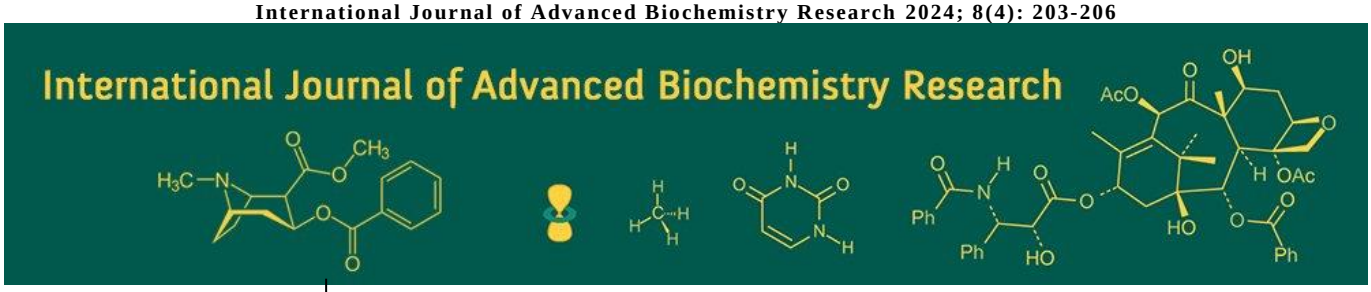

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(4): 203-206
www.biochemjournal.com
Received: 08-02-2024
Accepted: 11-03-2024

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Enzymatic activities in a vertisol as influenced by long term nutrient management practices in soybean-wheat cropping system

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DOI: https://doi.org/10.33545/26174693.2024.v8.i4c.923

Abstract
The present investigation entitled "Enzymatic Activities in a Vertisol as Influenced by Long Term Nutrient Management Practices in Soybean-Wheat Cropping System" was conducted during 2021-22 under All India Coordinated Research Project on Long-Term Fertilizer Experiment at the Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India. The aim of the study was to evaluate the impact of inorganic fertilizers and organic manure on enzymatic activities (acid & alkaline phosphatase) in a Vertisol under soybean-wheat cropping system. The present study was performed with eight treatments, *viz* 50% NPK, 100% NPK, 150% NPK, 100% NP, 100% N, 100% NPK+FYM, 100% NPK(-S) and Control, which is comprising with four replications in a randomized block design. The findings of the present investigation indicated that the treatments including 100% NPK and 150% NPK significantly raised the activities of acid and alkaline phosphatase as compared to treatments containing 100% N alone and control. The 100% NPK+FYM treatment showed the highest value of both acid and alkaline phosphatase activity, whereas the control plot found the lowest values. Further, findings revealed that the all the enzymatic activities were decreased with increasing soil depth at all the treatments. Therefore, the balanced application of inorganic fertilizers either alone or in combination with organic manure is required to enhance and sustain the soil fertility status of a Vertisol.

Keywords: Acid phosphatase, Alkaline phosphatise, FYM, LTFE, vertisols

Introduction
One of the major essential nutrients for plants in the soil is phosphorus (P), and without its adequate amount, plant can neither reach its yield potential nor complete a normal reproductive process. It is a major limiting factor for plant growth, and only 0.1% of soil P exists in available forms for plant uptake. It has been recognised as a major constraint for crop production in central Indian soil because, the finite reserve of this non-renewal resource is getting exhausted rapidly and its deficiency has become widely spread with high intensity cropping (Thakur *et al.*, 2010 and Gupta *et al.*, 2019) [21, 7].

Microorganisms play a crucial role in the cycling of P in soil through various mechanisms, such as excretion of extra cellular enzymes. Alkaline and acid phosphatases can be secreted by certain bacteria that possess phosphate regulons (Pho) in order to hydrolyze ortho-phosphate diesters and monoesters, which may produce up to 90 percent of the organic P in soils. They also play important parts in the development of aggregates, the humus formation, the cycling of nutrients, the breakdown of different chemicals, and other changes in the soil (Wu *et al.*, 2011, Meshram *et al.*, 2018 and Tiwari *et al.*, 2023) [24, 11, 22]. The physical, chemical, and biological characteristics of soils can be directly or indirectly changed by the continuous application of fertilization, which can alter fertility and the amount of accessible nutrients. This can lead to long-term changes in the efficiency and quality of soils (Kushwaha *et al.*, 2017, Nagwanshi *et al.*, 2018 and Thakur *et al.*, 2023) [9, 4, 1]. According to Vallejo *et al.*, (2010) soil microbial biomass, enzymatic activity, and microbial community structures and functions have been used to describe soil health at various farming practices. Through assimilation of nutrients and soil biomass production, microorganisms control the flow of nutrients in the soil (Dwivedi *et al.*, 2019 and Thakur *et al.*, 2022) [5, 20].

The variations in microbial biomass carbon and biological activity in the soil are also closely linked to the changes in soil organic carbon concentrations (Khandagle *et al*., 2019 and Bairwa *et al.*, 2021) [8, 2].

Materials and Method

The present investigation is a part of an ongoing All India Coordinated Research Project on Long-Term Fertilizer Experiment with soybean-wheat cropping sequence in a Vertisol which was initiated during 1972 at Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India. The Jabalpur is situated in north-central India, in the region of Madhya Pradesh, close to the south of the Tropic of Cancer, at 23°10' North latitude and 79°58' East longitude, at an elevation of 411.78 metres above mean sea level. The experimental soil is medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic Haplustert (Vertisol). The textural class of soil is clayey (Pathariya *et al.*, 2022) [16]. The basic soil properties before start of the experiment in the year 1972 are presented in Table 1.

The experiment was conducted and designed in a randomized block design with eight treatments and four replications. A permanent bund was used to divide each individual plot (17.0 m × 10.8 m), and a gap of 2.0 m was used to divide two blocks. The 100% optimal NPK doses based on initial (1972) soil test values were 20:80:20 and 120:80:40 kg NPK ha^{-1} for soybean and wheat, respectively. The treatment details and quantity of nutrients added are presented in Table 2.

Table 1: Basic soil (0-15 cm soil depth) properties of the experimental site (1972)

S. No.	Soil properties	Value
1.	$pH_{1:2.5}$	7.60
2.	Electrical conductivity ($EC_{1:2.5}$)	0.18 dSm^{-1}
3.	Soil organic carbon	5.7 g kg^{-1}
4.	Calcium carbonate	4.6%
5.	Soil available nitrogen (N)	193 kg ha^{-1}
6.	Soil available phosphorus (P)	7.60 kg ha^{-1}
7.	Soil available potassium (K)	370 kg ha^{-1}
8.	Soil available sulphur (S)	7.80 mg kg^{-1}
9.	Soil available zinc (Zn)	0.33 mg kg^{-1}

Table 2: Details of treatment and nutrient rates (kg ha^{-1}) in soybean and wheat

Treatments	Fertilizer nutrients applied (kg ha^{-1})					
	Soybean			Wheat		
	N	P	K	N	P	K
50% NPK	10	17.6	8.3	60	17.6	16.6
100% NPK	20	35.2	16.6	120	35.2	33.2
150% NPK	30	52.8	24.9	180	52.8	49.8
100%NP	20	35.2	NA	120	35.2	NA
100% N	20	NA	NA	120	NA	NA
100% NPK+FYM*	46.5	41.8	42.7	120	35.2	33.2
100% NPK (-S)	20	35.2	16.6	120	35.2	33.2
Control	NA	NA	NA	NA	NA	NA

NPK: The percent amount of Nitrogen (N), Phosphorous (P) and Potassium (K) applied through inorganic fertilizers

*FYM contains 0.53% N, 0.30% P_2O_5& 0.63% K_2O; NA: Not Applied

The sources of nitrogen (N), phosphorus (P) and potassium (K) which were applied included urea, single superphosphate (SSP) and muriate of potash (MOP). In 100% NPK (-S) treatment, diammonium phosphate (DAP) was used instead of SSP as a source of phosphorus. The farmyard manure (FYM) was applied at the rate of 5 t ha^{-1} yr^{-1} to soybean crop only during kharif season just 10-15 days before sowing. In soybean crop, all NPK fertilizers were applied as basal before the last harrowing during rainy season, however, in wheat crop 50% N and 100% PK was applied as basal before sowing and rest 50% N in two split applications, first half at 21–25 days (following the first irrigation) and the second half at 51–55 days.

Microbial Analysis

The fresh soil samples at 0-15 cm and 15-30 cm soil depth were collected after harvest of wheat crop during 2021-22 and immediately used for estimating biological properties. The soil enzymatic activities (phosphatase activity) in soil were estimated through a method developed by Tabatabai and Bermner (1969) [18].

Statistical Analysis

The data pertaining to enzymatic activities of Vertisols were statistically analyzed using analysis of variance (ANOVA) for randomized block design taking eight treatments with four replications to draw suitable inferences as per standard method described by Gomez and Gomez (1984) [6].

Results and Discussion

Acid Phosphatase Activity

The ability of the soil to support biochemical processes which are crucial for maintaining soil fertility is determined by studies of enzyme activity in soil. The acid phosphatise activities of a soil is illustrated in Figure 1 and revealed that the acid phosphatise activities of a soil was ranged between 9.51 µg p-nitrophenol $g^{-1}hr^{-1}$ (Control) to 13.54 µg p-nitrophenol $g^{-1}hr^{-1}$ (100% NPK+FYM) treatments at 0-15 cm soil depth. The acid phosphatise activities of soil was increased successively with the gradual application of fertilizers *i.e.* 50% NPK, 100% NPK and 150% NPK treatments. The highest value was registered 13.54 µg p-nitrophenolg^{-1} hr^{-1} with 100% NPK+FYM treatment followed by 150% NPK treatments (12.36 µg p-nitrophenol g^{-1} hr^{-1}). These results were similar to findings of Patel *et al.*, (2018) [15] showed that the long-term effect of nutrient management on soil biochemical properties in a Vertisol under soybean–wheat cropping sequence and noted that the he conjoint use of fertilizers and FYM was significantly superior to other treatments for soil enzymatic activities like acid phosphatise and alkaline phosphatise activities in a Vertisol. The phosphatases are extracellular enzymes that catalyze the organic phosphates to inorganic orthophosphates. Srinivasarao *et al.*, (2015) [17] and Dubey *et al.*, (2016) [3] found that the majority of crops had phosphorous use efficiency from applied fertilizer of between 15 and 25 percent, with the remaining portion being immobilised (Parihar *et al*., 2010 and Bagde *et al.*, 2023) [14, 1]. The mechanism which is involves in the solubilization of inorganic P by the production of acids, while enzymatic hydrolysis of organic phosphorous compounds through phosphates and phytase. Further, the acid phosphatise activities decreased with increasing soil depth in all the treatment plot.

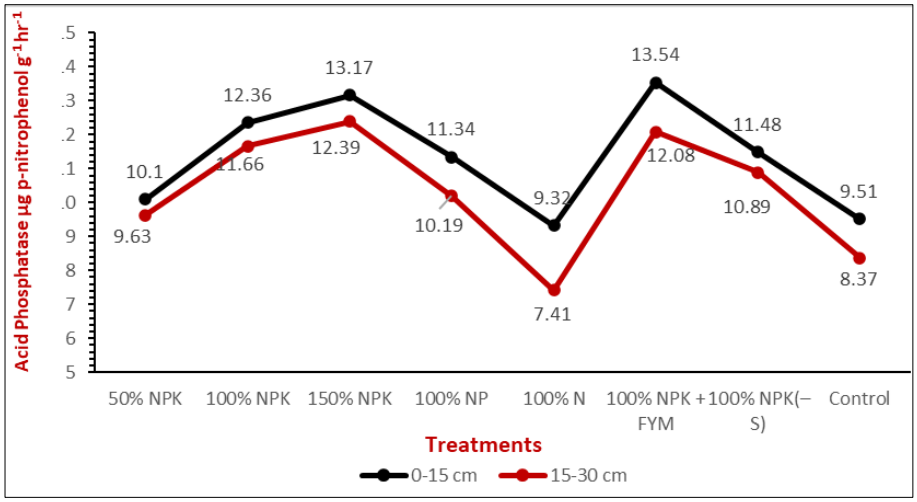

Fig 1: Effect of long-term application of fertilizers and manure on acid phosphatase activity at surface and sub surface soil

Alkaline Phosphatase Activity

The alkaline phosphatise activity of a soil depicted in Figure 2 and indicated that the highest value of alkaline phosphatise activity was found in 28.31 µg p-nitrophenol g^{-1} hr^{-1} in 100% NPK was applied along with FYM at surface soil (0-15 cm soil depth) However, the lowest value of alkaline phosphatise activity 17.81 µg p-nitrophenol g^{-1} hr^{-1} was observed in control plot at 0-15 cm soil depth. The application of graded doses of inorganic fertilizers i.e. 50% NPK, 100% NPK and 150% NPK increased alkaline phosphatise activities of soil. Similarly, the findings of Parham *et al.*, (2004) [13] found that the soil treated with cattle manure had significantly higher levels of phosphomonoesterase, phosphodiesterase, inorganic pyrophosphatase, and dehydrogenase. Further, the soil treated with chemical fertilizers showed significantly higher levels of acid phosphatase activity. Similar finding showed by Manna *et al.*, (2007) [10] examined the impact of fertilizer P and manures (FYM) on soil enzymes and microbial activities in soybean-wheat crop rotation and found that the alkaline phosphatase activity increased with an advancement of crop growth stages and also observed that there was a significant increase in alkaline phosphatase activity in the treatments that received both fertilizer P and manures. The findings further revealed that the value of alkaline phosphatase activity was a maximum in surface soil (0-15 cm) and decreased with increasing soil depth.

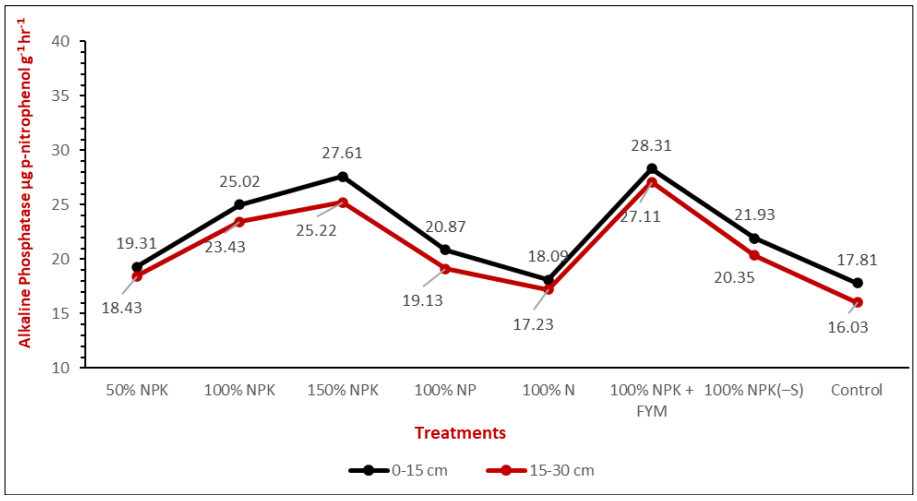

Fig 2: Effect of long-term application of fertilizers and manure on alkaline phosphatase activity at surface and sub surface soil

Conclusion

The findings of the present study, concluded that the enzymatic activities (acid and alkaline phosphatase) in a Vertisol was markedly enhanced and maintained by the long-term application of balanced fertilizers either alone or integration with organic manure (100% NPK, 150% NPK, and 100% NPK+FYM) under soybean-wheat cropping system. The best response as regard to the enzymatic activities was recorded in 100% NPK+FYM treatment. Thus, long-term fertility management practices provide the significant and valuable information to understand the biological and biochemical characteristics of a Vertisol. This will lead to the development of more reliable and consistent indicators for the assessment of the fertility sustainability of semi-arid sub-tropical soils.

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