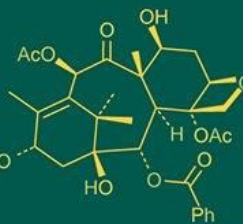
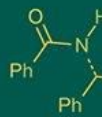


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Effect of phosphorus level and spacing on growth and yield of mustard (*Brassica juncea* L.)

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Abstract

A field experiment was carried out during *Rabi* season- 2024, at crop research farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P.) India. The experiment was entitled as “Effect of Phosphorus Level and Spacing on growth and yield of Mustard (*Brassica juncea* L.)”. The experiment was laid out in randomized block design (RBD) which consisted of ten treatment and replicated thrice viz. T1: Phosphorus 30 kg/ha + Spacing 25 cm × 15 cm, T2: Phosphorus 30 kg/ha + Spacing 35 cm × 15 cm, T3: Phosphorus 30 kg/ha + Spacing 45 cm × 15 cm, T4: Phosphorus 40 kg/ha + Spacing 25 cm × 15 cm, T5: Phosphorus 40 kg/ha + Spacing 35 cm × 15 cm, T6: Phosphorus 40 kg/ha + Spacing 45 cm × 15 cm, T7: Phosphorus 50 kg/ha + Spacing 25 cm × 15 cm, T8: Phosphorus 50 kg/ha + Spacing 35 cm × 15 cm, T9: Phosphorus 50 kg/ha + Spacing 45 cm × 15 cm, and Control Plot. The application of 50 kg/ha phosphorus combined with a spacing of 25 cm × 15 cm (Treatment 7) resulted in significantly higher growth and yield parameters, including maximum plant height (196.96 cm), highest plant dry weight (19.31 g/plant), greater number of branches per plant (16.33), increased number of seeds per silique (17), more siliques per plant (297.33), as well as the highest seed yield (2.15 t/ha) and stover yield (4.97 t/ha).

Keywords: Mustard, phosphorus, spacing, growth, yield

Introduction

Mustard (*Brassica juncea* L.), an important *rabi* oilseed crop of the family *Brassicaceae*, is widely cultivated across the world and is renowned for its adaptability, robust growth, and multipurpose uses. In India, mustard holds a special place not only in agriculture but also in culinary traditions, as its seeds are the primary source of mustard oil. Mustard oil is traditionally used in cooking, frying, pickling, and food preservation owing to its pungent flavour and high stability, while its by-products such as mustard oilcake serve as excellent organic manure and protein-rich cattle feed. The stover is also widely used as fodder, fuel, and soil-enriching organic material, thereby providing multiple benefits to farmers (Shekhawat *et al.*, 2012)^[13]. The seeds are also ground into a spice for indigenous recipes.

Globally, rapeseed-mustard ranks third among oilseeds after soybean and groundnut, contributing nearly 13-15% of the world's total edible oil supply (Food and Agriculture Organization, 2023). In India, rapeseed-mustard is cultivated on about 6.36 million hectares, producing 8.03 million tonnes of seeds annually, making the country the third largest producer after Canada and China, with a share of about 11% in global production; Rajasthan (44.97%), Haryana (12.44%), Madhya Pradesh (11.32%), Uttar Pradesh (10.60%), and West Bengal (7.53%) are the major contributing states (Directorate of Economics and Statistics, 2019)^[2].

Nutritionally, mustard seeds are a rich source of proteins, dietary fibre, vitamins (A, C, and K), and minerals such as calcium, iron, magnesium, and phosphorus, along with important phytonutrients and antioxidants including alpha-linolenic acid, erucic acid, palmitic acid, tocopherols, carotene, oryzanol, squalene, and thiamine, which make them valuable for human health; mustard oil, in particular, is noted for its balanced composition of saturated, monounsaturated, and polyunsaturated fatty acids and antioxidant properties, although its benefits are best realized when combined with a healthy diet and lifestyle (Sahu *et al.*, 2020)^[11]. Phosphorus is one of the most limiting macronutrients in mustard (*Brassica juncea* L.) cultivation and is second only to nitrogen in importance for growth and productivity. It is essential for root development, photosynthesis, and energy transfer through ATP formation,

thereby directly influencing crop establishment and subsequent yield performance. Phosphorus-deficient mustard plants often exhibit stunted growth, reduced branching, and poor siliquae development, leading to significant yield losses. Adequate phosphorus application improves plant height, dry matter accumulation, and chlorophyll content, while enhancing yield attributes such as number of siliquae per plant, seeds per siliqua, and 1000-seed weight. Phosphorus application not only enhanced dry matter accumulation but also increased nutrient use efficiency, adequate phosphorus levels improve harvest index and nutrient uptake efficiency, which are critical for maximizing yield potential in semi-arid conditions (Choudhary *et al.*, 2018) ^[1]. This nutrient also plays a vital role in root nodulation when mustard is intercropped with legumes, contributing to soil fertility and sustainability (Singh *et al.*, 2016) ^[14].

Alongside nutrient management, planting geometry is another vital factor influencing mustard growth and productivity. Spacing and arrangement, profoundly impacts the growth and yield. Plant density has been observed to have a huge influence on growth, development and seed yield of mustard (Kumar *et al.*, 2004) ^[7]. Plant spacing plays a vital role in determining mustard growth and yield by influencing competition for resources, canopy development, and overall productivity. Likewise, adjusting plant density is another key management practice to enhance yield per unit area. The optimum plant density depends on factors such as the crop variety, its growth characteristics, and the prevailing agro-climatic conditions, provided the crop is planted in a suitable geometry (Sondhiya *et al.*, 2019) ^[17]. Optimal spacing between plants ensures efficient light interception, air circulation, and nutrient availability, which are critical for photosynthesis, plant development, and ultimately, yield. Adequate spacing reduces competition among plants for resources like water and nutrients, promoting healthier growth and higher biomass accumulation.

Materials and Methods

The experiment was carried out during the Rabi season of 2024 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The site is geographically situated at 25°39'42" N latitude, 81°67'56" E longitude, and 98 m above mean sea level (MSL). The study aimed to evaluate the effect of phosphorus application and plant spacing on growth and yield of mustard. The experimental soil was characterized as sandy loam with a pH of 8.0, low organic carbon content (0.60%), and available Nitrogen (225 Kg/ha), Phosphorus (38.2 Kg/ha), and Potassium (240.7 Kg/ha). The experiment was laid out in Randomized Block Design with ten treatments, each replicated thrice. The treatment combinations are T1: Phosphorus 30 kg/ha + Spacing 25 cm × 15 cm, T2: Phosphorus 30 kg/ha + Spacing 35 cm × 15 cm, T3: Phosphorus 30 kg/ha + Spacing 45 cm × 15 cm, T4: Phosphorus 40 kg/ha + Spacing 25 cm × 15 cm, T5: Phosphorus 40 kg/ha + Spacing 35 cm × 15 cm, T6: Phosphorus 40 kg/ha + Spacing 45 cm × 15 cm, T7: Phosphorus 50 kg/ha + Spacing 25 cm × 15 cm, T8: Phosphorus 50 kg/ha + Spacing 35 cm × 15 cm, T9: Phosphorus 50 kg/ha + Spacing 45 cm × 15 cm, and T10: Control (RDF) - N:P:K - 80-40-40 kg/ha.

Mustard seeds of variety Sonalika were sown at a depth of 2-3 cm with a seed rate of 5 kg/ha. A recommended dose of 80-40-40 kg NPK/ha was established as the standard fertilizer application. Phosphorus was supplied as diammonium phosphate (DAP), applied basally during sowing, with the quantity adjusted according to the respective treatment plots. Nitrogen and potassium were applied as urea and muriate of potash (MOP), respectively, as per the recommended doses. A split application approach was adopted for nitrogen management, wherein 50% of the total nitrogen dose was incorporated as a basal application during sowing, with the remaining portion applied as a top-dressing at 35 days after sowing (DAS). Potassium fertilizer was applied entirely as a basal dose at the time of sowing. Phosphorus was applied as a single basal application, with dosage rates varying across experimental plots in accordance with specific treatment combinations.

Crop growth and development were observed at 20, 40, 60, and 80 days after sowing (DAS) evaluate the effects of different treatment combinations. Data of agronomic traits including plant height (cm), dry biomass per plant (g), crop growth rate (g/m²/day), relative growth rate (g/g/day), number of branches per plant, siliquae per plant, seeds per siliqua, test weight (g), seed yield (kg/ha), stover yield (kg/ha), and harvest index were recorded. Statistical analysis was performed using analysis of variance (ANOVA) to evaluate treatment effects (Fisher, R.A. 1950) ^[3]. Additionally, economic parameters such as cost of cultivation, gross returns, net returns, and benefit-cost ratio were computed to assess the economic viability of each treatment.

Results and Discussion

Growth and Growth attributes

1. Plant height (cm)

The application of phosphorus 50 kg/ha along with spacing 25 cm × 15 cm (T7) recorded significantly higher plant height (196.96cm). However, phosphorus 50 kg/ha with 35 cm × 15 cm (T8) and phosphorus 40 kg/ha with 25 cm × 15 cm (T4) were statistically at par with T7. Phosphorus effects become pronounced during active vegetative growth phases. The increase in plant height with the application of higher phosphorus doses may be attributed to improved root development, energy transformation, and enhanced cell division and elongation. Closer spacing might have contributed to vertical growth due to inter-plant competition for light. These findings are in close agreement with those reported by Kumar *et al.*, (2016) ^[6] and Singh *et al.*, (2018) ^[15], who observed that higher phosphorus application (up to 50 kg/ha) and closer spacing significantly improved mustard growth in terms of plant height. This also agrees with findings of Meena *et al.*, (2020) ^[8], who reported increased plant height at closer spacing due to inter-plant competition for light and nutrients.

2. Dry weight (g)

The application of phosphorus 50 kg/ha along with spacing 25 cm × 15 cm (T7) resulted in significantly higher dry weight (19.31 g). However, phosphorus 50 kg/ha with spacing 35 cm × 15 cm (T8) and phosphorus 40 kg/ha with spacing 45 cm × 15 cm (T6) were statistically at par with the application of phosphorus 50 kg/ha along with spacing 25 cm × 15 cm. The significant improvement in dry matter accumulation under higher phosphorus application may be related to phosphorus's crucial role in root development,

energy metabolism, and enhanced photosynthetic activity key contributors to increased biomass production. These results align with Ravutla *et al.*, (2020) ^[10]. Furthermore, closer spacing (25 cm × 15 cm) enhanced plant population per unit area, which in turn improved the overall dry matter accumulation per unit area through higher crop stand density. These findings are in line with the reports of Singh *et al.*, (2018) ^[15], who stated that closer spacing improved dry matter accumulation due to efficient resource utilization.

3. Crop growth rate (g/m²/day)

During 20-40 DAS and 40-60 DAS, T7 [Phosphorus 50 kg/ha + 25 cm × 15 cm] consistently recorded the highest CGR, while the lowest was observed in wider spacing with lower phosphorus (T3). A general decline in CGR was noted during the 60-80 DAS interval, though T7 again maintained superiority over all other treatments.

4. Relative growth rate (g/g/day)

The maximum RGR (0.026 g/g/day) was recorded in T3 [Phosphorus 30 kg/ha + 45 cm × 15 cm] and T10 [Control - RDF, 80:40:40 NPK], while the lowest value (0.022 g/g/day) was observed in T7 [Phosphorus 50 kg/ha + 25 cm × 15 cm]. However, the differences among treatments during this period were statistically non-significant, suggesting that the influence of phosphorus levels and spacing on RGR becomes less pronounced in the later growth stages. This reduction in RGR is attributed to the progressive senescence of older leaves, reduced photosynthetic activity, and the translocation of assimilates toward silique development and seed filling, which naturally slows down relative biomass accumulation at the final stages of crop growth.

5. Number of Branches/Plant

The data on the number of branches per plant of mustard as influenced by phosphorus levels and spacing revealed that by 80 DAS, the number of branches increased across treatments, with the highest (16.33) under [Phosphorus 50 kg/ha + 25 cm × 15 cm], followed by [Phosphorus 50 kg/ha + 45 cm × 15 cm] (16.20). Overall, the results suggest that higher phosphorus application (50 kg/ha) in closer spacing (25 cm × 15 cm) favoured greater branching, possibly due to improved nutrient uptake and better canopy management, highlighting the significance of balanced nutrient availability during the active vegetative and early reproductive phases. Meena *et al.*, (2020) ^[8]. Phosphorus is crucial as a structural element in cell components and is present in metabolically active molecules such as chloroplasts, mitochondria, nucleic acids, proteins, flavin nucleotides, and several enzymes, all of which are vital for plant growth and cellular functioning. This nutrient greatly enhances plant vigour and root development, which leads to healthier, more robust plants. Additionally, phosphorus encourages the growth of nitrogen-fixing bacteria, supports pod formation, and accelerates the maturity of pods, making it essential for overall plant reproductive success and productivity (Tisdale *et al.*, 2002) ^[17].

Yield and Yield attributes

1. Number of Silique/Plant

The data showed that phosphorus levels and plant spacing had a significant influence on siliques per plant. The maximum number of siliques per plant (297.33) was observed with 50 kg P₂O₅/ha at 25 cm × 15 cm spacing (T7), while the lowest was recorded in 30 kg P₂O₅/ha at 45 cm ×

15 cm spacing (T3). The increase in siliques per plant at higher phosphorus levels may be attributed to greater flower retention, improved pollen viability, and enhanced ovary development. These findings are in close agreement with Solanki *et al.*, (2016) ^[18], who reported that successive increases in phosphorus up to 50 kg/ha significantly enhanced the number of siliques per plant due to improved nutrient availability during flowering. Similarly, Premi and Kumar (2004) ^[9] observed that phosphorus application led to a notable increase in siliques per mustard plant.

2. Seeds per capsule

The data observed revealed that Treatment 7 [Phosphorus 50 kg/ha + 25 cm × 15 cm] recorded the maximum number of seeds per silique (17), followed closely by treatment 8 [Phosphorus 50 kg/ha + 25 cm × 15 cm] which recorded (16.77). The minimum value (15.27) was recorded in treatment 3 [Phosphorus 30 kg/ha + 45 cm × 15 cm]. The superiority of treatment 7 may be attributed to enhanced availability of phosphorus, which is known to improve pollen viability, flower retention, and seed setting by ensuring better energy metabolism and nutrient translocation during reproductive development. These results are in conformity with the findings of Kumar *et al.*, (2023) ^[5], who observed that higher phosphorus application improved reproductive traits, including seeds per silique, due to greater metabolic activity during flowering and fertilization.

3. Test weight (g)

Test weight differences among treatments were non-significant. Treatment 4 [Phosphorus 40 kg/ha + 25 cm × 15 cm] recorded the highest test weight of 4.78 g, followed closely by treatment 8 (4.75 g) and treatment 7 (4.70 g). The lowest test weight (4.24 g) was observed in treatment 2 [Phosphorus 30 kg/ha + 35 cm × 15 cm]. Test weight (4.24-4.78 g) did not vary significantly across treatments, suggesting that seed size remained unaffected by phosphorus and spacing.

4. Seed yield (t/ha)

The data shows that maximum seed yield (2.15 t/ha) was obtained from T7 [Phosphorus 50 kg/ha + 25 cm × 15 cm], followed by T9 [Phosphorus 50 kg/ha + 45 cm × 15 cm] (2.09 t/ha) and T4 [Phosphorus 40 kg/ha + 25 cm × 15 cm] (2.02 t/ha). The lowest seed yield (1.57 t/ha) was observed in T3 [30 kg/ha + 45 cm × 15 cm]. The increase in seed yield with higher phosphorus levels may be attributed to improved nutrient absorption, better root growth, and more efficient partitioning of assimilates to reproductive organs. These findings are consistent with Solanki *et al.*, (2016) ^[18], who reported that application of 50 kg P₂O₅/ha significantly increased mustard seed yield. Similarly, Singh *et al.*, (2025) ^[15] observed that phosphorus application within 40-80 kg P₂O₅/ha enhanced growth, root development, and overall yield of mustard, further confirming the positive effect of higher phosphorus doses on productivity.

5. Stover yield (t/ha)

The maximum stover yield (4.97 t/ha) was recorded in T7 [Phosphorus 50 kg/ha + 25 cm × 15 cm], followed by T9 [Phosphorus 50 kg/ha + 45 cm × 15 cm] (4.85 t/ha) and T4 (4.82 t/ha). The lowest stover yield (3.49 t/ha) was recorded in T10 [Control, RDF 80:40:40 NPK kg/ha]. The significantly higher stover yield under 50 kg/ha phosphorus treatments may be attributed to enhanced vegetative growth,

including greater plant height, more branches, and increased biomass accumulation. These results are in close agreement with the findings of Sahoo *et al.*, (2021) ^[12]. The effect of closer spacing (25 × 15 cm) is also evident with higher plant density per area, vegetative biomass and stover yield increased per hectare mirroring observations by Sondhiya *et al.*, (2019) ^[17].

6. Harvest index

The Highest Harvest Index (31.43%) was recorded in T10 [Control, RDF 80:40:40 NPK kg/ha], followed closely by T2 [Phosphorus 30 kg/ha + 35 cm × 15 cm] (30.84%). The minimum Harvest Index (28.08%) was observed in T3 [Phosphorus 30 kg/ha + 45 cm × 15 cm]. There was no significant difference among the treatments.

Conclusion

Based on the experiment, it is concluded that application of Phosphorus 50 kg/ha along with Spacing 25 cm × 15 cm was the most effective treatment for improving growth and yield characteristics.

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Table 1: Effect of Phosphorus and Spacing on growth and growth attributes of Mustard

80 DAS 60-80 DAS						
Sl no.	Treatment combination	Plant Height (cm)	No. of Branches/Plant	Dry weight (g)	CGR (g/m ² /day)	RGR (g/g/day)
1	Phosphorus 30 kg/ha + 25 cm × 15 cm	175.55	15.40	18.00	8.90	0.023
2	Phosphorus 30 kg/ha + 35 cm × 15 cm	174.59	14.33	17.69	6.41	0.024
3	Phosphorus 30 kg/ha + 45 cm × 15 cm	174.70	15.00	17.05	5.06	0.026
4	Phosphorus 40 kg/ha + 25 cm × 15 cm	183.63	14.47	18.29	9.12	0.023
5	Phosphorus 40 kg/ha + 35 cm × 15 cm	190.85	16.00	17.61	6.29	0.024
6	Phosphorus 40 kg/ha + 45 cm × 15 cm	191.92	15.07	18.90	5.19	0.023
7	Phosphorus 50 kg/ha + 25 cm × 15 cm	196.96	16.33	19.31	9.18	0.022
8	Phosphorus 50 kg/ha + 35 cm × 15 cm	194.69	15.27	19.17	6.77	0.023
9	Phosphorus 50 kg/ha + 45 cm × 15 cm	194.33	16.20	18.49	5.47	0.025
10	Control (RDF)- 80:40:40 (N:P: K)	191.09	14.67	17.45	6.78	0.026
	F - Test	S	NS	S	S	NS
	S.Em (±)	1.95	-	0.18	0.32	-
	CD (p = 0.05)	5.78	-	0.53	0.94	-

Table 2: Effect of Phosphorus and Spacing on yield and yield attributes of Mustard

At 80 DAS							
Sl no.	Treatment combination	No. of Siliqua/Plant	No. of Seed/Siliqua	Test Weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1	Phosphorus 30 kg/ha + 25 cm × 15 cm	281.00	15.67	4.54	1.96	4.71	29.40
2	Phosphorus 30 kg/ha + 35 cm × 15 cm	272.67	14.67	4.24	1.72	3.85	30.84
3	Phosphorus 30 kg/ha + 45 cm × 15 cm	267.00	14.33	4.52	1.57	4.02	28.08
4	Phosphorus 40 kg/ha + 25 cm × 15 cm	289.00	16.33	4.78	2.02	4.82	29.54
5	Phosphorus 40 kg/ha + 35 cm × 15 cm	279.33	16.00	4.62	1.80	4.47	28.75
6	Phosphorus 40 kg/ha + 45 cm × 15 cm	285.67	15.33	4.71	1.68	4.15	28.87
7	Phosphorus 50 kg/ha + 25 cm × 15 cm	297.33	17.00	4.70	2.15	4.97	30.24
8	Phosphorus 50 kg/ha + 35 cm × 15 cm	282.33	16.67	4.75	1.99	4.62	30.11
9	Phosphorus 50 kg/ha + 45 cm × 15 cm	284.67	16.33	4.62	2.09	4.85	30.06
10	Control (RDF)- 80:40:40 (N:P: K)	269.00	14.67	4.40	1.60	3.49	31.43
	F - Test	S	S	NS	S	S	NS
	S.Em (±)	5.64	0.57	-	0.05	0.08	-
	CD (p= 0.05)	16.74	1.69	-	0.15	0.25	-

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