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EVALUATION OF HIGH DENSITY PLANTATION ON VIGOR AND YIELD IN KINNOW MANDARIN (*Citrus reticulata* Blanco)

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Abstract

The effect of tree spacing on vegetative performance and yield of plant in 8 year old Kinnow mandarins (*Citrus reticulata* Blanco) growing on rough lemon rootstock was studied at Experimental Fruit Orchard (Square 9), Institute of Horticultural Sciences, University of Agriculture Faisalabad (Pakistan). Plants were grown at three planting distances D_1 (11 × 11 ft), D_2 (11 × 22 ft) and D_3 (22 × 22 ft). Maximum plant height (11.46 ft) was observed in D_1 while minimum plant height (8.83 ft) was observed in D_3 Maximum plant canopy volume (8.85 m^3) was found in the D_3 while minimum plant canopy volume (5.43 m^3) was found in D_1. Maximum numbers of flushes (12.80) were found in D_3 and minimum numbers of new flushes (9.25) were found in D_2. Maximum numbers of new leaves (80 leaves/branch) were found in D_1 whereas, minimum numbers of new leaves (55 leaves/branch) were found in the D_3. Maximum fruit set (27.56%) was found in D_1 and minimum fruit set (21.98%) was found in D_3 whereas, maximum yield was found in D_2 (593 fruits) and minimum yield was found in D_1 (414 fruits). In case of total soluble solids (TSS), highest (11.49) was observed in D_3 while minimum TSS (9.92°Brix) was found in D_1. Highest juice percentage (48.67%) was observed in D_1 while lowest juice percentage (43.43%) was observed in D_3. For most the parameters D_2 outclassed all the other treatments and proved to be the best planting distance for Kinnow mandarin under agro ecological conditions of the Punjab province of Pakistan.

Key words: Citrus, Kinnow, high density, yield, quality, vigor

INTRODUCTION

Citrus plantings should be planed so that the biological and management aspects are interrelated to maximize economic returns. Hutton (1989) reported that changes in labor relations, government regulations, and tree loss rates require continual evaluation of citrus plantings to establish systems. In Florida a number of changes have occurred which affect returns from citrus production; land values and taxes have increased, certain zoning laws favor the agricultural production; availability of good land for citrus has decreased; citrus on poor soil type results in smaller tree size due to various limiting factors; loss of trees to diseases has increased; and there have been increased in capital expenditures for equipments and irrigation, interest rates, and labor costs. Because of these changes, it appears that citrus production in the future must make more efficient use of the limited amounts of good land provide for more rapid recovery of investment capital in order to provide maximum average net return. Zekri (2000) reported tree spacing has

become an increasingly important consideration in citrus rootstock management because of the benefits of higher tree density on early production and financial returns. As Phillips, (1978) reported that by high density plantation we can get earlier return on investment; better spray coverage at less cost, easy harvesting and return to fulfill production sooner after tree damage or removal. Keeping this view the study was initiated to find out the appropriate planting distance for citrus grooves under the agro ecological conditions of Punjab province of Pakistan.

MATERIALS AND METHOD

The study was carried out at Experimental Fruit Orchard (Square 9), Institute of Horticultural Sciences, University of Agriculture Faisalabad during 2005-2006 for the two consecutive years. The laboratory work was carried out at the Pomology Lab., Institute of Horticultural Sciences University of Agriculture, Faisalabad. Seven years old 89 trees of Kinnow mandarin of moderate vigor and health grafted on rough lemon rootstock were grown at three planting distances. The experiment was consisted of following treatments.

D_1: Trees at planting distance 11 × 11 ft
D_2: Trees at planting distance 11 × 22 ft
D_3: Conventional planting distance 22 × 22 ft

The present work was under taken by keeping three treatments replicated six times. Treatment units in one treatment (11 × 11 ft) were different, in other two treatments were kept same. To determine the vigor of the trees, stem girth, plant height, canopy volume, number of new flushes, number of new leaves/flush and number of older leaves/flush, fruit set (%), yield, juice (%) and TSS were measured according to the standard procedure. Girth measurement was taken at a fixed height of 25 cm above the graft union; position was fixed for all the treatments. The measurements were analyzed by the least significant design for testing the significance of differences. No hedging or pruning of the trees was done. Height of the tree was measured with the help of telescopic pole. For measuring the spread of the tree two observations were taken from east to west and north to south at right angle with the help of measuring tape in cross section up to the maximum out growth of the plant in each direction and from the following formula the canopy volume was measured.

$$\text{Canopy volume} = 4/3\ \pi\ r^3$$

Data of new flushes was taken by counting the number of new flushes from the tagged branches from four sides of the tree. Number of new Leaves was counted from the new flushes on the tagged branches of the citrus. Number of older leaves was counted from the branches tagged in the four sides of the plant. When bloom was over fruit set on the selected trees was counted on marked branches in the third week of April 2005. Fruit set percentage was determined by using the following formula:

$$\text{Fruit set (\%)} = \frac{\text{Total fruit set}}{\text{Total bloom}} \times 100$$

Yield was recorded by counting the total number of fruits per plant at the time of harvesting whereas; TSS was measured by digital Refractometer (ATAGO-5000).

RESULTS AND DISCUSSION

Stem Girth

Mean stem girth among treatments ranged from 27.3-27.6 cm. Maximum stem girth was found in D_3 (27.6 cm) which was at wide spacing and statistically same with other treatments. While minimum stem girth was found in D_1 (27.3 cm) which was statistically same with other treatments as given in the Table 1. Generally trunk circumference increase was correlated with density planting but results indicated that increase or decrease in plant spacing had no significant effect on stem girth. This was due to the younger age of the plants was no difference in stem girth

of the treatments came into evidence. Bosswell et al. (1978) who found no difference in trunk circumference up to five years after planting. As treatment unit was of 7-8 years of age so there was no difference in trunk circumference among treatments. In addition to this our results confirm the findings of Tachibana, (1998) and Bosswell et al. (1970) who found that with increase in plant spacing there is an incremental trend in the stem girth because plants in normal spacing had more foliage or canopy volume as compared to closer spacing so to give support to a heavy canopy strong and vigorous stem is required.

Plant Height

As regards plant height, according to the mean values the plant height among treatments ranged from 8.83-11.46 ft. Maximum plant height was found in D_1 (11.46 ft) which was at close spacing and statistically different from other treatments. Minimum plant height was found in D_3 (8.83 ft) as shown in the Table 1.

Results indicated that plant height decreased with increase in plant spacing and there was more canopy spread. At closer plant spacing Kinnow plants grow taller than its normal pattern of spreading canopy and it was due to competition among plants for light transmittance in close spacing, owing to which plants get more height. The shading of lower parts is owed to more number of plants per unit area due to which plants compete for light interception and get more height in closer spacing for light interception. Tachibana (1998), Rabe and Aubert (1999), Phillips (1978) and Castle et al. (1986) found similar results in plant height and shape they found that natural growth habit of citrus upright changed to somewhat columnar in shape with increased plant density.

Canopy Volume

Cumulative influence of photosynthetically active reaction, water and other nutrients influence the canopy volume of the tree. The results showed significant difference in canopy volume. Plant canopy volume ranged from 5.43-8.85 m^3. Maximum plant canopy volume was found in the D_3 (8.85 m^3) followed by D_2 (7.99 m^3). Whereas minimum plant canopy volume was found in D_1 (5.43 m^3) which was statistically significant from other treatments as given in the Table 1. Results indicated that with decrease in plant spacing plant lost their original canopy shape and became columnar due to which canopy volume reduced and plants attained more height than canopy spread. At wider spacing plants have spherical type canopy because they have enough space for canopy spread. At wider spacing plants received more light around the canopy and lateral buds proliferate effectively leading to lateral branch development. Whereas in closer spacing shadowing of trees during early morning hours and late in the evening, terminal buds proliferate more as compared to lateral buds. As a response to more light interception at higher branches, the pattern of growth in Kinnow mandarin changed to upright as against spreading. This very particular behavior of canopy development in relevance to plant height is visible from results. So it could be inferred that at closer spacing plant canopy was less and affected the fruit set and yield. Huang (1997) found more canopy volume in wider plant spacing. Similarly, Wheaton et al., (1991) observed that canopy volume varied among different plant spacing he found more canopy volume in wider spacing as compared to close spacing.

New flushes per Branch

Maximum numbers of flushes were found in D_3 (12.80) followed by D_1 (12.03) whereas, minimum number of new flushes was found in D_2 (9.25) which were statically different from other treatments as shown in Table 1. According to the results highest numbers of new flushes were found in D_3 followed by D_1. In these treatments more initial fruit drop was recorded so the energy in the plants was utilized for producing more number of flushes i.e. energy consumed for vegetative growth rather than for reproductive growth. However less fruit drop was recorded in the D_2 as such there was less number of new flushes per tree. More light interception was recorded in close spacing which promotes vegetative growth and fruit set. Wheaton et al. (1992), Tachibana (1998), Hutton and Cullis (1981) studied the growth behavior of the citrus plant and found more

leaf density in the plants planted at close spacing which produce more number of new flushes and new leaves in the high density plantation as compared to the wider spacing.

New leaves per Branch

Leaves have a wider role in the productivity and nutritional requirements of perennial plants. These are considered as the most active part as for as photosynthesis is concerned. Maximum number of new leaves per branch were found in D_1 (80 leaves) followed by D_2 (55.95) whereas, minimum number of new leaves were found in the D_3 (55 leaves) as shown in Table 1. Results indicated that number of new leaves were more at close spacing; This was due to more light interception in close spacing which promotes vegetative growth. It was found by Syvertsen, (1984) that light intensity and quality received will enhance vegetative growth in citrus in close spacing. Tachibana (1998), Hutton and Cullis (1981) studied growth behavior of the citrus plants and found more leaf density in the plants at close spacing.

Old or Mature leaves per Branch

The role of leaves in productivity and nutritional requirements of perennial fruit trees is well established. Maximum number of old leaves were found in D_2 (140 leaves) which was statistically non-significant with other treatments while minimum number of older leaves were found in the D_1 (117 leaves) as given in Table 1. Results indicated that the numbers of old leaves were not affected by plant spacing. As maximum number of old leaves were found in D_2 so more yield was recorded in D_2 than other treatments which indicated that old leaves contributes for yield than the new leaves, because old leaves had more photosynthetic activity than the new leaves. Tachibana (1998) studied four planting densities in citrus D_1=1250, D_2=2500, D_3=5000 and D_4=10 000 trees/ha. Difference in annual growth and yields between planting densities were recorded. He found more leaf density in D_1 as compared to D_2, D_3 and D_4 which have low leaf density.

Fruit set (%)

Treatment means reflected that fruit set percentage ranged from 21.98-27.56%. Maximum fruit set was found in D_1 (27.56%) which was statistically significant from other treatments whereas minimum fruit set was found in D_3 (21.98%) as shown in Table 1. Results revealed that fruit set in the D_1 at close spacing was in the optimum range of fruit set in mandarins i.e. 25-30% as shown in Table 1 whereas in other two treatments it was slightly below to the average. The optimum fruit set in closer spacing could be due to more light interception and more number of new flushes and leaves. So it could be deduced that vegetative growth induces more bloom and fruit set at closer spacing. Bosswell et al. (1970) found that light intensity received by the leaf surface affects fruit set percentage and distribution. Due to crowding of trees in high density plantation trend fruit set in the trees shifted to the top foliage of the tree as found by Bosswell et al. (1975) that in crowded high density plantation skirt foliage was lost due to shading and fruit set was shifted to the top of the tree. Similarly in this study more fruit set was observed at the top than the skirt in close spacing. Also initial fruit set was more in D_1 while more fruit drop was also observed in D_1.

Yield (number of fruit per plant)

Maximum yield was found in D_2 (593 fruits) followed by D_3 (549) whereas, minimum yield was found in D_1 (414 fruits) as given in Table 1. Results indicated that more yield was obtained from D_2 which was at close spacing, although D_1 had more close spacing and there were more number of plants in D_1 but there was more fruit drop: so yield was even less even than D_3 at normal spacing. Overall the yield in close spacing was more which confirms the findings of the Bosswell et al. (1970), Hutton and Cullis (1989) and Wheaton et al. (1995) who found that there is an inverse relationship between tree spacing and yield but yield started declining owing to over crowding in close spacing after ten to twelve year of age of plants. Sharma et al. (1992) studied fruit drop in high density plantation and found more fruit drop in September-October.

Table 1: Effect of various planting densities on growth, yield and quality parameters

Treatments	D_1	D_2	D_3
Stem girth (cm)	27.38	27.53	27.68
Plant height (ft)	11.46a	9.98b	8.83c
Canopy volume (m^3)	5.43c	7.99b	8.85a
New flushes per branch	12.03a	9.25b	12.80a
New leaves per branch	80.33a	55.95b	55.00b
Older leaves per branch	117.48	140.48	129.45
Fruit set (%)	27.57a	23.75b	21.98c
Yield (number of fruit per plant)	413c	593a	549b
Total Soluble Solids (°Brix)	9.92c	10.90b	11.49a
Juice (%)	48.67a	46.20b	43.43c

CONCLUSION

As the value of land increasing and the available land for cultivation is decreasing, in this condition high density plantation is very important and effective as in it greatest amount of fruit bearing volume per hectare would be attained. Our preliminary results showed that D_2 (11 × 22 ft) can prove better for satisfactory yields as well as quality of the fruit. Whereas in D_1 (11 x11 ft) although the yield per hectare is increased but the fruits were of small sized and quality was inferior. However for further recommendations systematic efforts are required to study the relationship between planting densities and yield as well as quality of the fruit.

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