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Integrated phosphorus management using prom and inorganic fertilizers for enhanced growth, yield, and nutrient uptake of chickpea in Inceptisol

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Abstract
Phosphorus availability in soils is often limited due to fixation by sesquioxides, affecting crop productivity, particularly in leguminous crops like chickpea. A field experiment entitled *"Effect of Different Levels of PROM on Yield and Quality of Chickpea in Inceptisol"* was conducted during Rabi 2024-25 at the Agronomy Farm, College of Agriculture, Kolhapur. The experiment was laid out in a Randomized Block Design with ten treatments: T_1; control, T_2;100% P_2O_5 through single super phosphate (SSP),T_3; 100% P_2O_5 through Di-ammonium phosphate (DAP),T_4; 100% P through Phosphate Rich Organic Manure (PROM)), T_5; 75% P_2O_5 through PROM + 25% P_2O_5 through SSP, T_6; 75% P_2O_5 through PROM + 25% P_2O_5 through DAP, T_7; 50% P_2O_5 through PROM + 50% P_2O_5 through SSP, T_8; 50% P_2O_5 through PROM + 50% P_2O_5 through DAP, T_9; 25% P_2O_5 through PROM + 75% P_2O_5 through SSP and T_{10};. 25% P_2O_5 through PROM + 75% P_2O_5 through DAP. These treatments were replicated thrice and statistically tested using randomized block design. The results indicated that the treatment T_3; 100% P_2O_5 through Di-ammonium phosphate (DAP) recorded the highest plant height at harvest (40.33 cm), active root nodules plant^{-1} at 50% flowering (41.27), root length (14.03cm), root biomass(1.60gm), grain yield (22.12 q ha^{-1}), straw yield (25.1 q ha^{-1}), and total nutrient uptake for nitrogen, phosphorus and potassium (92.49, 17.80 and 51.48 respectively) were observed in the same treatment T_3; 100% P_2O_5 through DAP.

Keywords: Chickpea (*Cicer arietinum* L.), phosphorus management, phosphate rich organic manure (PROM), inceptisol, nutrient uptake

1.Introduction
Chickpea (*Cicer arietinum* L.), also known as Bengal gram, occupies a unique place in Indian agriculture and diets. It is often referred to as the "King of Pulses" because of its wide adaptability, nutritional richness, and significant contribution to pulse production. Chickpea is grown across diverse agro-climatic zones, making it the most important pulse crop in India and the third most important globally after common bean and field pea. With its seeds containing around 18-22 percent protein, chickpea plays a vital role in meeting dietary protein needs, particularly in vegetarian diets. It also contributes to food security and nutritional balance by supplying essential amino acids, minerals, and vitamins. Beyond human nutrition, chickpea contributes to farming system sustainability through its ability to fix atmospheric nitrogen in symbiosis with *Rhizobium* bacteria, thus reducing dependence on chemical nitrogen fertilizers.
India is the world's largest chickpea producer, accounting for nearly 49 percent of the global area and production under the crop.
In 2022-23, chickpea was cultivated on 10.47 million hectares with a production of 12.26 million tonnes and an average productivity of 1,172 kg ha^{-1} (Manisha *et al.,* 2024) [9]. Maharashtra, one of the leading chickpea-producing states, contributed 2.7 million hectares and 3.1 million tonnes, with an average productivity of 1,145 kg ha^{-1}. Despite its importance, the productivity of chickpea in India still lags behind its potential due to several production constraints, among which nutrient limitations, particularly phosphorus, are most critical.
Phosphorus is an essential macronutrient for crop growth, playing a central role in root development, energy transfer, photosynthesis, and reproductive growth. Its availability strongly influences nodulation and nitrogen fixation in pulses, thereby impacting both yield and seed quality. In Indian soils, however, phosphorus availability is generally low. When phosphate

fertilizers are applied, only 15-20 percent of the nutrient is actually taken up by plants in the first year, while the rest gets fixed into insoluble forms, remaining unavailable to crops (Chang & Jackson, 1957) [3]. Soil pH is one of the key factors controlling phosphorus availability. In acidic soils, phosphorus reacts with iron and aluminum to form insoluble compounds like strengite and variscite, while in alkaline soils it precipitates with calcium to form poorly soluble calcium phosphates. This strong fixation process reduces fertilizer efficiency and creates a major bottleneck for sustainable crop production.

In India, Inceptisols are one of the most widely distributed soil groups, covering about 40 percent of the geographical area (Bhattacharyya *et al.*, 2009) [2]. These soils, often red or alluvial in nature, are characterized by moderate weathering and mixed mineralogy (Bhattacharyya *et al.*, 2015) [1]. Inceptisols are considered transitional soils that do not meet the criteria of other orders, hence often described as a “catch-all” category (Dhir, 2004) [4]. A major challenge with Inceptisols is their tendency to fix phosphorus, leading to widespread phosphorus deficiency. Since phosphorus is directly linked to root branching, nutrient uptake, and energy supply, its deficiency reduces crop vigor and yield potential. Addressing phosphorus limitations in Inceptisols, therefore, becomes a priority for improving crop productivity.

Traditionally, chickpea farmers in India rely on inorganic phosphorus fertilizers such as Di-Ammonium Phosphate (DAP) and **S**ingle Super Phosphate (SSP) to meet crop requirements. DAP is one of the most widely used fertilizers because it supplies both phosphorus and nitrogen in immediately available forms, ensuring rapid crop establishment and strong early growth. SSP, on the other hand, provides multiple benefits. Apart from phosphorus, it supplies sulfur and calcium, which are crucial for legume crops. Sulfur enhances nodulation and protein synthesis, while calcium improves cell wall strength and seed quality. The combined benefits of DAP and SSP have made them the backbone of nutrient management in chickpea-based farming systems. Their use has significantly contributed to higher yields and improved seed quality over the decades, making them indispensable for pulse production in India.

However, despite their proven benefits, the efficiency of DAP and SSP is constrained by soil-related factors. A large proportion of applied phosphorus becomes fixed in unavailable forms, resulting in poor nutrient use efficiency and higher costs for farmers. Moreover, the heavy reliance on chemical fertilizers raises environmental concerns and increases dependency on imported raw materials. These challenges highlight the need for more sustainable and eco-friendly alternatives to maintain productivity while safeguarding soil health.

In recent years**,** Phosphorus Rich Organic Manure (PROM) has emerged as a promising option for improving phosphorus management in Indian agriculture. PROM is prepared by enriching organic residues such as farmyard manure or compost with finely ground rock phosphate and inoculating them with phosphate-solubilizing microorganisms. These microbes secrete organic acids that solubilize phosphorus from rock phosphate, making it gradually available to plants. Unlike chemical fertilizers, PROM not only supplies phosphorus but also improves soil organic matter, enhances microbial activity, and supports long-term soil fertility. PROM has been officially recognized under the Fertilizer Control Order (2019) as a green chemistry fertilizer, with a minimum requirement of 10.42 percent P_2O_5. India has nearly 300 million tonnes of rock phosphate reserves (TIFAC, 2011) [13], though only a fraction is of high grade. Deposits at Jhamar Kotda in Rajasthan, containing 18-31 percent P_2O_5, are widely used for PROM preparation. By blending these reserves with organic materials, PROM becomes an eco-friendly and cost-effective alternative to imported fertilizers.

2. Material and Methods

2.1 Experimental site

The field experiment entitled “Effect of different levels of PROM on yield and quality of chickpea in Inceptisol” A field experiment was conducted during *Rabi 2024-25* at the Agronomy field, RCSM College of Agriculture, Kolhapur (Maharashtra). The soil at the experimental site was classified under the Inceptisol order (medium-deep black). The initial soil analysis of the experimental field indicated that the soil was slightly alkaline in reaction, with a pH of 8.02, and had an electrical conductivity (EC) of 0.28 dS m^{-1}, classifying it as non-saline. The soil contained 0.52 percent organic carbon, reflecting a medium level of organic matter. Calcium carbonate content was 6.87 percent, suggesting calcareous characteristics. With respect to available nutrients, the soil was low in nitrogen (201.94 kg ha^{-1}) and phosphorus (13.08 kg ha^{-1}), while it was rich in available potassium (420 kg ha^{-1}). Overall, the soil fertility status indicated nitrogen and phosphorus as the most limiting nutrients for crop growth.

2.2. Experimental detail

After completion of preparatory tillage operations, the experimental units were laid out as per plan. The experiment was laid out in randomized block design (RBD) with ten (10) treatments each replicated three times. T_1; control, T_2;100% P_2O_5 through single super phosphate (SSP), T_3; 100% P_2O_5 through Di-ammonium phosphate (DAP),T_4; 100% P through Phosphate Rich Organic Manure (PROM)), T_5; 75% P_2O_5 through PROM + 25% P_2O_5 through SSP, T_6; 75% P_2O_5 through PROM + 25% P_2O_5 through DAP, T_7; 50% P_2O_5 through PROM + 50% P_2O_5 through SSP, T_8; 50% P_2O_5 through PROM + 50% P_2O_5 through DAP, T_9; 25% P_2O_5 through PROM + 75% P_2O_5 through SSP and T_{10};. 25% P_2O_5 through PROM + 75% P_2O_5 through Dap. Chickpea seed variety Phule Vikram was sown on 29 November 2024 by dibbling method as per randomly replicated plot having size 4.5 × 3 m^2 and 4 × 2.70 m^2 in gross and net plot respectively, maintained row to row spacing 30 cm and plant to plant 10 cm and using a seed rate of 75 kg ha^{-1}. During the sowing time, the complete recommended dosage of nitrogen, phosphorus, and potassium (25:50:30 N, P_2O_5 and K_2O kg ha^{-1}) was completed using Urea, DAP, SSP, MOP, and PROM. With 5tha^{-1} FYM. In this experiment, the recommended dose of phosphorus was supplied through organic sources, inorganic sources, or their combinations.

3. Results and Discussion

3.1 Effect of Different Levels and Sources of Phosphorus on Growth Parameters of Chickpea in Inceptisol

3.1.1 Plant height at harvest

The data pertaining to plant height is presented in Table 1 and graphically represented in Figure 1 The data indicated that the treatment $T_{3,}$ *i.e.* 100% P_2O_5 through DAP recorded significantly superior plant height (40.33 cm) over all the treatments and being at par with treatment T_2 (39.07cm), *i.e.* 100% P_2O_5 through SSP, and T_{10} (37.33cm) including 25% P_2O_5 through PROM + 75% P_2O_5 through DAP. The lowest plant height (28 cm) was observed in treatment T_1 (absolute control).

3.1.2 Active root nodules
The data in context to the active root nodules of chickpea was presented in Table 1 and Fig. 2 results revealed that treatment T_3, *i.e.* 100% P_2O_5 through DAP, showed significantly higher number of nodules per plant (41.27), which was at par with the treatment T_2 (37.87), *i.e.* 100% P_2O_5 through SSP. The lowest nodules count (21.73) was noted under the absolute control treatment.

3.1.3 Root length
The data related to the root length of chickpea are presented in Table no. 1 and Figure 3. The maximum root length (14.03cm) was observed in Treatment T_3, consisting of 100% P_2O_5 through DAP, over all the treatments and at par with treatment T_2 (13.27cm), *i.e.*, 100% P_2O_5 through SSP, and T_{10} (12.73cm), *i.e.*, 25% P_2O_5 through PROM + 75% P_2O_5 through DAP. The lowest root length (9.97 cm) was noted under the absolute control treatment (T_1).

3.1.4 Root biomass
The observations on root biomass of chickpea are illustrated in Table 1 and figure 4 the highest root biomass (1.60 g) was observed in treatment T_3, having 100% P_2O_5 through DAP, over all the treatments and at par with treatment T_2 (1.48g), *i.e.* 100% P_2O_5 through SSP. The lowest root biomass (0.94g) was noted under the absolute control treatment.

The notable increase in plant height under DAP treatment is linked to its readily available phosphorus, which is essential for energy transfer and various metabolic activities that drive vigorous plant growth. In addition, the higher number of active root nodules observed with DAP application can be explained by improved phosphorus availability, which promotes better root development and supports effective symbiotic nitrogen fixation. Together, these factors contribute to enhanced overall growth, including plant height, root development, and nodulation, leading to stronger and healthier chickpea plants. While, PROM doesn't contain readily available phosphorus which caused reduction in the growth and yield attributes.

These results are in corroboration with those of Sharma *et al*. (2018), who reported enhanced growth parameters such as plant height, branching, and nodulation in chickpea due to application of inorganic phosphorus fertilizers.

3.2.1 Effect of Different Levels and Sources of Phosphorus on Grain and Straw Yield of Chickpea in Inceptisol
3.2.2. Grain yield
The data presented in Table 2 and graphically illustrated in Figure 5 indicated that the treatment T_3, having 100% P_2O_5 through DAP, recorded a significantly higher chickpea seed yield ha^{-1} (22.12 qha^{-1}) as compared to other treatments, but it was found at par with treatment (T_2), *i.e.*, 100% P_2O_5 through SSP, and T_{10}, *i.e*. 25% P_2O_5 through PROM + 75% P_2O_5 through DAP, *i.e*., 20.35 and 20.05, respectively. The lowest seed yield ha^{-1} (12.30 q ha^{-1}) was noted under the absolute control treatment.

3.2.3 Straw yield
The data pertaining to straw yield of chickpea is presented in Table 2 and graphically represented in figure 5 The straw yield of chickpea followed a similar trend to that of grain yield. The data showed that the treatment with application of 100% P through DAP (T_3) recorded a statistically higher chickpea straw yield ha^{-1} (25.1 q ha^{-1}) as compared to other treatments, but it was found at par with treatment T_2 (23.17 q ha^{-1}), *i.e*. 100% P_2O_5 through SSP, and treatment T_{10} (22.55 q ha^{-1}) comprising 25% P_2O_5 through PROM + 75% P_2O_5 through DAP. The lowest straw yield (12.30 q ha^{-1}) was noted under the absolute control treatment.

The highest grain and straw yield of chickpea due to application of 100% recommended dose of phosphorus through DAP might be due to high solubility and immediate available of N and P for critical growth stages of crop. This could have resulted in higher growth performance and uptake of nutrient by chickpea. The results are in close agreement with that of Singh *et al.,* (2019) [12] and Kumar *et al.,* (2019) [7] who reported significant increase in chickpea grain and straw yields due to the application of water-soluble phosphorus sources like DAP and SSP. Similarly, Patel *et al*. (2017) [10] found that integrated use of PROM and chemical phosphorus fertilizers improved crop yield in Inceptisol soils. Overall, the findings emphasize the importance of using phosphorus sources like DAP and SSP to boost chickpea productivity in Inceptisol soils. However, strategically combining PROM with mineral sources may provide a sustainable method to support both yield and long-term soil fertility.

3.3.1 Effect of Different Levels and Sources of Phosphorus on Total Nutrient Uptake of Chickpea in Inceptisol
3.3.2 Total Nitrogen uptake
The data presented in Table 3 and Figure 6 indicate that the total nitrogen uptake varied from 45.43 to 92.49 kg ha^{-1} across the treatments. The highest uptake (92.49 kg ha^{-1}) was obtained with the application of 100% P_2O_5 through DAP (T_3), which was statistically at with the application of 100% P_2O_5 through SSP (T_2). The lowest uptake (45.43 kg ha^{-1}) was recorded in the unfertilized control (T_1). These results suggest that the application of phosphorus from different sources significantly improves nitrogen uptake in chickpea by enhancing nodulation, biological nitrogen fixation, and overall nutrient use efficiency.

3.3.2 Total Phosphorus uptake
The data presented in Table 3 and Figure 6 showed that the total phosphorus uptake under the treatments ranged between 17.80 to 8.07%. The significantly higher total uptake of phosphorus (17.80 kg ha^{-1}) was recorded in treatment T_3, having 100% P_2O_5 through DAP over all the other treatments, and at par with T_2 (16.00), having 100% P_2O_5 through SSP. The lowest total phosphorus uptake was found in the treatment T_1 (8.07).

3.3.3 Total Potassium Uptake
The data presented in table 3 and Fig. 6 showed that the significantly higher total uptake of potash (49.52 kg ha^{-1}) was recorded in treatment T_3, consisting of 100% P_2O_5 through DAP, and at par with T_2 (45.59), having 100% P_2O_5 through SSP. The lowest K uptake was recorded in the absolute control treatment.

The highest nutrient uptake was observed in treatment T_3, including 100% P_2O_5 through DAP. It may be due to it supplies phosphorus in a readily available, water-soluble form. This promotes early root development, which enhances the plant's ability to absorb not only phosphorus but also other essential nutrients like nitrogen and potassium. Additionally, DAP provides both nitrogen and phosphorus, supporting vigorous vegetative growth and improved nutrient use Efficiency, ultimately leading to higher nutrient uptake in chickpea grown on Inceptisol soils. Similar findings are also reported by Khan *et al.,* (2021) [6] found that the use of inorganic phosphorus fertilizers combined with *Bacillus sp.* significantly improved nitrogen, phosphorus, and potassium uptake in chickpea. A similar trend was noted in the study conducted by Kumawat *et al.* (2013) [8] reported that the combined application of DAP, 40 kg P_2O_5 ha^{-1} and PSB significantly enhanced nutrient uptake in black gram. Among the phosphorus sources, DAP was the most effective in improving nutrient utilization, highlighting its superiority over SSP and PROM in clay-loam soils.

Conclusions

The study concludes that the application of the recommended dose of phosphorus solely through inorganic sources was more effective in enhancing chickpea performance compared to the use of organic sources alone. However, the integrated application of organic and inorganic phosphorus sources proved to be a comparable and efficient phosphorus management strategy, resulting in improved growth, nutrient uptake, and both grain and straw yield of chickpea.

Table 1: Effect of Different Levels and Sources of Phosphorus on Growth Parameters of Chickpea in Inceptisol

Tr. No.	Treatment	Plant height (cm)	Active root nodules	Root length (cm)	Root biomass (gm)
T_1	Absolute control	28.00	21.73	9.97	0.94
T_2	100% P_2O_5 through SSP	39.07	37.87	12.67	1.48
T_3	100% P_2O_5 through DAP	40.33	41.27	14.03	1.60
T_4	100% P_2O_5 through PROM	34.13	26.37	11.13	1.10
T_5	75% P_2O_5 through PROM + 25% P_2O_5 through SSP	32.80	25.27	10.67	1.00
T_6	75% P_2O_5 through PROM + 25% P_2O_5 through DAP	33.20	26.20	10.83	1.04
T_7	50% P_2O_5 through PROM + 50% P_2O_5 through SSP	34.33	26.67	11.27	1.12
T_8	50% P_2O_5 through PROM + 50% P_2O_5 through DAP	35.53	27.33	12.00	1.14
T_9	25% P_2O_5 through PROM + 75% P_2O_5 through SSP	36.07	31.53	12.07	1.21
T_{10}	25% P_2O_5 through PROM + 75% P_2O_5 through DAP	37.33	33.37	12.73	1.29
	SEm (±)	1.43	1.95	0.51	0.04
	CD at 5%	4.25	5.81	1.53	0.13

Table 2: Effect of Different Levels and Sources of Phosphorus on Grain and Straw Yield of Chickpea in Inceptisol

Tr. No.	Treatment	Grain yield (qha^{-1})	Straw yield (qha^{-1})
T_1	Absolute control	12.30	17.33
T_2	100% P_2O_5 through SSP	20.35	23.17
T_3	100% P_2O_5 through DAP	22.12	25.10
T_4	100% P_2O_5 through PROM	17.27	19.93
T_5	75% P_2O_5 through PROM + 25% P_2O_5 through SSP	16.44	19.10
T_6	75% P_2O_5 through PROM + 25% P_2O_5 through DAP	16.77	19.81
T_7	50% P_2O_5 through PROM + 50% P_2O_5 through SSP	17.32	19.95
T_8	50% P_2O_5 through PROM + 50% P_2O_5 through DAP	17.72	20.70
T_9	25% P_2O_5 through PROM + 75% P_2O_5 through SSP	18.56	20.93
T_{10}	25% P_2O_5 through PROM + 75% P_2O_5 through DAP	20.05	22.55
	SEm (±)	0.71	0.98
	CD at 5%	2.12	2.93

Table 3: Effect of Different Levels and Sources of Phosphorus on Total Nutrient Uptake of Chickpea in Inceptisol

Tr. No.	Treatment	Total nutrient uptake (kg ha^{-1})		
		Nitrogen	Phosphorus	Potassium
T_1	Absolute control	45.43	8.07	29.11
T_2	100% P_2O_5 through SSP	85.24	16.00	47.53
T_3	100% P_2O_5 through DAP	92.49	17.80	51.48
T_4	100% P_2O_5 through PROM	65.81	11.91	37.71
T_5	75% P_2O_5 through PROM + 25% P_2O_5 through SSP	60.55	10.99	36.21
T_6	75% P_2O_5 through PROM + 25% P_2O_5 through DAP	62.88	11.42	37.35
T_7	50% P_2O_5 through PROM + 50% P_2O_5 through SSP	65.88	12.07	38.27
T_8	50% P_2O_5 through PROM + 50% P_2O_5 through DAP	68.22	12.44	39.23
T_9	25% P_2O_5 through PROM + 75% P_2O_5 through SSP	71.19	13.28	40.01
T_{10}	25% P_2O_5 through PROM + 75% P_2O_5 through DAP	77.96	14.64	44.48
	SEm (±)	2.44	0.60	1.48
	CD at 5%	7.26	1.80	4.41

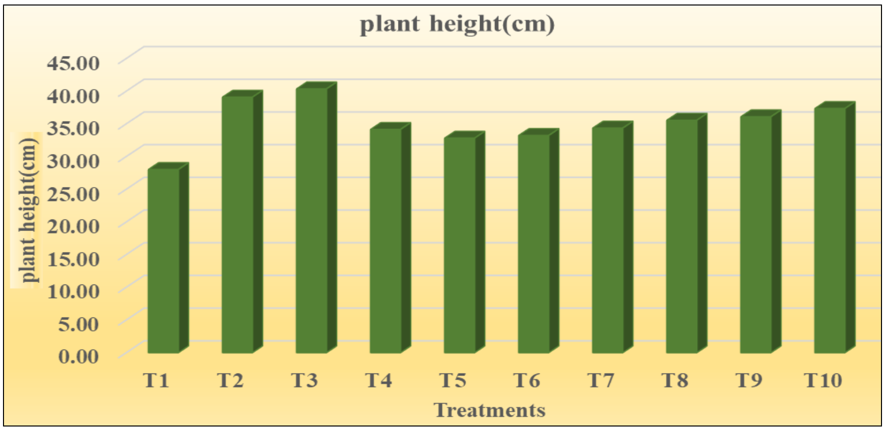

Fig 1: Plant height as influenced by different sources and levels of phosphorus

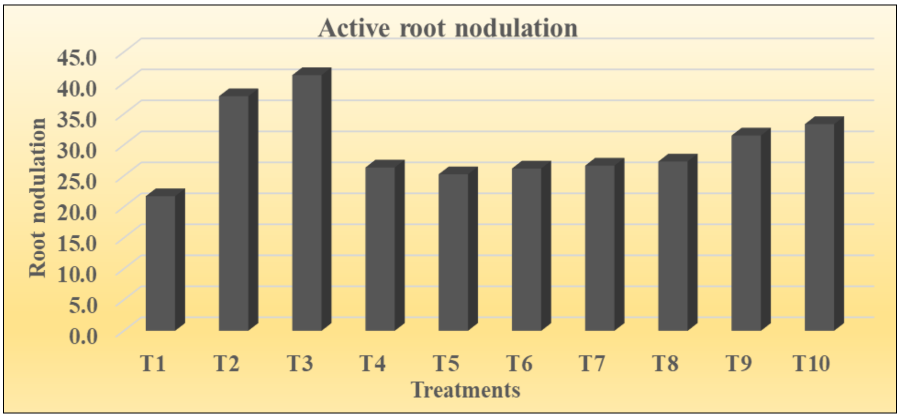

Fig 2: Root nodulation as influenced by different sources and levels of phosphorus

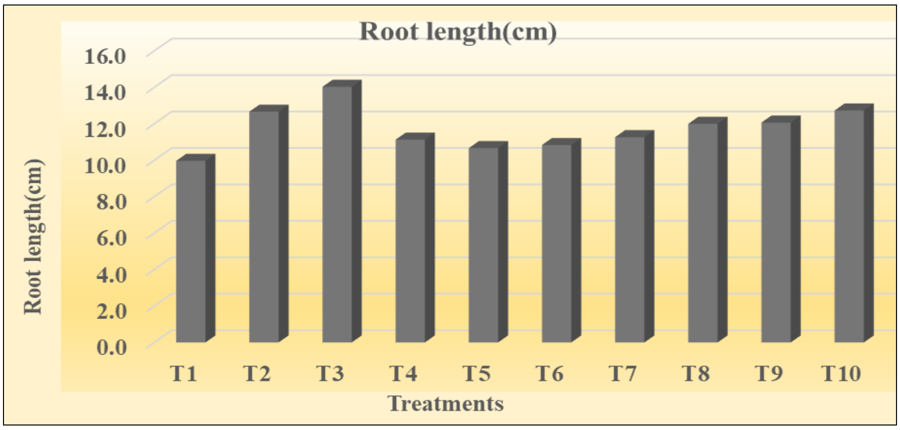

Fig 3: Root length as influenced by different sources and levels of phosphorus

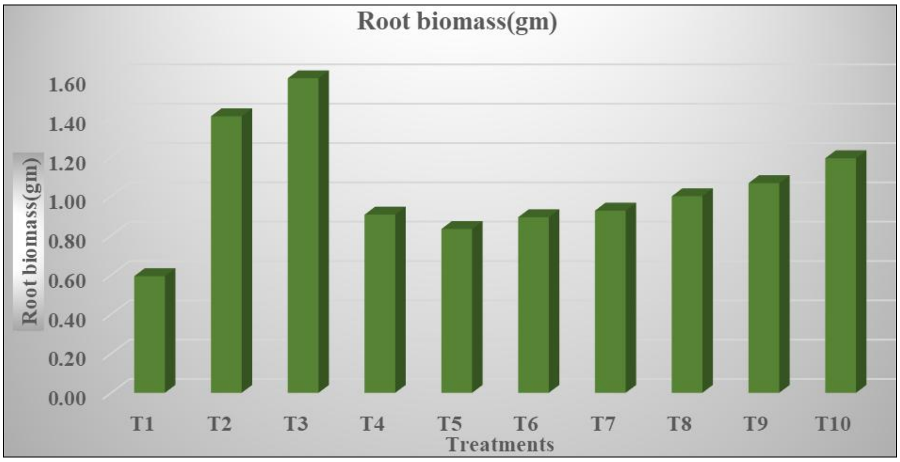

Fig 4: Root biomass as influenced by different sources and levels of phosphorus

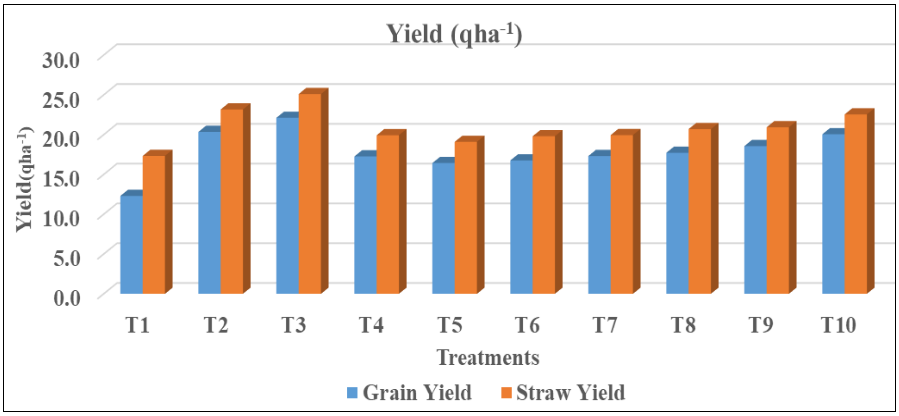

Fig 5: Yield (qha^{-1}) as influenced by different sources and levels of phosphorus

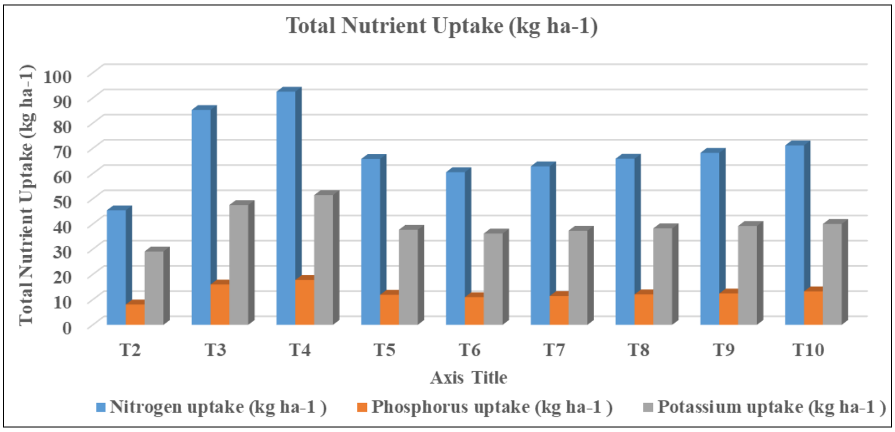

Fig 6: Total nutrient uptake as influenced by different sources and levels of phosphorus

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