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Performance of moringa (*Moringa oleifera*) and soil health under organic nutrition

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ABSTRACT

A field trial was conducted during 2016–17, 2017–18, 2018–19 and 2019–20 at the Main Horticultural Research and Extension Centre, Bagalkot under Northern Dry Zone-3 of the Agroclimatic zones of Karnataka with an intention to study the response of moringa (*Moringa oleifera* L.) crop to different organic sources of nutrients. There were five nutrition treatments, viz. T_1, 100% RDN through FYM; T_2, 100% RDN through vermicompost; T_3, 100% RDN through neem cake; T_4, 1/3 RDN through FYM+1/3 RDN through vermicompost+1/3 RDN through neem cake and; T_5, 50: 125: 30 kg NPK+20 tonnes FYM/ha (RDF) and replicated four times. The treatment T_4 recorded significantly higher green pod yield (87.99 q/ha) which was on par with RDF (83.83 q/ha) and T_3 (82.66 q/ha). However, most of the growth (except height) and yield contributing parameters, in all the organic treatments, were on par with RDF. Application of organic manures helped in improving available nutrients status, including micronutrients in soil. Among the different organic manures, the effect of FYM and VC in increasing the population of rhizosphere microorganisms was more than other treatments. Net return was found more in T_4 (₹124446/ha) followed by T_3 (₹118179/ha) and RDF (₹114079/ha). It was found that organic manure applied in equal proportion (T_4) and 100% substitution of N through neem cake (T_3) was found better in getting higher yield and returns.

Keywords: Moringa, Neem cake, Organic manures, Rhizosphere microorganisms, Soil properties, Vermicompost, Yield

Moringa (*Moringa oleifera* L.) popularly called as drumstick belonging to the family moringaceae is a multipurpose tree crop gaining importance during recent times due to its high nutritional values. Drumstick is a hardy crop and thrives well in all the arid and semiarid tropics. Drumstick is a medium size deciduous nitrogen fixing tree and can be grown in poor soil. The surge in demand for green tender pods is more during festive occasions and marriage functions. It is seven times richer in vitamin C than orange, four times more Ca than milk, four times more vitamin A than carrot, two times more protein than milk and three times more potassium than banana besides rich in iron. Drumstick pods and leaves are also rich in calcium, magnesium, potassium, zinc and iron (Pallavi and Anuja 2019). Hence, leaves, pods and flowers are widely used for culinary and medicinal purposes.

India is the largest producer of drumstick in the world. Andhra Pradesh is the largest drumstick producing state, both in area and production, followed by Karnataka and Tamil Nadu (Babita *et al.* 2019). As the demand for green pods is increasing hence, there is a need to increase the productivity of moringa crop. The consumer preference for organically grown drumstick is also more. The escalating cost of fertilizers and their negative impacts on environment and health are the other reasons which demand for growing drumstick organically. This compels the need for standardization of organic cultivation practices. Crop nutrition plays greater role in increasing the yield and productivity. There was positive response of drumstick crop to organic inputs (vermicompost) and biofertilizers (Abdou *et al.* 2016, Pallavi and Anuja 2019). Organic drumstick production can be sustainable and economically viable (Prabhakar and Hebbar 2007). Hence, the present field investigation was conducted to study the performance of moringa and soil health under various organic sources of nutrients.

MATERIALS AND METHODS

The present study was carried out at Main Horticultural Research and Extension Centre, University of Horticultural Sciences, Bagalkot, Karnataka consecutively for four years (2016–17, 2017–18, 2018–19 and 2019–20) to study the

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performance of moringa and soil health under various organic sources of nutrients. The location of the trial comes under Northern Dry Zone-3 of the Agroclimatic zones of Karnataka which has the climate of semiarid tropics with low rainfall, high temperature and high wind velocity with low soil fertility. The location of the experiment is situated at 16°12' N, 75°45' E and at 542 m amsl. The area receives an average rainfall of 552 mm with average 45 number of rainy days. The soil of the experimental area was well drained loamy soil with *p*H 8.3, EC 0.40 dS/m, OC 0.61% and available nitrogen, phosphorus and potassium were 310, 11.5 and 120 kg/ha, respectively. There were no noticeable pests and diseases affecting the crop however, the same were managed by natural means (use of sticky traps, neem oil etc.). During the first year one cubic feet pits were dug in which mixture of soil and manures were filled. The seeds of the drumstick variety KDM-1 (Bhagya) were sown in a pit of one cubic feet at spacing of 3 m × 3 m during rainy (*kharif)* season in 2016. Crop was irrigated by drip system so as to maintain optimum soil moisture throughout the growth period.

There were five treatments of different organic inputs and their combinations including recommended dose of fertilizer treatment for comparison, viz. T_1, 100% recommended dose of nitrogen (RDN) through farm yard manure (FYM); T_2, 100% RDN through vermicompost (VC); T_3, 100% RDN through neem cake (NC); T_4,1/3 RDN through FYM+1/3 RDN through VC+1/3 RDN through NC and; T_5, 50:125:30 kg NPK+20 tonnes FYM/ha (RDF: recommended dose of fertilizer). All the treatments were replicated four times and were laid out in randomized block design. The treatments were imposed during *kharif* every year. In RDF (T_5), 50% of recommended nitrogen, phosphorus and potassium was applied during *kharif* and remaining 50% was applied three months after the first application. The inputs thus applied were mixed thoroughly in soil. Field was maintained weed free by two to three hand weeding.

Growth and yield observations: All the observations on growth and yield parameters were recorded on five plants tagged for the purpose in each treatment and in all the four replications. Plant height was measured from base of the plant to the tip and expressed in meter. Number of branches and pods in all the five tagged plants in each treatment and in all the three replications were counted manually and averaged to get per plant basis. The pod length (cm) and girth (mm) of all the sizes in a plant were measured and averaged to get per pod basis. Green pods harvested from all the five plants were weighed and averaged to get per plant yield and expressed in kg/plant. Green pod yield per hectare (q) was worked out by taking average per plant yield.

Soil chemical parameters: All the soil parameters were determined after harvest of the crop. The soil *p*H and EC (dS/m) was estimated as per the procedure (Jackson 1973). The soil organic carbon (%) was determined as per the procedure laid down by Walkley and Black (1934). The available nitrogen (Subbiah and Asija 1956) and, available phosphorus and potassium (Jackson 1973) in soil were also determined by following standard procedure. The exchangeable calcium and magnesium were determined by adopting Versanate titration method (Jackson 1973). The available sulphur in soil was extracted by using 0.15% calcium chloride as outlined by Black (1965). After extracting the sulphur by turbidometric method, the turbidity was measured by using UV spectrophotometer at 420 nm. The available micronutrients in soil (Fe, Mn, Cu and Zn) were extracted by using DTPA-extractant as explained by Lindsay and Norwell (1978). The concentration in filtrate was estimated using atomic absorption spectrophotometer (Contra AA-700).

Soil biological parameters: Demography of rhizosphere soil microflora was estimated by serial dilution plate count method (Baruah and Barthakaur 1997). The microbial population was calculated as:

$$\text{Microbial count (CFU per g dry weight of the soil sample)} = \frac{\text{Population means (CFU)}}{\text{Dry weight of soil taken (g)}} \times \text{Dilution factor}$$

The economics including cost of cultivation, gross and net return, and B:C ratio was calculated by taking the prevailing price of inputs and output. The observations recorded were statistically analysed by adopting Fisher's method of analysis of variance (Gomez and Gomez 1984). The level of significance used in 'F' test was at 5%. The mean values were subjected to Duncan's multiple range test (DMRT) using the corresponding means sum of square and degree of freedom values. The data of four years (2016–17, 2017–18, 2018–19 and 2019–20) observations were analysed and presented on pooled basis.

RESULTS AND DISCUSSION

Effect of organic manures on growth and yield attributes: The pooled data of four showed that significantly lower plant height was recorded in treatment T_2 while all other treatments were on par with each other (Table 1). Number of branches per plant was not influenced significantly by different organic manures and was on par with recommended dose of fertilizers (RDF). The yield contributing parameters such as pod length, pod girth, number of pods and pod weight per plant did not differ significantly due to different organic manure treatments and were on par with RDF (T_5). However, yield per hectare was significantly higher in T_4 (87.99 q/ha) which was on par with RDF (T_5) (83.83 q/ha) and T_3 (82.66 q/ha) (Table 1). Significantly lower yield was recorded in T_1 and T_2which might be due to numerically lower number of pods per plant and lower yield per plant recorded in the above treatments. The increase in yield in T_4 treatment over the application of only FYM (T_1) and vermicompost (T_2) was 26 and 21%, respectively. The reduction in yield in T_1 and T_2 over T_5 (RDF) was 20.08 and 15.30%, respectively. Though different organic sources of nutrients and their combination were equally effective in influencing the growth and yield attributes in drumstick but, recommended dose of nitrogen (RDN) applied through neem

Table 1 Growth, yield and economics of moringa as influenced by different organic treatments

Treatment	Growth			Yield attributes and yield					Economics			
	Plant height (m)	No.of branches/ plant	Pod length (cm)	Pod girth (mm)	No.of pods/ plant	Pod weight (g)	Pod yield/ plant (kg)	Pod yield/ha (q)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
T_1	3.58^a	5.56	58.64	24.24	97.27	66.08	6.29	69.81^b	136079	209452	73373	1.54
T_2	3.53^b	5.38	55.54	24.46	101.42	64.08	6.55	72.71^b	150984	218137	67153	1.44
T_3	3.58^a	5.66	55.16	24.71	106.31	68.84	7.44	82.66^a	129793	247972	118179	1.91
T_4	3.57^a	5.34	53.67	24.12	114.84	68.03	7.92	87.99^a	139539	263985	124446	1.89
T_5	3.68^a	5.58	52.08	24.52	118.79	64.96	7.55	83.83^a	137396	251475	114079	1.83
SEm±	0.06	0.10	2.31	0.22	7.20	1.61	0.52	2.41	-	-	-	-
CD (P=0.05)	0.14	NS	NS	NS	NS	NS	NS	7.02	-	-	-	-

Treatment details are given under Materials and Methods.

cake (T_3) and through FYM+VC+NC in equal proportion (T_4) was found better as yields in these treatments were on par with RDF (T_5). There was decrease in yield levels in drumstick over the years, except during 2018–19 in T_3, T_4 and T_5. The positive response of drumstick to organic manures in terms of pod yield and yield attributes were also observed by earlier workers (Prabhakar and Hebbar 2007, Sellamuthu and Malathi 2021). It can be explained that the organic manures applied were able to supply required plant nutrients after mineralization in soil. The organic manures help in soil aggregate formation and their further stability. Enhanced porosity and water holding capacity of the soil might also have favourable influence to support root system through enhanced nutrients flow (Kandil and Gad 2009) which in turn increased the growth and yield of drumstick.

Economics: Higher net returns (₹124446 and ₹118172, respectively) and B:C ratio (1.89 and 1.91, respectively) was found in T_4 and T_3. Higher cost of cultivation, which in turn due to higher cost of vermicompost, might be the reason for lower net returns and B:C ratio in T_2. Hence, net return and B:C ratio was higher in T_3 and T_4 than in T_5 (Table 1).

Soil chemical properties: The soil *p*H and EC after harvest of drumstick was not influenced significantly by different organic treatments and were on par with RDF. However, significantly lower organic carbon content (0.63%) in soil was found in T_4 where equal proportions of all the three organic manures were applied (Table 1). The lower organic carbon content in T_4 might be due to mineralization of applied organic manures which in turn helped in higher yield in the above treatments as a result of more availability of nutrients in the soil. There was 45.9, 39.3, 29.5 and 46.6% increase in soil organic carbon in the treatments T_1, T_2, T_3 and T_5 respectively, compared to the initial organic carbon content (0.61%) in soil indicating the positive influence of organic manures on the improvement in soil organic carbon. Biofertilizer application in moringa also improved the soil organic carbon in some other studies (Youssef 2016). Higher organic carbon content in soil might also be due to decomposition of directly incorporated organic materials in soil (Kumari *et al.* 2019).

Available major and secondary nutrients: All the major and secondary nutrients in soil after harvest, except sulphur, were significantly influenced by the application of different organic manures. The available nitrogen (N) was found significantly lower in T_2 (338.25 kg/ha) while, all other treatments were on par with each other (Table 2). The lower N in soil after harvest in T_2 treatments, where vermicompost was applied, might be due to lower N content, and lower quantity of vermicompost applied. There might be early mineralization and easy uptake by the plants in the above treatments leading to lower available N in soil. The

Table 2 Effect of different organic treatments on *p*H, EC, organic carbon, available major and secondary nutrients in soil after harvest of moringa

Treatment	*p*H	EC (dS/m)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (meq/100g)	Mg (meq/100g)	S (ppm)
T_1	8.35	0.40	0.89^a	359.25^{ab}	15.25^a	162.00^a	10.40^b	6.03^a	19.50
T_2	8.27	0.44	0.85^a	338.25^b	13.00^{bc}	160.25^a	10.43^b	5.58^{ab}	19.00
T_3	8.29	0.43	0.79^a	387.25^a	13.63^b	136.75^{bc}	11.33^a	3.80^c	19.68
T_4	8.30	0.48	0.63^b	396.0^a	12.00^c	153.75^{ab}	9.60^c	4.93^b	19.38
T_5	8.32	0.45	0.87^a	385.0^a	12.13^c	121.75^c	10.7^b	5.00^b	19.68
SEm±	0.027	0.024	0.038	13.0	0.35	7.12	0.19	0.24	0.20
CD (P=0.05)	NS	NS	0.119	39.82	1.11	21.88	0.615	0.751	NS

Treatment details are given under Materials and Methods.

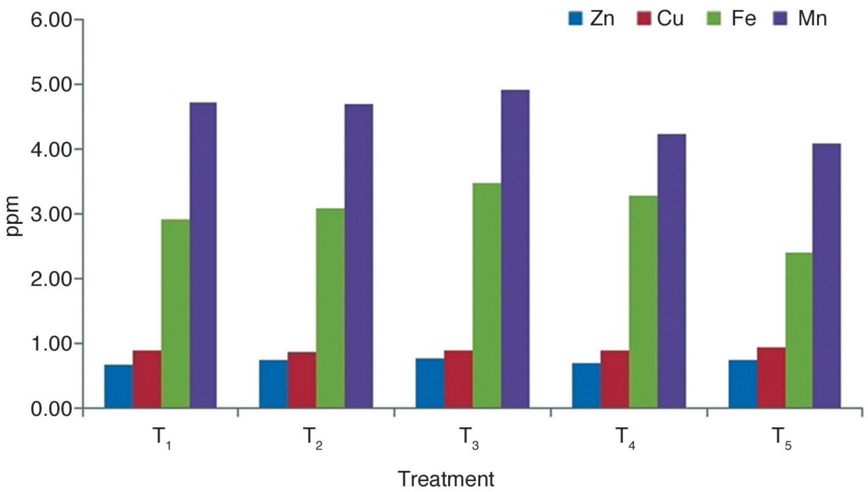

Fig 1 Effect of different organic treatments on the available soil micronutrients status after harvest of moringa.

available phosphorus (P_2O_5) in T_1 and potassium (K_2O) in T_1, T_2 and T_4 in soil was higher after harvest of drumstick. Available nutrients were found higher in RDF than in organic treatments. Higher microbial activity often leads to higher nutrient availability to crops (Tu Cong *et al.* 2006)

Micronutrients status in soil: There was no influence of different organic manures and RDF treatment on the DTPA-extractable zinc (Zn) and copper (Cu) status in soil after harvest of the crop. However, iron (Fe) and manganese (Mn) in soil was significantly influenced by different treatments. Except RDF, organic manure treatments were found on par with each other in respect of Fe availability in soil. But, Mn availability in soil was found significantly lower in T_4 and T_5 while, other treatments were on par with each other (Fig 1). As lesser quantity of manure was applied in T_4 and T_5, compared to other treatments, obviously lesser Fe and Mn was observed in the above treatments.

Rhizosphere microorganisms: Significantly higher number of bacteria, fungi, actinomycetes, phosphate solubilizing bacteria (PSB) and free living N_2 fixers were found in T_1 and T_2 compared to other treatments. But, all the above rhizosphere microorganisms were found significantly lower in T_3. Over the treatment T_5, the increase in the population of bacteria, fungi, actinomycetes, PSB and free living N_2 fixers in T_1 (1.6, 28, 3.2, 7.6, and 40%, respectively) and T_2 (8.3, 32, 7.4, 9.3 and 48%, respectively) was more as compared to other organic treatments. But, over the treatment T_3, the per cent increase in bacteria, fungi, actinomycetes, PSB and free living N_2 fixers in T_1 was 72, 60, 32.7, 120 and 66.7 and in T_2 it was 83.2, 65, 38.1, 123.8 and 76.2, respectively (Table 3). Higher number of beneficial microbial population in the rhizosphere in T_1 and T_2 might be due to favourable effect of FYM and vermicompost on the growth and development of microorganisms. Vermicompost helps in increasing microbial activity and enzyme production which in turn helps in enhancing aggregate stability of soil particles and binding of minerals (Ca, Mg and K) in the form of colloids of humus (Abdul 2008).

Soil organic matter stimulates soil microbial population and soil microbial activity (Bibhuti and Dkhar 2012). The microorganisms, especially N fixers and P solubilizers, tend to improve available nutrients and soil health (Pallavi and Anuja 2019). The FYM and vermicompost provided congenial soil environment in terms of providing food substrate, moisture and good aeration for the optimal growth of microorganisms. There exists a positive correlation between organic matter and microorganism population (Singh and Dhar 2011, Bhattarai *et al.* 2015). Contrarily, neem cake did not encourage the growth of rhizosphere microorganisms. This might be due to the inhibitory effect of neem cake on the growth of microbes (Elnasikh *et al.* 2011).

It can be inferred that the organic manures applied in equal proportion through FYM, VC and NC (T_4) and neem cake application (T_3) gave yield on par with RDF but, higher than application of FYM and VC alone (100% N equivalent). Application of organic manures helped in improving available nutrients status, including micronutrients in soil.

Table 3 Rhizosphere microorganisms in soil of moringa crop as influenced by different organic treatments

Treatment	Bacteria (No.×10^6 CFU/g of soil)	Fungi (No.×10^3 CFU/g of soil)	Actinomycetes (No.× 10^4 CFU/g of soil)	PSB (No.× 10^4 CFU/g of soil)	Free living N_2 fixers (No.× 10^4 CFU/g of soil)
T_1	4.92[a]	1.28[a]	2.23[a]	1.85[a]	1.40[a]
T_2	5.24[a]	1.32[a]	2.32[a]	1.88[a]	1.48[a]
T_3	2.86[d]	0.80[d]	1.68[d]	0.84[c]	0.84[c]
T_4	3.52[c]	1.20[c]	1.89[c]	1.68[b]	1.04[b]
T_5	4.84[b]	1.00[b]	2.16[b]	1.72[b]	1.00[b]
SEm±	0.12	0.04	0.06	0.05	0.06
CD (P=0.05)	0.37	0.14	0.18	0.15	0.18

Treatment details are given under Materials and Methods. CFU, Colony forming units; PSB, Phosphate solubilizing bacteria.

The effect of FYM and VC in increasing the population of rhizosphere microorganisms was more than other treatments. Hence, substitution of recommended nitrogen (100%) by different organic manures in equal proportion (T_4) and 100% substitution of N through neem cake (T_3) were found better in getting higher yield and returns, and improving the soil health.

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