Research Article

Effect of Different Plant Spacing on Growth, Yield and Fruit Quality of Kinnow Mandarin *Citrus reticulata* in Sargodha, Punjab, Pakistan

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Abstract | In genus citrus and family Rutaceae, Kinnow mandarin *Citrus reticulata* Blanco is widely grown edible species in the world including Pakistan. It is enriched with vitamin C and many other phytochemicals that are beneficial for health. In Pakistan, *Citrus reticulata* occupies the dominant position and it is 85% of total citrus production. The study was carried out at Research farm of Citrus Research Institute, Sargodha, Punjab, Pakistan during 2012-13 and 2013-14 to see the impact of four different plant spacing (T1: 10` × 10`, T2: 14` × 14`, T3: 18` × 18`, and T4: 22` × 22`) upon various physio-chemical parameters of *Citrus reticulata*. The experimental design was randomized complete block (RCB). The parameters evaluated were: plant height, plant spread, canopy volume, month wise incremental trend of fruit growth, fruit size, fruit weight, juice weight, juice%, no. of seeds per fruit, peel thickness, TSS, acidity%, TSS/acid ratio, and no. of fruit/plant (yield). Results revealed that plant height, spread and canopy volume was significantly higher in T4 as compared to T1. Fruit of larger size was obtained in 2013 in T4 while in 2012 no such effect was observed. Fruits obtained in the year 1 (2012) did not differ in weight but in the second year (2013) plants of T1 yielded fruits of significantly less weight. Significantly less number of seeds/fruit was found in plants grown at a distance of 10` × 10` as compared to others. Plants grown at 22` × 22` distance yielded more fruits as compared to others with less spacing. Chemical characteristics of *Citrus reticulata* such as juice percentage, TSS, acidity and TSS/acid ratio were also not affected by variation in plant to plant and row to row spacing. Overall, it can be concluded from these data that reduced plant spacing in citrus such as (10` × 10` and 14` × 14`) might result in poor attributes in some citrus plant and yield characters such as height, canopy, spread and yield. Moreover, chemical parameters of citrus fruit like juice percentage, TSS, acidity and TSS/acid ratio did not vary when plant to plant and row to row spacing was reduced from 22`×22`. However, only one benefit of reduced plant spacing observed was the occurrence of less number of seeds per fruit in T1 as compared to others. Based upon these findings, it is recommended to growers to grow Kinnow plants at spacing of 22` × 22` and 18` × 18` as these treatments resulted in fruitful results in many parameters studied.

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Introduction

Genus citrus belonging to family Rutaceae possess shrub like trees which are small to medium and are planted in various tropical and sub-tropical regions (Tomar *et al*., 2013). Citrus plants are known to have been originated from China, India and northern Australia (Ramana *et al*., 1981; Gmitter and Hu, 1990; Tomar *et al*., 2013). Citrus fruits, are one of the main fruit tree crops grown throughout the world and share in common their sweet and sour flavor. They possess refreshing juice and are available almost all round the year (Tomar *et al*., 2013). Citrus is enriched with nutrients and phytochemicals that are beneficial for health for example carbohydrates, fiber, vitamin C, potassium, folate, calcium, thiamine, niacin, vitamin B6, vitamin A, phosphorus, magnesium, copper, riboflavin, and pantothenic acid (Al-Snafi, 2016). Consumption of citrus fruits directly or indirectly has various health benefits such as prevention from various forms of cancer, harmful mutations, cataract, cardiovascular diseases, and inflammation of tissues. Vitamin C or ascorbic acid in citrus is immunity booster (Jansen, 2002; Mehmet *et al*., 2007; Maliheh *et al*., 2009; Liu *et al*., 2012).

Across the globe, cultivation of citrus fruits has spread to more than 140 countries on an of about 495199.184 acres with estimated yearly production of 158 million tons (Mahawer *et al*., 2023). Tropical and subtropical areas around the equator with latitudes of 35°N and 35°S in Northern Hemisphere are hub of citrus production (Ramana *et al*., 1981; UNCTAD, 1991). Among the world's leading citrus fruit-producing countries China, Brazil, the U.S.A., India, Mexico, and Spain, share 2-3rd of global production (FAO, 2009; Liu *et al*., 2012). In Pakistan, Kinnow Mandarin *Citrus reticulata* Blanco is produced at very large scale (85% of total citrus production) and among citrus producing countries Pakistan occupies 12th position (Shamoon *et al*., 2020).

Optimum plant to plant distance to get higher production and economic returns is extremely important in citrus cultivation. In Pakistan, citrus plants are usually planted at 20×20 feet distance to ensure proper light penetration and ease of other management operations such as pruning, irrigation and pest management. But increasing population demands more yield utilizing same area under cultivation and it can be possible by high density plantation of citrus. In high density plantation (HDP), the plant-plant distance is kept less than traditional one and multiple benefits can be obtained such as higher production and income along with optimum utilization of different inputs for example irrigation water and fertilizers etc. (Ladaniya *et al*., 2020). Phillips (1978) reported that HDP may result in getting earlier return on investment, better spray coverage at less cost and easy harvesting in citrus. According to Zekri (2000), in citrus rootstock management, tree spacing is an extremely important aspect due to positive outcomes of higher tree density on yield and monetary benefits reported. Various other reports upon the impact of HDP in different citrus cultivars have been published (Wheaton *et al*., 1991; Tachibana, 1998; Stuchi and Giradi, 2010; Singh and Saxena, 2012; Bordas *et al*., 2012; Chattopadhyay, 2012; Dalal *et al*., 2013; Dogar *et al*., 2017).

These studies provide us insight that it is important to determine the impact of different plant spacing (high and low) upon citrus yield and fruit quality characteristics Therefore, this study was conducted with the objective of to determine the impact of different plant spacing of citrus trees (Kinnow Mandarin) on fruit production and other quality parameters.

Materials and Methods

Location

The study was carried out at Research farm of Citrus Research Institute, Sargodha, Punjab, Pakistan during the years 2012-13 and 2013-14.

Plants

A single cultivar entitled as Kinnow Mandarin that is one of the potential bearing cultivar of Mandarin group was used in this study. The plant height and spread of this variety was 14 feet and 16 feet, respectively. This is regular bearing cultivar with attractive fruit size ranging from 70-75 mm. Plants of equal size and uniform health were selected for this trial from specified pocket of the Govt. Orchard of Citrus Research Institute Sargodha where desirable dense plantation was already available.

Experimental design

The trial was designed according to the randomized complete block (RCB) design with four treatments and three replications. There was one experimental

unit in each replication and total 12 plants were kept under study. Before start of the trial, their canopy was managed in such a way that they are not over lapped and sufficient place between the rows and plants was left to carry out the necessary field operations. The detail of treatments is given in Table 1. In case of T_1 (10`×10`), manual field operations were carried out due to minimal space while among the other treatment plants, mechanical field operations were performed.

Table 1: *Treatments plan.*

Treatment	Row to row and plant to plant distance (ft)
T1	10` × 10`
T2	14` × 14`
T3	18` × 18`
T4	22` × 22`

Management operations

Recommended dose of fertilizer (N= 1000 g/plant, P = 500 g/plant and K= 500g/plant) followed by irrigation (n= 7 per year) was given to all the experimental units as routine management practices. All the plant protection measures (insecticide, weedicides and fungicide sprays) were also carried out to keep the plants healthy for producing quality fruit.

Parameters studied

The data of following parameters were recorded: plant height, plant spread, canopy volume, month wise incremental trend of fruit growth, fruit size, fruit weight, juice weight, juice%, no. of seeds per fruit, peel thickness, TSS, acidity%, TSS/acid ratio, and no. of fruit/plant (yield).

Plant height, plant spread and canopy volume

The plant height of each experimental unit was measured by measuring rod in meters and average height was calculated by division method. Similarly, plant spread was also taken in the form of diameter by measuring rod in unit of meters. Canopy volume (m^3) of each plant was measured with the help of following formula (Thorne *et al.*, 2002).

$$\textit{Canopy volume} = \textit{plant height} \times \textit{plant spread}^2 \times 0.5238$$

Incremental trend in fruit growth

Twenty fruits from each treatment were selected and tagged on plant for calculation of month wise incremental trend in fruit growth. The baseline data of fruit size (diameter) of each fruit from each treatment was noted and later on increase in fruit size at the end of each month was recorded. The difference between baseline fruit size and the fruit size taken at the end of the respective months was calculated to determine incremental trend in size of the fruit. This practice was started from July of year 2012 and continued till the end of November.

Analysis of fruit quality parameters

After taking the data of growth parameters, physiochemical analysis of citrus fruit was done (AOAC, 1990). Twenty fruits from each treatment were taken. Fruit size (mm) of each fruit was taken in the form of diameter and average size was calculated by dividing the sum of size (diameter) of all fruit by 20. Similarly, average fruit weight (g) was calculated by dividing the sum of weight of all fruits by 20. Juice of twenty fruits was extracted in a beaker and their weight was divided by 20 to estimate average juice weight (g). The average juice% of fruit was measured with the help of following formula:

$$\textit{Juice \%} = \textit{Av. juice weight of a fruit/Av. weight of a fruit} \times 100$$

Seeds from each fruit were extracted and total seeds of all 20 fruit were divided by twenty to calculate average no. of seeds per fruit. Peel thickness of each fruit was taken by Vernier caliper in mm and average peel thickness was calculated by simple division method. TSS was calculated in degree bricks with the help of Refractometer in degree bricks. Acidity% age of the juice was calculated with the help of following formula.

$$\textit{Acidity\%} = \textit{Volume of base used (N/10 NaOH) / volume of juice} \times 100$$

Similarly, TSS/acid ratio was calculated as under:

$$\textit{TSS/Acid Ratio} = \textit{TSS/acidity\%}$$

Number of fruits per plant was calculated by counting method after harvesting of all fruit from plant and yield per plant was calculated in kg while perceived yield per acre was calculated in tons.

Data analysis

The raw data of different plant and fruit physio-morphic parameters, month wise incremental trend and

Table 2: *Effect of different plant spacing in year 2012.*

Parameters	T1 (10×10 ft)	T2 (14×14 ft)	T3 (18×18 ft)	T4 (22×22 ft)	ANOVA
Plant height (m)	2.46±0.06 C	3.14±0.08 B	3.42±0.08 AB	3.50±0.12 A	P = 0.0009; DF = 3,11; F = 24.97
Plant spread (m)	2.49±0.02 D	3.22±0.03 C	3.45±0.08 B	3.61±0.04 A	P = 0.0000; DF = 3,11; F = 133.81
Canopy volume (m^3)	8.22±0.15 C	17.05±0.77 B	21.33±0.81 A	23.28±0.88 A	P = 0.0000; DF = 3,11; F = 68.94
Fruit size (mm)	65.82±1.15 AB	67.79±0.24 A	63.98±0.89 B	64.96±0.61 AB	P = 0.0782; DF = 3,11; F = 3.77
Fruit weight (g)	138.49±4.95 A	145.31±6.91 A	141.51±4.83 A	142.92±3.05 A	P = 0.8328; DF = 3,11; F = 0.29
Peel thickness (mm)	2.78±0.03 BC	2.68±0.03 C	3.06±0.04 A	2.88±0.04 B	P = 0.0018; DF = 3,11; F = 19.22
No of seed/fruit	15±1.15 B	17.67±0.88 A	17.67±0.88 A	18.67±0.33 A	P = 0.0411; DF = 3,11; F = 5.24
Juice weight (g)	62.35±0.87 BC	63.31±0.44 B	61.35±0.41 C	67±0.08 A	P = 0.0003; DF = 3,11; F = 34.87
Juice percentage	43.95±0.12 C	47.35±0.46 A	46.17±0.20 B	46.96±0.18 A	P = 0.0002; DF = 3,11; F = 46.09
TSS (%)	12.90±0.15 A	13.43±0.27 A	13.00±0.58 A	12.73±0.15 A	P = 0.5708; DF = 3,11; F = 0.73
Acidity percentage	0.75±0.02 A	0.76±0.02 A	0.74±0.01 A	0.78±0.02 A	P = 0.6626; DF = 3,11; F = 0.56
TSS/Acid ratio	17.14±0.44 A	17.61±0.19 A	17.55±0.51 A	16.64±0.68 A	P = 0.5309; DF = 3,11; F = 0.81

Means within a row with different letters differ significantly (P≤0.05; LSD test).

yield obtained at tested planted densities were processed in Microsoft Office Excel Worksheet. Many of data were analyzed by Statistix software (version 1.8) using Randomized Complete Block Design (RCBD). The mean values were separated using *LSD* test at probability level of 0.05%.

Results

Plant height, spread and canopy volume

In 2012, plant height was significantly higher (3.50 ± 0.12 m) in T4 with plant to plant and row to row distance of 22 × 22 ft as compared to T1 (plant to plant and row to row distance = 10`×10`) and T2 (plant to plant and row to row distance = 14` × 14`). Similarly, significantly greater plant height was observed in T2 (3.14 ± 0.08 m) and T3 (3.42 ± 0.08 m) as compared to T1 (2.46±0.06 m) (Table 2). In 2013, plant height was also significantly higher in T3 and T4 as compared to T1 and T2; however, it remained statistically similar in T3 and T4 (Table 4).

Data on plant spread in 2012 showed that plant spread was significantly maximum in T4 (3.61±0.04 m) as compared to all other treatments. Moreover, it was significantly minimum in T1 (2.49±0.02 m) when compared with T2 (3.22±0.03 m) and T3 (3.45±0.08 m) (Table 2). In 2013, significantly greater plant spread was measured for T3 (3.67±0.01 m) and T4 (3.75±0.07 m) as compared to T1 (2.46±0.01 m) and T2 (3.23±0.01 m); however, it remained statistically similar in both T3 and T4 (Table 4).

Measurements on canopy volume in 2012 indicate that it was statistically similar in both T3 (21.33±0.81 m^3) and T4 (23.28±0.88 m^3) while in both of these treatments it remained significantly larger as compared to T1 (8.16±0.08 m^3) and T2 (17.70±0.03 m^3) (Table 2). In 2013, similar trend was obtained for canopy volume (Table 3).

Table 3: *Month wise incremental trend in fruit growth (mm) in year 2012.*

Month	T1 (10× 10 ft)	T2 (14× 14 ft)	T3 (18× 18 ft)	T4 (22× 22 ft)
July	10.02	8.53	8.74	7.99
August	10.46	9.59	10.44	9.13
September	7.69	9.68	8.84	9.68
October	5.63	7.30	7.19	8.07
November	4.06	3.47	3.44	2.69

Fruit size and weight

In 2012, fruit size measurements in all treatments indicated that there was no significant difference in the fruit size among T1 (65.82±1.15 mm), T2 (67.79±0.24 mm) and T4 (64.96±0.61 mm). However, significantly larger fruit size was observed in T2 (67.79±0.24 mm) as compared to T3 (63.98±0.89 mm), where plant distances were 14×14 ft and 18×18 ft, respectively (Table 2). In 2013, significantly larger fruit size was observed in T4 (74.68±1.88 mm) as compared to all other treatments; however, statistically similar fruit size was observed between T2 (66.23±1.63 mm) and T3 (69.68±1.29 mm) but it remained significantly higher in both of these treatments when compared to T1 (62.62±0.90 mm) (Table 4).

Table 4: *Effect of different plant spacing in year 2013.*

Parameters	T1 (10×10 ft)	T2 (14×14 ft)	T3 (18×18 ft)	T4 (22×22 ft)	ANOVA
Plant height (m)	2.57±0.02 C	3.25±0.02 B	3.64±0.01 A	3.70±0.04 A	P = 0.0000; DF = 3,11; F = 330.02
Plant spread (m)	2.46±0.01 C	3.23±0.01 B	3.67±0.01 A	3.75±0.07 A	P = 0.0000; DF = 3,11; F = 260.44
Canopy volume (m^3)	8.16±0.08 C	17.70±0.03 B	25.70±0.15 A	27.27±1.36 A	P = 0.0000; DF = 3,11; F = 148.60
Fruit size (mm)	62.62±0.90 C	66.23±1.63 B	69.68±1.29 B	74.68±1.88 A	P = 0.0008; DF = 3,11; F = 25.33
Fruit weight (g)	107.59±0.39 B	153.02±4.56 A	154.19±5.99 A	166.44±2.17 A	P = 0.0003; DF = 3,11; F = 34.94
Peel thickness (mm)	2.96±0.24 A	3.15±0.23 A	3.09±0.25 A	3.46±0.17 A	P = 0.3139; DF = 3,11; F = 1.47
No of seed/fruit	12.33±0.88 B	17.67±0.88 A	19±0.58 A	18.67±1.45 A	P = 0.0036; DF = 3,11; F = 14.69
Juice weight (g)	44.60±4.95 C	67.81±4.43 B	72.85±5.45 B	92.63±0.50 A	P = 0.0023; DF = 3,11; F = 17.49
Juice percentage	41.41±4.47 B	44.45±3.48 AB	47.29±3.49 AB	55.66±0.47 A	P = 0.1107; DF = 3,11; F = 3.10
TSS (%)	11.80±0.41 A	11.60±0.40 A	11.34±0.33 A	11.40±0.75 A	P = 0.9361; DF = 3,11; F = 0.13
Acidity percentage	0.84±0.03 A	0.81±0.01 A	0.80±0.03 A	0.83±0.03 A	P = 0.6269; DF = 3,11; F = 0.62
TSS/Acid ratio	14.13±0.89 A	14.37±0.28 A	14.31±1.06 A	13.73±0.77 A	P = 0.9496; DF = 3,11; F = 0.11

Means within a row with different letters differ significantly (P≤0.05; LSD test).

No significant difference was found in the fruit weight among all the four treatments measured in 2012 (Table 2). However, in 2013, significantly smaller fruit weight was recorded in T1 (107.59±0.39 g) as compared to all other treatments (T2, T3 and T4) in which fruit weight remained statistically similar (Table 4).

Peel thickness and seediness

In 2012, significantly thicker peel was observed in T3 (3.06±0.04 mm) as compared to all other treatments [(T1 = 2.78±0.03), (T2 = 2.68±0.03 mm), and (T4 = 2.88±0.04)] whose response was statistically similar to each other regarding peel thickness (Table 2). However, in 2013, no significant difference in peel thickness was observed among all the treatments (Table 4).

Data related to number of seeds/fruit in 2012 indicated that significantly less number of seeds per fruit were found in T1 (15±1.15) as compared to all other treatments in which number of seeds/fruit were at par [(T2 = 17.67±0.88), (T3 = 17.67±0.88), and (T4 = 18.67±0.33) (Table 2). Similar trend related to number of seeds/ fruit was also observed among all the treatments when data were taken in 2013 (Table 4).

Discussion

Juice weight and Juice percentage

According to data taken in 2012, significantly greater juice weight was found in T4 (67±0.08 g) as compared to all other treatments (Table 2). Similarly in 2013, juice weight was found significantly greater in T4 (92.63±0.50 g) as compared to all other treatments. Juice weight was significantly less in T1 (44.60±4.95 g), as compared to T2 (67.81±4.43 g) and T3 (72.85±5.45 g) (Table 4).

TSS (%)

Calculations of TSS in both years (2012 and 2013) revealed that there was no significant difference in TSS among all the treatments (Tables 2 and 4).

Acidity percentage and TSS/acid ratio

Measurements of acidity percentage in 2012 and 2013 showed that this parameter was at par among all the studied treatments. Values of TSS/acid ratio in all treatments were also non-significant in when determined in both 2012 and 2013 (Tables 2 and 4).

Number of fruits/ plant

In 2012, significantly maximum number of fruits per plant was obtained in T4 (406.33±8.82) as compared to all other treatments while they were significantly less in T1 (75±3.61) (P = 0.0000; DF = 3,11; F = 642.06) (Figure 1). Similar trend in number of fruits/ plant was also observed in 2013 (P = 0.0000; DF = 3,11; F = 551.64; Figure 2).

In this study, we have evaluated the effect of different citrus plant spacing upon different growth, yield and physiomorphic parameters of citrus variety, Kinnow mandarin, *Citrus reticulata*. All these parameters were evaluated for two years (2012 and 2013) from mature citrus plants grown with four different plant spacing [i.e., 10` × 10` (T1), 14` × 14` (T2), 18` × 18` (T3), and 22` × 22` (T4)].

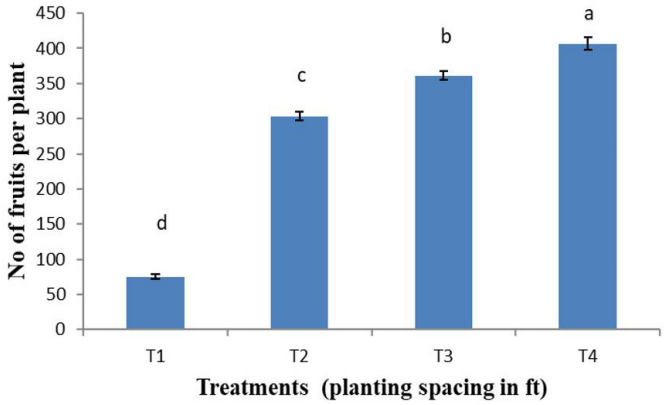

Figure 1: *Effect of different planting spacing on citrus yield (no of fruits per plant) in 2012. Bars with different letters differ significantly from each other (P≤0.05).*

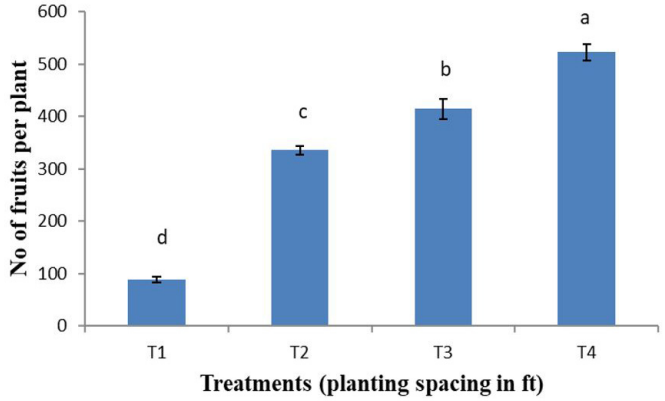

Figure 2: *Effect of different planting spacing on citrus yield (no of fruits per plant) in 2013. Bars with different letters differ significantly from each other (P≤0.05).*

Herein, we found that by reducing the row to row and plant to plant distance from 22` × 22` to 10` × 10`, the plant height, spread and canopy volume reduced significantly in *Citrus reticulata*. These findings illustrate that the plants grown in much closer space than the traditionally established plant to plant and row to row distance may show poor plant growth parameters. In contrast to our results, Ladaniya *et al.* (2020) reported that by differing the plant spacing in *Citrus aurantifolia*, the plant growth parameters such as plant height and canopy volume were not significantly influenced during the first three years of growth. However, from fourth year to onward, plant height was found to decrease with increase in plant spacing. Similarly, in contrast to our results Sharma *et al.* (1992) and Nasir *et al.* (2006) reported increase in plant height in *Citrus reticulata* by reducing the plant dstance reported that close plantation increased the plant height. However, similar to our results, Dalal *et al.* (2013) observed higher growth in Kinnow mandarin when they were planted at distance of 6 x 6 m as compared to 6 × 3 m. Moreover, similar to our results of canopy volume, Huang (1997) and Wheaton *et al.* (1991) also found more canopy volume in wider plant spacing as compared to close spacing in citrus.

Use of different plant spacing in 2012 did not affect the fruit size and it remained similar in all treatments; however, in 2013, significantly larger fruit size was obtained with 22` × 22` plant spacing. Fruit weight also remained similar in all treatments in 2012 despite different plant spacing but in 2013, slight variation was observed as fruits of significantly less weight were observed in T1 with plant to plant and row to row distance of 10` × 10`. These findings regarding fruit size and weight indicate that reduction in plant spacing from 22` × 22` to 10` × 10` may affect size and weight of *Citrus reticulata* fruits negatively which consumers will not love to purchase. According to Khan *et al.* (2014) fruit size i.e., length is affected by genetic makeup and nutritional status rather than plant spacing.

Data about peel thickness indicated that in 2012, significantly thick peeled citrus fruits were obtained in plants grown in 18` × 18` distance as compared to all other treatments; however, in 2013 this parameter was not affected in any of the treatment. Seediness (number of seeds/fruit) in citrus is highly important parameter and usually consumers don't like more seeds in citrus. In this work we studied whether seediness is affected by variable plant spacing or not. Our results revealed that in both years (2012 and 2013), significantly less number of seeds/fruit were found in plants grown at a distance of 10` × 10` as compared to plants with distance of 14` × 14`, 18` × 18`, and 22` × 22`. These findings depict the advantage of reduced plant spacing upon number of seeds in citrus fruit i.e., seediness may be reduced in more densely planted plants but it might be due to some other factors also which need to be explored in further studies.

Data regarding number of fruits per plant (yield) in both years revealed that reducing the citrus plant spacing may have disadvantageous effect as plants grown with 22` × 22` distance yielded more fruits as compared to others with less spacing. Yield is the most important aspect in any fruit crop production and higher yield is always desire of grower. Similar to our results, Wheaton *et al.* (1991) reported that dense planting in citrus did not result in higher yields in Florida climatic conditions. However, our findings

about fruit yield are not in line to the results published by Wheaton *et al*. (1995); Nawaz *et al*. (2007) and Azevedo *et al*. (2015) who reported more fruit yield in closely spaced citrus plants.

Some chemical parameters such as citrus juice percentage, TSS, acidity and TSS/acid ratio were also studied in Kinnow grown under different tree spacing. Results revealed that different plant spacing did not have profound effect upon these parameters in Kinnow in both years. This implies that chemical parameters of citrus fruit might not be affected by variation in plant spacing. Similar to our results, Ladaniya *et al*. (2020) also concluded that TSS, juice acidity and juice recovery did not improve in closely spaced grown *C. aurantifolia*. Similarly, reducing the plant spacing in mango, *Mangifera indica* L. also did not bring any changes in fruit quality parameters (Gaikwad *et al*., 2017).

Overall, it can be concluded from these data that reduced plant spacing in citrus such as (10` × 10` and 14`×14`) might result in poor attributes such as height, canopy, spread and yield in some citrus plants. Moreover, chemical parameters of citrus fruit like juice percentage, TSS, acidity and TSS/acid ratio did not vary when plant to plant and row to row spacing was reduced from 22`×22`. However, only one benefit of reduced plant spacing observed was the occurrence of less number of seeds per fruit in T1 as compared to others. Based upon these findings, it is recommended to growers to grow Kinnow plants at spacing of 22`×22` and 18`×18` as these treatments resulted in fruitful results in many parameters studied.

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Novelty Statement

In this study, less number of seeds/fruit were recorded in plants grown at 10 × 10 ft as compared to those grown at14 × 14 ft, 18 × 18 ft, and 22 × 22 ft.

Author's Contribution

Muhammad Raza Salik, Faheem Altaf, Muhammad Ihsan Ullah and Akbar Hayat: Conceptualization, investigation, methodology, data curation.
Muhammad Nawaz Khan: Visualization, resources and supervision.
Muhammad Babar Shahzad Afzal and **Hira Tariq:** Formal analysis, software.
Muhammad Nawaz Khan: Project administration and validation.
Muhammad Babar Shahzad Afzal, Ayesha Komal and Hira Tariq: Writing original draft.
Muhammad Babar Shahzad Afzal: Writing review and editing.

Conflict of interest

The authors have declared no conflict of interest.

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