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Influence of different sources of nutrients on growth, yield and quality of *Khasi* mandarin grown under mid hills of Arunachal Pradesh (India)

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Abstract

A field trial was laid out on 11 year old *Khasi* mandarin trees with 12 different doses organic sources (20, 40, 60, 80 kg each of FYM, pig manure and poultry manure) and three different doses (200, 100, 100; 400, 200, 200; and 600, 400, 400 g NPK / tree) of inorganic fertilizers to evaluate the effect of different nutrient sources on growth and yield performance of *Khasi* mandarin. Highest number of fruits per plant was recorded with 600, 400, 400 g NPK application. Plant height (6.96 m), crop canopy (5.7 x 5.6 m) and yield were also highest with full dose of NPK. However, stem diameter (86.8 cm) was highest with the application of 80 kg pig manure. The physico-chemical characteristics of fruits showed that peel weight (32.14 g) and thickness (4.2 mm) were more with full dose application of NPK, while segment weight (87.52 g) and fruit weight (120.4 g) were highest with 80 kg application of FYM. Inorganic fertilizers other than reducing TSS have profound effect on the increase in acidity which in turn reduced the TSS: acid ratio. It can be concluded that 80 kg FYM or 80 kg pig manure application would replenish the depleted nutrients on the *khasi* mandarin growing soils and maintain soil health.

Key words: Citrus, mandarin, organic manure, pig manure, poultry manure, fruit quality, yield

Introduction

Citrus occupies third place after mango and banana, grown in 0.92 million ha area to the production tune of 8.62 MT per annum in India. The most commercial citrus cultivars in India are mandarin, sweet orange and acid lime sharing 41, 23 and 21 % of the total cultivated area, respectively (NHB, 2011). It is the second important fruit crop in the world trade for fresh fruits and more than 50 countries are growing citrus commercially in different agro-climatic conditions for its diversified use and increasing demand world over. India is the sixth largest producer of citrus contributing 4.8% of the world's total citrus production. The north eastern Himalayan region is endowed with favourable agro-climatic conditions for the growth of different citrus species and is considered as the natural home of several citrus species (Gogoi *et al.,* 2004). Among the different citrus species, *Khasi* mandarin is the premier crop being grown in all subtropical belts of Arunachal Pradesh comprising around 60% of the total geographical area, in an extent of over 23,360 ha with the production of 27,251 tons with the modest productivity of 1.75 t ha^{-1} whereas the national average productivity of citrus is 12.25 t ha^{-1}. Very poor productivity in this region is mainly attributed to unscientific cultivation of crop and injudicious use of land resources (Suresh Kumar *et al.,* 2010). Quality production and high productivity of citrus mainly depends on the soil available pool of nutrients. Continuous exploitation and depletion of soil resources, in long run, tremendously influence the yield and quality of fruits and overall longevity and productivity of fruit trees. Long term field experiments have clearly indicated the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003). There is need to adopt practices, which can improve the soil health and increase crop yield. Nonetheless, slow breakdown and release rate of nutrients from organic sources helps the plant to uptake nutrient for longer time (Choudhary and Suresh Kumar, 2013). Farmers of this region occasionally apply organic wastes like pig and farm yard manure. Keeping this in view, the present investigation was carried out to study the effect of indigenously available organic manures on growth, yield and quality of *Khasi* mandarin fruits.

Materials and methods

Experimental site: The present study was conducted at ICAR Regional Centre, NEH Region, Basar, Arunachal Pradesh, situated between 26° 28′ to 29° 28′ N latitude and 91° 35′ to 97° 27′ E longitude, 631 m above MSL, for two consecutive seasons during 2008-09 and 2009-10. The area falls under the humid sub tropical climate. The soil in the farm is loamy clay with slightly acidic pH (5.6). Mean maximum (27.5 ^{o}C) and minimum (16.7 ^{o}C) temperature, relative humidity (64.7%) and 1787.37 mm of average rain fall were recorded during the growing period. Soil was high in organic carbon (1.5 g kg^{-1}), available N (205.6 kg ha^{-1}), available phosphorus (8.3 kg ha^{-1}) and available K (260 kg ha^{-1}). Moisture retention at 0.03 and 1.5 MPa, bulk density and saturated hydraulic conductivity were 29.6 and 17.2%, 1.45 Mg m^{-3} and 532.1 mm h^{-1}, respectively, in 0-20 cm soil depth.

Treatments: A field trial was laid out on 11 year old *Khasi* mandarin trees with 12 different doses of organic manures, three different doses of inorganic fertilizers and keeping one treatment as control (without any fertilizer application). In total, 16 treatments were imposed. The treatments were as follows: T_1- 20 kg, T_2- 40 kg, T_3- 60 kg, T_4- 80 kg FYM/ tree, T_5- 20 kg, T_6- 40 kg, T_7- 60 kg, T_8- 80 kg pig manure/tree, T_9- 20 kg, T_{10}- 40 kg, T_{11}- 60 kg, T_{12}- 80 kg poultry manure/tree, T_{13}- 200, 100, 100 , T_{14}- 400, 200, 200, T_{15}- 600, 400, 400 g NPK tree^{-1} and T_{16}- Control. The doses of organic manures were applied on nitrogen equivalent basis. The treatments of organic fertilizers were applied as single dose while the inorganic fertilizers were applied in split doses. Urea was applied in two splits *i.e.* immediately after harvesting and pruning (during mid January) and after fruit set (during August). Phosphorus and potassium were applied along with half dose of nitrogen after harvesting. All other scientific package of practices were followed uniformly to all the treatments.

Sampling and observations: The data on growth parameters *viz.*, plant height (m), stem diameter (cm), number of branches and crop canopy (m) were measured and pooled value were recorded. Yield per year was recorded both in terms of number of fruits per tree and further expressed in terms of t ha^{-1}. The pooled data was subjected to statistical analysis. The harvested fruits were categorized into different grades on the basis of fruit diameter and expressed in percent basis. Ten fruits per each replication were taken randomly and analyzed for physical characteristics of fruits *viz*; fruit length (cm), fruit width (cm), fruit weight (g), number of seeds per plant, peel weight (g), number of segments, peel thickness (mm), segment weight (g) and juice recovery (mL). Quality parameters like TSS (^{0}Brix), ascorbic acid (mg 100 g^{-1}), acidity (%) and sugars (%) were also analyzed as per the procedure given by Ranganna (2002).

Statistical analysis: All the treatments were executed in Randomized Block Design (RBD) in triplicate and average values were reported. The data obtained were subjected to statistical analysis, using AGRES software. The LSD values (P=0.05) were used for comparing different treatments. Correlation studies were under taken to workout the relationship among growth and yield attributes.

Results and discussion

Growth parameters: Growth and yield performance of *Khasi* mandarin under different nutrient sources is presented in Table 1. It was noticed that plant height was highest (6.36 m) with inorganic fertilizer application (T_{15}) while the poor growth was observed with control. Inorganic fertilizers produced better response compared to organic manures with respect to vegetative growth (Marathe and Bharambe, 2007). Among the organic manures, T_4 was at par with T_{15} in respect to plant height. Stem diameter (83.8 cm) was higher with T_{12} which was at par with T_{11}. FYM application also recorded the same effect with different doses in respect to stem diameter. Among the inorganic fertilizers, T_{13} and T_{16} were at par with each other in stem diameter. Number of branches/ tree (14.8) were maximum in trees receiving 600, 400, 400 g NPK tree^{-1} which was at par with T_{14} and T_4. Among the organic treatments, FYM responded well with regards to number of branches, however, least response was recorded with 20 kg poultry manure which was on par with control. Though, the variation among treatments in crop canopy was not significant, application of organic and inorganic nutrients significantly affected the canopy spread and thereby influenced the yield and quality of the produce. Similar results were recorded by Borah *et al.* (2001) on *Khasi* mandarin. Maximum percentage of flower drop was recorded in control followed by T_{13} and T_{14}. Higher growth in organic manure applied plots was due to the more availability of plant nutrients, enzymes, vitamins and congenial soil characters which helped the plant to uptake more soil nutrient along with water (Ayoola and Makinde, 2008). Organic manure especially pig manure and FYM supply balanced nutrients to plant roots and stimulate growth, increase organic matter content of the soil including the 'humic substances' that affect nutrient accumulation and promote root growth. Percentage of flower drop significantly reduced with higher application of organic manures and trees responded well even to minimum application of organic manures irrespective of sources. The reduction in fruit drop with increased dose of organic manure was expected as the flower drop was highly reduced with higher dose of organic manures. Fruit drop percentage followed the same pattern as flower drop in respect to different nutrient sources. It is clear from the Table 1 that higher fruit drop per plant was recorded with T_{15}. This may be due to heavy bearing and depleted nutrient availability as also reported by Mahendran and Muthuramalingam

Table 1. Growth and yield performance of *Khasi* mandarin under different nutrient treatments

Treatment	Plant height (m)	Stem diameter (cm)	Number of branches	Crop canopy (N-S) m	Crop canopy (E-W) m	Flower drop (%)	Fruit drop		Pooled Yield	
							Per plant	(%)	Fruits plant^{-1}	t ha^{-1}
T_1	5.01^{e}	69.4^{bc}	13.2^{b}	5.3^{ab}	4.7^{ab}	22.7^{c}	24^{b}	5.19^{b}	438^{cd}	18.3c
T_2	5.69^{c}	73.8^{b}	13.5^{b}	5.4^{ab}	5.0^{ab}	19.3^{cd}	19^{c}	3.42^{c}	537^{bc}	19.9bc
T_3	6.03^{ab}	76.1^{ab}	13.5^{b}	5.6^{a}	5.4^{a}	18.1^{d}	22^{bc}	3.57^{bc}	595^{ab}	21.7b
T_4	6.27^{a}	79.9^{ab}	14.0^{a}	5.6^{a}	5.5^{a}	17.5^{d}	23^{b}	3.69^{bc}	601^{ab}	23.5ab
T_5	5.38^{d}	66.8^{c}	11.7^{cd}	4.8^{b}	4.6^{b}	21.6^{c}	21^{bc}	4.00^{b}	504^{bc}	18.8c
T_6	5.39^{d}	70.5^{bc}	12.5^{c}	4.8^{b}	4.6^{b}	18.8^{d}	22^{b}	3.83^{b}	552^{bc}	19.5bc
T_7	5.62^{bc}	73.2^{b}	12.8^{c}	4.9^{ab}	4.8^{ab}	18.1^{d}	24^{b}	3.67^{b}	630^{ab}	21.6b
T_8	5.25^{b}	74.6^{b}	13.6^{b}	5.0^{bc}	4.9^{ab}	17.9^{d}	24^{c}	3.52^{bc}	658^{a}	23.2ab
T_9	5.03^{e}	73.6^{b}	11.3^{d}	4.1^{bc}	4.3^{bc}	23.4^{bc}	17^{c}	3.88^{b}	421^{d}	17.9cd
T_{10}	5.18d^{e}	78.2^{ab}	12.0^{cd}	4.4^{b}	4.2^{bc}	19.7^{cd}	19^{c}	3.84^{b}	476^{c}	18.3c
T_{11}	5.68^{c}	81.8^{a}	12.5^{c}	4.6^{b}	4.5^{b}	18.2^{d}	18^{bc}	3.54^{bc}	518^{bc}	18.9c
T_{12}	5.82^{b}	83.5^{a}	13.2^{b}	4.5^{b}	4.6^{b}	17.7^{d}	20^{b}	3.37^{c}	574^{b}	20.7b
T_{13}	5.25^{de}	59.2^{e}	13.4^{b}	5.6^{a}	5.3^{a}	26.8^{ab}	24^{a}	4.47^{b}	513^{bc}	16.6d
T_{14}	5.73^{b}	63.8^{d}	14.2^{a}	5.7^{a}	5.6^{a}	25.1^{b}	33^{a}	5.32^{a}	587^{ab}	20.8b
T_{15}	6.36^{a}	67.4^{bc}	14.8^{a}	5.7^{a}	5.6^{a}	22.3^{bc}	38^{a}	5.41^{a}	665^{a}	24.6a
T_{16}	4.81^{e}	55.3^{e}	11.6^{d}	4.0^{c}	3.8^{c}	27.9^{a}	23^{b}	5.24^{a}	416^{d}	18.3c
LSD (P=0.05)	0.84	9.0	1.9	0.6	0.7	2.5	1	0.79	63	2.3

In each column, means with similar alphabets do not differ significantly at P= 0.05 by DMRT

(2005). When organic manures are applied, there might be less problems of P fixation and it would be available to plants after decomposition (Asija *et al.,* 1984; Upadhaya and Patiram, 1995). Among different nutrient sources, T_{15} recorded higher fruit yield per tree and per hectare. It was observed that nutrients applied without organic matter were less effective in improving fruit production even at higher doses and more effective when applied with organic matter (Ghosh and Besra, 1997). All the yield attributes were higher in FYM treatment as it releases enzymes like amylase, lipase, cellulase and chitinase, which continue to break down organic matter in the soil to release the nutrients and make it available near rhizosphere and finally absorbed by the plant roots (Chaoui *et al.,* 2003).

Physical characteristics: Fruit length and width responded well to the application of manures and fertilizers (Table 2). It is interesting to note that manure application adversely affected the peel thickness though the difference was not significant. Correspondingly, the higher peel weight was also recorded with T_4. Increase in manure application profoundly affected the weight and number of segments. It is evident from Table 2 that high dose of manures and fertilizer were at par with each other on these parameters. No definite response was observed with different treatments. Fruit weight was profoundly affected by the applied manures and higher fruit weight was noticed with T_4 followed by T_8 and T_3. Presence of seed directly influenced the fruit weight and over all quality of the final produce. These observations were similar to the results of Mahendran and Muthuramalingam (2005) who found the similar effect on mandarin orange. Highest juice content (58.76) was observed with T_8 followed by T_4 and T_3. Though, inorganic fertilizers gave maximum yield, it resulted in low content of juice per fruit.

Quality characteristics: Quality parameters of *Khasi* mandarin fruits presented in Table 3 indicate that highest TSS was recorded with 80 kg pig manure (T_2) followed by 80 kg FYM. Under the influence of inorganic fertilizers reduced the TSS was reduced and acidity increased which in turn reduced the TSS: acid ratio in the fruits. This severely affected the organoleptic quality of the harvested oranges. Higher acidity was noticed with T_{13}

Table 2. Physical characteristics of *Khasi* mandarin fruits affected by different treatments

Treatment	Fruit length (cm)	Fruit breadth (cm)	Peel weight (g)	Peel thickness (cm)	Number of segments	Segment weight (g)	Fruit weight (g)	Number of seed fruit^{-1}	Juice content (mL)
T_1	5.2^{bc*}	5.4^{bc}	29.93^{ab}	0.30^{bc}	8.6^{c}	73.80^{c}	115.72^{ab}	8.83^{bc}	51.17^{ab}
T_2	5.7^{ab}	5.8^{ab}	30.66^{ab}	0.31^{bc}	9.5^{ab}	79.84^{ab}	114.48^{ab}	9.10^{b}	48.25^{b}
T_3	5.8^{a}	6.1^{a}	31.24^{a}	0.35^{b}	9.8^{ab}	80.52^{ab}	120.90^{a}	9.13^{b}	54.45^{ab}
T_4	5.8^{a}	6.2^{a}	34.00^{a}	0.37^{b}	10.6^{a}	88.56^{a}	119.19^{a}	9.21^{b}	56.83^{a}
T_5	5.4^{ab}	5.7^{ab}	26.77^{c}	0.29^{c}	9.8^{ab}	73.27^{c}	106.54^{b}	8.34^{cd}	42.76^{bc}
T_6	5.6^{a}	5.9^{a}	27.97^{bc}	0.33^{b}	9.5^{ab}	82.28^{ab}	105.73^{b}	8.22^{c}	44.49^{bc}
T_7	5.9^{a}	6.3^{a}	30.28^{ab}	0.33^{b}	9.9^{ab}	83.07^{ab}	107.36^{b}	9.19^{b}	43.67^{bc}
T_8	6.0^{a}	6.4^{a}	31.81^{a}	0.32^{bc}	10.3^{a}	85.13^{a}	117.70^{a}	10.15^{a}	58.72^{a}
T_9	5.0^{bc}	5.3^{bc}	27.03^{bc}	0.31^{bc}	9.6^{ab}	71.62^{c}	103.54^{bc}	7.94^{d}	41.73^{bc}
T_{10}	5.3^{bc}	5.5^{bc}	26.71^{bc}	0.31^{bc}	9.7^{ab}	75.54^{b}	106.82^{b}	8.05^{c}	43.16^{bc}
T_{11}	5.4^{b}	5.6^{b}	27.74^{bc}	0.33^{b}	9.9^{ab}	76.85^{b}	104.19^{b}	8.62^{bc}	42.38^{bc}
T_{12}	5.6^{b}	5.9^{ab}	28.62^{b}	0.33^{b}	10.1^{a}	76.92^{b}	113.56^{ab}	9.08^{b}	44.05^{b}
T_{13}	4.8^{c}	5.0^{c}	28.50^{b}	0.35^{b}	9.8^{ab}	68.73^{d}	92.27^{c}	7.82^{d}	38.27^{c}
T_{14}	5.0^{bc}	5.3^{bc}	28.22^{b}	0.37^{b}	9.7^{ab}	73.19^{c}	104.37^{b}	8.24^{cd}	42.91^{bc}
T_{15}	5.3^{bc}	5.5^{b}	30.23^{ab}	0.42^{a}	10.1^{a}	74.72^{bc}	109.95^{b}	9.47^{ab}	43.59^{bc}
T_{16}	4.9^{c}	5.1^{c}	26.04^{c}	0.33^{b}	8.3^{c}	66.38^{d}	94.6^{c}	8.93^{bc}	41.18^{bc}
LSD (P=0.05)	0.54	0.7	2.66	0.03	0.1	6.21	9.51	0.72	3.99

*In each column, means with similar alphabets do not vary significantly at P= 0.05 by DMRT

Table 3. Chemical and Quality parameters of *Khasi* mandarin fruits under different treatments

Treatment	TSS (^{0}Brix)	Acidity (%)	TSS: Acid ratio	Ascorbic acid (mg 100mL^{-1})	Sugars (%)		Fruit grades (pooled)			
					Reducing	Total	Extra special (>60 mm)	Special (55-60 mm)	Good (50-55 mm)	Average (< 55 mm)
T_1	9.47^{bc*}	0.58^{a}	16.21^{c}	53.5^{c}	4.47^{c}	7.45	29.3^{b}	33.6^{b}	22.8^{c}	14.5^{bc}
T_2	10.23^{b}	0.52^{b}	19.67^{ab}	56.8^{b}	4.91^{b}	8.27	34.7^{ab}	37.3^{ab}	14.2^{d}	13.8^{c}
T_3	11.20^{a}	0.51^{b}	21.96^{ab}	56.4^{b}	4.94^{b}	8.38	36.2^{ab}	38.4^{ab}	13.1^{d}	12.1^{cd}
T_4	11.58^{a}	0.49^{bc}	23.47^{a}	57.3^{a}	5.26^{a}	8.72	37.5^{a}	39.9^{a}	14.0^{d}	8.6^{d}
T_5	9.95^{bc}	0.56^{ab}	17.77^{b}	49.1^{d}	4.09^{d}	7.36	30.6^{b}	32.1^{b}	22.1^{c}	15.2^{b}
T_6	10.76^{b}	0.50^{ab}	21.40^{ab}	50.3^{d}	4.75^{bc}	8.01	33.8^{ab}	36.7^{ab}	16.4^{cd}	13.1^{c}
T_7	10.82^{b}	0.48^{bc}	22.61^{ab}	52.6^{cd}	4.84^{bc}	8.32	35.9^{ab}	37.3^{ab}	17.1^{cd}	9.7^{d}
T_8	11.23^{a}	0.46^{c}	24.73^{a}	53.7^{b}	4.98^{b}	8.59	38.1^{a}	40.2^{a}	14.3^{d}	7.4^{e}
T_9	9.85^{bc}	0.60^{a}	16.42^{c}	47.6^{e}	4.06^{d}	7.03	27.7^{c}	32.8^{bc}	22.8^{bc}	16.7^{b}
T_{10}	9.83^{bc}	0.59^{a}	16.95^{b}	48.4^{e}	4.19^{cd}	7.34	29.4^{b}	30.5^{c}	26.7^{b}	13.3^{c}
T_{11}	10.12^{bc}	0.55^{ab}	18.40^{b}	49.1^{e}	4.15^{cd}	7.42	31.8^{ab}	33.4^{bc}	22.2^{bc}	12.8^{cd}
T_{12}	10.48^{ab}	0.54^{ab}	18.78^{b}	50.7^{d}	4.39^{c}	7.85	36.7^{ab}	37.3^{ab}	14.3^{d}	11.7^{cd}
T_{13}	8.27^{c}	0.63^{a}	12.73^{d}	52.4^{cd}	4.17^{cd}	7.31	25.4^{d}	27.2^{d}	30.8^{a}	16.6^{b}
T_{14}	8.79^{c}	0.54^{ab}	16.20^{c}	51.5^{cd}	4.36^{c}	7.73	26.5^{cd}	33.4^{bc}	20.9^{c}	19.3^{a}
T_{15}	9.84^{bc}	0.51^{ab}	19.28^{b}	50.2^{d}	4.18^{cd}	7.85	31.3^{b}	34.8^{bc}	20.2^{c}	13.7^{c}
T_{16}	9.37^{bc}	0.56^{ab}	16.66^{c}	53.6^{c}	4.52^{bc}	7.47	27.7^{cd}	32.5^{c}	24.0^{ab}	15.8^{b}
CD (P=0.05)	0.91	0.13	2.53	1.4	0.53	NS	2.83	1.6	3.6	3.2

*In each column, means with similar alphabets do not vary significantly at P= 0.05 by DMRT

Table 4. Correlation among different growth, yield and quality attributes of *Khasi* mandarin under different nutrient sources

Parameters	Plant height	Number of branches	Crop canopy	Flower drop (%)	Fruit drop (%)	Fruit weight (g)	Number of seed /fruit	TSS: Acid	Fruits/Tree
Number of branches	0.78*								
Crop canopy	0.64	0.88**							
Flower drop (%)	-0.55	-0.17	-0.07						
Fruit drop (%)	-0.15	0.11	0.07	0.60					
Fruit weight (g)	0.55	0.44	0.33	-0.59	-0.33				
Number of seed /fruit	0.50	0.37	0.18	-0.69	-0.39	0.77*			
TSS:Acid	0.60	0.28	0.15	-0.79*	-0.51	0.70*	0.82*		
Fruits/Tree	0.87**	0.75*	0.59	-0.52	-0.23	0.43	0.57	0.68	
Yield/ha	0.87**	0.70*	0.48	-0.49	-0.15	0.68	0.66	0.76*	0.87**

, * significant at P=0.05 and P=0.01, respectively

followed by T_{10}. T_8 recorded highest TSS: acid ratio among the different treatments. Control was also on par with manure application for ascorbic acid content of fruit. Similar result was observed by Kumar *et al.* (2008) on *Khasi* mandarin. Nonetheless, little effect of applied manures and fertilizers was observed on reducing sugars, all the treatments did not have much impact on the sugar content of fruits. This was due to marginal variation in non reducing sugars. Pooled analysis of data on fruit grades show significant variation among treatments. Highest percentage of extra special grade was observed with T_8 followed by T_4. Conversely, more percentage of average fruits was observed with T_{14} followed by T_{13}, T_{15} and T_{10}. Therefore, yield loss due to organic manure application could be nullified by the production of more number of extra special and special grade oranges.

Correlations: To study the association among growth, yield and quality attributes, correlation were worked out (Table 4). Number of branches per tree had significant positive correlation with plant height and crop canopy. However, it was observed that flower drop and fruit drop had negative relationship with all the yield attributing characters, though the effect was not significant due to manure and fertilizer application. Earlier reports suggest that care should be taken to control the flower and fruit drop during economic growth period (Upadhaya and Patiram, 1996; Sharma and Josan, 2004). It is evident that fruit weight has direct positive correlation with number of seed per fruit, in the same way, fruit weight showed highly significant relationship with TSS: acid ratio. Fruit number per tree had highly significant positive correlation with the yield of oranges per tree and hectare.

From the study, it was concluded that the application of manures and fertilizers had significant impact on the production and quality of *Khasi* mandarin. FYM or pig manure @ 80 kg per tree could be applied to replenish the depleted nutrients in soils of *Khasi* mandarin growing areas of Arunanchal Pradesh.

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