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Impact of integrated nutrient management on yield of wheat and phosphorus release pattern in vertisol

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Abstract
The present investigation entitled " Impact of integrated nutrient management on yield of wheat and phosphorus release pattern in Vertisol " was conducted during the *Rabi* season of 2022-2023 at Research Farm, College of Agriculture, Nagpur.The experiment was laid out in Randomized Block Design with seven treatments comprises T_1:GM + 100%RDF, T_2: Ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos, T_3: Vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos, T_4: Neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos, T_5: Ghanajivamrut 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos, T_6: Vermicompost 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos, T_7: Neem cake 2 t ha^{-1} at incorporation of GM + jivamrut + Azophos with three replication. The result revealed that, the levels of available phosphorus in the soil at various growth stages of wheat were found to be significant. It is observed that the treatment involving vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos resulted in significantly higher available phosphorus levels in the soil, with measurements of 19.01 kg ha^{-1} at the tillering stage, 20.88 kg ha^{-1} at the flowering stage, and 23.31 kg ha^{-1} at the harvesting stage of wheat. The result also indicates that, the highest grain yield of wheat (30.50 q ha^{-1}) was achieved with the application of T_1 and it was found at par with T_3 (28.53 q ha^{-1}) and T_2 (26.06 q ha^{-1}). The significant higher straw yield of wheat was observed (40.48 q ha^{-1}) with T_1 which was found at par with T_3 (37.97 q ha^{-1}). The result showed that, the efficiency of inorganic fertilizers is likely increased when applied with well-decomposed organic manure, leading to improved grain yield.

Keywords: Green manuring (GM), RDF, vermicompost, ghanjivamrut

Introduction

Wheat (*Triticum aestivum* L.) stands as the world's most crucial and widely cultivated food crop. In India, wheat holds the position of the second most important cereal crop, contributing nearly 35% to the national food supply. The crop covers an area of 30.47 million hectares with a production of 106.84 million tonnes and a productivity rate of 3507 kg per hectare. In Maharashtra, wheat is grown on 1.17 million hectares, producing 3.83 million tonnes with a productivity of 2117 kg per hectare. Uttar Pradesh, Madhya Pradesh, and Punjab are the major wheat-producing states, accounting for 31.77%, 20.98%, and 14.82% of the total wheat cultivation area in the country, respectively (Anonymous, 2022) [1].

Phosphorus (P) ranks as the second most critical nutrient for plants, required in substantial quantities. It plays a crucial role in several physiological processes such as photosynthesis, respiration, energy storage, cell division, and cell enlargement. Additionally, phosphorus is essential for seed formation and root development. It is a structural component of nucleic acids, phospholipids, and various co-enzymes. In soil, phosphorus primarily exists in two forms: the organic P fraction, derived from plant material and soil microorganisms, and the inorganic fraction, predominantly associated with calcium (Ca), aluminum (Al), and iron (Fe). The transformation of P in soil can vary significantly depending on fertilizer management practices, which, in turn, influence crop productivity. The relative solubility of the inorganic soil P fraction determines the replenishment of the labile pool when it is depleted by plant uptake. Inorganic soil typically contains about 0.5% phosphorus, but only 0.1% of the total P is available to plants due to its low solubility, availability, and fixation in the soil. Consequently, most soils are deficient or marginal in P content, necessitating adequate P fertilization and management strategies to maintain soil and crop productivity.

Adequate phosphorus supply is particularly crucial during the early stages of crop growth. Insufficient phosphorus supply can cause irreversible damage, even if P is later applied in adequate amounts. Moreover, phosphorus enhances wheat crops at the tillering stage and ensures uniformity at the heading stage. Balanced fertilization, especially with NPK, is fundamental in improving the yield and quality of wheat crops. While inorganic fertilizers can rapidly increase crop yields, their misuse poses significant environmental risks. In contrast, natural sources not only supply sufficient NPK but also positively impact plant growth and development, water retention capacity, soil fertility, and soil biological activity.

In Indian Vertisols, the response to phosphorus (P) fertilizer is often unpredictable due to high P fixation attributed to the clay content and presence of smectite. Soil samples from Vidarbha region, for instance, show high smectite content ranging from 40% to 78%. Currently, only 5% of Indian soils have sufficient available P, with 49.3% categorized as low, 48.8% as medium, and merely 1.9% as high (Pattnayak *et al*., 2009) [3]. However, only a fraction (20-25%) of applied P is available to crops, as the majority is converted into insoluble forms. Microbial activity plays a crucial role in solubilizing inorganic phosphorus, primarily through the secretion of organic acids such as oxalic, malic, citric, and acetic acids. Phosphate-solubilizing bacteria (PSB) are major contributors to phosphorus solubilization (Moharana *et al*., 2015) [4].

Organic materials like farmyard manure (FYM), compost, and green manures are increasingly favored as nutrient sources. While FYM and compost availability is limited, green manures offer a feasible and cost-effective alternative for nitrogen and other nutrient supply. Upon decomposition, green manures liberate phosphorus in an available form, along with CO_2 and other organic intermediates (Hesse, 1962) [5].

In intensive cropping systems, reliance solely on chemical fertilizers or organic manures/biofertilizers is insufficient to sustain productivity due to imbalances in nutrient supply. Hence, integrating reduced chemical fertilizers with various organic manure sources and judicious management practices is crucial for sustainable crop productivity and nutrient efficiency.

Materials and Methods

The experiment titled "impact of integrated nutrient management on yield of wheat and phosphorus release pattern in Vertisol" was conducted during rabi season of 2022-23 at Research Farm, College of Agriculture, Nagpur. The experiment was laid out in randomized block design with Seven treatments each replicated thrice. The field for the experiment was uniformly levelled, ensuring consistency throughout the study. The soil in the experimental field exhibited a clayey texture and a slightly alkaline pH. It had a medium level of organic carbon content but was deficient in available phosphorus. Conversely, the soil was low in available nitrogen and had a very high potassium content. This combination of soil characteristics provides valuable insights into the fertility and nutrient composition of the experimental site. Sowing of sunhemp onto plots according to the designated layout was carried out on October 2022, using the broadcasting method and buried using a tractor-drawn rotavator in November 2022. Jivamrut and Ghanjivamrut were prepared in the Soil Science Section, College of Agriculture, Nagpur, following the proper procedure. The required quantities of vermicompost, FYM, cow dung, and cow urine were provided by the Animal Husbandry and Dairy Science Section, College of Agriculture, Nagpur. The seed of wheat variety AKW-1071 seeds were obtained from the Agronomy farm, College of Agriculture, Nagpur.

Sowing of wheat (AKW-1071) took place at an experimental site on November 20, 2022, using drilling method. Fertilizers were applied according to the treatment details, with nitrogen, phosphorus, and potassium doses administered through urea, DAP, and MOP, respectively. Nitrogen was split into two doses, with the first applied at sowing and the second at 30 days after sowing (DAS). Additionally, seed treatment with the biofertilizer azophos (Azotobacter + PSB) was carried out at a rate of 25 g each per kg of seed at the time of sowing. Necessary cultural operations like thinning, weeding, and hoeing were conducted according to schedule at appropriate intervals. Following this, a total of six irrigations were administered at key stages of wheat. Jivamrut spraying @ 500 liters ha^{-1} was applied at tillering and jointing stage of wheat.

Plot wise soil samples were collected from experimental area at the tillering, flowering, and harvest stages of wheat. These samples were then analyzed using proper analytical methods at the Soil Science Laboratory, Soil Science Section, College of Agriculture, Nagpur, to assess soil health and nutrient content throughout the crop growth stages.

Results and Discussion

Effect of integrated nutrient management on phosphorus availability at different growth stages of wheat

The data regarding available phosphorus in the soil at the tillering, flowering, and harvesting stages of wheat, as shown in Table 1. The data found statistically significant as influenced by different treatments. The use of Vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos, significantly influenced the dynamics of phosphorus release throughout the various growth stages of the crop due to phosphorus mineralization. Results observed that the treatment involving vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos resulted significantly higher available phosphorus levels in the soil, with measurements of 19.01 kg ha^{-1} at the tillering stage, 20.88 kg ha^{-1} at the flowering stage, and 21.94 kg ha^{-1} at the harvesting stage of wheat. This might be due to the slow release of phosphorus, which maintained a higher amount of phosphorus in the soil at the later stages of the crop. The significant increase in available phosphorus from the combined application of inorganic fertilizers and organic inputs clearly demonstrates the beneficial effects of integrated plant nutrient management in enhancing available phosphorus in the soil during different growth stages of wheat. Moharana *et al*. (2014) [6] reported that, the application of enriched compost and chemical fertilizers to wheat significantly impacted phosphorus release during the physiological growth stages.

Table 1: Soil phosphorus availability (kg ha^{-1}) at different growth stages of wheat under integrated nutrient management.

	Treatments	Available P (kg ha^{-1})		
		Tillering	Flowering	Harvesting
T_1	GM + 100%RDF	18.38	19.56	20.19
T_2	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	18.57	20.30	22.17
T_3	Vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	19.01	20.88	23.31
T_4	Neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	17.91	19.06	20.72
T_5	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	17.42	18.56	20.23
T_6	Vermicompost 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	17.69	19.07	21.06
T_7	Neem cake 2 t ha^{-1} at incorporation of GM + jivamrut + Azophos	16.68	17.93	19.16
	SE (m ±)	0.218	0.302	0.32
	CD at 5%	0.672	0.912	0.99

Effect of integrated nutrient management on chemical properties of soil after harvest of wheat

The results pertaining to chemical properties of soil after harvest of crop is presented in Table 2. The results of the present study clearly indicated that the effect of the integrated nutrient management (INM) on soil pH and electrical conductivity (EC) was non-significant, with soil pH values ranging between 7.25 and 7.81 and electrical conductivity values ranging from 0.23 to 0.26 dS m^{-1}. The study found that the highest organic carbon content was observed in treatment T_3 (5.32 g kg^{-1}), which involved vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos. In this study, the available nitrogen in the soil ranged from 207.3 to 225.6 kg ha^{-1}. The highest available nitrogen, 225.6 kg ha^{-1} was observed in the T_1 which involved the application of GM + 100% RDF which remained at par with T_3 (224.4 kg ha^{-1}) with application of vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos and T_2 (222.1 kg ha^{-1}) with application of Ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos. The increase in available N in soil might be attribute to the more N fixation in soil on account of microbial production leaving good mineralization of N with other nutrient application and management practices. In the present study, the available phosphorus of soil was found between 19.16 to 23. 31 kg ha^{-1}. Maximum availability of phosphorus (23.31 kg ha^{-1}) was recorded in the treatment T_3 receiving vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizers + jivamrut + azophos which is significantly superior over all other treatments. The available potassium in the soil ranged from 444 to 470 kg ha^{-1}. The highest available potassium level 470 kg ha^{-1}, was observed in T_1 GM + 100%RDF and T_3 with application of vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos and found at par with (T_2) vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos. In present study, the available potassium was found in very high category. The increase in soil potassium due to the addition of organic sources and chemical fertilizers can be attributed to the reduction in potassium fixation and the release of potassium resulting from the interaction between organic materials and clay. The value of available sulphur was observed from 12.92 to 17.19 mg kg^{-1} under the study. In the present study, available sulphur of soil was found significantly higher with the application of vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos (17.19 mg kg^{-1}) which remained at par with (T_2) ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos (17.12 mg kg^{-1}) and (T_4) neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos (16.33 mg kg^{-1}). Similar findings were reported by Dubey *et al.* (2015) [7], Sahu *et al.* (2022) [8] and Pradhan *et al.* (2024) [9].

Table 2: Effect of integrated nutrient management on chemical properties of soil after harvest of wheat

	Treatments	pH	EC (dS m^{-1})	OC (g kg^{-1})	Available N (Kg ha^{-1})	Available P (Kg ha^{-1})	Available K (Kg ha^{-1})	Available S (Kg ha^{-1})
T_1	GM + 100%RDF	7.65	0.25	5.18	225.6	20.19	470	15.01
T_2	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	7.73	0.24	5.30	222.1	22.17	456	17.12
T_3	Vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	7.81	0.23	5.32	224.4	23.31	470	17.19
T_4	Neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	7.50	0.26	5.23	214.2	20.72	453	16.33
T_5	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	7.75	0.25	5.25	215.9	20.23	448	14.37
T_6	Vermicompost 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	7.46	0.24	5.30	216.1	21.06	453	14.48
T_7	Neem cake 2 t ha^{-1} at incorporation of GM + jivamrut + Azophos	7.25	0.24	5.22	207.3	19.16	444	12.92
	SE (m ±)	0.03	0.04	0.043	3.08	0.32	4.79	0.32
	CD at 5%	-	-	0.13	9.23	0.99	14.57	0.98

Effect of integrated nutrient management on grain and straw yield of wheat (q ha^{-1})

Grain yield of wheat (q ha^{-1})

The data on grain yield of wheat, influenced by various treatments is shown in Table 3. The results clearly demonstrate that grain yield of wheat is significantly affected by the incorporation of green manuring and the combined application of inorganic fertilizers with organic manure and biofertilizers. Furthermore, these combined treatments not only improve soil fertility but also contribute to an increase in overall yield stability. The significantly highest grain yield of wheat (30.50 q ha^{-1}) was achieved with the application of GM + 100%RDF (T_1) and it was found at par with the application of vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos (28.53 q ha^{-1}) and ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos (26.06 q ha^{-1}). Application of (T_1) GM + 100%RDF produced significatly higher grain yield of wheat which was 6.45, 14.55 and 23. 60 per cent higher over (T_3) vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos, (T_2) ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos and (T_4) neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + azophos, respectively. The findings clearly indicate that the decomposition of succulent green manure, along with well-decomposed Ghanjivamrut and vermicompost, enhances nutrient release and supports microbial activity. This results in a continuous supply of major, secondary, and micronutrients in the soil, sustaining higher wheat grain yields. Additionally, the efficiency of inorganic fertilizers is likely increased when applied with well-decomposed organic manure, leading to improved grain yield. This combination not only boosts nutrient availability but also promotes higher grain yields by enhancing nutrient uptake efficiency and ensuring a steady nutrient supply throughout the growing season. Patyal *et al.* (2022) [10] reported that, 100% RDF +25% N through (vermicompost) + ZnSO4 @ 25 kg ha^{-1} proved to found better with respect to grain yield (55.32 q ha^{-1}), straw yield (81.14 q ha^{-1}).

Straw yield of wheat (q ha^{-1})

The data on straw yield of wheat, influenced by various treatments is shown in Table 2. The result revealed that, the straw yield of wheat was significantly affected by the various treatments of integrated nutrient management. In present study, the significant higher straw yield of wheat was observed (40.48 q ha^{-1}) with application of GM + 100%RDF which was found at par with vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos (37.97 q ha^{-1}). The increase in grain and straw yield could be attributed to the adequate and balanced supply of plant nutrients provided to the crops throughout their growth period, leading to favorable increases in both grain and straw yield. Singh *et al*. (2018) [11] reported that applying 100% NPK along with 10 t ha^{-1} of FYM resulted in the highest straw yield of wheat.

Table 3: Effect of integrated nutrient management on grain and straw yield of wheat

	Treatments	Yield (q ha^{-1})	
		Grain	Straw
T_1	GM + 100%RDF	30.50	40.48
T_2	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	26.06	34.95
T_3	Vermicompost 5 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	28.53	37.97
T_4	Neem cake 2 t ha^{-1} at incorporation of GM + 50% RD of NP through inorganic fertilizer + jivamrut + Azophos	23.30	30.82
T_5	Ghanajivamrut 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	19.08	25.14
T_6	Vermicompost 5 t ha^{-1} at incorporation of GM + jivamrut + Azophos	20.37	27.04
T_7	Neem cake 2 t ha^{-1} at incorporation of GM + jivamrut + Azophos	17.10	22.13
	S. E. (m ±)	1.37	1.82
	C. D. @ 5%	4.044	5.40

Conclusion

The present study concludes that applying vermicompost at 5 t ha^{-1} along with green manuring, combined with 50% of the recommended dose of chemical fertilizers is an effective nutrient source for maintaining soil phosphorus availability and soil fertility during different growth stages of wheat.

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