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Integrated nutrient management induced changes in nutrient uptake, fruit yield and quality of Kinnow mandarin

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ABSTRACT

The present study on the integrated nutrient management in Kinnow mandarin involved application of inorganic fertilizers, vermicompost and *Azotobacter* under different combinations. The pooled data analysis indicated that highest concentration of leaf and fruit N (2.57 and 0.06%), Ca (4.31 and 0.033%) and Mg (0.46 and 0.024%) with the combined application of *Azotobacter* + 25% nitrogen as vermicompost and 75% nitrogen as urea. Maximum leaf and fruit P (0.19 and 0.025%) were recorded with the application of vermicompost (to supply 50% N) and urea (to supply 50% N) augmented with *Azotobacter*. While highest leaf and fruit K (1.56 and 0.092%) were recorded with full doze of nitrogen applied as vermicompost along with *Azotobacter*. Maximum *Azotobacter* counts (31.6×10^6 cfu g soil), bacterial counts (28.9×10^6 cfu g soil) and fungal counts (35.5×10^5 cfu g soil) were recorded with the application of full doze of nitrogen through vermicompost alongwith *Azotobacter*. The results suggested that 25% nitrogen can be replaced through chemical fertilization along with vermicompost on N- equivalent basis plus *Azotobacter* inoculation.

Keywords: *Azotobacter*, Integrated nutrient management, Kinnow, Leaf nutrients, Quality, Yield

Kinnow mandarin is highly nutrient responsive and a balanced nutrition programme is mandatory to maintain a sustained productive life of orchard in addition to quality production (Ghosh 1990). There has been a surge of interest to adopt certain measures such as Integrated Nutrient Management (INM) for making its culture eco-friendly by reducing the tradition of inorganic fertilizers, pesticides and other synthetic formulations. Use of inorganic fertilizers along with organic manures and biofertilizers is a proven technology to build up the fertility status of the soil (Srivastava and Ngullie 2009a, Srivastava and Singh 2009b). Organic manure like vermicompost is rich in plant nutrients compared to other organic manures in respect of supply of N, P and K (Srivastava *et al*. 2001, Srivastava and Singh 2009c). Vermicompost application is one of the effective methods to rejuvenate the depleted soil fertility and enrich the available pool of nutrients, maintain soil quality and conserve more biological resources (Srivastava *et al*. 2001). On the other hand, biofertilizers are preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants uptake of nutrients by their interactions in the rhizosphere when applied through seed or to soil (Srivastava and Ngullie 2009a). *Azotobacter*, a free living microbe, acts as plant growth promoting rhizobacteria (PGPR) in the rhizosphere of almost all crops. (Gomare *et al*. 2013). *Azotobacter* produces many growth regulators such as IAA and GA which positively influence plant growth (Sharma and Kumar 2008). However, soil application of nutrients does not provide a clear picture of nutrient status of plant (Srivastava *et al.* 2001). In fruit crops like citrus, leaves have been found to be practically sensitive and convenient index of the nutrient status of the plant (Srivastava *et al.* 2008). Lot of research is being done on use of integrated supply of nutrients based on soil fertility status but information on leaf nutrient uptake and its correlation with yield and quality parameters is lacking (Marathe *et al*. 2012). Hence, the study was carried out to find the most suitable combination of inorganic fertilizers, organic manure and biofertilizer and its possible effects on nutrient status, yield, quality and soil microbial populations in Kinnow mandarin.

MATERIALS AND METHODS

This study was conducted on six year old Kinnow plants grafted on rough lemon rootstock having uniform shape, size and vigour. The experiment was laid out in the research orchard of Division of Fruit Science, Faculty of

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Agriculture, Udheywalla, SKUAST-Jammu during 2013 and 2014 in the sub-tropical zone at latitude of 32.43° North and longitude of 74.54° East. The experimental soil had pH 7.09, sand 65.5%, silt 18.5%, clay 17.0%, organic carbon 0.53%, electrical conductivity 0.14 ds/m, available nitrogen 222.5 kg/ha, available phosphorus 13.45 kg/ha, available potassium 140.5 kg/ha, available calcium 6.84 meq/100g, available magnesium 2.82 meq/100g. Recommended dose of NPK as per Package of practices for horticulture crops-SKUAST-J for Kinnow was maintained in the experiment, where only nitrogen was manipulated through different sources of fertilization. A total of 12 treatments replicated thrice were evaluated in a randomized block design: 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}: *Azotobacer* application and T_{12}: Absolute control.

The treatment wise application of vermicompost was applied to the trees around the trunk in the first week of January along with phosphatic fertilizers. Whole potash and first half dose of urea was applied 15 days before flowering and remaining half dose of urea was applied after fruit set. The biofertilizer *Azotobacter* was supplied with a uniform dose of 100 g / plant mixed with 10% jaggery solution prepared separately for each tree and was fed to the roots after one month of chemical fertilization.

Leaf samples were collected from seven months old spring cycle leaves on non fruiting terminals in the month of July (Chahill *et al*. 1988, Srivastava *et al*. 1994, Srivastava *et al*. 1999), thoroughly washed and ground to have a homogenous sample as per method described by Chapman (1964). Nitrogen was estimated by Micro-Kjeldahl's method as suggested by Jackson (1973). Phosphorus was determined by Vanado-molybdophosphoric acid yellow colour method (Jackson, 1973). Potassium was estimated using flame photometer and Ca, Mg was measured using atomic absorption spectrophotometer. Composite soil sample from the Kinnow rhizosphere of each treatment was used for estimation of soil microbial population following serial dilution method using specific media for each microbe (Black *et al*.1965). The pooled mean was generated during the course of study were subjected to statistical analysis and were tested on SPSS (Version 16) software using Duncan's multiple–ranged test to identify the homogeneous type of the data sets among different treatments.

RESULTS AND DISCUSSION

Leaf nutrient content

The effect of integrated sources of nitrogen on Kinnow showed significant differences among all the macro nutrients and are presented in Table 1 where, highest leaf nitrogen content (2.57%) was recorded in T_5 (*Azotobacter* + 100% N as urea) and T_6 (*Azotobacter* + 25% N as vermicompost and 75% N as urea). Leaf phosphorus reached to a highest level of 0.19% under T_7 (*Azotobacter* + 50% N as vermicompost and 50% N as urea) followed by T_8 (*Azotobacter* + 75% N as vermicompost and 25% N as urea) where leaf phosphorus 0.18% was obtained. T_9 (*Azotobacter* + 100% N as vermicompost) registered highest leaf potassium (1.56%) while, lowest leaf potassium content was obtained under control. Maximum leaf calcium (4.31%) was recorded in T_6 (25% nitrogen as vermicompost + 75% nitrogen as urea + *Azotobacter*) followed by plants receiving 50% nitrogen as vermicompost and 50% nitrogen as urea + *Azotobacter* (T_7). Treatment T_6 (25% nitrogen as vermicompost + 75% nitrogen as urea + *Azotobacter*) and T_7 (*Azotobacter* + 50% N as vermicompost and 50% N as urea) registered highest leaf magnesium content (0.46% each) followed by 0.45% under T_5 (100% nitrogen as urea in combination with *Azotobacter*). Minimum values for leaf macro nutrients were recorded under control. This may be due to the production of enzymatic complexes by nitrogen fixers which might have solubilized the unavailable form of nutrient elements and render them available. Increase in nitrogen content of the leaves with urea application has also been reported by Lal *et al.* (2000) in guava. The increase in phosphorus uptake might have been due to the better availability and translocation of phosphorus under *Azotobacter* application. Leaf nitrogen, phosphorus and potassium content of Kinnow mandarin were high when vermicompost was added as reported by Yadav *et al.* (2013) due to addition of organic manure in guava. Increase in foliar potassium content obtained in the present study is in conformity with the findings of Singh and Sharma (1993) in case of sweet orange cv. Mosambi.

Table 1 Leaf macronutrient composition of Kinnow mandarin as affected by different INM treatments (Pooled mean of two years)

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
T_1	2.51^{g}	0.13^{c}	1.47^{c}	4.25^{f}	0.42^{d}
T_2	2.51^{g}	0.13^{c}	1.50^{e}	4.28^{fgh}	0.43^{de}
T_3	2.47^{f}	0.15^{d}	1.51^{f}	4.27^{f}	0.42^{d}
T_4	2.38^{d}	0.15^{de}	1.53^{g}	4.09^{c}	0.39^{c}
T_5	2.57^{i}	0.16^{f}	1.48^{d}	4.29^{ghi}	0.45^{ef}
T_6	2.57^{i}	0.17^{g}	1.52^{fg}	4.31^{i}	0.46^{f}
T_7	2.54^{h}	0.19^{h}	1.54^{h}	4.30^{hi}	0.46^{f}
T_8	2.42^{e}	0.18^{g}	1.55^{hi}	4.21^{e}	0.42^{d}
T_9	2.39^{d}	0.15^{e}	1.56^{i}	4.18^{e}	0.42^{d}
T_{10}	2.35^{c}	0.15^{d}	1.48^{d}	4.12^{d}	0.37^{c}
T_{11}	2.33^{b}	0.12^{b}	1.45^{b}	3.79^{b}	0.34^{b}
T_{12}	2.25^{a}	0.09^{a}	1.42^{a}	3.42^{a}	0.24^{a}

Fruit nutrient content

Data regarding effect of different INM treatments on fruit nutrient content is presented in Table 2. Highest fruit nitrogen content (0.06%) was achieved under T_5 (100% nitrogen as urea in combination with *Azotobacter*) and T_6 (25% nitrogen as vermicompost + 75% nitrogen as urea + *Azotobacter*) followed by T_1 (100% nitrogen as urea), T_2 (25% nitrogen as vermicompost + 75% nitrogen as urea) and T_7 (50% nitrogen as vermicompost and 50% nitrogen as urea + *Azotobacter*) where 0.05% fruit nitrogen was recorded. Fruit phosphorus reached to a highest level of 0.025% under T_7. Highest fruit potassium (0.092%) was recorded under T_9 (100% nitrogen as vermicompost + *Azotobacter*). Calcium content (0.033%) was highest under T_6 (25% nitrogen as vermicompost + 75% nitrogen as urea + *Azotobacter*) and T_7 (50% nitrogen as vermicompost and 50% nitrogen as urea + *Azotobacter*). Magnesium content in fruits did not show much significant difference among different treatments and ranged from 0.018 to 0.024%, lowest being observed in control (T_{12}). The above results are in line with the studies of Rana (2001) who found increase in nitrogen, potassium and calcium content of strawberry due to nitrogen and *Azotobacter* application and also reported no effect of various nitrogen fixers and urea on magnesium content of the berries. The findings on leaf and fruit nutrient content with the integrated application of inorganic fertilizers, organic manures and biofertilizers are in conformity with those reported in guava (Sharma *et al*. 2013, 2016) and Nagpur mandarin (Srivastava *et al*. 2008, 2015).

Correlation of macronutrients with yield and quality parameters

The correlation coefficient values (Table 3) indicated that fruit yield was significantly correlated with all the macronutrients in leaf. Highest significant positive correlation was observed with N (r = 0.925) followed by Mg (r = 0.759), Ca (r = 0.677) and P (r = 0.558). These findings are in conformity with the works of Marathe *et al.* (2012) in sweet orange. Trivedi *et al*. (2012) observed that incorporation of vermicompost and biofertilizers resulted in the maximum uptake of nitrogen and higher fruit yield in guava cv. Sardar. Highest degree of correlation was observed in case of juice content % with N (r = 0.966) followed by Mg (r = 0.852), Ca (r = 0.837) and P (r = 0.559). Srivastava *et al*. (2001) reported significant correlation of % juice with leaf N levels. Total soluble solids showed a strong positive correlation with P (r = 0.927) followed by Mg (r = 0.900), Ca (r = 0.893), K (r = 0.793) and N (r = 0.679). Total sugar content in fruits had a positive correlation (r = 0.946) with leaf P content followed by K (r = 0.860) and Mg (r = 0.855). Ascorbic acid content was correlated with leaf K (r = 0.778) followed by Ca (r = 0.740), P (r = 0.727) and Mg (r = 0.722). Such information would lead to find out the multiple nutrient deficiencies to manage them through site specific nutrient management (Srivastava and Singh 2015)

Table 2 Fruit nutrient composition of Kinnow mandarin as affected by different INM treatments (pooled mean of two years)

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)
T_1	0.05^{e}	0.021^{e}	0.072^{b}	0.029^{g}	0.022^{c}
T_2	0.05^{de}	0.022^{a}	0.074^{c}	0.030^{h}	0.022^{c}
T_3	0.04^{c}	0.023^{e}	0.078^{d}	0.032^{ef}	0.022^{c}
T_4	0.04^{c}	0.022^{c}	0.079^{d}	0.028^{fg}	0.022^{c}
T_5	0.06^{g}	0.023^{g}	0.083^{e}	0.032^{g}	0.024^{d}
T_6	0.06^{f}	0.023^{c}	0.086^{f}	0.033^{cd}	0.024^{d}
T_7	0.05^{e}	0.025^{d}	0.088^{f}	0.033^{h}	0.024^{d}
T_8	0.04^{d}	0.023^{d}	0.091^{g}	0.031^{de}	0.021^{b}
T_9	0.04^{c}	0.022^{f}	0.092^{g}	0.029^{fg}	0.024^{d}
T_{10}	0.03^{bc}	0.019^{g}	0.081^{e}	0.028^{bc}	0.022^{c}
T_{11}	0.03^{b}	0.018^{f}	0.070^{b}	0.027^{b}	0.022^{c}
T_{12}	0.02^{a}	0.016^{b}	0.060^{a}	0.024^{a}	0.018^{a}

Table 3 Correlation of leaf nutrient content with yield and quality of kinnow mandarin

Leaf nutrient	Coefficient of correlation (r) values				
	Yield	Quality parameter			
		Juice content	TSS	Total sugars	Ascorbic acid content
N	0.925**	0.966**	0.679**	0.605*	0.365
P	0.558*	0.559*	0.927**	0.946**	0.727**
K	0.268	0.342	0.793**	0.860**	0.778**
Ca	0.677**	0.837**	0.893**	0.848**	0.740**
Mg	0.759**	0.852**	0.900**	0.855**	0.722**

* and ** Significant at 5% and 1% level, respectively.

Soil microbial population

Soil microbial populations showed significant differences under different integrated nutrient management

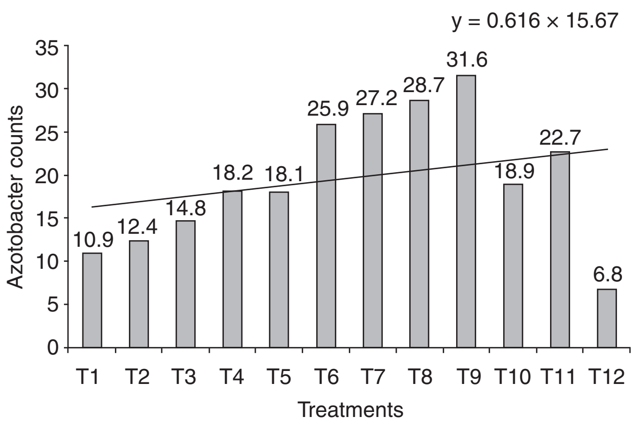

Fig 1 Effect of urea, vermicompost and *Azotobacter* treatments on *Azotobacter* population (× 10^6 cfu per gram soil) in rhizosphere of Kinnow mandarin (pooled mean of two years)

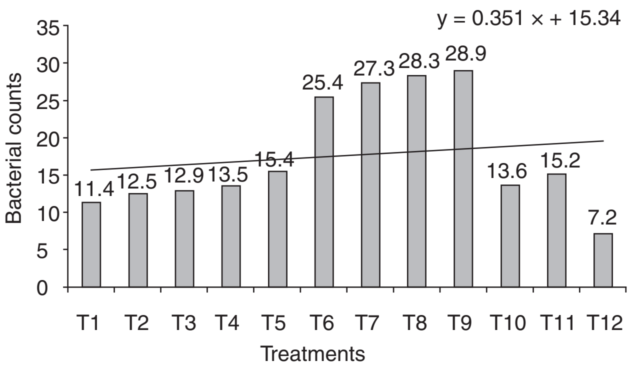

Fig 2 Effect of urea, vermicompost and Azotobacter treatments on bacterial population (×106 cfu per gram soil) in rhizosphere of Kinnow mandarin (pooled mean of two years)

treatments (Fig 1, 2 and 3). Maximum *Azotobacter* population (31.6×10^6 cfu per gram soil), bacterial population (28.9×10^6 cfu per gram soil) and fungal population (35.5×10^5 cfu/g soil) was observed in T_9 (100% nitrogen through vermicompost + *Azotobacter*). Panigrahi and Behera (1993) also observed higher *Azotobacter* population at lower level of nitrogen which is in conformity with the present finding. It has been observed that organic matter serves as energy source for growth and multiplication of *Azotobacter*. It was observed that increased nitrogen application reduced microbial population. Results are in agreement with the findings of Sharma *et al.* (2010, 2013) on apricot and Huchche *et al*. (1998).

From the present studies, it is evident that integrated nutrient management system standardized the schedule of manure and fertilizer application in Kinnow mandarin for sustaining the soil fertility to enhance the production potential and reduce the requirement of chemical fertilizers. The findings have clearly indicated that there was a positive effect of fertilizers when N was manipulated through different sources, viz. vermicompost, biofertilizers and inorganic fertilizers. The results also indicated that there was substantial improvement in leaf and fruit nutrient status of Kinnow mandarin through use of integrated nutrient management system comprising inorganic fertilizers, vermicompost and *Azotobacter*. The nutrient content in leaf further supplemented via significant correlation with fruit yield and quality parameters. Also integration of organic manure along with *Azotobacter* increased soil health in terms of microbial populations. Based on the experimental results obtained, it may finally be concluded that application of 25 % N applied through urea could be replaced with vermicompost application of nutrient equivalent basis along with inoculation of *Azotobacter* @100 g/tree for increasing the nutrient status of Kinnow mandarin. At the same time, integrated nutrient management could effectively address the environmental and sustainability concerns without losing out on productivity.

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