



Soil biological properties as influenced by phospho-enriched compost and fertility levels in maize (*Zea mays*)

KIRAN DOODHAWAL¹, R H MEENA², GAJANAND JAT³, DEVENDRA JAIN⁴, R S CHOUDHARY⁵,
ROSHAN CHOUDHARY⁶, JITENDRA KUMAR SHARMA⁷, MANISHA MEENA⁸ and S K YADAV⁹

Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001, India

Received: 15 April 2020; Accepted: 27 July 2021

ABSTRACT

The present investigation was carried out to evaluate the impacts of phospho-enriched compost and fertility levels on soil biological properties in Typic Haplustepts soil of Sub-humid Southern Plain and Aravalli Hills Region in Rajasthan. The experiment was undertaken during *kharif* 2018 and 2019 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur (Rajasthan). The treatments comprised four levels of phospho-enriched compost (PEC), i.e. control, PEC @ 2.0, 4.0 and 6.0 t/ha and four levels of fertility (kg/ha) i.e. control, 50% RDF + foliar spray of Zn @ 0.5%, 75% RDF + foliar spray of Zn @ 0.5% and 100% RDF + foliar spray of Zn @ 0.5%, respectively. The experiment was laid out in a factorial randomized block design with three replications. Significant improvement in different soil biological properties, i.e. alkaline phosphate activity, dehydrogenase activity and soil microbial biomass carbon was observed with increasing levels of phospho-enriched compost and fertility up to 6 t/ha and 100% RDF + foliar spray of Zn @ 0.5%, respectively after harvest of the maize (*Zea mays* L.) crop during both the years as well as in pooled analysis. In case of fertility levels, however, the microbial populations in soil after harvest of crop increase was significant up to 75% RDF + foliar spray of Zn @ 0.5% which was found statistically at par with 100% RDF + foliar spray of Zn @ 0.5%. The application of phospho-enriched compost @ 6 t/ha and 100% RDF + foliar spray of Zn @ 0.5% along with the recommended dose of fertilizer results in significantly higher biological properties of soil under Typic Haplustepts.

Keywords: Biological properties, Fertility, Maize, Phospho-enriched compost

Maize (*Zea mays* L.) crop regarded as a queen of cereals occupies a pride place among *kharif* crop in India and contributes around 24% of total cereal production (Singh *et al.* 2011). In India it is cultivated over an area of 9.03 m ha with an annual production and productivity of 27.72 m t and 3.70 t/ha, respectively. In the state of Rajasthan, it covers an area of 0.87 m ha with production and productivity of 1.16 million tonnes and 1335 kg/ha, respectively (FAI 2019-20). Organic sources improve the biological properties of the soil and helps to maintain and sustain soil fertility and enhance crop productivity in a framework of an ecologically compost is considered a valuable organic fertilizer as it supplies nutrients for the crop which results in saving cost of chemical fertilizers (Erhart *et al.* 2005). Phospho-enriched compost is used as a soil conditioner, which helps to boost the nutritional

status, physio-chemical and biological properties of the soil (Ingelmo *et al.* 2012). The role of rock phosphate enriched compost in increasing soil organic matter, soil microbial biomass, soil basal respiration, enzyme activity over sole mineral fertilizer application, thus perking up the quality of the soil (Manna and Ganguly 2000).

Soil organisms act as primary driving agents of nutrient cycling, regulating the dynamics of soil organic matter, soil carbon sequestration, enhancing the amount of nutrient acquisition by vegetation, conferring stress tolerance, resisting pathogens and improving plant health (Rao 2007). Soil enzymes and microbial biomass have been considered as major indicators of soil quality due to their relationship to soil fertility and high sensitivity to changes originated by the management and environmental factors (Diosma *et al.* 2006). Application of inorganic fertilizers results in higher soil organic matter accumulation and biological activity due to increased plant biomass production and organic matter returns to soil in the form of decaying roots, litter and crop residues (Brar *et al.* 2015). Hence, looking to the above facts the present investigation was conducted to study the soil biological properties as influenced by phospho-enriched compost and fertility levels in maize under Typic Haplustepts soil.

Present address: ¹Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. *Corresponding author e-mail: gaj_rahulsoil@yahoo.com.

MATERIALS AND METHODS

Experimental site and soil: The experiment was conducted during *kharif* 2018 and 2019 at the Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur situated at an altitude of 579.5 m above mean sea level and at 24°34' latitude and 73°42' longitude. The region falls under agro-climatic zone-IVa (Sub-humid Southern Plain and Aravalli Hills) of Rajasthan. Soil of the experimental site was clay loam in texture, alkaline in pH (8.25 ± 0.16), electrical conductivity is normal (0.63 ± 0.01 dS/m), medium in organic carbon ($0.62 \pm 0.01\%$), low in available N (272.13 ± 5.45 kg/ha), available P_2O_5 (17.55 ± 0.32 kg/ha), available zinc (0.595 ± 0.012 mg/kg) and high in available K_2O (353.23 ± 7.12 kg/ha).

Preparation of phospho-enriched compost (PEC): For the preparation of PEC, 15 kg air dried maize stover chopped into 5-6 cm size was soaked in water for 24 h. After soaking, it was mixed thoroughly with required quantities of rock phosphate (RP) and waste mica. To reduce the C:N ratio of maize stover, urea solution @ 0.25 kg N per 100 kg of maize stover and fresh cow dung @ 10 kg per 100 kg of maize stover was added as natural inoculants. Phosphate solubilizing microorganism @ 50 g per 100 kg was also added to maize stover. After that the whole composting mass was mixed thoroughly and put in the cemented pits and covered with jute bag sheets for maintaining moisture. To provide adequate aeration turning was performed after 15, 30 and 60 days of composting and throughout the experiment moisture was maintained to 60%

of water-holding capacity. The composting was continued for 120 days. The chemical composition of phospho-enriched compost (N 0.847 ± 0.017 , P 1.215 ± 0.024 , K 1.157 ± 0.023 and Zn 35.1 ± 0.7 , respectively) used in field experiment.

Experimental design and treatments: The experiment was laid out in factorial randomized block design and replicated thrice in the plot size of 4.0 m $\times$ 3.0 m (12 m²). The treatments comprised of four levels of PEC, viz. control, 2.0, 4.0 and 6.0 t/ha and four levels of fertility (kg/ha), viz. control, 50% RDF + foliar spray of Zn @ 0.5%, 75% RDF + foliar spray of Zn @ 0.5% and 100% RDF + foliar spray of Zn @ 0.5%.

Soil sampling, processing and analysis: The surface (0-15 cm depth) soil samples were collected at the harvest of crop at three randomly selected spots in each replication and composite samples were prepared. The soil was gently ground, well mixed and sieved through 2 mm mesh and utilized for laboratory analysis for biological properties in soil and stored at 4°C. In the soil material, soil microbial populations were determined by standard serial dilution and plate count method (Vance *et al.* 1987). Dehydrogenase activity was analyzed by anthrone extraction method (Cassida *et al.* 1964). The activity of alkaline phosphatase was determined by p-nitro phenol estimation method (Tabatabai and Bremner 1969) and soil microbial biomass carbon was analyzed by chloroform-fumigation incubation method (Vance *et al.* 1987).

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of

Table 1 Effect of phospho-enriched compost and fertility levels on alkaline phosphatase activity, dehydrogenase activity and microbial biomass carbon of soil after harvest of maize

Treatment	Alkaline phosphatase activity (μ g p-nitro phenol/g soil/h)			Dehydrogenase activity (μ g TPF/g soil/h)			Soil microbial biomass carbon (mg/kg)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
<i>Phospho-enriched compost (t/ha)</i>									
Control (PEC ₀)	130.82	133.68	132.25	9.94	10.39	10.17	167.40	170.99	169.20
2 (PEC ₁)	152.40	155.70	154.05	11.61	12.09	11.85	172.40	176.10	174.25
4 (PEC ₂)	169.73	173.38	171.55	13.32	13.84	13.58	183.89	187.82	185.86
6 (PEC ₃)	177.11	180.90	179.01	14.04	14.57	14.30	194.30	198.43	196.36
SEm $\pm$	2.17	2.21	1.11	0.17	0.17	0.09	1.06	1.07	0.54
CD (P=0.05)	6.27	6.40	3.13	0.50	0.51	0.25	3.05	3.11	1.52
<i>Fertility levels (kg/ha)</i>									
Control (F ₀)	130.84	133.71	132.27	9.98	10.42	10.20	167.47	171.07	169.27
50% RDF+ foliar spray of Zn @ 0.5% (F ₁)	152.36	155.66	154.01	11.48	12.06	11.77	172.41	176.11	174.26
75% RDF+ foliar spray of Zn @ 0.5% (F ₂)	170.24	173.90	172.07	13.44	13.85	13.65	183.98	187.91	185.94
100% RDF+ foliar spray of Zn @ 0.5% (F ₃)	176.61	180.39	178.50	14.02	14.55	14.28	194.12	198.25	196.18
SEm $\pm$	2.17	2.21	1.11	0.17	0.17	0.09	1.06	1.07	0.54
CD (P=0.05)	6.27	6.40	3.13	0.50	0.51	0.25	3.05	3.11	1.52

variance (ANOVA) technique for a factorial randomized block design. The results are presented at 5% level of significance ($P=0.05$).

RESULTS AND DISCUSSION

Alkaline phosphate activity and dehydrogenase activity

Effect of phospho-enriched compost: The application of increasing levels of PEC significantly increased the alkaline phosphate activity and dehydrogenase activity in soil over control (Table 1). The maximum value of alkaline phosphate activity and dehydrogenase activity ($179.01 \mu\text{g } p\text{-nitro phenol/g soil/h}$ and $14.30 \mu\text{g TPF/g soil/h}$) in soil after harvest of the maize crop was obtained under PEC_3 (6 t phospho-enriched compost/ha) which was significantly superior over the PEC_2 (4 t phospho-enriched compost/ha) and PEC_1 (2 t phospho-enriched compost/ha) treatments as well as control (PEC_0) in pooled analysis, respectively. The dehydrogenase enzyme activity is commonly used as an indicator of biological activity in soils. It might be due to increased microbial activity as a result of increased availability of organic carbon by phospho-enriched compost (Meena and Biswas 2015). Sriramachandrasekharan and Ravichandran (2011) reported that the addition of organic substances to the soil served as a carbon source that enhanced microbial biomass and phosphatase activity, showing that these enzymes are of microbiological origin and crop growth stage also significantly influenced soil enzyme activities. The addition of phospho-enriched compost led to significant increase in soil microbial respiration (Bohem *et al.* 2005). The soil microbial respiration is strongly linked to soil enzyme activity, indicating the intensity of soil metabolic processes and providing important information about nutrient cycling in the soil (Dsouza *et al.* 2018). Dehydrogenase activity is positively due to utilization of nutrients provided by the organic materials by microorganisms resulting in an increase in microbial activity (Albiach *et al.* 2000).

Effect of fertility: The application of fertility levels with foliar spray of zinc significantly increased alkaline phosphatase and dehydrogenase activity in soil over control (Table 1). The maximum value of alkaline phosphate activity and dehydrogenase activity ($178.50 \mu\text{g } p\text{-nitro phenol/g soil/h}$ and $14.28 \mu\text{g TPF/g soil/h}$) in soil were recorded under F_3 (100% RDF + foliar spray of Zn @ 0.5%) which was significantly superior over F_2 (75% RDF + foliar spray of Zn @ 0.5%) and F_1 (50% RDF + foliar spray of Zn @ 0.5%) treatments as well as control (F_0) in pooled analysis, respectively. The increased dehydrogenase and phosphatase activity by increasing levels of fertilizer application might be attributed to the fact that inorganic source of nutrient stimulated the activity of microorganisms to utilize the native pool of organic carbon as a source of carbon, which acts as substrate for these enzyme (Meena and Biswas 2015). The increase in dehydrogenase activity and phosphatase activity with integrated use of 100% NPK and FYM in soils might be due to the fact that enzyme activities directly associated with organic matter

and microbial response to soluble sugars of the added materials (Basu *et al.* 2011). Masto *et al.* (2006) reported that dehydrogenase activity was dependent on addition of number and amount of nutrient.

Soil microbial biomass carbon

Effect of phospho-enriched compost: The application of increasing levels of PEC significantly increased the soil microbial biomass carbon in soil (Table 1). The maximum value of soil microbial biomass carbon (196.36 mg/kg) in soil was obtained under PEC_3 (6 t phospho-enriched compost/ha) followed by PEC_2 (4 t phospho-enriched compost/ha) and PEC_1 (2 t phospho-enriched compost/ha) treatments as compared to control (PEC_0) in pooled analysis, respectively. The per cent increase in soil microbial biomass carbon in soil were in order of 16.06, 9.85 and 2.99 in pooled analysis due to application of 6, 4 and 2 t phospho-enriched compost/ha as compared to control (PEC_0), respectively. The amount of soil microbial biomass carbon increased significantly due to incorporation of phospho-enriched compost in to soil. In general, there was an increase in microbial growth and activities of enzymes with the addition of carbon substrate and declined as the available carbon exhausted (Manna and Ganguly 2000) as microbial carbon were positively correlated with soil organic matter. The increase in soil microbial biomass carbon might also is due to reduction in pH, electrical conductivity and exchangeable sodium percentage of soil on account of addition of organic material (Meena and Biswas 2015). The computation of biomass turnover can predict the flux of plant nutrients and the size at plant nutrient pool supplied by microbial biomass turnover in the soil (Dsouza *et al.* 2018).

Effect of fertility: The soil microbial biomass carbon in soil after harvest of the maize crop was significantly affected by fertility levels along with foliar spray of zinc (Table 1). The maximum value of soil microbial biomass carbon (196.18 mg/kg) in soil was recorded under F_3 (100% RDF + foliar spray of Zn @ 0.5%) followed by F_2 (75% RDF + foliar spray of Zn @ 0.5%) and F_1 (50% RDF + foliar spray of Zn @ 0.5%) treatments as compared to control (F_0) in pooled analysis, respectively. The per cent increase in soil microbial biomass carbon in soil were in order of 15.90, 9.85 and 2.99 in pooled analysis due to application of 100% RDF + foliar spray of Zn @ 0.5% (F_3), 75% RDF + foliar spray of Zn @ 0.5% (F_2) and 50% RDF + foliar spray of Zn @ 0.5% (F_1) as compared to control (F_0), respectively. The microbial biomass carbon increased with increase in dose of inorganic fertilizers, may be due firstly to increase in microbial population (Parewa *et al.* 2014) and secondly to the formation of fruit exudates, mucigel sougged of cells and underground roots of previous cut crops which also play an important role in increasing biomass carbon (Goyal *et al.* 1992).

Soil microbial population: Effect of phospho-enriched compost: The application of phospho-enriched compost significantly increased microbial population in soil over control (Table 2). The maximum value of bacteria, fungi

Table 2 Effect of phospho-enriched compost and fertility levels on microbial population of soil after harvest of maize

Treatment	Soil microbial population (cfu/g soil)								
	Bacteria			Fungi			Actinomycetes		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
<i>Phospho-enriched compost (t/ha)</i>									
Control (PEC ₀)	63.30	64.82	64.06	22.88	23.59	23.23	34.70	35.64	35.17
2 (PEC ₁)	68.77	70.39	69.58	24.11	24.85	24.48	38.08	39.09	38.58
4 (PEC ₂)	73.75	75.48	74.61	25.79	26.56	26.18	40.07	41.12	40.60
6 (PEC ₃)	76.75	78.53	77.64	26.98	27.77	27.38	42.66	43.76	43.21
SEm±	0.94	0.96	0.48	0.32	0.33	0.16	0.49	0.50	0.25
CD(P=0.05)	2.71	2.76	1.35	0.92	0.94	0.46	1.42	1.45	0.71
<i>Fertility levels (kg/ha)</i>									
Control (F ₀)	63.32	64.83	64.07	22.85	23.55	23.20	34.82	35.77	35.29
50% RDF+ foliar spray of Zn @ 0.5% (F ₁)	67.64	69.24	68.44	24.02	24.75	24.39	38.14	39.16	38.65
75% RDF+ foliar spray of Zn @ 0.5% (F ₂)	75.46	77.22	76.34	26.32	27.09	26.70	41.11	42.19	41.65
100% RDF+ foliar spray of Zn @ 0.5% (F ₃)	76.15	77.93	77.04	26.58	27.36	26.97	41.43	42.51	41.97
SEm±	0.94	0.96	0.48	0.32	0.33	0.16	0.49	0.50	0.25
CD(P=0.05)	2.71	2.76	1.35	0.92	0.94	0.46	1.42	1.45	0.71

and actinomycetes population (77.64, 27.38 and 43.21 cfu/g soil) in soil was obtained under PEC₃ (6 t phospho-enriched compost/ha) followed by PEC₂ (4 t phospho-enriched compost/ha) and PEC₁ (2 t phospho-enriched compost/ha) treatments as compared to control (PEC₀) in pooled analysis, respectively. The availability of carbon material and substrates such as sugar, amino acids and organic acids in the soil from the decomposing organic material and decay of roots under the plant canopy are important for supplying energy for microbial population (Bowen and Rovira 1991). The increased microorganism population might be due to addition of organic carbon in the form of phospho-enriched compost turn provides adequate biomass as nourish for the microbes and helps in increasing microbial population in soil (Mali *et al.* 2017). The amount of adsorbed soil microbial population has generally been attributed to increased microbial biomass resulting from organic matter enrichment in the soil (Dsouza *et al.* 2018).

Effect of fertility: The increasing levels of fertility along with foliar spray of zinc significantly increased microbial population in soil over control (Table 2). The highest value of bacteria, fungi and actinomycetes population (77.04, 26.97 and 41.97 cfu/g soil) in soil were recorded under F₃ (100% RDF + foliar spray of Zn @ 0.5%) followed by F₂ (75% RDF + foliar spray of Zn @ 0.5%) and F₁ (50% RDF + foliar spray of Zn @ 0.5%) treatments as compared to control (F₀) in pooled analysis, respectively. However, the increase was significant up to F₂ during both the years as well as in pooled analysis which was found statistically at par with F₃. The increase in microbial population might be due to increasing levels of fertility which increases the

root exudates, biomass and ultimately provides carbon and energy to the soil microbes resulting into multiplication of microbial population (Kumari and Shankar 1991). Parewa *et al.* (2014) reported that application of increasing levels of fertilizer increased the bacteria and fungi population in rhizosphere soil significantly up to 100% NPK.

On the basis of experimental finding, it can be concluded that the application of phospho-enriched compost @ 6 t and 100% RDF + foliar spray of zinc @0.5% along with the recommended dose of fertilizer results in significantly higher biological properties, i.e. alkaline phosphate activity, dehydrogenase activity, soil microbial biomass carbon, bacteria, fungi and actinomycetes population in soil after harvest of maize crop under Typic Haplustepts soil of Sub-humid Southern Plain and Aravalli Hills Region of Rajasthan.

REFERENCES

- Albiach R, Canet R, Pomares F and Ingelmo F. 2000. Microbial biomass content and enzymatic activities after the application of organic amendments to a horticultural soil. *Bioresource Technology* **75**(1): 43–48.
- Basu M, Bhadoria P B S and Mahapatra S C. 2011. Influence of soil ameliorants, manures and fertilizers on bacterial populations, enzyme activities, N fixation and P solubilization in Peanut rhizosphere under lateritic soil. *British Microbiology Research Journal* **1**(1): 11–25.
- Bohem L, Langer U and Bohem F. 2005. Microbial biomass, enzyme activities and microbial community structure in two European long-term field experiments. *Agriculture, Ecosystems and Environment* **109**:141-152.
- Bowen G D and Rovira A D. 1991. The rhizosphere, the hidden

- half. (In) Plant Roots: the Hidden Half. Waisel Y, Eshel A, Kafkafi U (Eds). Dekker, New York, 641–69.
- Brar B S, Singh J, Singh G and Kaur G. 2015. Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize-wheat rotation. *Agronomy* **5**: 220–38.
- Casida L E, Klein D A and Santoro T. 1964. Soil dehydrogenase activity. *Soil Science* **98**: 371–76.
- Diosma, G, Aulicino M, Chidichimo H and Balatti P A. 2006. Effect of tillage and N fertilization on microbial physiological profile of soil cultivated with wheat. *Soil Tillage Research* **91**: 236–43.
- Dsouza A, Deshmukh P W, Bhoyar S M and Rakesh R. 2018. Effect of phospho compost and nitro phospho-sulpho compost on soil chemical and biological properties under soybean in Vertisols. *International Journal of Plant and Soil Science* **21**(2): 1–7.
- Erhart E, Hartl W and Putz B. 2005. Biowaste compost affects yield, nitrogen supply during the vegetation period and crop quality of agricultural crops *European Journal of Agronomy* **23** (3): 305–14.
- FAI. 2019–20. Fertiliser Statistics. The Fertiliser Association of India, New Delhi.
- Goyal S, Mishra, M M Hooda, I S Singh, R Beri, V Choudhary, M R Sandhu, P S Pasricha, N S and Bajwa M S. 1992. Buildup of microbial biomass with continuous use of inorganic fertilizers and organic amendments. (In) *Proceeding of the International Symposium on Nutrient Management for Sustained Productivity* **2**: 149–51.
- Ingelmo F, Jose M M, Desamparados S M, Gallardo A and Lapena L. 2012. Influence of organic matter transformations on the bioavailability of heavy metals in a sludge based compost. *Journal of Environment Management* **95**: 104–09.
- Kumari G V L and Shankar S K. 1991. Studies on organic amendment and CO₂ enrichment in ragi- soybean intercropping systems. *Indian Journal of Agronomy* **36**: 202–06.
- Mali M K, Meena R H and Jat G. 2017. Effect of composted rock phosphate with organic materials on yield nutrient uptake and soil fertility after harvest of maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Science* **6**(6): 901–09.
- Manna M C and Ganguly T K. 2000. Rock phosphate and pyrite in compost technology. *Fertilizer News* **45**(7): 41–45.
- Masto R E, Chhonkar P K, Singh D and Patra A K. 2006. Changes in soil biological and biochemical characteristics in a long-term field trial on a sub-tropical Inceptisol. *Soil Biology and Biochemistry* **38**: 1577–82.
- Meena M D and Biswas D R. 2015. Effect of rock phosphate enriched compost and chemical fertilizers on microbial biomass phosphorus and phosphorus fraction. *African Journal of Microbiology Research* **9**(23): 1519–26.
- Parewa H P, Yadav J and Rakshit A. 2014. Effect of fertilizer levels, FYM and bio-inoculants on soil properties in Inceptisol of Varanasi, Uttar Pradesh, India. *International Journal of Agriculture, Environment and Biotechnology* **7**(3): 517–25.
- Rao D L N. 2007. Microbial diversity, soil health and sustainability. *Journal of the Indian Society of Soil Science* **55**: 392–403.
- Singh R, Sharma A R, Dhyani S K and Dube R K. 2011. Tillage and mulching effects on performance of maize (*Zea mays*) – wheat (*Triticum aestivum*) cropping system under varying land slopes. *Indian Journal of Agricultural Sciences* **81**(4): 330–35.
- Sriramachandrasekharan M V and Ravichandran M. 2011. Enzyme dynamics and soil properties in paddy soil fertilized with mineral and green manures sources. *Agricultural Segment* **2**(2): 1558.
- Tabatabai M A and Bremner J M. 1969. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. *Soil Biology and Biochemistry* **1**: 301–07.
- Vance E D, Brookes P C and Jenkinson D S. 1987. An extraction method for measuring soil microbial biomass carbon. *Soil Biology and Biochemistry* **19**: 703–07.