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Integrating fertilizer N rates with organics on soil-available nutrients and yield of sapota under semi-arid conditions of Karnataka

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ABSTRACT

A field experiment was conducted for three consecutive years to study the effect of various combinations of nitrogenous fertilizer (in the form of urea), vermicompost and FYM on yield and soil-available nutrients in sapota. Largest number of fruits (4820 tree^{-1}) and maximum fruit yield (31 tons ha^{-1}) were recorded with 10kg vermicompost + 350:50:450g NPK tree^{-1}, and was on par with application of 40kg FYM + 350:50:450g NPK tree^{-1}. The net profit and yield trend over the years showed that application of 10kg vermicompost + 350:50:450g NPK tree^{-1} was more suitable for meeting nutrient requirement for enhanced yield in sapota. Application of organics (irrespective of source) showed positive, significant effect on organic matter content of the soil after three years. Highest build-up of organic matter in the soil was recorded with 10kg vermicompost alone (T10), which was at par with 40kg FYM alone (T5). Moreover, there was a clear trend of increasing total soil nitrogen content in plots supplied with increased levels of inorganic nitrogen with organic manures, and, this was subsequently reflected in potentially mineralized nitrogen, suggesting an improved labile pool of plant-available nitrogen. Therefore, there is an obvious need to include organic manures along with the inorganic nitrogenous fertilizer for optimizing the use-efficiency of soil and applied N to achieve sustainable yields in sapota for profit.

Key words: FYM, vermicompost, inorganic fertilizers, sapota, potential mineralized nitrogen, plant-available nutrients

INTRODUCTION

Reports indicate that about 28Mt of primary plant nutrients (NPK) are removed annually by crops in India, while 18Mt (even much less in semi-arid condition) are applied as fertilizer, leaving a net negative balance of about 10Mt of primary plant nutrients (NAAS, 2006). This imbalanced and skewed fertilization status is a major causative factor for stagnant /reduced crop yields by declining crop response to applied fertilizers and impaired nutrient use efficiency. Use of inorganic fertilizer alone has not been helpful under intensive agriculture owing to its high cost, and is often associated with reduced crop yields, with soil degradation, nutrient imbalance and acidity (Obi and Ebo, 1995). The need for renewable forms of energy and reduced cost of fertilizing the crops, has revived use of organic manures worldwide (Ayoola and Adeniran, 2006), more so in India (NAAS, 2006). Thus, integrated nutrient management has shown promising results not only in sustaining productivity, but also has proved to be effective in maintaining soil health besides enhancing nutrient efficiency (Kadrekar, 1993; Thakur *et al*, 2011).

Sapota (*Manilkara achras* Mill.), popularly known as *'Chiku'*, is one of the important tropical fruit crops of India. It is the most popular fruit crop in Karnataka, Gujarat and Maharashtra, these being the major sapota producing states in India. It is a hardy crop and tolerates salinity to some extent (Sulladmath and Reddy, 2001). It responds well to water and nutrients (Bhuva *et al*, 1990; Boora *et al*, 2002; Singh *et al*, 2003). Therefore, productivity in sapota can be increased significantly through application of fertilizers in combination with organic manures (Devashi, 2012). A complementary use of organic and inorganic fertilizers has been recommended for sustenance of long-term cropping in the tropics (Ipimoroti *et al*, 2002; Yadukumar *et al*, 2012). Fuchs *et al* (1970) reported that nutrients from mineral fertilizers enhanced establishment of crops, while, those from mineralization of organic manures promoted yield when both types of fertilizer were combined. Murwira and Kirchman (1993) observed that nutrient use efficiency could be increased through a combination of manure and inorganic fertilizer. This study was, therefore, conducted to investigate the effects of varying rates of inorganic nitrogenous fertilizers

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and various organic manures on sapota yield and soil-fertility status under semi-arid climate of Karnataka, as a long-term management practice.

MATERIAL AND METHODS

The study was carried out to examine a conjunctive use of inorganic nitrogen and organic nutrient sources, in the form of vermicompost and farm yard manure, on soil fertility and productivity of sapota as part of developing integrated production packages. The experiment was conducted at Experimental Farm, College of Horticulture, University of Horticultural Sciences, Arabhavi, Karnataka, India, under AICRP (Tropical Fruit Crops) over three years (2009-10 to 2011-12). The study was initiated in a ten-year-old sapota orchard of var. 'Kalipatti' (1990 planting) under normal planting density (10m x 10m). The experimental soil was silty-clay in texture (15.6% sand, 39.5% silt and 43.8% clay), with pH (1:2.5 w/v) 7.93, EC 0.55 dS m^{-1}, organic carbon 6.1g kg^{-1}, available nitrogen 259kg ha^{-1}, Olsen-P 8.2kg ha^{-1}, available potassium 334kg ha^{-1}, DTPA-Fe 2.86mg kg^{-1}, Mn 6.72mg kg^{-1}, Zn 0.20mg kg^{-1}, Cu 0.40mg kg^{-1} and boron 0.15mg kg^{-1}.

The experiment was laid out in Randomized Block Design, with ten treatments comprising various combinations of nitrogenous fertilizer (in the form of urea), vermicompost and FYM, with three replicates per treatment (15 trees per replicate). Details of the treatments are shown in Table 1. Vermicompost and FYM were collected from small farm-holdings in the vicinity of the experimental farm, and, FYM was dried before use. Total N, P and K content of the FYM was 0.50, 0.24 and 0.59%, respectively, and that of vermicompost was 2.10, 0.18 and 1.06%, respectively.

Table 1. Levels and doses of organic and inorganic fertilizers supplied to sapota trees

Treatment	Treatment details (dose per tree per year)
T1	40kg FYM + 200g N
T2	40kg FYM + 250g N
T3	40kg FYM + 300g N
T4	40kg FYM + 350g N
T5	40kg FYM alone
T6	10kg vermicompost + 200g N
T7	10kg vermicompost + 250g N
T8	10g vermicompost + 300g N
T9	10kg vermicompost + 350g N
T10	10kg vermicompost alone

Recommended dose of P_2O_5 (50g $tree^{-1}$ $year^{-1}$) and K_20 (450g $tree^{-1}$ $year^{-1}$) was applied as basal, in the form of di-ammonium phosphate and muriate of potash, in all treatments except T5 and T10).

Recommended dose of P_2O_5 (50g $tree^{-1}$ $year^{-1}$) and K_20 (450g $tree^{-1}$ $year^{-1}$) was applied as basal in the form of di-ammonium phosphate and muriate of potash in all the treatments except T5 and T10. Vermicompost, FYM, and N in the form of urea, were applied in two equal splits during June and September/ October. At the time of application of fertilizers, a trench of 30cm width and equal depth, 1m away from trunk of the tree, was prepared. All the fertilizers were applied in the trench and covered with soil.

Tree height and tree spread (N-S and E-W directions) were recorded as vegetative growth parameters. Yield and yield parameters such as fruit weight, number of fruits per tree and fruit yield were recorded. Total soluble solids (TSS) were determined using a hand refractometer. At the end of three years of cropping, soil and leaf samples were collected three months after the last fertilizer and /or manure application. Root activity in sapota was high (72%) within 2m radius around the tree, and in the top-soil (0-30cm). Soil samples within 2m radius of tree were collected from each replication of individual treatment plots and analyzed for pH, EC, organic carbon, available N, P and K using standard procedures (Dhyan Singh *et al*, 2005). Exchangeable Ca and Mg in the soil were extracted with 1N ammonium acetate (pH 7.0) solution and determined using an Atomic Absorption Spectrophotometer (AAS). DTPA-extractable soil Fe, Mn, Zn and Cu were determined as per Lindsay and Norvell (1978) using AAS. Soil organic matter content was estimated as per Nelson and Sommers (1982). An aliquot of dried soil was ground to a fine powder (<1 mm), and soil total nitrogen was analyzed using a CHN analyzer. The pool of potentially mineralizable nitrogen in soil was analyzed according to Lober and Reeder (1993). Data were analyzed using Analysis of Variance, as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Yield and yield parameters

Significant variation in fruit weight, number of fruits per tree and fruit yield was observed in different levels of integration of nutrient sources (Table 2). Highest fruit weight (67.5g), maximum number of fruits per tree (4820) and highest fruit yield (310.6kg) were obtained in treatment T9 receiving 10kg vermicompost and 350:50:450g NPK $tree^{-1}$. However, this was on par with application of 40kg FYM + 350:50:450g NPK $tree^{-1}$. An increase in fruit yield over the years (Table 3) was observed in treatment T9 (10kg vermicompost and 350:50:450g NPK $tree^{-1}$) and T4 (40kg

Table 2. Effect of integrating organic manure with inorganic nitrogen on yield and yield attributes in sapota cv. Kalipatti (2011-12)

Treatments	Number of fruits per tree	Fruit weight (g fruit^{-1})	Fruit yield (kg tree^{-1})	TSS (°B)
T_1 : 40kg FYM +200g N	3678	65.00	243.50	22.50
T_2 : 40kg FYM +250g N	3800	65.50	250.00	22.60
T_3 : 40kg FYM +300g N	3966	66.10	262.10	23.50
T_4 : 40kg FYM +350g N	4550	67.00	297.50	23.70
T_5 : 40kg FYM alone	3420	64.50	227.40	25.10
T_6 : 10kg VC +200g N	3715	66.00	245.70	22.50
T_7 : 10kg VC +250g N	3968	66.30	259.90	23.40
T_8 : 10kg VC +300g N	4460	66.50	289.50	23.90
T_9 : 10kg VC +350g N	4820	67.50	310.60	24.40
T_{10}: 10kg VC alone	3600	65.00	236.50	25.50
SEm±	98.6	0.86	5.13	2.93
CD *(p=0.05)*	286.00	2.60	16.40	0.90

VC= Vermicompost

Table 3. Effect of integrating organic manure with inorganic nitrogen on fruit yield in sapota and benefit-cost ratio under various treatments

Treatment	Fruit yield (t ha^{-1} year^{-1})				Benefit:Cost ratio	
	2009-10	2010-11	2011-12	Pooled	2010-11	2011-12
T_1 : 40kg FYM + 200g N	15.6	14.2	24.3	18.03	3.19	3.21
T_2 : 40kg FYM +250g N	17.0	15.6	25.0	19.20	4.80	4.73
T_3 : 40kg FYM +300g N	19.1	17.8	26.2	21.03	5.15	5.00
T_4 : 40kg FYM +350g N	21.9	20.3	29.7	23.97	6.76	5.80
T_5 : 40kg FYM alone	12.7	11.7	22.7	15.70	3.05	3.00
T_6 : 10kg VC +200g N	16.4	14.3	24.5	18.40	3.12	3.10
T_7 : 10kg VC +250g N	17.5	16.3	26.9	20.23	5.06	4.80
T_8 : 10kg VC +300g N	21.7	19.1	28.9	23.24	5.65	5.20
T_9 : 10kg VC +350g N	23.2	21.7	31.1	25.33	6.78	5.96
T_{10}: 10kg VC alone	13.6	11.6	23.7	16.30	3.05	3.00
S Em ±	0.50	0.52	0.70	0.64		
CD *(p=0.05)*	1.35	1.53	1.64	1.61		

VC= Vermicompost

FYM + 350:50:450g NPK tree^{-1}). Fruit yield in sapota increased significantly with increase in dose of nitrogen fertilizer applied together with vermicompost and /or FYM over the years. Benefits accruing from an integrated use of FYM/vermicompost with inorganic fertilizers may be attributed to higher mineralization of soil- and applied N (high PNM rates), leading to a build-up of available N and, therefore, better supply of nutrients, with a conducive physical environment thus leading to better root activity and higher nutrient absorption. This resulted in better tree growth and superior yield attributes, responsible for high yield. Increased fruit weight and fruit yield, due to application of higher levels of nitrogen integrated with organic manure, was also reported by Devashi (2012) and Yadukumar *et al* (2012). Lowest fruit weight (64.5g) and fruit yield (227.4kg) obtained with application of 40kg FYM alone, was most likely due to lower nitrogen content, thereby slower availability of nitrogen without inorganic fertilizers. Highest total soluble solids (TSS) (25.5°B) was obtained with application of 10kg vermicompost alone (T10); but this was on par with the application of 40kg FYM alone (T5). Quality parameters such as TSS (Table 2) improved significantly with application of organic manure, irrespective of the source. This may be due to a gradual and steady release of nutrients during the growth period (Devashi, 2012).

Economics were worked out for a period of two years (2010-11 and 2011-12) (Table 3). The highest net profit in both the years was obtained in plots treated with 10kg vermicompost + 350:50:450g NPK per plant (T9), with benefit:cost ratio of 6.78 and 5.96, respectively. However, this was on par with application of 40kg FYM + 350:50:450g NPK tree^{-1} (T4), with B:C ratio of 6.76 and 5.80, respectively. This suggests that depending on availability of vermicompost and/or FYM, one can apply inorganic fertilizers (350:50:450g NPK tree^{-1}) with the organic manures to meet optimum nutrient requirement for enhancing yield in sapota, as, yield and net profits in these treatments were on par.

Soil available-nutrient status

A perusal of data in Table 4 shows that continuous application of chemical fertilizers with organics resulted in non-significant changes in pH and EC of soil at the end of three years. However, lower pH was observed in plots treated with inorganic fertilizers compared to that with organic manure alone, irrespective of the source. Organic carbon content of the soil increased significantly with application of FYM and /or vermicompost, together with graded doses of NPK fertilizers (Table 4). Application of organics, irrespective of source, showed a positive significant effect on organic carbon content of the soil at the end of three years. Highest build-up of organic carbon in soil was recorded with 10kg vermicompost alone (T10), which was at par with 40kg FYM alone. Addition of FYM and /or vermicompost may have created an environment conducive for formation of humic acid, which ultimately resulted in an increase in organic carbon content in the soil (Hati *et al*, 2007). These results are in agreement with findings of Verma *et al* (2005) and Hazarika *et al* (2011).

Data in Table 4 indicate a slight declining trend (210 to 273kg ha^{-1}) from an initial level (259kg ha^{-1}) of available N status at the end of three years of cropping. The magnitude of decline decreased with increasing levels of nitrogenous fertilizers. However, there was a significant build-up of available N in the soil in treatments T4 and T9 receiving 40kg FYM and 10kg vermicompost, respectively, along with 350:50:450g NPK $tree^{-1}$. Increase in available N may be attributed to enhanced multiplication of microbes by incorporating manures. This, with high dose of N fertilizers, facilitates mineralization of soil N, leading to a build-up of higher available N (Vipan Kumar and Singh, 2010). All the plots that treated with FYM and /or vermicompost along with inorganic fertilizers, had positive significant effect on available P status. Significant reduction in available P status of soil observed in plots receiving FYM alone (T5) or vermicompost alone (T10) occurred due to removal of P by the crop in the absence of any external source of P. Incorporation of FYM and /or vermicompost along with inorganic P increased availability of P to the crop and mineralization of organic P due to microbial action, and, enhanced the mobility of P (Prasad *et al*, 2010). The status of available K increased in all the treatments except in T5 and T10 (Table 4). Highest build-up of available K in the soil was observed in plots receiving 40kg FYM + 350:50:450g NPK $tree^{-1}$ (T4), and 10kg vermicompost + 350:50:450g NPK $tree^{-1}$ (T9). Available K depleted in treatments receiving FYM alone (T5) or vermicompost alone (T10), with no K fertilizer after three years, thus indicating that continuous omission of K in crop nutrition caused mining of the native pools, which resulted in decreased crop yields (Dwivedi *et al*, 2007). Addition of organic manures like FYM or vermicompost along with inorganic fertilizers had a beneficial effect on increasing K availability.

A perusal of data in Table 5 also indicates that addition of organic manures (either FYM or vermicompost alone, or, in combination with inorganic fertilizers) had positive significant effect on concentration of micronutrients in the soil at the end of three years. Incorporation of FYM increased significantly availability of zinc and copper in the soil compared to all other treatments, while, manganese was significantly lower in plots supplied with organic manure, irrespective of source. In the case of iron, no specific trend was observed among treatments. Application of organic manures may have contributed to build-up of these nutrients and led to prevention of fixation of these cations by chelation action of organic compounds released during decomposition of manures. These results are in agreement with those of Devaraja *et al* (1980) and Philip *et al* (2012).

Table 4. Effect of integrating organic manure with inorganic nitrogen on physico-chemical properties of soil after three years

Treatment	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1}) Nitrogen	Phosphorus	Potassium
T_1 : 40kg FYM +200g N	7.85	0.486	6.70	212.34	12.70	395
T_2 : 40kg FYM +250g N	7.77	0.521	7.39	245.80	14.60	545
T_3 : 40kg FYM +300g N	7.91	0.517	8.10	231.22	17.31	383
T_4 : 40kg FYM +350g N	7.86	0.635	7.80	266.36	10.60	720
T_5 : 40kg FYM alone	7.94	0.385	9.00	245.80	9.11	255
T_6 : 10kg VC +200g N	7.90	0.555	7.60	223.12	11.72	420
T_7 : 10kg VC +250g N	7.92	0.423	8.30	254.46	14.00	715
T_8 : 10kg VC +300g N	7.83	0.537	7.40	239.32	18.50	565
T_9 : 10kg VC +350g N	7.70	0.527	8.60	273.12	16.00	615
T_{10}: 10kg VC alone	7.93	0.419	9.30	250.66	6.30	200
SEm±	-	-	0.23	7.81	0.30	13.79
CD *(p=0.05)*	NS	NS	0.66	19.52	0.91	38.48

VC= Vermicompost

Table 5. Effect of integrating organic manure with inorganic nitrogen on concentration of micronutrients in soil after 3 years

Treatment	Micronutrient (mg kg^{-1}) Fe	Mn	Zn	Cu	B
T_1 : 40kg FYM +200g N	3.94	5.44	0.24	0.40	0.23
T_2 : 40kg FYM +250g N	2.72	7.36	0.30	0.40	0.20
T_3 : 40kg FYM +300g N	3.42	6.84	0.28	0.38	0.15
T_4 : 40kg FYM +350g N	2.72	6.78	0.28	0.40	0.15
T_5 : 40kg FYM alone	3.40	5.30	0.32	0.44	0.15
T_6 : 10kg VC +200g N	2.38	6.48	0.22	0.38	0.23
T_7 : 10kg VC +250g N	2.96	6.66	0.28	0.40	0.15
T_8 : 10kg VC +300g N	2.82	7.52	0.26	0.36	0.23
T_9 : 10kg VC +350g N	3.34	8.86	0.26	0.40	0.15
T_{10}: 10kg VC alone	3.18	4.80	0.26	0.38	0.15
SEm±	0.081	0.190	0.061	0.090	0.004
CD *(p=0.05)*	0.24	0.57	0.18	0.27	0.012

VC= Vermicompost

Table 6. Organic matter, total nitrogen, exchangeable Ca, Mg, soil cation exchange capacity and potentially mineralized nitrogen as influenced by integrating organic manure with inorganic N

Treatment	Organic matter (%)	Total nitrogen (%)	Exchangeable Ca (cmol (p+) kg^{-1})	Exchangeable Mg (cmol (p+) kg^{-1})	Soil CEC	Potentially Mineralized Nitrogen (µg N g^{-1})
T_1:40kg FYM +200g N	1.18	0.027	18.58	4.77	24.46	20.06
T_2:40kg FYM +250g N	1.25	0.032	12.63	4.77	18.51	21.83
T_3:40kg FYM +300g N	1.38	0.033	20.03	5.81	26.95	22.16
T_4:40kg FYM +350g N	1.33	0.035	20.78	3.73	25.62	25.35
T_5:40kg FYM alone	1.46	0.041	19.73	3.77	24.61	21.62
T_6:10kg VC +200g N	1.41	0.031	15.80	3.21	20.13	25.91
T_7:10kg VC +250g N	1.36	0.036	21.88	3.73	26.72	27.66
T_8:10kg VC +300g N	1.30	0.036	23.68	4.25	29.05	33.31
T_9:10kg VC +350g N	1.46	0.043	21.78	5.29	28.19	37.70
T_{10}:10kg VC alone	1.53	0.044	22.10	5.29	28.51	26.27
SEm±	0.020	0.001	0.385	0.088	0.636	0.497
CD *(p=0.05)*	0.06	0.003	1.14	0.26	1.91	1.42

VC= Vermicompost

Overall, soil organic matter content significantly increased in plots supplied with organic manure alone (FYM / Vermicompost) (Table 6). This linear increase in organic matter is important in semi-arid conditions where soils are subjected to intense degradation. Other soil properties, directly or indirectly linked to soil organic matter content, also increased with application of organic manure, although this depended on the number of years of application. Our data confirm that the content of total soil nitrogen, and soil cation exchange capacity, were significantly affected due to treatments and showed a linear trend with organic matter. Total soil nitrogen content in the treatments T5 (40kg FYM alone) and T10 (10kg vermicompost alone) were comparable, and this was significantly higher than that in plots receiving chemical fertilizers when these organic manures was applied consecutively for three years. Nonetheless, there was a clear trend in improvement of total soil nitrogen content in plots supplied with increased levels of inorganic nitrogen with organic manures, and, this subsequently reflected in the potentially mineralized nitrogen (Table 6), suggesting an improved labile pool of plant-available nitrogen. Potentially mineralized nitrogen content was higher in treatments receiving inorganic nitrogenous fertilizers than in plots supplied with organic manure alone. This result suggests that organic nitrogen present in FYM and /or vermicompost is resistant to mineralization and, is therefore, retained in the soil. These results further indicate that after continuous application of organic manure, the overall microbial demand for ammonium to be immobilized is higher than that which is nitrified. Therefore, application of FYM or vermicompost alone may result in short-time reduction of nitrogen availability in these soils, suggesting that initial application of the organic manure to the soils should be accompanied by another source of available nitrogen, as evident with potentially mineralized nitrogen, in the present study.

It may be concluded from the present study that fruit yield in sapota increases significantly with application of increased levels of nitrogen fertilizers, integrated with vermicompost and /or FYM over the years. Integrated application of organic manures (40kg FYM or 10kg vermicompost tree^{-1}) with inorganic fertilizers (350:50:450g NPK tree^{-1}) not only produced higher yields in sapota, and higher net profits over the years, but also improved soil fertility compared to application of organic manures alone. Thus, optimum mineral nutrition, in conjunction with organic manures, can play a vital role in exploiting higher yield potential in sapota through a favorable effect on plant-available nutrient supply.

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