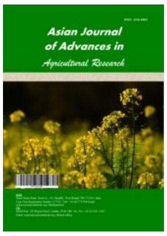

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Influence of Phosphorus Fertilization and Seed Rates on Yield Components and Yield of Black Cumin (*Nigella sativa* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Authors TM and KK planned the experiment and lead the research. Authors MRK, TM and KK designed and carried out the research. Authors MA Samad performed the statistical analysis. Author MRK, AK and MT carried out the research on the field. Authors MMS, AAI, MA Sumi and MT collected the data. Authors MRK, MMS and AAI wrote the manuscript. Authors MA Sumi, AAI, AK and MRK managed the literature searches. All authors provided critical feedback and helped shape the research, analysis and manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out at the "Horticulture Farm" of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh from November 2019 to March 2020 to study the influence of phosphorus fertilization and seed rates on yield components and yield of black cumin. The experiment consisted of two factors. Factor A: Four levels of phosphorus viz., P_0= control, P_1= 35 P kgha^{-1}, P_2= 40 P kgha^{-1} and P_3= 45 P kgha^{-1}and Factor B: Three seed rates viz., R_1= 8 kg seeds ha^{-1}, R_2= 10 kg seeds ha^{-1}and R_3= 12 kg seeds ha^{-1}. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data were recorded on growth, yield components

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and yield of black cumin and significant variation was observed for most of the studied characters. Growth related data was maximum on P_3 (45 P kgha^{-1}) treatment but in case of seed yield, P_2 (40 P kgha^{-1}) treatment showed the best result. In case of growth characters, R_1 (8 kg seeds ha^{-1}) treatment revealed the best result but in case of seed yield, R_2 (10 kg seeds ha^{-1}) treatment showed the best result. The highest seed yield (1.27 t ha^{-1}) was obtained from P_2R_2 (40 P kgha^{-1}+ 10 kg seeds ha^{-1}) treatment combination. On the other hand, the lowest seed yield (0.94 t ha^{-1}) was obtained from of P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination. So, it was revealed that the P_2R_2 treatment combination appeared to be best for achieving the higher growth and seed yield of black cumin.

Keywords: Phosphorus; seed rates; yield and black cumin.

1. INTRODUCTION

Nigella (*Nigella sativa* L.) is well known as black cumin or kalojira. The name nigella derives from the Latin nigellus or niger, meaning black kalajira is an annual herbaceous plant belonging to the Ranunculaceae family. *Nigella* is an important seed spice has originated from Mediterranean region of Asia to North India. *Nigella* is widely cultivated throughout South Europe, Syria, Egypt, Saudi Arabia, Iran, Pakistan, India and Turkey [1]. In Bangladesh, it covers 14742 hectares of land, with a total annual production of 16526 tons [2], over the Faridpur, Sariatpur, Madaripur, Pabna, Sirajganj, Jessore, Kushtia, Bogra, Rangpur and Natore districts [3],[4]. The ripe seed of black cumin contains 7% moisture, 4.34% ash, 23% protein, 0.39% fat, 4.99% starch and 5.44% raw fiber [5]. The seeds are rich in fats, fiber, and minerals such as Fe, Na, Cu, Zn, P, Ca and vitamins such as ascorbic acid, thiamin, niacin, pyridoxine, and folic acid [6]. *N. sativa* seeds contain 30-35% oil and 0.5-1.5% essential oil which has several uses in the pharmaceutical and food industries [7]. The seed has an essence and a bitter nigeline substance. Black cumin seeds contain protein, alkaloids (nigellicines andnigelledine), saponin (α-hederin) fixed and essential oil [8]. The popularity of the plant was highly enhanced by the ideological belief in the herb as a cure for multiple diseases like anti-tumor, anti-diabetic, cardio-protective, gastro-protective, anti-asthmatic, nephron-protective, hepato-protective, anti-inflammatory, immune-modulatory, neuro-protective, anti-convulsant, anxiolytic, antioxidant, anti-nociceptive, anti-oxytocic, contraceptive, anti-bacterial, anti-fungal and anthelmintic activities were immensely appreciated. The major medicinal components are *thymoquinone* and *nigellone* (a dimer of thymoquinone). These were attributed to impart anti-tumour, anti-inflammatory and anti-diabetic properties [9],[10].The yield of Black cumin in our country is not satisfactory in comparison to our requirement. Now a days, nutrients content in soil is the most limiting factor for proper growth and yield of plants. The requirements of different plant nutrients vary with different crops. Phosphorus (P) is critical in plant metabolism which plays an important role in cellular energy transfer, respiration and photosynthesis and it is a key structural component of nucleic acids coenzymes, phosphoproteins and phospholipids. Phosphorus fertilization is a major input in crop production [11]. Phosphorus is essential for the general health of the plant and root development and more stem strength. It improves flower formation and makes seed production more uniform. It also improves seed quality and is resistant to plant disease. Plant growth and seed yield were increased when phosphorus was applied [12],[13]. Seed rate is one of the main key factors for obtaining high yield and quality in the production of crops. Seed rate is the key factor determining affecting the yield and yield components. Several studies carried out in countries where systematically cultivated, have demonstrated that suitable seed rate can increase the growth and yield of *Nigella sativa* [14]. Unfortunately, very limited research have been carried out regarding the effect of phosphorus fertilization and seed rates on yield components and yield of black cumin (*Nigella sativa* L.). A detailed and systematic study is needed to find out the effect of phosphorus fertilization, its influence on seed rates and a suitable combination of phosphorus fertilization and seed rates for better growth and higher seed yield of black cumin in Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental Site and Experimental Framework

The research work was conducted at “Horticulture Farm” of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2019 to March 2020. The location of the site was 23°74′ N Latitude and 90°35′ E Longitude with an elevation of 8.2 meters from the sea level. The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were distributed randomly. There were 36 unit plots altogether in the experiment. The size of each plot was 1.2 m × 1.2 m. The distance maintained between two blocks and two plots were 50 cm and 50cm, respectively. The plots were raised to 10 cm.

2.2 Planting Materials

In this experiment black cumin variety, BARI Kalozira-1 was used. BARI Kalozira-1 was developed by Spices Research Centre, BARI in 2009. It's average plant height is 55-60cm, number of primary branches is 5-7, the number of pods/plants is 20-25, the number of seeds/pod is 75-80, the seed weight/pod is 0.20-0.27g, the seed weight/plant is 5-7g, the 1000 seeds weight is 3.00 - 3.25 g.

2.3 Application of Manures and Fertilizers

The source of N, P and K were urea, triple super phosphate and muriate of potash. Half of the urea and the total amount of muriate of potash fertilizers of each plot were applied and incorporated into the soil during final land preparation. The rest of the urea was top-dressed after 30 days of sowing (DAS). Triple super phosphate was applied as per treatment. Cowdung @ 5 tone per hectare was applied during the land preparation.

2.4 Statistical Analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by [15].

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

A statistically significant variation was observed on plant height at 45, 90and 135 DAS due to different levels of phosphorus under the experiment (Fig. 1). At 135 DAS, the highest plant height (52.84 cm) was obtained from P_3 (45 P kgha^{-1}) treatment and the lowest plant height (34.64 cm) was revealed from P_0 (control) treatment. It was revealed that the plant height increased with the increase in days after sowing (DAS) i.e., 45, 90 and 135 DAS. It also revealed that the plant height increased with different levels of phosphorus as well. Similar results were also observed by [9,16,17]. They reported that phosphorus fertilizer increases plant height.

Seed rates showed significant influence on the height of black cumin plants at 45, 90 and 135 DAS (Fig. 2). At 135 DAS, the highest plant height (45.33 cm) was observed from R_1 (8 kg ha^{-1} of seeds) treatment. On the other hand the lowest plant height (41.45 cm) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. The result of the study was in coincided with the findings of [18] who reported that seed rate significantly affected plant height.

Significant influence was observed on plant height due to the combined effect of different levels of phosphorus and seed rates (Table 1). From the results of the experiment showed that the highest plant height at 135 DAS (55.18 cm) was observed from the treatment combination of P_3R_1 (45 P kg ha^{-1} + 8 kg ha^{-1} of seeds). On the other hand the lowest plant height at 135 DAS (32.81 cm) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

3.2 Number of Primary Branches per Plant

Significant variation was observed in number of primary branches per plant of black cumin due to different levels of phosphorus under the experiment (Table 2). At 135 DAS, the maximum number of primary branches per plant (8.39) was obtained from P_3 (45 P kg ha^{-1}) treatment where the minimum number of primary branches per plant (5.43) was observed from P_0 (control) treatment. It was revealed that the number of primary branches per plant increased with the increase in days after sowing (DAS). It also revealed that the number of primary branches per plant increased with different levels of phosphorus as well. [16] observed similar trends.

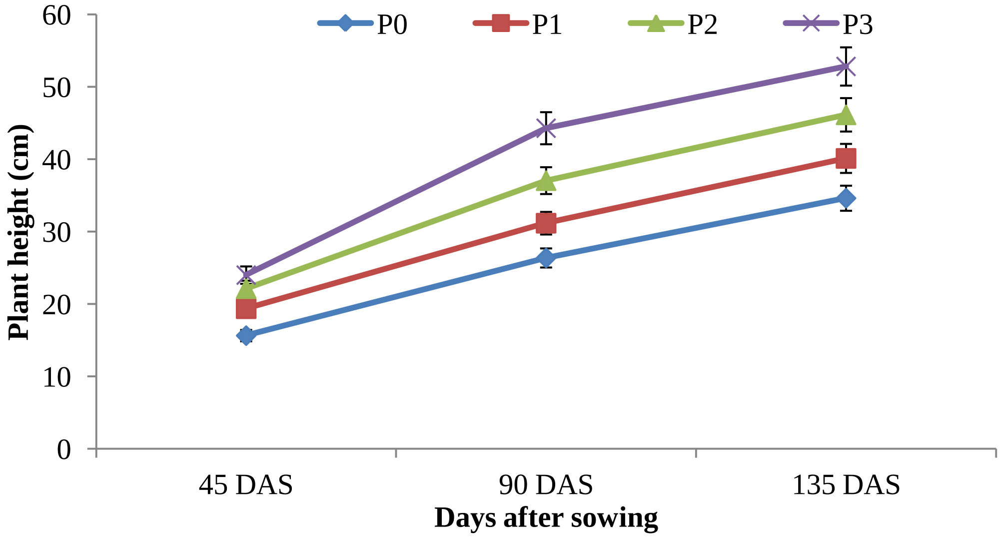

Fig.1. Effect of different levels of phosphorus on plant height at different days after sowing of black cumin

Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}

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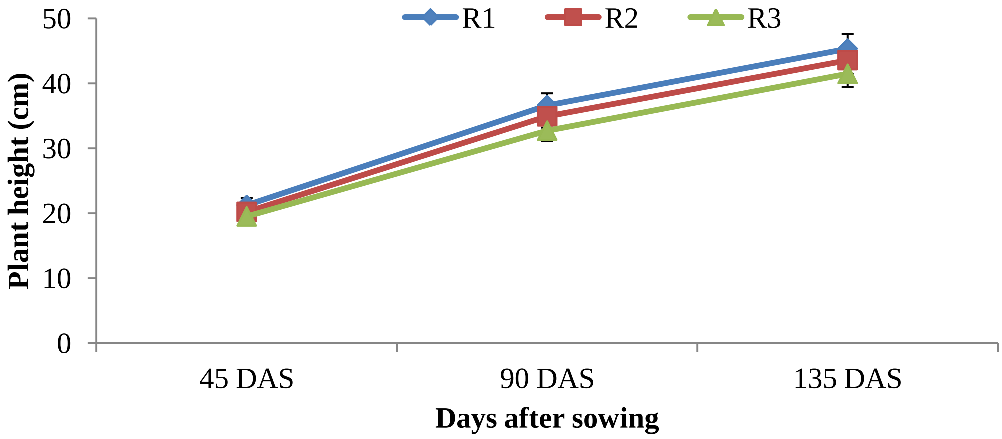

Fig. 2. Effect of seed rates on plant height at different days after sowing of black cumin

Here, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

Statistically seed rates showed a significant variation in the number of primary branches per plant of black cumin (Table 3). At harvest, the maximum number of primary branches per plant (7.26) was observed from R_1 (8 kg ha^{-1} of seeds) treatment. On the other hand the minimum number of primary branches per plant (6.64) was observed from R_3 (12 kg seeds ha^{-1}) treatment [19] found similar results.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by the number of primary branches per plant (Table 4). At harvest, the maximum number of primary branches per plant (8.67) was achieved from P_3R_1 (45 P kg ha^{-1} + 8 kg ha^{-1} of seeds) treatment combination which was statistically similar (8.40) to P_3R_2 treatment. On the other hand the minimum number of primary branches per plant (4.92) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

4.3 Days to First Flowering

A significant variation on days to the first flowering of black cumin was observed due to different levels of phosphorus (Table 2). The

Table 1. Combined effect of different levels of phosphorus and seed rates on plant height at different days after sowing of black cumin

Treatment Combinations	Plant height (cm) at		
	45 DAS	90 DAS	135 DAS
P_0R_1	16.75 h	28.15 hi	36.19 gh
P_0R_2	15.67 i	26.53 i	34.92 hi
P_0R_3	14.55 j	24.48 j	32.81 i
P_1R_1	20.52 f	32.41 f	42.27 ef
P_1R_2	19.15 g	31.33 fg	40.53 f
P_1R_3	18.47 g	29.85 gh	37.62 g
P_2R_1	22.81 cd	39.13 d	47.67 c
P_2R_2	22.00 de	37.28 d	46.19 cd
P_2R_3	21.62 e	34.81 e	44.63 de
P_3R_1	24.83 a	46.75 a	55.18 a
P_3R_2	23.91 ab	44.50 b	52.60 b
P_3R_3	23.33 bc	41.67 c	50.75 b
$LSD_{(0.05)}$	0.94	1.89	2.47
CV%	2.75	3.22	3.36

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.
Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

minimum days to the first flowering of black cumin (51.31) was obtained from P_3 (45 P kg ha^{-1}) treatment. On the other hand the maximum days to the first flowering of black cumin (57.52) was obtained from P_0 (control) treatment. It was revealed that the days to the first flowering of black cumin increased with the different levels of phosphorus as well. [9] observed similar results.

A statistically significant difference on days to the first flowering of black cumin was observed due to varied seed rates (Table 3). It was revealed that the minimum days to the first flowering of black cumin (53.61) was obtained from R_1 (8 kg ha^{-1} of seeds) treatment. On the other hand the maximum days to the first flowering of black cumin (55.23) was observed from R_3 (12 kg ha^{-1} of seeds) treatment which was statistically similar (54.50) to R_2 treatment. [19] reported that days to flowering were significantly influenced by the seed rate.

The combined effect of different levels of phosphorus and seed rates was significantly influenced by the days to first flowering of black cumin (Table 4). The results of the experiment revealed that the minimum days to first flowering of black cumin (50.15) was observed from P_3R_1 (45 P kg ha^{-1} + 8 kg ha^{-1} of seeds) treatment combination. On the other hand the maximum days to the first flowering of black cumin (58.45) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination which was statistically similar to P_0R_2, P_0R_1 and P_1R_3 treatment combination, respectively.

4.4 Days to 50% Flowering

Days to 50% of flowering of black cumin was significantly influenced by different levels of phosphorus (Table 2). The minimum days to 50% flowering of black cumin (61.60) was obtained from P_3 (45 P kg ha^{-1}) treatment. On the other hand the maximum days to 50% flowering of black cumin (67.34) was obtained from P_0 (control) treatment. It was revealed that the days to 50% flowering of black cumin increased with the different levels of phosphorus as well. [21] found similar trends.

A statistically significant variation on days to 50% flowering of black cumin was observed due to varied seed rates (Table 3). It was observed that the minimum days to 50% flowering of black cumin (63.58) was obtained from R_1 (8 kg ha^{-1} of seeds) treatment. On the other hand the maximum days to 50% flowering of black cumin (65.10) was observed from R_3 (12 kg ha^{-1} of seeds) treatment which was statistically similar (64.36) to R_2 treatment. The result of the experiment was in coincided with the findings of [14].

The combined effect of different levels of phosphorus and seed rates was significantly influenced by days to 50% flowering of black cumin (Table 4). The results of the experiment revealed that the minimum days to 50% flowering of black cumin (60.85) was observed from P_3R_1 (45 P kg ha^{-1} + 8 kg ha^{-1} of seeds) treatment combination. On the other hand the maximum

Table 2. Effect of different levels of phosphorus on number of primary branches per plant, number of secondary branches per plant, days to first and 50% flowering of black cumin

Treatments	Number of primary branches per plant	Days to first flowering	Days to 50% flowering
P_0	5.43 d	57.52 a	67.34 a
P_1	6.53 c	55.44 b	65.16 b
P_2	7.56 b	53.52 c	63.28 c
P_3	8.39 a	51.31 d	61.60 d
$LSD_{(0.05)}$	0.21	1.36	1.59
CV%	3.13	2.56	2.53

A column means having a similar letter(s) are statistically similar at 0.05 level of probability.
Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}

Table 3. Effect of different levels of seed rates on the number of primary branches per plant, number of secondary branches per plant, days to first and 50% flowering of black cumin

Treatments	Number of primary branches per plant	Days to first flowering	Days to 50% flowering
R_1	7.26 a	53.61 b	63.62 b
R_2	7.03 b	54.50ab	64.36 ab
R_3	6.64 c	55.23 a	65.10 a
$LSD_{(0.05)}$	0.18	1.18	1.37
CV%	3.13	2.56	2.53

A column means having a similar letter(s) are statistically similar at 0.05 level of probability.
Here, Here, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

Table 4. Combined effect of different levels of phosphorus and seed rates on the number of primary branches per plant, number of secondary branches per plant, days to first and 50% flowering of black cumin

Treatment Combinations	Number of primary branches per plant	Days to first flowering	Days to 50% flowering
P_0R_1	5.81 h	56.80 abc	66.09 abc
P_0R_2	5.55 h	57.30 ab	67.67 ab
P_0R_3	4.92 i	58.45 a	68.25 a
P_1R_1	6.75 f	54.67 c-f	64.67 cde
P_1R_2	6.51 fg	55.50 b-e	65.00 bcd
P_1R_3	6.33 g	56.15 a-d	65.81 abc
P_2R_1	7.81 cd	52.82 fg	62.70 d-g
P_2R_2	7.67 d	53.75 efg	63.00 d-g
P_2R_3	7.20 e	54.00 def	64.15 c-f
P_3R_1	8.67 a	50.15 h	60.85 g
P_3R_2	8.40 ab	51.45 gh	61.75 fg
P_3R_3	8.11 bc	52.33 fgh	62.20 efg
$LSD_{(0.05)}$	0.37	2.36	2.76
CV(%)	3.13	2.56	2.53

A column means having a similar letter(s) are statistically similar at 0.05 level of probability.
Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

days to 50% flowering of black cumin (68.25) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination which was statistically similar to P_0R_2, P_0R_1 and P_1R_3 treatments, respectively.

4.5 Capsules per Plant

A statistically significant variation on capsules per plant of black cumin was observed due to different levels of phosphorus (Table 5). The maximum number of capsules per plant (20.69) were observed from P_2 (40 P kg ha^{-1}) treatment while the minimum capsules per plant (16.32) were obtained from P_0 (control) treatment.

It was observed that the number of capsules per plant increased with the different levels of phosphorus. [9] reported that the highest number of capsules per plant was obtained when judicious applying of phosphorus fertilizer. [17] also observed similar results.

A significant difference on capsules per plant of black cumin was observed due to varied seed rates (Table 6). It was revealed that the maximum number of capsules per plant (19.20) were obtained from R_2 (10 kg ha^{-1} of seeds) treatment. On the other hand the minimum number of capsules per plant (17.86) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. [14] reported that the number of capsule and the number of seeds in the capsule were generally affected by seed rate applications.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by capsules per plant of black cumin (Table 7). The results of the experiment revealed that the maximum number of capsules per plant of black cumin (21.80) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination. On the other hand the minimum number of capsules per plant of black cumin (15.37) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.6 Length of Capsule (cm)

A statistically significant variation on the length of capsule of black cumin was observed due to varying levels of phosphorus (Table 5). The maximum length of the capsule (1.51 cm) was observed from P_2 (40 P kg ha^{-1}) treatment while the minimum length of capsule (1.11 cm) was obtained from P_0 (control) treatment. It was observed that the length of capsule per plant increased with the different levels of phosphorus. [17] found the similar result.

A significant difference on the length of capsule per plant of black cumin was observed due to varied seed rates (Table 6). It was revealed that the maximum length of the capsule (1.35 cm) was obtained from R_2 (10 kg ha^{-1} of seeds) treatment. On the other hand the minimum length of capsule (1.25 cm) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. [20] observed similar trends.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by length of capsule per plant of black cumin (Table 7). The results of the experiment revealed that the maximum length of capsule (1.59 cm) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination. On the other hand the minimum length of capsule (1.07 cm) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

4.7 Breadth of Capsule (cm)

A significant variation on the breadth of capsule of black cumin was observed due to varied levels of phosphorus (Table 5). The maximum breadth of capsule (1.05 cm) was obtained from P_2 (40 P kg ha^{-1}) treatment while the minimum breadth of capsule (0.77 cm) was obtained from P_0 (control) treatment. It was revealed that the breadth of capsule per plant increased with the different levels of phosphorus. [22] revealed a similar result.

A marked difference on the breadth of capsule per plant of black cumin was observed due to varied seed rates (Table 6). It was revealed that the maximum breadth of capsule (0.94 cm) was obtained from R_2 (10 kg ha^{-1} of seeds) treatment. On the other hand the minimum breadth of capsule (0.87 cm) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. [18] reported that an increase in the seed rate decreased the breadth of capsule relate to the yield.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by the breadth of capsule per plant of black cumin (Table 7). The results of the experiment revealed that the maximum breadth of capsule (1.10 cm) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds)treatment combination. On the other hand the minimum breadth of the capsule (0.74 cm) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.8 Number of Seeds per Capsule

The number of seeds per capsule of black cumin was significantly influenced bythe different levels of phosphorus (Table 5). The maximum number of seeds per capsule (80.07) was observed from P_2 (40 P kg ha^{-1}) treatment while the minimum number of seeds per capsule (66.24) was obtained from P_0 (control) treatment. It was revealed that the number of seeds per capsule increased with the increase of phosphorus. Similar results were also observed by [17],[23],[24]. They reported that number of capsules and the number of seeds per capsule increased with the level of application of P and generally maximum values were observed in the highest P application.

Statistically significant influence on the number of seeds per capsule of black cumin was observed due to varied seed rates (Table 6). It was revealed that the maximum number of seeds per capsule of black cumin (74.18) was achieved from R_2 (10 kg ha^{-1} of seeds) treatment which was statistically identical (72.64) to R_1 treatment. On the other hand the minimum number of seeds per capsule (70.92) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. Increasing seed rate inversely affected yield components per plant. [19] observed a similar result.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by the number of seeds per capsule of black cumin (Table 7). The results of the experiment observed that the maximum number of seeds per capsule of black cumin (82.15) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination which was statistically similar (79.93) to P_2R_1 treatment combination. On the other hand the minimum number of seeds per capsule (64.71) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

4.9 1000-seeds Weight (g)

A significant variation in 1000-seeds weight was observed due to different levels of phosphorus (Table 5). The results of the experiment showed that the maximum 1000-seeds weight (3.08 g) was obtained from P_2 (40 P kg ha^{-1}) treatment. On the other hand the minimum1000-seeds weight (2.74g) was obtained from P_0 (control) treatment. [24] reported that the application of nutrient (NPK) elements had a positive effect on plant height, branches per plant, capsule setting, umbels per plant, capsules per plant, capsule size, seeds per capsule, 1000-seed weight and seed yield of black cumin.

Statistically significant influence on 1000-seeds weight was observed due to different seed rates under the present experiment (Table. 6). The maximum1000-seeds weight (2.94 g) was obtained from R_2 (10 kg ha^{-1} of seeds) treatment. On the other hand the minimum1000-seeds weight (2.84 g) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. [14,25] observed similar results.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by 1000-seeds weight (Table 7). The results of the experiment revealed that the maximum 1000-seeds weight (3.15 g) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination which was statistically similar (3.08 and 3.02) to the treatment combination of P_2R_1 and P_2R_3. On the other hand the minimum1000-seeds weight (2.68 g) was observed from P_0R_3 (control + 12 kg seeds ha^{-1}) treatment combination.

4.10 Yield per Plot (g)

A significant variation in yield per plot was observed due to varying levels of phosphorus (Table 5). The results of the experiment showed that the highest yield per plot (175.68 g) was obtained from P_2 (40 P kg ha^{-1}) treatment. On the other hand the lowest yield per plot (141.08 g) was obtained from P_0 (control) treatment. [9],[16],[17],[21],[22],[26] observed the similar results. [23] reported that the use a combination of 45 N kg and 40 P kg ha^{-1} followed by 15 kg N and 20 P kg ha^{-1} for black cumin production in the area.

Statistically significant influence on yield per plot was observed due to varied seed rates during the experimentation (Table 6). It was observed that the highest yield per plot (164.46 g) was obtained from R_2 (10 kg ha^{-1} of seeds) treatment. On the other hand the lowest yield per plot (154.45 g) was observed from R_3 (12 kg ha^{-1} of seeds) treatment. [20] reported that yield and yield attributing factors such as seed yield per plot and seed yield ha^{-1} (kg) were significantly influenced by the seed rate. Seed yield increased from 462 kg ha^{-1} to 634 kg ha^{-1} as seed rate increased from 5 kg ha^{-1} to 20 kg ha^{-1} and showed a decrease in yield from 601 kg ha^{-1} to 507 kg ha^{-1} as inter-row spacing increased from 20 cm to 40 cm.

Yield per plot showed significant influence due to the combined effect of different levels of phosphorus and seed rates (Table 7). The results of the experiment observed that the highest yield per plot (182.88 g) was obtained from P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination. On the other hand the lowest yield per plot (139.27 g) was observed from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

4.11 Yield per Hectare (t)

Significant variation was observed in yield per hectare due to different levels of phosphorus in the present study (Fig. 3). The results of the experiment showed that the highest yield per hectare (1.22 t) was obtained from P_2 (40 P kg ha^{-1}) treatment. On the other hand the lowest yield per hectare (0.98 t) was obtained from P_0 (control) treatment. The result of the experiment was in coincided with the findings of [14],[21],[23],[26]. [24] reported that The highest seed yield (1277 kg ha^{-1}) was obtained from 75% RDCF + 25% cowdung-N treatment followed by 100% RDCF ($N_{80}P_{45}K_{50}S_{20}Zn_5B_2$ kg ha^{-1}) and the lowest seed yield (420 kg ha^{-1}) was recorded with 50% RDCF.

Statistically significant influence on yield per hectare was observed due to different seed rates (Fig. 4). It was revealed that the highest yield per hectare (1.14 t) was revealed from R_2 (10 kg seeds ha^{-1}) treatment. On the other hand the lowest yield per hectare (1.07 t) was obtained from R_3 (12 kg ha^{-1} of seeds) treatment. [20] observed a similar result. They reported that seed yield ha^{-1} (kg) was significantly influenced by the seed rate. [25] reported that 8 kg seed/ha would be the optimum seed rate and line sowing in raised bed would be the most effective method for higher seed yield of the black cumin. But for broadcasting seeds should be shown at 10 kg/ha.

The combined effect of different levels of phosphorus and seed rates were significantly influenced by yield per hectare of black cumin (Table 7). The results of the experiment revealed that the highest yield per hectare (1.27 t) was observed from P_2R_2 (40 P kg ha^{-1} + 10 kg seeds ha^{-1}) treatment combination which was statistically similar (1.21 t) to P_2R_1 treatment combination. On the other hand the lowest yield per hectare (0.94 t) was obtained from P_0R_3 (control + 12 kg ha^{-1} of seeds) treatment combination.

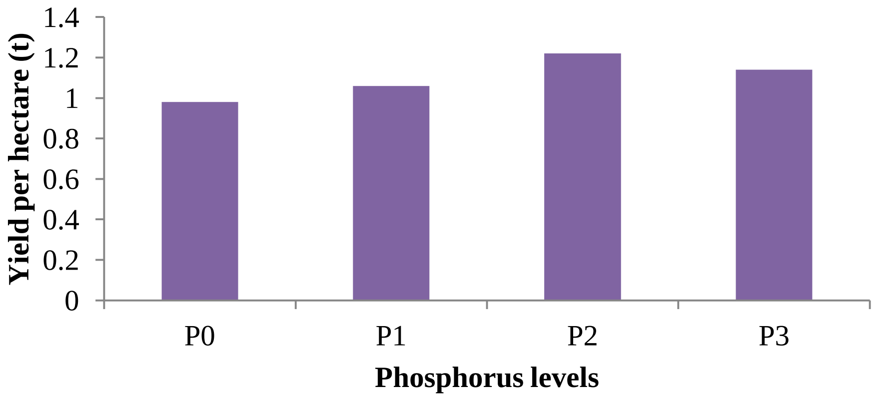

Fig. 3. Effect of different levels of phosphorus on yield per hectare of black cumin

Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}

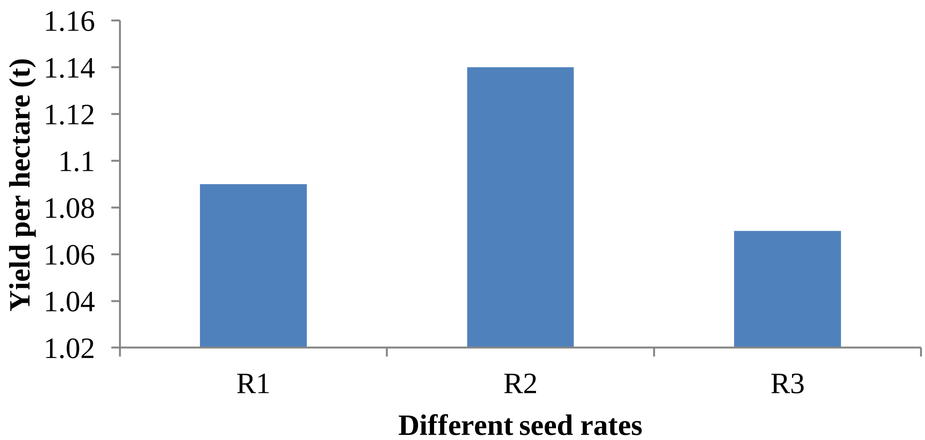

Fig. 4. Effect of different seed rates on yield per hectare of black cumin

Here, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

Table 5. Effect of different levels of phosphorus on number of capsules per plant, length of capsule, breadth of capsule and number of seeds per capsule, 1000-seeds weight (g), yield per plot (g) of black cumin

Treatments	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule	1000-seeds weight (g)	Yield per plot (g)
P_0	16.32 d	1.11 d	0.77 d	66.24 d	2.74 d	141.08 d
P_1	17.93 c	1.24 c	0.85 c	69.59 c	2.83 c	154.46 c
P_2	20.69 a	1.51 a	1.05 a	80.07 a	3.08 a	175.68 a
P_3	19.14 b	1.35 b	0.95 b	74.42 b	2.93 b	164.64 b
$LSD_{(0.05)}$	0.43	0.04	0.02	1.87	0.08	2.28
CV%	2.42	3.37	2.54	2.65	2.92	1.47

In a column means having similar letter(s) are statistically similar at 0.05 level of probability.
Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1}

Table 6. Effect of different levels of seed rates on number of capsules per plant, length and breadth of capsule and number of seeds per capsule, 1000-seeds weight (g), yield per plot (g) of black cumin

Treatments	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule	1000-seeds weight (g)	Yield per plot (g)
R_1	18.51 b	1.30 b	0.91 b	72.64 a	2.89 ab	157.98 b
R_2	19.20 a	1.35 a	0.94 a	74.18 a	2.94 a	164.46 a
R_3	17.86 c	1.25 c	0.87 c	70.92 b	2.85 b	154.45 c
$LSD_{(0.05)}$	0.37	0.03	0.01	1.62	0.07	1.97
CV%	2.42	3.39	2.54	2.65	2.92	1.47

In a column means having similar letter(s) are statistically similar at 0.05 level of probability.
Here, R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

Table 7.Combined effect of different levels of phosphorus and seed rates on capsules per plant, length of capsule, breadth of capsule and number of seeds per capsule, 1000-seeds weight (g), yield per plot (g), yield per hectare (t) of black cumin

Treatment Combinations	Capsules per plant	Length of capsule (cm)	Breadth of capsule (cm)	Number of seeds per capsule	1000-seeds weight (g)	Yield per plot (g)	Yield per hectare (t)
P_0R_1	16.48 h	1.12 hi	0.78 g	66.77 hi	2.75 fg	141.12 h	0.98fg
P_0R_2	17.11 gh	1.15 h	0.80 g	67.25 hi	2.78 fg	146.75 g	1.01 fg
P_0R_3	15.37 i	1.07 i	0.74 h	64.71 i	2.68 g	135.36 i	0.94 g
P_1R_1	18.00 ef	1.25 fg	0.85 f	69.52 fgh	2.83 def	152.40 f	1.05 def
P_1R_2	18.33 e	1.27 f	0.88 f	70.81 fg	2.85 def	161.18 e	1.11cde
P_1R_3	17.47 fg	1.19 gh	0.81 g	68.44 gh	2.80 efg	149.81 fg	1.04 ef
P_2R_1	20.40 b	1.51ab	1.04 b	79.93 ab	3.08 ab	174.24 b	1.21ab
P_2R_2	21.80 a	1.59 a	1.10 a	82.15 a	3.15 a	182.88 a	1.27 a
P_2R_3	19.87 bc	1.43 c	1.01 bc	78.12 bc	3.02 abc	169.92 c	1.18 bc
P_3R_1	19.15 cd	1.35 de	0.95 de	74.33 de	2.93 cde	164.16 de	1.14 bc
P_3R_2	19.56 c	1.39 cd	0.98 cd	76.50 cd	2.97 bcd	167.04 cd	1.16bc
P_3R_3	18.72 de	1.30 ef	0.93 e	72.42 ef	2.89 c-f	162.72 e	1.13bcd
$LSD_{(0.05)}$	0.75	0.07	0.03	3.25	0.14	3.95	0.08
CV(%)	2.42	3.39	2.54	2.65	2.92	1.47	4.52

In a column means having similar letter(s) are statistically similar at 0.05 level of probability.
Here, P_0=control, P_1= 35 P kg ha^{-1}, P_2= 40 P kg ha^{-1} and P_3= 45 P kg ha^{-1} , R_1= 8 kg ha^{-1} of seeds, R_2= 10 kg ha^{-1} of seeds and R_3= 12 kg ha^{-1} of seeds

5. CONCLUSION

This study observed that different levels of phosphorus and seed rates have a positive effect on the growth and yield of black cumin.

- **I.** In the case of the yield of black cumin, P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) treatment combination was given a better performance of all the yield contributing parameters and yield (1.27 t per ha) of black cumin than the other treatment combinations.
- **II.** So, the treatment combination of P_2R_2 (40 P kg ha^{-1} + 10 kg ha^{-1} of seeds) can be repeated in different agro-ecological zones of Bangladesh for a better yield of black cumin.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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