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Effect of Nitrogen Levels, Plant Density and Climate on Yield Quantity and Quality in Cumin (*Cuminum cyminum* L.) Under the Conditions of Iran

[1]K. Azizi and [2,3]D. Kahrizi
[1]Department of Agronomy, Lorestan University, Khoramabad, Iran
[2]Department of Agronomy and Plant Breeding, Razi University, Kermanshah, Iran
[3]Department of Biotechnology for Drought Resistance, Razi University, Kermanshah, Iran

Abstract: An experiment was conducted to study the effects of nitrogen fertilizer (N) (Urea 46%) and plant density (D) on the growth, seed yield, quantity and quality of seed essential oil of cumin (*Cuminum cyminum* L.) under the climatic conditions (L) of Lorestan Province (Poldokhtar, Khoramabad and Azna as tropical, temperate and cold regions, respectively) of Iran. Nitrogen as main factor (0, 2.5, 5.0 and 10.0 g m^{-2} and plant density as subsidiary factor (80, 120 and 160 plants m^{-2}) were applied. The results showed that the highest umbel number per plant (42.34), seed number per umbel (9.78) and biological yield (2231) were related to the 2.5 g m^{-2} nitrogen fertilizer and 120 plants m^{-2} treatment (N_2D_2) and the highest harvest index (53.22%) obtained in N_3L_1 in this manner the highest value of variable include weight of thousand seeds (4.9 g) in N_3L_2, seed yield (108.4 g m^{-2}) and percentage of seed essential oil (2.89%) in N_2L_1 ($p<0.01$). Seed yield, yield components, biological yield, harvest index and percentage of seed essential oil were significantly affected by nitrogen fertilizer, plant density and climate. The highest those conducted to 2.5 g m^{-2} nitrogen fertilizer, 120 Plants m^{-2} plant density and Moderate climate. The most principle compounds composing the essential oil were cuminaldehyde (maximum 32.65%) and sum of P-mentha-1, 3-dien-7-al and P-mentha-1, 4-dien-7-al (maximum 55.42%). As a final point the temperate location was offered as the most suitable for cumin growing and production.

Key words: Cumin (*Cuminum cyminum* L.), nitrogen fertilizer, plant density, yield, essential oil

INTRODUCTION

Cumin (*Cuminum cyminum* L.), an important commercial seed spice belonging to the umbellifereae family, is valued for its aroma, medicinal and therapeutic properties. Its seeds contain 3-4% volatile oil and about 15% fixed oil (Muthamma *et al*., 2008). Yields fluctuate greatly, from as little as 5.0 g m^{-2} for a failed crop, to an acceptable 25.0 g m^{-2} and may be as much as 100 g m^{-2} in the best conditions (Sumamad, 2004).

Positive ecological effects of cumin are that it leaves residual water for the following crop and, if grown under supplemental irrigation, it requires less water than wheat. Cumin is an important rainfed option for dry areas and one of the few cash crops that can generate income locally. Yet it has management and marketing problems (Sumamad, 2004).

Agronomic research has established that proper agronomic management includes the dates of planting, crop rotation, seeding rates and labour demand, as well as fertilizer use (Sumamad, 2004).

Research will need to focus on improved management, recommend ways to reduce production risks. All farmers use fertilizers, although only a few have successfully applied herbicides.

In order to improve the use of N fertilizer and to reduce the environmental pollution in agriculture, a number of integrated N-management strategies have been developed. There is further potential to optimize rate and timing of N-fertilization to better meet the actual requirements of the plants and thus, reduce N fertilization substantially. Generally, all these strategies will increase the agronomic N-efficiency (Singh *et al*., 2007).

Temperature is the major factor determining the success and timing of agricultural crop production (Laine *et al*., 1995). Germination, vernalization, biomass production, average growth rate and growth duration all are controlled by temperature (Morison and Morecroft, 2006).

Plant density has been observed to have a huge influence on growth, development and seed yield of crops (Momoh and Zhou, 2001).

Corresponding Authors: Khosro Aziz, Department of Agronomy, Lorestan University, Khoramabad, Iran
Danail Kahrizi, Department of Agronomy and Plant Breeding, Razi University, Kermanshah, Iran
Tel: +98 918 332 2235 Fax: +98 831 832 3731

Cumin production has undergone an increase in recent decades in regions of Iran. Given this development, the question arises whether such an increase might be enhanced by integrated N-management strategies.

Chemical composition of cumin seed essential oil has been studied by a number of researchers (Varo and Heinz, 1970a, b; Eikani *et al*., 1999; Sowbhagya *et al*., 2008). The headspace solvent microextraction (HS-SME) method is most appropriate for monitoring variations in the volatile components of say a plant sample planted under various conditions or grown with different treatments. The essential oil yield and content of a plant may be influenced by nitrogen fertilizer. In canola, fertilizer nitrogen decreased the oil concentration but it increased the yield of oil (Taylor *et al*., 1991). Application of 30.0 g m^{-2} nitrogen fertilizer produced higher herbage and oil yields in rosemary, compared with 15.0 or 0.0 g m^{-2} nitrogen fertilizer in a study by Singh *et al*. (2007). Recently, Ashraf *et al*. (2006) studied the effect of nitrogen fertilization on the content and composition of oil, essential oil and minerals in black cumin (*Nigella sativa* L.). They reported that the seed essential oil content did not vary with the change in applied N level but the major component of the oil, p-cymen, increased at 3.0 g m^{-2}.

The aim of the present study was to investigate the effects of different nitrogen doses, plant density and climate upon yield quantity and quality in cumin (*C. cyminum* L.) under the climatic conditions of Lorestan regions of Iran.

MATERIALS AND METHODS

Plant materials: Cumin (*Cuminum cyminum* L.) seeds were the plant materials of this research that were collected from the National Botanical Garden of Iran during May-June 2004. The seed had high germination percent (>99).

Aims of research and experiment design: The experiment was conducted to study the effects of two agronomical factors nitrogen fertilizer and plant density on the growth, seed yield, quantity and quality of seed essential oil of cumin (*Cuminum cyminum* L.) under the climatic conditions of Lorestan regions ((Poldokhtar, Khoramabad and Azna as tropical, temperate and cold regions, respectively) of Iran. This experiment was carried out as split-plot based on randomized complete block design in four replications at the Province of Lorestan in 2005-2006.

Nitrogen fertilizer (Urea 46%) as main factor with four levels (0, 2.5, 5.0 and 10.0 g m^{-2}) and plant density as subsidiary factor with three levels (80, 120 and 160 plants m^{-2}) were applied in 7×5 m^2 plots. A total of 12 treatments were arranged and executed as split-plot based on randomized complete block design with four replications in three climates (a total of 144 experiments). The names given to each treatment is shown in Table 1.

Table 1: The conditions for different treatments of *Cuminum cyminum* L.

Nitrogen fertilizer (g m^{-2})	Plant density (plant m^{-2})		
	80	120	160
0.0	N_0D_1	N_0D_2	N_0D_3
2.5	N_1D_1	N_1D_2	N_1D_3
5.0	N_2D_1	N_2D_2	N_2D_3
10.0	N_3D_1	N_3D_2	N_3D_3

Nitrogen fertilizer was applied as the half in post emergence and another half in flowering initiation stages.

Cultivation activities and recorded variables: Before seed sowing, the soil in three climates was analyzed for its physico-chemical characteristics including elements absorbability and percent, pH, EC (Electrical Conductivity), total organic carbon, total nitrogen and texture soil. Then soil bed was prepared via cultivation activities.

In the study, the seeds were sown based on climate in different dates. Planting dates in tropical, temperate and cold regions were on 20 Oct., 6 Feb. and 1 Mar. 2005 and harvested on 27 May, 13 Jun. and 29 Jun. 2005, respectively. The collected seeds were dried at room temperature and stored in capped bottles.

Effect of above factors (N fertilizer, plant density and climate) were investigated on variables including crop growth rate (CGR), umbel number per plant, seed number per umbel, harvest index were, seed yield, weight of thousand seeds, biological yield and percentage of seed essential oil. For sampling, three rows in 0.5×0.5 m^2 dimensions were used.

Climates characterizations: Lorestan Province is situated in the west of Iran. This province has a variation in weather and climate (a range from warm to cold climates). For study of effect of climate in this research, we candidate three regions of this province. Poldokhtar region as a tropical, Khoramabad as a temperate and Azna as a cold region. The Characterization of these climates from the viewpoint of rainfall, temperature and geography is showed generally in Table 2 and details are sign in Table 3-5.

Oil extraction and analysis: Cumin seeds were ground in a laboratory dry grinder and 50 g of powder was subjected to hydro-distillation. Essential oil seed was prepared and extracted by hydro-distillation of ground cumin using a

Table 2: Characterization of climates used in this research from the viewpoint of rainfall, temperature geography

Climate	Region	Longitude	Latitude	Altitude (m)	Rainfall Avg. (mm)	Temperature Avg. (°C)
Cold	Azna	48° 36' E	33° 23' N	1620	620.40	14.30
Temperate	Khoramabad	48° 22' E	33° 29' N	1125	471.55	16.48
Temporal	Poldokhtar	47° 43' E	33° 9' N	713	387.62	22.60

Table 3: Rainfall, humidity and temperature data mean about Azna (cold region) from 1987-2005

		Humidity (%)		Temperature (°C)		
Month	Rainfall (mm)	Min.	Max.	Avg.	Min.	Max.
Jan.	97.50	27.00	95.24	0.33	3.01	8.50
Feb.	86.20	19.94	93.73	0.24	4.20	10.60
Mar.	98.10	29.00	98.34	1.15	9.30	14.30
Apr.	90.23	19.03	82.70	6.11	13.11	20.50
May	41.70	13.24	78.30	9.20	15.21	25.20
Jun	0.90	8.35	59.45	16.40	22.70	32.20
Jul.	0.20	8.11	64.58	17.20	25.80	35.90
Aug.	0.20	6.70	63.77	18.50	25.20	35.50
Sep.	1.00	10.34	67.20	14.20	22.70	32.50
Oct.	37.80	16.21	69.15	13.01	16.90	25.20
Nov.	68.57	14.99	88.23	4.70	9.38	17.20
Dec.	98.10	27.26	96.18	1.20	4.11	10.30
Annually mean	620.40	16.68	86.45	14.30	8.50	22.30

Table 4: Rainfall, humidity and temperature data mean about Khoramabad (temperate region) from 1987-2005

		Humidity (%)		Temperature (°C)		
Month	Rainfall (mm)	Min.	Max.	Avg.	Min.	Max.
Jan.	72.04	28.00	99.14	5.53	-0.52	11.59
Feb.	68.14	20.14	98.23	5.54	-0.65	11.73
Mar.	76.53	28.11	96.76	9.11	2.52	15.80
Apr.	77.17	18.05	92.76	12.77	5.44	20.08
May	46.89	15.41	88.17	17.66	9.42	25.89
Jun	3.98	9.46	69.82	23.15	13.29	32.96
Jul.	0.03	7.46	54.46	28.53	18.59	38.48
Aug.	0.24	7.70	53.99	29.24	19.08	39.38
Sep.	0.12	7.94	57.99	25.09	14.03	36.14
Oct.	4.24	10.29	71.29	19.90	9.86	29.94
Nov.	44.26	17.11	90.93	13.44	5.61	21.26
Dec.	77.91	26.70	94.11	7.83	1.45	14.20
Annually mean	471.55	16.36	80.63	16.48	8.17	24.78

Table 5: Rainfall, humidity and temperature data mean about Poldokhtar (temperal region) from 1987-2005

		Humidity (%)		Temperature (°C)		
Month	Rainfall (mm)	Min.	Max.	Avg.	Min.	Max.
Jan.	63.45	48.16	85.66	9.12	4.86	13.38
Feb.	88.23	44.83	82.16	9.99	5.63	14.36
Mar.	37.68	30.50	69.33	14.49	9.00	19.98
Apr.	61.71	31.33	68.83	18.40	12.55	24.21
May	24.31	20.83	56.16	24.55	18.11	30.98
Jun	0.11	10.66	27.66	31.81	24.71	38.91
Jul.	0.00	10.16	25.66	35.27	27.86	42.68
Aug.	0.05	10.16	26.33	36.24	28.91	43.58
Sep.	0.01	9.96	26.83	32.26	24.28	40.25
Oct.	2.98	14.00	34.00	28.50	22.13	34.88
Nov.	37.66	19.83	60.00	18.58	13.06	24.10
Dec.	71.43	40.16	79.66	12.00	7.33	16.68
Annually mean	387.62	24.21	53.52	22.60	16.53	28.66

Clevenger distillation method, as earlier described (Sowbhagya *et al*., 2008). The plant materials were steam-distilled for 90 min in full glass apparatus. The extraction was carried out for 2 h after 4 h maceration in 620 mL of water. The oils were stored in dark glass bottles in a freezer until they were used. 1/2, 1/4 and 1/8 dilutions of the oils were made with dimethylsulphoxide (DMSO). These dilutions were used in antibacterial analysis. Undiluted oil was taken as dilution 1.

The GC-MS analysis was conducted using a gas chromatograph (Shimadzu, Japan, model GC-17A) coupled to a mass spectrometer (Shimadzu, Japan, model GC-MS-

QP5050). A BP-5 Shimadzu fused silica capillary column (30 m×0.32 mm, film thickness 0.25 μm) was used for separations. Helium, with a flow rate of 1.4 mL min^{-1}, was used as the carrier gas. The detector and injection port temperatures were 250 and 240°C, respectively. The column initial temperature was 40°C. It was then raised to 140°C with a rate of 5°C min^{-1}. After a 1 min hold time, the temperature was raised to 250°C with a rate of 40°C min^{-1} and was hold on that temperature for 5 min. Peak identification was carried out by calculation of Kovats retention indexes (RI) from retention times of n-alkanes (C6–C24) and sample components (Salehi *et al.*, 2007). The identifications were confirmed by comparison of their retention indices with those of authentic compounds or with the literature data.

RESULTS AND DISCUSSION

Table 8 show that the main effects of N_2 (2.5 g m^{-2} nitrogen fertilizer), D_2 (120 plants m^{-2}) and L_2 (Moderate climate) have the highest effect on the variables and these variable suggested for cumin production.

Analysis of variance showed that nitrogen in plant density (N×D) interaction effects are significantly difference for the umbel number per plant (UPP), seed number per umbel (SPU), harvest index (HI), weight of thousand seeds (TSW), biological yield, (BY), seed yield (SY) and percentage of seed essential oil (EOP) variables. The nitrogen in location (climate) (N×L) interaction effects was significant for some of above trails and other interaction effects have not significantly difference (p<0.01) for above. These trails have been explained in the following (Table 6, 7).

Umbel number per plant (UPP): The results of analysis of variance showed that nitrogen in plant density interaction effects is significantly difference for the umbel number per plant (UPP) variable. The highest (42.34) and lowest (22.73) UPP were related to the 2.5 g m^{-2} nitrogen fertilizer and 120 Plants m^{-2} (N_2D_2) and N_0D_3 treatments, respectively. In the N×L interaction effects, maximum (41.87) and minimum (30.30) UPP showed in N_2L_1 and N_1L_2, respectively (Table 6, 7).

Seed number per umbel (SPU): The N_2D_2 interaction effect has the highest effect on seed yield (9.78) and the lowest effect (5.59) showed in N_1D_3 effect. Other interaction effects have not significantly difference for SPU (Table 6, 7).

Table 6: Mean performance of nitrogen fertilizer (N) in plant density (D) interaction effects for considered trials in cumin (*Cuminum cyminum* L.)

Treatments	UPP (Num.)	SPU (Num.)	HI (%)	TSW (g)	BY (g m^{-2})	SY (g m^{-2})	EOP (%)
N_0D_1	35.22^{c}	7.58^{c}	46.44^{abcd}	4.17^{bcd}	131.4^{d}	59.97^{ef}	1.45^{bc}
N_0D_2	28.27^{e}	6.14^{ef}	48.54^{abcd}	3.50^{ef}	135.2^{cd}	67.82^{de}	1.54^{bc}
N_0D_3	22.73^{f}	6.60^{de}	41.10^{bcd}	3.09^{f}	134.0^{cd}	55.40^{f}	1.44^{bc}
N_1D_1	36.55^{bc}	7.60^{c}	47.66^{abcd}	3.71^{de}	151.1^{bcd}	70.62^{cd}	1.73^{bc}
N_1D_2	34.31^{cd}	7.17^{cd}	53.63^{a}	4.10^{bcd}	145.4^{bcd}	77.86^{bc}	1.55^{bc}
N_1D_3	31.76^{d}	5.59^{f}	50.31^{ab}	3.46^{ef}	137.5^{cd}	68.35^{cde}	1.37^{c}
N_2D_1	39.05^{b}	9.35^{a}	48.32^{abcd}	4.33^{abc}	170.1^{b}	81.75^{b}	1.58^{bc}
N_2D_2	42.34^{a}	9.78^{a}	48.00^{abcd}	4.80^{a}	223.1^{a}	105.00^{a}	2.69^{a}
N_2D_3	38.43^{b}	8.43^{b}	49.64^{abc}	3.96^{cd}	170.2^{b}	84.15^{b}	1.92^{b}
N_3D_1	39.20^{b}	7.60^{c}	39.06^{d}	4.54^{ab}	155.5^{bcd}	58.61^{ef}	1.46^{bc}
N_3D_2	38.50^{b}	9.11^{ab}	40.61^{cd}	4.21^{bc}	158.6^{bc}	63.63^{def}	1.70^{bc}
N_3D_3	28.24^{e}	7.57^{c}	39.54^{d}	3.47^{ef}	144.8^{bcd}	57.44^{f}	1.54^{bc}

Groups with the same letter(s) represent non-significant differences ($p \geq 0.01$) and groups with different letter(s) represent significant differences at a $p \leq 0.01$ confidence level

Table 7: Mean performance of nitrogen fertilizer (N) in climate (L) interaction effects for considered trials in cumin (*Cuminum cyminum* L.)

Treatments	UPP (Num.)	SPU (Num.)	HI (%)	TSW (g)	BY (g m^{-2})	SY (g m^{-2})	EOP (%)
N_0L_1	26.36^{h}	5.98^{g}	43.17^{c}	2.60^{d}	117.4^{e}	50.70^{g}	1.15^{d}
N_0L_2	31.44^{fg}	6.65^{efg}	47.12^{abc}	3.05^{d}	119.4^{de}	56.03^{fg}	1.04^{d}
N_0L_3	38.26^{bc}	8.61^{bc}	44.87^{bc}	3.83^{c}	169.7^{bc}	72.98^{cde}	1.22^{cd}
N_1L_1	32.20^{ef}	7.44^{de}	45.15^{bc}	3.56^{c}	150.0^{c}	67.45^{de}	1.09^{d}
N_1L_2	30.30^{g}	7.51^{de}	47.75^{abc}	3.71^{c}	141.7^{cde}	70.09^{de}	1.56^{bcd}
N_1L_3	36.30^{cd}	7.22^{ef}	51.26^{ab}	3.84^{c}	166.6^{bc}	83.34^{bc}	1.88^{bc}
N_2L_1	41.87^{a}	9.70^{a}	51.20^{ab}	4.93^{b}	213.1^{a}	10.840^{a}	2.89^{a}
N_2L_2	38.38^{bc}	8.71^{bc}	43.35^{c}	4.31^{b}	145.3^{cd}	62.58^{ef}	2.04^{b}
N_2L_3	29.55^{g}	6.82^{fg}	45.17^{bc}	4.45^{b}	141.6^{cde}	62.40^{ef}	1.72^{bcd}
N_3L_1	34.58^{de}	6.49^{fg}	53.22^{a}	4.40^{b}	148.1^{c}	77.47^{cd}	1.72^{bcd}
N_3L_2	39.69^{ab}	9.25^{ab}	49.90^{abc}	4.90^{a}	180.6^{b}	89.56^{b}	1.10^{b}
N_3L_3	34.37^{de}	8.13^{cd}	30.71^{d}	4.34^{b}	163.5^{bc}	49.65^{g}	1.55^{bcd}

Groups with the same letter(s) represent non-significant differences ($p \geq 0.01$) and groups with different letter(s) represent significant differences at a $p \leq 0.01$ confidence level

Table 8: Mean performance of nitrogen levels (N), plant densities (D) and climates or locations (L) for considered trails in cumin (*Cuminum cyminum* L.)

Treatments	UPP (Num.)	SPU (Num.)	HI (%)	TSW (g)	BY (g m^{-2})	SY (g m^{-2})	EOP (%)
N_0	28.74[c]	6.77[c]	45.36[b]	3.59[c]	133.5[c]	61.06[c]	1.48[b]
N_1	34.21[b]	6.79[c]	50.53[a]	3.76[c]	144.7[bc]	72.28[b]	1.55[b]
N_2	39.94[a]	9.19[a]	48.66[ab]	4.37[a]	187.8[a]	90.30[a]	2.07[a]
N_3	35.31[b]	8.09[b]	39.74[c]	4.07[b]	152.9[b]	59.89[c]	1.56[b]
D_1	37.51[a]	8.03[a]	45.37[b]	4.19[a]	152.0[b]	67.74[b]	1.55[b]
D_2	35.85[b]	8.05[a]	74.70[a]	4.15[a]	165.6[a]	78.58[a]	1.87[a]
D_3	30.29[c]	7.05[b]	45.15[b]	3.49[b]	146.6[b]	66.34[b]	1.57[b]
L_1	32.31[c]	7.17[c]	45.08[b]	3.25[c]	139.1[b]	61.79[c]	1.12[c]
L_2	36.79[a]	8.28[a]	48.39[a]	4.57[a]	166.7[a]	81.09[a]	2.09[a]
L_3	34.55[b]	7.67[b]	44.75[b]	4.06[b]	158.4[a]	69.77[b]	1.77[b]

Groups with the same letter(s) represent non-significant differences ($p \geq 0.01$) and groups with different letter(s) represent significant differences at a $p \leq 0.01$ confidence level

Harvest index (HI): The highest harvest index (53.63 and 53.22%) showed in N_1D_2 and N_3L_1 interaction effects respectively, but N_3D_1 effect had the lowest effect, (39.06%) on it. The harvest index (HI), the proportion of seed dry matter to aboveground biomass, is a major parameter that limits yield (Table 6, 7).

Weight of thousand seeds (TSW): The highest TSW (4.8 g) showed in N_2D_2 interaction effect, but N_0D_3 effect had the lowest effect (3.09) on it. In the N×L interaction effects, N_3L_2 had the maximum (4.9 g) on TSW (Table 6, 7).

Biological yield (BY): The N_2D_2 interaction effect has the highest effect on BY (223.1 g m^{-2}) and the lowest effect (131.4 g m^{-2}) showed in N_0D_1 effect. In the N×L interaction effects, N_2L_1 had the maximum (213.1 g m^{-2}) on BY (Table 6, 7).

Seed yield (SY): The N_2D_2 and N_2L_1 interaction effect has the highest effect on seed yield (105.0 and 108.4 g m^{-2}, respectively) and the lowest effect (55.4 g m^{-2}) showed in N_0D_3 effect. The yield potential of a crop is a theoretical assessment of the maximum yield that can be generated when high yielding biological material is grown in an optimum physical-chemical environment (Table 6, 7).

Percentage of seed essential oil (EOP): The highest EOP (2.69%) showed in N_2D_2 interaction effect, but N_1D_3 effect had the lowest effect (1.37%) on it. In the N × L interaction effects, N_2L_1 and N_1L_1 had the maximum (2.89) and minimum (1.09%) effects on EOP (Table 6, 7).

Temperature has been found to be an important environmental factor affecting the oil and protein content of oilseed crops. Oil and protein content of the seed are negatively correlated and therefore, react opposite to temperature. High temperatures during ripening reduce oil content while increasing protein content. Conversely, crops growing at cool temperature are characterized by high oil content and low protein content. Moreover, temperature influences the fatty acid composition. Several researchers have shown that low temperature increases the degree of polyunsaturated C-18 fatty acids. At low temperature and under conditions of water stress, the C18:1 content decreased and the C18:3 content increased (Walton *et al*., 1999).

Moreover, increased N-supply is linked to decreased N-efficiency, mainly due to altered N-uptake during different growth phases (Singh *et al*., 2007).

Fertilizer N-use efficiency in agriculture is generally low (Raun and Johnson, 1999). This might cause severe yield limitations where there is a lack of N-supply. Moreover, this might increase the risk of environmental pollution where high N-fertilizer doses are applied to achieve maximum yields (Horst *et al*., 2002; Beyaert, 2005). Subsequent N-uptake is high until flowering but low during the reproductive phase associated with an incomplete N translocation from vegetative organs to seed (Lickfett, 2001; Wiesler *et al*., 2001).

In these experiments, it was found that the seed yield of evening primrose was positively influenced by different concentrations of nitrogen.

Essential oil yield and composition: The headspace solvent microextraction (HS-SME) method was used for the study of the influences of nitrogen fertilization, plant density and climate on the essential oil yield and composition of cumin seeds and the results were compared to those of an ordinary hydrodistillation technique.

Statistical analysis showed that there was no significant different between climates for essential oil yield and composition.

Table 9 indicates the percent of volatile components of cumin seeds grown under 12 different conditions. For estimation of the oil yield by HS-SME a summation of peak areas of all components in this method was used. Since cuminaldehyde (maximum 32.65%) and sum of P-mentha-1, 3-dien-7-al and P-mentha-1, 4-dien-7-al (maximum 55.42%). are the characteristic and major component of cumin seeds (Hashemi *et al*., 2008).

Table 9: Concentrations of the volatile components obtained by HS–SME for different cumin treatments under the optimized conditions

Compounds	N_0D_1	N_0D_2	N_0D_3	N_1D_1	N_1D_2	N_1D_3	N_2D_1	N_2D_2	N_2D_3	N_3D_1	N_3D_2	N_3D_3
α-Pinene	0.09	0.30	0.17	0.26	0.29	0.24	0.29	0.27	0.28	0.29	0.27	0.26
Sabinene	0.14	0.29	0.25	0.43	0.37	0.34	0.30	0.26	0.36	0.34	0.34	0.37
β-Pinene	2.99	5.26	3.32	4.35	4.67	3.94	4.88	4.82	4.62	4.92	4.95	4.62
Myrcene	0.16	0.54	0.39	0.46	0.56	0.51	0.59	0.53	0.51	0.54	0.47	0.50
α-Phellandrene	0.20	0.61	0.30	0.23	0.37	0.56	0.45	0.32	0.34	0.38	0.29	0.29
α-Terpinene	0.03	0.14	0.04	0.04	0.06	0.07	0.12	0.05	0.06	0.10	0.06	0.04
p-Cymene	4.79	5.02	6.81	5.89	5.30	5.48	4.78	5.92	5.24	4.60	5.07	5.62
γ-Terpinene	6.34	9.06	6.57	6.57	8.00	7.33	8.88	7.75	7.29	8.85	8.36	7.62
Cuminaldehyde p-Mentha-1, 3-dien-7-al	32.65	23.59	32.33	31.90	26.94	26.96	26.04	28.56	27.33	24.54	25.87	28.71
p-Mentha-1, 4- dien-7-al	52.59	55.21	49.81	49.85	53.41	54.55	53.66	51.51	53.32	55.42	54.29	51.94

Regression analysis indicated an increase of the oil yield by N fertilization up to 6.0 g m^{-2} level and a decrease in higher N levels. The effect of plant density apparently did not show any considerable effect on the oil.

Increasing nitrogen fertilizer caused a slight and insignificant decrease in the cuminaldehyde yield of the seed and a minimum cuminaldehyde concentration was observed at the medium plant density. Other components also showed more or less similar trends, but some discrepancies were observed in the magnitude of concentration variations.

CONCLUSION AND RECOMMENDATIONS

The effect of 2.5 g m^{-2} nitrogen fertilizer, 120 plants m^{-2} plant density and moderate climate have the highest effect on the growth, seed yield, quantity and quality of seed essential oil of cumin (*Cuminum cyminum* L.) and these variable suggested for cumin production. An increase of the oil yields by N fertilization up to 6.0 g m^{-2} level and a decrease in higher N levels. The effect of plant density apparently did not show any considerable effect on the oil. The most principle compounds composing the essential oil were cuminaldehyde, P-mentha-1, 3-dien-7-al and P-mentha-1, 4-dien-7-al. The temperate location was offered as the most suitable for cumin growing and production.

Lastly, its recommended that this experiment would be done in other climates in the world and investigate the effect of genotype of cumin, other fertilizers and other treatment that are importance in climates.

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