International Journal of Research in Agronomy 2024; 7(6): 48-50

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; 7(6): 48-50
Received: 27-04-2024
Accepted: 31-05-2024

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Effect of integrated phosphorus management on the productivity of wheat (*Triticum aestivum* L.)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i6a.794

Abstract
A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Effect of Integrated Phosphorus Management on the Productivity of Wheat (*Triticum aestivum* L.). The soil was normal in pH of 7.66, electrical conductivity (EC) of 0.26 dSm^{-1}, organic carbon content of 0.43%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 216.0, 18.5, and 148.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24. The experiment consisted of 11 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications.

Keywords: Phosphorus, wheat, VAM

Introduction
The "Green Revolution" is a pivotal period in India's post-independence history that has allowed for the transition from science-driven intensive farming to subsistence agriculture and has assisted the nation in moving from a state of chronic shortage and excessive reliance on food imports to one of surplus and self-sufficiency.

Currently, India is the world's second-largest producer of wheat, behind China but ahead of the United States. With the introduction of high-yielding varieties that are resistant to rust and responsive to increased input, wheat production has continued to rise dramatically. During 2022–2023, wheat production increased overall in all of the major wheat-growing states, including Punjab, Haryana, U.P., Bihar, M.P., Gujarat, and Rajasthan. In 2022–2023, productivity increased significantly. The 26 q ha^{-1} national average yield is still lower than that of agriculturally developed nations like the United States, China, and the United Kingdom.

Although increasing the use of commercial fertilizers is actually the fastest and most reliable way to increase crop productivity, the high cost of the chemical inputs required to maintain crop productivity, issues with their availability, and the pollution they cause to the environment have made research into alternative energy sources necessary. Utilizing bacteria is one such energy source that can boost agricultural output without posing a pollution risk. The goal of sustainability must be connected to our production target.

Bio-fertilizers are effective microorganisms that fix nitrogen, phosphorus, or break down cellulose. When applied to seed or soil, they increase the amount of nutrients available to plants and offer a cost-effective and environmentally friendly way to partially replace chemical fertilizers as a supplemental source of nutrients.

Unlike nitrogen, which can be fixed back into the soil by air, phosphorus is not found in soils as frequently as other major nutrients. Instead, phosphorus can only be replaced externally. Furthermore, even in optimal field conditions, only 15–25% of applied phosphorus is recovered, which leads to a significant amount of phosphorus fixation in the soil. In addition, 95–99% of soil phosphorus exists in a form that is not directly accessible to plant roots (Bielsh, 1973). A significant portion of the inorganic phosphorus fertilizer applied to soil is quickly transformed into a form that is poorly soluble and unavailable (Sanyal and Datta, 1991) [2].

Through a variety of solubilization reactions involving rhizosphere microorganisms, PSMs aid in the release of soluble phosphorus from insoluble phosphate (Kapoor *et al*., 1989) [4]. PSMs generate organic acids that aid in the solubilization of phosphate, such as tartaric acid, succinic acid, and oxalic acid. In addition to organic acids, other substances such as siderophores, humic substances, H2S, Co2, mineral acids, and protein intrusion mechanisms are also produced (Gaur, 1990) [3]. Additionally, PSMs are known to produce vitamins, amino acids, and substances that promote plant growth, such as IAA and C.A.

Consequently, the use of phosphate-solubilizing microorganisms in cereals, legumes, and other commercial crops could result in the effective and economical use of phosphate fertilizers. Phosphorus uptake, plant growth, and seed yield were all enhanced when different crops were injected with phosphate-solubilizing microorganisms. Sapatnakar *et al*. (1994) [6] also noted an increase in wheat yield as a result of PSM inoculation.

According to Dewedi and Adkar (1994) [8], VAM inoculation increased onion yield by 8.13 percent. Research carried out at PAU on the efficacy of VAM inoculation has demonstrated the possibility of saving 10–20 kg P_2O_5 ha^{-1} for soybean and chickpea (Kaur, 1996) [7].

Material and Methods

A field experiment was conducted during rabi season of 2023-24 on loamy sand of in the rural area of Kanpur district of Mandhana, located 10 km from Kanpur in Uttar Pradesh to Effect of Integrated Phosphorus Management on the Productivity of Wheat (*Triticum aestivum* L.). The soil was normal in pH of 7.66, electrical conductivity (EC) of 0.26 dSm-1, organic carbon content of 0.43%, and available nutrients including nitrogen (N), phosphorus (P), and potassium (K) at levels of 216.0, 18.5, and 148.50 kg ha^{-1}, respectively. The experiment was laid out during Rabi season of 2023-24.The experiment consisted of 11 treatment combinations, was laid out in Randomized Block Design (RBD) with three replications. T_{13} 0 kg P_2O_5 ha^{-1} + 5 tonnes FYM ha^{-1}, $T_4$30 kg P_2O_5 ha^{-1}, $T_5$60 kg P_2O_5 ha^{-1}, $T_6$30 kg P_2O_5 ha^{-1} + PSB + VAM, $T_7$30 kg P_2O_5 ha^{-1} + 5 tonnes FYM ha^{-1}, T_8 30 kg P_2O_5 ha^{-1} + PSB + VAM + 5 tonnes Data were collected on five plants selected from each plot: $T_9$60 kg P_2O_5 ha^{-1}+ PSB + VAM, T_{10}60 kg P_2O_5 ha^{-1}+ 5 tonnes FYM ha^{-1}, and T_{11}60 kg P_2O_5 ha^{-1}+ PSB + VAM + 5 tonnes FYM ha^{-1}.

Results and Discussion

Yield Attributes

Length of spike

The data clearly shows that farm yard manure and microbial fertilizers have a positive impact on wheat ear length throughout the year. With the exception of T_9 and TI0, T_8 produced the longest ear length, which was achieved with T_{11}. These treatments were found to be significantly superior to all other treatments. But with the exception of T_9 and T_{10}, all other treatments received noticeably longer earlobes from Tl (control).

Number of Fertile Spikelet's per Spike

The information compiled in Table 1 showed that microbial fertilizers had a positive impact on the quantity of fertile spikelets per wheat spike. When compared to the control, the application of FYM greatly increased the number of fertile spikelets per spike. T_8 had the greatest number of fertile spikelets per spike. The greatest number of fertile spikelets per spike was reported by T_{11}. T_8 and T_{11} were found to be statistically equivalent, and both treatments were found to be significantly better than T_7, T_9, and T_{10}. However, Tl (control) produced the minimum number of fertile spikelets per spike, and the difference between Tl and T_2 was not significant.

Number of unfertile spikelets per spike

According to Table 1 the T_8 and T_{11} were found to be statistically equivalent and to be significantly better than all other treatments in terms of the quantity of sterile spikelets per spike. However, the control plot (T_1) produced the highest number of infertile spikelets per spike, and this was found to be significantly worse than all other treatments.

Number of total spikelet's per spike

The data compiled in Table 1 showed that the various treatments had a significant impact on the total number of spikelets per spike of wheat. T_8 was used to determine the maximum number of total spikelets per spike. The highest number of total spikelets per spike was reported by T_5. In experiments, T_8 was found to be statistically equivalent to T_5, and both treatments were found to be significantly better than T_6, T_7, T_9, and T_{10}. With the exception of T_2 (PSB + VAM), all other treatments were found to be significantly inferior to Tl (control).

Number of grain per ear

Table 1 showed that, in terms of the number of sterile spikelets per spike, T_8 and T_{11} were found to be statistically equivalent and both to be significantly better than any other treatment. However, the control plot (T_1) produced the highest number of infertile spikelets per spike, and this was found to be significantly worse than all other treatments Majjigudda *et al* (2021) [11].

Grain weight per spike

Table 1 showed that, in terms of the number of sterile spikelets per spike, T_8 and T_{11} were found to be statistically equivalent and both to be significantly better than any other treatment. However, the control plot (T_1) produced the highest number of infertile spikelets per spike, and this was found to be significantly worse than all other treatments.

Yield Studies

Grain yield

According to the data compiled in Table 2, T_{11} (60 kg P_2O_5 ha^{-1} + PSB + VAM + 5 tonnes FYM ha^{-1}) produced the highest grain yield of wheat. In the experimentation, these treatments were found to be statistically equivalent to and significantly better than all other treatments, with the exception of T_{10} (60 kg P_2O_5 ha^{-1} + 5 tonnes FYM ha^{-1}) and T_7 (30 kg P_2O_5 ha^{-1} + 5 tonnes FYM ha^{-1}). All other treatments received a significantly higher yield from Tl (control), Liu *et al*. (2022) [10].

Straw Yield

T_{11} (60 kg P_2O_5 ha^{-1} + PSB + VAM + 5 tonnes FYM ha^{-1}) had the highest straw yield of wheat, according to Table 2 under reference. In the experiment, T_{11} was found to be statistically equivalent to T_8, and treatments were found to be significantly better than all other treatments with the exception of T_{10} (60 kg P_2O_5 ha^{-1} + 5 tonnes FYM ha^{-1}) and T_9 (60 kg P_2O_5 ha^{-1} + PSB + VAM). Nevertheless, Tl (control) produced the lowest straw yield, which was found to be noticeably lower than that of all other treatments Mohiuddin *et al* (2020) [12].

Bio-mass

The biomass data in Table 2 made it abundantly evident that T_{11}

(60 kg P_2O_5 ha^{-1} + PSB + VAM + 5 tomes FYM ha^{-1}) had the highest biomass production (9962 kg ha^{-1}). On the other hand, T_8 and T_{11} were found to be significantly better than all other treatments, with no discernible differences in biomass production. Plots treated with PSB and VAM were found to produce significantly more biomass than the control. It was concluded that T_1 (control) was statistically worse than the other treatments.

Harvest index

Table 2 also demonstrated that the combination of (60 kg P_2O_5 ha^{-1} + PSB + VAM + 5 tonnes FYM ha^{-1}) produced the highest harvest index. T_{11} and T_8, which were both determined to be statistically superior to T_1, T_2, and T_3, did not differ enough to be considered statistically significant. T_2, T_3, T_4, and T_6 were unable to surpass the significance threshold.

Table 1: Yield attributes of wheat as influenced by various treatments

Treatments	Spike length (cm)	No. of fertile spikelets spike^{-1}	No. of unfertile spikelets spike^{-1}	Total spikelets spike^{-1}	No. of grain spike^{-1}	Number of grain per ear	Grain weight per spike
T_1	8.57	18.08	3.51	30.16	58.40	32.51	1.80
T_2	9.33	18.72	3.44	31.49	60.43	50.71	2.74
T_3	9.44	19.32	3.31	32.67	61.34	48.43	2.92
T_4	9.65	20.18	3.05	32.89	62.48	54.57	2.59
T_5	9.74	20.36	2.95	33.05	63.19	48.95	2.45
T_6	9.88	20.63	2.87	33.49	63.24	46.47	3.32
T_7	10.16	20.74	2.79	33.69	63.67	43.75	2.59
T_8	10.26	21.20	2.54	34.00	63.88	54.96	3.40
T_9	10.89	21.68	2.75	35.33	63.95	49.55	2.61
T_{10}	11.02	21.74	2.70	35.46	64.01	46.47	2.10
T_{11}	11.19	22.02	2.54	35.75	64.26	55.36	3.50
S.Em±	0.27	0.28	0.24	0.22	0.24	0.26	0.22
C.D.aT5%	0.59	0.69	0.84	0.70	0.64	0.54	0.61

Table 2: Grain yield, straw yield, bio-mass yield and Harvest index of wheat as influenced by various treatments

Treatments	Grain yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Bio-mass (kg ha^{-1})	Harvest Index (%)
T_1	3889	5830	8302	46.84
T_2	4039	6022	8437	47.87
T_3	4083	6132	8699	46.93
T_4	4185	6214	8722	47.98
T_5	4206	6259	8894	47.29
T_6	4324	6289	8992	48.08
T_7	4367	6349	9250	47.21
T_8	4429	6440	9387	47.18
T_9	4467	6474	9545	46.79
T_{10}	4471	6489	9674	46.21
T_{11}	4521	6494	9962	45.38
S.Em±	42.0	37.1	57.9	0.36
C.D.at 5%	117.5	112.1	162.2	0.89

Conclusion

The region's high wheat grain yield may be sustained by the use of biofertilizers (PSB and VAM), farm yard manure (5 tonnes ha^{-1}), and 30 kg P_2O_5 ha^{-1}

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