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Spraying with organic fertilizer Appetizer and phosphate fertilization, and their effect on some growth characteristics and yield of cumin *Cuminum cyminum* L., and the accumulation of some active substances

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Abstract

Al-Mafrajee, W. M., Almtarfi, H. I. & AL-Duhami, A. Sh. (2025). Spraying with organic fertilizer Appetizer and phosphate fertilization, and their effect on some growth characteristics and yield of cumin *Cuminum cyminum L.*, and the accumulation of some active substances. *Bulg. J. Agric. Sci., 31*(6), 1070–1078

A field experiment was conducted during the 2022–2023 agricultural season on soil with a sandy mixture texture, at the research station of the College of Agriculture, affiliated with the University of Wasit, It employed a randomized complete block design (RCBD) with three replications to study the effect of spraying Appetizer fertilizer at three concentrations (0, 0.75 and 1.5 ml per liter of water) symbolized as (C_3, C_2, C_1), and phosphate fertilizer at three levels (0,50, and 100 kg ha^{-1}), symbolized as (L_3, L_2, L_1) along with urea on the growth, yield, and accumulation of certain active substances in the volatile oil of *Cuminum cyminum* L. The results of the analysis of variance indicated significant differences among the fertilizer levels in the experiment. The phosphate fertilizer at the L_3 level recorded the most significant increase in growth traits, yield, and the accumulation of active substances in the volatile oil. The highest plant height averaged of 26.61 cm, with the highest average number of branches reached 7.11 branches Plant^{-1}. The maximum average number of inflorescences was 75.64 inflorescences Plant^{-1}, while the highest average weight of 1000 fruits reached 7.47 g Plant^{-1}. The highest individual plant yield averaged 1.66 g Plant^{-1}. Furthermore, the most notable averages were recorded for certain characteristics of the active substances in the volatile oil. The average percentage of protein in oil was 20.04%, the average percentage of oil in seeds was 2.85%, the highest average refractive index characteristic of the oil reached 1.47 degrees, and the concentration of some active substances in the volatile oil, with the highest average recorded for the substances p-cyinene at 174.2 and terpinene at 1234.3 respectively. The Appetizer fertilizer exhibited a significant increase in plant height, number of inflorescences, weight of 1000 fruits, individual plant yield, percentage of oil protein, and the active compounds in the oil, specifically p-cyinene and terpinen, at concentration C3. The interaction of the experimental factors was significant for most of the study's traits. Plants treated at the L_3 level with the C_3 concentration exhibited the highest average in plant height, number of inflorescences, individual plant weight, percentage of oil, refractive index, and active compounds in cumin oil such as a-pinene, p-cyinene, and terpinene.

Keywords: cumin; phosphate fertilizer; Appetizer; essential oils

Introduction

Cumin (*Cuminum cyminum* L.) is an annual winter herbaceous plant that belongs to the Apiaceae family. It thrives in limited-growing conditions (De et al., 2013). Its original habitats include Egypt, the Eastern Mediterranean, Turkestan, and Iran. It is also extensively cultivated in China, Japan, Indonesia, India, southern Russia, Morocco, Algeria, and Turkey, particularly in arid and semi-arid regions (Rabbani et al., 2011). Cumin has been integral to the production of various food items, including bread, cake, cheese, sauce, and curry powder. It enhances the flavor of meat and fish dishes and is predominantly used in its seed form, characterized by an aromatic scent and bitter taste. Notably, it is a key ingredient in soup recipes. Throughout history, cumin has held significance in ancient Babylonian and Egyptian cultures, serving as both a spice and a form of medicine. The ancient Egyptians even used it in the mummification process. Beyond culinary uses, cumin finds application in the perfume industry. Its essential oil serves the pharmaceutical industry by providing a pleasant scent and sterilizing threads.

Additionally, it contributes to veterinary and agricultural treatments, chemical preparations, and cosmetics (Keerthiga et al., 2019). The medicinal properties of cumin are noteworthy. Its seeds are used in the treatment of toothaches, diarrhea, epilepsy, diabetes, and gastric issues (Zolleh et al., 2009). Chemical studies have revealed its effectiveness against various bacteria and fungi, primarily attributed to the compound [p-isopropyl benzaldehyde], predominantly found in its dried fruits (Tbaileh et al., 2007). Reports from the World Health Organization and the United Nations highlight that many ailments arise from adverse reactions to chemical drugs. At the same time, remedies derived from medicinal plants, such as cumin, have minimal adverse effects. Chemical analysis of cumin oil demonstrates active substances like Terpinene at 84%, Cuminaldehyde at 60%, Pinene at 4.69%, and p-cymene at 1.77% (Romeilah et al., 2010). Despite these advantages, interest in developing medicinal and aromatic plants in the Arab world remains underutilized, despite favorable factors such as geographical location, climate, and rich biodiversity in medicinal herbs. The Arab world exports only a third of the global percentage of these natural resources compared to other nations (Abu Zaid, 2000). Nutrients play a crucial role in plant life, especially considering the higher rate of nutrient loss from soil compared to replenishment through weathering and mining. When chemical or organic fertilizers are not added to compensate for this loss, a deficit emerges (Sabet & Mortazaeinezhad, 2018). Given the limited mineral elements in Iraqi soil and the cumin plant's requirement for these elements, especially phosphorus, it becomes crucial to improve morphological characteristics, increase vegetative branches, flower fertility rate, seed yield, and active substances. Phosphorus is essential for nucleic acid energy (Jan et al., 2011). Micronutrients, such as zinc and manganese, provided through foliar nutrition with marine algae extract, offer the necessary elements that plants may struggle to absorb from the soil. This method enhances the plant's vital systems, stimulates growth, encourages flowering, increases yield, regulates cell osmotic potential, and boosts the plant's content of antioxidants, phenols, and flavonoids (Al-Hamdani and Ibrahim, 2018). Hence, this study aims to explore the impact of the Appetizer fertilizer and the phosphate fertilizer on specific growth characteristics, yield, and the accumulation of active substances in *Cuminum cyminum* L.

Materials and Methods

The field experiment took place at the research site (College of Agriculture, Wasit University) during the agricultural season (2022 – 2023). Soil analysis involved three random samples taken at depths of 0–30 cm. After air-drying, the soil was ground and sieved using a two mm-diameter sieve, and homogeneous samples were analyzed in the Soil and Water Resources Department laboratories at Wasit University's College of Agriculture. The analysis aimed to determine the physical and chemical characteristics, as shown in Table 1. The field experiment consisted of two factors: the first factor involved three levels of phosphorus fertilizer (0, 50, and 100 kg ha^{-1}) in the form of triple superphosphate (P_2O_5, 46% P), denoted as L_3, L_2, and L_1. This fertilizer was applied in a single batch before planting by thoroughly mixing it with the soil according to the study's prescribed levels for each experimental unit. It was applied in a line parallel to the planting line, at a distance of 15–20 cm. The second factor included three concentrations of Appetizer, at rates of (0, 0.75, and 1.5 ml $liter^{1}$ of water), symbolized as C_3, C_2, and C_1, respectively. Appetizer, manufactured by the French company Quimar, is a foliar fertilizer containing marine algae (Mn, Zn, GA142). It was sprayed on the plants using a backpack sprayer (16-liter capacity) in three stages, with one spray every 15 days. The first spray occurred when the first flower appeared, as instructed by the manufacturer. A dispersing material (cleaning solution) was added to the spray solution at a ratio of 15 cm^3 for every 100 liters of water to enhance absorption efficiency and reduce water surface tension (Al-Bayati, 2013).

Spraying was performed early in the morning to allow sufficient time for the fertilizer solution to contact the cumin plant's vegetative system. The experiment, following a randomized complete block design (RCBD), was implemented with three replications. The field was prepared by two perpendicular plowings using a rotary plow, followed by smoothing using disc harrows and leveling with a leveling machine. Each of the three replicates consisted of nine experimental units, with each unit measuring 4 m^2 (2 × 2 m). A gap of approximately 0.5 m was maintained between each experimental unit to prevent overspray when applying the Appetizer fertilizer. Each experimental unit comprised four rows, each 2 meters long, with a spacing of 50 cm between rows and 20 cm between holes at a depth of 2 cm, accommodating 40 plants per unit. Cumin seeds were planted on 15/10/2022, and seedlings emerged 14 days after planting. Subsequent thinning was carried out, leaving one plant per hole. Routine agricultural practices, including irrigation, hoeing, weeding, and pest control, were performed as required due to the plant's sensitivity to drought. Nitrogen fertilizer in the form of urea (46% N) was added to all treatments to stimulate growth, divided into two batches at a rate of 80 kg N ha^{-1} per batch (Talaei et al., 2014). The first batch was applied 30 days after planting, followed by the second batch 45 days after the initial application. The plants were harvested when the fruits reached an olive color, indicating maturity, just before complete drying. Some vegetative growth characteristics were recorded at this stage, with the following results:

- Plant height (cm): Ten plants from the two middle rows were randomly selected per experimental unit. During the flowering stage, plant height was measured from the soil surface to the top of the plant.
- Vegetative branches: The count of vegetative branches. $Plant^{1-}$ was calculated for ten randomly selected plants from each experimental unit.
- The number of flower inflorescences. $Plant^{1-}$ was determined for ten plants from the two middle rows of each unit.
- Thousand-fruits weight: The weight of 1000 fruits formed within each treatment and experimental unit was measured to estimate the yield per plant. Grams.

The volatile oil of cumin fruit was extracted using hydro-distillation with a Clevenger apparatus and stored in opaque, airtight glassware at 4°C (British, 1986).

Several oil properties were studied:

Estimate the percentage of the volatile oil according to the equation:

Percentage of oil = (Weight of resulting oil (g) / Weight of sample (g)) × 100 (Chen et al., 1993).

Additionally, the protein percentage in the oil was assessed. The refractive index of the oil was measured in $mg.\mu L^{-1}$ using an Abbe Refractometer at a temperature of 20°C. This was conducted by extracting 200 microliters of oil with a micropipette at 25°C, then determining its volume at the same temperature, following the methodology outlined by British (1986). The active constituents of cumin oil were separated through High-Performance Liquid Chromatography (HPLC) using a Koyota HPLC system (Shimadzu Zul C-6A) connected to a UV-Vis detector (Shimadzu SPD.6AV). The setup includes a pump that facilitates the movement of the mobile phase into the separation column at a flow rate ranging from 0.2 – 10 ml. min^{-1}, using standard solutions available under the conditions specified in Table 2. By comparing the peaks of unknown sample components with the known standard solution peaks, the retention time for the standard models in Table 3 was determined. Concentrations of identified substances in the sample were calculated using the equation:

Concentration of substance in the sample = (area of active substance in sample/area of active substance in standard solution) × concentration of standard solution.

Table 1. Chemical and physical characteristics of field soil before planting

Adjective measurement		The value	Unit	
Soil tissue components	The sand	544	$G. kg^{-1}$	Mineral Sandy
	Green	276	$G. kg^{-1}$	
	Clay	180	$G. kg^{-1}$	
Ready nitrogen		28	$Mg.kg^{-1}$soil	
Ready phosphorus P		4.2	$Mg.kg^{-1}$soil	
Ready potassium K		126.23	$Mg.kg^{-1}$soil	
Organic matter OM		7.6	$G. kg^{-1}$	
$CaCo_3$		150.3	$G. kg^{-1}$	
Ca ++		24.62	$Liter^{-1}$millimeters	
Solid sodium Na+		10.24	$Liter^{-1}$millimeters	
Mg ++ melodic magnesium		11.31	$Liter^{-1}$millimeters	
CI chlorine		27.81	$Liter^{-1}$millimeters	
Solving potassium		9.71	$Liter^{-1}$millimeters	
HCO_3 dissolved picarbonate		1.2	$Liter^{-1}$millimeters	
EC		8.76	Desmond M^{-1}	
Hydrogenic PH		7.29	------------	

Source: Authors' own elaboration

Table 2. Diagnosis of standard separated models of cumin fruits

The condition	Active ingredients in volatile oils
Column	Inverted phase shaft (I.D mm 4.6 × 50)
Mobile phase	(Phosphate buffer solution: methanol pH 4- (V/V30:70
Detector type	Ultraviolet radiation (Uv) has a wavelength of 245 nm
Flow speed of the mobile phase	1ml.min
Volume of the injected sample	microml 9
Separation temperature	35°c
Recording paper speed on the calculator	2cm/min

Source: Authors' own elaboration

Table 3. Retention time for samples diagnosed using the chromatographic separation method

Standard form	Sample holding time/min
a-penine	1.2
p-cymene	1.8
Terpinene	2.55
Cuimaldehyde	3.5

Source: Authors' own elaboration

Statistical analysis was performed using the GenStat Release 10.3DE program to compare mean experimental parameters via the least significant difference (LSD) at a probability level of 0.05 (Glaser and Biggs, 2010).

Result and Discussion

Plant Height (cm):

The results from the analysis of variance (Table 4) indicate a significant impact of the average fertilizer coefficients on plant height. The phosphate levels, specifically L_3 and L_2, exhibited notably higher average plant heights at 26.61 cm and 24.17 cm, respectively, surpassing the control treatment. Similarly, the concentration levels of Appetizer fertilizer, particularly C_3 and C_2, resulted in significantly increased plant heights, measuring 25.15 cm and 24.18 cm, respectively, compared to the control treatment. Regarding the interaction effect, there was a noteworthy increase in plant height at the L_3 and C_3 levels, reaching 28.48 cm. Conversely, the control treatment exhibited the lowest plant length at 21.61 cm. This rise in plant height may be attributed to the pivotal role of phosphorus in ATP synthesis, crucial for energy transfer and nucleic acid formation (DNA and RNA). This positively impacts the efficiency of carbon assimilation and boosts cell division activity by contributing to the formation of energy-rich compounds, such as ATP, UTP, CTP, and GTP, which are essential for phospholipid synthesis. Consequently, these enzymes and NADPH facilitate carbohydrate assimilation, promoting increased cell size and count, thus contributing to overall plant height (Al-Halbousi, 2013). The significant increase in plant height can also be linked to the application of Appetizer fertilizer on the cumin plant's vegetative system. This fertilizer, containing marine algae extract and micronutrients, compensates for potential soil nutrient deficiencies, thereby enhancing enzymes responsible for plant cell division and subsequently augmenting vegetative growth (Tanya et al., 2020).

Number of Branches (branch Plant^{1-})

The results in Table 5 show significant differences in the levels of phosphate fertilization regarding the number of branches on the plant. The L_3 phosphate level showed the highest average number of branches per plant, reaching 7.11branches. Plant^{-1}. However, no significant differences were observed for the concentration of the Appetizer fertilizer or the interaction between the two study factors regarding this trait compared to the control treatment, which recorded the lowest number of plant branches at 4.69 branches.

Table 4. Effect of spraying the Appetizer fertilizer, phosphate fertilization, and their interaction on plant height (cm)

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	21.61	21.91	22.84	22.12
L_2 (50)	23.78	24.25	24.49	24.17
L_3 (100)	24.95	26.40	28.48	26.61
l.s.d 0.05		1.086		0.623
Average Appetizer fertilizer	23.44	24.18	25.15	
l.s.d 0.05		0.624		

Source: Authors' own elaboration

Plant1-. The increase in the number of plant branches may be attributed to phosphorus, which plays a crucial role in various biological processes such as carbon metabolism and cell division. This is manifested in the emergence of new sites on the plant, particularly in the formation of new plant branches. Consequently, the plant size increases due to the higher levels of phosphate fertilizer (Al-Rubaie, 2010).

Number of Inflorescences (inflorescence.plant^{-1})

Table 6 exhibits significant differences among phosphate fertilization treatments in terms of the number of inflorescences per plant. The L_3 phosphate level showed the highest average number of inflorescences, reaching 75.64 inflorescences. Plant^{-1}, compared to the control treatment at the L_1 level, registered a lower average of 60.13 inflorescences.Plant^{-1} due to its lower phosphate fertilizer concentration. Regarding the Appetizer fertilizer, a noteworthy increase was observed at concentration C_3, averaging 71.21 inflorescences.Plant^{-1}, while the control treatment C_1 recorded a lower average of 66.62 inflorescences.Plant^{-1} for this trait. Concerning the interaction effect, the table results indicate a significant enhancement in the trait at Level L_3 and C_3, reaching 77.82 inflorescences.Plant^{-1}. Conversely, the control treatment displayed a lower average for the trait, amounting to 56.80 inflorescences.Plant^{-1}.

Weight of 1000 Fruits (g plant^{-1})

Table 7 illustrates significant differences among phosphate fertilization levels, specifically at the L_3 and L_2 levels, which scored averages of 7.47 and 6.84 g plant$^{-1,}$ respectively. Conversely, the control treatment exhibited the lowest average of

Table 5. The effect of Appetizer fertilizer and phosphate fertilization and their interaction on the number of branches (branch.Plant1-)

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	4.52	4.61	4.94	4.69
L_2 (50)	5.64	6.34	6.41	6.13
L_3 (100)	6.31	7.72	7.31	7.11
l.s.d 0.05		N.S		0.69
Average Appetizer fertilizer	5.49	6.22	6.22	
l.s.d 0.05		N.S		

Source: Authors' own elaboration

Table 6. The effect of Appetizer fertilizer, phosphate fertilization, and their interaction on the number of inflorescences (Inflorescence. Plant1-)

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	56.80	61.15	62.43	60.13
L_2 (50)	69.42	71.87	73.58	71.62
L_3 (100)	73.64	75.48	77.82	75.64
l.s.d 0.05		2.37		1.44
Average Appetizer fertilizer	66.62	69.50	71.21	
l.s.d 0.05		1.43		

Source: Authors' own elaboration

Table 7. Effect of the Appetizer fertilizer, phosphate fertilization, and the interaction between them on weight (1000 fruits)

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	5.21	5.38	6.24	5.61
L_2 (50)	6.41	6.69	7.44	6.84
L_3 (100)	7.36	7.22	7.82	7.47
l.s.d 0.05		N.S.		0.57
Average Appetizer fertilizer	6.33	6.43	7.16	
l.s.d 0.05		0.58		

Source: Authors' own elaboration

5.61 g plant^{-1} for this trait. This increase in phosphate fertilizer levels is attributed to its effectiveness in enhancing plant height, the number of branches, and the number of inflorescences, as shown in Tables 4, 5, and 6. These effects positively impact the carbon synthesis process, leading to increased food storage within plant cells. Subsequently, this stored food contributes to the development and augmentation of fruits downstream in the plant, thereby enhancing their size and weight (Talaei and Dehaghi, 2015). Regarding the results related to the Appetizer fertilizer, significant differences were observed at concentrations C_3 and C_2, averaging 7.16 and 6.43 g.plant^{-1}, respectively, while the control treatment at the C_1 level recorded a lower average of 6.33 g.plant^{-1}. Concerning the interaction effect, the results indicate no significant difference between the two study factors for this characteristic.

Weight of Individual Plant Yield (g)

Table 8 indicates significant differences in phosphate fertilizer levels, where the L_3 level achieved the highest yield for the individual plant trait, averaging 1.66 g per plant.Plant^{-1}. Conversely, the control treatment recorded a lower average at L_1, amounting to 1.17 g.Plant^{-1}. Similar to previous findings, the behavior of phosphate fertilizer in achieving this distinction aligns with previous observations that enhance individual plant yield. These findings corroborate those of Al-Halbousi (2013). Additionally, significant differences were observed with the application of Appetizer fertilizer at C_3, which attained the highest average of 1.49 g.Plant^{-1}. In comparison, the control treatment at the C_1 level recorded a lower average of 1.32 g.Plant^{-1}.

Regarding the interaction effect, the analysis of variance table displays a significant difference for the trait at levels L_3 and C_3, resulting in a difference of 1.79 g Plant^{-1}, while the control treatment yielded the lowest level for this characteristic at 1.12 g Plant^{-1}. This discrepancy is attributed to the role of nutrients in increasing the weight of 1000 fruits, consequently leading to an overall rise in the average weight of individual plants.

Studied Characteristics of Volatile Oil

Percentage of Protein in Seeds

Table 9 highlights significant differences among various phosphate fertilization levels. The L_3 level attained the highest percentage of protein in seeds, averaging 20.04%, while the control treatment L_1 exhibited the lowest percentage at an average of 16.21%. Additionally, at the C_3 concentration, the seeds showed the highest average percentage of protein, reaching 18.88%, whereas the C_1 concentration recorded a lower average of 16.58% for this trait. Notably, the results did not indicate any interaction between the two study factors. The increase in the percentage of protein can be attributed to the role played by phosphate fertilizer and

Table 8. The effect of the Appetizer fertilizer, phosphate fertilization, and their interaction on the yield of an individual plant

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	1.12	1.18	1.23	1.17
L_2 (50)	1.31	1.43	1.45	1.40
L_3 (100)	1.53	1.67	1.79	1.66
l.s.d 0.05		0.059		0.034
Average Appetizer fertilizer	1.32	1.43	1.49	
l.s.d 0.05		0.033		

Source: Authors' own elaboration

Table 9. The effect of the Appetizer fertilizer, phosphate fertilization, and their interaction on the percentage of protein in seeds

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	15.08	16.63	16.92	16.21
L_2 (50)	15.73	17.58	18.95	17.42
L_3 (100)	18.93	20.43	20.78	20.04
l.s.d 0.05		N.S		0.92
Average Appetizer fertilizer	16.58	18.21	18.88	
l.s.d 0.05		0.93		

Source: Authors' own elaboration

nano-form Appetizer in providing essential nutrients, particularly nitrogen, and enhancing its absorption efficiency from the soil. This enhancement contributes to an increase in polymerization enzymes, aiding in protein formation. Furthermore, it enhances the efficiency of the plant's carbon metabolism, facilitating nitrogen assimilation and the formation of essential acids, DNA, and RNA, which are crucial for the protein synthesis process (Akbari et al., 2013).

Percentage of Oil in Seeds

Table 10 displays significant differences among various phosphate fertilizer levels. Levels L_3 and L_2 achieved the highest average percentages of oil in seeds, reaching 2.85% and 2.78% respectively, while the lowest average for this trait was recorded at level L_1, amounting to 2.69%. Notably, applying Appetizer fertilizer at concentration C_3 also yielded a significant difference, registering a higher average of

Table 10. The effect of the Appetizer fertilizer, phosphate fertilization, and their interaction on the percentage of oil in seeds

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	2.55	2.69	2.82	2.69
L_2 (50)	2.69	2.79	2.88	2.78
L_3 (100)	2.73	2.84	2.98	2.85
l.s.d 0.05		0.08		0.04
Average Appetizer fertilizer	2.65	2.77	2.89	
l.s.d 0.05		0.05		

Source: Authors' own elaboration

Table 11. The effect of the Appetizer fertilizer, phosphate fertilization, and their interaction on the refractive index character

Phosphate fertilizer levels kg.ha^{-1}	ml wate^{-1} Appetizer fertilizer concentration			Average phosphate fertilizer
	C_1(0)	C_2(0.75)	C_3(1.50)	
L_1 (0)	1.41	1.40	1.42	1.41
L_2 (50)	1.43	1.44	1.46	1.44
L_3 (100)	1.45	1.47	1.49	1.47
l.s.d 0.05		0.017		0.0096
Average Appetizer fertilizer	1.43	1.44	1.45	
l.s.d 0.05		0.0095		

Source: Authors' own elaboration

Table 12 The effect of Appetizer and phosphate fertilization and the interaction between them Concentration of active substances in the volatile oil (µg. ml^{1-})

Appetizer ml.L^{-1}	P kg ha^{-1}			
		$0L_1$	$50L_2$	$100L_3$
$0C_1$	a-pinene	31.8	66.7	85.7
	p-cyinene	56.1	69.3	94.4
	Terpinen	121.4	538.9	740.5
	Cuminaldehyde	152.7	640.7	1052.3
$0.75C_2$	a-pinene	46.3	78.4	92.7
	p-cyinene	78.2	57.9	129.8
	Terpinen	657.1	673.8	861.2
	Cuminaldehyde	126.4	533.2	943.2
C_3**1.5**	a-pinene	48.6	74.8	89.4
	p-cyinene	107.2	86.6	174.2
	Terpinen	887.4	323.7	1238.3
	Cuminaldehyde	174.8	823.5	973.4

Source: Authors' own elaboration

2.89% compared to concentration C_1, which recorded the lowest average at 2.65%. Regarding the interaction effect, the analysis results demonstrate significant differences for this characteristic at levels L_3 and C_3, reaching 2.98%, while the control treatment showed a lower average for this trait at 2.55%. The increase in the percentage of oil in the seeds may be attributed to the elevated levels of phosphorus and the nutritious components present in the Appetizer fertilizer. These elements play a vital role in essential plant processes such as carbon synthesis and respiration. These processes produce compounds and secondary chemicals, including the volatile oil of the cumin plant (Rezaeieh et al., 2016).

Refractive Index of Volatile Oil

The results presented in Table 11 demonstrate significant differences among the various levels of phosphate fertilization. Level L_3 of fertilization achieved a higher average for the oil's refractive index, reaching 1.47 degrees, while the control treatment recorded the lowest average at 1.41 degrees. Moreover, significant differences were observed for plants treated with Appetizer fertilizer, with concentration C_3 achieving a higher average of 1.45 degrees. In comparison, the control treatment at concentration C_1 displayed the lowest average at 1.43 degrees. Regarding the interaction effect, it was notable between the two study factors concerning the oil's refractive index at levels L_3 and C_3, recording the highest average at 1.49 degrees. In contrast, the control treatment exhibited the lowest average at 1.40 degrees for this trait.

Concentration of Some Active Substances in the Volatile Oil

The investigation aimed to identify four types of active substances present in cumin oil: a-pinene, p-cymene, terpinene, and cuminaldehyde. Table 12 presents the differences in substance concentrations across various fertilization treatments in comparison to the control treatment. Plants treated with L_3 fertilization and sprayed with C_3 concentration exhibited the highest concentrations of p-cymene and terpinene at 174.2 and 1234.3, respectively. Meanwhile, plants fertilized at the L_3 level and sprayed with C_2 concentration recorded the highest concentration of a-pinene, averaging 92.7. Similarly, at concentration C_1, the highest average concentration of cuminaldehyde was recorded at 1052.3. The results indicate that increasing phosphate fertilizer levels has resulted in higher concentrations of active ingredients in cumin oil. This escalation might be attributed to the role of phosphorus in enhancing the efficiency of vital plant processes and physiological activities, resulting in the production of substantial quantities of secondary chemical compounds. These compounds serve as fundamental building blocks for the production of the oil's active substances.

Regarding the Appetizer fertilizer, variations in its effect on oil's active substance concentrations were observed. However, concentration C_3 appeared to be optimal in increasing the oil's active substance concentrations. This may be due to its components, including marine algae extract, organic and amino acids, and vitamins, which influence cell vitality, regulate cell osmotic potential, and enhance the production of by-products that contribute to the formation of medically beneficial active substances (Abou El-Yazied et al., 2012).

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