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Effect of potassium and plant geometry on the growth and yield of cumin (*Cuminum cyminum* L.) in Helmand Afghanistan

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Abstract

A field experiment was carried out at the research farm of Helmand University, Afghanistan during December 2021 to April 2022 to investigate the effect of different potassium levels (0, 40, 80,120,160 and 200 kg K_2SO_4 ha^{-1}) and plant geometries (20 cm×10 cm and 30 cm ×10cm) on the growth and yield of cumin (*Cuminum cyminum L.*). The experiment was laid-out in a randomized complete block design (RCBD) replicated three times. The results revealed that wider spacing (30 cm×10 cm) exhibited greater plant height (33.56 cm), seed yield 472.6 kg ha^{-1}, 1000-seed weight (3.55 g), dry matter accumulation (3.79 g plant^{-1}), umbels plant^{-1} (26.1), seeds umbel^{-1} (23.7), umbellate umbel^{-1} (5.11), straw yield (767.16 kg ha^{-1}), biological yield (1252.9 kg/ha), harvest index (37.5 %), and B: C ratio (2.73), production efficiency (4.29 kg ha^{-1} day^{-1}), water-use efficiency (1.02 kg ha^{-1} mm^{-1}) and monetary efficiency (756.3 AFN ha^{-1} day^{-1}). Application of potassium at the highest rate (200 kg K_2SO_4 ha^{-1}) recorded the highest growth, yield attributes, yield, economics and resource-use efficiencies (production efficiency, water-use efficiency and monetary efficiency). Likewise, plots that were treated with wider spacing and the highest rate of potassium (200 kg K_2SO_4 ha^{-1}) produced higher yield, and yield components (200 >160 >120 >80 >40 > control). However, the difference between 160 and 200 kg K_2SO_4 ha^{-1} was not significant. Overall, results of this study showed that cumin growth, yield and yield components increased with wider spacing (30 cm × 10 cm) and with the application of 160-200 kg K_2SO_4 ha^{-1} potassium level; seed yield and important yield attributes did not increase significantly beyond 160 K_2SO_4 ha^{-1}. Thus, the study suggests that cumin should be planted at (30 cm × 10 cm) and fertilized with 160 K_2SO_4 ha^{-1}.

Keywords: Cumin, economics, growth, potassium, resource-use efficiency, yield

Introduction

Cumin (*Cuminum cyminum* L.) has assumed its status as a high-value, low-volume spice crop, providing significant economic returns to farmers, particularly in India, which contributes 70% of the world's production. Its popularity in global cuisine and traditional medicine is driven by its distinct, strong aroma and flavor, which is primarily due to the presence of cumin aldehyde (2.5%–4.5%) (Brar *et al.*, 2022). There are several types of cumin found in Afghanistan, such as black and wild mountain cumin, which are priced for their potent perfume and flavor. Afghanistan's varied climate and topography enable the production of a large variety of crops at various periods of the year (World Bank, 2014). Less than 10% of Afghanistan's total land area is used for crops; instead, much of it is used for vast grazing because of the country's difficult terrain and scar-

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city of water (Caiserman *et al.,* 2025). Given the emerging climate change scenarios, cumin stands out among horticulture crops due to its tolerance to drought**.**

Crop geometry plays a significant role in the growth and development of crops (Dass and Chandra, 2013; Aliveni *et al.,* 2025). Optimal plant population balances the translocation of photosynthates within the plant; an over-populated field creates competition for resources, which reduces the amount of dry matter that accumulates in plants**.** Planting geometry maintains ideal plant population and improves light interception, enhances nutrient availability, increases water- use efficiency, facilitates intercropping (Dass *et al.,* 2016) and eases the use of machinery. In cowpea, crop geometry have a beneficial impact on the growth parameters viz., plant height, shoot dry weight, and root dry weight (Ahmadi *et al.,* 2023). Wheat yield attributing factors, grain yield, straw yield, and harvest index were shown to be significantly affected by the application of nitrogen and crop geometry of 25 cm × 10 cm spacing (Kumar *et al.,* 2024).

Among the 3 macronutrients, nitrogen (N), phosphorus (P), and potassium (K), farmers mainly focus on the management of N fertilizers and give less concern to P and K fertilizers. However, each fertilizer has equal function and importance in plants. Applying N, P, and K in a balanced manner can boost crop yield, enhance fertilizer-use efficiency, and lessen environmental effects. Potassium is engaged is involved in several essential physiological processes, including the regulation of enzymes and the synthesis of organic compounds, water relations and stomata functions, photosynthesis, and tolerance to biotic and abiotic stress. K can affect photosynthetic carbon assimilation and sugar metabolism (Shah *et al.,* 2024). Depletion of plant-available K^+ in soils following years of insufficient K fertilization causes a number of detrimental effects in developing nations, such as impairing the best use of supplied N and P fertilizers and lowering farmer incomes (Cakmak, 2010). In the case of the spice root crop, application of K greatly enhanced plant height, number of leaves, tillers, mother, and primary and secondary rhizomes (Chanchan *et al.,* 2018). With this backdrop the current study was conducted to study the response of cumin (*Cuminum cyminum* L.) to different crop geometries and potassium application rates in Helmand region of Afghanistan

Materials and Methods

The field experiment entitled 'Effects of different levels of potassium and plant geometry on the growth and yield of cumin (*Cuminum cyminum* L.)' was conducted at the Helmand University Agriculture Faculty Experimental Farm, Lashkar Gah Helmand Afghanistan during 2021-2022. The climate of the experimental site is generally desert type and features fairly dry conditions during the summer season of the year, with virtually there is less rainfall. The average annual temperature hovers around 18 °C; with respect to rainfall, ~180 mm of precipitation occurs annually. The site receives only 6–8 inches of rainfall year^{-1} with a relative average humidity of ~41%. On an average, February is the most humid month and June is the least humid month of the year. The warmest month of the year is July, with an average temperature of ~35.5 °C, and the coolest month of the year is January, with an average temperature of ~5–6 °C. The highest precipitation occurs in the month of January and February.

The experiment was arranged in a split-plot design with three replications. The distance between adjacent plots and replications was maintained at 0.5 m and 2.0 m, respectively. Thus, the gross plot-size was [3m (w) × 4 m (L) = 12.0 m^2]. Net-plot size was 2.6 m × 3.5m for plant spacing (20 cm × 10 cm) and 2.4m × 3.5 m for 30 cm × 10 cm spacing. The experiment was laid-out in East-West direction. As per the layout plan, treatments were applied to all the experimental plots. All recommended packages of practices, except treatments (fertilization), were followed uniformly to raise a satisfactory experimental crop. The experiment consisted of two crop geometries *viz.,* 20 cm × 10 cm and 30 cm × 10 cm, and six potassium fertilization treatments including 0 kg K_2SO_4 ha^{-1} (control), 40 kg K_2SO_4 ha^{-1}, 80 kg K_2SO_4 ha^{-1}, 120 kg K_2SO_4 ha^{-1}, 160 kg K_2SO_4 ha^{-1} and 200 kg K_2SO_4 ha^{-1}. Except treatments, other fertilizers were applied uniformly based on recommendations.

The experimental field was Moldboard–ploughed once before sowing and then levelled.

All agronomic cultivation practices were followed as per the recommended conventional practices.

In this experimentation, fertilizers were applied from different sources: K fertilizer through potassium sulphate (50 % K_2O), P fertilizer through DAP (46% P_2O_5), and (N 18%) fertilizer was applied, uniformly based on recommendations. Nitrogen fertilizers were applied at the rate of 50 kg N ha^{-1} and DAP 45 kg P ha^{-1}. Application dose of each fertilizer ha^{-1} and specific amount of each fertilizer $plot^{-1}$ mentioned in the Table 1.

The cumin seeds were soaked in water for 12 hours before sowing, which is helpful in getting good germination, and dried under shade for 1-2 hours to facilitate dibbling and the crop was sown on 12th December, 2021, and was lightly irrigated after sowing to good germination and uniform plant population.

The cumin crop was harvested at the physiological maturity stage as indicated by dark brown color. The border row plants were first harvested manually from all sides of each plot. The harvested plants are stacked on the clean threshing floor for drying in the sun. After drying, the seeds are separated by light beating with the sticks, and seeds were cleaned by winnowing, the weight of the clean seeds from each of the experimental plots was converted to seed yield per hectare.

Results and Discussions

Growth parameters

Plant height

The tallest plant height (26.8 cm and 33.5 cm) was recorded in the plots with larger space (30 cm × 10 cm) at 90 DAS and at harvest stage, respectively, whereas the shorter plants (26.3 cm and 32.2 cm) were recorded in the plots with (20 cm × 10 cm) at 90 DAS and at harvest, respectively (Table 2). Koli (2013) found similar results, with the lowest plant height reported at 15 cm × 15 cm spacing and the highest at 25 cm × 15 cm. A suitable plant population density enhances plant development because of the efficient use of natural resources (Ibrahim *et al*., 2022) and minimum competition between plant (Iddrisu *et al.*, 2024). In fact, all potassium levels starting from 40 to 200 kg ha^{-1} significantly improved plant height over the control. In a similar way, Panhwar *et al.* (2018) and Ali *et al.* (2015) reported that higher fertilizer levels were associated with the maximum plant height at harvest, while lower fertilizer levels were associated with the minimum plant height.

Dry matter accumulation

The effect of spacing and potassium levels on dry matter accumulation was significant, as given in Table 2. The wider spacing (30 cm × 10 cm) produced higher dry matter (3.79 g $plant^{-1}$) over the narrow space (20 cm × 10 cm). This may be explained by wider-spaced plants having less competition for nutrients, light, and water, which promotes higher growth and biomass buildup. It agrees with what Choudhary *et al.* (2021) found. Tak *et al.* (2023) also mentioned that crop geometry has a major impact on the efficiency of heat and radiation consumption in terms of dry matter accumulation. Compared to lesser spacing of 20 cm × 10 cm, the spacing of 30 cm × 10 cm has recorded considerably higher dry matter of reproductive parts.

The increasing rates of potassium application from 0 to 200 kg K_2SO_4 ha^{-1} caused increase in dry matter. K levels had a major impact on the buildup of dry matter as well. In contrast to the lowest

Table 1. Different levels of potassium with the amount of DAP $plot^{-1}$ and the recommended doses of N with the amount of urea $plot^{-1}$.

Treatment (Levels of phosphorus)	K_2SO_4 (50%)(g $plot^{-1}$)	Applied DAP (kg P ha^{-1})	Urea (46% N)(g $plot^{-1}$)
T1 : 0 kg K_2SO_4 ha^{-1} (Control)	0.0	54	50.28
T_2 : 40 kg K_2SO_4 ha^{-1}	96	54	50.28
T_3 : 80 kg K_2SO_4 ha^{-1}	192	54	50.28
T_4 : 120 kg $K_2SO_4 ha^{-1}$	288	54	50.28
T_5 : 160 kg K_2SO4 ha^{-1}	384	54	50.28
T_6 : 200 kg K_2SO_4 ha^{-1}	480	54	50.28

value (2.23 g/plant) in the control, the maximum dry matter (3.42 g/plant) was seen at the highest potassium level (200 kg K_2SO_4 ha^{-1}). This suggests that K fertilizer improves cumin plants' overall growth and biomass production. According to reports from Ali *et al.* (2015), the application of K had a substantial impact on the buildup of dry matter.

Yield attributes and yields

Number of umbels plant^{-1}

The number of umbels per plant of cumin differed significantly due to different spacing (Table 3). The spacing of 30 cm ×10 cm resulted in significantly higher number of umbels per plant (26.1) over the spacing at 20 cm ×10 cm (25.71). Application of 200 kg K_2SO_4 had recorded significantly higher number of umbels per plant (26.6) than 160, 120, 80, 40, and 0 kg K_2SO_4 ha^{-1}. Kiran *et al*. (2020) noted that fertilizer dosages, plant geometry, and their interactions had a substantial impact on the number of umbels per plant in spices.

Number of seeds umbel^{-1}

The number of seeds umbel^{-1} of cumin was significantly higher at 30 cm ×10 cm (23.66 seeds umbel^{-1}) over spacing at 20 cm ×10 cm (22.16 seeds umbel^{-1}). The application of 200 kg ha^{-1} of K_2SO_4 and a wider spacing of 30 cm x 10 cm resulted in a considerable increase in the quantity of seeds per plant (Table 3). According to Choudhary *et al.* (2021), an increase in spacing resulted in the largest number of seeds/plant^{-1}.

Number of umbellate umbel^{-1}

The number of umbellate umbel^{-1} of cumin was significantly higher at 30 ×10 cm (5.11 umbellate umbel^{-1}) over spacing at 20 cm × 10 cm (4.55 umbellate umbel^{-1}). The application of potassium levels also had a significant effect on umbellate umbel^{-1}. More umbellate umbel^{-1} were also a result of elevated K levels and when the gap becomes broader (Table 3). According to research by Choudhary *et al.* (2021), there were more umbellate/umbel with wider spacing and there was a rise in the number of umbellate per plant as K levels rose (Solanki *et al.,* 2017).

Seed index (1000-seed weight)

Thousand-seed weight of cumin was significantly influenced by spacing and potassium levels. Cumin sown in wider spacing at 30 cm ×10 cm resulted in higher seed weight (3.558 g) over narrow spacing (3.528 g) at 20 cm ×10 cm. Similarly, Choudhary *et al.* (2021) observed that the broader the spacing, the higher the 1000-seed weight. K fertilization significantly affected the

Table 2. Plant height and dry matter accumulation of cumin crop as affected by plant spacing and potassium levels matter accumulation

Treatment	Plant height (cm)				Dry matter accumulation (g/plant) at harvest
	30 DAS	60 DAS	90 DAS	Harvest (%)	
Plant spacing					
20 cm × 10 cm	5.34	13.78	26.37	32.03	2.46
30 cm × 10 cm	5.63	14.52	26.88	33.56	3.79
SEm (±)	0.144	0.091	0.05	0.04	0.002
LSD (P=0.05)	NS	0.59	0.36	0.26	0.012
Potassium levels (kg K_2SO_4 ha^{-1})					
0	4.63	11.7	22.86	28.50	2.23
40	5.53	13.85	26.11	32.28	3.22
80	5.36	14.30	26.88	32.93	3.25
120	5.58	14.61	27.33	33.45	3.29
160	5.78	14.88	27.85	34.38	3.35
200	6.05	15.55	28.73	35.23	3.42
SEm (±)	0.212	0.10	0.21	0.18	0.01
LSD (Pd"0.05)	0.631	0.30	0.62	0.55	0.033

1000-seed weight. The highest value (4.208 g) was recorded at the highest K level (200 kg K_2SO_4 ha^{-1}), which was substantially greater than the control treatment (2.805 g) (Table 3).

Seed yield

Cumin seed yield as affected by various K levels and spacing has been presented in (Table 4). There was a discernible trend wherein broader spacing (30 cm × 10 cm) produced somewhat higher seed weight (472.611 kg ha^{-1}) compared to narrower spacing (20 cm × 10 cm), which produced 461.111 kg ha^{-1}, however, it was not statistically significant. It has also been reported by Chaudhary *et al.* (2023) that optimal spacing increases seed yield.

The highest K level (200 kg K_2SO_4 ha^{-1}) produced noticeably more seed weight (530.333 kg ha^{-1}) than the control (0 kg K_2SO_4 ha^{-1}), which produced only 309.333 kg ha^{-1}. K levels had a more noticeable effect on seed weight. This suggests that K fertilizer significantly increased cumin seed production. Sawan *et al.* (2011) had earlier found the same results.

Straw and biological yield

The wider spacing 30 cm × 10 cm recorded significantly higher straw yield (767.16 kg ha^{-1}) over narrow spacing at 20 cm × 10 cm (755.61 kg ha^{-1}). Wider spacing is associated with a larger

Table 3. Effect of spacing and potassium fertilization on yield attributes of cumin

Treatment	Umbels $plant^{-1}$	Seeds $Umbel^{-1}$	Umbellate $umbel^{-1}$	1000-seed weight (g)
Plant spacing				
20 cm × 10 cm	25.7	22.2	4.55	3.52
30 cm × 10 cm	26.1	23.7	5.11	3.55
SEm (±)	0.07	0.107	0.07	0.018
LSD (P=0.05)	0.23	0.315	0.21	NS
Potassium levels (kg K_2SO_4 ha^{-1})				
0	25.21	19.5	3.0	2.80
40	25.75	21.8	4.3	3.30
80	25.85	22.8	4.8	3.34
120	26.07	23.7	5.3	3.75
160	26.13	24.2	5.5	3.84
200	26.58	25.5	6.0	4.20
SEm (±)	0.13	0.18	0.12	0.02
LSD (P≤0.05)	0.39	0.54	0.36	0.07

Table 4. Effect of spacing and potassium fertilization on yield and harvest index

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Plant spacing				
20 cm × 10 cm	461.1	755.61	1231.5	37.3
30 cm ×10 cm	472.6	767.16	1252.9	37.5
SEm (±)	2.04	1.47	1.80	0.11
LSD (P=0.05)	NS	9.6	11.8	NS
Potassium levels (kg K_2SO_4 ha^{-1})				
0	309.3	578.8	886.8	34.8
40	471.7	590.5	1277.6	36.8
80	483.5	793.7	1304.3	37.3
120	494.0	796.7	1307.5	37.8
160	512.3	801.6	1331.8	38.5
200	530.3	807.0	1356.5	39.2
SEm (±)	8.5	1.74	4.31	0.62
LSD (P≤0.05)	25.26	5.180	12.81	1.85

biomass yield, as confirmed by (Tak *et al.*, 2023). Regarding spacing, a higher biological yield (1252.9 kg ha^{-1}) was recorded with wider spacing (30 cm × 10 cm) compared to narrow spacing of 20 cm × 10 cm (1231.5 kg ha^{-1}). On the other hand, Moodi (1999) concluded that, for the majority of crops, higher density results in higher biological production.

Application of 200 kg K_2SO_4 ha^{-1} resulted in significantly higher straw yield (807 kg ha^{-1}) compared to 0, 40, 80, 120, and 160 kg K_2SO_4 ha^{-1}.Regarding the levels of potassium, the highest yield (1356.5 kg ha^{-1}) was recorded from the application of 200 kg K_2SO_4 $ha^{-1,}$ whereas the lowest biological yield (886.8 kg ha^{-1}) was produced in 0 kg K_2SO_4 ha^{-1} (Table 4). According to Adnan *et al.* (2016), biological yield grew progressively as K levels climbed and responded favorably to changes in K levels. Potassium increased yield by improving physiological activities, water-use efficiency, and plant resistance to abiotic stress (Mulet *et al.*, 2023).

Harvest index

The plant at 30 cm × 10 cm spacing recorded significantly higher harvest index (37.5 %) than planting geometry at 20 cm x 10 cm (37.3 %). Agronomic practices that come before crop and soil tillage, such as row spacing and plant density, are among those that have a significant impact on the harvest index (Ion *et al.*, 2015). Plant density has a substantial effect on the harvest index; according to research by Bannayan *et al.* (2008), an increase in plant population density raised the harvest index.

Potassium application also had a significant effect on the harvest index of cumin. A significantly higher harvest index of cumin was recorded with the application of 200 kg K_2SO_4 ha^{-1} (39.2%) as compared to 0, 40, 80 and 120 kg K_2SO_4 (Table 4). This implies that K increased the crop's productivity by increasing both the overall biomass and the percentage of biomass devoted to the economic output. According to Nikju *et al.* (2015), applying a larger dose of K fertilizer improved plant growth and harvest index.

Economics

Cost of cultivation

Wider spacing (47180 AFN ha^{-1}) decreased cost of cultivation marginally by over narrow spacing (48180 AFN ha^{-1}). Successive increase of 40 kg K_2SO_4 ha^{-1}, from 0 to 200 kg K_2SO_4 ha^{-1} resulted in proportionate increments in cost of cultivation, being highest with the highest potassium level (58680 AFN) (Table 5). But as higher yields outweigh higher cultivation costs, raising crop yields can significantly lower production costs (Srivastava *et al.*, 2017).

Gross return

Wider pacing (30 cm ×10 cm) produced higher (131379 AFN ha^{-1}) gross return than narrow spacing (20 cm ×10cm) (128244 AFN ha^{-1}). Wider spac-

Table 5. Effect of spacing and potassium fertilization on gross return, net return and B:C ratio

Cost of cultivation	AFN ha^{-1}	Gross return AFN ha^{-1}	Net return AFN ha^{-1}	B: C ratio
Plant spacing				
20 cm × 10 cm	48180	128244	81064	2.72
30 cm × 10 cm	47180	131379	83199	2.73
SEm (±)		550.3	549.8	0.012
LSD (P=0.05)		NS	NS	NS
Potassium levels (kg K_2SO_4 ha^{-1})				
0	36680	86604	49924	2.36
40	41080	131315	90235	3.20
80	45480	134476	88996	2.95
120	49880	137298	87418	2.75
160	54280	142181	87901	2.61
200	58680	146993	88313	2.50
SEm (±)		2257	2257	0.04
LSD (P≤0.05)		6705	6705	0.13

ing reduced competition for resources, such as nutrients, sunlight, and water, as evidenced by the higher gross return. Moreover, significantly more gross return was obtained with higher K levels (160–200 kg KSO ha^{-1}); however, these treatments were statistically at par with each other (Table 5).

Net return

Wider spacing showed significant improvement in net return (83199 AFN ha^{-1}) over narrow spacing (81064 AFN ha^{-1}). Narrow spacing produced a lesser net return (90235 AFN ha^{-1} and gross return (128244 AFN ha^{-1}) due to higher plant density, which may have limited access to resources and decreased plant output (Iddrisu *et al.,* 2024). The application of K levels 40 kg K_2SO_4 (90235 AFN ha^{-1}) stood superior to all other treatments (200,160,120, 80 kg K_2SO_4 ha^{-1}) (Table 5). The results indicated a diminishing benefit with higher K levels, even though the changes were statistically nonsignificant. An eventual price increase on a cost item typically adds 5% to the overall cost of crop production (Watkins, 2021).

B: C ratio

The B: C was not much different in both wider and narrow spacing; the wider spacing had a slightly higher (2.73) B: C than the narrow spacing (2.72), which suggests that it may not exceed narrow spacing by a significant amount but still has some economic advantages. Among the K levels, the highest (B: C) ratio was recorded with 40 kg KSO ha^{-1} (3.20), followed by 80 kg KSO ha^{-1} (2.95). Both these levels were significantly superior to the remaining K treatments. Overall, the application of 40 and 80 kg KSO ha^{-1} resulted in the maximum B: C ratio, indicating greater economic efficiency due to a more favorable balance between input costs and returns.

Resource-use efficiency

Water-use efficiency

The water use efficiency increases somewhat in the 30 cm x 10 cm measurement, going from 0.99 kg ha^{-1} mm^{-1} to 1.02 kg ha^{-1} mm^{-1}. When adequate space is maintained, there is less competition from above and below ground, which enables plants to efficiently use the resources needed for growth. This is related to reports by (Iddrisu *et al.,* 2024 and Sadeghi *et al.,* 2009). However, over control, water use efficiency increased from 0.66 kg ha^{-1} mm^{-1} to 1.14 kg ha^{-1} mm^{-1} with increasing K levels of 200 kg K_2SO_4 ha^{-1} (Table 6).

Production efficiency

From 4.19 kg ha^{-1} day^{-1} at spacing 20 cm × 10 cm to 4.29 kg ha^{-1}day^{-1} at spacing 30 cm x 10 cm, the production efficiency indicates a modest rise. Production efficiency of the two spacing, however, did not differ significantly. However, as K levels increased, the production efficiency increased from 2.81 kg ha^{-1} day^{-1} to 4.82 kg ha^{-1} day^{-1} over

Table 6. Effect of spacing and potassium fertilization on resource-use efficiency

Treatment	Production efficiency (kg ha^{-1} day^{-1})	Water-use efficiency (kg ha^{-1} mm^{-1})	Monetary efficiency (AFN ha^{-1} day^{-1})
Plant spacing			
20 cm × 10 cm	4.19	0.99	736.9
30 cm × 10 cm	4.29	1.02	756.3
SEm (±)	0.04	0.01	11.39
LSD (P=0.05)	NS	NS	NS
Potassium levels (kg K_2SO_4 ha^{-1})			
0	2.81	0.66	453.85
40	4.28	1.02	820.32
80	4.39	1.04	809.05
120	4.49	1.06	794.71
160	4.65	1.10	799.10
200	4.82	1.14	802.85
SEm (±)	0.07	0.018	19.73
LSD (P≤0.05)	0.21	0.05	58.25

control at various K levels (40 to 200 kg ha^{-1} K_2SO_4) (Table 6). The optimal spacing between plants is necessary to achieve maximum production efficiency since plant geometry has a crucial impact on increasing yield (Kumar *et al.,* 2017). When agricultural resources are used efficiently, a suitable plant population density reduces intra and inter-specific plant competition and increases plant growth (Sadeghi *et al.,* 2009). This illustrates how cumin plants benefit from more space, which boosts resource use efficiency and, ultimately, accelerates growth, development, and productivity. Both spacing and K level have a positive interaction on production efficiency, as the assimilate translocation and accumulation were more in both cases due to efficient use of resources and the role of K in plant physiology. Singh *et al.* (2012) also reported the same interaction.

Monetary efficiency

The monetary efficiency due to varying spaces, from narrow to wide spacing, leads to slightly (statistically not significant) increased value of 735.9 AFN ha^{-1} day^{-1} to 756.3 AFN ha^{-1} day^{-1} (Table 6). At ideal plant density, resources are used effectively, stability is promoted, erratic stressors are mitigated, and the environment and natural resources are preserved (Tokatlidis, 2022). The value of monetary efficiency improved drastically at 6 various levels of K, receiving 453.85 AFN ha^{-1} day^{-1} to 820.32 AFN ha^{-1} day^{-1}, while with 200 kg ha^{-1} K_2SO_4 demonstrating the level of K 802.85 AFN ha^{-1} day^{-1}. In addition, K augments assimilate partitioning to roots and increases leaf photosynthetic rates, which improves dry matter accumulation and, thus, the monetary efficiency (Gerardeaux *et al.,* 2010). Higher growth, development, and yield due to higher K application (200 kg ha^{-1} K_2SO_4) leads to superior monetary efficiency compared to lower K application.

Conclusion

Overall**,** the study suggests that cumin should be planted at (30 cm × 10 cm) spacing and fertilized with 160 K_2SO_4 ha^{-1} to achieve better growth, yield, profitability and resource-use efficiency.

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