



Investigating the Effects of Different Levels of Phosphorus on Morphological Characteristics of Black Cumin (*Nigella sativa* L.)

Bakhtyar Rezaee ^{1*}, Nesar Ahmad Qasani ²

¹Department of Horticulture and Forestry, Faculty of Agriculture, Baghlan University, Baghlan, Afghanistan

²Department of Agronomy, Faculty of Agriculture, Baghlan University, Baghlan, Afghanistan (na.qasani@gmail.com)

*Corresponding Author: janrezaee2014@gmail.com

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Keywords

Baghlan, Black cumin, Morphological, Phosphorus, Yield

Abstract

Black cumin (*Nigella sativa* L.) is an annual medicinal herb of the Ranunculaceae family, widely used for food, medicine, and therapeutic purposes for centuries. Globally, 20 to 24 species have been identified, with 12 to 15 species distributed across various regions. This valuable medicinal and aromatic plant can be successfully cultivated under the climatic conditions of Baghlan province. This study was conducted in 2024 at the research farm of the Faculty of Agriculture, Baghlan University, using a randomized complete block design (RCBD). Four levels of phosphorus fertilizer (0, 65, 130, and 195 kg/ha) were applied to evaluate their effects on morphological traits and yield. The objective was to assess the influence of phosphorus on plant growth and productivity. Results showed that phosphorus application significantly affected morphological traits. Higher levels, particularly 130 and 195 kg/ha, improved plant height, number of capsules per plant, seeds per capsule, and overall yield, highlighting the importance of proper phosphorus management.

Research/Review Article

1. Introduction

Today, the economic and therapeutic importance of the medicinal plant black cumin is highlighted in various fields, including health, industry, pharmaceuticals, and food. Therefore, the identification and introduction of medicinal plants for their management and utilization is essential (Tabatabaei *et al.*, 2019). Given the increasing reliance of people on medicinal plants and the beneficial effects of these plants, along with the recognition of the negative impacts of chemical drugs, it seems necessary to explore the local reserves of available medicinal plants, considering the diverse conditions of each country (Long and Rong, 2014). Local communities possess a rich treasury of medicinal plants' effects and therapeutic properties, yet indigenous knowledge regarding these plants is rapidly being forgotten and lost. In light of the recent trend towards herbal medicine and the lack of information on medicinal plants, it appears that indigenous knowledge and traditional practices could play a significant and foundational role in future scientific research (Ramezani and Minaei Far, 2016). Medicinal plants are the most natural remedy for human diseases that nature has provided for humanity. Despite the advancements in modern pharmaceutical science that have liberated humanity from various diseases, the role of medicinal plants and their positive effects cannot be overlooked. The primary and effective compounds found in medicinal plants are continuously used as irreplaceable materials (Gol Mohammadi *et al.*, 2010). Medicinal plants have been utilized for food, medicinal purposes, and therapeutic applications for centuries (Bayram *et al.*, 2010). Black cumin (*Nigella sativa* L.) is an annual herb from Ranunculaceae family. There are 20 to 24 species of black cumin worldwide, with 12 to 15 of these species reportedly found in Turkey's flora (Ayhan, 2012; Baser, 2010). Morphologically, black cumin typically grows to a height of 35 to 70cm, with its seeds being black and measuring between 2.5 and 4 mm (Baydar, 2013).

Nutrient management and regulation are crucial for achieving optimal yield. Improper management of nutrients leads to decreased performance and lower product quality. The limited availability of phosphorus in the soil poses significant challenges to crop productivity (Khan *et al.*, 2023; Khan *et al.*, 2024). Different levels of phosphorus have a positive impact on the growth and yield of black cumin (Khan *et al.*, 2022). The use of phosphorus fertilizer facilitates the absorption of other nutrients,

enhances chlorophyll production, and promotes grain yield and root growth (Turkmen, 2025). N.P.K fertilizers at a rate of 65:65:70 kg/ha had a significant effect on the growth and yield of black cumin (Varun *et al.*, 2020).

Medicinal plants hold particular significance in Afghanistan due to the country's unique climatic conditions and their diverse range of uses. Furthermore, these plants contribute to the livelihoods of residents and serve as a source of income for rural communities. The cultivation of this plant, in accordance with the appropriate use of nutrient elements, can transform agricultural conditions and increase the income of farmers in rural areas.

Black cumin (*Nigella sativa* L.) is a short-lived annual plant typically found in semi-arid regions. This plant matures in one year and grows to a height of between 1-2 feet (30 to 60 cm). Its leaves are gray-green, its flowers range from white to blue, and its fruits are capsules containing numerous aromatic black grains. The seeds contain up to 40% oil and approximately 1.4% essential oil. This plant is recognized as a medicinal plant with extensive therapeutic, nutritional, and health applications (Yagoub, 2023). Proper dosing of fertilizers is essential for achieving maximum yield. The use of too little or too much fertilizer can negatively affect plant growth. Nitrogen and phosphorus are two important nutrients in plant nutrition (Turkmen, 2025). Based on conducted studies, it can be concluded that biological phosphorus and chemical phosphorus fertilizers influence the growth, yield, and quality of *Nigella sativa* L. (Rana, 2012). Phosphorus deficiency, due to the chemical properties of calcareous compounds, is one of the most significant challenges in the sustainable nutrition of black cumin (*Nigella sativa* L.), especially in dry and semi-dry areas (Seyyedi *et al.*, 2019). Phosphorus is one of the most crucial nutrients for plant growth and high yield, being stored in the seeds (Whit and Veneklass, 2012).

Bairagi (2014) generally states that phosphorus is essential for the overall health of the plant, root development, and increased stem strength. This element enhances flower formation and uniform seed production. It also improves seed quality and increases the plant's resistance to diseases. Plant growth and seed yield increase when phosphorus is added to the soil. Numerous studies on *N. sativa* have been conducted by various researchers, and this plant is widely used for therapeutic purposes due to its antihypertensive, digestive, liver-enhancing, diuretic, soothing, antibacterial, anti-diarrheal, and

appetite-stimulating properties, as well as in skin disorders (Ahmad *et al.*, 2013). The goal of commercially cultivating black cumin is to achieve high yields of essential and fixed oils per hectare. Black cumin contains 4.8% crude fibre. Balanced fertilizer application is one of the important methods that impacts yield and quality (Ramadan, 2015). Therefore, the required amount of fertilizer, the timing of fertilizer application, and the method of use should be determined based on studies for each species of plant and the region where production takes place. The phosphorus content in plants generally varies between 0.05% to 0.1% based on dry matter, with inorganic phosphorus converting into various organic compounds, including enzymes, nucleic acids, and proteins. Additionally, compounds such as adenosine monophosphate (AMP), adenosine diphosphate (ADP), and adenosine triphosphate (ATP), along with other organic phosphate groups, play an important role in the energy transfer required for metabolic events in plants (Turan, 2014). Muhammad *et al.* (2017) reported that phosphorus fertilizer significantly improves growth parameters, yield, yield components, and nutrient content in black cumin. High levels of phosphorus and nitrogen have been reported to lead to significant increases in fixed oil, essential oil, protein, and phosphorus content, possibly due to the effect of phosphorus on root development, flower formation, grain and fruit development (Hammo, 2008). Phosphorus is essential for the overall health of plants, root development, and increased stem strength. This element enhances flower formation and uniform seed production, improves seed quality, and increases plant resistance to diseases. Plant growth and seed yield increase when phosphorus is added to the soil (Bairagi, 2014).

2. Materials and Methods

This study investigated the impact of varying phosphorus levels on the yield and yield components of the medicinal plant black cumin, taking into account the climatic conditions in Baghlan Province. This experiment was conducted to study the effect of different levels of phosphorus on the morphological traits and yield of the medicinal plant black cumin in 2024 at the research farm of the Agriculture Faculty at Baghlan University. The seeds of black cumin were sourced from the research farm of Gorgan University of Agricultural Sciences and Natural Resources, Iran, and have not yet been cultivated in Afghanistan's agricultural areas. In this experiment, three different levels of phosphorus fertilizer, along with a control (no phosphorus fertilizer), were used. The treatments examined in this experiment are as follows:

T1= 0 P kg/ha

T2= 65 P kg/ha

T3= 130 P kg/ha

T4= 195 P kg/ha

This experiment was conducted using a Randomized Complete Block Design (RCBD) with three replications. A total of 12 plots were included in this study, with each plot measuring $1.5 \times 2=3\text{m}^2$. The distance between blocks was 1m, and the distance between plots was 50cm. The total phosphorus fertilizer required (0, 65, 130, and 195 kg/ha) was uniformly applied and mixed with the soil in each block as a part of the urea combination before planting. After preparing the land, the seeds of black cumin were sown in rows at a depth of 1 to 2cm with 35cm between rows and 10cm between plants within the rows. To collect the desired data, ten plants were randomly selected and marked in each plot. Morphological traits such as plant height, number of branches per plant, number of capsules per plant, capsule weight, thousand seed weight, number of seeds per capsule, and overall yield were measured. Data analysis was performed using the OPSTAT software, which included an ANOVA test with a significance level of 95%.

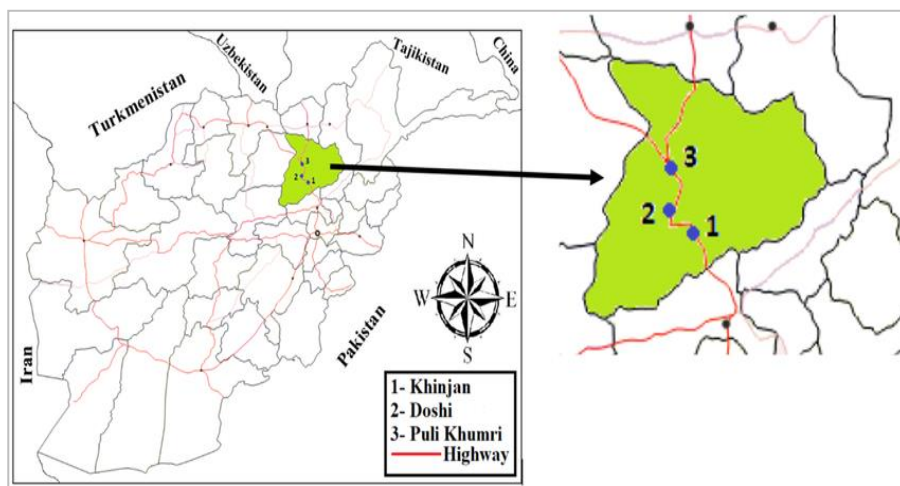


Fig 1. Map of research area, Puli-Khumri-Baghlan-Afghanistan

3. Results

The results of the statistical analysis in Table 1) indicate that phosphorus fertilizer had a significant effect on plant height and the number of capsules in the medicinal plant black cumin at 95% probability level. However, phosphorus fertilizer did not show a significant effect on the number of branches per plant in terms of biological yield.

Table 1: Analysis of variance for some morphological traits of black cumin under the influence of phosphorus fertilizer

Source of variation	DF	Plant height (cm)	No. Branches	No. capsules per plant	Plant weight
Replication	2	36.29	15.31	4.80	0.232
Phosphorus(Ph.)	3	816.39*	56.09 ^{ns}	272.82*	45.343 ^{ns}
Error	6	87.88	34.33	113.51	28.525
C.V.		9.00	46.076	37.96	56.018

*is significant at the level of 5%; ns non-significant.

According to (fig. 2), black cumin plants treated with 195 and 130kg/ha of phosphorus fertilizer exhibited greater heights compared to the control and 65kg/ha phosphorus. However, no significant difference in height was observed between the 65kg/ha phosphorus treatment and the control. Similarly, there was no significant difference between 195kg/ha and 130kg/ha of phosphorus fertilizer. Therefore, it is suitable to use 130kg/ha of phosphorus.

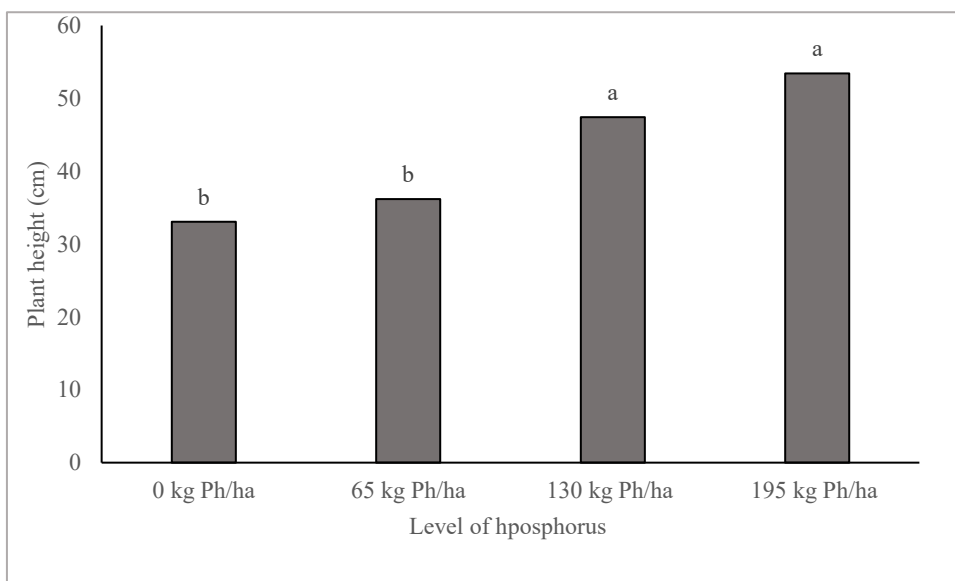


Fig 2. The height of black cumin plants is affected by different levels of phosphorus

Fig. 3: Plants that received 195 and 130kg/ha of phosphorus fertilizer had a higher number of capsules compared to the control. However, no significant difference in the number of capsules was observed between the 195kg/ha and 130kg/ha of phosphorus. Similarly, there was no significant difference in the number of capsules between 65kg/ha of phosphorus and the control. Therefore, based on the obtained results, it is recommended to use 130kg/ha of phosphorus fertilizer per hectare for black cumin plants.

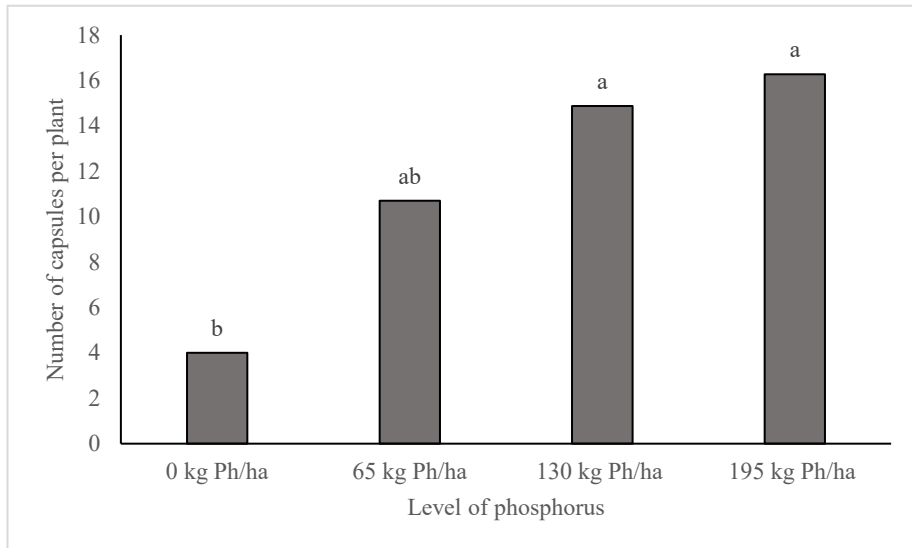


Fig 3: Number of capsules in black cumin plants affected by phosphorus fertilizer

Based on the analysis of Table 2, the results of the statistical analysis indicated that phosphorus fertilizer had a non-significant effect on the weight of 1000 seeds in black cumin plants. However, the number of seeds per capsule was significantly affected by phosphorus fertilizer at 95% probability level. The weight of the capsule was not significantly influenced by phosphorus fertilizer. Additionally, the high phosphorus fertilizer application had a significant effect on the yield of black cumin plants at 95% probability level.

Table 2: Analysis of variance for yield components in black cumin plants affected by phosphorus fertilizer

Source of variation	DF	Capsules 1000 Weight (gr)	No. seeds per capsule	Capsules weight	Yield
Replication	2	0.002	475.71	0.07	0.063
Phosphorus (Ph)	3	0.025 ^{ns}	3,044.38*	0.06 ^{ns}	7.315*
Error	6	0.017	821.54	0.03	1.701
C.V.		24.057	19.419	40.656	22.667

*is significant at the level of 5%; ns non-significant.

According to the results of statistical analysis, the application of 195, 130, and 65 kg/ha of phosphorus fertilizer had a significant effect on the number of seeds per capsule compared to the control. However, no significant differences were observed in the number of seeds per capsule between the 195, 130, and 65 kg/ha of phosphorus fertilizer (Fig 4).

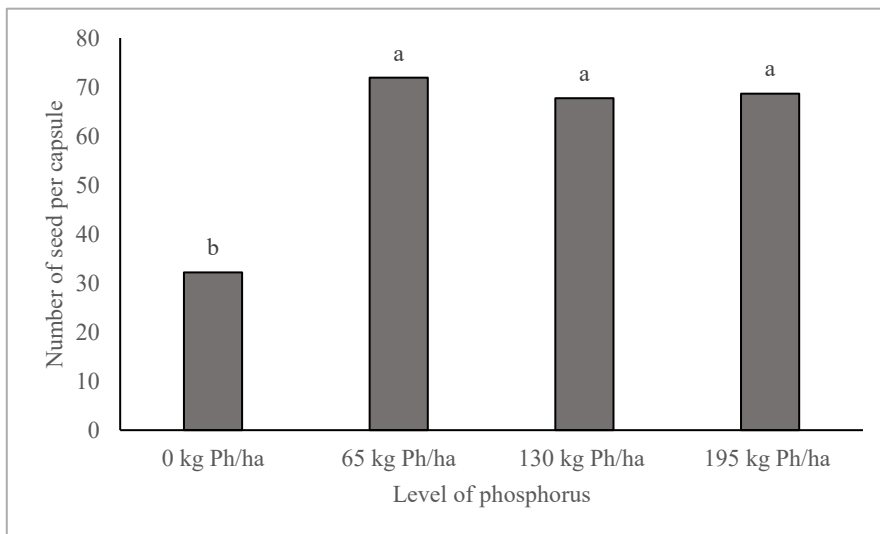


Fig 4: Number of seeds per capsule in black cumin plants affected by phosphorus fertilizer Fig (5) indicates that the application of 195 kg/ha of phosphorus resulted in a higher yield compared to 130 and

65 kg/ha of phosphorus, as well as the control. However, no significant difference in yield was observed between 130 kg/ha and 65 kg/ha of phosphorus compared with control in black cumin.

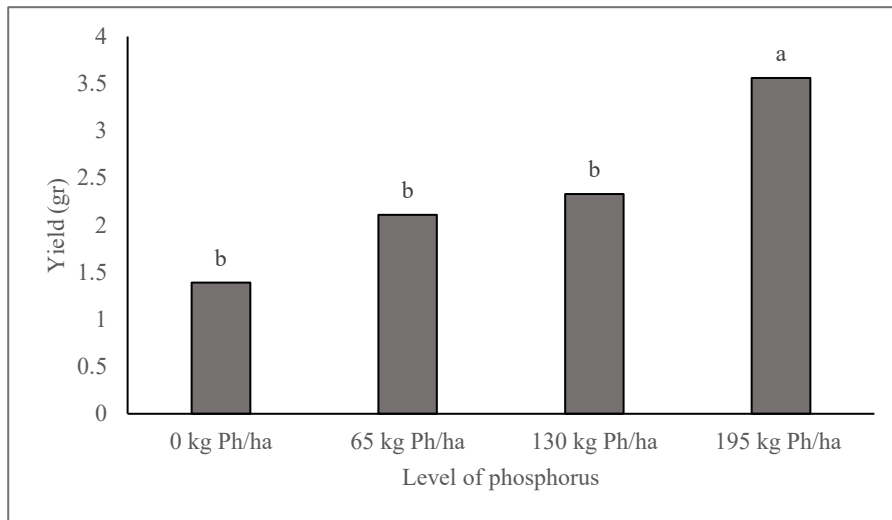


Fig 5: Yield of black cumin plants affected by different levels of phosphorus fertilizer

4. Conclusion and Discussion

The results of this study indicate that high levels of phosphorus have a significant effect on certain morphological traits of black cumin, while this element did not influence other parameters. Specifically, doses of 195 and 130 kg/ha of phosphorus fertilizer had a positive and significant effect on plant height, the number of capsules per plant, the number of seeds per capsule, and the overall yield. Therefore, to ensure a comprehensive understanding, it is recommended that further research is conducted to determine the optimal phosphorus levels and to investigate its interactions with other nutrients and environmental conditions.

The results indicate that phosphorus fertilizer, as an essential element, plays a significant role in growth, development, and yield of plants. Additionally, examining the effect of phosphorus fertilizer on the morphological traits of black cumin is a topic of interest in scientific research. Studies conducted by scientists in this field support this notion. For instance, Haghghat *et al.* (2020) reported that increasing phosphorus levels led to increase the number of capsules, the number of seeds per capsule, the weight of one thousand seeds, and ultimately, the yield, which aligns with some parameters of this study. Kizilkaya (2008) express that, response to different levels of phosphorus may vary depending on the

genotype of different black cumin types. This genetic diversity can significantly impact how plants respond to phosphorus fertilizers. Furthermore, phosphorus fertilizer promotes root, shoot, and biological yield growth in black cumin, which contradicts the findings of this study. Khan *et al.* (2023) reported that phosphorus is an essential nutrient and plays a central role in plant growth and development. However, limited availability of phosphorus in the soil poses significant challenges for agricultural productivity. Experimental results by Ali *et al.* (2015) at the research farm of Bangladesh University during 2013-2014 showed that the initiation of the first flower bud, capsule formation, and capsule maturation in 50% of black cumin plants were not affected by N-P-K fertilizer. Khan *et al.* (2022) conducted experiments at the Horticultural farm of Sher-e-Bangla Agricultural from 2019 to 2020. The study demonstrated that different phosphorus levels and seed rates positively affected the growth and yield of black cumin. Türkmen (2025) showed in a study in Turkey that applying 60 kg/ha of phosphorus fertilizer significantly increased seed yield and improved root growth. He emphasized that phosphorus aids in the better absorption of other nutrients and increases chlorophyll production. Khan *et al.* (2024) reported that improper nutrient management leads to reduce the quality and yield of *Nigella sativa* L.

5. Statements and Declarations

5.1 Competing interests

The author(s) declare no competing interests.

5.2 Data availability

Data is Available

Ethical Approval

Not Applicable

5.4 Consent to participate/Consent to publish

Not Applicable

5.5 Funding

This research received no external funding.

5.6 Acknowledgments

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5.7 Author Contributions

Bakhtyar Rezaee: Wrote the report, collected and analyzed data. **Nesar Ahmad Qasani:** planning, design, and management of work in the research area.

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