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Soil nutrient status and biological environment as influenced by nutrient management practices under rice-wheat cropping system

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Abstract
The present investigation entitled "Assessment of soil enzyme activity as influenced by nutrient management practices in a *Vertisol* under rice-wheat cropping system" was conducted during *Kharif* 2020 in a *Vertisol* at Long Term Fertilizer Experiment, Research cum instructional Farm, IGKV, Raipur (Chhattisgarh). The treatments of this long-term experiment comprised of control, 50% NPK, 100% NPK, 150% NPK, 100% NPK + $ZnSO_4$@ 10 kg/ha, "100% NP, 100% N, 100% NPK + FYM @ 5t/ha, 50% NPK + BGA @ 10 kg/ha, 50% NPK + Green Manure" (Sunhemp). The treatments were laid out in Randomized Block Design (RBD) with four replications. Soil bio-chemical characteristics were recorded to be improved with continuous addition of chemical fertilizers in conjunction with organic over only chemical fertilizers. The soil pH and EC doesnot shows to have any significant effect of application of inorganic fertilizers either alone or in combination with organic manure. The organic carbon was recorded to be highest (6.84 g kg^{-1}) in treatment T_8 (100% NPK + FYM @ 5 tonnes/ha) and the lowest value (4.14 g kg^{-1}) is observed in treatment T_1 (control). The result indicated that application of 150% NPK and conjoint application of organic and inorganic nutrient sources tends to improve the available N, P, K status of soil. The soil enzyme activity, *viz*. dehydrogenase (55.39 TPF µg 24 $hr^{-1}g^{-1}$), urease (44.08 µg $NH4^{+}$ - N g^{-1} soil hr^{-1})"acid phosphatase"(76.30"µg p-nitrophenol g^{-1} hr^{-1}) and "alkaline phosphatase" (52.23"µg p-nitrophenol g^{-1} hr^{-1}") were significantly influenced due to addition of 100% NPK + FYM @ 5 tonnes/ha. The results also showed that application 150% NPK and 100% NPK + FYM @ 5 tonnes/ha recorded higher grain (6930 kg/h and 6850 kg/ha respectively) and straw yield (7785 kg ha^{-1} and 7415 kg ha^{-1} respectively) as compared to 100% N alone and control. The findings of experiment clearly indicated that continuous balanced use of fertilizers with organic manures, either alone or in combination is vital for enhancing nutrient status, enzyme activity, and yield in a rice-wheat cropping system on *Vertisols*.

Keywords: Nutrient, biological, environment, nutrient, practices, cropping

Introduction
Rice- wheat cropping systems (RWCS) are the important source of food, employment, income and livelihood for millions of residents occupying 13.5 million ha of cultivable land in the Indo-Gangetic Plains (IGP) of South Asia (Nawaz *et al.*, 2019). The Indian portion of the IGP covers about 10 million hectares of rice-wheat system and supplies about half of the country's total food grain (Dhillon *et al*., 2010). The total area under rice cultivation in Chhattisgarh is 3.67 million hectares and produced about 8.37 million tonnes of rice during 2019-20. The "present land-use practices in South Asia more particularly in" RWCS are energy, capital water and labour intensive these are upsetting the ecological balance and exhausting the ground water "resources and soil organic carbon (SOC) along with adverse effects on soil physicochemical" properties (Bhatt and Singh 2018; Srinivasrao *et al.* 2010). A large number of problems have cropped -up due to intensive cultivation in many parts of South Asia including northwest India, threatening the sustainability of conventional rice-wheat production system. (Dwivedi *et al.*, 2012).
Soil enzymes are known to play an important role in biochemical functioning of soils (Wang *et al.* 2011), including organic residue decomposition (Lei 2011), cycling of nutrients (Makoi & Ndakidemi., 2008), and maintenance of soil structure (Dick *et al.* 1994, Balota *et al.* 2004) [12, 1, 2]." In the soil, these enzymes are constantly synthesized, accumulated, inactivated, and/or decomposed," and thus play "an important role in agriculture," especially in nutrient cycling. Soil enzymes are very specific in terms of the types of reactions in which they participate.

For example, the amount of available carbon has a large impact on soil microbial behaviour, which"is reflected in dehydrogenase activity (Januszek, 2011)."Dehydrogenase "is responsible for dehydrogenation of organic matter by transferring hydrogen and electrons from substrate to acceptors during biological oxidation of soil organic matter. (Maurya *et al.* 2011). Phosphatase, which is produced by root exudates and microorganisms, cleaves phosphate from organic substrate and participates in the phosphorus cycle in soil. (Huang *et al.*, 2011). "Urease enzyme is" carried out "the hydrolysis" reaction of urea fertilizer in the soil into NH_3 and CO_2 with the supplementary "rise in soil pH" (Byrnes and Amberger., 1989) [9]. Urease enzyme belongs to amidohydrolase group that hydrolases the linear amide having nonpeptide carbon to nitrogen bonds ("Bremner and Mulvaney 1978," Karaca *et al.* 1999) [8, 26].

Soil enzyme "activity" are important in soil functioning because of their role in, degradation of"organic materials and the transformation of organic matter; release of available nutrients to plants; participation in N_2 fixation, nitrification and denitrification processes, and in the detoxification of xenobiotics, such as pesticides, industrial wastes, etc. Soil enzyme activities have been" recognized as useful measures of improvements in soil quality caused by various soil and crop management practices under various cropping systems. (Nannipieri *et al.* 2011; Bandick and Dick 1999; Trasar-Cepeda *et al.* 2000;) [36, 3]. Their activities have been used as indicators of soil fertility because they are a reflection of the effects of cultivation, soil properties, and pedological amendments (Ceccanthi *et al.* 1993; Skujins 1978). Enzyme activity, when correlated "with measurements of other related biological and biochemical parameters"(for example, soil respiration, microbial carbon biomass, soil pH etc.)." gives an indication of the extent of biological activity in soil. (Frankenberger and Dick, 1983) [16] and soil quality (Roldan *et al*, 2005) [43].

Many factors can influence the activity of enzymes in the soil which includes "natural parameters (e.g. seasonal changes, geographic location, in situ distribution, organic matter content and clay) that typically affect the level of activity of the enzyme by influencing enzyme production, physical and chemical properties of the soil (Amador *et al.,* 1997), soil microbial community (Kourtev *et al.,* 2002), type of vegetation (Sinsabaugh *et al.,* 2002) [51] and ecological disturbance" (Boerner *et al.,* 2000)"as well as complex biochemical processes that involve interconnected and ecologically related synthetic processes, immobilization and enzyme stability. "A high concentration of clay or humus colloids is generally associated with stable but less active enzyme. Agricultural practices and environmental pollutants (e.g., fertilizers, pesticides, tillage, heavy metals) may change the chemical composition and structural characteristics of soil, influencing the species composition and abundance of soil microorganisms, their metabolic function, the enhancement or suppression of enzyme production, and the overall activity of an enzyme in soil.

Long -term fertilization experiments (LTFEs) are valuable assets for studying changes in soil nutrient dynamics and balance, predicting soil carrying capacity, and assessing soil quality and system sustainability. "Many previous studies have shown that long-term fertilization, especially organic manure input, can either directly or indirectly influence" soil organic carbon (SOC) and soil enzyme activities in long-term experimental sites (Bohme *et al.*,2005). The assay of soil enzymatic activity under Long -term fertilization experiments (LTFEs) could provide an early and responsive indicator of changes caused by management techniques like organic manuring, green manuring, crop residue integration, tillage interventions, herbicide application, and so on."(Dick *et al.*, 1988; Nannipieri, 1994; Aparna *et al.*, 2014; Tamilselvi 2015) [13, 14, 35, 54]."

Materials and Methods

The long term fertilizer experiment was initiated at instructional cum research farm, IGKV, Raipur, Chhattisgarh. Soil samples were collected from respective treatments and lab work was conducted in laboratory of department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The experiment comprised ten treatments replicated four times in RBD. The soil of experimental site was deep, clayey black soil taxonomically classified as very fine, smectitic, hyperthermic family of Typic Haplusterts. The soil is having low hydraulic conductivity and high water holding capacity.

The treatments consisted of control (T1), 50% NPK (T2), 100% NPK (T3),150% NPK (T4), 100% NPK + 10 kg Zn/ha (T5), 100% NP (T6),100% N (T7),100% NPK + FYM @ 5 tonnes/ha (T8), 50% NPK + BGA @ 10kg/ha (T9), 50% NPK + Green Manure (Sunhemp) (T10), 75% RDF (T11). The 21st cycle of the experiment during 2019-2020 was studied in the present investigation. N, P and K nutrients were applied through Urea, Single Super Phosphate and Muriate of Potash, respectively. One third of Urea and recommended dose of P and K were applied at the transplanting. Remaining equal two splits (1/3rd of Urea) of nitrogen were given at tillering and panicle initiation stage of rice.

Soil pH was determined in 2.5:1 water-soil suspension (by Piper, 1966) than soil suspension after pH determination was stored overnight and EC of the supernatant liquid was determined by Solu-bridge as described by Black (1965). The organic carbon was determined by Walkley and Black rapid titration method (1934). Available nitrogen was estimate by alkaline potassium

permanganate method (Subbiah and Asija. 1956), available phosphorus by Olsen *et al.* (1954) method and available potassium was determined by neutral normal ammonium acetate extractant and detected by Flame photometer as described by Hanway and Heidal (1952). Soil dehydrogenase activity was determined by the method as described by Cassida *et al.*, (1964) [10]. Urease activity was measured by the protocol given by Douglas and Bremner (1970). Acid and alkaline phosphatase activities were assayed by the method given by Tabatabai and Bremner (1969) [53].

Calculation for assay of enzyme activity following procedure were adopted to calculate enzyme activity in soil-

i. Calculation of moisture percent

$$\frac{\text{(wt. of moist soil) - (wt. of dry soil)}}{\text{(wt. of dry soil)}} \times 100$$

ii. Calculation of enzyme activity

Concentration = Y value x Sample reading

$$\text{Enzyme Activity} = \frac{\text{Concentration x D}}{\text{It} \times \text{W}}$$

Where
Y = Value taken from standard curve
It = Incubation time
D = Dilution
W = Dry weight of soil (g)

Results and Discussion
Soil Chemical Properties
The soil pH and EC after the incorporation of organic sources i.e. FYM and GM with inorganic fertilizers over the period of 21 year were found to have no significant effect even after "continuous" addition of "variable amount of fertilizers alone"or in combination (Table 1). The reason behind this could be "high buffering capacity of "these" soil (*Vertisol*) and the "presence of calcium carbonate in the soil. Inconsistent" variation in the "pH of the soil was observed in different treatments indicating that imposed treatments failed to influence the pH of soil. Patel (2014) also reported soil pH and EC was not affected significantly under continuous "application of fertilizers and manure after 42 cropping cycle of continuous application of "Soybean-Wheat in sequence.

The soil organic carbon significantly enhanced due to different treatment. The treatment T8 (100% NPK + FYM @ 5t ha^{-1}) recorded highest organic carbon content (6.84 g kg^{-1}) followed by treatment T4 (150% NPK, 6.80 g kg^{-1}) and lowest value was recorded in control (4.14 g kg^{-1}). This is because of higher concentration of "biomass to soil in form of crop" residues and higher root biomass.

The integrated use of organic manure along with inorganic fertilizers where shown (Table 1) to enhance available N, P and K status of soil significantly. The available nitrogen status of soil" and maximum value (279.10kg ha^{-1}) was observed in T8 (100% NPK + FYM @ 5t ha^{-1}) and minimum value (134.85 kg ha^{-1}) was recorded in "control" plot. The application of super optimal dose i.e. 150% NPK followed by 100% NPK + FYM @ 5t ha^{-1} recorded maximum available P (31.45 "kg ha-1" and 31.11 "kg ha-1") Similarly, available K was found maximum (484.57 kg ha^{-1} and 430.58 kg ha^{-1}) in "treatment" receiving 150% "NPK" followed by 100% NPK + FYM @ 5t ha^{-1} whereas minimum value was observed in control plots. These findings were in close conformity to those obtained by Katkar *et al.* (2011), Meshram *et al.* (2016) [33], V.K. Kharche (2013) [27].

Table 1: Effect of application of organic and inorganic fertilizer on Available macronutrients of soil in *Vertisols* at harvested (After 21 crop cycles)

S. No.	Treatments	pH	EC (dS m^{-1})	Organic Carbon (g kg^{-1})	Available N of Soil (kg ha^{-1})	Available P of Soil (kg ha^{-1})	Available K of Soil (kg ha^{-1})
T_1	Control	7.25	0.21	4.14	134.85	8.96	307.44
T_2	50% NPK	7.24	0.24	5.56	172.48	19.29	370.50
T_3	100% NPK	7.22	0.24	6.40	225.79	25.69	426.33
T_4	150% NPK	7.22	0.28	6.80	275.97	31.45	484.57
T_5	100% NPK + Zn @kg ha^{-1}	7.25	0.28	6.30	228.93	25.94	422.60
T_6	100% NP	7.24	0.22	5.27	232.06	24.68	316.60
T_7	100% N	7.23	0.23	4.43	210.11	9.83	314.78
T_8	100% NPK + FYM @ 5t t ha^{-1}	7.25	0.25	6.84	279.10	31.11	430.58
T_9	50% NPK + BGA @ 10 kg ha^{-1}	7.24	0.24	5.61	185.02	20.43	372.79
T_{10}	50% NPK + GM	7.25	0.23	6.16	222.66	22.42	397.21
	S.Em±	0.07	0.012	0.39	17.07	1.68	19.09
	CD (P=0.05)	NS	NS	1.12	49.8	4.88	55.41
	Intial (1999)	7.7 0.20		0.6	236	16	474

Dehydrogenase activity
The dehydrogenase activity which has been widely used as a generalized comparative index of microbial activity, increased with the increase in the dose of fertilizers from 50 to 150 per cent RDF. Application of 100% + FYM @ 10 tonnes/ha recorded significantly highest dehydrogenase activities (55.393 TPF µg 24 $hr^{-1}g^{-1}$) than all other treatments. The application of FYM @ 10 tonnes/ha increased dehydrogenase activity as compared to optimal dose of fertilizer (Table 2). This increase in dehydrogenase enzyme activity is associated with the organic sources acting as the sole sources of carbon and energy for heterotrophs. A significant increase in dehydrogenase activity in the plots with organic treatments, especially with NPK was also observed by Saha *et al.* (2008) [43]. The results are in line with the findings by Bhattacharyya *et al.* (2008) wherein four folds increase was observed in dehydrogenase activity due to farmyard manure application along with NPK. Imbalanced and inadequate application of fertilizers (100% RD of NP or N) caused significant decline in the dehydrogenase activity. The decreased DHA under 100% N alone is associated with the redox potential of soil. The redox potential (Eh) of the soil might have been increased due to accumulation of nitrate over the year of cropping (21st year) resulting into positive and high redox potential of the soil, thereby decreasing dehydrogenase activity.

Table 2: Effect of application of organic and inorganic fertilizer on Urease activity, Dehydrogenase activity, Acid phosphatase activity and Alkaline phosphatase activity.

Treatment	Dehydrogenase Activity (TPF µg 24 $hr^{-1}g^{-1}$)	Urease Activity (µg $NH4^{+}$ - N g^{-1} soil h^{-1})	Acid Phosphatase Activity (µg p-nitrophenol g^{-1} hr^{-1})	Alkaline Phosphatase Activity (µg p-nitrophenol g^{-1} hr^{-1})
T1- Control	35.06	20.04	55.11	130.81
T_2- 50% NPK	45.15	34.13	61.60	137.77
T3- 100% NPK	49.28	39.37	65.85	142.21
T4- 150% NPK	52.00	41.28	72.75	157.65

T5-100% NPK + Zn @ 10 kg ha^{-1}	54.13	40.37	68.52	149.15
T6- 100% NP	43.38	32.40	64.01	141.12
T7- 100% N	42.22	30.13	58.17	134.17
T8- 100% NPK + FYM @ 5 t ha^{-1}	55.39	44.08	76.30	160.67
T9- 50% NPK + BGA @ 10 kg ha^{-1}	49.15	32.34	65.53	135.58
T10- 50% NPK + GM	50.74	35.61	66.30	133.96
S.Em±	1.46	0.95	2.04	3.49
CD (5%)	4.68	3.04	6.52	11

Urease activity

Application of NPK + FYM @ 10 tonnes/ha recorded significantly highest urease activity (44.083 µg NH4 + N g-1 soil h-1) whereas urease activity was reduced in control (20.04 µg NH4 + N g-1 soil h-1). The significantly higher value of dehydrogenase activity was obtained in 100% NPK + Zn (40.37 µg NH4 + N g-1 soil h-1) as compared to 50% NPK + BGA (32.34 µg NH4 + N g-1 soil h-1), 50% NPK + GM (35.61 µg NH4 + N g-1 soil h-1) and 100% NP (32.40 µg NH4 + N g-1 soil h-1). Imbalanced and insufficient application of fertilizers 100% N alone (30.13 µg NH4 + N g-1 soil h-1) caused significant decline in the dehydrogenase activity (Table 2). This could "be attributed to the fact" that organic manure act as "sole source of carbon and energy for heterotrophs" and provide sufficient nutrition for proliferation of microbes and their activities in terms of soil enzymes." The values of soil enzyme activity were lower in treatment T6 (100% NP), T_7 (100% N) due to lack of sufficient substrate i.e. organic carbon which act as source of food for proliferating microbial population and the lowest value was recorded in control. Ingle *et al.* (2014) [24], N. Goutami (2018) [22] and Meshram *et al.* (2016) [33] also observed that long-term balance applications of organic manures and inorganic fertilization have been found to Caused consistent improvement in urease enzyme activity in soil over its initial status and control.

Acid Phosphatase Activity

The acid phosphatase activity in soil increased successively and significantly from 55.11 "µg p-nitrophenol g^{-1} hr^{-1} (control) to 61.60, 65.85, and 72.75 µg p-nitrophenol g^{-1} hr^{-1} in 50%, 100% and 150% NPK treatments, respectively (Table 2). The highest value of 76.30 µg p-nitrophenol g^{-1} hr^{-1} was observed with 100% NPK+FYM, followed by 150% NPK treatments (72.75 µg p-nitrophenol g^{-1} hr^{-1}) however both were statistically at par. The slightly higher value of acid phosphatase activity was obtained in 100% NPK + Zn (68.52 µg p-nitrophenol g^{-1} hr^{-1}) as compared to 50% NPK + GM (66.30 µg p-nitrophenol g^{-1} hr^{-1}) and 50% NPK + BGA (65.53 µg p-nitrophenol g^{-1} hr^{-1})".

Meshram *et al.* (2016) [33] also observed the similar result where significantly more phosphatase enzyme activity in soil was recorded in balanced fertilized plot receiving "100% NPK + FYM." Similar result were also reported by Santhy *et al.* (2004) and Rai and Yadav (2011) [40] in long-term fertilizer experiments where combined application of NPK + FYM. Long term effect of incorporation of organic source along with fertilizers resulted greater amount of carbon input, root exudation to the soil, enhanced humus content, abundance of carbohydrates coupled with greater microbial activities with pronounced increase in phosphatase enzyme activities in soil (Vandana *et al.* 2012).

Alkaline phosphatase activity

Application of FYM in combination with inorganic fertilizer also enhanced the alkaline phosphatase enzyme activity in *Vertisol.* The highest value (160.67 µg p-nitrophenol g^{-1} hr^{-1}) of alkaline phosphatase activity was noted where 100% NPK was applied along with FYM. While, the lowest content of alkaline phosphatase activity was found in control (130.81 µg p-nitrophenol g^{-1} hr^{-1})" and it increases with successive addition of fertilizers *viz*. 50% (137.77 µg p-nitrophenol g^{-1} hr^{-1}), 100% (142.21 µg p-nitrophenolg^{-1} hr^{-1}) and 150% NPK (157.65 µg p-nitrophenol g^{-1} hr^{-1}), respectively. Whereas, the value 134.17 µg p-nitrophenol g^{-1} hr^{-1} was observed in 100% N which was significantly lower as compared to 100% NP (141.12 µg p-nitrophenol g^{-1} hr^{-1}), 50% NPK + BGA (135.58 µg p-nitrophenol g^{-1} hr^{-1}), 50% NPK + GM (133.96 µg p-nitrophenol g^{-1} hr^{-1}) and significantly lesser than 100% NPK + Zn (149.15 µg p-nitrophenol g^{-1} hr^{-1}). Among all the treatments, balance application of organic manure with inorganic fertilizer (NPK+FYM) showed superiority as compare to application of fertilizer alone. In case of inorganic applications, super optimal dose of fertilizer (150% NPK) showed its significantly superior effect over rest of the treatments might be due to addition of higher amount of root residue for building of soil organic carbon.

Similar results were also reported by Kanchikerimath and Dhyan Singh (2001) [25] in long term fertilizer experiments and found that alkaline phosphatase activities were increased significantly with the addition of balanced nutrients and manure in Typic Haplusterts. Rai and Yadav (2011) [40] also reported the higher activities of alkaline phosphatase in the organically treated soils due to manure input over the year.

Correlation

It is evident from the above that there is highly positive and significant correlation between yield and activity of urease (0.859) and phosphatase (acid phosphatase 0.720, alkaline phosphatase 0.686) enzyme. Further yield shows significant positive correlation with available N (0.70) and phosphorous (0.845). This indicate that enzyme activity play a vital role in nutrient cycling and its availability to rice crop especially of N and P. also higher activities of urease and phosphatase may be related to better and efficient utilization of native and applied N and P by rice as exhibited higher yields with increasing enzyme activity.

Table 3: Correlation among soil enzyme activity, organic carbon, major nutrients and yield of rice

Parameters	Organic Carbon	Dehydrogenase Activity	Urease Activity	Acid Phosphatase Activity	Alkaline Phosphatase Activity	N	P	K	Yield
Organic Carbon									
Dehydrogenase Activity	0.754								
Urease Activity	0.749	0.860							

Acid Phosphatase Activity	0.615	0.734	0.764						
Alkaline Phosphatase Activity	0.484	0.532	0.730	0.706					
N	0.429	0.580	0.705	0.671	0.737				
P	0.720	0.747	0.797	0.765	0.640	0.580			
K	0.563	0.679	0.669	0.715	0.612	0.548	0.623		
Yield	0.654	0.708	0.859	0.720	0.686	0.700	0.845	0.636	

Conclusion
It can be concluded from the above result that long term application of organic manure along with inorganic fertilizers was found to be efficient in enhancing the chemical and biological properties of soil resulting in better soil quality. The soil enzyme dehydrogenase, urease, acid and alkaline phosphatase activity was found to significantly superior in treatments receiving 100% NPK + FYM than all other treatments this is attributed to the fact that organic manure act as sole source of carbon i.e energy for proliferation of microbes resulting in greater enzyme activity in soil to build biological fertility of soil. Among different treatments balanced application of 150% NPK was also noted better option for nutrient management and enzyme activity through inorganics. Long term balanced application of fertilizers in combination with organic manure was also recorded to productive in increasing yield.

References

1. Balota EL, Calegari A, Nakatani AS, Coyne MS. Benefits of winter cover crops and no-tillage for microbial parameters in a Brazilian Oxisol: a long-term study. *Agric Ecosyst Environ* 2014;197:31-40.
2. Balota EL, Kanashiro M, Colozzi Filho A, Andrade DS, Dick RP. Soil enzyme activities under long-term tillage and crop rotation systems in subtropical agroecosystems. *Braz J Microbiol* 2004;35:300-06.
3. Bandick AK, Dick RP. Field management effects on soil enzyme activities. *Soil Biol Biochem* 1999;31:1471-79.
4. Basak N, Datta A, Mitran T, Mandal B, Mani PK. Impact of organic and mineral inputs onto soil biological and metabolic activities under a long-term rice-wheat cropping system in sub-tropical Indian Inceptisols. J Environ Biol 2016;37:83-89.
5. Basak N, Datta A, Mitran T, Mandal B, Mani PK. Impact of organic and mineral inputs onto soil biological and metabolic activities under a long-term rice-wheat cropping system in sub-tropical Indian Inceptisols. Journal of environmental biology 2016;37(1):83.
6. Bhavani S, Chandra SK, Jayasree G, Padmaja B. Effects of long term application of inorganic and organic fertilizers on soil biological properties of rice. *J Pharmacogn Phytochem* 2017;6:1107-10.
7. Bhavani S, Shaker CK, Jayashree G, Padmaja B. Effects of long term application of inorganic and organic fertilizers on soil biological properties of rice. Journal of Pharmacognosy and Phytochemistry 2017;6(5):1107-1110.
8. Bremner JM, Mulvaney RL. Urease activity in soils. In: Bums R G (ed) *Soil Enzymes*. Academic Press, London 1978, 149-96.
9. Byrnes BH, Amberger A. Fate of broadcast urea in a flooded soil when treated with N-(n-butyl) thiophospheric triamide, a urease inhibitor. *Fertil Res* 1989;18:221-31.
10. Casida LE, Klein DAK, Santoro T. Soil dehydrogenase activity. Soil Sci 1964;98:37176.
11. Chang EH, Chung RS, Tsai YH. Effect of different application rates of organic fertilizer on soil enzyme activity and microbial population. Soil Science and Plant Nutrition, 2007;53(2):132-140.
12. Dick RP. Soil enzyme activities as indicators of soil quality. In: Doran J W, Coleman, D C, Bezdicek D F and Stewart B A (ed) *Defining Soil for a Sustainable Environment.* Soil Science Society of America, Madison, WI, 1994, 107-24.
13. Dick RP, Rasmussen PE, Kerle EA. Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. *Biol Fert Soils* 1988;6:159-64.
14. Dick RP, Rasmussen PE, Kerle EA. Influence of long-term residue management on soil enzyme activities in relation to soil chemical properties of a wheat-fallow system. Biology and Fertility of Soils 1988;*6*(2):159-164.
15. Dwivedi BS, Singh VK, Kumar V. Maximizing the rice-wheat system productivity through balanced fertilizer use under Typic Ustochrept soils of western Indo-Gangetic Plain. J Farming Systems Res Dev 2011;17:1-14.
16. Frankenberger WT, Dick WA. Relationships between enzyme activities and microbial growth and activity indices in soil. Soil Sci Soc Am J 1983;47:945-51.
17. Gajendra Patel. “Microbiological and enzymatic studies in a Vertisol as influenced by long term application of fertilizer and FYM on soybean” at All India Coordinated Research Project on “Long term fertilizer experiment, JNKVV, Jabalpur during 2013-14.
18. Gao S, Hoffman-Krull K, DeLuca TH. Soil biochemical properties and crop productivity following application of locally produced biochar at organic farms on Waldron Island, WA. Biogeochemistry, 2017;136(1):31-46.
19. Garg AK, Milkha SA. Effect of long term fertilizer management and crop rotation on accumulation and downward movement of phosphorous in semi-arid subtropical irrigated soil. Communication in Soil Sci and plant Ana 2010;41:848-864.
20. Gathala MK, Kumar V, Sharma PC, Saharawat YS, Jat HS, Singh M *et al*. Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the north western Indo-Gangetic Plains of India. Agric Ecosyst Environ 2013;177:85-97.
21. Gautam A. Long-Term Impacts of Manure and Inorganic Fertilization on Soil Physical, Chemical and Biological Properties 2019.
22. Goutami N, Rao CS, Sireesha A, Rao CP, Vijaya Gopal A. Effect of Long-Term Use of Inorganic Fertilizers, Organic Manures and Their Combination on Soil Properties and Enzyme Activity in Rice-Rice Cropping System. Int. J. Curr. Microbiol. App. Sci, 2018;7(09):469-486.
23. Humphreys E, Kukal SS, Christen EW, Hira GS, Balwinder-Singh, Sudhir-Yadav, *et al*. Halting the groundwater decline in north west India-which crop technologies will be winners? Adv Agron 2010;109:155-217.
24. Ingle SS, Jadhao SD, Kharche VK, Sonune BA, Mali DV. Soil biological properties as influenced by long-term

manuring and fertilization under sorghum (Sorghum bicolor)-wheat (Triticum aestivum) sequence in Vertisols. Indian Journal of Agricultural Sciences 2014;84(4):452-457.
25. Kanchikerimath Manjaiah, Dhyan Singh. Soil organic matter and biological properties after 26 years of maize – wheat – cowpea cropping as affected by manure and fertilization in a Cambisol in semiarid region of India. Agriculture, Ecosystem & Environment 2001;86:155-162.
26. Karaca A, Haggblomb MM, Tate RL. Effects of the land application of sewage sludge on soil heavy metal concentrations and soil microbial communities. *Soil Biol Biochem* 1999;31:1467-70.
27. Kharche VK, Patil SR, Kulkarni AA, Patil VS, Katkar RN. Long-term integrated nutrient management for enhancing soil quality and crop productivity under intensive cropping system on vertisols. Journal of the Indian Society of Soil Science 2013;61(4):323-332.
28. Lakaria BL, Singh Muneshwar, Reddy RS, Biswas AK, Jha P, Chaudhary RS, Singh AB *et al*. Carbon addition and storage under integrated nutrients management in soybean-wheat cropping sequence in a Vertisol of central India. National Academy Science Letters 2012;35(3):131-137.
29. Li CH, Ma BL, Zhang TQ. Soil bulk density effects on soil microbial populations and enzyme activities during the growth of maize (Zea mays L.) planted in large pots under field exposure. Canadian journal of soil science, 2002;82(2):147-154.
30. Madejón E, Murillo JM, Moreno F, López MV, Arrúe JL, Álvaro-Fuentes J, *et al*. Effect of long-term conservation tillage on soil biochemical properties in Mediterranean Spanish areas. Soil and Tillage Research 2009;105(1):55-62.
31. Makoi JH, Ndakidemi PA. Selected soil enzymes: examples of their potential roles in the ecosystem. African Journal of Biotechnology 2008;7(3).
32. Mali DV, Kharche VK, Jadhao SD, Jadhao SM, Saoji BV, Gite PA *et al*. Soil biological health under long-term fertilization in sorghum-wheat sequence on swell-shrink soils of central India. Journal of the Indian Society of Soil Science 2015;63(4):423-428.
33. Meshram NA, Ismail S, Patil VD. Long-term effect of organic manuring and inorganic fertilization on humus fractionation, microbial community and enzymes assay in Vertisol. Journal of Pure and Applied Microbiology 2016;10(1):139-150.
34. Mishra B, Sharma A, Singh SK, Prasad J, Singh BP. Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. Journal of the Indian Society of Soil Science 2008;56(1):71-75.
35. Nannipieri P. The potential use of enzymes as indicators of productivity, sustainability and pollution. In: Pankhurst C E, Doube B M, Gupta V V S R and Grace P R (ed) *Soil Biota- Management in Sustainable Farming Systems*. CSIRO, East Melbourne Australia 1994, 238-44.
36. Nannipieri P, Giagnoni L, Landi L, Renella G. Role of phosphatase enzymes in soil. In: Bunemann E K, Obreson A and Frossard E (ed) *Phosphorus in action*. Springer, Berlin 2011, 215-43.
37. Parewa HP, Yadav J, Rakshit A. Effect of fertilizer levels, FYM and bioinoculants on soil properties in inceptisol of Varanasi, Uttar Pradesh, India. International Journal of Agriculture, Environment and Biotechnology 2014;7(3):517-525.
38. Parewa HP, Yadav J, Rakshit A. Effect of fertilizer levels, FYM and bioinoculants on soil properties in inceptisol of Varanasi, Uttar Pradesh, India. International Journal of Agriculture, Environment and Biotechnology 2014;7(3):517-525.
39. Qi R, Li J, Lin Z, Li Z, Li Y, Yang X *et al*. Temperature effects on soil organic carbon, soil labile organic carbon fractions, and soil enzyme activities under long-term fertilization regimes. Applied Soil Ecology 2016;102:36-45.
40. Rai TN, Yadav J. Influence of inorganic and organic nutrient sources on soil enzyme activities. Journal of Indian Society of Soil Science 2011;59:54-59. 24.
41. Rao MA, Scelza R, Gianfreda L. Soil enzymes. Enzymes in agricultural science. Omics Group eBooks, USA. 2014, 10-24.
42. Roldán A, Salinas-García JR, Alguacil MM, Díaz E, Caravaca F. Soil enzyme activities suggest advantages of conservation tillage practices in sorghum cultivation under subtropical conditions. *Geoderma* 2005;129:178-85.
43. Saha S, Prakash V, Kundu S, Kumar N, Lal MB. Soil enzymatic activity as affected by long term application of farm yard manure and mineral fertilizer under rainfed soybean-wheat system in N-W Himalaya. Eur J Soil Biol 2008;44:309-15.
44. Salazar S, Sánchez LE, Alvarez J, Valverde A, Galindo P, Igual JM *et al*. Correlation among soil enzyme activities under different forest system management practices. Ecological Engineering, 2011;37(8):1123-1131.
45. Shambhavi S, Kumar R, Sharma SP, Verma G, Sharma RP, Sharma SK. Long-term effect of inorganic fertilizers and amendments on productivity and root dynamics under maize-wheat intensive cropping in an acid Alfisol. Journal of Applied and Natural Science 2017;9(4):2004-2012.
46. Sherene T. Role of soil enzymes in nutrient transformation: A review. Bio Bull 2017;3(1):109-131.
47. Singh G, Marwaha TS, Kumar D. Effect of resource-conserving techniques on soil microbiological parameters under long-term maize (*Zea mays*)–wheat (*Triticum aestivum*) crop rotation. Indian J Agric Sci 2009;79:94-100.
48. Singh G, Kumar D, Sharma P. Effect of organics, biofertilizers and crop residue application on soil microbial activity in rice–wheat and rice-wheat mungbean cropping systems in the Indo-Gangetic plains. Cogent Geoscience 2015;1(1):1085296.
49. Sinsabaugh RL. Fungal enzymes at the community scale. In: Dighton J, Oudermans P and White J (ed) *The Fungal Community* third ed. CRC Press 2005, 17.
50. Sinsabaugh RL, Carreiro MM, Repert DA. Allocation of extracellular enzymatic activity in relation to litter composition, N deposition, and mass loss. *Biogeochem* 2002;60:1-24.
51. Swarup A, Yaduvanshi NPS. Effect of integrated nutrient management on soil properties and yield of rice in alkali soil. J Indian Soc Soil Sci 2000;48(2):279282.
52. Tabatabai MA. Soil enzymes. In: Weaver R W, Angel G

S and Bottomley P S (ed) Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties. Soil Science Society of America Book Series, Madison, WI, 1994, 775.

53. Tabatabai MA, Bremner JM. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biol Biochem 1969;1:301-07.
54. Tamilselvi SM, Chinnadurai C, Ilamurugua K, Arulmozhiselvan K, Balachandar D. Effect of long-term nutrient managements on biological and biochemical properties of semi-arid tropical Alfisol during maize crop development stages. Ecol Indic 2015;48:76-87.
55. Thakur RK, Sawarkar SD, Vaishya UK, Singh Muneshwar. Impact of continuous. use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. J Indian Soc Soil Sci 2011;59(1):74-81.
56. Trasar-Cepeda C, Leiros MC, Jenkinson DS, Seoane S, Gil-Sotres F. Hydrolytic enzyme activities in agricultural and forest soil, some implications for their use as indicators of soil quality. Soil Biology & Biochemistry 2008;40:2146-2155.