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Research Article

Enhancing wheat productivity, quality and nutrient uptake through application of phosphate rich organic manure and soil amendments under Typic Hapludalfs

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Abstract

The present investigation was undertaken at Experimental Farm of Department of Soil Science, CSK Himachal Pradesh Agricultural University, Palampur to study the effect of phosphate rich organic manure and soil amendments like FYM and lime on wheat productivity, quality and nutrient uptake. The experiment was laid out in Randomized Block Design with nine treatments and were replicated three times. The highest grain yield (38.7 qha^{-1}), straw yield (62.7 qha^{-1}) and P uptake (28.5 kgha^{-1}) were observed in the treatment receiving 50% recommended dose of phosphorus from inorganic fertilizer + phosphate rich organic manure (PROM) @ 1.5 tha^{-1} along 100 % NK. The maximum crude protein content (12.9 %), P content (0.54 %), K content (0.39 %) was also recorded under same treatment. Application of farm yard manure and lime along with 100 % NPK also improved crop productivity, quality and nutrient uptake as compared to solo application of inorganic fertilizers.

Keywords: Crude protein, Nutrient content and uptake, Phosphorus, Phosphate rich organic manure, Soil amendments, Wheat yield

1. Introduction

Cereals play a pivotal role to satisfy the global food demand of growing population, particularly in developing nations like India where cereal-based production system is the only predominant source of nutrition and calorie intake (Yashavanthakumar *et al.,* 2023). Among cereals, wheat (*Triticum aestivum L.*) is the second most important crop after rice in the country (Kaur *et al.,* 2023; Trethowan *et al.,* 2018). Nutrients play a vital role in the production of wheat. Among essential nutrients, phosphorus (P) after nitrogen is reportedly the most limiting macronutrient in majority of the soils (Shehzad *et al.,* 2022). The most significant roles of P in plants are storage and transfer of energy produced by important processes like photosynthesis (Pandey *et al.,* 2020). Its optimum levels help to promote root growth and hardiness, enhance tillering and hasten the maturity of crops (Ditta and Khalid, 2016).

In India, nearly 60 per cent of soils are low in available phosphorus (Motsara, 2002), which is mainly due to affinity of P to get fixed by calcium carbonate in alkaline and calcareous soils and by the hydroxides of iron and aluminium in acidic soils, resulting in low phosphorus use efficiency. This acts as a major constraint for attaining the maximum achievable yield for most of the crops including wheat (Ditta *et al.,* 2018). A significant amount of phosphatic fertilizer is required to get a respectable crop yield and apart from this, the phosphatic fertilizers are expensive as in developing countries like India, they are either imported or manufactured using imported raw materials. Due to this increase in cost in the recent past, there has been a decreasing trend in the amounts of P fertilizer applied in India (Bairwa *et al.,* 2019). Hence, it has become quite imperative to search for an alternative phosphorus source which is cheaper and preferably indigenous like phosphate rich organic manure (PROM). Rock phosphate is a natural, non-renewable and a basic raw material for the production of water soluble phosphatic fertilizers (Ditta *et al.,* 2018). RP is also known as 'Phosphorite' and contains 15–20% phosphorus but it is unavailable to plants as RP is not soluble in water. PROM is also produced by co-composting organic manure with high grade (32 % P_2O_5 ± 2 %) rock phosphate mineral in 1:2 ratio (Mihir and Jagadeesh, 2016). Furthermore, addition of organic manure through PROM improves physico-chemical as well as biological properties of the soil and also act as significant source of macro and micro- nutrients which had positive effects on crop. Application of soil amendments like organic (FYM) and inorganic (lime) also significantly improves soil properties and increases nutrient availability for crop uptake (Gourav *et al.,* 2019). Chauhan *et al.* (2020) highlighted the long-term effect of soil amendment's (FYM and lime) on wheat productivity, quality and nutrient content under Typic Hapludalf. Considering the significance of soil health for crop productivity and the nutritional value of produce, the present investigation was aimed to appraise the effect of PROM, FYM and lime along with inorganic fertilizers on productivity, quality and nutrient uptake by the wheat crop.

2. Materials and Methods

The experiment was conducted during R*abi* season 2021-2022 in randomized block design (RBD) with three replications at Research Farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Kangra district of Himachal Pradesh, India. There was total 27 plots and 9 treatments which were as follows: T_1: Control; T_2:100 % NPK; T_3: 100 % NPK + lime; T_4: 100 % NPK + 10 tha^{-1} FYM; T_5: 0.5 tha^{-1} *Ghan jeevamrit + Jeevamrit* Sprays at 21 days interval (Natural Farming); T_6: 100 % NK + 3 tha^{-1} PROM; T_7: 100 % NK + 75% P + 0.75 tha^{-1} PROM; T_8: 100 % NK + 50% P + 1.5 tha^{-1} PROM and $^{T}_{9}$: 100 % NK + 25% P + 2.25 tha^{-1} PROM. The recommended dose of NPK fertilizer for wheat crop was 120, 60 and 30 $kgha^{-1}$, respectively. The sources of N, P and K were urea, single super phosphate and muriate of potash, respectively. Lime was applied in T_3 treatment as per the requirement @ 6 tha^{-1} as marketable lime ($CaCO_3$). The digested plant samples were analyzed for crude protein and nutrient content like N, P, K, Ca, Mg and micronutrient cations *viz.* Fe, Mn, Zn, Cu. For the analysis of crude protein, the nitrogen content in wheat grain was multiplied by a factor of 6.25 (Jones, 1941). The nutrient uptake was calculated by multiplying % concentration of a particular nutrient with grain and straw yields. The uptake of the nutrient obtained in respect of grain and straw were summed up to compute the amount of total nutrient removal by the crop. Relationship of yield and soil properties with nutrients uptake was worked out by computing simple correlation coefficients.

3. Results and Discussion

3.1 Effect on yield

Results present in Figure 1 depicted that the highest grain (38.7 qha^{-1}) and straw (62.1 qha^{-1}) yield of wheat was obtained in $^{T}_{8}$ treatment comprising 100 % NK + 50 % P + 1.5 t/ha PROM. The increase of 24.4 and 11.4 per cent in grain yield were recorded in T_4 over T_2 and T_3 treatments, respectively. Application of lime with 100 % NPK also resulted in increasing the wheat yield over 100 % NPK. The lowest grain yield was recorded in T_1 (18.2 qha^{-1}) that was statistically at par with T_5 treatment (19.7 qha^{-1}). Continuous supply of nutrients especially P along with improved physico-chemical and biological conditions of the soil due to the addition of organic matter through PROM, resulted in significantly higher wheat yield in T_8 treatment. Besides this, management of phosphorus through integrated application of chemical fertilizer (SSP) and organic sources (PROM) resulted in expansive root proliferation thereby enhancing the nutrient uptake ensuing robust plant growth (Rajput *et al.,* 2014). Increase in wheat yield on application of FYM along with recommended fertilizers was also reported by Chauhan *et al.* (2020). Higher wheat productivity due to the application of 100 % NPK + lime over sole application of 100 % NPK could be attributed to increase in soil pH by reducing H^+ and Al^{+3} toxicity, more cation exchange capacity, increased availability of nutrients like P, Ca, Mg and uptake of the nutrients (Gourav *et al.,* 2019). Inadequate supply of nutrients in control and T_5 treatment could be possible reason for lowest productivity in these treatments. Significant and positive relationship between grain yield and available N (r = .929*), P (r = .819*) and K (r = .948*) have been observed as given in Table 2.

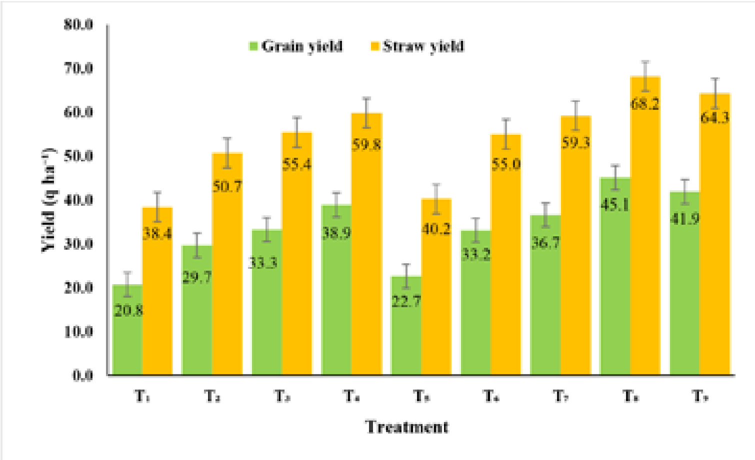


Fig 1: Effect of phosphate rich organic manure and soil amendments on wheat productivity

3.2 Effect on crude protein

The maximum crude protein content was recorded under T_8 (12.9 %) which was statistically at par with T_9 (12.8 %). T_8 treatment resulted in 27.7, 7.5 and 1.6 per cent increase in crude protein content over T_1, T_2 and T_4, respectively. The crude protein content in 100 % NPK + 10 tha^{-1} FYM increased by 25.7 % over control, 5.8 % over 100 % NPK and 3.3 % over 100 % NPK + lime (Table 1). Application of 100 % NPK + lime resulted in higher crude protein content (12.3 %) than 100 % NPK (12.0 %). The lowest crude protein content was recorded in control (10.1 %) which was statistically at par with T_5 treatment comprising 0.5 tha^{-1} *Ghanjeevamrit+ Jeevamrit* spray (10.2 %). The increase in protein content in wheat with integrated application of PROM and SSP might be due to synergistic relationship between N and P that resulted in more protein synthesis in presence of phosphorus by formation of some stable phospho - protein compounds (Bairwa *et al.,* 2019). Crude protein is significantly and highly correlated with P content (r = .911*) (Table 2). Additional amount of sulphur applied through 50 % SSP in T_8 also had significant role in synthesis of proteins as it is a structural component of amino acids *viz.* cysteine, cystine and methionine, and thus important for protein synthesis (Patel *et al.*, 2019). In addition, it also helps in formation of disulfide bonds that are vital for regulating stability and activity of the protein structures in wheat (Pandey *et al.,* 2020). The increase in protein content in grain with increasing level of P was also recorded by Waghmare *et al.* (2020) in wheat crop. Higher crude protein content in T_4 treatment might be ascribed to increased availability of nitrogen (r = .859*), its uptake (r = .925*) and storage in grains (Chauhan *et al.,* 2020). Low supply of macro and micronutrients affecting nutrient absorption and transformation in crops, that might have resulted in low crude protein content in control and T_5 treatment.

Table 1: Effect of phosphate rich organic manure and soil amendments on crude protein and nutrient content in wheat grain

Treatments	Crude protein	P	K	Ca	Mg	Fe	Zn
	(%)					(mg/kg)	
T_1	10.1	0.29	0.31	0.25	0.08	60.1	28.9
T_2	12.0	0.38	0.33	0.28	0.10	63.4	31.6
T_3	12.3	0.45	0.34	0.37	0.11	68.5	34.1
T_4	12.7	0.48	0.39	0.31	0.12	71.8	37.8
T_5	10.2	0.30	0.31	0.24	0.08	61.6	30.2
T_6	12.5	0.44	0.34	0.32	0.10	68.2	33.4
T_7	12.7	0.49	0.35	0.30	0.11	67.3	32.7
T_8	12.9	0.54	0.39	0.33	0.12	69.2	35.5
T_9	12.8	0.52	0.38	0.34	0.11	68.7	34.3
CD (P= 0.05)	0.2	0.02	0.03	0.02	0.01	2.6	2.3

3.3 Effect on nutrient content

The data presented in Table 1 revealed that the highest phosphorus content (0.54 %) in wheat grains was recorded in T_8 treatment, that increased by 86.2 % over control, 42.1 % over 100 % NPK and 12.5 % over 100 % NPK + 10 tha^{-1} FYM. As compared to control, 100 % NPK and 100 % NPK + lime, application of 100 % NPK + 10 t/ha FYM recorded 65.5, 26.3 and 6.7 % higher P content, respectively. The highest K content in wheat grain was also recorded under 100 % NK + 50 % P + 1.5 tha^{-1} PROM (0.39 %) which was statistically at par with 100 % NPK + FYM (0.39 %) and 100 % NK + 25 % P + 2.25 tha^{-1} PROM treatment (0.38 %). Calcium (Ca) content in wheat grain was recorded highest under 100 % NPK + lime treatment (0.37 %). Ca content in T_9 (0.34 %) and T_8 treatment (0.33 %) were found to be statistically at par with each other. In T_4 treatment, Ca content increased by 24 % over control and 11 % over 100 % NPK. The magnesium (Mg) content varied from 0.08 % in control to 0.12 % in T_8. Treatment with 100 % NPK along with 10 tha^{-1} FYM was significantly superior in terms of Mg content over control (0.08 %), 100 % NPK (0.10 %) and 100 % NPK + lime (0.11 %). Significantly higher Fe and Zn content in wheat grain was recorded under T_4 treatment (71.8 and 37.8 mg kg^{-1}, respectively) over rest of the treatments. Application of 100 % NK + 50 % P + 1.5 tha^{-1} PROM also significantly increased Fe content in wheat grain by 15.1 % over control and 9.1 % over 100 % NPK. The application of 100 % NK + 25 % P + 2.25 tha^{-1} PROM and 100 % NK + 50 % P + 1.5 tha^{-1} PROM recorded 8.5 and 12.3 % higher Zn content over 100 % NPK, respectively. The lowest phosphorus, potassium, calcium, magnesium, iron and zinc content recorded in T_1 and T_5 treatment. Significantly higher nutrient concentration in wheat grains under T_8 treatment might be due to gradual and continuous increase in nutrient concentration especially P in the soil as SSP acted as a starter dose that enhanced the root growth and activity and increased the dissolution rate of rock phosphate as compared to solo rock phosphate treatment (Sarangi *et al.,* 2020). Whereas, PROM increases P availability in the soil by forming complexes with sesquioxides through humus coating and reduces P sorption by displacing sorbed phosphate through organic anions that increased P content in grains ($r = .974^*$). Moreover, during the decomposition of PROM, certain organic acids secreted by microbes that enhanced the release of native fixed- nutrients like N, P, K, Ca and Mg in the soil (Mashori *et al.,* 2013) and ultimately increased their content in wheat grains. The synergistic relationship between phosphorus- potassium and phosphorus- magnesium (Weih *et al,* 2021) might also be a possible reason for increased uptake and storage of K and Mg within grains in T_8 treatment as P content is significantly correlated with K content ($r = .848^*$) and Mg content ($r = .831^*$) as mentioned in Table 2. Furthermore, addition of organic matter like PROM, increases CEC of the soil that prevents leaching of cations and increases the length of duration during which nutrients are released in soil solution to meet the crop requirement. Ca content in wheat grain was recorded highest under 100 % NPK + lime treatment could be attributed to direct addition of Ca through lime and additional supply Ca through SSP (20 % Ca in SSP) in the soil. Besides this, amelioration of soil pH due to lime application might have improved the availability of Ca and increased Ca uptake and content in grains. Chauhan *et al.* (2020) had also reported positive effect of lime application on increasing the calcium content in wheat grains. Increase in Fe and Zn content on addition of FYM along with 100 % NPK might be attributed to addition of micronutrients in the soil on decomposition of organic matter, as FYM is considered as a store house of plant nutrients. Moreover, leaching losses of nutrients are also reduced as FYM improves physico-chemical and biological properties of the soil and thus, increases uptake of nutrients.

3.4 Effect on nutrient uptake

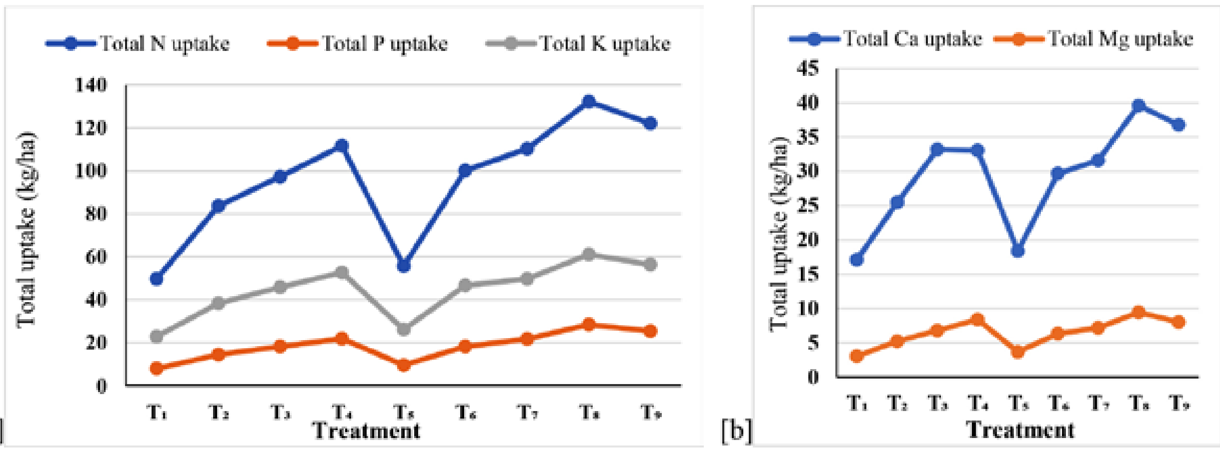
Data presented in Figure 2 revealed that highest nutrient uptake by the crop was recorded in 100 % NK + 50 % P + 1.5 tha^{-1} PROM treatment. NPK uptake significantly increased in T_8 treatment by 58.1, 96.5, 58.9 per cent over 100 % NPK and 18.5, 30.1 and 15.5 per cent over 100 % NPK + 10 tha^{-1} FYM, respectively. Integrated application of FYM or lime with 100 % NPK also significantly increased N, P, K, Ca and Mg uptake as compared to 100 % NPK. Whereas, the lowest total nutrient uptake was recorded in control which was statistically at par with T_5 treatment. Nutrient uptake is a function of its concentration within the plant (grain and straw) and yield of the crop (Gourav *et al.* 2019). Maximum growth and accumulation of a nutrient increases the uptake of that respective nutrient. Therefore, total nutrient uptake by the crop was found to

Table 2: Correlation between grain yield, nutrient content, their uptake and soil available nutrients

	Crude Protein	P content	K content	Ca content	Mg content	Fe content	Zn content	N uptake	P uptake	K uptake	Avl. N	Avl. P	Avl. K
Grain Yield	.948*	.807*	.743*	.848*	.868*	.793*	.995*	.987*	.980*	.876*	.929*	.81⁹*	.948*
Crude Protein		.911*	.784*	.784*	.853*	.805*	.774*	.925*	.880*	.921*	.859*	.850*	.852*
P content			.848*	.745*	.831*	.847*	.822*	.964*	.974*	.959*	.897*	.948*	.839*
K content				.586*	.834*	.782*	.727*	.830*	.835*	.857*	.819*	.909*	.677*
Ca content					.738*	.734*	.692*	.756*	.718*	.761*	.658*	.676*	.723*
Mg content						.896*	.871*	.866*	.834*	.870*	.750*	.858*	.705*
Fe content							.914*	.872*	.857*	.859*	.830*	.865*	.788*
Zn content								.806*	.791*	.809*	.737*	.818*	.684*
N uptake									.989*	.989*	.896*	.936*	.843*
P uptake										.976*	.886*	.956*	.817*
K uptake											.890*	.935*	.827*
Avl. N												.877*	.942*
Avl. P													.788*

Note: *Correlation is significant at the 0.05 level be significantly higher in 100 % NK + 50 % P + 1.5 tha^{-1} PROM treatment than the other treatments. This might also be ascribed to increase in nutrients' concentration in the soil as PROM acts as additional source of NPK and Ca. In addition to this, 50 % P through water soluble inorganic source (SSP) fulfilled the initial requirement of the crop favouring lateral as well as fibrous root growth (Saleem *et al.,* 2013) and thus increases the uptake of nutrients from the soil. Moreover, optimum uptake of phosphorus has beneficial effect on nitrogen ($r = .989^{*}$), potassium ($r = .976^{*}$) and magnesium uptake and buildup in plants. Increase in primary nutrient uptake by the application of PROM along with chemical fertilizers was also reported by Bairwa *et al.* (2019) and Noor *et al.* (2021) under varied agro-climatic conditions. Billah *et al.* (2020) as well reported that nutrients accumulation in the plant were enhanced by the use of rock phosphate enriched compost and inorganic materials. Similarly, FYM amended plots (T_4) recorded significantly higher NPK uptake by wheat over 100 % NPK + lime (T_3) and 100 % NPK (T_2) and which might be due to the favorable conditions for crop growth and supply of nutrients through FYM in addition to chemical fertilizers. Positive influence of FYM in combination with inorganic fertilizers on NPK uptake by wheat has also been observed by Gourav *et al.* (2019) and Chauhan *et al.* (2020). The increase in Ca and Mg uptake by the crop with the integrated application of PROM along with chemical fertilizers (T_8) might be attributed to increased Ca and Mg concentration in the soil and its availability, as well as improved physico- chemical and biological soil characteristics, which resulted in higher yield and ultimately the uptake. It is also reported that phosphate enriched compost is an effective source of Ca (Qureshi *et al.,* 2014) and Mg (Jagadeesha *et al.,* 2021) that increases their concentration in soil solution and enhances their uptake and storage in plants. On the other hand, plots under control (T_1) and natural farming (T_5) treatment recorded lowest nutrient uptake due to low yield as a result of low availability of nutrients.

[a]



[b]

Fig. 2: Effect of phosphate rich organic manure and soil amendments on (a) Total NPK uptake and (b) Total Ca and Mg uptake

Conclusion

It can be inferred that there was a significant increase in yield, quality and nutrient uptake by crop by integrated application of PROM, FYM and lime along with inorganic fertilizers as compared to yield and quality of crop obtained by using sole inorganic fertilizer or control. Significant and positive correlation between soil available nutrients and yield, quality and nutrient uptake by the crop was observed. It was also revealed by the results that by using combination of PROM and soil amendments with Single superphosphate (SSP), significantly increased nutrient content like P, K, Ca, Mg, Fe, Zn and crude protein in wheat crop. T_8 treatment comprising recommended NK + 50 % P from SSP + 50 % P from PROM showed maximum crop yield and nutrient uptake among all the treatments where complete doses of PROM and SSP were given to the soil. In this way, available P and its concentration in wheat plant was enhanced. Thus, it was proved that PROM worked as effective alternating phosphorus to synthetic fertilizers. However, more field experiments with different crops are required to ensure a successful performance of PROM under Typic Hapludalfs.

Ethical Approval

This article does not contain any studies involving human or animal participants performed by any of the authors.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' contribution

This article is fully based on M.Sc. research work of the first author (R. Ranjha) under the supervision of D. Singh as major advisor. D. Singh and S.K. Sharma conceptualized and designed the experiment. P. Chopra has supervised the research. Data collection, interpretation and manuscript has been drafted by R. Ranjha. All the authors have provided critical feedback in preparation of the manuscript.

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