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Effect of con-joint application of inorganic and organic sources of nutrients with biofertilizers on growth, yield and fruit quality of Kinnow mandarin

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ABSTRACT

Investigations were conducted to study the effect of integrated use of organic manures, inorganic fertilizers and biofertilizers on growth, yield and fruit quality attributes of kinnow mandarin. Maximum (0.70 m) trunk girth was recorded in T_4 (70% NPK (560g N:350g P: 420g K) + 42 kg FYM + 9 kg vermicompost + biofertilizers (*Azotobacter*, VAM and PSB @ 200g each/tree). Tree height was also higher (3.65m) in T_4 along with tree volume in T_4 (29.53 m^3). Maximum tree spread was 3.98 m in EW and 3.86 m in NS directions was recorded in T_4 closely followed by T_1 (100% NPK ((800gN:500gP:600gK) + 60kg FYM). Application of 70% of the recommended doses of NPK (560g N:350g P:420g K) in the mid of December except N (urea) in two split doses (first during spring before flowering and remaining half dose after fruit set) with farmyard manures @ 42 kg and vermicopost @ 9kg alongwith biofertilizers (*Azotobacter*, VAM and PSB) @ 200g each/tree) during September in a ring placement at a depth of 30 cm and one meter away from the tree trunk gave significantly highest number of fruits/ tree (213), fruit yield (41.89kg/tree) and maximum fruit size and fruit weight. The same treatment recorded the highest gross income (Rs. 1505.76), net income (Rs. 1157.74) and benefit cost ratio (3.3).

Key Words:

INM, Organic manures, Biofertilizers, kinnow mandarin

INTRODUCTION

Kinnow (*C. nobilis* X *C. deliciosa*) mandarin is an important fruit crop among different citrus fruits. It is the heaviest bearer than any other citrus fruit. Citrus fruits are the second most important fruit crop in Himachal Pradesh after mango in

terms of area (24869 hectares) and production (29344 MT). The area under Mandarins (Kinnow and other loose skinned oranges) is 8,816 hectares and production of 14,978MT (Anonymous, 2018). Kinnow mandarin is having dominant share out of the total area under mandarins. Application of inorganic fertilizers through complex and simple inorganic fertilizers like NPK (12:32:16), Diammonium Phosphate, Urea, SSP and MOP is being practiced by the farmers in a manner that has resulted into imbalance of NPK nutrients resulting in low production from kinnow orchards in the state. Further, an inadequate nutrition coupled with indiscriminate use of chemical fertilizers (imbalance use of nutrients), neglecting organic and biofertilizers affect the trees growth and production adversely (Kannur et al. 2020). In order to maintain soil health and to obtain optimum yield of better quality fruits, it is essential to adopt integrated nutrient management (INM) approach where application of different nutrient supplements like organic manures, inorganic fertilizers in combination with biofertilizers holds a good potential to overcome some of the soil physical constraints to a greater extent. Ibe et al. (2011) and Srivastava (2012) advocated the complementary use of organic and inorganic for sustainable citrus production as a sound fertility management strategy**.** The practice has a greater beneficial residual that can be derived from the use of either inorganic fertilizer or organic manure when applied alone**.** Application of inorganic nutrients plays an important role in improving the yield attributes besides uptake of nutrients and their continuous use leads to the problem of soil health. Organic manures like well rotten farm yard manures and vermicompost alone are not capable of supplying all the required nutrients for plant growth. Farmyard manure is very important components of nutrient management as it is helpful in maintaining soil fertility and fruit quality (Arekar et al. 2019). Vermicompost enriches soil organic matter and nutrient content, improves the soil structure and increase cation exchange capacity. The earthworms utilize organic wastes as food and the undigested material excreted by them has gained the name vermicompost**.** Biofertilizers are live formulations of beneficial microorganism containing living cells of different microorganisms, which have the ability to mobilize plant nutrients of soil from unusable to usable form through biological process. They are environment friendly and play significant role in crop production. However, integration of inorganic fertilizers, organic manures and biofertilizers in proper proportions can improve tree health besides improving physical condition of soil and thus the yield of the crop. There have been no attempts made on integrated nutrient management for standardizing the nutritional requirements and yield economics of kinnow mandarin under diverse soil and climatic conditions in the subtropical areas of HP. Therefore, in order to ensure sustainable production and productivity of kinnow mandarin the present investigations are planned to study the integrated use of organic manures, inorganic fertilizers with Azotobacter, VAM and PSB on the response of kinnow mandarin in terms of growth, yield and quality of fruits.

MATERIALS AND METHODS

The investigations were conducted during 2016-2019 at Regional Horticultural Research and Training Station, Jachh (Kangra), Dr YS Parmar University of Horticulture and Forestry, Solan (HP) located in sub tropical, submontane low hill representing Zone-1 of Himachal Pradesh and lies at latitude of $32^0$18' N and longitude of $75^0$55' E at an elevation of 428 m above mean sea level. The experiment consisted of six treatments and four replications and was laid out in randomized block design. Twelve year old uniform looking trees were selected. Different levels of inorganic fertilizers (urea, SSP and MOP), organic manures (FYM and Vermicompost) and biofertilizers (*Azotobacter*, VAM and PSB) were applied in different treatments

except control to form the six treatments viz., T_1- Control 100% NPK ((800gN:500gP:600gK) + 60kg FYM , T_2- 90% NPK (720gN:450gP: 540gK) + 54 kg FYM +3kg Vemicompost + Biofertilizers (*Azotobacter*, VAM and PSB @ 100g each/tree), T_3- 80% NPK (640gN:400gP: 480gK) + 48kg FYM + 6kgVemicompost + Biofertilizers (*Azotobacter*, VAM and PSB @ 150g each/tree), T_4- 70% NPK (560gN:350gP: 420gK) + 42 kg FYM + 9kg vermicompost + biofertilizers (*Azotobacter*, VAM and PSB @ 200g each/tree), T_5-60 % NPK (480g N: 300gP: 360gK) + 36 kg FYM + 15kg Vermicompost + Biofertilizers(*Azotobacter,* VAM and PSB @ 250g each/tree), T_6-50% NPK (400gN:250gP: 300gK) + 30 kg FYM + 18kg Vermicompost + Biofertilizers (*Azotobacter*, VAM and PSB @ 300g each/tree). The chemical fertilizers (SSP and MOP) along with FYM were applied at the mid of December except N (urea) which was applied in two split dozes *i.e.* first during spring before flowering and remaining half dose after fruit set. Biofertilizers (PSB, *Azotobacter* and VAM) were mixed with FYM and were applied in the month of September in a ring placement at a depth of 30 cm and one meter away from the tree trunk. The average NPK content of the FYM used in the study contained 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 percent K_2O. Observations on various growth parameters like trunk girth, tree height, tree volume, and tree spread (NS and EW) directions were recorded. The growth parameters of kinnow mandarin plants (plant height, stem girth, tree spread and canopy volume) were recorded initially and after harvesting of the crop during experimentation. The plant trunk girth was taken 20 cm above the soil surface. Plant height and tree spread in EW and NS directions was recorded and expressed in meters. The canopy volume (m^3) of the mandarin tree was calculated according to formula given below:

$$\text{Canopy volume} = 4/6\ \pi\ r^2\ h$$

where r = Sum (EW+NS)/4 and h= tree height

The data on yield parameters like number of fruits, fruit weight, fruit yield/tree was recorded after fruit harvest after in the month of December using electronic weighing balance and counting of fruits. Fruit yield (t/ha) basis was calculated by multiplying the fruit yield/tree with number of plants/ha. The samples of ten fruits per tree were randomly taken to determine fruit quality parameters as per AOAC (juice content, acidity and total soluble solids and vitamin C. The data of two years was pooled and analyzed statistically as per Cochran and Cox (1990) for interpretation of results and drawing conclusions. Regarding economics of different treatments, cost incurred per tree on each treatment was worked out by calculating expenditures on variable as well as fixed inputs in each treatment. Simultaneously, gross returns were also calculated by existing market rate of produce and unit fruit production of each treatment. Benefit cost was calculated by deducting expenditure from the gross return/income and benefit cost ratio was then calculated for each treatment.

RESULTS AND DISCUSSIONS

Effect on growth characters

Significant differences were observed for different growth parameters in different are depicted in Table 1.Maximum (0.70 m) trunk girth was recorded in treatment the T_4 ie.70% NPK 560g N:350g P: 420g K + 42 kg FYM + 9kg vermicompost + biofertilizers (*Azotobacter*, VAM and PSB @ 200g each/tree),was found statistically at par with the treatmentsT_1, T_2 and T_3 treatments, whereas the minimum (0.49 m) was recorded in treatmentT_5 (60 % NPK (480gN: 300gP: 360gK) + 36 kg FYM + 15kg Vermicompost + Biofertilizers(*Azotobacter,*VAM and PSB @ 250g each/tree). The increase in trunk diameter could be attributed to the stimulatory activity of microflora in the rhizosphere leading to increased nutrient availability and hence vigorous plant growth. These results are in agreement with the findings of Singh et al. (2000) in sweet orange. Tree height was found to vary from 2.75m (T_5) to

3.65m (T4). Highest tree volume was recorded in T_4 (29.53 m^3), wheras, the treatment T_6 had the lowest (13.74 m^3) tree volume. Plant height increased significantly by bio-fertilization with *Azotobacter* in combination with FYM and inorganic fertilizer. Increment in height might be due to the fact that nitrogen is fixed by *Azotobacter* and being a constituent of protein and chlorophyll, plays a vital role in photosynthesis. It enhances accumulation of carbohydrates which, in turn, increases the growth of the plants (Boughalleb et al. 2011). It is evident from the data presented in Table 1 on tree spread (EW & NS) that the application of inorganic and organic nutrients along with biofertilizers influenced the tree spread significantly. The maximum (3.98 m in EW and 3.86 m in NS directions) tree spread was recorded in T_4 closely followed by T_1 which was observed to be statistically at par with T_3 and T_2 treatments**.** The minimum values for tree spread in EW (3.25 m) and NS (2.65 m) directions were noted in T_5 and T_6 treatments, respectively. The increase in tree spread might be due to better root growth by biofertilizer in combination with FYM and chemical fertilizer. The increase in tree spread and growth may be due to better supply of nutrients by microorganisms. Plant spread increased significantly with the inoculation of biofertilizers which may be due to increased cell metabolism as a result of increased enzyme activity, chlorophyll content and photosynthetic processes. It has resulted in improvement of the hormonal status of the plant due to biofertilization (Mukhopadhyay and Sen, 1997). The increase in tree height, spread and volume find the support from earlier studies of Aseri et al. (2008), Dutta et al. (2009) and Goswami et al. (2012) who also observed improved vegetative growth with the application of different fertilizers, organic manures and biofertilizers.

Table 1: Effect of integrated nutrient management with respect to growth attributes in kinnow mandarin

S.N	Treatments	Trunk girth (m)	Tree height (m)	Tree volume (m^3)	Tree spread (m)	
					EW	NS
1	T_1 (Control)	0.65	3.35	25.13	3.90	3.65
2	T_2	0.60	3.40	24.31	3.75	3.62
3	T_3	0.66	3.10	23.75	3.89	3.74
4	T_4	0.70	3.65	29.53	3.98	3.86
5	T_5	0.49	2.75	15.77	3.25	3.35
6	T_6	0.50	2.90	13.74	3.35	2.65
	$CD_{0.05}$	0.09	0.23	2.57	0.34	0.48

Effect on fruit yield and its parameters

Integrated nutrient management practices exhibited significant differences among treatments in fruit size, fruit weight, number of fruits, fruit yield/tree and the calculated fruit yield/ha (Table 2). Among all the treatments, application of 70% RDF (560g N:350g P:420g K) + 42 kg FYM + 9kg Vermicopost + Biofertilizers (*Azotobacter*, VAM and PSB @ 200g each/tree) recorded significantly highest (213) number of fruits/ tree and fruit yield (41.89 kg/tree). The fruits harvested in the same treatment had the maximum fruit size in term of length (64.7mm), breadth (76.3mm) and fruit weight (196.7g). These findings indicated that integrated application of inorganic fertilizers, vermicompost and green manures was successful in maintaining higher levels of sweet orange productivity. The increase in the yield may be mainly attributed to relative increase in the availability of nutrients and better solute uptake by the plants. The present findings are in line with the earlier reported results of Korwar et al. (2006), and Sharma et al. (2013).

Table 2: Effect of integrated nutrient management on yield parameters in kinnow mandarin

S.N.	Treatment	Fruit Size (mm)		Fruit weight (g)	Number of fruits/plant	Fruit yield (kg/plant)	Fruit yield (t/ha)
		L	B				
1	T_1 (Control)	61.6	71.9	177.4	197	34.94	11.63
2	T_2	62.3	75.2	174.7	192	33.54	11.17
3	T_3	60.1	73.4	185.9	188	34.95	11.64
4	T_4	64.7	76.3	196.7	213	41.89	13.95
5	T_5	61,8	72.1	165.4	177	29.28	9.75
6	T_6	62.7	73.1	161.6	168	27.15	9.04
	$CD_{0.05}$	0.5	0.7	9.4	11	2.1	1.2

Effect on fruit quality parameters

Various fruit quality parameters viz., acidity, TSS/acidity ratio, peel thickness, juice content and vitamin content were affected significantly by various treatment combinations. However, fruit quality parameters like total soluble solids (TSS) and juice content (%) were not affected significantly in various treatment combinations as shown in Tasble3. The treatment T_3(80% NPK (640gN:400gP: 480gK) + 48kg FYM + 6kgVemicompost + Biofertilizers (*Azotobacter*, VAM and PSB @ 150g each/tree) had the maximum acidity content (1.56 %) while T_2 (90% NPK (720gN:450gP: 540gK) + 54 kg FYM +3kg Vemicompost + Biofertilizers (*Azotobacter*, VAM and PSB @ 100g each/tree) gave highest TSS/acidity ratio (8.62) and vitamin C content was the highest(26.6mg/100g) in treatment T_4(70% NPK 560gN:350gP: 420gK + 42 kg FYM + 9kg vermicompost + biofertilizers (*Azotobacter*, VAM and PSB @ 200g each/tree). Maximum TSS (10.4°B) and juice content (49.2%) was also recorded in treatment T_4. Fruits harvested from trees receiving treatmentT_4 also had least (2.80 mm) peel thickness. The results are in conformity with that of Gawande et al. (1998), Marathe and Bharambe (2007), Singh and Banik (2011) and Singh et al. (2017) who has reported that effect of integrated nutrient management practices had significant influence on fruit quality parameters.

Table 3: Effect of integrated nutrient management on fruit quality parameters in kinnow mandarin

S.No.	Treatment	TSS (°B)	Acidity (%)	TSS/Acidity ratio	Peel thickness (mm)	Juice Content (%)	VitC (mg/100g)
1	T_1 (Control)	10.2	1.23	8.29	3.28	47.4	22.3
2	T_2	10.0	1.16	8.62	3.30	48.3	23.4
3	T_3	9.5	1.56	6.08	3.16	48.9	21.3
4	T_4	10.4	1.24	8.38	2.80	49.2	26.6
5	T_5	9.8	1.31	7.48	3.23	47.2	21.6
6	T_6	10.0	1.29	7.75	3.27	46.7	22.9
$CD_{0.05}$		NS	0.12	0.98	0.16	NS	1.4

Economic analysis of different treatments

The highest gross income (Rs. 1505.76), net income (Rs. 1157.74) and benefit cost ratio (3.3) was observed with the treatment T_4 followed by T_6 having, and gross income (Rs. 1289.46), net income (Rs. 826.42) and benefit cost ratio (1.8) (Table 4). The results are in close proximity to the findings of Dalal et al. (2004).

Table 4: Economics of different treatments of Integrated Nutrient Management in kinnow mandarin

S. N.	Treatments	Gross Returns (Rs)	Net Returns (Rs)	B:C Ratio
1	T_1 (Control)	1065.75	676.12	1.7
2	T_2	976.18	625.65	1.8
3	T_3	1186.76	796.63	2.0
4	T_4	1505.76	1157.74	3.3
5	T_5	1276.45	711.43	1.3
6	T_6	1289.46	826.42	1.8
	$CD_{0.05}$	53.55	38.76	0.08

CONCLUSIONS

Application of 70% of the recommended doses of NPK (560g N:350g P:420g K) in the mid of December except N (urea) in two split doses (first during spring before flowering and remaining half dose after fruit set) with organic manures like farmyard manures @ 42 kg and vermicopost @9kg alongwith biofertilizers (*Azotobacter*, VAM and PSB) @ 200g each/tree) during September in a ring placement at a depth of 30 cm and one meter away from the tree trunk was found out to be the best for improving the tree growth, fruit yield, fruit quality and was also found economical as it has highest benefit cost ratio**.**

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