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Enriching vermicompost with rock phosphate applied with inorganic fertilizers improves soil biological quality in calcareous soil

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Abstract
Vermicompost prepared from household waste and the organic residue enriched with rock phosphate could improve its quality and nutrient content. Further applying enriched vermicompost in soil could positively impact on soil C content, microbial biomass, and enzymatic activities. The above facts were used and a field experiment on maize crops with treatment combinations of inorganic fertilizers and enriched vermicompost was planned at RPCAU, Pusa (Bihar). After two years of study in calcareous alluvial soil, we found that treatments full of enriched vermicompost, zinc and combined with mineral fertilizers enhanced soil C concentration and microbial biomass. Organic C in the soil was improved by 24-30% and microbial biomass C by 21-26% compared to no fertilizer application (control). The use of zinc micronutrient in combination with enriched vermicompost in the soil significantly increased enzyme activity (dehydrogenase, alkaline phosphatase) in comparison with the control and recommended dose of fertilization. Overall, this study concludes that enriching vermicompost with rock phosphate applied with inorganic fertilizers improves soil biological quality under calcareous alluvial soil.

Keywords: Vermicompost, enrichment, maize, enzyme, microbial biomass

1. Introduction
According to World Bank research, cities throughout the world produced 2.24 billion tonnes of waste in 2020, about three times as much as was generated in the past decade. Every year, India generates about 3 billion tonnes of organic waste. Thus, effective waste management is the major challenge as current systems in India and the world cannot cope fully with the volumes of waste generated and it negatively affects public health and the ecology.
Unscientific disposal of organic wastes i.e. open dumping and landfilling in low-lying areas outside the cities or rural areas reflect an unpleasant look and causes an adverse impact on human health, water pollution, methane emission, and soil degradation which leads to loss of vegetation and decline in agricultural productivity that ultimately affects the ecology. The recycling of organic wastes through vermicomposting methods is the key technology for the production of vermicompost which can be used as an organic amendment for soils as it helps to build up soil fertility thus greater productivity from agricultural land.
Vermicompost, the end product of vermicomposting by earthworms on organic waste materials is rich in different nutrients and organic matter. But the vermicompost has a low concentration of phosphorus which can be improved in concentration by amending rock phosphate during vermicomposting. The enrichment of vermicompost with rock phosphate when applied with inorganic fertilizers, may lead to an enhanced microbial population as well as microbial load.
Bihar state grew maize crops in high-productivity areas of India. Maize is a nutrient-exhausting crop and the intensive cultivation of the crop can decline soil fertility and productivity. The calcareous alluvial soil of Bihar due to intensive cultivation of different cereal crops caused poor soil quality and currently affecting crop yield. Therefore, studies report that soil sustainability is a big challenge in the calcareous alluvial soil of Bihar, and hence organic amendment can be one of the options to manage soil sustainability. Research reported that integrated nutrient management could be the best management practice for yield sustainability and maintaining soil health.
But inadequate information is accessible that signifies the application of enriched vermicompost on soil biological quality in maize crops under calcareous alluvial soil.

For this, we hypothesized that vermicomposting utilizing household waste and the organic residue amended with rock phosphate improves the microbes' population and their activity. We also hypothesized further that the addition of organic sources in calcareous alluvial soil enhances soil biological quality in the post-collected soil. The purpose of this study is to assess the effect of the combined practice of vermicompost amended with rock phosphate on soil biological quality in maize crops under calcareous alluvial soil.

2. Materials and Methods

2.1 Study site, and vermicomposting

The research was undertaken to assess the different types of vermicompost prepared from organic residue and household waste with or without enriched rock phosphate at RPCAU, Pusa, Samastipur (Bihar). The location site was at the coordinate's 25° 58' 12" N latitude, 85° 41' 24" E longitudes, and at 55 m above msl.

The different organic materials used for vermicompost preparation were organic residues and household wastes. Organic residues namely, rice straw was obtained from the research farm of RPCAU, Pusa, Samastipur. The household wastes were collected from the university residential blocks which were screened for plastic bags, polythene bags, and unwanted materials before utilizing for vermicompost preparation. Then all these waste materials were sun-dried in shade for about 2-3 days then it was processed for vermicompost preparation. To each of the composting masses, cattle dung was supplemented as usual inoculants to speed up disintegration. The total organic carbon of the substrates was 39.10, 44.77 and 49.78% for cow dung, organic residues, and household wastes, respectively. Rock phosphate was used for enriching the vermicompost with a P_2O_5 content was 18-20%.

2.2 Crop management

Initial soil samples were composed and further examined for soil parameters (Table 1).

Table 1: Initial characteristics of the investigational plots

SI. No.	Soil parameters	Value obtained	References
1.	Soil pH	8.45	Jackson (1973) [13]
2.	Electrical conductivity	0.45 dS m^{-1}	
3	Bulk density	1.51 Mg m^{-3}	Singh, (1980)
4.	Oxidizable organic C	0.51%	Walkley & Black (1934)
5.	Nitrogen	155 kg ha^{-1}	Subbiah & Asija (1956)
6.	Phosphorus	20.28 kg ha^{-1}	Olsen *et al*. (1954) [25]
7.	Potassium	125.2 kg ha^{-1}	Jackson (1967) [14]
8.	Free calcium carbonate	24.68%	Piper (1966) [26]
9	Soil microbial biomass C	215.7 µg g^{-1} soil	Jenkinson and Powlson (1976) [15]
10	CO_2 evolution	27.7 mg g^{-1} 24 h^{-1}	Zibilske (1994) [35]
11	Dehydrogenase	0.41 µg TPF g^{-1} soil h^{-1}	Casida *et al.* (1964) [6]
12	Alkaline phosphatase	20.19 µg PNP g^{-1} h^{-1}	Tabatabai and Bremner (1969) [32]
13	Acid phosphatase	15.91 µg PNP g^{-1} h^{-1}	

Maize crops were grown following treatments detailed for nutrient management (Table 2).

Table 2: Treatments detail

T_1	No fertilizer application
T_2	100% $_{inrog}$NPK
T_3	75% $_{inrog}$N + 25% $_{org1}$N
T_4	75% $_{inrog}$N + 25% $_{org1rpzn1/2}$N
T_5	75% $_{inrog}$N + 25% $_{org1rpzn}$N
T_6	75% $_{inrog}$N + 25% $_{org2}$N
T_7	75% $_{inrog}$N + 25% $_{org2rpzn1/2}$N
T8	75% $_{inrog}$N + 25% $_{org2rpzn}$N

Note: $_{inorg}$NPK- Recommended dose of fertilizer; $_{org1}$ and $_{org2}$- household waste vermicompost and organic residue vermicompost; Full recommended of zinc (zn)-25 kg zinc sulphate; Half recommended of zinc (zn1/2)-12.5 kg zinc sulphate treatments laid in RBD and replicated thrice

Further, intercultural operations and irrigation were applied as per the crop requirement. The crop was harvested at maturity.

2.3 Soil sample analysis

Fresh soil samples after harvesting of the crop were collected and stored in the refrigerator at 4 degrees Celsius to analyze microbial biomass C and enzymes. A portion of the collected samples was processed and further analyzed for soil parameters. The references of analysis is given in Table 1 shown with initial soil parameters.

2.4. Statistical analysis

Through the Duncan Multiple Range Test (DMRT), the variation in the data for various parameters was examined while considering the treatments represented by the treatments with the LSD at 5 percent.

3. Results and Discussions

3.1 Soil Organic Carbon

The impact of different types of vermicompost (household waste-based and organic residue) with or without rock phosphate enrichment combined with two different levels of zinc as discussed in Table 2 & in combination with inorganic fertilizers on SOC at post-harvest soil presented in Table 3.

In general integration of vermicompost (either enriched or without enrichment) with chemical fertilizers recorded significantly higher SOC of post-harvest soil when it was compared with control and RDF. During both years (2021 & 2022), treatment T_8 recorded the highest SOC (0.60 and 0.61%) which was statistically *at par* with T_5 (0.58 and 0.60%) whereas the control (T_1) showed the lowest value of SOC during the observation (0.44 and 0.43%). Increased efficiency of chemical fertilizers supplied in combination with enriched vermicompost as regards SOC buildup at post-harvest soil. Noor *et al*. (2020) reported similar outcomes. The addition of rock phosphate-enriched vermicompost significantly increased SOC content. Mahmood *et al* (2017) findings were likewise in favour of these findings.

Composting or using it in combination with synthetic fertilizers enhanced the SOC content. SOC increase may be one possible reason that enhanced organic matter in soil & total biomass generated with respect to enriched vermicompost and growing of maize crop which generates more organic acids that mobilize the soil calcium. These results are supported by (Agbede *et al*., 2008) [1].

3.2 Soil Microbial Biomass C (SMBC)

SMBC of two years of experiment influenced by the addition of different types of vermicompost (household waste-based and organic residue) with or without Rock-Phosphate enrichment combined with two different levels of Zinc and 75% N through chemical fertilizer presented in Table 3.

In the first year, SMBC ranged from 214.61 to 282.82 µg g^{-1} whereas, during the second year, its values were between 216.57 to 290.58 µg g^{-1} starting from the treatment T_1 to T_8, respectively at post-harvest soil.

During both the years (2021 and 2022) treatment T_8 showed a greater value of SMBC (282.82 and 290.58 µg g^{-1}) which was statistically *at par* with T_5 (269.17 and 275.94 µg g^{-1}) whereas control (T_1) recorded the lowest value of SMBC during the observation (214.61 and 216.57 µg g^{-1}). The increase in the SMBC is due to the availability of more nutrients caused by enhanced rhizospheric effects, secretion of organic acids, and root exudates leading to more microbial activities thus more MBC. These outcomes are steady with Moharana *et al*. (2019), who found that applying rock phosphate-amended compost alone or in integration with mineral fertilizers after wheat crop harvest significantly boosted the SMBC content. A higher soil C content of microbial biomass may be due to a greater turnover of root biomass produced when combined either enriched or without enriched vermicompost and inorganic fertilizers. Other researchers have reported similar results (Meena and Biswas, 2014).

Table 3: Combined impact of chemical fertilizers and vermicompost on SOC and SMBC in calcareous soil

Treatment	SOC (%)		SMBC (µg g^{-1} soil)	
	2021	2022	2021	2022
T_1	0.44	0.43	214.61	216.57
T_2	0.51	0.53	223.43	230.20
T_3	0.53	0.55	240.93	247.93
T_4	0.55	0.58	261.63	266.26
T_5	0.58	0.60	270.91	275.94
T_6	0.52	0.52	233.46	232.94
T_7	0.57	0.59	269.17	267.85
T_8	0.60	0.61	282.82	290.58
S.Em ±	0.026	0.020	7.59	15.26
CD(P=0.05)	0.08	0.06	23.03	46.29

3.3 Soil respiration

Data pertaining to soil respiration (CO_2 evolution) have been represented in Table 4. Scrutiny of data showed that the addition of vermicompost (either enriched or without enriched) along with chemical fertilizer had significantly higher soil respiration values of post-harvest soil as compared to the untreated. In the first year, soil respiration varied from 0.27 to 1.01 mg g^{-1} 24 h^{-1} whereas, during the second year, its values were between 0.29 to 1.16 mg g^{-1} 24 h^{-1}. During both the years (2021 and 2022) the treatment T_5 showed higher values of soil respiration (1.06 and 1.26 mg g^{-1} 24 h^{-1}), which were statistically *at par* compared to T_8 (1.01 and 1.16 mg g^{-1} 24 h^{-1}) whereas the T_1 recorded the lowest value of soil respiration during the observation (0.27 and 0.27 mg g^{-1} 24 h^{-1}). Vermicompost integration with chemical fertilizers may increase microbial activities which are able to break down the soil organic matter resulting in increased humus content and increased CO_2 evolution. These results are consistent with those of Lata and Marschner (2013) [17] who narrated that compost addition increased the cumulative respiration of soil. Changes in microbial activities are tortuously attribute to variations in the decomposition of SOM, resulting in increased microbial respiration (Innerebner *et al.*, 2006) [12].

3.4 Dehydrogenase activity

Data relating to dehydrogenase enzym**e** in post-harvest have been presented in Table 4. Scrutiny of data indicated that the addition of vermicompost (either enriched or without enriched) along with chemical fertilizer had significantly higher dehydrogenase enzym**e** values of post-harvest soil in comparison to T_1 and T_2 during both years.

In the first year, dehydrogenase enzym**e** activity varied from 0.39 to 1.91 µg $TPFg^{-1}$soil h^{-1} whereas, during the second year, its values were between 0.40 to 2.09 µg $TPFg^{-1}$soil h^{-1}. During both the years (2021 & 2022) treatment T_5 showed a higher value of dehydrogenase enzym**e** (2.09 and 2.25 µg $TPFg^{-1}$soil h^{-1}), which were statistically *at par* with T_8 (1.91 and 2.09 µg $TPFg^{-1}$soil h^{-1}) whereas T_1 exhibited the minimum value of dehydrogenase during the observation (0.39 and 0.40 µg $TPFg^{-1}$soil h^{-1}). The same results were also reported by Mandal *et al*. (2007) [19]. The application of organic sources (vermicompost) and combination with inorganic sources increased dehydrogenase activity that could be attributed due to the availability of nutrients increased microbial activities thus enhancing dehydrogenase enzymatic activities, which was in conformity with Goutami *et al*. (2015) [9].

Table 4: Combined influence of chemical fertilizers and vermicompost on CO_2 evolution (Soil respiration) (mg g^{-1} 24 h^{-1}) and dehydrogenase (DHA) activity (µg TPF g^{-1} soil h^{-1}) in calcareous soil

Treatment	Soil respiration		DHA	
	2021	2022	2021	2022
T_1	0.27	0.29	0.39	0.40
T_2	0.55	0.59	0.88	0.91
T_3	0.61	0.65	1.21	1.45
T_4	0.88	1.01	1.79	1.89
T_5	1.06	1.26	2.09	2.25
T_6	0.59	0.68	0.69	0.78
T_7	0.90	0.96	1.01	1.12
T_8	1.01	1.16	1.91	2.09
S.Em ±	0.066	0.06	0.095	0.103
CD(P=0.05)	0.20	0.18	0.29	0.31

3.5 Alkaline (ALK) phosphatase

In general integration of vermicompost (either enriched or without enrichment) with mineral fertilizers showed significantly higher alk phosphatase in post-harvest soil when it was compared with control (unfertilized), (Table 5). In the first year, alk phosphatase enzyme activity varied from 17.88 to 47.57 µg PNP g^{-1} h^{-1} whereas, during the second year, its values were between 19.51 to 49.56 µg PNP g^{-1} h^{-1}.

During both the years (2021 & 2022) T_8 recorded higher values of alk phosphatase enzym**e**, which were *at par* with the T_5 whereas T_1 recorded the lowest value of alk phosphatase enzym**e** during the observation. According to Tarafdar and

Marschner (1994) [31], the addition of rock phosphate-enriched compost increased alk phosphatase and could change the insoluble P into free ions later taken up by harvests. As reported by Meena and Biswas (2015) [21], rock-phosphate enriched compost & synthetic fertilizers in combination maintained the highest alk phosphatase activity in soil than chemical fertilizers or compost alone. Higher phosphate activity was found in the soil following the combined use of vermicompost and mineral N fertilizer than following the alone application of synthetic fertilizers (Srivastava *et al*., 2012) [29]. Criquet *et al* (2007) stated an increase in alkaline phosphatase activity when organic fertilizers, such as compost, vermicompost, & manure, were applied to soils. A soil amendment with organic materials stimulates microbial growth and enriches SOM, thereby affecting alk phosphatase.

3.6 Acid (Ac) phosphatase

Scrutiny of data indicated that the addition of vermicompost (either enriched or without enriched) along with chemical fertilizer had significantly higher ac phosphatase activity of post-harvest soil as related to the control and RDF during both the years (Table 5). In the first year, ac phosphatase activity varied from 16.21 to 27.77 whereas, during the second year, its values were between 17.40 to 29.89. During both years (2021 & 2022) treatment T_5 showed a higher value of acid phosphatase, respectively which were at par with T_8. Whereas the T_1 showed the lowest value of acid phosphatase during the observation. The pH value of the soil greatly influences ac phosphatase activity in different treatments. The application of RP-enriched vermicompost to soil improves soil pH and P availability in general. Haynes and Swift (1988) [11] discovered and confirmed that ac phosphatase is generally reduced in response to chemical fertilization. Ac phosphatase activity in T_2 was lower than in the integrated application of vermicompost with chemical fertilizers.

Table 5: Combined impact of chemical fertilizers and vermicompost on acid and alkaline phosphatase (μg PNP g^{-1} h^{-1}) in calcareous alluvial soil

Treatment	Ac phosphatase		Alk phosphatase	
	2021	2022	2021	2022
T_1	16.21	17.40	17.88	19.51
T_2	19.33	21.50	33.09	35.00
T_3	23.25	25.60	33.99	35.73
T_4	25.66	29.61	38.99	40.19
T_5	28.33	31.23	44.59	46.71
T_6	21.01	22.45	32.99	35.69
T_7	26.88	28.09	42.69	44.41
T_8	27.77	29.89	47.57	49.56
S.Em ±	1.54	1.68	3.33	2.18
CD(P=0.05)	4.68	5.11	10.10	6.62

4. Conclusion

The study reports SMBC as influenced by the integrated application of enriched household-based and organic residue vermicompost in combination with inorganic fertilizer in *Zaid* maize crop production. We concluded that the use of enhanced organic manures combined with synthetic fertilizers is necessary for the short-term maintenance of SMBC and soil enzyme activity. Enzymatic characteristics and soil microbial biomass were also closely correlated with the carbon inputs.

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