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Response of Growth and Yield of Indian Mustard (Brassica juncea L.) to Phosphorus–Potassium Fertilizer Combinations and Plant Spacing

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Abstract

A field experiment was conducted at the Agricultural Research Station, College of Agriculture, University of Basrah, Karma Ali site, during the 2024–2025 season in a sandy loam soil to investigate the effect of nine phosphorus and potassium fertilizer combinations (P0K0, P0K30, P0K60, P40K0, P40K30, P40K60, P80K0, P80K30, P80K60 kg ha⁻¹), designated as T0–T8, and two plant spacings (30 cm = S1, 40 cm = S2) on the growth and yield of local Indian mustard (*Brassica juncea* L.). The experiment was arranged in a factorial randomized complete block design (RCBD) with three replications. Results indicated that treatment T5 (P40K60) accelerated flowering by reaching 50% flowering earlier, while T8 (P80K60) recorded the highest plant height, branch number, leaves number, leaf area, plant yield and total seed yield. Plant spacing of 40 cm produced higher leaf numbers, leaf area, and seed yield compared to 30 cm. The interaction between T8 and 40 cm spacing achieved the highest mean values of plant yield (47.13 g plant⁻¹) and total yield (2.356 µg ha⁻¹). However, no significant interaction effects were observed for all growth traits.

Keywords: Phosphorus, Potassium, Plant spacing, Seed yield, Mustard

1. Introduction

Indian mustard (*Brassica juncea* L.), belonging to the Brassicaceae family, is one of the world's most important oilseed crops, occupying about 24.27% of the total global oilseed cultivation area and contributing approximately 26.30% of total oilseed production (USDA, 2018). In Iraq and the Arab region, mustard is considered a winter annual crop, whereas in Europe and Canada it is grown during summer, and in parts of Asia and Africa it is cultivated as a forage crop. Globally, mustard is valued not only as an oilseed crop but also for its multipurpose uses, including medicinal and aromatic applications. Its seeds contain 20–25% protein and 40.3–49.5% oil (FAO, 2007). Mustard oil is widely used in alternative medicine due to its medicinal properties and has industrial applications in pharmaceuticals, cosmetics, plastics, and biofuels (Sahu *et al*., 2020; Komatineni *et al*., 2023). Mustard seed meal is also rich in protein and serves as a valuable livestock feed that enhances milk and meat production.

Nutrient management is a critical factor in maximizing the growth and productivity of mustard (Chauhan *et al*., 2020). Among the essential macronutrients, phosphorus is involved in energy transfer (ATP) and nucleic acid synthesis, which enhance metabolic efficiency, whereas potassium regulates enzyme activity, stomatal conductance, water-use efficiency, and carbohydrate accumulation in seeds. When supplied together in

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balanced amounts, phosphorus and potassium exert a synergistic effect, improving photosynthesis and physiological balance.

Another important factor influencing mustard productivity is plant spacing, which determines plant density and the extent of competition for light, nutrients, and water. Proper plant density optimizes resource utilization, thus improving growth, seed yield, and oil quality. Given the scarcity of research on mustard production in Iraq and its potential as a drought- and salt-tolerant crop (Hassan, 2023), this study was undertaken to evaluate phosphorus–potassium fertilization levels and plant spacing to determine their impact on growth and yield performance, with the goal of developing appropriate agronomic recommendations for this crop.

Materials and Methods

The field experiment was carried out at the Agricultural Research Station, College of Agriculture, University of Basrah (Karma Ali site, 10 km north of Basrah center; latitude 30°57′ N, longitude 47°80′ E), during the 2024/2025 season. The soil was sandy loam with pH 7.53, EC 7.53 dS m^{-1}, organic matter 0.2%, and available N, P, and K concentrations of 20.07, 12.56, and 91.05 mg kg^{-1}, respectively. The experimental layout followed a factorial RCBD design with three replications. Treatments consisted of nine phosphorus–potassium combinations:

T0 = P0K0 (control), T1 = P0K30, T2 = P0K60, T3 = P40K0, T4 = P40K30, T5 = P40K60,

T6 = P80K0, T7 = P80K30, T8 = P80K60, and two plant spacings: S1 = 30 cm, S2 = 40 cm.

The field was plowed, leveled, and divided into three blocks, each containing 18 experimental units of 2 × 2 m^2, with 50 cm between rows. Sowing was conducted manually on October 15, 2024, using 3–4 seeds per hill. Nitrogen fertilizer was applied as urea (46% N) at 240 kg ha^{-1} in two splits: 21 days after sowing and 21 days thereafter (Hassan, 2023). Standard agronomic practices such as thinning, weeding, and irrigation were followed. Harvesting was done on March 18, 2025, when pods matured and seeds hardened. The studied traits included: days from sowing to 50% flowering, plant height (cm), number of branches per plant, number of leaves per plant, leaf area (cm^2), individual plant seed yield (g $plant^{-1}$), and total seed yield (Mg ha^{-1}). Data were analyzed using GenStat software, and treatment means were compared using the Least Significant Difference (LSD) test at 0.05 probability level (Al-Rawi & Khalaf-Allah, 2000).

Results and Discussion

Days to 50% Flowering

According to Table 1, this characteristic was significantly impacted by fertilizer combinations, but not by planting distance or interaction. Treatment. T5 (P40K60) reached 50% flowering earliest, averaging 74.50 days, which was statistically similar to T7 and T8, in contrast, the control (T0) took the longest (109.67 days). This acceleration can be attributed to phosphorus enhancing ATP and nucleic acid formation and potassium improving photosynthesis and hormonal regulation, thereby promoting early flowering (Kashif *et al.*, 2014).

plant height(cm)

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The addition of fertilizer combinations and the two planting distances had significant effects on this characteristic, according to Table 1, but the interaction had no significant impact. Compared to the comparison treatment, which recorded the lowest average of 114.90 cm, the two combinations T7 and T8 achieved the highest plant height with an average of 144.50 and 144.60 cm, respectively. There was no significant difference between the two combinations, with an increase rate of 25.76 and 25.85% for the two combinations, respectively. High phosphorus and potassium levels promote the growth tips, which are in charge of cell elongation, enhanced root branching and depth, and improved nutrition and water absorption. In turn, this promoted height growth (Lakhan, 2017; Chetry *et al*., 2018). Additionally, Table 1 showed that plant height increased as plant distance decreased. The maximum average plant height was 132.24 cm at distance S1 (30 cm), while the lowest average plant height was found at distance S2 (40 cm), reaching 128.86 cm. It appears that planting plants 30 cm from one another increased plant density, which in turn increased shading. This, in turn, allowed auxin to work with gibberellins to push the cells to elongate, which in turn elongated the internodes, increasing plant height. These findings were consistent with Ferdous *et al.,* (2017) and Yadav *et al*., 2018).

Number of Branches per Plant

The number of branches per plant was significantly affected by fertilizer treatments and spacing, but not by their interaction, as shown in Table 1. with an average of 20.20 branches per plant^{-1}, the T8 fertilizer combination produced the most branches, it was at a par with treatments T6 and T7, which produced 17.93 and 18.48 branches per plant^{-1} respectively and with a 110.20% increase over the control treatment, which produced the lowest number of branches overall, 9.61 branches per plant^{-1}. It is concentrated in the most effective locations and is vital and required for the growth, development, and division of plant cells. These results were in line with Chetry et al., (2018) and Atkari, (2022). Compared to the S2 planting distance, which produced the greatest number of branches, with 17.21 branches per plant^{-1}, the S1 planting distance saw a substantial drop in branch count of 18.30% (Table 1). Plant spacing greatly influenced the total amount of mustard plant branches because it created the perfect environment for branch growth by increasing lateral buds' exposure to light, decreasing shadowing, and promoting cell division and lateral tissue growth. Plant spacing greatly influenced the total amount of mustard plant branches because it created the perfect environment for branch growth by increasing lateral buds' exposure to light, decreasing shadowing, and promoting cell division and lateral tissue growth. These results are consistent with those of Sondhiya et al., (2019), Meena et al., (2022), and Kumar et al., (2023).

Number of Leaves per Plant

As presented in Table 1, fertilizer application and spacing significantly affected leaf number, while the interaction had no significant effect on this trait. With an increase of 36.20, 34.30, and 28.10% over the control treatment, which produced the lowest average of 20.00 leaves per plant^{-1}, the combinations T8, T7, and T6 recorded the highest average number of leaves per plant, totaling 27.24, 26.88, and 25.62 leaves per plant^{-1}, respectively. These combinations did not differ significantly from each other. The reason could be that both potassium and phosphorus play a part in improving photosynthesis efficiency and the accumulation of metabolic products, which in turn promoted cell division and the formation of new green buds, increasing the number of leaves and branches in plants. These findings agree with those of Mir (2021) and Patel et al. (2022). Wider spacing (S2) also enhanced leaf number by giving 25.83 leaf plant^{-1} compared with closer spacing (S1 = 30 cm) which gave the lowest (21.86 leaf plant^{-1}). This might be the result of more branches,

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which in turn produced more leaves. These findings are in line with those of Sondhiya et al. (2018), who found that mustard crops with narrow spacings produced fewer leaves, whereas those with broad spacing produced more leaves.

Leaf Area (cm^2)

According to Table 1, this characteristic was significantly impacted by the addition of fertilizer combinations and the two planting distances, but not by the interaction. With an average of 2375.68, 2331.29, 2225.69, and 2177.34 cm^2, respectively, combinations T8, T7, T5, and T6 had the largest leaf area, increasing by 128.50, 124.23, 114.07, and 109.42% over the control treatment, which had the smallest leaf area of 1039.69 cm^2. This might be explained by the large amounts of both fertilizers added in the T8, T7, and T5 combinations, as well as the higher amount of phosphorus added in the T6 treatment, which stimulated cell division and the development of new tissues. The superiority of the previously described combinations resulted in a better nutritional balance of these two components within the plant, which enhanced leaf area development and leaf count. With an average leaf area of 1897.50 cm^2, planting distance S2 significantly outperformed planting distance S1, as shown in Table 1, whereas planting distance S1 produced an average of 1778.37 cm^2. This could be explained by the fact that planting at a wide distance led to reduced competition and enhanced light-receiving opportunities, which resulted in more photosynthesis and larger leaf areas. As for the narrow distance, in addition to the small number of leaves, the competition and shade of the lower leaves resulted in a drop in the quantity of leaf area, which in turn affected the rate of photosynthesis by reducing the generation of carbohydrates needed for tissue construction. The same results were also reported by Yadav *et al.,* (2018).

Plant Yield (g $plant^{-1}$)

Fertilizer combinations, spacing, and their interaction have a significant effect on plant yield. (Table2). With an average of 39.248 g plant-^{1}, the T8 combination produced the most seeds, whereas the control treatment produced the lowest average of 13.747 g $plant^{-1}$. High phosphate and potassium fertilizer levels may have contributed to the yield rise by improving photosynthetic efficiency and strengthening the source and sink, which in turn raised seed weight, also the increase is not just a quantitative response, but rather a result of stimulating metabolic pathways associated with flowering, mustard formation, and improving dry matter accumulation (Mykolaiko *et al.,* 2024). With an average yield of 31.694 g $plant^{-1}$, planting distance S2 produced the maximum yield, whereas planting distance S1 produced the lowest yield, 20.786 g $plant^{-1}$. This might be explained by the large planting spacing, which produced optimal conditions for growth and raised plant production. These findings are in line with those of Ren *et al*. (2017) and Gan *et al*. (2016). As shown in the interaction of T8 × S2 produced the maximum yield of 47.133 g $plant^{-1}$, whereas T0 × S1 produced the lowest yield of 11.433 g $plant^{-1}$ (Fig.1). This indicates that the effect of fertilizer combinations on the yield depended on expanding the planting distance and utilizing the largest amount of combinations added to the plant, and thus was positively reflected on the production of the plant yield (Ren *et al*. 2017).

Total Seed Yield (µg ha^{-1})

Total Seed Yield was influenced significantly due to various levels of phosphorus-potassium combinations, plant spacing and their interaction (Table2). The seed yield (2.208 µg ha^{-1}), of mustard increased significantly due to application of T8, while the control gave the lowest (0.786 µg ha-^{1}). The combination of high phosphate and potassium fertilizer levels increased plant production, which in turn increased total seed yield. These findings concurred with Singh *et al*. (2017) and Sharma *et al*. (2020). The narrow planting distance had the lowest average of 1.363 µg ha^{-1}, whereas the S2 planting distance had the highest total plant yield, averaging 1.585 µg ha^{-1}, as the planting distance increases, the

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total yield rises because the plant density decreases, improving the efficiency of photosynthesis per plant due to better light, water, and food resources. This is reflected in the increased rate of photosynthesis and the accumulation of nutrients and carbohydrates in the seeds, which raises the total seed yield. This result is in agreement with Kumar *et al.,* (2023). As shown in Fig.2 The highest total yield (2.357 µg ha^{-1}) was recorded with T8 × S2, whereas the interaction of distance T0 ×S1 produced the lowest yield (0.7662 µg ha^{-1}).

Table-1 Effect of application of phosphorus and potassium on growth of mustard.

Treatments		Days to flowering 50%	Plant height (cm)	No. of branch plant^{-1}	No. of leaves plant^{-1}	Leaf area(cm^2)
Plant Spacing	S1	88.07	132.24	14.06	21.86	1778.37
	S2	89.59	128.86	17.21	25.82	1897.50
LSD (P ≤ 0.05)		N. S	2.374	1.385	1.183	99.90
Fertilizer Combinations	T0	109.67	114.90	9.61	20.00	1039.69
	T1	105.00	119.30	12.56	22.62	1333.86
	T2	95.00	121.07	13.74	22.17	1409.34
	T3	91.67	124.24	15.27	23.80	1594.36
	T4	80.17	131.24	15.63	22.67	2054.20
	T5	74.50	136.84	17.08	23.61	2225.69
	T6	90.00	138.27	17.93	25.62	2177.34
	T7	78.67	144.50	18.48	26.88	2331.29
	T8	74.83	144.60	20.40	27.24	2375.68
LSD (P ≤ 0.05)		5.588	5.036	2.939	2.510	212.00

Table-2 Effect of application of phosphorus and potassium on plant and total yield

Treatments		Plant yield (g plant^{-1})	Seed yield (µg ha^{-1})
Plant Spacing	S1	20.786	1.3632
	S2	31.694	1.5850
LSD (P ≤ 0.05)		0.3579	0.09691
Fertilizer Combinations	T0	13.747	0.7861
	T1	15.612	0.8915
	T2	18.533	1.0552
	T3	21.390	1.2105
	T4	26.088	1.4658
	T5	30.783	1.7240
	T6	33.602	1.8447
	T7	37.157	2.0810
	T8	39.248	2.2082
LSD (P ≤ 0.05)		0.7593	0.06852

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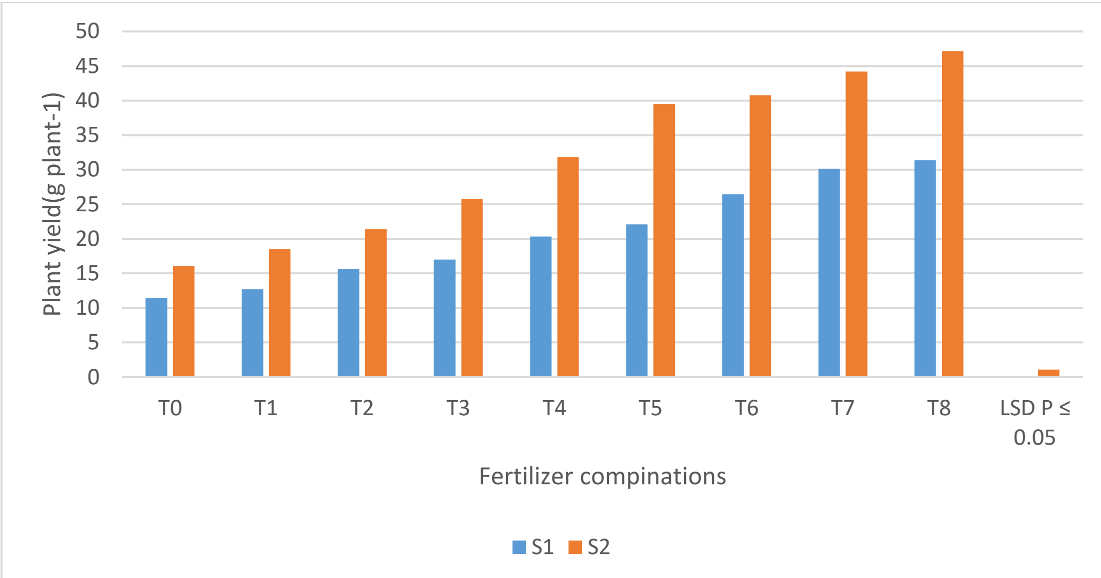

Fig.1.Interaction of fertilizer combinations and spacing on plant yield (g plant^{-1})

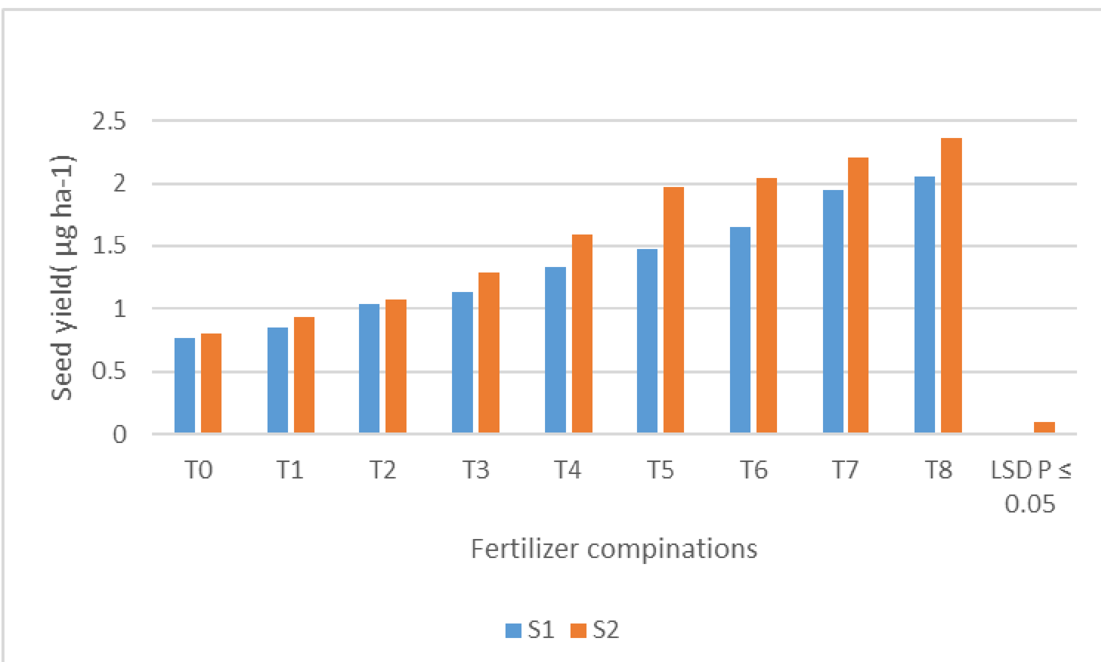

Fig.2.Interaction of fertilizer combinations and spacing on total seed yield (µg ha^{-1})

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Conclusions

The study demonstrated that phosphorus–potassium fertilization had a significant effect on most growth and yield traits of mustard. The combination P80K60 (T8) consistently produced superior growth and yield parameters. Wider plant spacing (40 cm) also improved leaf number, leaf area, and seed yield. The results highlight the importance of balanced phosphorus–potassium fertilization in combination with optimum spacing to maximize mustard productivity under Basrah conditions.

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