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IMPACT OF DIFFERENT LEVELS OF PHOSPHORUS ON THE GROWTH, YIELD AND OIL CONTENT OF SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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ABSTRACT

Phosphorus (P) is the second most important limiting mineral nutrient for crops. In the current study randomized complete block design was kept to determine impact of different levels of phosphorus on the growth, yield and oil content of sunflower. Experiment consists of six treatments of phosphorus levels repeated three times. The variety HO-1 was treated with different phosphorus levels: 00, 40, 50, 60, 70, and 80 kg ha^{-1}. Experiment analysis of variance (ANOVA) shows significant difference ($P<0.05$) for all growth, yield and oil content characteristics due to treatments. Maximum plant height (185.00 cm), maximum stem girth (5.00 cm), maximum head diameter (29.51 cm), maximum seed head^{-1}(1624.50 head^{-1}), maximum seed weight head^{-1} (55.60g), maximum seed index (1000-seed weight, g) (105.67g), maximum seed yield (2782.2 kg) ha^{-1} and maximum oil content (41.00%), were recorded in P_6 where phosphorus was applied @ 80 kg ha^{-1}, followed by P_5 where phosphorus was applied @ 70 kg ha^{-1} with (180.58cm) maximum plant height, (4.86 cm) maximum stem girth, (24.71 cm) maximum head diameter, (1606.20 head^{-1}) maximum seed head^{-1}, (54.30 g) maximum seed weight head^{-1}, (105.40 g) maximum seed index (1000-seed weight, g), (2720.5kg) maximum seed yieldha^{-1} and (40.59%) maximum oil content. However, P_1 00 kg ha^{-1} (control) shows that the smallest plant height (162.18 cm), minimum stem girth (4.04 cm), minimum head diameter (24.12 cm), minimum seeds head-1 (1307.30head-1), minimum seed weight.perhead^{-1} (50.70 g), seed index (103.33 g), minimum seed yield (2539kg ha^{-1}) and minimum oil content (39.28%). It was also observed that sunflower performance was at par with T_6 and T_5. From the present study it is concluded that sunflower performed equally better at T_5 and T_6. Hence, for economic yield T_6 is recommended. It was concluded that the impact of varying phosphorus levels on sunflower growth, yield, and oil content reveals significant correlations, emphasizing the critical role of phosphorus in optimizing sunflower productivity.

Keywords: Crop yield, Growth; Phosphorus; Sunflower

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INTRODUCTION

Sunflower is produced at around 23 million hectares in 40 countries of the world. Sunflower as significant decor ability as manufacturing of heads changeable by size and color of flower from cream to yellow. Sunflower cultivation area in world is 22.3 mha while seed production is 45 million metric tons and average yield stands at 1.2 tons per hectare, respectively (FAO, 2017). Sunflowers, which are oleaginous plants, are cultivated all over the world (Kostenkova et al., 2019), especially in Russia, Ukraine, the United States of America, Argentina, and China. China is the largest producer of sunflower oil. Chemicals that were extracted from the

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seeds of this oilseed's achenes (dried fruit) provide both a high nutritious content and a medicinal value. Achenes are the dried fruits of the plant. For the production of grain, sunflower is a crop having a high phenotypic adaptability that can be cultivated in all continents (Arif et al., 2017; Mokhtari et al., 2022). Pakistan is facing huge challenge of the acute shortage of edible oil. The demand for edible oil in Pakistan is increasing with the uncontrollable increase in population; however, edible oil production is not increasing at the same rate each year. Pakistan ranked world third largest importer in edible oil. The country's oil requirement was about 2.966 million tons in which 0.83 million tons (28%) were locally produced and the rest edible oil was imported (Khan and Inamullah, 2019).

Sunflower seeds are the source of the world's third-largest crop of oil, which is produced from the seeds. Its seeds are a good source of antioxidants, flavonols, phytosterols, amino acids, and dietary fibre and are also high in lipids, proteins, amino acids, potassium, and other beneficial substances (Feng et al., 2020; Guo et al., 2017). Oleic acid and linoleic acid are the two primary types of unsaturated fatty acids that are found in sunflower oil (saturated fatty acid). Seed output, oil content, and fatty acid content of sunflower oil may change based on the kind of plant, the growth conditions, and additional elements like fertilizer. Sunflower oil is popular cooking oil (Adeleke and Babalola, 2020). Sunflowers are often considered to be among the most valuable oilseed plants. It ranges between 34.26 and 39.13% in terms of its oil content. Vitamins A, D, E, and K are all found in fat-soluble form in sunflower oil. Four of the most important oilseed crops grown in this nation are sunflowers, canolas, cotton, and rapeseed/mustards. It was estimated that domestic production of edible oil would account for 0.374 million metric tonnes in 2020–21, while imports would account for 2.917 million metric tonnes (with a value of U$$ 3.419 billion). The global demand for edible oil was estimated to be 3.291 million metric tonnes in 2020–21. Sunflowers are responsible for the yearly production of 33,000 metric tonnes of oil. Due to the fact that oilseed crops satisfy more than 17 percent of Pakistan's need for edible oil, these crops play an essential role in the economy of the nation. Sunflower oil contributes around 11% of the total amount of edible oil produced in the United States (GOP, 2021).

Phosphorus (P) is the second most important limiting mineral nutrient for crops. Numerous plant cells have phosphorus as a prominent constituent of cell components. It plays a vital role in several metabolic processes of plants such as respiration, photosynthesis, energy reservation, cell-cell transfer, cell enlargement, and cell division. Early growth of plants and root formation requires a significant quantity of phosphorus. It is also needed for improving crop quality and seed formation. Phosphorus use proficiency of sunflower genotypes, a trail was conducted by Soomro et al. (2018). Eight cultivars were used, and nitrogen and phosphorus were applied at 100-50 and 100-90 kg ha^{-1}. Phosphorus also plays a vital role in oilseed crops to attain a higher quantity of oil. As it has well-known impacts on seed yield, oil quality and oil yield. Thus, phosphorus application has become a critical part of a fertilizer program for the production of oilseed crops (Iqbal et al., 2022; Khan and Inamullah, 2019). Phosphorus (P) is an essential macronutrient required for plant development and reproduction. However, an acute conflict in modern agriculture arises between increasing demand for agricultural output and inefficient application of non-renewable P as a fertilizer (Yan et al., 2021). The low concentration and poor mobility of plant-available phosphate (P) in soils greatly limits plant growth and crop production (Abbas et al., 2021; Sun et al., 2018). Moreover, P in mineral fertilizers is mainly obtained from phosphate rock, which is a non-renewable resource. Therefore, the development of P-efficient cultivars that produce high yields with reduced fertilizer inputs is seen as an important strategy for sparing global P resources and minimizing environmental problems (Zak et al., 2018).

MATERIALS AND METHODS

Experimental design

In the fall of 2022, a field experiment was conducted at Sindh Agricultural University, Tandojam, Student's Experimental Farm Department of Agronomy to examine the effects of varying phosphorus levels on sunflower growth, yield, and oil content. The HO-1 sunflower variety was chosen for this experiment and a three-replicated randomized complete block design (RCBD) with a net plot size of 6 m 5 m was implemented (30 m^2).The trial area was meticulously tilled, and canals were constructed according to the plan. To ensure uniform irrigation water, each plot was meticulously leveled.

Experimental treatments

There were six phosphorus levels in the treatments, and each plot got the necessary amounts of nitrogen and potash. The treatments were as fallows: T_1 = No Phosphorus @ 00 $kgha^{-1}$ (control), T2= Phosphorus @ 40 $kgha^{-1}$, T_3 = Phosphorus @ 50 $kgha^{-1}$, T_4 = Phosphorus @ 60 $kgha^{-1}$, T_5 = Phosphorus @ 70 $kgha^{-1}$ and T_6 = Phosphorus @ 80 $kgha^{-1}$. The seedbed was well-prepared for sunflower cultivation and applied different recommended dose of P (phosphorus) to all treatments, except for the control plot, based on soil testing. The sunflower crop received two timely irrigations, and measures were taken to control diseases, weeds, and pests at the experimental sites. Observations were recorded as: Plant height (cm), stem girth (cm), head diameter (cm), seed head^{-1}, seed weight head^{-1} (g), seed index (1000-seed wt., g), seed yield (kg ha^{-1}) and oil content (%).

Statistical analysis

The collected data was subjected to statistical analysis using 8.1 computer software Statistix ver. 8.1. The (LSD) test was applied to compare treatments superiority, where necessary.

RESULTS

Plant height (cm)

The effect of phosphorus levels on the plant height was statistically significant (P<0.05). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum plant height of 185.00 cm, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean plant height of 180.58 cm and 174.49 cm respectively. Similarly, the followed mean plant height 170.69 cm and 165.31 cm was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied (Table 1). Further, the lowest mean plant height 162.18 cm was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO^{-1} is concerned for its plant height (cm) trait.

Stem girth (cm)

The effect of phosphorus levels on the stem girth was statistically significant (P<0.05). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum stem girth of 5.00 cm, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean stem girth of 4.86 cm and 4.71cm respectively. Similarly, the followed mean stem girth 4.42cm and 4.19 cm was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean stem girth 4.04 cm was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control) (Table 1). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its stem girth (cm) trait.

Table 1. Different levels of phosphorus on the growth parameters of sunflower.

Treatments	Plant height (cm)	Stem girth (cm)	Head diameter (cm)	Seeds head^{-1}	Seed weight head^{-1} (g)	Seed index (1000-seed weight, g)
T_1 = No Phosphorus @ 00 kg ha^{-1} (control)	162.18 f ± 2.3	4.04 f ± 0.3	24.12 f ± 4.0	1307.30 f ± 10.0	112.20 f ± 3.1	103.33 f ± 2.9
T_2 = Phosphorus @ 40 kg ha^{-1}	165.31 e ± 2.0	4.19 e ± 0.5	25.60 e ± 3.2	1382.40 e ± 8.0	130.33 e ± 5.8	103.47 e ± 3.2
T_3 = Phosphorus @ 50 kg ha^{-1}	170.69 d ± 2.8	4.42 d ± 0.6	26.78 d ± 6.0	1422.50 d ± 3.6	147.87 d ± 2.9	103.67 d ± 4.2
T_4 = Phosphorus @ 60 kg ha^{-1}	174.49 c ± 3.0	4.71 c ± 0.4	27.48 c ± 5.0	1565.80 c ± 3.8	156.53 c ± 3.5	104.53 c ± 3.3
T_5 = Phosphorus @ 70 kg ha^{-1}	180.58 b ± 1.9	4.86 b ± 0.3	24.71 b ± 3.7	1606.20 b ± 2.7	161.47 b ± 4.2	105.40 b ± 3.0
T_6 = Phosphorus @ 80 kg ha^{-1}	185.00 a ± 4.0	5.00 a ± 0.5	29.51 a ± 4.3	1624.50 a ± 1.8	165.87 a ± 3.4	105.67 a ± 4.0
S.E.±	0.0276	0.0248	9.8513	2.0262	0.5092	0.1355
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LSD 0.05	0.0614	0.0551	0.0219	4.5147	1.1345	0.3020

Head diameter (cm)

The effect of phosphorus levels on the head diameter was statistically significant (P<0.05). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum head diameter of 29.51 cm, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean head diameter of 24.71 cm and 27.48 cm respectively. Similarly, the followed mean head diameter 26.78 cm and 25.60 cm was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean head diameter 24.12 cm was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its head diameter (cm) trait.

Seeds head^{-1}

The effect of phosphorus levels on the seeds head^{-1} was statistically significant ($P<0.05$). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum seeds head^{-1} of 1624.50, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean seeds head^{-1} of 1606.20 and 1565.80 respectively. Similarly, the followed mean seeds head^{-1} 1422.50 and 1382.40 was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean seeds head^{-1}1307.30 was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its seeds head^{-1} trait (Table 1).

Seed weight head^{-1} (g)

The effect of phosphorus levels on the seed weight head^{-1} was statistically significant ($P<0.05$). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum seed weight head^{-1} of 165.87 g, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean seed weight head^{-1} of 161.47 g and 156.53 g respectively. Similarly, the followed mean seed weight head^{-1} 147.87 g and 130.33 g was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean seed weight head^{-1}112.20 g was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control) (Table 1). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its seed weight head^{-1} (g) trait.

Seed index (1000-seed weight, g)

The effect of phosphorus levels on the seed index was statistically significant ($P<0.05$). The treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum seed index of 105.67 g, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean seed index of 105.40 g and 104.53 g respectively. Similarly, the followed mean seed index103.67 g and 103.47 g was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean seed index103.33 g was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control) (Table 1). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its seed index (1000-seed weight, g) trait.

Seed yield (kg ha^{-1})

The effect of phosphorus levels on the seed yield was statistically significant ($P<0.05$).Seed yield (kg ha^{-1})of sunflower as affected by different levels of phosphorus were recorded and the treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum seed yield of 2782.2 kg ha^{-1}, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean seed yield of 2720.5 kg ha^{-1} and 2678.9 (kg ha^{-1} respectively. Similarly, the followed mean seed yield2619.2 kg ha^{-1} and 2569.8 kg ha^{-1}was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied. Further, the lowest mean seed yield2539 kg ha^{-1} was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its seed yield (kg ha^{-1}) trait (Table 2).

Table 2. Different levels of phosphorus on the yield and oil content of sunflower.

Treatments	Seed yield (kg ha^{-1})	Oil content (%)
T_1 = No Phosphorus @ 00 kg ha^{-1} (control)	2539.3 f ± 14.3	39.28 f ± 1.3
T_2 = Phosphorus @ 40 kg ha^{-1}	2569.8 e ± 10.4	39.42 e ± 2.0
T_3 = Phosphorus @ 50 kg ha^{-1}	2619.2 d ± 11.3	39.71 d ± 1.9
T_4 = Phosphorus @ 60 kg ha^{-1}	2678.9 c ± 9.5	40.36 c ± 2.7
T_5 = Phosphorus @ 70 kg ha^{-1}	2720.5 b ± 12.0	40.59 b ± 3.0
T_6 = Phosphorus @ 80 kg ha^{-1}	2782.0 a ± 13.3	41.00 a ± 2.2
S.E.±	4.2715	0.0315
P value	0.0000	0.0000
LSD 0.05	9.5176	0.0701

Oil content (%)

The effect of phosphorus levels on the oil content was statistically significant ($P<0.05$). Oil content (%)of sunflower as affected by different levels of phosphorus were recorded and the treatment T_6 = Phosphorus @ 80 kg ha^{-1}produced maximum oil content of 41.00%, while the crop receiving T_5 = Phosphorus @ 70 kg ha^{-1} and T_4 = Phosphorus @ 60 kg ha^{-1}resulted in mean oil content of 40.59% and 40.36% respectively. Similarly, the followed mean oil content39.71% and 39.42%was observed when crop treated with T_3 = Phosphorus @ 50 kg ha^{-1} and T_2 = Phosphorus @ 40 kg ha^{-1} were applied (Table 2). Further, the lowest mean oil content 39.28% was noted with T_1 = No Phosphorus @ 00 kg ha^{-1} (control). This suggested that T_6 = Phosphorus @ 80 kg ha^{-1} could be considered as an optimum level so far the response of sunflower variety HO-1 is concerned for its oil content (%) trait.

DISCUSSION

The present study shows that the sunflower crop receiving T_6 = Phosphorus @ 80 kg $ha^{-1}$with 185.00 cm plant height, 5.00 cm stem girth, 29.51 cm head diameter, 1624.50 seed $head^{-1}$, 165.87 g seed weight $head^{-1}$, 105.67 g seed index (1000-seed weight, g), 2782.2kg ha^{-1} seed yield and 41.00% oil content. Sunflower crop under T_1 = No Phosphorus @ 00 kg ha^{-1} (control) resulted with 162.18 cm plant height, 4.04 cm stem girth, 24.12 cm head diameter, 1307.30 seed $head^{-1}$, 112.20 g seed weight $head^{-1}$, 103.33 g seed index (1000-seed weight, g), 2539kg ha^{-1} seed yield and 39.28% oil content. After going through the findings of the present research, it was concluded that the growth and yield of sunflower increased simultaneously with increasing phosphorus levels; and the sunflower fertilized with T_6 = Phosphorus @ 80 kg ha^{-1} resulted in highest seed yield (2782.2 kg ha^{-1}), followed by T_5 = Phosphorus @ 70 kg ha^{-1} (2720.5 kg ha^{-1}) and T_4 = Phosphorus @ 60 kg ha^{-1} (2678.9 kg ha^{-1}).The findings of the present research are further confirmed by many past researchers of Akpojotor et al. (2019) reported that application of P fertilizer as split or single substantially improved height of plant at R5 and R9, 100 achene weight, achene weight per head and seed yield in both years. The Phosphorus is a micronutrient that is essential for the growth and development of plants, and it is also used in the process of soil enrichment. Soil P availability is an essential element limiting plant production in ecosystems. According to some estimates, around one-fourth of the arable land on the planet is situated on soils that have a low P availability (Alfredo and Setter, 2000). Phosphorus is an element that is absolutely necessary for the healthy operation of all cells and organisms. Phosphorus deficiency is one of the most significant factors limiting plant development, growth, and harvest around the globe (Ashraf et al., 2008; Zhang et al., 2015). Phosphorus is one of the primary factors that contribute to decreased crop yields (Zaidi et al., 2017). As a consequence of this, the use of phosphatic fertilizers is necessary in order to achieve maximum crop yields in agricultural settings (Zhang et al., 2015). As a result, it is very necessary to give sufficient P via the use of P fertilizers. Phosphorus plays an essential part in the control of metabolic pathways and has a significant impact on the activities of core enzymes (Zhu et al., 2017). Phosphorus has to be added to the soil since around 90 percent of Pakistan's soils are deficient in P to varied degrees. Phosphorus is a macronutrient that plants requires at relatively high quantities (0.2 to 0.8% of the soil's total concentration) as it is a structural component of nucleic acids, many coenzymes, phospho-proteins, and phospho-lipids (Zhu et al., 2016).

CONCLUSIONS

It was concluded that the growth and yield of sunflower increased simultaneously with increasing phosphorus levels; and the sunflower fertilized with T_6 = Phosphorus @ 80 kg/ha resulted in maximum seed yield (2782.2 kg ha^{-1}) and 41% highest oil content.

RECOMMENDATIONS

From the present study it was recommended that sunflower variety HO-1 recommended for general cultivation due to its better yield performance. phosphorus @ 80 kg ha^{-1} recommended on the basis of higher seed yield.

STATEMENTS AND DECLARATIONS

This research paper contributes to the growing body of literature on the effects of human and soil health. Understanding the relationship between fertilizer and sunflower usage can inform interventions and strategies to promote a positive effect of phosphorus fertilization.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

AUTHORS’ CONTRIBUTION

All authors contributed and supported in this manuscript.

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