International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(2): 1714-1718
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Received: 04-01-2019
Accepted: 08-02-2019

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Impact of integrated application of vermicompost, farmyard manure and chemical fertilizers on okra (*Abelmoschus esculentus* L.) performance and soil biochemical properties

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Abstract
A field experiment was conducted to investigate the effect of organic manures *viz.* vermicompost and farmyard manure (FYM) in combination with inorganic fertilizers on yield, nutrient uptake by okra (*Abelmoschus esculentus* L.) and on soil biochemical properties in Inceptisol for consecutive two years. The treatments were: T_1- control; T_2 - 100% NPK alone; T_3 - 100% NPK + 5 t FYM ha^{-1}; T_4 - 100% NPK + 10 t FYM ha^{-1}; T_5 - 100% NPK + 5 t vermicompost ha^{-1}; T_6 - 100% NPK + 10 t vermicompost ha^{-1}. The highest yield of okra was recorded under T_6 during both the years. The treatments with the same quantity of vermicompost recorded higher yield in comparison to FYM. The application of FYM @ 10 t ha^{-1} (T_4) recorded 15 and 17% increase in fruit yield of okra over 100% NPK (T_2) during 2012 and 2013, respectively, whereas vermicompost @10 t ha^{-1} (T6) recorded 33 and 34% increased fruit yield. Furthermore, yield of okra obtained with 5 t vermicompost ha^{-1} plus 100% NPK (T_5) during both the years was at par with that received under 10 t FYM ha^{-1} plus 100% NPK (T_4) demonstrating superiority of vermicompost over FYM. Application of vermicompost @ 10 t ha^{-1} (T_6) also increased N uptake over 100% NPK alone (T_2) by 64 and 68% by okra during both the consecutive years, respectively. The corresponding increase in P uptake was 108 and 88% whereas in case of K, it was 85 and 128%. The highest soil available N, P and K content was observed with T_6, as 300, 27.7 and 340 kg ha^{-1}. The treatment T_6 also increased organic carbon content over 100% NPK treated plots (T_2) by 61%. Microbial population increased by 147% cfu × 10^{-4} and 72% cfu × 10^{-4} in T_6 over control and T_2, respectively. Soil microbial biomass varied considerably among treatments and ranged from 43 to 146 mg kg^{-1}. The highest microbial biomass was recorded in T_6 with 74% increase over control. Phosphatase activity exhibited increasing trend with the application of both FYM and vermicompost and the highest value was observed in T_6. NPK fertilizers recorded significantly higher phosphatase activity and it increased by 27% over control, but it was almost similar with vermicompost at 5 t ha^{-1} (T_5). Use of chemical fertilizers alone i.e. 100% NPK exhibited a lower dehydrogenase activity compared with conjoined use of inorganic and organic treatments.

Keywords: Vermicompost, farmyard manure, chemical fertilizers, okra, yield, nutrient uptake and soil biochemical properties

Introduction
Use of chemical fertilizers alone increases the crop yields in the initial years but adversely affects the sustainability at later stage**.** Okra is a fast growing annual which has captured a prominent position among the vegetables in India for its immature fruits which are eaten as cooked vegetable and dried seeds contain up to 20% protein (Lyngdoh *et al.,* 2013) [9]. Indiscriminate use of inorganic fertilizers leads to nutrient imbalance in soil causing ill effect on soil health and microflora. Integrated use of organic and inorganic fertilizers can improve crop productivity (Mal *et al.,* 2013) [10]. There is an urgent need to develop nutrient management package involving use of renewable resources of plant nutrients locally available to the farmers. Although FYM is commonly used organic manure but is not adequately available. The huge amounts of farm wastes can be recycled effectively by preparing vermicompost (Sanjay-Swami, 2012). Vermicompost application improves bulk density, water holding capacity, and humic substances of the soil (Sanjay-Swami and Bazaya, 2010) [13]. Its application also improves soil biology by increasing population of beneficial microbes, enzyme activities, and enhancing hormone concentration in optimum range (Sharma and Garg, 2017) [14]. However, there is a lack of information regarding the performance of vermicompost

and farm yard manure in relation to productivity and fertility of soil particularly under okra crop grown in Inceptisol under Sub-tropical zone of Jammu, Jammu & Kashmir. Moreover, the field evaluation of vermicompost in vegetable crops is important as the farmers are diversifying from cereals to vegetables. The present study was undertaken with the objective to study the performance of vermicompost and FYM in combination with chemical fertilizers on okra and soil biochemical properties.

Materials and Methods

The experiment was conducted during year 2012 and 2013 at the Research Farm of Sher-e-Kashmir University of Agriculture Sciences & Technology of Jammu. The soil was sandy loam in texture with pH 6.9 (1:2.5 soil to water); organic carbon 7.6g kg^{-1}; cation exchange capacity 10.3 cmol (p+) kg^{-1}; available N, P and K 208, 15.2 and 134 kg ha^{-1}, respectively. The experiment was laid out in a randomized block design with three replications taking okra as test crop (cv. Arka Anamica). The treatments consists of T_1- control; T_2- 100% NPK alone; T_3- 100% NPK + 5 t FYM ha^{-1}; T_4- 100% NPK + 10 t FYM ha^{-1}; T_5- 100% NPK + 5 t vermicompost ha^{-1} and T_6- 100% NPK + 10 t vermicompost ha^{-1}. Organic manures i.e. FYM and vermicompost were applied as pre treatment. The vermicompost was prepared using crop residues and earthworm *Eisniea foetida* and it contained 1.80% N, 1.0% P and1.0% K whereas FYM contained 0.55% N, 0.47% P and 0.60% K. The recommended dose of NPK for okra was 60, 30 and 30 kg ha^{-1}, respectively. Full dose of FYM, vermi-compost along with chemical fertilizers of P, K and half dose of N were given at the time of transplantation of the crop. Nitrogen was applied through urea, P through single superphosphate and K through muriate of potash. The crop was raised following recommended package of practices under subtropical conditions. The row to row and plant to plant distance was maintained at 45 and 15 cm for okra. The uptake of nutrients (NPK) was calculated from data on concentration (%) of the given nutrient multiplied by the corresponding dry matter yield. The soil samples were collected at the end of experimentation to determine soil organic carbon, available N, P and K as per standard methods given by Walkley and Black (1934) [21], Subbiah and Asija (1956) [19] and Olsen *et al.* (1954) [11], respectively. Microbial population was determined by plate count method of Wollum (1982) [22] through serial dilution using respective media. Dehydrogenase and phosphatase activities were determined by Klein *et al.*, (1971) [7] and Tabatabai and Bremner (1969) [20] and MBC by Jenkinson and Powlson (1976) [6]. The data were statistically analyzed as per the procedure outlined by Gomez and Gomez (1984) [3].

Results and discussion

Yield of okra

Okra produced significantly higher yield under all the treatments over control during both the years (Figures 1). Further, the yield was significantly superior under the conjoint use of organic manure and chemical fertilizers over the sole use of chemical fertilizers. The highest yield of okra was recorded under T_6 during both the years. The increase in yield was much higher with the equal amounts of vermicompost in comparison to FYM. The application of FYM @ 10 t ha^{-1} in (T_4) recorded 15 and 17% increase in fruit yield of okra over 100% NPK (T_2) during year 2012 and 2013, respectively, whereas the use of vermicompost @10 t ha^{-1} (T_6) was 33 and 34%. The beneficial effect of organic manures on yield might be due to additional supply of plant nutrients as well as improvement in physical and biological properties of soil (Datt *et al.*, 2003, Konyak and Sanjay-Swami, 2018) [2, 8]. It could also be attributed to the fact that after decomposition and mineralization, the manures supplied available nutrients directly to plants and also had solubilizing effect on fixed form of nutrients (Sinha *et al.*, 1981) [18]. Yield of okra obtained with 5 t vermicompost ha^{-1} plus 100% NPK at T_5 (7.82 and 7.92 t ha^{-1} during 2012 and 2013) was at par with that obtained under 10 t farmyard manure ha^{-1} plus 100% NPK at T_4 with 7.32 and 7.68 t ha^{-1}. This demonstrated the superiority of vermicompost over farmyard manure in okra crop. The similar results were also obtained by Konyak and Sanjay-Swami (2018) [8] in cabbage.

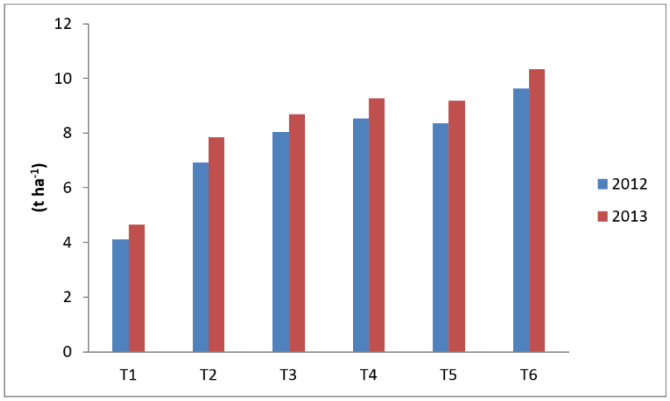

Fig 1: Effect of integrated use of organic manures and fertilizers on yield (t ha^{-1}) of okra

Nutrient concentration

Application of chemical fertilizers, either alone or in combination, with organic manures *viz.* farmyard manure and vermicompost increased the N, P and K content in okra significantly and consistently over control (Table 1). Highest content of N, P and K in okra fruit was recorded in case of 100% NPK + 10 t vermicompost ha^{-1}. When equal doses of vermicompost and farmyard manure were applied, the contents of N, P and K were significantly higher in case of vermicompost in okra during both the years. The higher contents of N, P and K in okra due to the application of vermicompost may be attributed to better supply of nutrients through this manure. These results corroborate the findings of Sharma *et al.*, (2017) [14] and Konyak and Sanjay-Swami (2018) [8].

Table 1: Effect of integrated use of organic manures and chemical fertilizers on nutrient concentration (%) of okra fruit

Treatment	2012			2013		
	N	P	K	N	P	K
T1	1.72	0.38	0.40	1.88	0.42	0.47
T2	2.43	0.46	0.45	2.58	0.50	0.51
T3	2.56	0.50	0.48	2.68	0.54	0.56
T4	2.73	0.56	0.51	3.05	0.57	0.60
T5	3.06	0.62	0.54	3.09	0.56	0.62
T6	3.20	0.61	0.56	3.48	0.59	0.64
CD (P=0.05)	0.12	0.04	0.03	0.20	0.03	0.02

Nutrient uptake

Nutrient uptake by okra increased significantly and consistently with the integrated use of organic manures and chemical fertilizers over control (Table 2). Nutrient uptake increased significantly with increasing levels of

vermicompost as well as farmyard manure. Application of vermicompost @ 10 t ha^{-1} (T_6) increased N uptake over 100% NPK alone (T_2) by 64 and 68% in okra during year 2012 and 2013, respectively. The corresponding increase in P uptake was 108 and 88% in okra. In case of K uptake, the respective increase was 85and 128% in okra. These results are in consonance with the findings of Sharma *et al.,* (2003) [2, 15].

Table 2: Effect of integrated use of organic manures and chemical fertilizers on nutrient uptake (kg ha^{-1}) by okra

Treatment	2012			2013		
	N	P	K	N	P	K
T1	28.8	4.28	6.22	19.9	3.04	5.64
T2	46.2	7.19	10.92	47.92	8.02	11.13
T3	54.2	9.52	13.32	55.24	10.02	18.24
T4	64.23	11.32	16.23	66.32	12.45	22.46
T5	63.98	12.0	18.02	71.8	13.24	22.52
T6	76.0	15.01	20.29	80.9	15.14	25.41
CD (P=0.05)	3.2	1.02	1.59	2.6	0.91	2.51

Soil fertility build-up

Organic carbon

Organic carbon content in the soil increased significantly in the plots that had received organic manures (either vermicompost or farmyard manure) plus chemical fertilizers than in the plots that had received chemical fertilizers alone (Table 3). Application of vermicompost @ 10 t ha^{-1} (T_6) increased the organic carbon content over 100% NPK-treated plots (T_2) by 61%. At a given level, the increase in organic carbon content was more in case of vermicompost as compared to farmyard manure. The increase in organic carbon content may be attributed to addition of organic materials and better root growth. These observations are in agreement with the findings of Sharma *et al.,* (2005) [16].

Available nitrogen: The treatment comprising of 10 t ha^{-1} vermicompost plus 100% recommended NPK (T_6) maintained highest available nitrogen content of 300 kg ha^{-1} after completion of the experiment (Table 3). This treatment (T_6) increased available nitrogen content over 100% NPK alone (T_2) by 30%. Application of chemical fertilizer alone (T_2) did not improve the nitrogen content significantly over control (T_1). Increase in available nitrogen with vermicompost or farmyard manure application might be attributed to the direct addition of nitrogen through vermicompost and farmyard manure to the available pool of the soil. Sharma *et al.,* (2005) [16] noticed enhancement in available N content of soil with the use of organics in Entisol.

Available phosphorus: Significantly higher available P contents were recorded in the plots receiving organic manures *viz*. vermicompost or farmyard manure, besides NPK than in the plots which had received chemical fertilizers alone (Table 3). Application of vermicompost @ 10 t ha^{-1} increased the available phosphorus content over 100% NPK alone (T_2) by 53%. Different treatments maintained slightly higher available P status than control. Levels of vermicompost or farmyard manure did not differ significantly among each other. The increase in available P content of soil due to the incorporation of organic manures may be attributed to the direct addition of P as well as solubilization of native P through release of various organic acids. Similar improvement in available P status due to integrated use of manures and fertilizers has been noted by Sharma *et al.,* (2005) [16].

Table 3: Effect of integrated use of organic manures and chemical fertilizers on physico-chemical and microbial properties of soil after harvesting of okra

Treatment	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1})			Microbial properties		
		N	P	K	Dehydrogenases activity µg TPF g^{-1} h^{-1}	Acid Phosphatase activity µgpNP g^{-1} h^{-1}	Microbial Biomass Carbon mg kg^{-1}
T1	7.3	201	14.0	130	2.34	62.50	43
T2	8.3	227	18.1	166	6.50	85.32	84
T3	10.1	235	22.0	216	8.20	92	96
T4	11.4	258	23.1	264	9.14	98	116
T5	11.8	267	25.1	267	10.32	102	134
T6	13.4	300	27.7	340	11.64	108	146
CD (P=0.05)	1.0	27	3.2	22	0.24	0.20	7

Available potassium

The available potassium content differed significantly due to various levels of organics in combination with inorganic fertilizers (Table 3). Like available nitrogen and phosphorus, highest available K content (340 kg ha^{-1}) was recorded in case of the treatment consisting of 10 t vermicompost ha^{-1} plus 100% recommended dose of NPK (T_6). This treatment (T_6) registered an increase in available potassium content over 100% NPK alone (T_2) to the extent of 104%. The beneficial effect of vermicompost and farmyard manure on available K status may be ascribed to the direct potassium addition in the potassium pool of the soil. Sharma *et al.,* (2003) [2, 15] also recorded higher contents of available K under conjoint use of organics and fertilizers than the sole use of fertilizers under high hills dry temperate conditions of North-Western Himalayas. It suggests that the vermicompost release nutrients slowly and steadily into the soil and enables the plants to absorb the available nutrients as reported by Ansari (2008) [1].

Biological properties

Microbial biomass plays a critical role in regulating the carbon and nitrogen bio-geochemical processes in the soil and the size of microbial biomass pool is strongly influenced by soil management practices. Soil microbial biomass varied considerably among treatments and ranged from to 43 to 146 mg kg^{-1} (Table 3). The highest microbial biomass was recorded with T_6 treatment and exhibited 74% increase over control. NPK fertilizer exhibited higher biomass carbon than control but was almost similar to vermicompost at T_5 treatment. The addition of vermicompost has increased MBC and is related to the decomposition of these materials which is important for proliferation of microorganism in soil. Phosphatase activity exhibited increasing trend with the application of both FYM and vermicompost and the highest value was observed in T_6 treatment. NPK fertilizers recorded significantly higher phosphatase activity and increased by 27% than control, but it was almost similar with vermicompost at 5 t ha^{-1} in T_5 treatment. Similarly

dehydrogenase activity increased at all treatments over control. Use of chemical fertilizer i.e. 100% NPK exhibited a lower dehydrogenase activity compared with conjoined use of inorganic and organic treatments. The inorganic source of nutrient simulated the activity of microorganisms to utilize the native pool of organic carbon as a source of carbon, which acts as substrate for dehydrogenase activity. Secondly, the addition of nitrogen doses solely and partially through chemical fertilizers resulted in accumulation of nitrate in soil, thus inhibiting the activity of enzyme through interfering in the process of electron acceptors as reported by Goyal *et al.*, (1992) [4].

Microbial population was increased with the use of both organic and chemical fertilizer. The total microbial population increased under all the treatments over control during both the years (Table 4). Microbial population increased by 147% cfu $\times 10^{-4}$ in T_6 over control while the increase recorded was 72% cfu $\times 10^{-4}$ in T_6 over T_2. Most of the soil microorganisms are chemo-autotrophs which require organic source of carbon as food and oxidation of organic substances provides energy which might be the reason in improving microbial population in soils applied with organics (Ingle *et al.*, 2014) [5].

Table 4: Effect of integrated use of organic manures and chemical fertilizers on microbial population in soil (cfu*$\times 10^4$ g^{-1}) after harvesting of okra

Treatment	Rhizosphere soil			Bulk soil		
	Bacterial Population	Fungal Population	Total Population	Bacterial Population	Fungal Population	Total Population
T1	70	35	137	62	30	113
T2	90	47	164	84	41	142
T3	96	54	184	91	48	178
T4	113	65	230	106	58	214
T5	125	74	267	118	69	247
T6	137	86	295	125	81	279
CD (P=0.05)	5.1	2.2	4.1	4.0	3.2	3.0

cfu*-- colony forming unit

Conclusion

Integrated use of organic manures *viz.*, FYM and vermicompost along with chemical fertilizers increased the yield, content and uptake of NPK by okra significantly over sole use of chemical fertilizers. Substantial improvement was recorded in residual soil fertility as the contents of organic carbon, available nitrogen, phosphorus and potassium were significantly higher in case of the plots receiving either FYM or vermicompost in combination with chemical fertilizers than the plots which had received chemical fertilizers alone. It can be concluded from the study that vermicompost @ 10 t ha^{-1} in combination with 100% NPK is the best suitable option for getting maximum production of okra and maintaining soil health of Inceptisol under Sub-tropical zone of Jammu.

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