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Short communication

Effect of planting density on canopy parameter, yield and water use efficiency of Kinnow mandarin

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ABSTRACT

The effect of tree spacing on growth performance, yield parameters and water use efficiency of five and six-year-old Kinnow mandarin growing on rough lemon rootstock was studied. Plants were grown at three spacing, 6 m × 6 m, 6 m × 5 m and 6 m × 3 m. Plant growth parameters were not influenced significantly by different planting densities. However, maximum plant height, plant spread, canopy volume, canopy surface area, canopy foot print and trunk cross sectional area was observed under low density planting (6 m × 6 m) and minimum under high density (6 m × 3 m). Maximum crop load (276.64 fruits/plant) and yield (46.65 kg/tree) on per tree basis was found in low density (6 m × 6 m), while resource distribution was found maximum (2.64 fruits/cm²tcsa) in 6 m × 5 m spacing. The maximum fruit weight (171.83 g), yield (220.99 tonnes/ha) on unit area basis and water use efficiency (24.72 kg/ha/cm) was observed at a spacing of 6 m × 3 m and minimum values in 6 m × 6 m spacing. Net profit ranged from Rs. 82,904 to Rs. 1,33,417/ha in 6 m × 6 m and 6 m × 3 m spacing. Overall, the closest spacing of 6 m × 3 m may be adopted by the Kinnow growers for getting better productivity, WUE and profit per unit area in the initial years of planting, *i.e.* up to age of six year.

Key words: Planting density, Kinnow, canopy, yield, water use efficiency, economics.

Kinnow, a mandarin hybrid, is gaining popularity among the citrus growers of North India. Its easy adaptability to varied agro-climatic conditions, heavy bearing potential and excellent fruit quality characters have boosted its cultivation. Among different fruit crops in Punjab, Kinnow occupies maximum area 42,795 ha with a production of 9,15,005 tonnes. However, favourable reports in terms of high production per unit area and better management, the emphasis is on high density plantation (Arora *et al*., 1). It is more so in case of citrus fruit trees which have limited productive age where the orchardists would like to get maximum production per unit area. Improper spacing may be one the reason for low productivity. In North India a spacing of 6.0 m × 6.0 m was found to be optimum for Kinnow budded on rough lemon. Due to precocity and heavy bearing, growers are of the view that in the initial years of bearing, more number of plants should be planted to realize better returns. Tree spacing is one method used to obtain efficient and profitable land use. Its basic function is to confine the exploitation zone of the plant with regard to light, water, and nutrients so the highest total yield potential can be reached in the smallest possible area. With ever increasing land cost, taxes, production cost, and the need for early returns on invested capital, there is a worldwide trend toward high density planting.

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Studies on high density citrus planting have increased and considerable data has been published in different agro climatic conditions (Arora *et al*., 1; Sharma *et al*., 10; Nawaz *et al*., 8). Therefore, the anxiety for exact information about row and tree spacing for Kinnow under semi-arid irrigated ecosystem of south western Punjab is imperative for high production where a lot of new plantation is coming up.

The experiment was conducted at Punjab Agricultural University, Regional Station, Bathinda during the year 2009 & 2010. The soil of the experimental site is classified as loamy sand with pH-8.2, EC- 0.28 ds/m, OC-0.46%, P- 14kg/ha and K-252 kg/ha. Plants raised on rough lemon (*Citrus jambhiri* Lush) rootstock were planted at different spacing, *i.e.*, 6 m × 6 m, 6 m × 5 m and 6 m × 3 m during the spring of 2005 in a randomized block. Each space has been surrounded by guard row of the standard spacing and replicated seven times and there were three plants unit in each replication. The data was analyzed statistically using randomized block design at 5% level of significance. Plants were maintained under uniform cultural schedule. Trunk diameter was recorded 5 cm above the bud union, which was 6 inches above ground level, in the month of December with the help of verniercaliper and height and spread of the plant with graduated plastic pole. Canopy parameters were calculated by the formulae suggested by Smith (11):

Trunk cross-sectional area (T): = $0.7854D_t^2$
Canopy foot print (F) = $0.7854 (D_{c1} \times D_{c2})$
Canopy surface area (S): $F + H \{3.1416[(D_{c1} + D_{c2})/2]\}$
Canopy volume (V): F × H

Where, T is the cross sectional area of the trunk in meter square; 0.7854 is a constant; D_t is the trunk diameter in centimetre: D_{c1} & D_{c2} are the canopy diameters in meters at right angle from each other: 3.1416 is a constant; H is the height of the tree in meter and V is the canopy volume in cubic meter. Productive efficiency was calculated by dividing the number of fruits/ plant by the trunk cross sectional area (TCSA). Crop load was expressed in average number of fruits/ tree. Average weight of the fruit from each unit of the replication was recorded. Average weight of the fruit/ plant was multiplied by the number of fruit/ plant to work out the yield/ plant. The water use efficiency (WUE) was computed by dividing yield kg/ ha with total water applied (cm) including effective rainfall. Comparative cost and income was worked out. Costs that were essentially equal regardless of spacing were not included in the cost analysis. These excluded costs are; land value, taxes, depreciation, interest on investment, miscellaneous costs, management costs, development costs and costs after planting and until second year production begin.

Canopy parameters,*viz*., average plant height; average plant spread, canopy volume, canopy foot print, canopy surface area and trunk cross sectional area were not found significantly influenced by different plant spacing . However, there was a gradual decrease in all the canopy parameters with the increase in planting density but could not reach to the level of significance. Similarly, Kumar *et al.* (7) observed that trunk cross-sectional area of the tree and canopy volume increased with decrease in plant densities in almond. Plant height, average plant spread, canopy foot print, canopy surface area, canopy volume and trunk cross sectional area varies from (2.83-2.89 m), (2.63-2.73 m), (5.23-5.76 m^2), (28.55-30.63 m^2), (14.82-16.52 m^3) and (94.24-107.03 m^2), respectively. This shows that there is no significant effect on canopy at different spacing to the age of six years and trees were not crowded at this stage and hence this is probably due to no competition for water, light and nutrients up to the age of six year and even, there is no difference in the shape as no much difference in canopy foot print and canopy surface area. Huang (5) found more canopy volume in wider plant spacing. Similarly, Wheaton *et al.* (13) observed that canopy volume varied among different plant spacing and found more canopy volume in wider spacing as compared to closer spacing. However, in present study the plants are not fully mature and still there is better light interception and no shading effect, hence, these results are contradictory with the earlier findings (Chundawat *et al*., 4) in guava and Kinnow (Nawaz *et al*., 8). They reported that in closer spacing plants having the tendency to grow tall with less lateral growth and plant becomes columnar in shape due to poor light interception or shading effect and plant in wider spacing had optimum space for lateral growth and hence balanced growth. Nawaz *et al.* (8) did not find any difference in trunk circumference upto 7 year of age in Kinnow mandarin. Addition to this our results confirm the findings of Tachibana (12) and Boswell *et al.* (2) who found that with increase in plant spacing there is incremental trend in the stem girth because plant in normal spacing had more foliage or canopy volume as compared to closer spacing.

Results of the study on the yield and yield contributing characters revealed that the yield per hectare was significantly influenced by different spacing/ densities, whereas, fruit yield/plant was non-significant (Table 1). The maximum crop load (276.64 fruits/tree) was observed with a spacing of 6 m × 6 m and minimum (231.76 /tree) with a spacing of 6 m × 3 m. Crop load at a spacing of 6 m × 5 m was at par with 6 m × 6 m and significantly more with 6 m × 3 m. Similarly, fruit yield decreased significantly with every increase in planting density during the year 2009, but yield/ tree with a spacing of 6 m × 6 m was at par with 6 m × 5 m during the year 2009. The maximum fruit yield/ tree (46.65 kg) was found with 6 m x6m spacing and minimum (39.82 kg/tree) with a spacing of 6 m × 3 m. This may be due to the differences in the canopy parameters (canopy volume, foot print and surface area) which are the fruit bearing area as evident from the present investigation. Average fruit weight was not found significantly affected by the planting densities. Larger fruit size was credited to less crop load at high density (Phillips, 9; Boswell *et al.*, 3). Fruit yield per unit area basis was found significantly increased with every increase in planting density. The maximum yield (220.99 tonnes/ ha) was recorded with closest spacing of 6 m × 3 m and minimum (129.23 tonnes/ha) with wider spacing of 6 m × 6 m. At medium spacing 6 m × 5 m fruit yield was recorded (142.12 tonnes/ha). Sharma *et al.* (10) also obtained more yield per acre from 6 m × 3 m spacing and the minimum yield at 7.6 m × 7.6 m spacing in Kinnow mandarin. This may be because under wider spacing plant has comparatively higher vegetation, high leaf fruit ratio. Trees with bigger vegetative dimension normally give larger number of fruit per tree. However, if productivity per unit area basis is considered, it is clear that yield/ ha had given significantly higher yield under closest spacing due to higher plant population/ unit area. The results clearly revealed that productivity

Table 1. Effect of spacing on yield and its attributing characters of Kinnow mandarin.

Spacing (m)	Crop load (fruits/tree)		Av. fruit weight (g)		Yield (kg/tree)		Yield (tonnes/ha)	
	2009	2010	2009	2010	2009	2010	2009	2010
6 × 6	175.64	276.64	171.15	166.79	30.01	46.65	83.15	129.23
6 × 5	173.07	251.36	171.06	169.94	29.49	42.68	98.22	142.12
6 × 3	137.71	231.71	174.49	171.83	24.03	39.82	133.38	220.99
CD at 5%	13.04	16.89	NS	NS	1.93	2.41	7.38	9.55

of individual tree under different spacing were at par but accommodation of more plant population in closest spacing led to almost more production than wider spacing. Such an increase in production through higher number of plants per unit area in Kinnow mandarin has been demonstrated by (Arora *et al*., 1; Ingle and Athawale, 6; Nawaz *et al*., 8).

The productive efficiency decreased non-significantly and water use efficiency increased significantly with every increase in planting density (Table 2). The maximum productive efficiency (2.63 fruits/cm^2) was found with low density (6 m × 6 m) and minimum (2.49 fruits/cm^2) with high density (6 m × 3 m). This may be due to the decreased crop load and trunk cross sectional area with increase in planting density. The maximum water use efficiency (24.72 kg/ha/cm) was observed under high density planting and minimum (13.84 kg/ha/cm) under low density (6 m × 6 m). The improved/ increased WUE might be due to the fact that high density planting accommodates more number of plants/area and give more yield which permit better utilization of water as compared to wider spacing as evident from the present investigation.

Cost involved in establishing and maintaining plant at different spacing and the monetary returns determines the economic feasibility of high density planting. Comparative costs and income are shown in (Table 3). Costs that were essentially equal regardless of spacing were not included in the cost analysis. Six year old plants and second bearing season crop of Kinnow bears minimum cost of Rs. 33,403/- at wider spacing (6 m × 6 m) and maximum (Rs. 65,474/-) at closer spacing (6 m × 3 m), whereas, intermediate spacing (6 m x 5 m) costs about (Rs. 39,972/-). All the spacing showed a net profit ranged from Rs. 82,904/- ha for 6 m × 6 m spacing to Rs.1,33,417/- ha for closer spacing (6 m × 3 m). The cost for Rs. 87,936/- ha was registered with intermediate spacing (6 m × 5 m).

Table 2. Effect of spacing on productive and water use efficiency in Kinnow mandarin.

Spacing (m)	Productive efficiency (fruits/cm^2)		Water applied (mm)		Effective rainfall (mm)		Total water applied (mm)		Water use efficiency (kg/ha/cm)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
6 × 6	2.15	2.63	576	648	195	286	771	934	10.79	13.84
6 × 5	2.21	2.64	554	632	195	286	749	918	13.13	15.48
6 × 3	2.01	2.49	530	610	195	286	725	894	18.40	24.72
CD at 5%	NS	NS	-	-	-	-	-	-	1.00	1.05

Table 3. Cost and income of Kinnow mandarin per hectare under different spacings.

Spacing (m)	No. of trees/ha	Cost (Rs.)							Income (Rs.)	
		Trees	Planting	Pruning	Fertilizer	Weed control	Pest control	Total	Gross	Net
6 × 6	275	6,875	8,525	2,640	3,591	3,960	7,812	33,403	1,16,307	82,904
6 × 5	330	8,250	10,230	3,120	4,310	4,752	9,310	39,972	1,27,908	87,936
6 × 3	550	13,750	17,050	5,280	7,184	7,520	14,690	65,474	1,98,891	1,33,417

Cost per budded plant = Rs. 25/-; Planting cost per plant = Rs. 31/- (including digging, refilling, cost of FYM, Fertilizer & planting); Manual weed control thrice a year; Pest control including cost of insecticides and fungicides; Labour cost based on Rs. 240 /day; Sale of Kinnow fruit @ Rs. 9/kg.

This increased cost and net profit with the increasing densities are due to the increased plant and more population and yield/ha under closer spacing. Similar results were earlier reported by Boswell *et al.* (3) in Atwood Navel orange trees.

Based on the observations on various aspects, the overall results on high density planting has demonstrated that closest spacing (6 m × 3 m) may be adopted by Kinnow growers for getting better productivity, WUE and profit per unit area in the initial years of bearing.

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