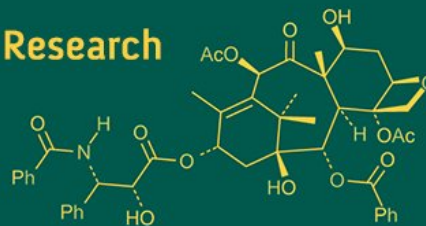


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Evaluate the relationship between organic and inorganic sources of nutrients on microbial population dynamics and enzyme activities in soil

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Abstract

A field experiment was conducted during Rabi seasons of 2024-25 and 2025-26 at the Student Instructional Farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, (U.P.) The investigation was undertaken to studies on the effect of organic and inorganic sources of nutrients on soil health, growth and yield attributes of wheat (*Triticum aestivum* L.).The treatments consisted three levels of organic sources (control, FYM @ 5 t ha⁻¹,vermicompost @ 2.5 t ha⁻¹), two levels of inorganic sources (control, ZnSO₄ @ 5 kg ha⁻¹ + boron @ 2 kg ha⁻¹) and three levels of bio-inoculants (control, *Azotobactor*, PSB). The experiment was replicated thrice in a factorial randomized block design (FRBD). The results revealed that application of different treatments affect the microbial biomass carbon, soil dehydrogenase, alkaline phosphatase activity and microbial population of soil after the harvest of wheat were improved significantly due to the integration of organic and inorganic sources of nutrients. The significant higher values of microbial biomass carbon, soil dehydrogenase, alkaline phosphatase activity and microbial population of soil under FYM @ 5 t ha⁻¹ compared to control clearly indicate the effect of organic sources of nutrients in an improvement of soil. Positive impact of biological and organic manure application has been recorded with an additional advantage of reduction of chemical fertilizer use.

Keywords: Bio-inoculants, micronutrients, microbial biomass carbon, organic manures, soil dehydrogenase activity, wheat

Introduction

Wheat (*Triticum aestivum* L.) is an essential cereal crop belonging to the Poaceae family and has emerged as a staple food in various regions across the globe due to its nutritional value and palatability Wheat is one of the oldest cereals widely consumed by human being.

Wheat requires a good supply of nutrients for its growth and yield but chemical fertilizers alone are unable to maintain the long-term soil health and crop productivity (Subba Rao and Srivastava 1998) ^[1], because they are unable to supply many other minor and trace elements. Improper and imbalanced use of chemical fertilizers coupled with less addition of organic manures has resulted in deterioration of soil health in terms of emerging multinutrient deficiencies and deterioration of physical soil properties. The addition of organic manures not only supplies the nutrients for crop growth but also improves different soil physical, chemical and biological properties.

Balanced fertilizers through organic and inorganic sources improve the soil health as well as boost the productivity of wheat. Efficacy of organic sources to meet the nutrient requirement of crop is not as assured as mineral fertilizers, but the joint use of chemical fertilizers along with various organic sources is capable of improving soil quality and higher crop productivity on long- term basis. Majorly poor management of fertilizer has key role to play in obtaining low yield productivity, so in order to achieve optimum crop productivity management of nutrients through judicious application of organic sources, bio-fertilizers and micro-nutrients are required. Besides it has manorial proteins and it has valuable supports soil biological activities besides improving soil structure, water holding capacity and other physicochemical properties of soil. Highest productivity of crops in sustainable manner without deteriorating the soil and other natural resources could be achieved only by applying

appropriate combination of different organic manures and inorganic fertilizers (Chandra shekara *et al.* 2020).

Organic manures are keys to enhance soil quality and crop yield since they perform numerous functions in agroecosystems (Jones *et al.* 2007) [3]. Their inputs are in general beneficial for the overall health of the agro-environment (Jedidi *et al.* 2004) [4]. Organic sources of nutrients include farmyard manure (FYM) generated from sheep, poultry litter (PL), green manures, sewage sludge, and press mud (Farhad *et al.* 2011; Iqbal *et al.* 2014) [5, 6]. Bio-fertilizers are inputs containing microorganism which are capable of mobilizing nutritive elements from complex and non-usable form to simple and usable form through biological processes (Cakmakc *et al.* 2007) [7].

Biofertilizers are the live formulation of microorganisms which have the ability to mobilize plant nutrients in the soil and offer a cheap, low capital intensive, non-bulk and eco-friendly source to boost productivity (Kloepper *et al.* 1989) [8]. Biofertilizers due to its renewable, cheap and eco-friendly nature has gained increasing popularity in the past one decade in the field of agriculture and food production. Bio-fertilizers are one of the important components of the sustainable agriculture for increasing the yield and maintain the soil fertility (Narula *et al.* 2005) [9]. In this context, organic manures (biofertilizers) would be the viable option for farmers to increase productivity per unit area.

2. Materials and methods

2.1 Experimental location and season

The experiment was conducted at “Students’ Instructional Farm”, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, (U.P.) which is situated between 25° 26' to 26° 58' North latitude, 79° 31' to 31° 34' East longitude and at the 125.9 meters above sea level in the alluvial tract of Indo - Gangatic Plain zone of central part of Uttar Pradesh, India during the Ravi Season 2024-25 to 2025-26.

2.2 Soil condition

The soil of experimental field was sandy loam in texture having low soil organic carbon (0.42 %), low available N (180.87 kg ha⁻¹), medium available P (12.9 kg ha⁻¹) and K (130.10 kg ha⁻¹), bulk density (1.32 Mg M⁻³), particle density (2.68 Mg M⁻³) contents with neutral pH 8.13 (1:2.5 soil: water ratio). The biological properties of the initial soil sample viz. dehydrogenase activity ranging from 21.67 to 22.89 µg TPF g⁻¹ soil day⁻¹, phosphatase 200.17 to 207.67 g PNP g⁻¹ h⁻¹ soil, soil microbial biomass carbon (SMBC) 212.09 to 215.87 MBC g⁻¹ soil and bacterial, fungal and actinomycetes population 12.87 to 13.18 cfu x 10⁵ g⁻¹ soil, 9.87 to 10.08 cfu x 10⁵ g⁻¹ soil and 10.23 to 11.87 cfu x 10⁵ g⁻¹ soil, respectively, during the 1st and 2nd year of experiments.

2.3 Experimental design and treatments details

The experiment was arranged in a Factorial Randomized Block Design with 54 treatment combinations involving three levels of organic sources (control, FYM @ 5 t ha⁻¹, vermicompost @ 2.5 t ha⁻¹), two levels of inorganic sources (control, ZnSO₄ @ 5 kg ha⁻¹ + boron @ 2 kg ha⁻¹) and three levels of bio-inoculants (control, *Azotobactor*, PSB, replicated thrice. Wheat var. K- 1317 was taken as a test crop to observe direct effect of the treatments. The 100% NPK recommended dose of fertilizer for wheat was 120 kg N, 60 kg P₂O₅ and 60 kg K₂O ha⁻¹, respectively. Half dose of N and full dose of P and K were applied as basal in the form of urea, di ammonium phosphate and muriate of potash manually by placement method into open furrows,

respectively. The remaining N was applied in two equal splits at tillering and flower initiation stages, respectively during both the years. Soil samples were collected after harvesting of the crop and analysed by the standard procedure.

3. Results and discussion

Biological properties

The data pertaining to biological properties under different treatments are presented in Table 1 and figure 1. The activity of dehydrogenase and phosphatase enzymes differed significantly amongst all the treatments. The data showed significant variation of soil dehydrogenase and phosphatase enzymes due to organic, inorganic source of nutrients and bioinoculants practices at amongst all the treatments during both years and on pooled basis also. Pooled analysis data of both year that, dehydrogenase activity of soil and phosphatase enzymes was recorded significantly maximum (25.43 µg TPF g⁻¹ soil day⁻¹) and (229.66 g PNP g⁻¹ hr⁻¹ soil) under the organic source at FYM @ 5 t ha⁻¹ (O₁) followed by vermicompost @ 2.5 t ha⁻¹ (O₂) (24.93 µg TPF g⁻¹ soil day⁻¹) and (225.11 g PNP g⁻¹ hr⁻¹ soil) and minimum dehydrogenase activity of soil and phosphatase enzymes (22.61 µg TPF g⁻¹ soil day⁻¹), (204.15 g PNP g⁻¹ hr⁻¹ soil) were recorded under the treatment of control (O₀). Among the inorganic source of nutrients practices significantly maximum dehydrogenase activity of soil and phosphatase enzymes (25.33 µg TPF g⁻¹ soil day⁻¹) and (228.76 g PNP g⁻¹ hr⁻¹ soil) during both years were recorded under ZnSO₄ @ 5 kg ha⁻¹ + boron @ 2 kg ha⁻¹ (I₁) as compared to without inorganic source (23.31 µg TPF g⁻¹ soil day⁻¹) and (210.53 g PNP g⁻¹ hr⁻¹ soil) treatment (I₀). Bioinoculants practices also significantly influenced by application of *Azotobactor* (B₁) recorded significantly highest dehydrogenase activity of soil and phosphatase enzymes (25.63 µg TPF g⁻¹ soil day⁻¹) and (231.49 g PNP g⁻¹ hr⁻¹ soil) followed by PSB (B₂) (24.63 µg TPF g⁻¹ soil day⁻¹), (222.38 g PNP g⁻¹ hr⁻¹ soil) and lowest dehydrogenase activity of soil and phosphatase enzymes (22.71 µg TPF g⁻¹ soil day⁻¹) and (205.06 g PNP g⁻¹ hr⁻¹ soil) was recorded under the treatment of control (B₀). This increased might be due to manure promote biological and microbial activities and accelerated the breakdown of organic substances in the added manure, which is known to stimulate the dehydrogenase activity (Pedrazzini and Mckee, 1984) [10]. The increased 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 enzymes. Masto *et al.*, (2006) [18] reported that dehydrogenase activity was dependent on addition of number and amount of nutrient. The significant increase of enzyme activity was also found by the use of bioinoculants as compared to no inoculation control. Increased the enzyme activity of soil significantly over no inoculation, may possibly be due to the improvement in the porosity and more availability of nutrients (especially P) to the plant (Shinde and Bangar, 2003) [19].

It is evident from data presented in Table 1, that the contents of soil microbial biomass carbon (SMBC) varied significantly under different treatments during both years and on pooled basis also. On the basis of pooled analysis data, it is clear that organic source significantly affected soil microbial biomass carbon and application of FYM @ 5 t ha⁻¹ (O₁) recorded significantly highest soil microbial biomass carbon (255.75 µg MBC g⁻¹ soil) followed by vermicompost @ 2.5 t ha⁻¹ (250.60 µg MBC g⁻¹ soil) and lowest soil microbial biomass carbon (213.36 µg MBC g⁻¹ soil) was

recorded under the treatment of control (O_0). Under the inorganic source of nutrients practices soil microbial biomass carbon significantly affected by application of $ZnSO_4$ @ 5 kg ha^{-1} + boron @ 2 kg ha^{-1} (I_1) recorded significantly highest soil microbial biomass carbon (243.24 μg MBC g^{-1} soil) over to without inorganic source (I_0) treatment (236.57 μg MBC g^{-1} soil). Bioinoculants practices also significantly influenced soil microbial biomass carbon and application of *Azotobacter* (B_1) recorded significantly highest soil microbial biomass carbon (252.92 μg MBC g^{-1} soil) and followed by PSB (B_2) (248.48 μg MBC g^{-1} soil) and lowest soil microbial biomass carbon (218.31 μg MBC g^{-1} soil) was recorded under the treatment of control (B_0). The higher microbial biomass in FYM might be due to higher below ground plant residues as well as added FYM (Grego *et al.*, 1998) [16]. Microbial biomass carbon increased with increase in doses of inorganic fertilizers may be due firstly to increase in microbial population (Hasebe *et al.*, 1985) [17] and secondly to the formation of root exudates, mucigel sloughed off cells and underground roots of previous cut crops, which also play an important role in increasing biomass carbon (Goyal *et al.*, 1992) [15]. The SMBC increased with fertilizer level were also reported by Gogoi *et al.*, (2010) [14]. Moreover, the use of bioinoculants in an integrated manner enhanced the microbial biomass carbon during both the years. The increase might be due to integrated use of fertilizer, FYM and bioinoculants add more organic matter, which provide carbon and energy to the soil microbes resulting into multiplication of microbial population and increase in soil microbial biomass carbon during both the years. The results of the present investigation are in accordance with the finding of Datt *et al.*, (2013) [12].

The data pertaining to biological properties under different treatments are presented in Table 2 and figure 2. The microbial population showed higher bacterial population as compared to actinomycetes and fungi in wheat rhizosphere after harvest of the wheat in both the years. The data showed significant variation of soil bacteria, actinomycetes and fungi due to organic, inorganic source of nutrients and bioinoculants practices at amongst all the treatments during both years and on pooled basis also. Pooled analysis data of both year that, soil bacteria, actinomycetes and fungi was recorded significantly maximum (19.68×10^5 cfu g^{-1} soil), (18.27×10^5 cfu g^{-1} soil) and (18.06×10^5 cfu g^{-1} soil) under

the organic source at FYM @ 5 t ha^{-1} (O_1) and minimum soil bacteria, actinomycetes and fungi (18.97×10^5 cfu g^{-1} soil), (16.35×10^5 cfu g^{-1} soil), (16.35×10^5 cfu g^{-1} soil) and (13.73×10^5 cfu g^{-1} soil), (12.92×10^5 cfu g^{-1} soil), (12.52×10^5 cfu g^{-1} soil) were recorded under the vermicompost @ 2.5 t ha^{-1} (O_2) and control (O_0). Among the inorganic source of nutrients practices significantly maximum soil bacteria, actinomycetes and fungi (17.96×10^5 cfu g^{-1} soil), (16.75×10^5 cfu g^{-1} soil) and (16.35×10^5 cfu g^{-1} soil) during both years were recorded under $ZnSO_4$ @ 5 kg ha^{-1} + boron @ 2 kg ha^{-1} (I_1) as compared to without inorganic source (16.96×10^5 cfu g^{-1} soil), (14.94×10^5 cfu g^{-1} soil) and (14.94×10^5 cfu g^{-1} soil) treatment (I_0). Bioinoculants practices also significantly influenced by application of *Azotobacter* (B_1) recorded significantly highest soil bacteria, actinomycetes and fungi (19.48×10^5 cfu g^{-1} soil), (17.76×10^5 cfu g^{-1} soil) and (17.56×10^5 cfu g^{-1} soil) followed by PSB (B_2) (17.96×10^5 cfu g^{-1} soil), (16.75×10^5 cfu g^{-1} soil), (16.55×10^5 cfu g^{-1} soil) and lowest soil bacteria, actinomycetes and fungi (14.94×10^5 cfu g^{-1} soil), (13.02×10^5 cfu g^{-1} soil) and (12.82×10^5 cfu g^{-1} soil) was recorded under the treatment of control (B_0). The increased microbial population might be due to application of organic manures in turn provides adequate biomass as a feed for the microbes and helps in increasing microbial population in soil (Singh *et al.*, 2012) [20]. The increase in microbial population might be due to increasing levels of N, P and K which increases the biomass, root exudates and ultimately provides carbon and energy to the soil microbes resulting into multiplication of microbial population (Geetha kumari and Shivashankar, 1991). The results are harmony with the finding of Chand *et al.*, (2010) [11]. The bioinoculants *Azotobacter*, PSB either singly or in combination significantly increased the population of microbes viz., bacteria, actinomycetes and fungi in rhizosphere soil after harvest of wheat over no inoculation during both the years. The bioinoculants trigger the microbial population might be possibly due to the improvement in the porosity and more availability of nutrients (especially P) to the plant by the bioinoculants (Shinde and Bangar, 2003) [19]. Sushila and Giri (2000) [21] also reported increase in microbial population in rhizosphere of wheat with *Azospirillum* and *Azotobacter* inoculations biomass as a feed for the microbes and helps in increasing microbial population in soil (Singh *et al.*, 2012) [20].

Table 1: Effect of organic and inorganic sources of nutrients on biological properties of soil

Treatments	Soil dehydrogenase (μg TPF g^{-1} soil day^{-1})			Alkaline Phosphatase activity (g PNP g^{-1} hr^{-1} soil)			Microbial biomass carbon (μg MBC g^{-1} soil)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Organic sources (O)									
O_0	22.40	22.82	22.61	202.27	206.02	204.15	211.40	215.32	213.36
O_1	25.20	25.67	25.43	227.55	231.77	229.66	253.40	258.10	255.75
O_2	24.70	25.16	24.93	223.04	227.18	225.11	248.30	252.90	250.60
SEm $\pm$	0.086	0.094	0.045	0.802	0.832	0.408	0.846	0.885	0.433
C.D at 5%	0.246	0.272	0.127	2.305	2.390	1.153	2.431	2.543	1.221
Inorganic sources (I)									
I_0	23.10	23.53	23.31	208.59	212.46	210.53	234.40	238.75	236.57
I_1	25.10	25.57	25.33	226.65	230.86	228.76	241.00	245.47	243.24
SEm $\pm$	0.057	0.063	0.030	0.535	0.554	0.272	0.564	0.590	0.288
C.D at 5%	0.164	0.181	0.085	1.537	1.593	0.768	1.621	1.695	0.814
Biofertilizers (B)									
B_0	22.50	22.92	22.71	203.17	206.94	205.06	216.30	220.31	218.31
B_1	25.40	25.87	25.63	229.36	233.62	231.49	250.60	255.25	252.92
B_2	24.40	24.85	24.63	220.33	224.42	222.38	246.20	250.77	248.48
SEm $\pm$	0.086	0.094	0.045	0.802	0.832	0.408	0.846	0.885	0.433
C.D at 5%	0.246	0.272	0.127	2.305	2.390	1.153	2.431	2.543	1.221

Table 2: Effect of organic and inorganic sources of nutrients on biological properties of soil

Treatments	Total microbial count (cfu g soil ⁻¹)								
	Bacteria (a×10 ⁵ cfu g ⁻¹)			Fungi (b×10 ⁵ cfu g ⁻¹)			Actinomycetes (c×10 ⁵ cfu g ⁻¹)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
Organic sources (O)									
O ₀	13.60	13.85	13.73	12.40	12.63	12.52	12.80	13.04	12.92
O ₁	19.50	19.86	19.68	17.90	18.23	18.06	18.10	18.44	18.27
O ₂	18.80	19.15	18.97	16.20	16.50	16.35	16.20	16.50	16.35
SEm±	0.071	0.065	0.034	0.060	0.059	0.030	0.063	0.056	0.030
C.D at 5%	0.203	0.188	0.096	0.174	0.168	0.084	0.182	0.161	0.084
Inorganic sources (I)									
I ₀	16.80	17.11	16.96	14.80	15.07	14.94	14.80	15.08	14.94
I ₁	17.80	18.13	17.96	16.20	16.50	16.35	16.60	16.91	16.75
SEm±	0.047	0.044	0.023	0.040	0.039	0.020	0.042	0.037	0.020
C.D at 5%	0.136	0.125	0.064	0.116	0.112	0.056	0.121	0.107	0.056
Biofertilizers (B)									
B ₀	14.80	15.07	14.94	12.70	12.93	12.82	12.90	13.14	13.02
B ₁	19.30	19.66	19.48	17.40	17.72	17.56	17.60	17.93	17.76
B ₂	17.80	18.13	17.96	16.40	16.70	16.55	16.60	16.91	16.75
SEm±	0.071	0.065	0.034	0.060	0.059	0.030	0.063	0.056	0.030
C.D at 5%	0.203	0.188	0.096	0.174	0.168	0.084	0.182	0.161	0.084

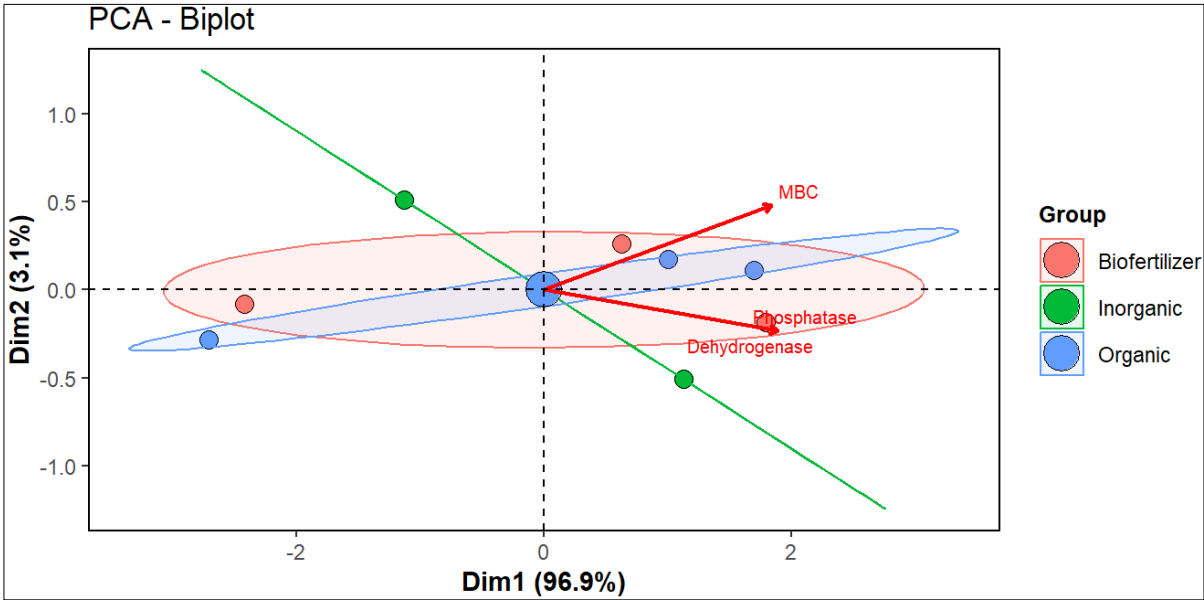


Fig 1: Effect of organic and inorganic sources of nutrients on biological properties of soil

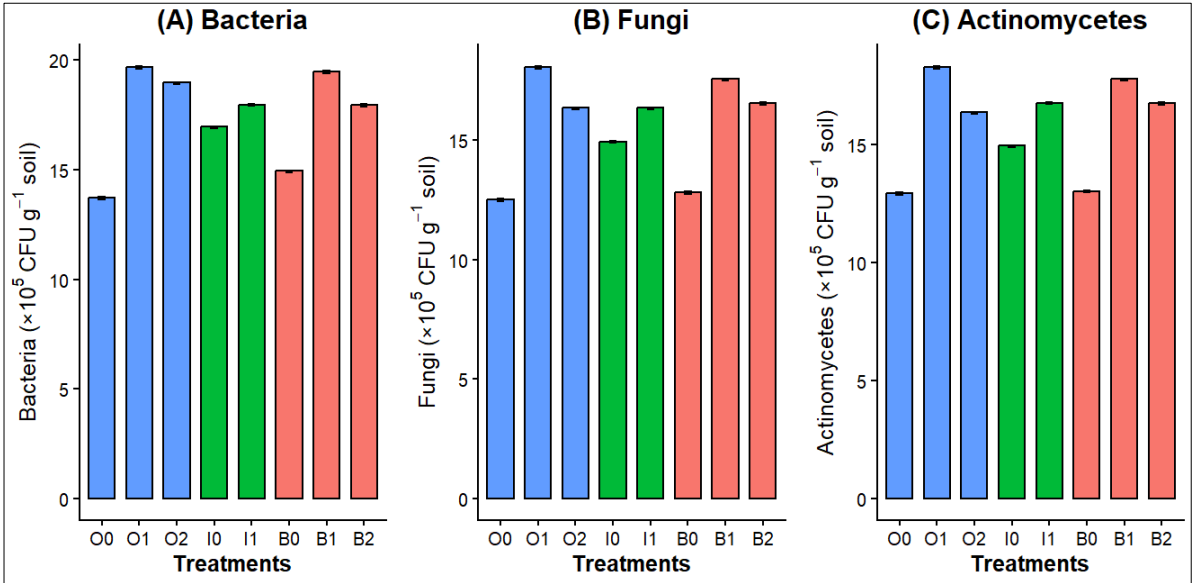


Fig 2: Effect of organic and inorganic sources of nutrients on biological properties of soil

4. Conclusion

The overall results demonstrated that enzyme activity, soil microbial biomass carbon and microbial properties of soil were improved by combined application of organic source of nutrients, inorganic source of nutrients and bioinoculants over control. Hence, it can be concluded that integration of all the treatment in balance form improve the physico chemical and biological properties of the soil. Finally, the goal is to integrate the use of all natural and manmade sources of plant nutrients, so that crop productivity increases in an efficient and environmentally benign manner, without sacrificing soil productivity of future generations.

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