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Soil enzymes, microbial biomass carbon and microbial population as influenced by integrated nutrient management under onion cultivation in sub-tropical zone of Jammu

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Abstract
A field trial was conducted for two consecutive years to evaluate onion (*Allium cepa* L.) performance, soil fertility build-up and estimation of soil enzymes, soil microbial biomass and microbial population under integrated nutrient management with two organic manures *viz.* vermicompost and farmyard manure (FYM) in combination with NPK fertilizers in sub-tropical zone of Jammu. The treatments tested were: T_1- control; T_2 - 100% NPK alone; T_3 - 100% NPK + 12.5 t FYM ha^{-1}; T_4 - 100% NPK + 25 t FYM ha^{-1}; T_5 - 100% NPK + 12.5 t vermicompost ha^{-1}; T_6 - 100% NPK + 25 t vermicompost ha^{-1}. The maximum onion yield was recorded with the application of 100% NPK + 25 t vermicompost ha^{-1} (T_6) during both the years i.e. 9.63 and 10.34 t ha^{-1}. The application of FYM @ 25 t ha^{-1} (T_4) recorded 23 and 18% increase in yield of onion over 100% NPK alone (T_2) during 2012-13 and 2013-14, respectively, whereas vermicompost @ 25 t ha^{-1} (T_6) recorded 39 and 31% increased onion yield. A comparison between FYM and vermicompost receiving treatments revealed that the treatments receiving same quantity of vermicompost recorded higher yield in comparison to FYM. Furthermore, yield of onion obtained with 12.5 t vermicompost ha^{-1} plus 100% NPK (T_5) during both the years was at par with that received under 25 t FYM ha^{-1} plus 100% NPK (T_4) demonstrating superiority of vermicompost over FYM. Application of vermicompost @ 25 t ha^{-1} plus 100% NPK (T_6) also increased N uptake over 100% NPK alone (T_2) by 120 and 138% by onion during both the consecutive years, respectively. The corresponding increase in P uptake was 164 and 130% whereas in case of K, it was 112 and 171%. The highest soil available N, P and K content was observed with T_6, as 296, 25.7 and 343 kg ha^{-1}. The treatment T_6 also increased organic carbon content over 100% NPK treated plots (T_2) by 58%. Microbial population increased by 149% cfu $\times 10^{-4}$ and 70% cfu $\times 10^{-4}$ in T_6 over control and T_2, respectively. Soil microbial biomass varied considerably among treatments and ranged from 41 to 143 mg kg^{-1} and the highest microbial biomass was recorded in T_6. Phosphatase activity exhibited increasing trend with the application of both FYM and vermicompost and the highest value was observed in T_6. NPK fertilizers alone recorded significantly higher phosphatase activity and it increased by 36% over control. Use of chemical fertilizers alone i.e. 100% NPK exhibited a lower dehydrogenase activity compared with conjoined use of inorganic and organic treatments.

Keywords: Integrated nutrient management, onion, yield and soil biochemical properties

Introduction
Onion (*Allium cepa* L.) is the second most important commercial crops of the India, next to potato. Globally, it is grown in about 5.30 million hectare area with an annual production of 88.48 million tons with productivity 16.70 tons per hectare. China stands first in the onion production (22.61 million tons from an area 1.03 million hectares area) in the world with productivity 21.85 tons per hectare followed by India. During 2016-17, India had produced 22.4 million tones of onion crop to which Jammu and Kashmir contributed only 0.31 per cent producing 0.069 million tons (MoA&FW, GoI, 2018) [1].

Onion is a highly nutrient-responsive crop. Continuous use of inorganic fertilizers alone tends to reduce the crop yields over time by affecting the soil properties, depleting micronutrients and organic matter. Depletion of soil micronutrients resulted in deficiency of micronutrients, while the reduction of soil organic matter affected the water holding capacity, soil structure, water infiltration and increased soil compaction (Dutta *et al.*, 2003) [2]. Soil organic matter is a key component as it influences soil biological, physical and chemical properties that define soil quality (Doran and Parkin, 1994; Sanjay-Swami and Bazaya, 2010; Sanjay-Swami, 2012) [3,4,5] and acts as a reservoir of plant nutrients and serves as a substrate for soil microorganisms (Dutta *et al.*, 2003) [6]. Good soil condition for crop growth not only related to its ability to produce healthy and abundant crops but also includes the soil's capacity to function as a

mature and sustainable agro-ecosystem (Trasar-Cepeda *et al.*, 2008) [7]. Soil enzymatic activities have been proposed as appropriate indicators because of their intimate relationship to soil biology and rapid response to changes in nutrient management. Microbial biomass provides an insight into the composition and activity of microorganisms and signifies the main source of soil enzymes.

As onion is a heavy feeder of nutrients, addition of organic manures is essential for restoring soil quality and sustaining production. However, application of organic manures alone improves soil health, whereas, the bulb-yield in organic systems was reduced by 22-45% over inorganic system (Lawande *et al.*, 2009) [8]. Therefore, nutrient management practices involving organic manures and chemical fertilizers are essential for increasing the bulb yield and for maintaining soil health. It is also important to understand how soil biological properties respond to integrated management of nutrients in onion. Estimations of soil enzymes, soil microbial biomass and, microbial population are the primary phase in characterizing soil metabolic potential, fertility and quality, as well as pondering guidance to the resilience of the soil (Schloter *et al.*, 2003) [9]. As little information is available on the combined effect of NPK and organic manures on onion, this study was undertaken to evaluate the performance of onion, soil fertility build-up and estimation of soil enzymes, soil microbial biomass and microbial population under integrated nutrient management with two organic manures *viz.* vermicompost and farmyard manure (FYM) in combination with NPK fertilizers in sub-tropical zone of Jammu.

Materials and methods

The experiment was conducted during year 2012-13 and 2013-14 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 onion as test crop (cv. N-53). The treatments consists of T_1- control; T_2- 100% NPK alone; T_3- 100% NPK + 12.5 t FYM ha^{-1}; T_4- 100% NPK + 25 t FYM ha^{-1}; T_5- 100% NPK + 12.5 t vermicompost ha^{-1} and T_6- 100% NPK + 25 t vermicompost ha^{-1}. Organic manures i.e. FYM and vermicompost were applied as pre treatment. The vermi compost 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 onion was 125, 32.7 and 50 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 sub-tropical conditions of Jammu. The row to row and plant to plant distance was maintained at 15 and 08 cm for onion. 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) [10], Subbiah and Asija (1956) [11] and Olsen *et al.*, (1954) [12], respectively. Microbial population was determined by plate count method of Wollum (1982) [13] through serial dilution using respective media. Dehydrogenase and phosphatase activities were determined by Klein *et al.*, (1971) [14] and Tabatabai and Bremner (1969) [15], and microbial biomass carbon (MBC) by Jenkinson and Powlson (1976) [16]. The data were statistically analyzed as per the procedure outlined by Gomez and Gomez (1984) [17].

Results and discussion

Yield of onion

Onion produced significantly higher yield under all the treatments over control during both the years (Fig. 1). Further, the yield was significantly superior under the conjoint use of organic manure and chemical fertilizers over sole use of chemical fertilizers. The highest yield of onion was recorded under T_6 during both the years. The increase in yield was much higher when equal amounts of vermi compost were applied in place of FYM. The application of FYM @ 25 t ha^{-1} (T_4) recorded 23 and 18% increase in onion yield over 100% NPK (T_2) during 2012-13 and 2013-14, respectively, whereas the use of vermi compost @ 25 t ha^{-1} (T_6) recorded 39 and 31% increased yield. 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) [18, 19]. 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) [20]. Yield of onion obtained with 12.5 t vermicompost ha^{-1} plus 100% NPK at T_5 (8.36 and 9.18 t ha^{-1} during 2012-13 and 2013-14) was statistically at par with that obtained under 25 t farmyard manure ha^{-1} plus 100% NPK at T_4 as 8.53 and 9.26 t ha^{-1}. This demonstrated the superiority of vermicompost over farmyard manure in onion crop. The higher yield of vegetable crops with the use of vermicompost in comparison to FYM may be ascribed to higher nutrient content of vermicompost. The similar results were also obtained by Reddy *et al.*, (1998) [21] in pea and Konyak and Sanjay-Swami (2018) [22] in cabbage.

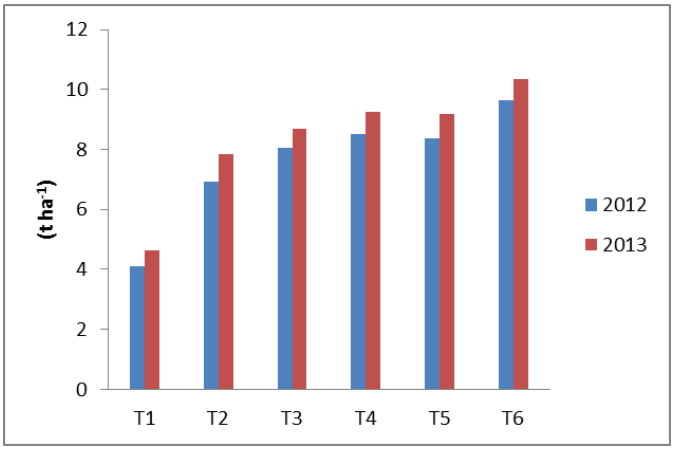

Fig 1: Effect of integrated use of organic manures and chemical fertilizers on onion yield (t ha^{-1})

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 concentration in onion significantly and consistently over control (Table 1). Highest concentration of N, P and K in onion was recorded with the application of 100% NPK + 25 t vermicompost ha-1. When equal doses of vermi compost and farmyard manure were applied, the concentration of N, P and K were recorded

significantly higher in the treatments receiving vermicompost in onion during both the years. The higher contents of N, P and K in onion 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) [23] and Konyak and Sanjay-Swami (2018) [24].

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

Treatments	2012-13			2013-14		
	N	P	K	N	P	K
T1	1.28	0.12	0.81	1.24	0.15	0.78
T2	1.24	0.25	1.13	1.20	0.22	0.91
T3	1.45	0.28	1.19	1.48	0.25	1.04
T4	1.52	0.30	1.26	1.56	0.27	1.05
T5	1.68	0.37	1.42	1.80	0.30	1.08
T6	1.97	0.40	1.52	2.16	0.32	1.34
CD (P=0.05)	0.09	0.04	0.05	0.08	0.04	0.09

Nutrient uptake

Nutrient uptake by onion 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 vermi compost as well as farmyard manure. Application of vermi compost @ 25 t ha^{-1} (T_6) increased the N uptake over 100% NPK alone (T_2) by 120 and 138% in onion during 2012-13 and 2013-14, respectively. The corresponding increase in P uptake was 164 and 130% in onion. In case of K uptake, the respective increase was 112 and 171% in onion. These data signify the importance and need of integrated nutrient supply system for onion. These results are in consonance with the findings of Sharma *et al.,* (2003) [25].

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

Treatments	2012-13			2013-14		
	N	P	K	N	P	K
T1	6.26	0.68	3.98	6.02	0.88	4.02
T2	13.2	2.27	11.37	20.19	3.12	11.12
T3	17.13	3.42	14.58	25.36	4.32	18.09
T4	22.01	4.46	19.28	30.28	5.29	20.48
T5	22.14	4.39	19.42	35.13	5.98	21.12
T6	29.12	6.01	24.12	48.18	7.19	30.17
CD (P=0.05)	1.08	0.52	1.30	1.92	0.43	1.56

Soil fertility build-up

Organic carbon: Organic carbon content in the soil increased significantly in the plots that had received organic manure (either vermi compost or farmyard manure) plus chemical fertilizers than in the plots that had received chemical fertilizers alone (Table 3). Application of vermicompost @ 25 t ha^{-1} to okra (T_6) increased the organic carbon content over 100% NPK-treated plots (T_2) by 58%. 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) [26].

Available nitrogen: The treatment comprising of 25 t ha^{-1} vermicompost plus 100% recommended NPK to onion (T_6) maintained highest available nitrogen content of 296 kg ha^{-1} after the 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) [27] also noticed enhancement in available N content of soil with the use of organics in Entisol of Himachal Pradesh.

Available phosphorus: Significantly higher available P contents were recorded in the plots receiving organic manures *viz.* vermicompost or farmyard manure in combination with NPK than in the plots which had received chemical fertilizers alone (Table 3). Application of vermi compost @ 25 t ha^{-1} to onion (T_6) increased the available phosphorus content over 100% NPK alone (T_2) by 43%. Different treatments maintained slightly higher available P status than control. Levels of vermi compost 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) [28].

Table 3: Effect of integrated use of organic manures and chemical fertilizers on soil fertility build-up

Treatments	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1})		
		N	P	K
T1	7.5	203	13.8	126
T2	8.6	228	18.0	160
T3	10.4	233	21.8	214
T4	11.7	255	22.8	260
T5	12.2	262	24.9	262
T6	13.6	296	25.7	343
CD (P=0.05)	1.02	26.8	3.12	23

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 (343 kg ha^{-1}) was recorded with the treatment T_6 consisting of 25 t vermi compost ha^{-1} plus 100% recommended dose of NPK to onion. This treatment (T_6) registered an increase in available potassium content over 100% NPK alone (T_2) to the extent of 114%. The beneficial effect of vermi compost 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) [29] also recorded higher contents of available K under conjoint use of organics and chemical fertilizers than the sole use of chemical fertilizers under high hills dry temperate conditions of North-Western Himalayas. It suggests that vermicompost released nutrients slowly and steadily into the soil and enables the plants to absorb the available nutrients as reported by Ansari (2008) [30].

Soil biological properties

Soil dehydrogenase (DH) involved in oxidative phosphorylation, and is an important indicator of microbial activity in the soil which has been found to increase significantly in soils applied in combination of organic,

inorganic and bio-fertilizer. It increased in all the treatments over control with the highest value in T_6 (Table 4). This might be due to increased microbial activity and MBC in the same treatment. Incorporation of bulky sources of potential beneficial microbes may provide microbial diversity and activity of microorganisms accompanied by better DH activity. Kumar *et al.,* (2017) [31] also observed maximum DH activity (136.90 µg TPF g^{-1} h^{-1}) under INM practice with 50% recommended dose of NPK + vermicompost @ 2 t ha^{-1} (mixed with microbial consortium) after okra cultivation. Nayak *et al.* (2007)[32] also described a generalized short to medium term increase in DH activity following organic matter addition. Further, use of chemical fertilizer i.e. 100% NPK alone exhibited lower dehydrogenase activity compared with conjoined use of inorganic and organic treatments. It was increased by 77% in T_6 over 100% NPK fertilizer alone (T_2). 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) [33]. Similarly, acid phosphatase activity exhibited an 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 than control. Acid phosphatase activity at T_6 was increased by 27% over 100% NPK fertilizer at T_2.

Soil microbial biomass carbon (MBC), the most active and dynamic pool of the soil organic matter, acts as transient nutrients sinks and is responsible for releasing nutrients from organic matter for use by plants. It plays a critical role in regulating the carbon and nitrogen biogeochemical processes in the soil and the size of microbial biomass carbon pool is strongly influenced by soil management practices. Soil microbial biomass carbon varied considerably among treatments and it ranged from 41 to 143 mg kg^{-1} (Table 4). The highest microbial biomass was recorded with T_6 treatment and exhibited 79% increase over T_2 treatment. NPK fertilizer exhibited higher biomass carbon than control but was almost similar to vermi compost 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. This might be due to the fact that INM plots have provided a steady source of organic carbon to support the microbial community compared to 100% NPK treated plots. Improvement of MBC in the vermi compost treated plots might be largely due to the microbes contained in the organic residues and the addition of substrate carbon, which stimulates the indigenous soil micro-biota. These results confirms the finding of Kumar *et al.,* (2017)[34] who recorded highest MBC (244.86 mg kg^{-1}) under INM practice with 50% recommended dose of NPK + vermi compost @ 2 t ha^{-1} (mixed with microbial consortium) after okra cultivation.

Table 4: Effect of integrated use of organic manures and chemical fertilizers on soil biological properties after harvesting of onion

Treatment	Microbial properties		
	Dehydrogenases activity µg TPF g^{-1} h^{-1}	Acid Phosphatase activity µg p NP g^{-1} h^{-1}	Microbial Biomass Carbon mg kg^{-1}
T1	2.42	62.5	41
T2	6.42	85.3	80
T3	8.16	92.2	91
T4	9.10	98.1	112
T5	10.22	102.4	129
T6	11.42	108.2	143
CD (P=0.05)	0.23	0.22	6.8

Microbial population was increased with the use of both organic and chemical fertilizers. The total microbial population increased under all the treatments over control during both the years (Table 5). Microbial population increased by 149% cfu × 10^{-4} in T_6 over control plot while over T_2, the increase recorded was 70% cfu × 10^{-4}. The results illustrated that the greater part of the favorable effects of elevated and reasonably stabilized specific populations of fungi and bacteria were related to the added microorganisms as well as the application of organic manure for a longer period (Nath *et al.,* 2012) [35]. The increase in microbial population and enzymatic activity in treatment T_6 probably due to the fact that most of the soil microorganisms are chemo-autotrophs which require organic source of carbon as food, and oxidation of organic substances provides energy (Ingle *et al.,* 2014) [36].

Table 5: Effect of integrated use of organic manures and chemical fertilizers on microbial population in soil (cfu*× 10^4 g^{-1}) after harvesting of onion

Treatments	Rhizosphere soil			Bulk soil		
	Bacterial Population	Fungal Population	Total Population	Bacterial Population	Fungal Population	Total Population
T1	72	33	133	60	28	109
T2	90	47	174	84	41	160
T3	96	54	184	91	48	174
T4	113	65	230	106	58	210
T5	125	74	267	118	69	240
T6	137	86	295	125	81	272
CD (P=0.05)	4.5	2.2	4.1	3.9	2.8	2.6

cfu*-- colony forming unit

Conclusion

Integrated use of organic manures *viz.*, FYM and vermi compost along with chemical fertilizers increased the yield, concentration and uptake of NPK by onion significantly over sole use of chemical fertilizers and control. Substantial improvement was recorded in residual soil fertility as the contents of organic carbon, available nitrogen, phosphorus and potassium were significantly improved with the application of either FYM or vermicompost in combination with chemical fertilizers, in comparison to sole application of chemical fertilizers. Moreover, addition of good quality organic matter along with NPK fertilizers helped in increasing soil biological properties which have been considered as a good indicator of high-quality soil.

It can be concluded from the study that INM involving vermi compost @ 25 t ha^{-1} in combination with 100% NPK is the best suitable option for getting maximum production of onion and maintaining soil production potential for a longer period under Sub-tropical zone of Jammu.

References

1. MoA & FW, GoI. Monthly Report Onion, January 2018. Horticulture Statistics Division, Department of Agriculture, Cooperation & Farmers Welfare, 2018, 03.
2. Dutta S, Pal R, Chakeraborty A, Chakrabarti K. Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. Arch. Agron. Soil Sci. 2003; 49:631-37.
3. Doran JW, Parkin TB. Defining and assessing soil quality. In: Defining Soil Quality for a Sustainable Environment, Doran J.W., Coleman, D.C., Bezdicek, D.F. and Stewart, B.A. (Eds.), SSSA Inc., Madison, Wisconsin, USA, 1994.
4. Sanjay-Swami, Bazaya BR. Vermi-compost technology. In: Quality Seed Production of Vegetable Crops: Technological Interventions, (ed.) Sharma, J.P., Kalyani Publishers, Ludhiana, Punjab, 2010, 344-356.
5. Sanjay-Swami. Vermicomposting: Transforming garbage into gold, 2012. http://www.krishisewa.com/articles/organic-agriculture/ 6-vermicomposting.html.
6. Dutta S, Pal R, Chakeraborty A, Chakrabarti K. Influence of integrated plant nutrient supply system on soil quality restoration in a red and laterite soil. Arch. Agron. Soil Sci. 2003; 49:631-37.
7. Trasar-Cepeda C, Leiros MC, Seoane S, Gil-Sotres F. Hydrolytic enzyme activities in agricultural and forest soils: Some implications for their use as indicators of soil quality. Soil Biol. Bio chem. 2008; 40:2146-2155.
8. Lawande KE, Anil Khar, Mahajan, V, Srinivas PS, Sankar V, Singh RP. Onion and garlic research in India. J Hort. Sci. 2009; 4:91-119.
9. Schloter M, Dilly O, Munch JC. Indicators for evaluating soil quality. Agric. Ecosys. Environ. 2003; 98:255-262.
10. Walkley A, Black CA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 1934; 37:29-38.
11. Subbiah B, Asija GL. A rapid procedure for the estimation of available N in soils. Curr. Sci. 1956; 25:259-260.
12. Olsen SR, Cole CW, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with 0.5 M $NaHCO_3$ (pH 8.5). United States Department of Agriculture Cir. 939, Washington DC, USA, 1954.
13. Wollum AG. Cultural methods for soil microorganisms. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. Amer. Soc. Agron., Madison, Wisconsin, USA, 1982, 781-813.
14. Klein DA, Loh TC, Goulding RL. A rapid procedure to evaluate the dehydrogenase activity of soils low in organic matter. Soil Biol. Bio chem. 1971; 3(4):385-387.
15. Tabatabai MA, Bremner JM. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biol. Bio chem. 1969; 1(4):301-307.
16. Jenkinson DS, Powlson DS. The effects of biocidal treatments on metabolism in soil V: A method for measuring soil biomass. Soil Biol. Bio chem. 1976; 8(3):209-213.
17. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, USA, 1984, 20-30.
18. Datt N, Sharma RP, Sharma GD. Effect of supplementary use of farmyard manure along with chemical fertilizers on productivity and nutrient uptake by vegetable pea (*Pisum sativum* var arvense) and build-up of soil fertility in Lahaul valley of Himachal Pradesh. Indian J Agric. Sci. 2003; 73:266-268.
19. Konyak CPW, Sanjay-Swami. Effect of organic and inorganic nutrient sources on yield, quality and nutrient uptake by cabbage (*Brassica oleracea* L. var capitata) in acid Inceptisol. Int. J Curr. Microbiol. Appl. Sci. 2018; 7(7):3035-3039.
20. Sinha NP, Prasad B, Ghosh AB. Effect of continuous use of fertilizers on yield and nutrient uptake in wheat in wheat-soybean-potato cropping system. J Indian Soc. Soil Sci. 1981; 29:537-542.
21. Reddy R, Reddy MAN, Reddy YTN, Reddy NS, Anjanappa N, Reddy R. Effect of organic and inorganic sources of NPK on growth and yield of pea [*Pysum sativum* (L.)]. Legume Res. 1998; 21(1):57-60.
22. Konyak CPW, Sanjay-Swami. Effect of organic and inorganic nutrient sources on yield, quality and nutrient uptake by cabbage (*Brassica oleracea* L. var capitata) in acid Inceptisol. Int. J Curr. Micro biol. Appl. Sci. 2018; 7(7):3035-3039.
23. Sharma TR, Agrawal SB, Singh NK. Effect of integrated nutrient management on soil fertility, organic carbon and productivity of okra. Horti. Soc. India. 2017; 74(1):142-145.
24. Konyak CPW, Sanjay-Swami. Effect of organic and inorganic nutrient sources on yield, quality and nutrient uptake by cabbage (*Brassica oleracea* L. var capitata) in acid Inceptisol. Int. J Curr. Microbiol. Appl. Sci. 2018; 7(7):3035-3039.
25. Sharma RP, Datt N, Sharma PK. Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (*Allium cepa*) under high hills, dry temperate conditions of North-Western Himalayas. Indian J Agric. Sci. 2003; 73:225-227.
26. Sharma RP, Sharma A, Sharma JK. Productivity, nutrient uptake, soil fertility and economics as affected by chemical fertilizers and farmyard manure in broccoli (*Brassica oleracea* var Italica) in an Entisol. Indian J Agric. Sci. 2005; 75:576-579.
27. Sharma RP, Sharma A, Sharma JK. Productivity, nutrient uptake, soil fertility and economics as affected by chemical fertilizers and farmyard manure in broccoli (*Brassica oleracea* var Italica) in an Entisol. Indian J Agric. Sci. 2005; 75:576-579.

28. Sharma RP, Sharma A, Sharma JK. Productivity, nutrient uptake, soil fertility and economics as affected by chemical fertilizers and farmyard manure in broccoli (*Brassica oleracea* var Italica) in an Entisol. Indian J Agric. Sci. 2005; 75:576-579.
29. Sharma RP, Datt N, Sharma PK. Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (*Allium cepa*) under high hills, dry temperate conditions of North-Western Himalayas. Indian J Agric. Sci. 2003; 73:225-227.
30. Ansari AA. Effect of vermicompost and vermiwash on the productivity of spinach (*Spinacia oleracea*), onion (*Allium cepa*) and potato (*Solanum tuberosum*). World J Agric. Sci. 2008; 4(5):554-557.
31. Kumar V, Saikia J, Barik N, Das T. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. Int. J Biochem. Res. Rev. 2017; 20(4):1-7. ISSN: 2231-086X.
32. Nayak DR, Babu YJ, Adhya TK. Long term application of compost influences microbial biomass and enzyme activities in a tropical Aeric Endoaquept planted to rice under flooded condition. Soil Biol. Bio chem. 2007; 39:1897-190.
33. Goyal S, Mishra MM, Hooda IS, Singh R. Organic matter-microbial biomass relationships in field experiments under tropical conditions: Effects of inorganic fertilization and organic amendments. Soil Biol. Bio chem. 1992; 24(11):1081-1084. doi.org/10.1016/0038-0717(92)90056-4.
34. Kumar V, Saikia J, Barik N, Das T. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. Int. J Biochem. Res. Rev. 2017; 20(4):1-7. ISSN: 2231-086X.
35. Nath DJ, Ozah B, Baruah R, Borah DK, Gupta M. Soil enzymes and microbial biomass carbon under rice-toria sequence as influenced by nutrient management. J Indian Soc. Soil Sci. 2012; 60:20-24.
36. Ingle AP, Duran N, Rai M. Bioactivity, mechanism of action, and cytotoxicity of copper-based nano-particles: A review. Appl. Microbiol. Bio tech. 2014; 98(3):1001-1009.