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Short communication

Effect of inorganic and organic fertilizers along with *Azotobacter* on growth, yield and quality of Kinnow mandarin

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ABSTRACT

A study was conducted during 2013 and 2014 on the effect of integrated use of inorganic and organic fertilizers (vermicompost) along with bio-inoculants on plant growth, yield and quality of Kinnow mandarin. Vegetative growth parameters like plant height and canopy volume showed maximum increase with cent per cent nitrogen through urea augmented with *Azotobacter*. Replacing 25 per cent of nitrogen in the form of vermicompost resulted in maximum number of fruits, fruit weight, fruit volume, fruit length and width and fruit yield. TSS, Total sugars (reducing and non-reducing) and ascorbic acid contents of the fruits improved with the integrated application of vermicompost along with inorganic fertilizers and biofertilizers.

Key words: Kinnow mandarin, vermicompost, *Azotobacter*, growth, quality.

Kinnow mandarin (*Citrus nobilis* Lour × *Citrus deliciosa* Tenore) occupies a discrete position among citrus fruits due to its high yield, fresh consumption and aromatic flavour. In recent years, the quick and substantial response to fruit production due to mineral fertilization eclipsed the use of organic manures; the inadequate supply of latter sources exacerbated this change. Integrated plant nutrient supply system encourages integration of different sources of nutrients such as organic, biological and inorganic fertilizers *etc*. Incorporation of inoculants like *Azotobacter* either sole or in combination with inorganic and organic fertilizers have shown to improve nitrogen nutrition of plants through biological nitrogen fixation and also secretion of some growth promoting substances, which affect the growth, nutrition and microbial activity in the rhizosphere.

Experiment was carried out at Research farm of Division of Fruit Science, Faculty of Agriculture, SKUAST-J, Udheywalla during 2013 and 2014 on seven-year-old Kinnow mandarin trees grafted on *Jhatti khatti* rootstock, having uniform size and vigour. Vermicompost (N: 1.78%, P: 2.93% and K: 1.25%) was used as organic manure along with inorganic fertilizers and biofertilizer (*Azotobacter*). The experiment was laid out in a randomized block design with three replications. The treatments consisted of T_1 (100% N as urea), T_2 (25% N as vermicompost and 75% N as urea), T_3 (50% N as vermicompost and 50% N as urea), T_4 (75% N as vermicompost and 25% N as urea), T_5 (*Azotobacter* + 100% N as urea), T_6 (*Azotobacter* + 25% N as vermicompost and 75% N as urea), T_7 (*Azotobacter* + 50% N as vermicompost and 50% N as urea), T_8 (*Azotobacter* + 75% N as vermicompost and 25% N as urea), T_9 (*Azotobacter* + 100% N as vermicompost), T_{10} (100% N as vermicompost), T_{11} (*Azotobacter* application @ 100 g per tree) and T_{12} (control). Plant height was measured using graduated stick. Canopy volume was calculated as per Westwood *et al*. (7). The fruit quality parameters were analyzed following standard procedures as described by AOAC (1). The total phenols content in the fruit juice was determined using the Folin-Ciocalteu colorimetric method (Singleton and Rossi, 6). Statistical analysis was performed on pooled data of two years using statistical analysis programme SPSS V.16.

Results revealed that maximum increase in plant height (13.49%) and canopy volume (38.97%) was recorded with the application of cent per cent nitrogen in the form of urea along with *Azotobacter* (T_5) whereas minimum increase in plant height (6.32%) and canopy volume (16.10%) was recorded under control (T_{12}). However, treatment T_6 was equally effective (Table 1). Application of nitrogen resulted in vigorous vegetative growth of the plants. This favoured photosynthetic activity of the plants and greater synthesis of carbohydrates, which was responsible for building up of new tissues and better development of plants as reported by Rao *et al.* (4).

Data regarding fruit length, fruit width, peel thickness and yield characteristics of Kinnow mandarin is presented in Table 1. Maximum fruit

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Table 1. Effect of vermicompost, urea and *Azotobacter* on plant height, canopy volume, fruit length, fruit width, peel thickness and yield characteristics of Kinnow mandarin.

Treatment	% increase in plant height	% increase in canopy volume	Fruit length (cm)	Fruit width (cm)	Peel thickness (cm)	No. of fruits/ tree	Yield (kg/ tree)	Yield (t/ ha)
T_1	12.15 ± 1.6^{ef}	36.71 ± 3.39^{de}	5.50 ± 0.01^{f}	6.13 ± 0.02^{e}	0.53 ± 0.005^{e}	121.83 ± 1.47e	21.53 ± 0.31^{f}	5.96 ± 0.08^{f}
T_2	10.74 ± 0.35^{de}	32.65 ± 3.33^{cd}	5.61 ± 0.04^{h}	6.26 ± 0.03^{g}	0.53 ± 0.007^{de}	124.83 ± 1.47e	21.76 ± 0.20^{f}	6.03 ± 0.05^{f}
T_3	10.58 ± 1.56^{de}	30.81 ± 7.85^{c}	5.49 ± 0.03^{f}	6.20 ± 0.04^{f}	0.53 ± 0.010^{de}	117.67 ± 2.65^{d}	19.90 ± 0.63^{e}	5.51 ± 0.17^{e}
T_4	9.53 ± 1.48^{bcd}	23.79 ± 1.34^{b}	5.41 ± 0.02^{d}	5.97 ± 0.04^{d}	0.52 ± 0.006^{d}	112.33 ± 2.25^{cd}	18.31 ± 0.31^{d}	5.07 ± 0.08^{d}
T_5	13.49 ± 2.03^{f}	38.97 ± 6.07^{f}	5.71 ± 0.03^{i}	6.39 ± 0.05^{h}	0.54 ± 0.005^{de}	151.67 ± 2.94^{g}	28.32 ± 0.58^{h}	7.84 ± 0.16^{h}
T_6	13.10 ± 2.22^{f}	37.31 ± 2.69^{de}	5.75 ± 0.02^{j}	6.46 ± 0.05^{i}	0.52 ± 0.005^{d}	162.50 ± 3.72^{h}	30.45 ± 0.72^{i}	8.43 ± 0.19^{i}
T_7	11.97 ± 2.77^{ef}	33.87 ± 3.39^{cde}	5.68 ± 0.02^{ij}	6.37 ± 0.02^{h}	0.52 ± 0.0^{a}	138.33 ± 5.88^{f}	24.08 ± 1.31^{g}	6.67 ± 0.36^{g}
T_8	9.99 ± 1.18^{cde}	24.32 ± 1.47^{b}	5.54 ± 0.02^{g}	6.24 ± 0.02^{fg}	0.52 ± 0.007^{d}	118.33 ± 3.32^{d}	19.89 ± 0.60^{e}	5.51 ± 0.17^{e}
T_9	8.68 ± 0.95^{bcd}	23.09 ± 4.54^{b}	5.44 ± 0.03^{e}	6.14 ± 0.04^{e}	0.52 ± 0.006^{d}	114.00 ± 4.38^{c}	18.21 ± 0.81^{d}	5.04 ± 0.22^{d}
T_{10}	8.19 ± 1.99^{abc}	21.27 ± 2.44^{ab}	5.36 ± 0.04^{c}	5.87 ± 0.05^{c}	0.51 ± 0.007^{c}	112.33 ± 2.22^{c}	17.17 ± 0.43^{c}	4.76 ± 0.12^{c}
T_{11}	7.32 ± 0.99^{ab}	19.55 ± 5.36^{ab}	5.32 ± 0.03^{b}	5.62 ± 0.03^{b}	0.50 ± 0.005^{b}	110.33 ± 2.73^{b}	15.56 ± 0.40^{b}	4.31 ± 0.11^{b}
T_{12}	6.32 ± 0.84^{a}	16.10 ± 2.04^{a}	5.09 ± 0.02^{a}	5.29 ± 0.05^{a}	0.49 ± 0.008^{b}	100.00 ± 2.44^{a}	14.10 ± 0.48^{a}	3.91 ± 0.13^{a}

Data are expressed as pooled mean ± standard deviation. Means with different letters, in the same column, indicate significant differences ($P \leq 0.05$)

length (5.75 cm), fruit width (6.46 cm), number of fruits (162.50), fruit yield (30.45 kg per plant) and per hectare yield (8.43 t/ha) was recorded under treatment T_6. However, results for these parameters were at par with treatment T_5. Different treatments had non-significant effect on peel thickness of Kinnow mandarin fruits. Application of inorganic fertilizers and organic fertilizers alongwith biofertilizer inoculation showed the highest response in respect of fruit attributes as compared to application of inorganic and organic manures without bio-fertilizers. The higher uptake and accumulation of nutrients in the tissues and fruits of Kinnow mandarin with recommended dose of NPK might have occurred due to stimulation of the rates of various physiological and metabolic processes resulting in better fruit yield. The results are in conformity with those of Perungkotturselvi and Koilraj (3) on acid lime.

Maximum fruit weight (187.37 g) and fruit volume (189.33 cc) as compared to other treatments was observed under treatment T_6 (Table 2). Specific gravity of Kinnow mandarin did not show any significant difference among treatments. Maximum juice recovery (53.91%) was recorded under T_5, whereas minimum juice content was recorded in control (T_{12}). The pH of fruit juice showed non-significant results among different treatments. The notable improvement with respect to fruit growth parameters with the combined use of organic, inorganic and bio-fertilizers may be attributed to sufficient availability of nitrogen, phosphorus, potassium and other essential nutrients. Results are in line with the findings of Ravishankar *et al*. (5). Highest total polyphenols content (61.26 mg GAE per 100 ml of juice) was recorded in fruits of plants receiving no fertilization (T_{12}). Plants under stress produced more secondary metabolites and phenols and under this experiment; while nitrogen was the limiting factor under the control treatment that led to increased production of phenols as compared to all other treatments. Similar findings have been reported by Wu *et al*. (8).

Table 3 reveals chemical characteristics of Kinnow fruits. Maximum TSS of 11.02°B was recorded under treatment T_7. Acidity of fruits did not show much variation among different treatments. Maximum ascorbic acid content (26.50 mg/100 g fruit) was recorded under T_9. Maximum total sugars (5.91%) were recorded under treatment T_7 and maximum reducing sugars were recorded under treatment T_8. However, maximum non-reducing sugars (2.96%) were recorded maximum with the application of 50 per cent nitrogen as vermicompost and 50 per cent as urea along with *Azotobacter* (T_7). Better physico-chemcal characteristics of

Table 2. Effect vermicompost, urea and *Azotobacter* on fruit weight, fruit volume, specific gravity, per cent juice recovery and total polyphenols content of Kinnow mandarin fruits.

Treatment	Fruit wt. (g)	Fruit vol. (cc)	Specific gravity	Juice recovery (%)	pH	Total polyphenols (mg GAE/ ml of juice)
T_1	176.73 ± 1.99^h	179.83 ± 2.78^h	0.98 ± 0.008^b	53.26 ± 1.86^i	4.02 ± 0.78^f	54.85 ± 1.49^b
T_2	174.28 ± 1.17^g	176.50 ± 1.04^g	0.99 ± 0.007^{bc}	52.08 ± 1.21^h	3.95 ± 0.68^e	55.82 ± 1.51^b
T_3	169.10 ± 2.23^f	170.83 ± 2.78^f	0.99 ± 0.004^{bcd}	51.22 ± 1.98^f	3.90 ± 0.62^{cde}	59.52 ± 1.62^{cd}
T_4	162.98 ± 1.99^e	163.50 ± 1.51^d	1.00 ± 0.005^{de}	49.93 ± 1.83^d	3.87 ± 0.59^{abcd}	60.35 ± 1.89^{cd}
T_5	186.72 ± 0.41^i	188.67 ± 1.36^j	0.99 ± 0.006^{bcd}	53.91 ± 0.68^j	4.08 ± 0.81^a	52.24 ± 1.27^a
T_6	187.37 ± 0.50^i	189.33 ± 1.03^i	0.99 ± 0.004^{bc}	53.83 ± 0.54^j	4.02 ± 0.80^{abc}	53.07 ± 1.39^a
T_7	174.03 ± 3.01^g	173.83 ± 2.78^f	1.00 ± 0.000^e	51.68 ± 2.89^g	3.92 ± 0.77^g	55.13 ± 1.41^b
T_8	168.10 ± 1.74^f	168.83 ± 1.32^e	1.00 ± 0.005^{de}	50.32 ± 1.83^e	3.88 ± 0.72^f	58.52 ± 1.44^c
T_9	159.73 ± 2.11^d	163.83 ± 2.99^d	0.98 ± 0.005^a	48.28 ± 1.79^c	3.83 ± 0.69^{de}	59.43 ± 1.57^{cd}
T_{10}	154.92 ± 1.46^c	156.00 ± 0.63^c	0.99 ± 0.005^{cde}	48.28 ± 1.54^c	3.82 ± 0.68^{abcd}	60.99 ± 1.82^d
T_{11}	150.57 ± 2.06^b	152.00 ± 1.78^b	0.99 ± 0.008^{cde}	46.80 ± 1.89^b	3.85 ± 0.72^{ab}	61.13 ± 1.94^d
T_{12}	140.98 ± 1.59^a	143.00 ± 1.54^a	0.99± 0.008^f	45.54 ± 1.62^a	3.88 ± 0.74^{cd}	61.26 ± 2.01^d

Data are expressed as pooled mean ± standard deviation. Means with different letters, in the same column, indicate significant differences ($P \leq 0.05$)

Table 3. Effect of vermicompost, urea and *Azotobacter* on total soluble solids (TSS), titratable acidity, ascorbic acid, total sugars, reducing sugars and non-reducing sugars of Kinnow mandarin.

Treatment	TSS (°B)	Titratable acidity (%)	TSS: acid ratio	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	10.62 ± 0.04^c	0.75 ± 0.005^b	14.25 ± 0.09^b	25.51 ± 0.12^i	5.65 ± 0.02^c	2.63 ±0.01^b	2.87 ± 0.02^{de}
T_2	10.73 ± 0.05^d	0.74 ± 0.0^b	14.50 ± 0.06^c	25.30 ± 0.09^g	5.70 ± 0.02^{de}	2.77 ±0.02^f	2.78 ± 0.01^{bc}
T_3	10.73 ± 0.05^d	0.74 ± 0.005^b	14.60 ± 0.12^d	25.21 ± 0.55^{fg}	5.72 ± 0.03^e	2.77 ±0.01^f	2.79 ± 0.02^c
T_4	10.78 ± 0.04^d	0.73 ± 0.005^b	14.87 ± 0.14^e	24.49 ± 0.15^d	5.70 ± 0.02^{de}	2.80 ± 0.03^{fg}	2.75 ± 0.03^b
T_5	10.78 ± 0.07^d	0.76 ± 0.005^b	14.28 ± 0.18^b	23.23 ± 0.17^g	5.68 ± 0.02^{cd}	2.67 ±0.03^c	2.87 ± 0.04^d
T_6	10.90 ± 0.08^f	0.75 ± 0.005^b	14.63 ± 0.18^d	23.77 ± 0.16^h	5.84 ± 0.02^g	2.80 ±0.01^{fg}	2.89 ± 0.02^{def}
T_7	11.02 ± 0.04^g	0.74 ± 0.005^b	14.99 ± 0.14^f	25.27 ± 0.11^i	5.91 ± 0.01^h	2.80 ±0.01^{fg}	2.96 ± 0.01^g
T_8	10.87 ± 0.08^{ef}	0.74 ± 0.005^b	14.79 ± 0.19^e	26.24 ± 0.18^e	5.89 ± 0.02^h	2.82 ±0.01^g	2.92 ± 0.02^{fg}
T_9	10.75 ± 0.05^d	0.74 ± 0.005^b	14.63 ± 0.18^d	26.50 ± 0.10^f	5.78 ± 0.03^f	2.76 ±0.02^e	2.87 ± 0.03^d
T_{10}	10.80 ± 0.06^{de}	0.73 ± 0.0^b	14.79 ± 0.08^e	24.28 ± 0.44^c	5.76 ± 0.03^f	2.69 ±0.04^c	2.91 ± 0.03^{ef}
T_{11}	10.53 ± 0.05^b	0.73 ± 0.0^b	14.43 ± 0.07^c	24.98 ± 0.09^b	5.57 ± 0.05^b	2.63 ±0.08^d	2.79 ± 0.03^c
T_{12}	10.03 ± 0.08^a	0.72 ± 0.0^b	13.94 ± 0.11^a	21.42 ±0.12^a	5.32 ± 0.01^a	2.54 ±0.02^a	2.63 ± 0.04^a

Data are expressed as pooled mean ± standard deviation. Means with different letters, in the same column, indicate significant differences ($P \leq 0.05$)

fruits with the application of vermicompost along with biofertilizers may be attributed to adequate supply of nitrogen that stimulates the functioning of number of enzymes in the physiological process. Our results are in agreement with Kumar and Kumar (2) who reported that application of vermicompost alleviated the physico-chemical characteristics of mango cv. Dashehari. On the basis of the aforesaid findings, it can be concluded that among the different treatments, application of 25 per cent nitrogen as vermicompost along with 75 per cent nitrogen as urea augmented with *Azotobacter* recorded vegetative growth at par with T_1, recorded the highest physical and yield parameters and was found to be best on overall basis.

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