS: acid ratio was recorded from fruits which were obtained from trees on Volkamer lemon

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(15.63) and it was significantly higher than those on Rough lemon (15.07), NRCC-3 (14.97), NRCC-6 (14.39) and NRCC-5 (14.20). However, fruits from trees on CRH-12 (9.96) gave the lowest value of TSS: acid ratio (*Table 4*). An analogous trend was observed by Georgiou (2002) where maximum TSS: acid ratio was recorded on sour orange rootstock and minimum TSS: acid ratio was on Palestine sweet lime. Similarly, Marisol clementine trees on sour orange produced fruits with low TSS: acid ratio whereas, the highest TSS: acid ratio was on Carrizo citrange (Bassal, 2009). One of the leading cause of variations in the quality attributes of most citrus fruits may be due to the unequal aggregation of TSS that may be a result of disparity of plant-water interactions for inherent differences in rootstock (Barry et al., 2004).

Ascorbic acid content and citrus colour index (CCI)

Data presented in *Table 4* shows significant variations in content of fruit ascorbic acid on different rootstocks. Maximum ascorbic acid content was recorded on CRH-12 (25.01 & 24.86), whereas fruits on Carrizo citrange (20.85 & 20.64) had lowest ascorbic acid content, in both seasons (*Table 4*). In this regard, Sau et al. (2018) on Nagpur mandarin and Demirkeser et al. (2005) on Rohde Red Valencia orange reported that the effects of rootstocks on ascorbic acid were not statistically significant. Color of the fruit is a deciding external factor for its quality and consumer acceptance. Kinnow trees budded onto NRCC-2 produced fruits with deepest orange peel colour during first year of experiment while fruits from CRH-12 rootstock produced orange color in second year. On the other hand, Rough lemon induced deepest orange colour in flesh whereas, in second year no significant variation was found among all the rootstocks. The above findings are in agreement with those obtained by Legua et al. (2011) on Lane Late navel orange, where they found out fruits on *C. macrophylla* and *C. volkameriana* had richest external colour and poorest on Gou Tou. In addition, Forner-Griner et al. (2003) also observed that Cleopatra mandarin induced lower colour index in Navelina oranges. Rootstock FA 418 had induced lower index of fruit color than other rootstocks (Forner-Giner et al., 2014).

Correlation coefficient

Simple coefficient correlation between tree and fruit morphology and biochemical factors of Kinnow mandarin were calculated and are presented in *Table 5*. Fruit weight showed significant negative correlation with the rind percent (r = -0.70) and rind thickness (r = -0.77). Fruit width showed positive correlation with fruit height (0.77) and yield efficiency (0.76), however, it was found negatively correlated with spread of the tree (r = -0.74) and tree volume (r = -0.75). The fruit height showed high positive correlation with flesh citrus colour index (r = - 0.68) and had negative correlation with spread of the tree (r = -0.69), tree volume (r = -0.75) and tree height (r = -0.79). Spread of the tree showed strong positive correlation with tree volume (r = 0.96) tree height (r = 0.82), rootstock girth (r = 0.86), scion girth (r = 0.75), number of fruits per tree, (r = 0.77) and fruit yield (r = 0.78) while negatively correlated with TSS (r = -0.66) and titratable acidity (r = -0.85). The tree volume was found positively correlated with tree height (r = 0.93), rootstock girth (r = 0.91), scion girth (r = 0.80), number of fruits per tree, (r = 0.76) and fruit yield (r = 0.81) whereas, it was negatively correlated with TSS (r = -0.79). Tree height showed high significant positive correlation with rootstock girth (r = 0.82), scion girth (r = 0.71) and fruit yield (r = 0.0.73).

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Table 5. *Correlation coefficient between tree and fruit morphology and biochemical factors of Kinnow mandarin*

	Fwt	Fd	Fl	Sot	Tvol	Tht	RoG	ScG	ToF	Tss	TA	T:A	Asa	Yeff	Fyi	Pup	Rip	Jup	Rit	Pet	Rcci	Fcci
Fwt	1.00																					
Fd	-0.39	1.00																				
Fl	-0.41	0.77**	1.00																			
Sot	0.03	-0.74*	-0.69*	1.00																		
Tvol	0.17	-0.75*	-0.75*	0.96**	1.00																	
Tht	0.42	-0.78**	-0.79**	0.82**	0.93**	1.00																
RoG	0.05	-0.49	-0.56	0.86**	0.91**	0.82**	1.00															
ScG	-0.02	-0.30	-0.46	0.75*	0.80**	0.71*	0.96**	1.00														
ToF	-0.21	-0.29	-0.47	0.77**	0.76*	0.61	0.86**	0.88**	1.00													
Tss	-0.04	0.54	0.51	-0.85**	-0.79**	-0.62	-0.67*	-0.57	-0.60	1.00												
TA	0.09	0.48	0.50	-0.66*	-0.56	-0.35	-0.47	-0.40	-0.45	0.81**	1.00											
T:A	-0.07	-0.41	-0.43	0.49	0.39	0.22	0.36	0.31	0.32	-0.63*	-0.95**	1.00										
Asa	0.36	-0.45	-0.45	-0.00	0.04	0.20	-0.05	-0.05	-0.22	0.21	0.01	0.12	1.00									
Yeff	-0.28	0.76**	0.47	-0.40	-0.41	-0.46	-0.10	0.08	0.20	0.30	0.22	-0.15	-0.47	1.00								
Fyi	0.05	-0.36	-0.56	0.78**	0.81**	0.73*	0.90**	0.90**	0.95**	-0.63	-0.42	0.30	-0.16	0.17	1.00							
Pup	-0.06	-0.36	-0.22	0.18	0.18	0.19	0.27	0.26	0.29	0.13	-0.16	0.32	0.33	0.07	0.27	1.00						
Rip	-0.70*	-0.09	-0.14	0.30	0.14	-0.12	0.09	0.07	0.22	-0.18	-0.44	0.40	-0.00	-0.19	-0.00	0.10	1.00					
Jup	-0.25	0.33	0.26	-0.06	-0.07	-0.10	-0.00	0.03	0.32	-0.13	0.03	-0.11	-0.68*	0.59	0.29	-0.05	-0.28	1.00				
Rit	-0.77**	0.12	0.07	0.24	0.15	-0.07	0.22	0.28	0.26	-0.18	-0.22	0.14	-0.09	-0.12	0.03	-0.16	0.79**	-0.23	1.00			
Pet	-0.22	0.03	-0.23	0.12	0.06	-0.02	-0.10	-0.09	0.05	-0.06	0.07	-0.24	0.00	-0.22	-0.04	-0.56	0.50	-0.18	0.47	1.00		
Rcci	-0.07	-0.17	-0.19	-0.00	-0.02	0.04	-0.28	-0.37	0.00	0.02	0.11	-0.23	-0.14	-0.11	-0.04	-0.02	0.03	0.49	-0.23	0.33	1.00	
Fcci	-0.29	0.20	0.68*	-0.27	-0.31	-0.37	-0.15	-0.15	-0.28	0.36	0.28	-0.16	-0.18	0.09	-0.34	0.33	-0.00	-0.09	0.08	-0.54	-0.38	1.00

Abbreviation of Fwt- Fruit weight, Fd- Fruit width, Fl- Fruit length, Sot- Spread of the tree, Tvol- Tree Volume, Tht- Tree height, RoG- Rootstock girth, ScG- Scion girth, ToF- Number of fruits per tree, Tss- Total soluble solids, TA- Titratable acidity, T: A- TSS: acid ratio, Asa- Ascorbic acid, Yeff- Yield efficiency, Fyi- Fruit yield, Pup- Pulp %, Rip- Rind %, Jup- Juice %, Rit- Rind thickness, Pet- Pedicel thickness, Rcci- Rind Citrus Colour Index, Fcci- Flesh Citrus Colour Index. *Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed)

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Rootstock girth was positively correlated with scion girth (r = 0.96), number of fruits per tree (r = 0.86) and fruit yield (r = 0.90) but had a negative correlation with TSS (r = - 0.67). Scion girth had significant positive correlation with number of fruits per tree (r = 0.88) and fruit yield (r = 0.90). TSS showed significant positive correlation with titratable acidity (r = -0.81) and negative correlation with TSS: acid ratio (r = -0.63). Titratable acidity and ascorbic acid were found to have negative correlation with TSS: acid ratio (r = -0.95) and juice % (r = -0.68), respectively. Number of fruits per tree and rind % had a significant positive correlation with fruit yield (r = 0.95) and rind thickness (r = 0.79), respectively. All other biochemical and morphological parameters were found non-significantly correlated for the rootstocks under investigation.

Conclusion

The study highlighted the effect of different rootstocks in determining different qualitative aspects of Kinnow mandarin and suggest that pedological condition can be a limiting factor in the choice of alternative rootstocks of Rough lemon, at least in the considered experimental area. It can be inferred from the current findings that rootstocks bring considerable number of alterations that influence fruit quality, yield and plant growth of Kinnow mandarin. Fruit yield, yield efficiency and juice content on Carrizo citrange was highest while, peel content and peel thickness were the lowest. Fruit quality attributes, like TSS was maximum on NRCC-1, ascorbic acid was maximum on CRH-12 whereas, minimum titratable acidity was observed on Volkamer lemon and NRCC-3 but it was not significantly lower than NRCC-6 and Rough lemon in the first year and Volkamer lemon in second year. The fruit weight was recorded highest on CRH-12 but the maximum fruit height and fruit width was recorded on NRCC-12. Scion girth was maximum on NRCC-6 but it was statistically similar to Rough lemon in the first year and to Carrizo citrange in the second year of the experiment. Lowest tree height, tree spread and tree volume were recorded on NRCC-1. In nutshell, the profitability of citrus production is limited by the rootstock and the findings of this experiment we can say Carrizo citrange will be helpful in future for Kinnow mandarin on the basis of yield efficiency and will provide a better production over rough lemon in north-western India.

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