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Different Phosphorus Levels in Sindh Pakistan: Disclosing the Oil Yield And Oil Content of Soybean (Glycine Max L.).

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ABSTRACT:

In response to Pakistan's pressing shortage of edible oil, a research investigation was launched to pinpoint superior soybean varieties with high yields and excellent oil quality for local production. Ten exotic and one local soybean genotype were evaluated in (RCBD) design. The variety NARC-1 was treated with different phosphorus levels: T_1 = phosphorus at 00 kg ha^{-1} (control), T_2 = phosphorus at 25 kg ha^{-1}, T_3 = phosphorus at 50 kg ha^{-1}, T_4 = phosphorus at 75 kg ha^{-1}, and T_5 = phosphorus at 100 kg ha^{-1}. Experiment analysis of variance (ANOVA) shows significant differences ($P<0.05$) for all growth, yield, and oil content characteristics due to treatments. On T_5 = phosphorus at 100 kg ha^{-1}, we recorded the maximum plant height (cm) (51.02), the number of pod bearing branches plant^{-1} (4.9), the number of pods plant^{-1} (42.5), the pod length (cm) (4.0), the number of seeds pod^{-1} (2.7), the seed yield (1981.7 kg ha^{-1}), the oil content (19.35%), and the oil yield (382.9 kg ha^{-1}). Similarly, T_4 = Phosphorus @ 75 kg ha^{-1} exhibited a high plant height (cm) of 49.1, a high number of pod^{-1} bearing branches plant^{-1} (4.5), a high number of pods plant^{-1} (40.3), a pod length (cm) of 3.8, a high number of seeds pod^{-1} (2.6), a seed yield of 1832.4 kg ha^{-1}, an oil content (19.27%), and an oil yield of 354.7 kg ha^{-1}. However, T_1 = Phosphorus @ 00 kg ha^{-1} (control) showed the lowest results in terms of minimum plant height (cm) (43.9), number of pod-bearing branches plant^{-1} (2.7), number of pods plant^{-1} (36.1), pod length (cm) (3.1), number of seeds pod^{-1} (2.1), seed yield (1323.7 kg ha^{-1}), oil content (19.2%), and oil yield (243.1 kg ha^{-1}). It was concluded that the impact of varying phosphorus levels on soybean growth, oil yield, and oil content reveals significant correlations, emphasizing the critical role of phosphorus in optimizing soybean productivity.

Keywords: Soybean, Phosphorus, levels, Oil content, Growth, Yield.

1. Introduction

Introduced alongside sunflower a few years back, soybean, a notable member of the Leguminosae family (*Glycine max* L.) and holds significant promise as an oilseed crop in Pakistan. However, subpar yields, averaging 1178 kg ha^{-1}, have hindered its journey and limited its widespread adoption. Predominantly cultivated in Sindh and Khyber Pakhtunkhwa Provinces, soybean's potential, stemming from its high protein and fat content, remains untapped in the country's agricultural landscape (Asad et al., 2023). Pakistan introduced enhanced soybean varieties sourced from the United States in the early 1960s, and commercial planting began in the early 1970s to bolster production and economic viability. Since then, their cultivation in Pakistan has been unstable, never reaching excess production levels. The decline in soybean yields in Pakistan may be due to a lack of information on production techniques, high temperatures, poor conditions, poor adaptability, and low sales (Kaleri et al., 2023). Among them, sowing time. Sowing time is one of the key factors influencing the productivity of soybean crops (Fatima et al., 2023). Sowing time has a major impact on seed germination nutritional and reproductive characteristics, and grain yield (Bashir et al., 2023). Temperature changes in the field have a significant impact on plant growth. During the soybean growing season, when the temperature rises from the ideal temperature, it causes stress conditions and has a devastating effect on flowering, pod development, seed formation, and complete maturity of the crop (Batool et al., 2023). Soybeans stand out as a prized reservoir of protein, soybean oil, and soybean meal, boasting the highest protein content among food and edible crops, ranging from 40 to 42% (Solangi et al., 2023). This leguminous marvel carries nitrogen-fixing bacteria, enriching soil fertility. Although overshadowed by wheat in Pakistan's agricultural scene, soybeans boast a prestigious history as one of the oldest food crops globally, reigning supreme among oilseed crops (Shah et al., 2023). Containing 18–22% cholesterol-free oil, 40–44% protein, and 85% unsaturated fatty acids, soybeans offer a nutritionally rich alternative to protein sources like meat, fish, and eggs, all at a more affordable cost (Alamzeb et al., 2023). In every province of Pakistan, they adapt flexibly, thriving as sole crops, intercrops, or in mixed cultivation with sorghum or maize in areas that receive both rain and irrigation (Rahman et al., 2023). Forecasts predict that global soybean production for 2017 and 2018 will reach a staggering 347.4 million metric tonnes, primarily processed into soybean meal and oil, with only a mere 2% directly consumed by humans, or approximately 3 million metric tons. Notably, Pakistan saw an uptick in soybean oil production, climbing from 240 tons in 2016 to 260 tons in 2017. Phosphorus has a critical role in several plant functions, including photosynthesis, nitrogen fixation, root growth, blooming, seed formation, fruiting, and overall crop quality (Vieira et al., 2023). Symbiotic nitrogen fixation is a pivotal process in bolstering agricultural productivity, serving as a primary source of fixed nitrogen in cultivated soils. Studies have underscored the positive Studies have underscored the positive response of soybean plants to inoculation with Brady rhizobium japonicum, leading to increased nodule formation and higher seed yields (Ran et al., 2024). Surprisingly, research has shown that adding certain bacterial strains to soybean seeds can increase seed production by up to 75% over a ten-year period, involving 66 field trials and many research plots. It has been proven to be a profitable practice (Crespo et al., 2024) as well. er 300% within this timeframe. However, scant data on soybean cultivation in certain regions, such as Tando Jam in Sindh, has impeded further exploration in this domain (Rani et al., 2023). The primary goal of the ongoing study was to examine the influence of seed rate and row spacing on soybean yields' physiochemical attributes. This research endeavor strives to forge efficient production practices and technological interventions aimed at refining crop management strategies and elevating overall crop yields (Raza et al., 2023).

2. Material and Method

Experimental design and management practices

A research endeavor unfolded at the Students' Farm within the Department of Agronomy at Sindh Agriculture University in Tando Jam, aimed at scrutinizing the impact of phosphorus fertilizers on soybean growth and yield. Employing a randomized block design, each plot spanned 6m x 5m (30m²). Tailored land preparation techniques conducive to soybean cultivation were executed, and on May 15, 2023, the NARC-I variety was sowed with three replications. Employing the drilling method, seeds were sown, accompanied by the application of ½ bags of DAP fertilizer per acre during sowing. The initial irrigation commenced 26 days post-sowing. Adhering to local agricultural practices, plant protection measures, including insect pest management through insecticides, were diligently implemented. Soybean harvest ensued once the leaves had withered, the lower pods had transitioned to a yellowish hue and desiccated, and the seed moisture content had dwindled to 12-13%.

Fertilizer application and other Culture Practices

Before sowing, the soil underwent meticulous preparation, undergoing two rounds of ploughing and leveling to ensure optimal conditions for seed planting. Phosphorus, in the form of DAP (18-46-0), was incorporated during sowing. Plant density was meticulously managed by thinning at the four to six-leaf stages, maintaining 5 cm spacing between plants. Weeding activities were conducted twice to uphold a pristine crop field. All other agricultural practices remained uniform across all treatment groups. Phosphorus application was administered at various stages of soybean growth throughout the duration of the study. To monitor agronomic characteristics, five plants were selected from each plot every five days during the initial 10 days post-emergence of the crops.

1. T_1 =(P) @ 00 kg ha^{-1} (Control)
2. T_2 =(P) @ 25 kg ha^{-1}
3. T_3 = (P) @ 50 kg ha^{-1}
4. T_4=(P) @ 75 kg ha^{-1}
5. T_5 =(P) @ 100 kg ha^{-1}

The soybean crop received two timely irrigations, and measures were taken to control diseases, weeds, and pests at the experimental sites. In order to measure the plant height (cm), number of pod-bearing branches per plant, number of pods per plant, and pod length (cm), 15 plants were chosen at the maturity stage from each experimental unit. The seed heads were separated from each plant, threshed, and used to calculate the No. of seeds pod^{-1}, Seed yield (kg ha^{-1}) , Oil content (%) and Oil yield (kg ha^{-1}) all of which were recorded.

Statistical analysis

With the use of the computer program Statistix-8.1, the acquired data were examined using ANOVA (Statistix, 2006). The LSD test was used, as necessary, to assess how well different therapies worked.

3. RESULTS

Plant height (cm)

Table. 1 The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. The treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the maximum plant height (cm) of 51.02, while the treatment T_4 = phosphorus @ 75 kg ha^{-1} recorded the plant height (cm) of 49.01. Similarly, we observed mean plant heights (cm) of 47.5 and 45.7 when we applied crop treatments with T_3 = @ 50 kg ha^{-1} and phosphorus = 25 kg ha^{-1}. Furthermore, the control group, T_1 = phosphorus @ 00 kg ha^{-1}, showed a minimum plant height (cm) of 43.9. This suggests that T_5 = phosphorus @ 100 kg ha^{-1} could be considered the optimum level up to this point. NARC-I is concerned about the plant height (cm) trait.

Number of pod bearing branches plant^{-1}

Table. 1 The number of pod-bearing branches is shown in Table 1. The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. Treatment T_5 = phosphorus at 100 kg ha^{-1} recorded the highest number of pod-bearing branches, plant plant^{-1}, of (4.9), followed by T_4 = phosphorus at 75 kg ha^{-1}, and the highest number of pod-bearing branches, plant plant^{-1}, of (4.5). Similarly, we observed a mean of 14.1 and 3.8 pod-bearing plants when we applied crop treatments with T_3 = phosphorus at 50 kg ha^{-1} and T_2 = phosphorus at 25 kg ha^{-1}. Furthermore, we observed a minimum of 2.7 pod-bearing branches per plant when we applied control T_1 = phosphate at 00 kg ha^{-1}. This suggests that T_5 = phosphorus at 100 kg ha^{-1} could be considered the optimum level to date. The soybean variety NARC-I is concerned about its number of pod-bearing branches, a trait known as "plant^{-1}."

Number of pods plant^{-1}

Table 1. Number of pods plant^{-1} The study's results showed significant variations ($p<0.05$) in soybeans with different phosphorus levels. Treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the largest number of pods in plant^{-1} (42.5). Treatment T_4 = phosphorus @ 75 kg ha^{-1} followed, producing the maximum number of pods in plant^{-1} (40.3). Similarly, the application of crop treatments with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus @ 25 kg ha^{-1} produced, respectively, a mean of 138.9 and 37.1 pod plants. Moreover, control T_1 = phosphate at 00 kg ha^{-1} (control) showed the fewest pods per plant (36.1). Accordingly, T_5 = phosphorous @ 100 kg ha^{-1} may be the current maximum amount. The response of the soybean variety NARC-I is significant, as it increases the number of pods it yields per plant.

Pod length (cm)

Table. 1 The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. Treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the maximum pod length (cm) of (4.0), followed by T_4 = phosphorus @ 75 kg ha^{-1} and pod length (cm) of (3.8). Similarly, we observed mean pod lengths (cm) of 3.6 and 3.3 when we applied crop treatments with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus @ 25 kg ha^{-1}. Further, the minimum pod length (cm) of (3.1) was observed in control T_1 = phosphate at 00 kg ha^{-1} (control). This suggests that T_5 = phosphorus @ 100 kg ha^{-1} could be considered the current optimum level. The NARC-I soybean variety's response is concerned with its pod length (cm) trait.

Table.1 Influence of phosphorus levels on the growth, productivity, and quality of soybean crop

Treatments	plant height (cm)	Number of pod bearing branches plant^{-1}	Number of pods plant^{-1}	Pod length (cm)
T_1=Phosphorus @ 00 kg ha^{-1}(Control)	43.9 e	2.7 e	36.1 e	3.1 e
T_2=Phosphorus @ 25 kg ha^{-1}	45.7 d	3.8 d	37.1 d	3.3 d
T_3=Phosphorus @ 50 kg	47.5 c	4.1 c	38.9 c	3.6 c

ha^{-1}				
T_4=Phosphorus @ 75 kg ha^{-1}	49.1 b	4.5 b	40. 3 b	3.8 b
T_5=Phosphorus @ 100 kg ha^{-1}	51.02 a	4.9 a	42.5 a	4.0 a
S.E.±	0.0280	0.0319	2.7223	0.0260
LSD	0.696	0.159	0.355	0.109
P value	0.0000	0.0000	0.0000	0.0000

Number of seeds pod^{-1}

Table 2. A cultivated plant's potential size is determined by its height growth seed yield (kg ha^{-1}). The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. Treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the maximum number of seeds pod^{-1} of (2.7), followed by T_4 = phosphorus @ 75 kg ha^{-1} and the maximum number of seeds pod-1 of (2.6). Similarly, we observed a mean number of seeds pod^{-1} of 2.5 and 2.3 when we applied crop treatments with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus at 25 kg ha^{-1}. Furthermore, we observed that the control group, T_1 = phosphorus @ 00 kg ha^{-1} , had the lowest number of seeds pod^{-1} (2.1). This suggested that T_5 = phosphorus @ 100 kg ha^{-1} could, regarding the reaction of the soybean variety NARC-I to the trait of the number of seeds pod^{-1}, be considered an ideal level.

Seed yield (kg ha^{-1})

Table 2. The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. The treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the maximum seed yield of 1981.7 kg ha^{-1}, while T_4 = phosphorus @ 75 kg ha^{-1} followed with a seed yield of 1832.4 kg ha^{-1}. Similarly, we observed mean seed yields of 1721.6 kg ha^{-1} and 1538.2 kg ha^{-1} in crops treated with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus at 25 kg ha^{-1}. Furthermore, the application of T_1 = phosphate at 00 kg ha^{-1} (control) resulted in the minimum seed yield of 1323.7 kg ha^{-1}. This suggests that T_5 = phosphorus @ 100 kg ha^{-1} could be a viable option. Regarding the soybean variety NARC-I, it can be said that its response to the trait measuring seed yield (kg/ha) has reached an optimal level.

Oil content (%)

Table 2. The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. Treatment T_5 = phosphorus @ 100 kg ha^{-1} recorded the maximum oil content of 19.35%, while T_4 = phosphorus @ 75 kg ha^{-1} followed with an oil content of 19.27%. Similarly, the following mean oil content of 19.22% and 19.24% was observed when crops treated with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus at 25 kg ha^{-1} were applied. Further, the minimum oil content of 19.2% was observed in control T_1 = phosphate @ 00 kg ha^{-1} (control). This suggests that T_5, which has a phosphorus content of 100 kg ha^{-1}, could be considered the optimum level so far. NARC-I is concerned about the oil content (%) trait.

Oil yield (kg ha^{-1})

Table 2. The result proved the significant difference ($p<0.05$) in soybean at various levels of phosphorus. Treatment T_5 = phosphorus at 100 kg ha^{-1} recorded the maximum oil yield of 382.9 kg ha^{-1}, while T_4 = phosphorus at 75 kg ha^{-1} yielded an oil yield of 354.7 kg ha^{-1}. Similarly, the following mean oil yields of 336.2 kg ha^{-1} and 312.4 kg ha^{-1} were observed when crops treated with T_3 = phosphorus @ 50 kg ha^{-1} and T_2 = phosphorus at 25 kg ha^{-1} were applied. Furthermore, the application of T_1 = phosphate at 00 kg ha^{-1} (control) resulted in the minimum oil yield of 243.1 kg ha^{-1}. This suggests that T_5, which has phosphorus at a

level of 100 kg ha^{-1}, could be considered the optimal level so far. NARC-I is concerned for its oil yield (kg ha^{-1}) trait.

Table.2 Influence of phosphorus levels on the growth, productivity, and quality of soybean crop

Treatments	Number of seeds pod^{-1}	Seed yield (kg ha^{-1})	Oil content (%)	Oil yield (kg ha^{-1})
T_1=Phosphorus @ 00 kg ha^{-1}(Control)	2.1 e	1323.7 e	19.2	243.1 e
T_2=Phosphorus @ 25 kg ha^{-1}	2.3 d	1538.2 d	19.24	312.4 d
T_3=Phosphorus @ 50 kg ha^{-1}	2.5 c	1721.6 c	19.22	336.2 c
T_4=Phosphorus @ 75 kg ha^{-1}	2.6 b	1832.4 b	19.27	354.7 b
T_5=Phosphorus @ 100 kg ha^{-1}	2.7 a	1981.7 a	19.35	382.9 a
S.E.±	0.0361	0.0247	0.0315	3.8538
LSD	0.024	20.61	0.0701	4.251
P value	0.0000	0.0000	0.0000	0.0000

4. Discussion

The findings showed that T_5 = phosphorus @ 100 kg ha^{-1} produced the following results: plant height (cm) (51.02), number of pod-bearing branches (4.9), number of pods plant^{-1} (42.5), pod length (cm) (4.0), number of seeds pod^{-1} (2.7), seed yield (1981.7 kg ha^{-1}), oil content (19.35%), and oil yield (382.9 kg ha^{-1}). Similarly, T_4 = Phosphorus @ 75 kg ha^{-1} exhibited a high plant height (cm) of 49.1, a high number of pod-bearing branches (plant^{-1}) of 4.5, a high number of pods (plant^{-1}) of 40.3, a pod length (cm) of 3.8, a high number of seeds (pod^{-1}) of 2.6, a seed yield of 1832.4 kg ha^{-1}, an oil content (19.27%), and an oil yield of 354.7 kg ha^{-1}. However, T_1 = Phosphorus @ 00 kg ha^{-1} (control) showed the lowest results in terms of minimum plant height (cm) (43.9), number of pod-bearing branches (plant^{-1}) (2.7), number of pods (plant^{-1}) (36.1), pod length (cm) (3.1), number of seeds (pod^{-1}) (2.1), seed yield (1323.7 kg ha^{-1}), oil content (19.2%), and oil yield (243.1 kg ha^{-1}). After analyzing the results of the present study, it was determined that growing phosphorus levels were accompanied by increases in soybean growth and production, and that soybeans fertilized with T_5 = phosphorus @ 100 kg ha^{-1} resulted in the highest oil yield (382.9 kg ha^{-1}), followed by T_4 = phosphorus @ 75 kg ha^{-1} (354.7 kg ha^{-1}) and T_3 = phosphorus @ 50 kg ha^{-1} (336.2 kg ha^{-1}). The yield of hexane extracted oil from various soybean seed varieties, including Bovender Special, Foster, and F-8827, ranged from 15.85% to 19.49%, exhibiting a notable disparity in oil content across the analyzed samples. Among them, the F-8827 variety demonstrated the highest oil content at 19.84%, whereas the Bovender Special variety exhibited the lowest at 15.85% (Tian et al., 2022). Genetic distinctions among the soybean varieties are responsible for such fluctuations in oil content. This observed oil content, spanning from 15.85% to 19.49%, echoes findings from prior research. Khan et al. (2020) documented oil content in diverse soybean genotypes ranging from 198 to 267 g/kg, or 15.84% to 21.35%. Similarly, Anjum 19 reported a comparable spectrum of oil content for various soybean varieties. Nonetheless, it's worth noting that soybean seed oil content falls below that of other oilseed crops like Cucurbita pepo (35%) and sunflower hybrids (36-39%) (Carver et al., 2022). In terms of protein content, soybean seed residues exhibited a noteworthy range of 41.675% to 45.645%, with the Bovender Special variety registering the highest protein content and the F-8827 variety showcasing the lowest. This protein content (40.57–47.60%) aligns with previous findings by Antonangelo et al. (2019) but surpasses the values reported by Taliman et al. (2019). In this study, the soybean samples had a much higher protein content than safflower (20–22%), sunflower (16.5–19.6%), and cottonseed (19.40%), which is in line with what another research has found (Yin et al., 2016). Interestingly, oil-rich oilseed specimens tended to display lower levels of protein, fibre, and ash. Notably, soybean protein boasts simple digestibility and primarily comprises destine and albumin, crucial constituents akin to those found in human blood plasma (Hansel et al., 2017). The residual crushed soybean byproduct emerges as a suitable feed for both animals and humans owing to its rich amino acid profile (Hertzberger et al., 2021). The analysis underscored soybean meal's (post-oil extraction) significance as a valuable protein source, particularly in poultry feed, serving as a cost-effective calorie source. The tested soybean seeds had protein levels between 6.6 and 7.6% and ash levels between 5.5 and 6.9%. The fibre and ash levels were the same across all varieties (Appelhans et al., 2020). This ash content aligns with previous studies on soybean varieties (5.81–6.54%). Interestingly, phosphorus (P) fertilization exhibited a correlation with heightened P losses, potentially attributed to elevated P concentrations on the soil surface or runoff stemming from applied P fertilizers (Rabbani et al., 2023). Multiple studies have corroborated a positive association between soil P levels, total P, and dissolved reactive P (DRP) concentrations in runoff (Bansal et al., 2020). Soybeans and other nitrogen-fixing legumes have a crucial dependence on phosphorus for optimal growth and nitrogen fixation. Beans, in particular, are highly sensitive to low phosphorus availability due to the demanding nature of nitrogen fixation, which requires ample phosphorus levels. Imran et al. (2022) highlight that phosphorus application can mitigate the challenge of insufficient phosphorus, which can impede nodule formation. Researchers found that a phosphorus rate of 100 kg/hectare achieved the highest soybean yield, leading to a significant increase in grain production up to 50 kg/hectare. Notably, the use of Single Super Phosphate (SSP) demonstrated a marked advantage over Di-Ammonium Phosphate (DAP) in terms of phosphorus sources, resulting in the highest grain yield (Hassan et al., 2023). Additionally, the straw yield of green gramme showed significant improvement with higher phosphorus rates, particularly at 75 kg per hectare, as reported by (Guera et al., 2020). This treatment did better than single or combination treatments in a number of agronomic areas. A three-year field trial was used to look at how different amounts of phosphorus and nitrogen affected soybean growth, yield, contributing factors, and economic aspects (Valle et al., 2022).

5. Conclusions

The study determined that simultaneously increasing the phosphorus application levels in soybean oil yield and oil content led to a maximum oil yield (382.9 kg ha1) and the highest oil content of 19.35%.

Recommendations

From the present study it was recommended that soybean variety NARC-I recommended for general cultivation due to its better yield performance T_5 = Phosphorus @ 100 kg ha^{-1} recommended on the basis of higher oil yield and oil content.

6. References

1. Alamzeb, M., & Inamullah. (2023). Management of phosphorus sources in combination with rhizobium and phosphate solubilizing bacteria improve nodulation, yield and phosphorus uptake in chickpea. Gesunde Pflanzen, 75(3), 549-564.
2. Antonangelo, J. A., Firmano, R. F., Alleoni, L. R. F., Oliveira, A., & Zhang, H. (2019). Soybean yield response to phosphorus fertilization in an Oxisol under long-term no-till management. Soil Science Society of America Journal, 83(1), 173-180.
3. Appelhans, S. C., Barbagelata, P. A., Melchiori, R. J. M., & Gutierrez Boem, F. (2020). Assessing soil P fractions changes with long-term phosphorus fertilization related to crop yield of soybean and maize. Soil Use and Management, 36(3), 524-535.
4. Asad, S. A., Shaheen, F., Ahmad, I., Mahmood, I., & Farooq, M. (2023). Thermo-temporal Changes in Soybean Productivity under Rainfed and Irrigated Conditions in Pakistan. Gesunde Pflanzen, 75(6), 2437-2447.
5. Bansal, S., Yin, X., Savoy, H. J., Jagadamma, S., Lee, J., & Sykes, V. (2020). Long-term influence of phosphorus fertilization on organic carbon and nitrogen in soil aggregates under no-till corn–wheat–soybean rotations. Agronomy Journal, 112(4), 2519-2534.
6. Bashir, M. R., ud Din, A. M., Sajid, M., ul Hassan, E., Khan, Q. A. T., Khurshid, M. R., ... & Iqbal, U. (2023). The application of genomics and bioinformatics to recognize soybean pathogen interaction in a changing climate. Plant Bulletin, 2(2), 88-92.
7. Batool, A., Rajput, N. A., Atiq, M., Khan, N. A., Hameed, A., Khan, M. E., & Tariq, H. (2023). Evaluation of antifungal potential of phytoextracts and chemicals against root rot of soybean caused by Rhizoctonia solani. Plant Protection, 7(3), 585-593.
8. Carver, R. E., Nelson, N. O., Roozeboom, K. L., Kluitenberg, G. J., Tomlinson, P. J., Kang, Q., & Abel, D. S. (2022). Cover crop and phosphorus fertilizer management impacts on surface water quality from a no-till corn-soybean rotation. Journal of Environmental Management, 301, 113818.
9. Crespo, C., Wyngaard, N., Rozas, H. R. S., Pizzuto, A., Barbagelata, P., Barraco, M., & Barbieri, P. A. (2024). Cover crops affect phosphorus fractions in soybean-based sequences with different phosphorus availability in Mollisols. Soil and Tillage Research, 240, 106096.
10. Fatima, S., Afzal, A., Rashid, H., Iqbal, S., Zafar, R., Khalid, K., & Carter, C. G. (2023). Dietary replacement of soybean meal with black soldier fly larvae meal in juvenile Labeo rohita and Catla catla: Effects on growth, nutritional quality, oxidative stress biomarkers and disease resistance. Plos one, 18(11), 0294-452.
11. Guera, K. C. S., Fonseca, A. F. D., & Harkatin, S. (2020). Phosphorus use in soybean in integrated production system under anticipation of phosphate fertilization. Revista Ciência Agronômica, 51, 2019-6881.
12. Hansel, F. D., Amado, T. J., Ruiz Diaz, D. A., Rosso, L. H., Nicoloso, F. T., & Schorr, M. (2017). Phosphorus fertilizer placement and tillage affect soybean root growth and drought tolerance. Agronomy Journal, 109(6), 2936-2944.
13. Hassan, I., Abbas, G., Hussain, J., Abbas, Z., Mehmood, T., Amer, M., & Hussain, S. (2023). Optimization of Phosphorus and Potassium Fertilization for Mungbean Under Arid Agroclimatic Conditions of Thal, Punjab, Pakistan. Sciences, 25(1&2), 27-36.
14. Hertzberger, A. J., Cusick, R. D., & Margenot, A. J. (2021). Maize and soybean response to phosphorus fertilization with blends of struvite and monoammonium phosphate. Plant and Soil, 461, 547-563.
15. Imran, Amanullah, & Altawaha, A. R. (2022). Carbon assimilation and dry matter partitioning in soybean ameliorates with the integration of nano-black carbon, along

with beneficial microbes and phosphorus fertilization. Journal of Plant Nutrition, 45(12), 1799-1812.

16. Kaleri, G. S., Jat, I., Magsi, M. A., & Manzoor, D. (2023). The effect of various sowing dates on the growth, yield and quality of soybean. Journal of Agriculture and Rural Studies, 1(01), 22-25.
17. Khan, B. A., Hussain, A., Elahi, A., Adnan, M., Amin, M. M., Toor, M. D., & Ahmad, R. (2020). Effect of phosphorus on growth, yield and quality of soybean (Glycine max L.): A review. Ijar, 6(7), 540-545.
18. Rabbani, M. G., Salam, M. A., Kheya, S. A., & Paul, S. K. (2023). Effect of phosphorus fertilization on nodulation, growth, yield and quality of soybean varieties. Journal of Aridland Agriculture, 9, 99-107.
19. Rahman, S. U., Raza, G., Zubair, M., Ahmed, N., Domier, L. L., Jamil, N., & Amin, I. (2023). Multiple begomoviruses infecting soybean; a case study in Faisalabad, Pakistan. Biologia, 78(2), 609-620.
20. Ran, Q. X., Pang, J., Dong, R., & He, J. (2024). Enhanced seed yield, essential amino acids and unsaturated fatty acids in soybean seeds with phosphorus fertilizer supply. Journal of Food Composition and Analysis, 125, 105813.
21. Rani, R., Arif, M., Rahman, S. U., Hammad, M., Mukhtar, Z., Rizwan, M., & Raza, G. (2023). Field Screening of Diverse Soybean Germplasm to Characterize Their Adaptability under Long-Day Condition. Agronomy, 13(9), 2317.
22. Raza, H., Ahmed, Z., Hassan, M., Sarwar, S., Saleem, S., Shazad, S., & Rehman, A. (2023). Assessment of genetic variability among soybean exotic genotypes for adaptability and yield. Biological and Clinical Sciences Research Journal, 2023(1), 298-298.
23. Sayem, M. A., Taslima, N., Sidhu, G. S., & Ferry, J. W. (2024). A QUANTITATIVE ANALYSIS OF HEALTHCARE FRAUD AND UTILIZATION OF AI FOR MITIGATION. International journal of business and management sciences, 4(07), 13-36.
24. Shabbir, A., Anwar, A. S., Taslima, N., Sayem, M. A., Sikder, A. R., & Sidhu, G. S. Analyzing Enterprise Data Protection and Safety Risks in Cloud Computing Using Ensemble Learning.
25. Shah, G. A., Sadiq, M., Iqbal, Z., Shakoor, N., Shahid, M., Aulakh, A. M., ... & Rashid, M. I. (2023). Field co-inoculation of Bradyrhizobium sp. and Pseudomonas increases nutrients uptake of Vigna radiata L. from fertilized soil. Journal of Plant Nutrition, 46(7), 1296-1313.
26. Solangi, F., Zhu, X., Khan, S., Rais, N., Majeed, A., Sabir, M. A., & Kayabasi, E. T. (2023). The global dilemma of soil legacy phosphorus and its improvement strategies under recent changes in agro-ecosystem sustainability. ACS omega, 8(26), 23271-23282.
27. Taliman, N. A., Dong, Q., Echigo, K., Raboy, V., & Saneoka, H. (2019). Effect of phosphorus fertilization on the growth, photosynthesis, nitrogen fixation, mineral accumulation, seed yield, and seed quality of a soybean low-phytate line. Plants, 8(5), 119.
28. Taslima, N., Sayem, M. A., Sidhu, G. S., & Chowdhury, F. MITIGATING INFLATION: A COMPREHENSIVE ANALYSIS OF POLICY MEASURES AND THEIR IMPACTS ON THE US ECONOMY.
29. Tian, J., Lu, X., Chen, Q., Kuang, X., Liang, C., Deng, L., & Tian, J. (2022). Phosphorus fertilization affects soybean rhizosphere phosphorus dynamics and the bacterial community in karst soils. Plant and Soil, 1-16.

30. Valle, S. F., Giroto, A. S., Guimarães, G. G., Nagel, K. A., Galinski, A., Cohnen, J., & Ribeiro, C. (2022). Co-fertilization of sulfur and struvite-phosphorus in a slow-release fertilizer improves soybean cultivation. Frontiers in plant science, 13, 861574.
31. Vieira, N. D., Moreira, A., Moraes, L. A. C., Cabrera, R. A. D., & Marubayashi, R. Y. P. (2023). Soybean yield, yield components, and phosphorus concentration under different phosphate sources. Communications in Soil Science and Plant Analysis, 54(9), 1239-1249.
32. Yin, X., Bellaloui, N., McClure, A. M., Tyler, D. D., & Mengistu, A. (2016). Phosphorus fertilization differentially influences fatty acids, protein, and oil in soybean. American Journal of Plant Sciences, 7(14), 1975-1992.