Indian Journal of Agricultural Sciences **85** (11): 1455–60, November 2015/Article

Effect of nutrition, harvesting date and fruit canopy position on yield and quality of Kinnow mandarin (*Citrus nobilis* × *Citrus deliciosa*)

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Received: 24 April 2015; Accepted: 24 August 2015

ABSTRACT

Attractive peel colour and quality development in Kinnow (*Citrus nobilis* Lour × *Citrus deliciosa* Tenara) is a prime requisite for its fair market price. The objective of study was to find out the impact of canopy position, date of harvesting and nutrition on yield and quality of Kinnow mandarin. A field experiment was conducted in a four year old Kinnow orchard using factorial randomized block design with three replications. There were nine treatments comprised of various N, P, K levels and one control; two canopy positions (external and internal) and three harvesting dates (06.12.13, 26.12.13 and 16.01.14). Statistical analysis using SAS 9.3 software and Tukey's HSD test revealed the significance of various treatments, canopy positions and harvesting dates ($P<0.01$).The treatment comprising 400g+600g+240g ($N+P_2O_5+K_2O$/plant) was found the best among other treatments with respect to yield (20.06 kg/tree) and other quality parameters (TSS, acidity, ascorbic acid and total carotenoids). Fruits which are present on external canopy of tree were superior in terms of quality (TSS, ascorbic acid, total carotenoids) as compared to fruits present on internal canopy of the tree.The Kinnow fruits harvested during the last week of December were found superior in terms of total carotenoids in juice and peel and ascorbic acid content. While the fruits harvested in second week of January were found superior in terms of TSS and acidity. Application of 400g, 600g and 240g of NPK respectively was found beneficial for quality fruit production of Kinnow. Quality of Kinnow fruits vary as per canopy position and date of harvesting, hence they should harvest at different times and also from different canopy positions according to purpose.

Key words: Canopy position, Harvesting date, Kinnow, Nutrition, Quality

Nutrient management is a very important factor to produce the good quality fruits Kinnow (*Citrus nobilis* Lour × *Citrus deliciosa* Tenara) (Iqbal *et al.* 1999, Ioannis *et al.* 2004). The supply of macro-nutrients particularly nitrogen (N), phosphorus (P) and potassium (K) and canopy position plays an important role in yield, as well as fruit quality (Lester *et al.* 2010, Liu *et al.* 2010, Khalid *et al.* 2013), especially N is needed for optimum vegetative, as well as reproductive growth (Alva *et al.* 2006). Date of harvesting also affects the quality of fruits significantly (Iqbal *et al.* 2012). Therefore, proper fertilization is a basic step to increase Kinnow yield and quality. Deviation from optimum nutrition in both directions results in decrease in fruit yield (Bernardi *et al*. 2000; Ruschel *et al*. 2004). Nirogen fertilization at high rates is responsible to decrease the concentration of vitamin C in citrus fruits (Mozafar 2008).Vitamin C contents in fruit juice are correlated with sugar metabolism and can be improved by proper potassium nutrition management (Mengel 1997). Foliar application of potassium has been found effective in improving the ascorbic acid content (Asharaf *et al*. 2013).

Fruit quality is also affected by the position of fruits within canopy. Jawanda *et al.* (1973) reported that fruit juice content, acidity and TSS were higher, and fruit size and rind percentage were lower in the upper canopy of citrus trees. Uchida *et al.* (1985) found in orange fruits harvested from upper canopy positions with high contents of reducing sugars. Izumi *et al.* (1990) also reported that citrus fruit harvested from the southern top canopy position had higher TSS and juice contents than fruit from other canopy positions. Agabbio *et al*. (1999) also reported that Tarocco orange harvested from the external southern side of the tree had higher TSS and lower acid levels, which resulted in higher TSS: acid ratio and improved taste. However, Fallahi and Moon (1989) reported that fruit mass, total juice/fruit, rind fresh and dry mass, and rind thickness of fruit from internal canopies of Kinnow mandarin, Red blush grapefruit, Valencia orange and Lisbon lemon were significantly higher compared with fruit from external canopy positions. By keeping in view the above mentioned points, the study has been conducted to study the effects of fruit canopy position, harvesting date and nutrition on yield and

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quality of Kinnow mandarin.

MATERIALS AND METHODS

The experiment was conducted in a four year old Kinnow orchard located at Todapur farm of IARI, Pusa, New Delhi during 2013-14. The site was located at N 28p 38.043' and E 77p 09.830'; 224 m above mean sea level. There were nine treatments comprised various N(g):P(g):K(g) levels (T_1=250:600:160; T_2=250:600:240; T_3= 250:600:320; T_4=300:600:160; T_5=300:600:240; T_6=300:600:320; T_7=400:600:160; T_8=400:600:240; T_9=400:600:320) and one control (T_{10}); two canopy positions [external (P1) and internal (P2)] and three harvesting dates [06.12.13 (D1), 26.12.13 (D2) and 16.01.14 (D3)]. The Kinnow is planted at a distance of 4.5 m × 4.0 m. The soil of orchard is sandy loam. The fertilizer doses were applied in the form of urea (46 % N), di-ammonium phosphate (18 % N and 46% P_2O_5) and potassium sulphate (60 % K_2O) in three split doses. Half dose was applied on February and one fourth dose of whole fertilizer was applied on June and remaining one fourth doses was applied on September. The 50% outer periphery of the tree was considered as external canopy and 50% inner area was considered as internal canopy. Observations were recorded on physical (fruit weight, fruit diameter, and fruit length), chemical parameters of fruits (TSS, acidity, ascorbic acid, total chlorophyll in peel, total carotenoids in peel, total carotenoids in juice) and yield.

Freshly harvested Kinnow fruits were brought to the laboratory of the division and washed thoroughly with tap water to remove adhering dust and other materials. Each sample comprised of twenty fruits, was used for physico-chemical parameters. Average fruit weight (g), fruit length (cm) and fruit diameter (cm) were measured and calculated as per standard procedure. The total soluble solids content of fully ripened Kinnow fruits were recorded with the help of refractometer (Hyanna, HI 96801) and results were expressed in ºB. The acidity and ascorbic acid of juice was determined by the procedure given by Ranganna (1986) and expressed as per cent and mg/100 ml of juice respectively. Total chlorophyll and carotenoids in peel was estimated by non-maceration method of Hiscox and Israelstam (1979) with the help of UV visible spectrophotometer and absorbance was read at 450, 645 and 663 nm. The amount of total chlorophyll and carotenoids in peel were calculated using equation given by Arnon (1949) and presented as µg/g fw. Total carotenoids in juice were determined by a modified method as described by (Sadler *et al*. 1990) with the help of UV visible spectrophotometer and absorbance was read at 450 nm and expressed as µg/100ml of juice. Data were analyzed by analysis of variance (ANOVA) using SAS 9.3 software in factorial Randomized Block Design with three replications. Further, a multiple comparison was done by using Tukey's HSD test. All other statistical analysis was done using MS Excel 2007.

RESULTS AND DISCUSSION

Replicated data obtained for different treatments were subjected to statistical analysis and the treatment means along with letter grouping based on Tukey's HSD test also worked out and is given in different tables for various parameters.

Physical parameters of fruits

The maximum fruit weight (251.86g) was recorded in treatment T_3 (250:600:320) followed by treatment T_2 (250:600:240) (Table 1). These findings are supported by work of Monga *et al.* (2004) that showed beneficial effect of fertilizers on fruit weight. In the present study, potassium has more pronounced effect on fruit weight as compared to nitrogen. In each group T_1, T_2, T_3; T_4, T_5, T_6 and T_7, T_8, T_9, treatments consists of higher potassium (i.e. T_3, T_6, and T_9) recorded higher fruit weight. The similar trends were also reported by Asharaf *et al*. (2013). The control recorded higher fruit weight (208.40g) as compared to some of the treatments. It may be due to the less number of fruits (recorded lowest yield, 12.56 kg/tree) which favoured more weight gain. Fruits harvested from external canopy were recorded more weight (212.06g) as compared to internal canopy (200.37g). This is may be due to fact that better light exposure of outer canopy leaves reported to gain higher photosynthetic (Feng *et al.* 2014) and supported fruits to

Table 1 Effect of fertilizer doses, date of harvesting and canopy position on yield attributes and yield

Treatment	Fruit diameter (mm)	Fruit length (mm)	Fruit weight (g)	Fruit yield (kg/tree)
Fertilizer doses (g/plant)				
T_1=250:600:160	75.68	64.73	202.85	14.00
T_2= 250:600:240	79.23	67.20	226.09	18.37
T_3= 250:600:320	80.90	68.83	251.86	16.64
T_4= 300:600:160	74.62	64.68	192.18	12.71
T_5= 300:600:240	74.87	66.22	197.71	17.17
T_6= 300:600:320	73.10	63.71	199.56	18.05
T_7= 400:600:160	76.86	65.51	190.34	18.84
T_8= 400:600:240	73.50	64.35	195.14	20.06
T_9= 400:600:320	74.85	64.66	198.02	18.75
T_{10}= Control	75.56	67.31	208.40	12.56
CD (P=0.01)	1.09	1.20	3.58	1.73
Date of harvesting				
D1= 06.12.13	71.79	62.50	193.98	15.87
D2= 26.12.13	77.22	66.80	211.90	17.28
D3= 16.01.14	78.75	67.80	212.75	17.00
CD (P=0.01)	0.60	0.66	1.96	0.77
Canopy positions				
P1= External	76.72	65.69	212.06	NC
P2= Internal	75.11	65.75	200.37	NC
CD (P=0.01)	0.49	0.54	1.60	NC

NC=Not calculated (Because it is not justified to calculate yield with respect to canopy position).

develop in to bigger in size. Similarly, Feng *et al.* (2014) also harvested larger fruits from the outer canopy than the inner canopy in McIntosh, Gala and Mutsu apple cultivars. In contrast, significantly higher fruit weight was reported from internal canopies compared with external canopy fruits in Kinnow mandarin (Fallahi and Moon 1989) and grape fruit (Syvertsen *et al*. 1980). The second and third date of harvesting was differed non-significantly with respect to fruit weight and recorded higher fruit weight as compared to first harvesting date. It shows that there is non-significant increment in fruit weight of Kinnow after second fortnight of December. The treatment T3 (250:600:320) recorded maximum fruit diameter (80.90 mm) and fruit length (68.83 mm) compared with all other treatments (Table 1). Rodríguez *et al*. (2005) also reported that higher fertilization levels of K along with Zn increased medium and big fruits production in Valencia orange. External canopy fruits recorded more fruit diameter as compared to internal one. But, both positions differed non-significantly with respect to fruit length. The D3 (78.75 mm) recorded highest fruit diameter followed by D2 (77.22 mm) and D1 (71.79 mm). But in case of fruit length, D2 and D3 differed non- significantly. Here, potassium played major role for the development of physical parameters of fruits, viz. fruit weight, diameter and length. It can be explained in this way that potassium can adjust plant's transpiration rates by affecting the stomatal activities. It means that the trees which are obtaining higher rates of K will have higher water use efficiencies (Popsova and Golldack 2008). But, higher water use efficiency will result production of light weighted fruits, unless addition of K compensated by addition of N. Nitrogen contributes to the vegetative growth of the plant which results in increment in the amount of fruit juice and weight (Ashkevari *et al*. 2010). Hence, an appropriate combination of fertilizer is desired and both played significant role in attainment of the above mentioned fruit parameters in the present study.

Chemical parameters of fruits

There was no clear trend found with respect to TSS as a result of fertilizer application (Table 2). However, the highest TSS (9.07 ºB,) was recorded with the treatment T_8 (400:600:240). Ashkevari *et al*. (2010) found that the effects of potassium fertilization on the soluble solids in the citrus juice were not significant. External canopy fruits recorded higher TSS as compared to internal fruits. Khalid *et al.* (2012) also reported that external canopies had higher soluble solids as compared to fruit from internal canopies in Kinnow. Khan *et al.* (2009) also reported that fruits from top canopies recorded higher TSS in Kinnow. Similarly, Syvertsen and Albrigo (1980) reported that there were greater fruit loads with higher brix in the outside than in the inside canopy positions in grapefruit cv. Ruby. Three dates of harvesting differed significantly and D3 (16.01.14) recorded highest TSS.

There was no clear trend with respect to acidity of fruits in different treatment (Table 2). The treatment T3 (250:600:320) recorded highest acidity followed by T_8 (400:600:240) and T1 (250:600:160). Potassium fertilization affects fruit acidity. Some workers reported that potassium fertilization increased fruit titratable acidity (TA) (Spironello *et al*. 2004, Alva *et al*. 2006), others that potassium fertilization decreased fruit acidity (Vadivel and Shanmugavelu 1978, Ramesh and Kumar 2007), and still others that it had no significant effect (Cummings and Reeves 1971). The correlation of nitrogen fertilization and titirable acidity was reported positive (Spironello *et al*. 2004), negative (Spironello *et al*. 2004) as well as not significant (Cummings and Reeves 1971). Nitrogen fertilization affects fruit acidity indirectly by stimulating the vegetative growth of plants. Increased vegetative growth may affect the fruit in different ways like by shading them (which would lower their temperature and reduce transpiration), or by diverting

Table 2 Effect of different doses of NPK, date of harvesting and canopy position on bio-chemical parameters

Treatment	TSS (°B)	Acidity (%)	Ascorbic acid content (mg/100 ml of juice)	Total chlorophyll in peel (µg/g fw)	Total carotenoids in peel (µg/g fw)	Total carotenoids juice (µg/100 ml of juice)
Fertilizer doses (kg/plant)						
T_1= 250:600:160	8.00	1.06	18.50	36.98	24.67	857.10
T_2= 250:600:240	7.40	0.93	17.62	38.04	17.02	811.00
T_3= 250:600:320	7.40	1.13	17.69	36.18	17.37	758.63
T_4= 300:600:160	7.57	1.01	17.58	40.87	20.46	701.33
T_5= 300:600:240	8.58	0.91	20.14	34.25	21.86	858.78
T_6= 300:600:320	7.53	0.83	16.22	37.76	17.49	788.80
T_7= 400:600:160	8.08	0.73	16.44	38.99	21.93	778.30
T_8= 400:600:240	9.07	1.09	22.79	38.32	21.77	980.86
T_9= 400:600:320	7.28	0.67	21.32	33.25	21.32	787.96
T_{10}= Control	7.73	0.77	16.78	41.20	20.68	720.37
CD (P=0.01)	0.12	0.02	0.59	0.41	0.26	7.56
Date of harvesting						
D1= 06.12.13	6.93	1.32	18.13	41.67	5.85	562.28
D2= 26.12.13	8.07	0.85	21.38	37.48	41.90	948.67
D3= 16.01.14	8.59	0.56	15.99	33.61	13.62	901.76
CD (P=0.01)	0.07	0.01	0.32	0.22	0.14	4.14
Canopy positions						
P1= External	8.13	0.93	19.43	33.51	21.89	808.09
P2= Internal	7.60	0.90	17.57	41.66	19.03	800.71
CD (P=0.01)	0.05	0.01	0.26	0.18	0.12	3.38

assimilates towards vegetative growth (which would reduce the supply of assimilates to the fruits). Here both nutrients are interacting. Adjusting the fruit properties by using the appropriate amount of potassium was also reported by Palmgren (2001). External canopy fruits (0.93 %) were acidic as compared to internal one (0.90 %, Table 2) (Fallahi and Moon 1989, Jawanda *et al.* 1973, Verreynne *et al.* 2004). Contrary to this many workers (Syvertsen and Albrigo 1980, Agabbio *et al*. 1999) find higher acidity in internal fruits as compared to external fruits. These variations in the acidity are due to position of fruit in the different directions which affects the light availability.

Highest ascorbic acid content (22.79 mg/100 ml of juice, Table 2) was recorded with the treatment T_8 (400:600:240) followed by T_9 (21.32 mg/100 ml of juice). Potassium is responsible to increase ascorbic acid content of fruits (Kumar *et al.* 2006). Nitrogen fertilizers, especially at high rates, seem to decrease the concentration of vitamin C in many different fruits including citrus fruits (Mozafer 2008). When nitrogen is applied in excess it increases the concentration of NO_3 in plant foods and simultaneously decreases that of ascorbic acid (Mozafer 2008). Hence, an optimum combination of nitrogen and phosphorous required. External canopy fruits recorded higher ascorbic acid content as compare to internal one (Remorini *et al.* 2007). Zabedah *et al.* (2009) also reported more ascorbic acid content in fruits exposed to irradiance in star fruit. Immature fruit has the highest levels. The position on the tree also affects vitamin C levels. Since sunlight exposure enhances vitamin C levels, fruit positioned on the outside of the tree have higher levels as compared to shaded fruits present in inner canopies.

The internal canopy fruits were more green [higher total chlorophyll (41.66µg/g fw) and lower total carotenoids (19.03µg/g fw) in fruit peel] as compared to external one (Table 2). In other fruits like mango (Lechaudel *et al*. 2010) and star fruit (Zabedah *et al.* 2009), the internal canopy fruits recorded higher total chlorophyll and lower total caotenoids. The Kinnow fruits harvested later were recorded lower total chlorophylls in peel [D3 (33.61 µg/g fw) followed by D2 (37.48µg/g fw) and D1(41.67µg/g fw)]. However, the highest total carotenoids in peel were recorded on D2 (41.90 µg/g fw) as compared to D3 (13.62µg/g fw). There was no trend with respect to various treatments.

Highest total carotenoids in juice (980.86 µg/g fw, Table 2) were recorded with T_8 (400:600:240) followed by T1 (857.10 µg/g fw) and T2 (811.00 µg/g fw). This effect is due to nitrogen fertilizer known to increase the concentration of carotenoids (Mozafar 2008) in combination of potassium (Ashraf *et al*. 2010). The external canopy fruits recorded more total carotenoids in juice (808.09 µg/g fw) as compared to internal canopy fruit (800.71 µg/g fw). In general, D2 recorded highest total carotenoids in juice followed by D3 and D1.

Yield

The highest yield was recorded with the treatment T_8 (20.06 kg/tree) which differed non-significantly with the treatment T_2, T_6, T_7 and T_9 (Table 1). Shukla *et al.* (2000) reported in nine year old Kinnow that fruit yield was highest with the combinations 400 g N and 256 g P followed by 500 g N and 230 g P. The combination of 400 g N and 256 g P resulted in fruit yields of 34.65 (in 1998) and 35.78 (in 1999) kg/plant. Ashkevari *et al*. (2010) also reported that application of potassium increased fruit yield in citrus. The combined application of nitrogen and potassium required because high rates of N can be utilized by the plant and transformed into high yield only in the presence of high K levels (Kumar *et al*. 2006). Monga *et al.* (2004) also reported improved fruit yield of Kinnow mandarin with increase in nitrogen dose alone as well as in combination with phosphorous and potassium.

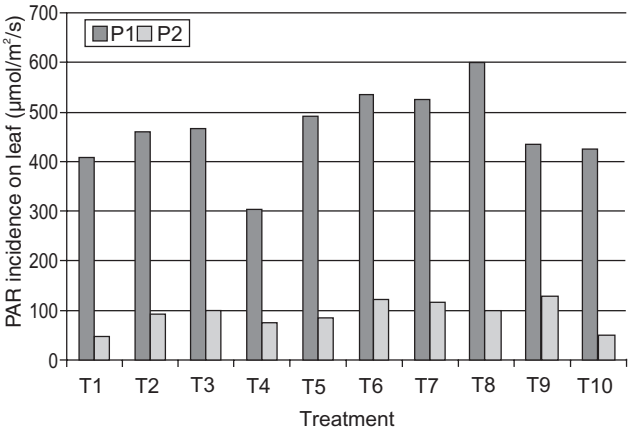

Fig 1 PAR incidence on leaf (µmol/m²/s) of Kinnow

PAR incidence on leaf and photosynthesis

Fig 1 clearly indicates that the external canopy received more PAR incidence as compared to internal one. It indicates more photosynthesis in external canopy as compared to internal one (Fig 2). Exposure to light resulted in higher fruit quality attributes fruit weight, fruit diameter, TSS, ascorbic acid, total carotenoids content (Singh *et al.* 2004 and Ahmed *et al.,* 2006) of external canopy fruit as compared

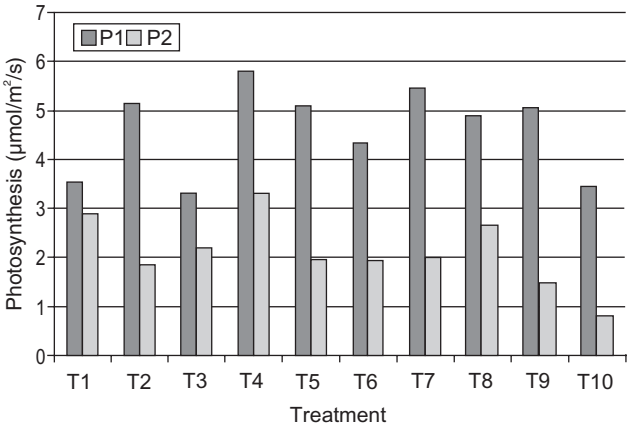

Fig 2 Photosynthesis (µmol/m²/s) of Kinnow

to internal one. This indicates the importance of light exposure for quality development in Kinnow (Feng *et al.* 2014).

Application of 400g + 600g + 240g ($N+P_2O_5+K_2O$/ plant) was found best for quality production of Kinnow fruits in four year old Kinnow. Fruits which are present on external canopy of tree were superior in terms of quality as compared to fruits present on internal canopy of the tree. Hence, they should harvest seperatly. For fresh eating purpose, Kinnow fruits should be harvested in the second week of January and for processing purposes in the last week of December. This will help grower to fetch better quality and market price for their produce.

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