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Research Article
Nitrogen Application and Different Plant Densities Effectiveness on the Productivity of Parsley Crop

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Abstract
Background and Objective: Parsley is used for many purposes such as food and pharmaceutical industries. Nitrogen and plant densities play important roles in various growth processes and synthesis of the constituents of different crops especially in arid and semi arid regions. The evaluation of morphological characters and active principals (essential oil) of parsley under N, plant density and their interaction had not been investigated before. So, this study aimed to investigate the effect of Nitrogen and plant density and their interaction on parsley crop productivity. **Materials and Methods:** Parsley plants were subjected to different nitrogen (N) doses (0, 100, 150 and 200 kg ha^{-1}) with three plant densities (8, 12 and 20 plant m^{-2}). Fresh and dry weights, fruit yield, essential oil composition and NPK content were measured. The averages of data were statistically analyzed using two-way analysis of variance (ANOVA-2) with significance level LSD at 0.05. **Results:** The greatest values of fresh and dry weights, fruit yield per plant were recorded with the treatment of 200 kg ha^{-1} (N) $\times$ 8 Plant m^{-2} while the mass production (g m^{-2}) were obtained with 200 kg ha^{-1} (N) x20 Plant m^{-2}. Plants treated with 200 kg ha^{-1} (N) $\times$ 8 Plant m^{-2} resulted in the highest values of essential oil (%, mL $Plant^{-1}$ and mL m^{-2}), main constituents of essential oil and nutrient contents (NPK). **Conclusion:** Nitrogen treatment and plant densities caused different variations in fresh and dry weights, fruit yield, essential oil composition and NPK content.

Key words: Parsley, nitrogen, plant densities, fruit yield, essential oil, nutrient content

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Parsley (*Petroselinum crispum* Mill.) belongs to Apiaceae family, it is a biennial plant and cultivated in various places in the world i.e., United States, Germany, France, Hungary and several other European countries for its aromatic and attractive leaves[1]. Fresh leaves and dried fruits are used for garnishing such food dishes as meat, fish and vegetables. Also parsley has traditionally been used as an antispasmodic, carminative, diuretic, emmenagogue and stomachic[1]. The essential oil of parsley fruits is widely used as a flavoring agent or fragrance in perfumes, soaps and creams[1].

The reclaimed lands in Egypt located in arid or semi arid regions which characterized by poor elements especially nitrogen (N) and unfavorable environmental conditions which negatively affect yield and production of aromatic plants including parsley as important economic crop[2,3]. Nitrogen plays very important roles in various synthesis of the constituents of different crops through the action of several enzymes[3]. The essential oil of thyme (*Thymus vulgaris*) was significantly increased under various N treatments[4]. Seed and fruit yields of *Nigella sativa* L. and coriander (*Coriandrum sativum* L.) were positively increased with different N doses[5,6]. The highest values of herb yield, essential oil and major components of essential oil of *Agastache foeniculum* Purch plant were recorded under the treatment of 100 kg N per hectare[7]. Omidbaigi *et al.*[8] studied the effect of five doses of N (0, 50, 100, 150 and 200 kg ha^{-1}) on herb yield and essential oil of *Tagetes minuta*, the treatment of 200 kg ha^{-1}produced the highest values of fresh herb, dry herb, essential oil content(%) and essential oil constituents such as p-cymene, limonene, dihydrotagetone, (E)-tagetone, (Z)-tagetone, (Z)-ocimenone and (E)-ocimenone. The maximum plant height, total biomass production and essential oil composition of lemon grass herb were recorded with the dose of 50 kg N per hectare[9]. The N treatment at 94 kg ha^{-1} resulted in higher increases of davana (*Artemisia pallens* Wall) growth characters than untreated plants[10]. The greatest values of growth characters, essential oil yield and NPK of dill (*Anethum graveolens* L.) crop were obtained with the treatment of 100 kg N per hectare[11]. Khalid[3] reported that N caused significant increments in growth characters, essential oil percentages and nutrient contents (NPK) of anise, coriander and sweet fennel grown in arid regions. Significant increases were found in essential oil and its major constituents of some spices due to N fertilization in arid zones[12]. The effects of N application on *Schinus terebinthifolius* Raddi were investigated[13], N levels (6, 36, 60, 84 and 114 kg ha^{-1}) resulted in significant changes in plant height, stem diameter, fresh mass, dry matter, essential oil content and major constituents of essential oil (α-pinene, limonene, sabinene, β-pinene, α-copaen and Z-zalvene). The level of N (120 kg ha^{-1}) produced significantly stimulated of the growth, yield and NPK content of *Zingiber officinale* Rosc[14]. The highest amounts of black cumin essential oil content and the major constituents of essential oil (p-cymene and α-thujene) were recorded under 100 kg N per hectare[15].

Plant density (or spacing) is a non-monetary agronomical practice that determines the spatial distribution of plants which affects canopy structure, light intercept ion and radiation use efficiency and consequently, biomass production of crops[16]. Fresh and dry mass and number of flowers per plant of chrysanthemum were significantly decreased as plant density increase[17]. The effects of plant density on strawberry were investigated[18], obtained results indicated that plant growth and yield per plant increased as plant density decreased. Growth characters (fresh and dry weights of herb and dry weight of leaves) and essential oil content were significantly changed due to plant densities[19]. Decreasing plant densities produces a significant increase in essential oil content (%) and different changes in various essential oil constituents of fennel plants[20]. Plant densities had an appreciable effect on the yield and chemical contents of bell pepper[21]. The densities of 20 and 60 marigold plants m^{-2} resulted in the highest values of herb dry weight, flower number, branch number, flower dry weight and amount of essential oil extracted from dried flower[22,23]. Flower yield of clary sage (*Salvia sclarea* L.) was significantly increased under narrow spacing while essential oil content and yield were not affected[24]. Basil plants were subjected to five plant densities, i.e., 10, 16, 20, 25 and 40 plants m^{-2}, the highest leaf fresh mass, leaf area and total plant fresh mass were produced[25] from 40 plants m^{-2}. Planting density significantly affected growth, yield and essential oil composition of *Satureja sahendica* Bornm[26]. Significant increases were found in fresh and dry biomass of peppermint (*Mentha piperita*) under the decreasing of plant density while increasing the plant density resulted in significant increments in essential oil yield[27]. Higher plant densities produced greater yield than low plant density through an increase in biomass accumulation of soybean[28].

Previous studies concerned the study of the effect of N on growth and chemical components on Apiaceae plants such as anise, coriander and fennel in arid zones and did not mention the effect of N on parsley[3,29]. There is one study on the effect of N on the morphological characteristics of parsley plant under sandy soil and did not mention the chemical ingredients and the active substances[30]. On the other hand the evaluation of growth, yield and active principals (essential oil) of parsley under N, plant density and their interaction had not been investigated before. So, in this study, the effect of N, plant density and their interaction on growth, yield, essential oil composition and nutrient contents of parsley plant grown in arid zones of Egypt were evaluated.

MATERIALS AND METHODS

Experimental: Experiments were carried out in arid land at the Experimental Farm of National Research Centre (NRC) located at Nubaria region, Egypt, during two successive seasons, 2015/2016 and 2016/2017. The area of Nubaria had been recently reclaimed and parsley had not cultivated before in this area. Physical and chemical properties of the soil used in this study were determined according to Carter and Gregorich[31] and Margenot *et al*.[32] and data were presented in Table 1. The experimental area (plot) was 9 m^2 (3×3 m) containing 6 lines, the distance between hills were 20, 30 and 40 cm apart (20, 12 and 8 plants m^{-2}). Parsley seeds were sown during the second week of October in both seasons. Thinning for 2 plants per hill was made 45 days after sowing. All agriculture practices operations other than experimental treatments were performed according to the recommendations of the Ministry of Agriculture, Egypt. Plots were divided into three groups. The first group was subjected to different levels of N (0.0, 100, 150 and 200 kg ha^{-1})×20 plants m^{-2}, the second and third groups were subjected to the same levels of N×12 or 8 plants m^{-2}. The source of N was ammonium sulfate (21% N). Sprinkler irrigation was used in this trial.

Growth characters: Fresh and dry weights of aerial part and fruit yield were recorded during the fruiting stage, 230 days after sowing (230 DAS).

Essential oil isolation: Fresh fruits were collected, air dried and weighed to extract the essential oil, then 100 g from each replicate of all treatments was subjected to hydro-distillation for 3 h using a Clevenger-type apparatus[33]. The essential oil content was calculated as a relative percentage (v/w). Total essential oil per plant and per m^{-2} was calculated. The essential oils extracted from parsley fruits were collected from each treatment and dried over anhydrous sodium sulfate to identify the chemical constituents.

Gas chromatography-mass spectrometry (GC-MS): The GC-MS analysis was carried out with an Agilent 5975 GC-MSD system. DB-5 column (60 m×0.25 mm, 0.25 mm film thickness) was used with helium as carrier gas (0.8 mL min^{-1}).

Table 1: Physical and chemical properties of soil used in this study

Property	Values
Physical	
Sand (%)	85.8
Silt (%)	12.1
Clay (%)	2.1
Chemical	
pH (1:2.5)	8.2
EC (dS m^{-1})	1.3
Soluble cations (mq L^{-1})	
Na	3.2
K	0.1
Ca	2.2
Mg	0.5
Soluble anions (mq L^{-1})	
Cl	3.4
HCO_3	4.5
CO_3	0.2
SO_4	1.3
N (ppm)	0.6
P (ppm)	1.1
K (ppm)	1.7

The GC oven temperature was kept at 60°C for 10 min and programmed to reach 220°C at a rate of 4°C min^{-1} and then kept constant at 220°C for 10 min followed by elevating the temperature to 240°C at a rate of 1°C min^{-1}. Split ratio was adjusted at 40:1. The injector temperature was set at 250°C. Mass spectra were recorded at 70 eV. Mass range was m/z 35-450.

GC analysis: The GC analysis was carried out using an Agilent 6890N GC system using FID detector temperature of 300°C. To obtain the same elution order with GC-MS, simultaneous auto-injection was done on a duplicate of the same column at the same operational conditions. Relative percent amounts of separated compounds were calculated from FID chromatograms.

Identification of components: Identification of essential oil components was carried out by comparison of their relative retention times with those of authentic samples or by comparison of their retention index (RI) to series of n-alkanes. Computer matching was against commercial (Wiley GC/MS Library, Mass Finder 3 Library)[34,35] and in-house Başer Library of essential oil constituents built up by genuine compounds and components of known oils. Additionally, MS literature data[36,37] were used for identification.

Determination of mineral content: Total nitrogen and phosphorus in leaves at the first and second seasons of each treatment were determined using the methods described by the Association of Official Agricultural Chemists[38]. The samples of leaves in the first and second harvests were dried, ground and K extracted by acid digestion[32]. Concentrations were determined by atomic absorption spectrophotometry using a Perkin-Elmer[32].

Statistical analysis: In this experiment, 2 factors were considered, plant densities (3 densities) and N (4 levels). For each treatment there were four replicates. The experimental design followed a randomized complete block design using STAT-ITCF program (Statistica, ver. 7. 1, Statsoft Inc., Tulsa, OK) According to De-Smith[39]. Averages of data of both seasons were analyzed using 2-way analysis of variance. Significant values were determined according to LSD (0.05)[40].

RESULTS

Effect of nitrogen, plant densities and their interactions on the growth measurements and mass production: Plant densities and/or different N levels affected the all growth measurements [fresh and dry weights of aerial part (g Plant^{-1}) and fruit yield (g Plant^{-1})] of both seasons (Table 2). Thus, reduce the plant densities and increase the N levels caused different increases in all growth measurements. Greatest growth measurements were recorded at the treatment of 200 kg ha^{-1} (N)×8 Plant m^{-2} with values of 53.7 and 54.2 g Plant^{-1}, 15.8 and 15.8 g Plant^{-1}, 34.8 and 36.9 g Plant^{-1} during the first and second seasons respectively. The increases in various growth measurements were significant for plant densities, N levels and plant densities×N levels (Table 2).

The values of mass production (m^{-2}) of fresh and dry weights of aerial part and fruit yield were affected by N doses, plant densities and their interactions (Table 3). All N levels and different plant densities caused various changes in the mass production of all characters. The highest growth characters were obtained from the treatment of 200 kg ha^{-1} (N)×20 Plant m^{-2} with the values of 692 and 694 g m^{-2}, 142 and 146 g m^{-2}, 316 and 336 g m^{-2} during both seasons, respectively. The changes in mass production were significant for plant densities, N levels and plant densities×N levels (Table 3).

Effect of nitrogen, plant densities and their interactions on essential oil content: The contents of essential oil isolated from parsley fruits (%, mL Plant^{-1} and mL m^{-2}) were significantly affected by plant densities, N doses and their

Table 2: Effect of N, plant density and their interaction on growth measurements

		Growth measurements (g plant^{-1})					
		Fresh weight		Dry weight		Fruit yield	
	Nitrogen	1st	2nd	1st	2nd	1st	2nd
Treatments	(kg ha^{-1})	Seasons					
Plant density (plant m^{-2})							
20	Control	22.6	19.6	4.4	4.8	5.9	6.9
	100	28.9	28.6	6.3	4.9	8.7	9.8
	150	32.7	31.7	6.9	5.9	12.7	13.7
	200	34.6	34.7	7.1	7.3	15.8	16.8
Overall 20		29.7	28.7	6.2	5.7	10.8	11.8
12	Control	25.1	23.5	4.7	5.1	7.9	7.9
	100	32.5	33.6	7.4	5.4	11.7	11.7
	150	37.8	37.9	7.5	6.8	18.8	17.8
	200	42.8	44.6	9.7	8.4	20.9	21.6
Overall 12		34.6	34.9	7.3	6.4	14.8	14.8
8	Control	32.7	29.6	6.9	6.9	12.8	11.9
	100	39.5	36.6	9.7	7.8	17.8	18.4
	150	44.9	42.8	12.8	11.9	29.7	32.7
	200	53.7	54.2	15.8	15.8	34.8	36.9
Overall 8		42.7	40.8	11.3	10.6	23.8	25.0
Overall nitrogen (kg ha^{-1})	Control	26.8	24.2	5.3	5.6	8.9	8.9
	100	33.6	32.9	7.8	6.0	12.7	13.3
	150	38.5	37.5	9.1	8.2	20.4	21.4
	200	43.7	44.5	10.9	10.5	23.8	25.1
LSD: 0.05							
Nitrogen		2.3	2.8	1.1	0.8	2.1	3.3
Plant density		2.1	2.4	0.9	0.7	1.9	2.7
Nitrogen×plant density		3.5	3.6	1.3	1.1	2.5	3.9

Table 3: Effect of N, plant density and their interaction on the mass production

		Mass production ($g\ m^{-2}$)					
		Fresh weight		Dry weight		Fruit yield	
	Nitrogen	1st	2nd	1st	2nd	1st	2nd
Treatments	($kg\ ha^{-1}$)	Seasons					
Plant density ($plant\ m^{-2}$)							
20	Control	452	392	88	96	118	138
	100	578	572	126	98	174	196
	150	654	634	138	118	254	274
	200	692	694	142	146	316	336
Overall 20		594	573	124	115	216	236
12	Control	301	282	56	61	95	95
	100	390	403	89	65	140	140
	150	464	454	90	82	226	214
	200	514	535	116	101	251	259
Overall 12		417	419	88	77	178	177
8	Control	277	237	55	55	102	95
	100	262	293	78	62	142	147
	150	316	342	102	95	238	262
	200	359	434	126	126	278	295
Overall 8		304	327	90	85	190	200
Overall nitrogen ($kg\ ha^{-1}$)	Control	343	304	66	71	105	109
	100	410	423	98	75	152	161
	150	478	477	110	98	239	250
	200	522	554	128	124	282	297
LSD: 0.05							
Nitrogen		5.9	5.6	7.8	4.6	3.8	3.7
Plant density		4.3	4.1	1.9	2.3	2.9	2.5
Nitrogen×plant density		6.2	5.9	3.5	3.1	4.1	3.8

interactions (Table 4). Plants treated with various levels of N X 8 Plant m^{-2} had higher essential oil contents than the untreated plants (control) and other treatments in both seasons. The greatest essential oil contents were due to treatments with 200 kg ha^{-1} (N)×8 Plant m^{-2} with the values of 1.7 and 1.9%, 0.6 and 0.7 mL $Plant^{-1}$, 4.8 and 5.6 mL m^{-2} during the first and second seasons, respectively.

Effect of nitrogen, plant densities and their interactions on essential oil constituents: Sixteen components were detected by GC-MS analysis under nitrogen doses, various plant densities and their interactions (Table 5, 6). Apiol, myristicin, α-pinene and β-pinene were identified as the main components which reflected the highest values of essential oil isolated from parsley fruits. Increasing the N doses x reducing plant density resulted in an increase in main components of essential oil. The highest amounts of main constituents were obtained with the treatment of 150 kg ha^{-1} (N)×8 Plant m^{-2} with the values of 31.5, 27.1, 11.5 and 13.1, respectively (Table 5). All detected compounds divided into four chemical groups, monoterpene hydrocarbons (MCH) and oxygenated sesquiterpenes (SCHO) were the major groups while oxygenated monoterpenes (MCHO) and sesquiterpenes hydrocarbons (SCH) formed the minor groups. The highest values of MCH (33.3%) and SCHO (62.3%) were produced with the treatment of 150 kg ha^{-1} (N)×8 Plant m^{-2}. The greatest amount of SCH (6.1%) was produced with the treatment of 100 kg ha^{-1} (N)×12 Plant m^{-2}. The treatments of 0.0 kg ha^{-1} (N)×12 Plant m^{-2}, 150 kg ha^{-1} (N)×12 Plant m^{-2} and 200 kg ha^{-1} (N)×8 Plant m^{-2} produced the highest content (1.9%) of MCHO (Table 5). The changes in all constituents and chemical groups were significant for N×plant densities. Different increases and changes were found in the main constituents and various chemical groups due N doses. The highest amounts of apiol (31.3%), myristicin (26.9%), α-pinene (12.8%) and β-pinene (11.3%), MCHO (1.8%) and SCHO (61.6%) were recorded with the treatment of 150 kg ha^{-1} (N) (Table 6). The level of 100 kg ha^{-1} (N) produced the highest values of MCH (31.6%) and SCH (4.9%) (Table 6). The changes in all identified components and chemical groups were insignificant for N treatments except the camphene, β-pinene, myrcene, β-phellandrene, γ-terpinene, β-caryophyllene, trans-α-bergamotene and (Z)-β-farnesene were significant.

Table 4: Effect of N, plant density and their interaction on the chemical contents

		Essential oil											
				Yield				Nutrient content (%)					
		Percentage		mL plant^{-1}		mL m^{-2}		N		P		K	
	Nitrogen	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Treatments	(kg ha^{-1})	Seasons											
Plant density (Plant m^{-2})													
20	Control	0.5	0.6	0.1	0.1	0.8	0.8	0.1	0.1	0.3	0.2	0.5	0.7
	100	0.6	0.7	0.1	0.1	2.0	2.0	0.2	0.2	0.4	0.3	0.6	0.8
	150	0.6	0.8	0.1	0.1	2.0	2.0	0.2	0.3	0.4	0.4	0.6	0.8
	200	0.7	0.9	0.1	0.2	2.0	4.0	0.3	0.4	0.4	0.5	0.6	0.8
Overall 20		0.6	0.8	0.1	0.1	2.0	2.0	0.2	0.3	0.4	0.4	0.6	0.8
12	Control	0.7	0.7	0.1	0.1	1.2	1.2	0.2	0.2	0.4	0.3	0.6	0.8
	100	0.8	0.9	0.1	0.1	1.2	1.2	0.3	0.3	0.5	0.5	0.7	0.9
	150	1.1	1.2	0.2	0.2	2.4	2.4	0.4	0.4	0.6	0.6	0.7	1.1
	200	1.3	1.4	0.3	0.2	3.6	2.4	0.4	0.5	0.6	0.7	0.8	1.2
Overall 12		1.0	1.1	0.2	0.2	2.4	2.4	0.3	0.4	0.5	0.5	0.7	1.0
8	Control	0.9	0.8	0.1	0.1	0.8	0.8	0.3	0.3	0.6	0.4	1.1	1.3
	100	1.2	1.4	0.2	0.3	1.6	2.4	0.5	0.5	0.8	0.7	1.4	1.5
	150	1.5	1.7	0.5	0.6	4.0	4.8	0.8	0.8	0.9	0.9	1.5	1.7
	200	1.7	1.9	0.6	0.7	4.8	5.6	0.9	1.1	1.2	1.1	1.7	1.9
Overall 8		1.3	1.5	0.4	0.4	3.2	3.2	0.6	0.7	0.9	0.8	1.4	1.6
Overall nitrogen (kg ha^{-1})	Control	0.7	0.7	0.1	0.1	0.9	0.9	0.2	0.2	0.4	0.3	0.7	0.9
	100	0.9	1.0	0.1	0.2	1.6	1.9	0.3	0.3	0.6	0.5	0.9	1.1
	150	1.1	1.2	0.3	0.3	2.8	3.1	0.5	0.5	0.6	0.6	0.9	1.2
	200	1.2	1.4	0.3	0.4	3.5	4.0	0.5	0.7	0.7	0.8	1.0	1.3
LSD: 0.05													
Nitrogen		0.2	0.2	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.2	0.2	0.2
Plant density		0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Nitrogen×plant density		0.3	0.3	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2

Table 5: Effect of N x plant density the constituents of essential oil

			20 Plant m^{-2}×N				12 Plant m^{-2}×N				8 Plant m^{-2}×N				LSD
Number	Components	Class	0.0	100	150	200	0.0	100	150	200	0.0	100	150	200	0.05
1	α-Thujene	MCH	0.9	0.8	0.7	0.6	1.7	0.8	0.9	1.7	0.8	0.9	0.8	0.7	0.2
2	α-Pinene	MCH	12.3	12.4	12.6	12.5	12.4	12.5	12.7	12.6	12.5	12.8	13.1	12.9	0.1
3	Camphene	MCH	1.5	1.3	1.2	0.5	1.3	0.4	0.7	0.7	1.6	1.7	1.9	1.7	0.2
4	Sabinene	MCH	2.6	1.4	1.5	1.6	0.9	0.8	0.9	1.7	0.9	1.8	1.7	0.8	0.3
5	β-Pinene	MCH	10.8	10.9	11.1	11.0	10.9	11.0	11.2	11.0	11.1	11.3	11.5	11.4	0.1
6	Myrcene	MCH	1.8	1.9	1.8	1.6	0.8	1.1	1.3	1.5	1.7	1.9	0.6	0.9	0.2
7	β-Phellandrene	MCH	1.5	1.6	1.5	1.5	2.1	1.9	0.7	1.1	1.9	1.8	1.8	1.4	0.4
8	γ-Terpinene	MCH	1.8	1.3	1.4	1.6	0.4	1.7	0.6	1.5	0.9	0.8	1.9	1.7	0.2
9	Myrtenal	MCHO	1.7	1.5	1.7	1.8	1.9	1.8	1.9	1.3	1.5	1.2	1.7	1.9	0.1
10	β-Caryophyllene	SCH	1.6	1.5	1.8	1.8	2.2	1.6	1.5	2.8	1.8	0.7	0.9	1.5	0.5
11	Trans-α-Bergamotene	SCH	1.8	1.9	1.6	1.6	1.9	2.3	2.1	1.9	1.7	1.8	0.8	1.5	0.4
12	(Z)-β-Farnesene	SCH	0.7	1.7	1.5	1.4	1.8	2.2	2.4	0.6	0.9	0.8	0.7	0.9	0.6
13	Myristicin	SCHO	26.4	26.5	26.7	26.6	26.5	26.7	26.9	26.8	26.7	26.9	27.1	27.0	0.1
14	Elemicin	SCHO	1.4	1.5	1.2	1.9	1.6	1.9	2.1	1.6	1.9	2.1	1.8	1.7	0.6
15	Carotol	SCHO	1.5	1.4	1.3	1.6	1.7	1.7	1.9	1.7	1.8	0.8	1.9	1.8	0.2
16	Apiol	SCHO	30.6	30.7	30.9	31.1	30.7	30.8	31.3	31.1	30.9	31.1	31.5	31.4	0.1
MCH			33.2	31.6	31.8	30.9	30.5	30.2	29.0	31.8	31.4	33.0	33.3	31.5	0.3
MCHO			1.7	1.5	1.7	1.8	1.9	1.8	1.9	1.3	1.5	1.2	1.7	1.9	0.2
SCH			4.1	5.1	4.9	4.8	5.9	6.1	6.0	5.3	4.4	3.3	2.4	3.9	0.7
SCHO			59.9	60.1	60.1	61.2	60.5	61.1	62.2	61.2	61.3	60.9	62.3	61.9	0.3
Total identified			98.9	98.3	98.5	98.7	98.8	99.2	99.1	99.6	98.6	98.4	99.7	99.2	

MCH: Monoterpene hydrocarbons, MCHO: Oxygenated monoterpenes, SCH: Sesquiterpene hydrocarbons, SCHO: Oxygenated sesquiterpenes

Table 6: Effect of N or plant density the constituents of essential oil

			Overall								
			N (kg ha^{-1})				Plant density (plant m^{-2})			LSD	
Numbers	Components	Class	0.0	100	150	200	20	12	8	N	Plant density
1	α-Thujene	MCH	1.1	0.8	0.8	1.0	0.8	1.3	0.8	ns	0.1
2	α-Pinene	MCH	12.4	12.6	12.8	12.7	12.5	12.6	12.8	ns	ns
3	Camphene	MCH	1.5	1.1	1.3	1.0	1.1	0.8	1.7	0.2	0.5
4	Sabinene	MCH	1.5	1.3	1.4	1.4	1.8	1.1	1.3	ns	0.4
5	β-Pinene	MCH	10.8	11.1	11.3	11.1	11.0	11.0	11.3	0.2	0.6
6	Myrcene	MCH	1.4	1.6	1.2	1.3	1.8	1.2	1.3	0.1	0.5
7	β-Phellandrene	MCH	1.8	1.8	1.3	1.3	1.5	1.5	1.7	0.3	0.3
8	γ-Terpinene	MCH	1.0	1.3	1.3	1.6	1.5	1.1	1.3	0.3	0.5
9	Myrtenal	MCHO	1.7	1.5	1.8	1.7	1.6	1.7	1.6	ns	ns
10	β-Caryophyllene	SCH	1.9	1.3	1.4	2.0	1.7	2.0	1.2	0.3	0.5
11	.trans-α-Bergamotene	SCH	1.8	2.0	1.5	1.7	1.7	2.1	1.5	0.3	0.5
12	(Z)-β-Farnesene	SCH	1.1	1.6	1.5	1.0	1.3	1.8	0.8	0.2	0.4
13	Myristicin	SCHO	26.5	26.7	26.9	26.8	26.6	26.7	26.9	ns	ns
14	Elemicin	SCHO	1.6	1.8	1.7	1.7	1.5	1.8	1.9	ns	ns
15	Carotol	SCHO	1.7	1.3	1.7	1.7	1.5	1.8	1.6	ns	ns
16	Apiol	SCHO	30.7	30.9	31.3	31.2	30.8	31.0	31.2	ns	ns
MCH			31.5	31.6	31.4	31.4	32.0	30.6	32.2	ns	ns
MCHO			1.7	1.5	1.8	1.7	1.6	1.7	1.6	ns	ns
SCH			4.8	4.9	4.4	4.7	4.7	5.9	3.5	ns	ns
SCHO			60.5	60.7	61.6	61.4	60.4	61.3	61.6	ns	ns
Total identified			98.5	98.7	99.2	99.2	98.8	99.5	98.9		

MCH: Monoterpene hydrocarbons, MCHO: Oxygenated monoterpenes, SCH: Sesquiterpene hydrocarbons, SCHO: Oxygenated sesquiterpenes

Different variations were observed in the constituent of essential oil due to various plant densities. Decreasing the plant densities reflected an increase in all main constituents. The highest amounts of apiol (31.2%), myristicin (26.9%), α-pinene (12.8%) and β-pinene (11.3%), MCH (32.2%) and SCHO (61.6%) were recorded with 8 Plant m^{-2}. The greatest values of MCHO (1.7%) and SCH (5.9%) were obtained under 12 Plant m^{-2}. The variations in all detected components and chemical groups were insignificant for plant densities except the α-thujene, camphene, sabinene, β-pinene, myrcene, β-phellandrene, γ-terpinene, β-caryophyllene, trans-α-bergamotene and (Z)-β-farnesene were significant.

Effect of nitrogen, plant densities and their interactions on the nutrient contents: Applying N and using different plant densities resulted in different variations in the accumulation of nutrients (NPK) during first and second seasons (Table 4). The greatest amounts of all nutrients were obtained with the treatment of 200 kg ha^{-1} (N)×8 Plant m^{-2} which recorded the values of 0.9 and 1.1%, 1.2 and 1.1, 1.7 and 1.9% during both seasons. The changes in NPK contents were significant for N, plant densities and their interactions.

DISCUSSION

Obtained results indicted that N doses and plant densities caused a significant variations on growth, yield, essential oil and NPK accumulations. Similar previous investigations were carried out on the effect of N on the morphological and chemical characters on some Apiaceae plants grown under arid land. Khalid[3] studied the effect of N with phosphorous (P) and trace elements on the growth, yield and chemical composition on anise, coriander and sweet fennel, the obtained data indicated that NP and trace elements resulted in significant effects in growth (plant height, leaf number, branch number, umbel number, fresh weight, dry weight and fruit yield per plant), essential oils, fixed oil, total carbohydrates, soluble sugars and nutrient contents. Khalid[29] investigated the influence of N (as individual factor) on the growth, yield and chemical contents of anise, coriander and sweet fennel, N caused a significant increase in growth characters and chemical contents of anise, coriander and sweet fennel crops. The effect of irrigation intervals with N sources and nitrogen levels on some characters of parsley (*Petroselinum crispum* Mill) were evaluated under sandy soil[30], results recorded that significant effect of the all studied factors on vegetative growth and yield characters. Application of 2 days as irrigation interval with urea form as source of nitrogen and 200 kg N ha^{-1}, produced the highest mean values of plant height, number of branches/plant, number of leaflets/plant, fresh weight of plants m^{-2} and fresh weight of 5 plants. On the other way our present investigation concentrated on the effect of the interactions between N and plant densities on growth, yield and chemical composition of parsley which has not been studied before.

The significant effects of different nitrogen doses on growth, essential oil composition and NPK content may be due to decrease in soil pH that reflected to increase the nutrient availability of the soil in arid regions, it has been reported by use of ammonium sulfate[41]. The significant effects of N treatments may be due to the important physiological role of N on molecule structure as porphyrin. The porphyrin structure is found in such metabolically important compounds as the chlorophyll pigments and the cytochromes, which are important in photosynthesis and respiration. Nitrogen plays an important role in synthesis of the plant constituents through the action of different enzymes activities and protein synthesis[42] that reflected in the increase of growth, yield, essential oil composition and NPK of some aromatic plants such as anise, coriander and sweet fennel. Obtained results are in accordance with those reported by some previous investigators: Ashraf *et al.*[5], Akbarinia *et al.*[6] and Hellal *et al.*[11] reported that N fertilizer caused a significant improvement on the growth, yield and chemical composition of cumin, coriander and dill. On the other hand, the increments in NPK due to the N application may be due to the increase in the dry matter of plant materials[43]. Optimum plant density of a crop varies considerably depending upon climatic conditions of the growing area and fertility status of the soil. Plant distance is an important factor for higher production and gives equal opportunity to plants for their survival and the best use of other inputs. Spacing has critical effects on quantitative and qualitative characteristics of plants[16]. Narrow row spacing results in higher leaf photosynthesis and suppresses weed growth due to a smothering effect, compared with a wide row spacing[16]. To achieve the highest yield of economic product per unit area, crops should intercept solar radiation fully during the growth stage, in which photosynthesis provides carbohydrates for the economic product[16]. In general, increasing a plant population produces a greater biological yield per unit land area for most crops up to some upper limit or threshold density, after which further increases in plant density either maintain the same yield or cause yield decline. The threshold plant population, beyond which yield does not increase, depends on environmental factors[16]. Therefore, it seems that plant geometry could be used as a management tool for maximizing crop growth and yield, so it is advisable to carry out trials in each planting zone to establish adequate plant population density for that particular area. Taleie *et al.*[44] studied the effects of plant density on *S. rebauiana* Bertoni and examined that spacing significantly affected plant height, herbage fresh and dry weights and also chemical contents.

CONCLUSION

It may concluded that the greatest growth characters per plant were recorded with 200 kg ha^{-1} (N)$\times$8 Plant m^{-2} while the highest mass productions (per m^{-2}) were recorded under the treatment of 200 kg ha^{-1} (N)$\times$20 Plant m^{-2}. The essential oil percentage or yields (per plant or per m^{-2}) were reported at 200 kg ha^{-1} (N)$\times$8 Plant m^{-2}. The greatest accumulation of NPK contents were observed with treatment of 200 kg ha^{-1} (N)$\times$8 Plant m^{-2}.

SIGNIFICANCE STATEMENT

This study discovered that application with high level of N (200 kg ha^{-1}) and the highest plant density (20 Plant m^{-2}) produce higher mass production [herb (fresh or dry) and fruit yield] than other treatments. The Lowest plant density (8 Plant m^{-2}) with high level of N (200 kg ha^{-1}) resulted in higher values of essential oil yield (per plant or per m^2) and main constitutes of essential oil than other treatment. Thus the farmers or producers can select if they need produce herb, fruit or essential oil.

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