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EFFECTS OF PHOSPHORUS APPLICATION RATE ON THE GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract
Phosphorus is an important element in promoting plant growth. It serves as a crucial primary nutrient, playing a key role in facilitating the absorption of nutrients and water from deeper layers in the soil, which then improves root growth. Phosphorus is necessary for achieving higher and sustained productivity in wheat crops. The experiment was laid out at the Students' Experimental Farm, Sindh Agriculture University, Tandojam, in a three-replicated randomized complete block design. The treatments included T1 = control (no fertilizer), T2 = 40 kg ha^{-1}, T3 = 50 kg ha^{-1}, T4 = 60 kg ha^{-1}, T5 = 70 kg ha^{-1}, and T6 = 80 kg ha^{-1}. Experiment analysis of variance statistical analysis via ANOVA through Statistix-8.1 (ANOVA) revealed a noteworthy distinction ($P<0.05$) for all yield and growth characteristics appropriate to treatments. The wheat crop fertilized with 80 kg ha^{-1} phosphorus resulted in plant population (168.00 m2), tillers (365 m2), plant height (95.00 cm), spike length (12.00 cm), grain spike-1 (40.00), 48.00 (g) seed index (1000 grain g), biological yield (8600 kg ha^{1}), and grain yield (4300 kg ha^{1}). The wheat was fertilized with T5 = 70 kg ha^{-1} phosphorus 162.00 m^2 plant population, tillers (359 m^{-2}), plant tallness (94.31 cm), spike length (11.52 cm), 39.69 grains spike-1, 47.68 g seed index (1000 grains wt, g), biological yield (8543 kg ha^{-1}), and grain yield (4268 kg ha^{-1}). However, the minimum lowest crop performance was T1 = Control (No Fertilizer) with 137.33 m2 plant population, tillers (317 m^2), plant height (90.02 cm), spike length (9.06 cm), grain spike-1 (35.00), 42.02 g seed index (1000 grain swt), biological yield (7887 kg ha1), and grain yield (3640 kg ha1). The study revealed that while higher rates of phosphorus had a positive impact on crop performance, the treatment with T6 = 80 kg ha^{1} of phosphorus proved to be the most effective in achieving maximum values for crop growth traits and grain yield (4300 kg ha^{1}). This was followed by the treatments with T5 = 70 kg ha^{-1} yielding (4268 kg ha^{-1}) and T4 = 60 kg ha^{-1} yielding (4052 kg ha^{-1}). The results also indicated that wheat performed equally well under treatments T5 and T6. Therefore, for optimal economic yield, it is recommended to use treatment T5. Hence, the differences between T5 and T6 are statistically almost the same. The seed yield increased linearly with increasing phosphorus levels. However, the plot fertilized with fertilizer containing phosphorus at 80 kg ha-1 produced the maximum (4300 kg ha^{-1}), followed by phosphorus at 70 kg ha^{-1} (4216 kg ha^{-1}) and phosphorus at 60 kg ha^{-1} (4052 kg ha^{-1}).
Keywords: *Growth, Levels, Phosphorus, Wheat, Yield*

INTRODUCTION

The largest notable food crop in Pakistan is wheat, which is grown in Sindh and Punjab-irrigated areas during the Rabi season. According to the situation, wheat appears to be the most valuable crop during the Rabi season and a staple food for people (1, 2). In our country, wheat holds the position of the second-most significant food crop. It is predominantly consumed in the northern and northwestern regions. Wheat serves as a valuable supplement to meet the nutritional requirements of the human body, containing approximately 9–10% protein and 60–80% carbohydrates. With its richness in protein, vitamins, and carbohydrates, wheat provides a well-rounded source of nourishment for millions of individuals every day (3). P is the essential plant nutrient that plants require in significant quantities for their growth (4). By appropriately applying phosphorus, it is possible to achieve a 20% increase in wheat grain yield (5). Nearly all soils in Pakistan have poor fertility due to a lack of organic matter. It is estimated that 80–90% of the soil has low to medium levels of phosphorus and is highly calcareous (6). Increasing phosphorus applications can enhance the taking in of nitrogen and phosphorus by plants (7). Phosphorus plays a crucial role in various plant physiological activities, especially photosynthesis, carbon metabolism, and membrane production (8). In soils that lack fertilization, particularly those with high levels of calcium carbonate that decrease the solubility of phosphorus, phosphorus deficiency consistently emerges as a prevalent constraint on crop growth and yield (9). When these conditions are present, only a small portion of the applied phosphorus becomes accessible to crop plants, leading to reduced crop productivity. However, the application of beneficial microorganisms (BMO) in such soils can enhance phosphorus availability and, consequently, improve crop productivity. A varied community of soil microflora has been found to play a role in solubilizing insoluble phosphorus complexes, facilitating easier phosphorus absorption by plants (10). Phosphorus contributes to the promotion of root development and growth during the early stages of seedling growth, facilitating the rapid establishment of seedlings. Additionally, it enhances the formation of tillers in cereal crops and improves the grain-to-straw ratio, resulting in a higher proportion of desirable grain yield compared to non-grain biomass (11). Soil nutrient status is crucial for maintaining high-quality and sustainable crop production. It is essential to keep soil nutrients at sufficient levels. While applying fertilizers is an option, their high costs make them less feasible for farmers, and extensive use is not profitable (12, 13).

MATERIALS AND METHODS

The field experiment was carried out at the student's farm department of Agronomy Sindh Agriculture University, Tando Jam, to determine the impact of soil-applied fertilizers on wheat growth and yield. The net plot size was 5 m x 4 m = 20 m2, and the three replicates of each treatment were arranged in a randomized complete block design. The land preparation methods recommended for wheat plantations were implemented. The study focused on the local variety Benazir.

CULTURE PRACTICES

A good seed bed was prepared by two dry plowings and leveling the land. The recommended dose of N and K was applied to all treatments during the sowing time. Throughout this study, during seeding, phosphatic fertilizer was applied in clay loam soil to different stages of wheat. The agronomical traits of the plants were observed by selecting five plants in each plot at five-day intervals during the initial 10 days following crop formation.

1. T_1 = Control (No Phosphorus)
2. T_2 = 40 kg ha^{-1}
3. T_3 = 50 kg ha^{-1}
4. T4 = 60 kg ha^{-1}
5. T5 = 70 kg ha^{-1}
6. T6 = 80 kg ha^{-1}

WATER MANAGEMENT

The crop necessitates 4 to 6 irrigations, contingent upon the soil type and rainfall. The wheat crop, in particular, requires at least five irrigations at specific critical stages.

1. After sowing
2. Crown root initiation: 15-20 days after sowing (DAS)
3. Tillering stage: 35–40 days after sowing (DAS)
4. Flowering stage: 50–55 days after sowing (DAS)
5. Grain filling stage: 70–75 days after sowing (DAS)

WEED MANAGEMENT

For effective weed control, the following chemicals should be sprayed as a solution in 400 to 600 liters of water per hectare. A mixture of Isoproturon at 0.75 kg active ingredient per hectare and 2,4-D at 0.4 kg active ingredient per hectare, or Isoguard-plus at 1.2 kg active ingredient per hectare, applied 30-35 days after sowing, will control both narrow and broadleaf weeds.

MANAGEMENT OF INSECTS

Termites are social insects that live underground in colonies; they attack both young seedlings and mature plants. Apply Fipronil 0.3% GR or Chlorpyrifos 10% GR at a rate of 10 kg per acre to the soil at the time of sowing.

Stem-borer: These insects lay eggs in clusters inside the leaf sheaths. The pinkish-brown caterpillars bore into stems, killing central shoots and causing dead hearts. In the initial stage, remove and destroy dead hearts; spray Chlorpyrifos 20% EC at 2 ml/l.

Cutworms: These caterpillars are general feeders. Spray Chlorpyrifos 20% EC at 2 ml/l.

Armyworm: Caterpillars march from field to field, voraciously feeding on foliage. They appear after heavy rains or early floods. Trap caterpillars in grass heaps or plough-infested fields; spray Profenofos 50% EC or Dichlorvos (DDVP) 76% EC at 1 ml/l.

Thrips: Nymphs and adults lacerate tender leaves, causing characteristic whitish streaks. They multiply rapidly at favorable temperatures. Spray Dimethoate 30% EC at 1 ml/l, Diazinon 20% EC at 1.5 ml/l, or Acetamiprid 20% SP at 0.5 g/l.

Wheat aphids: Nymphs and adults suck sap from leaves, tender shoots, and immature grains, forming large colonies quickly. Spray Dimethoate 30% EC at 1 ml/l, Diazinon 20% EC at 1.5 ml/l, or Imidacloprid 17.8% SL at 0.5 ml/l.

Shoot fly: Maggots attack seedlings and kill the central shoots, causing dead hearts. Apply phorate (10%) or disulfoton (5%) to the soil at the time of sowing.

During the maturity stage, 15 plants were sampled from each experimental unit to measure their plant population (m^{-2}) with the help of measuring tap, tillers (m^{-2}), plant height (cm), spike length (cm), grain spike^{-1}, seed index (1000 grains/g), biological yield (kg ha^{-1}), and grain yield (kg ha^{-1}).

STATISTICAL ANALYSIS

The statistics collected underwent statistical analysis via ANOVA through Statistix-8.1 computer software (Statistix, 2006). When required, the LSD test was utilized to evaluate the advantages of treatments.

RESULTS

PLANT POPULATION (m^{-2})

The result proved aa significant difference ($p<0.05$) in wheat at various levels of phosphorus. The phosphorus 80 kg ha^{-1} produced better with maximum. The plant population reached its highest level at maturity (168.00 m^2) when the wheat crop was given application of T_6 = 80 kg ha^{-1}, followed by (162.00 m^2 and 157.00 m^2) under phosphorus levels of T_5 = 70 kg ha^{-1} and T_4 = 60 kg ha^{-1}. The plant population at maturity of the wheat crop was additionally, there was a subsequent decrease in the plant population of 150.33 m^2 and 144.00 m^2 for phosphorus application T_3 = 50 kg ha^{-1} and T_2 = 40 kg ha^{-1}, respectively. The minimum (137.33 m^2) plant population of the wheat crop was detected under control T_1 = Control (No Phosphorus).

TILLERS (m^{-2})

Tillers at maturity were at their maximum (365 m2) when the wheat crop was addicted to the application of T_6 = 80 kg ha^1, followed by 359 m2 and 354 m2 under phosphorus levels of T_5 = 70 kg ha^1 and T_4 = 60 kg ha^1. The tillers at wheat crop maturity were further lowered to 348 m2 and 341 m2 for phosphorus, which finds various practical uses. T_3 = 50 kg ha^1 and T_2 = 40 kg ha^1.

PLANT HEIGHT (cm)

Phosphorus has diverse applications, each serving different purposes (317 m^{-2}). The wheat crop demonstrated maximum plant height at maturity when the phosphorus fertilizer was not controlled (95.00 cm). When the wheat crop received an application of phosphorus, an increase in plant height maturity was observed. At T6 = 80 kg ha1, a subsequent application of phosphorus to the wheat crop resulted in an observed increase in plant height at maturity (94.31 cm and 93.79 cm). Under different levels of phosphorus, variations in plant height at maturity were observed in the wheat crops T_5 = 70 kg ha^{-1} and T_4 = 60 kg ha^{-1}. The application of P resulted in a further reduction in the height of mature wheat plants, with measurements recorded at 92.48 cm and 91.18 cm of phosphorus T_3 = 50 kg ha^{-1} and T_2 = 40 kg ha^{-1}, respectively. When wheat crops were given a control fertilizer of phosphorus, the observed plant height reached its minimum at 90.02 cm.

SPIKE LENGTH (cm)

On the other hand, the spike length at maturity was at its maximum, measuring 12.00 cm, when the wheat crop received the application of a different treatment, T_6 = 80 kg ha^{-1}, followed by 11.52 cm and 11.08 cm under phosphorus levels of T_5 = 70 kg ha^{-1} and T_4 = 60 kg ha^{-1}. The spike length maturity of the wheat crop experienced an additional decrease of 10.70 cm and 10.26 cm for the use of phosphorus T_3 = 50 kg ha^{-1} and T_2 = 40 kg ha^{-1}, respectively (9.06 cm) spike-length wheat crop was seen when phosphorus fertilizer was the control.

Table I. Effects of phosphorus application rate on the growth and yield of wheat

Treatments	Plant population (m^{-2})	Tillers (m^{-2})	Plant height (cm)	Spike length (cm)
T_1= Control (No Phosphorus)	137.33 f	317 f	90.02 f	9.06 f
T_2= 40 kg ha^{-1}	144.00 e	341 e	91.18 e	10.26 e
T_3= 50 kg ha^{-1}	150.33 d	348 d	92.48 d	10.70 d
T_4= 60 kg ha^{-1}	157.00 c	354 c	93.79 c	11.08 c
T_5= 70 kg ha^{-1}	162.00 b	359 b	94.31 b	11.52 b
T_6= 80 kg ha^{-1}	168.00 a	365 a	95.00 a	12.00 a
S.E. ±	1.4581	1.9303	0.0207	0.0235
LSD 0.05	3.2488	4.3009	0.0462	0.0524
P value	0.0000	0.0000	0.0000	0.0000

GRAIN SPIKE^{-1}

The maximum grain $spike^{-1}$ at maturity (40.00) when the wheat crop was given treatment of T_6 = 80 kg ha^{-1}, following that (39.69 and 38.66) under phosphorus levels of T_5 = 70 kg ha^{-1}&T_4 = 60 kg ha^{-1}. The grains $spike^{-1}$ at full growth of wheat crop was further lowered to 37.41 and 36.19 for phosphorus application T_3 = 50 kg ha^{-1} &T_2 = 40 kg ha^{-1}, respectively. The lowest (35.00) grains $spike^{-1}$ of wheat crop seen when phosphorus fertilizer was used as a control.

SEED INDEX (1000 grain weight, g)

The seed index (1000-grain weight) at maturity was highest (48.00 g) when the wheat crop was given application of T_6 = 80 kg ha^{-1}, following that (47.68 g and 46.21 g) under phosphorus levels of T_5 = 70 kg ha^{-1} &T_4 = 60 kg ha^{-1}. The seed index (1000 grains wt, g) When the wheat crop reached maturity, it further shrank to 44.49 g and 43.30 g for phosphorus application T_3 = 50 kg ha^{-1} and T_2 = 40 kg ha^{-1}, respectively smallest (42.02 g) seed index (1000 grains wt, g).

BIOLOGICAL YIELD (Kg ha^{-1})

The wheat crop exhibited the highest biological yield at maturity (8600 kg ha^{-1}) when the application phosphorus fertilizer was reformulated kept under control when fertilizer was applied to the wheat crop of T_6 = 80 kg ha^{-1}, following that (8543 kg ha^{-1} and 8489 kg ha^{-1}) under phosphorus levels of T_5 = 70 kg ha^{-1} and T_4 = 60 kg ha^{-1}. The application of P developed in a further decrease in the biological yield at maturity of the wheat crop, with yields reaching 8242 kg ha^{-1} and 7908 kg per hectare. T_3 = 50 kg ha^{-1} and T_2 = 40 kg ha^{-1}, respectively the smallest (7887 kg ha^{-1}) biological yield of wheat observed when fertilizer of phosphorus was controlled.

GRAIN YIELD (Kg ha^{-1})

The highest grain yield achieved at maturity was 4300 kg ha^{-1} when the wheat crop received a specific application T_6 = 80 kg ha^{-1}, following that (4268 kg ha^{-1}and 4052 kg ha^{-1}) under phosphorus levels of T_5 = 70 kg ha^{-1} and T_4 = 60 kg ha^{-1}. The grains yield at maturity of the wheat crop experienced a decrease to 3839 kg ha^{-1} and 3709 kg ha^{-1} when applying 50 kg ha^{-1}of phosphorus (T_3) & 40 kg ha^{-1} of phosphorus (T_2), individually. The lowest grains yield observed was 3640 kg ha^{-1} when no phosphorus fertilizer was applied (control).

Table II. Effects of phosphorus application rate on the growth and yield of wheat

Treatments	Grains spike^{-1}	Seed index (1000 grains weight, g)	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})
T_1= Control (No Phosphorus)	35.00 f	42.02 f	7887 f	3640 f
T_2= 40 kg ha^{-1}	36.19 e	43.30 e	7908 e	3709 e
T_3= 50 kg ha^{-1}	37.41 d	44.49 d	8242 d	3839 d
T_4= 60 kg ha^{-1}	38.66 c	46.21 c	8489 c	4052 c
T_5= 70 kg ha^{-1}	39.69 b	47.68 b	8543 b	4268 b
T_6= 80 kg ha^{-1}	40.00 a	48.00 a	8600 a	4300 a
S.E. ±	0.0218	0.0210	2.3649	2.5806
LSD 0.05	0.0486	0.0467	5.2693	5.7498
P value	0.0000	0.0000	0.0000	0.0000

DISCUSSION

The results indicated that the application of various phosphorus concentrations had an impact on various increase parameters and grains yield of the wheat crop. While 80 kg ha^{-1} of phosphorus (P_6) was useful, the crop exhibited a plant population of 168.00 m^{-2}, 365 m^{-2} tillers, a plant height of 95.00 cm, spike length (12.00 cm), grains spike^{-1} (40.00), a seed index (1000 grains wt, g) of 48.00 (g), a biological yield (8600 kg ha^{-1}), and a grain yield of (4300kg ha^{-1}). Similarly, applying 70 kg ha^{-1} of phosphorus (P_5) resulted in a plant population of 162.00 m^{-2}, 359 m^{-2} tillers, a plant tallness of 94.31 cm, spike length of 11.52 cm, grains spike^{-1} (39.69), (47.68 g)a seed index (1000grainswt, g), a biological yield(8543kg ha^{-1})and grains yield of (4268 kg ha^{-1}). When P was supplied at 60 kg ha^{-1} (P_4), the wheat crop displayed a plant population of 157.00 m^{-2}, 354 m^{-2} tillers, a plant tallness of 93.79 cm, spike length of 11.08 cm, 38.66 grains per spike, a seed index (1000grainswt, g) of 46.21 (g), a biological yield (8489 kg ha^{-1}), and grains yield (4052 kg ha^{-1}). For phosphorus submission at 50 kg ha^{-1} (P_3), the plant population was 150.33 m^{-2}, 348 m^{-2} tillers, a plant tallness of 92.48 cm, spike length of 10.70 cm, 37.41 grains spike^{-1}, a seed index (1000grainswt, g) of 44.49 (g), a biological yield (8242 kg ha^{-1}), and a grain yield (3839 kg ha^{-1}). When 40 kg ha^{-1} of phosphorus (P_2) was used, the crop exhibited a plant population of 144.00 m^{-2}, 341 m^{-2} tillers, a plant height of 91.18 cm, spike length of 10.26 cm, grains spike^{-1} (36.19), a seed index (1000grainswt, g) of 43.30 (g), a biological yield of (7908 kg ha^{-1}), and a grain yield of (3709 kg ha^{-1}). In contrast, the control group without phosphorus application (P_1) showed the lowest performance, with a plant population of 137.33 m^{-2}, 317 m^{-2} tillers, a plant tallness of 90.02 cm, spike length of 9.06 cm, (35.00) grains spike^{-1}, a seed index (1000grainswt, g) of 42.02 g, a biological yield (7887 kg ha^{-1}), and a grains yield (3640 kg ha^{-1}). These judgments lead to the conclusion that higher phosphorus rates positively influenced crop performance, with the treatment of 80 kg ha^{-1} of phosphorus (P_6) demonstrating the highest standards for growth personality and grains yield (4300 kg ha^{-1}). Maximum phosphorus dose enhanced the number of grains spike^{-1}, tillers number, thousand-grain weights and grain yield due to the highest accumulation of photosynthates in the plants and increased grain ripening which resulted in heavier grains. The results were also in close consistency with the findings of (14). Phosphorous is the most important essential nutrient for plant growth that's why it is component of fertilizers in most regions (15).These improvements revealed that application of P with HA improved the storage of photosynthates in the plants. This accumulation of photosynthates in plants enhances the enzymatic, microbial and catalytic activities in plants and thus produces higher grains spike^{-1}, grain yield, straw yield and biomass as well (16). Results regarding the grain yield showed that the percent increases of 41.7% with HA and 67.5 kg P_2O_5 ha^{-1} is closely resembled to 40.9 and 51% obtained with SSP alone at 90 and 112.5 kg P_2O_5 ha^{-1}, respectively, revealing a reduction in P requirements and increase in P fertilizer use efficiency with the addition of HA. A similar effect was noted by Rafiullah *et al.,* 2020 (17). This was followed by phosphorus at 70 kg ha^{-1} (P_5) with grains yield of 4268 kg ha^{-1}, and P at 60 kg ha^{-1}. P plays a crucial role in plants, contributing to vital processes such as photosynthesis, plant evolution, and importance alleviation (18). These findings align with a study which demonstrated that when applied topically, a nutrient mixture containing N, K_2O, Zn, Fe, Cu, B, and Mn enhanced both straw and grains yield in wheat. Additionally, this treatment positively influenced various yield-related characteristics such as grain weight, quantity of grains, harvest index, biological yield, and plant height. Similarly, Haider *et al.,* 2023 testified that the combination of foliar request of phosphorus and potassium not alone encouraged root growth, but also indirectly greater nitrogen use efficiency (19). This combination treatment also aided in maintaining the plant's tolerance to dry matter stress, possibly by fulfilling the plant's macronutrient requirements for phosphorus and potassium. Furthermore, Noor *et al.,* 2017 detected an upsurge in both the roots and the shoots' dry weight in mung bean plants with the foliar spray application of K_2SO4 (20, 21). In summary, these studies highlight the importance of phosphorus in supporting crucial plant processes, as well as the potential benefits of foliar applications containing various nutrients for enhancing crop yield and improving plant characteristics.

CONCLUSION

It is determined that the wheat Phosphorus levels considerably ($p<0.05$) impacted growth and seed yield as compared to control (no fertilizer). The seed yield increased linearly with increasing phosphorus levels. However, the plot fertilized with fertilizer of phosphorus 80 kg ha^{-1} produced maximum (4300 kg ha^{-1}) followed by phosphorus @ 70 kg ha^{-1}(4268 kg ha^{-1}) and 60 kg ha^{-1} phosphorus (4052 kg ha^{-1}).

Conflict of Interest:

Authors have no conflict of interest.

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