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Response of Inorganic, Organic Fertilizer and Microbial Inoculants on Physico-chemical Properties of Soil in Cultivation of Wheat (*Triticum aestivum*. L) var. PBW-373

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of the experiment was to evaluate the response of inorganic fertilizer, organic fertilizer and microbial inoculants on soil health of wheat. The design applied was 3x3 randomized block design. It was observed that treatment T9 (100% RDF +FYM @ 15 t ha-1 + PSB 6.0 kg ha-1) improved the soil WHC, OC, available N,P and K resulted in a slight change in soil pH 7.34, EC

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0.49 dS m-1, bulk density 1.14 Mg m-3 and particle density 2.54 Mg m-3. In post-harvest soil of fertilizers observations were resulted in significant increase in pore space 48.97 %, water holding capacity 46.85 %, organic carbon 0.48 %, and available N 286.92 kg ha-1 ,P20.05 kg ha-1,K 201.87 kg ha-1,significant increase in case of Nitrogenkg ha-1, Phosphorus kg ha-1, Potassium kg ha-1 was found to be significant among other treatments in wheat cultivation.

Keywords: Farm yard manure; inorganic fertilizers; phosphorus solubilizing bacteria; soil health; wheat etc.

1. INTRODUCTION

In addition to providing nutrients, the soil serves as a natural habitat for plant growth. Certain soils are productive and allow for lush plant development with minimal human intervention, whereas other soils may not support any useful plant life at all even with extensive human intervention. The soil needs to be easily tillable and fertile, have all the nutrients needed in amounts that plants can easily access, be physically sound enough to support plants, and have the right amount of moisture and air content for healthy root development in order to be considered productive. The soil must consistently supply these requirements for the duration of theplant's life.

"Wheat (*Triticum aestivum L.*) is the first important *Rabi* cereal crop for the majority of world's populations. It belongs to grass family *Poaceae* (*Graminae*). It is the most important staple food of about two billion people (36% of the world population). India is the second largest producer of wheat (99.70 million tons) next only to China(125.60 million tons) and cover the largest area under its cultivation (29.58 mha), which is about14 percent of the world wheat area and average productivity of 3377 kg ha^{-1}"(MoA and FW 2018).

"Nitrogen (N) is major factor for yield of wheat" [1]. "Wheat is an important cereal crop and requires a good supply of nutrients especially nitrogen" for its growth [2] and yield (Krylov and Pavlov, 1989).

"Phosphorus is essential for enhancing seed maturity and seed development" [3]. "Phosphorus plays a significant role in several vital functions such as photosynthesis, transformation of sugar to starch, protein information, nucleic acid production, nitrogen fixation and formation of oil. It is also, the part of all biochemical cycles in plants"[4].

"Potassium controls the permeability of cellular membranes, maintaining correct protoplasmic hydration, and stabilizing emulsions with high colloidal characteristics, all of which contribute to the preservation of cellular organization. Potassium stabilizes numerous enzyme system and has a considerable buffering effect. Potassium is known as "quality element" and it was considered as a key factor in crop production" [5].

"Judicious use of FYM with chemical fertilizers improves soil physical, chemical and biological properties and improves the crop productivity" [6].

"Biofertilizer enhance soil fertility also crop productivity by fixing atmospheric nitrogen, mobilizing sparingly soluble P and by facilitating the release of nutrients through decomposition of crop residues. Phosphorous solubilizing bacteria (PSB) as bio-fertilizers have been found effective in solubilizing the fixed soil P and applied phosphates resulting in higher crop yields. Seed or soil inoculation with PSB, particularly belonging to the genera *Pseudomonas* and *Bacillus,* have been known to improve plant uptake of nutrients and there by increase the use efficiency of applied chemical fertilizers" [7,8,9,10].

Inorganic fertilizers provide essential nutrients like nitrogen, phosphorus, and potassium, while organic fertilizers enrich the soil with organic matter, improving its structure and fertility. Microbial inoculants introduce beneficial microorganisms that enhance nutrient uptake and plant growth. Inorganic fertilizers, when used excessively, can lead to soil degradation, nutrient imbalances, and reduced microbial activity[11-13]. Conversely, organic fertilizers and microbial inoculants promote soil health by increasing microbial diversity, improving soil structure, and enhancing nutrient cycling. They also help in retaining soil moisture and reducing erosion[14-16]. By reducing reliance on synthetic fertilizers, the study of organic fertilizers and microbial inoculants promotes sustainable agricultural practices[17,18]. This approach minimizes the environmental impact of farming, including reducing greenhouse gas emissions, nitrogen runoff, and groundwater pollution. Building soil health through the use of organic fertilizers and microbial inoculants can enhance the resilience of wheat crops to climate change. Healthy soils are better able to withstand extreme weather events, such as droughts or heavy rainfall, and maintain productivity in changing environmental conditions. Optimizing fertilizer and inoculant use based on crop and soil requirements can lead to cost savings for farmers. Additionally, improved soil health and increased yields contribute to long-term economic sustainability in agriculture [19].

2. METHODOLOGY

The present experiment was conducted during winter season (2022-2023) at Department of Soil Science and Agricultural Chemistry Crop Research Farm of the Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh. Prayagraj is located at 25^{0}47’69” N latitude and 81^{0}85’74” E longitude at an elevation of 98 m from the mean sea level. This region has a sub-tropical climate prevailing in the South-East part ofUP.

The soil of the experimental site is alluvial and falls under Inceptisol order. The soil samples were randomly collected from five different sites in the experimental plot prior to tillage operation from a depth of 0-15 cm (furrow slice layer).The soil sample will be reduced in volume by quartering and canning the composites. The soil sample will then be air dried and run through a 2 mm sieve in order to prepare it for chemical analysis (pH, EC, organic carbon, available nitrogen, phosphorus, and potassium, as well as physical analysis (bulk density, particle density, pore space%, water holding capacity%).

3. RESULTS AND DISCUSSION

3.1 Bulk Density (Mg m^{-3})

“The data presented in Table 1 shows that bulk density of soil is influenced by various treatments” [20]. The application of inorganic and organic source of nutrients along with biofertilizer had significant effect on bulk density of soil. The range of values of bulk density varies from 1.14 to 1.24 Mg m^{-3} at 0-15 cm depth and 1.19 to 1.31 Mg m^{-3} at 15-30 cm depth. Among various treatments the maximum bulk density (1.31 Mg m^{-3}) was recorded in treatment T_1(Absolute Control) and minimum bulk density was reported in T_9 (100% RDF +FYM @ 15 t ha^{-1} + PSB 6 kg ha^{-1}). The soil structure improves when less dense inorganic, organic, and biofertilizer are used.Similar result has been recorded by Mestdagh et al.[21].

3.2 Particle Density (Mg m^{-3})

A scrutiny of data presented in Table 1 revealed that application of FYM with inorganic fertilizers and biofertilizer had non-significant effect on particle density of soil. The range of particle density varies from 2.53 to 2.55 Mg m^{-3} (0-15 cm depth) & 2.61 to 2.62 Mg m^{-3}. Similar result also found by Toppo et al*.*, [22].

3.3 Water Holding Capacity (%)

The data regarding the water holding capacity in soil as influenced by different treatments is given in Table, the application of various treatments had significant effect on water holding capacity of soil in wheat. The range of water holding capacity varies from 46.29 to 46.85 % at 0-15 cm depth and 41.76 to 43.43 % at 15-30 cm depth. Among various treatments the maximum water

Table 1. Treatment combination of wheat var.PBW-373

S.No.	Treatment combination
T_1	Absolute Control,
T_2	(RDF @ N: P: K (120:60:40 kg ha^{-1}),
T_3	(100% RDF + FYM @ 5 t ha^{-1}),
T_4	(100% RDF + FYM @ 10 t ha^{-1}),
T_5	(100% RDF + FYM @ 15 t ha^{-1}),
T_6	(100 % RDF + FYM @ 5 t ha^{-1}+ PSB 1.5 kg ha^{-1}),
T_7	(100% RDF + FYM @ 10 t ha^{-1}+ PSB 3.0 kg ha^{-1}),
T_8	(100% RDF +FYM @ 15 t ha^{-1}+PSB 4.5 kg ha^{-1}),
T_9	(100% RDF +FYM @ 15 t ha^{-1} + PSB 6.0 kg ha^{-1}).

Table 2. Response of Inorganic, Organic Fertilizer and microbial inoculants on physical properties of soil

Treatment	BD (Mg m^{-3})		PD (Mg m^{-3})		Pore space (%)		WHC (%)	
	0-15 cm	15-30cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Absolute Control	1.24	1.31	2.55	2.62	47.26	44.46	46.29	41.76
RDF @ N:P:K(120:60:40)	1.23	1.29	2.54	2.61	47.28	44.26	46.34	41.94
100% RDF + FYM @ 5 t ha^{-1}	1.22	1.29	2.54	2.61	47.20	44.18	46.38	42.08
100% RDF + FYM @ 10 t ha^{-1}	1.21	1.27	2.53	2.62	47.66	44.93	46.44	42.50
100% RDF + FYM @ 15 t ha^{-1}	1.20	1.26	2.54	2.62	48.32	43.50	46.50	42.74
100 % RDF + FYM @ 5 t ha^{-1}+PSB 1.5 kg ha^{-1}	1.19	1.25	2.53	2.62	49.39	43.46	46.57	42.97
100% RDF + FYM @ 5 t ha^{-1} + PSB 3 kg ha^{-1}	1.18	1.24	2.54	2.62	49.13	43.21	46.64	43.19
100% RDF +FYM @ 10 t ha^{-1}+ PSB 4.5 kg ha^{-1}	1.16	1.22	2.54	2.61	48.94	43.78	46.73	43.35
100% RDF +FYM @ 15 t ha^{-1} + PSB 6 kg ha^{-1}	1.14	1.19	2.54	2.62	49.40	43.98	46.85	43.43
F-Test	NS	NS	NS	NS	S	S	S	S
S.Em. (±)	_	_	_	_	0.18	0.36	0.06	0.37
C.D. at 5%	_	_	_	_	0.52	1.06	0.19	1.08

Table3. Response of different levels of inorganic fertilizer, organic fertilizer and microbial inoculants on chemical properties of soil

Treatment	**pH**		**EC (dS m^{-1})**		**Organic carbon (%)**	
	0-15 cm	**15 -30 cm**	**0–15 cm**	**15 – 30 cm**	**0-15 cm**	**15 – 30 cm**
Absolute Control	7.43	7.43	0.36	0.38	0.38	0.38
RDF @ N:P:K(120:60:40)	7.40	7.48	0.39	0.41	0.42	0.41
100% RDF + FYM @ 5 t ha^{-1}	7.47	7.49	0.42	0.45	0.44	0.45
100% RDF + FYM @ 10 t ha^{-1}	7.46	7.45	0.44	0.45	0.44	0.42
100% RDF + FYM @ 15 t ha^{-1}	7.34	7.40	0.42	0.41	0.43	0.46
100 % RDF + FYM @ 5 t ha^{-1}+PSB 1.5 kg ha^{-1}	7.40	7.43	0.40	0.42	0.46	0.48
100% RDF + FYM @ 5 t ha^{-1} + PSB 3 kg ha^{-1}	7.46	7.53	0.41	0.44	0.45	0.45
100% RDF +FYM @ 10 t ha^{-1}+ PSB 4.5 kg ha^{-1}	7.36	7.40	0.47	0.49	0.49	0.48
100% RDF +FYM @ 15 t ha^{-1} + PSB 6 kg ha^{-1}	7.34	7.37	0.49	0.53	0.51	0.52
F-Test	S	S	S	S	S	S
S.Em. (±)	0.04	0.03	0.01	0.01	0.01	0.01
C.D. at 5%	0.10	0.10	0.02	0.02	0.02	0.03

Table 4. Response of different levels of inorganic fertilizer, organic fertilizer and microbial inoculants on chemical properties of soil

Treatment	Available Nitrogen (kg ha^{-1})		Available Phosphorus (kg ha^{-1})		Available Potassium (kg ha^{-1})	
	0 – 15 cm	**15-30 cm**	**0 – 15 cm**	**15 – 30 cm**	**15 – 30 cm**	**15 – 30 cm**
Absolute Control	240.32	231.75	17.22	17.39	192.21	193.59
RDF @ N:P:K (120:60:40)	242.18	236.22	18.34	18.21	195.83	197.93
100% RDF + FYM @ 5 t ha^{-1}	245.93	232.43	17.85	18.46	200.75	198.26
100% RDF + FYM @ 10 t ha^{-1}	257.48	246.17	18.41	18.52	200.31	199.12
100% RDF + FYM @ 15 t ha^{-1}	267.30	252.09	18.35	18.55	198.15	197.67
100 % RDF + FYM @ 5 t ha^{-1}+PSB 1.5 kg ha^{-1}	255.98	245.26	18.75	18.80	203.13	198.45
100% RDF + FYM @ 5 t ha^{-1} + PSB 3 kg ha^{-1}	272.88	265.74	19.21	19.34	205.94	199.26
100% RDF +FYM @ 10 t ha^{-1}+ PSB 4.5 kg ha^{-1}	279.76	274.77	19.53	19.79	203.37	201.52
100% RDF +FYM @ 15 t ha^{-1} + PSB 6 kg ha^{-1}	286.92	280.38	20.05	19.89	218.14	200.64
F-Test	S	S	S	S	S	S
S.Em. (±)	1.09	1.14	0.29	0.27	3.40	0.38
C.D. at 0.5%	3.19	3.33	0.85	0.79	9.98	1.12

holding capacity (46.85 %) was recorded in treatment T_9 (100% RDF +FYM @ 15 t ha^{-1} + PSB 6 kg ha^{-1}) and minimum water holding capacity was reported in T_1 (Absolute Control). Similar result also found by Das et al. [23].

3.4 Pore Space (%)

The effect of different treatments on pore space is presented in Table shows that pore space (%) vary significantly by the application of FYM with inorganic nutrient source and biofertilizer. However, the range of pore space varied from 47.13 to 48.97 % at 0-15 cm depth and 42.13 to 43.84 % at 15-30 cm depth. Among various treatments the maximum pore space (48.97 %) was recorded in treatment T9(100% RDF +FYM @ 15 t ha-1 + PSB 6 kg ha-1) and minimum pore space was reported in T1 (Absolute Control). Similar result also found by Das et al., [23].

3.5 pH

It clearly revealed from the table that there was significant difference in the values of pH after each harvest of wheat due to different treatments applied in wheat. The soil pH over control due to various treatments applied in wheat. The maximum reduction in soil pH was recorded with the treatment of T9(100% RDF +FYM @ 15 t ha-1 + PSB 6 kg ha-1). Similar result also found by Selvi et al. [24].

3.6 EC

It clearly revealed from the table that there was significant difference in the values of EC after each harvest of wheat due to different treatments applied in wheat. The EC tended to decrease over control due to various treatments applied in wheat. The maximum reduction in soil EC was recorded with the treatment of T1(Absolute Control). Similar result also found by Das et al., [23].

3.7 Organic Carbon (%)

The perusal of data pertaining to organic carbon content in soil after harvest of wheat has been furnished in table. The maximum build up organic carbon content was recorded with the application of T9 (100% RDF +FYM @ 15 t ha-1 + PSB 6 kg ha-1) which was significantly superior over rest of the treatments. It clearly indicated that the combined application of RDF with FYM along with PSB has significant influence on organic carbon build up in soil. Similar result also found by Das et al. [23].

3.8 Available N,P,K

The available N, P, K after harvest of wheat varied in treatments. It has been observed that N, P, K content in the soil was increased due to different treatments over control. The maximum N, P, K was recorded in the treatments of T9 (100% RDF +FYM @ 15 t ha-1 + PSB 6 kg ha-1). The maximum build up of available N, P, K was noted in the treatments of T9 closely followed by T8. Similar result also found by Karahne et al., [25] and Gopinath et al. [26].

4. CONCLUSION

Use of inorganic fertilizers, organic fertilizers and microbial inoculants in the field can improve soil parameters and crop production. The available NPK in soil increased with application of recommended dose of nitrogen through higher amounts of organic manures over application of recommended dose of nitrogen through inorganic fertilizers. The implementation of treatment T_9 (100% NPK + FYM@ 15 t ha^{-1} + PSB6 kg ha^{-1}) has significantly increase pore space, water holding capacity. Treatment combination T_9(100% NPK + FYM@ 15 t ha^{-1} + PSB6 kg ha^{-1})is the best for significant increase of soil physical and chemical properties. It also contributes to soil fertility and soil resource management.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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