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Effect of nitrogen fertilization on morphological and biochemical traits of some Apiaceae crops under arid region conditions in Egypt

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Abstract. *Khalid KA. 2013. Effect of nitrogen fertilization on morphological and biochemical traits of some Apiaceae crops under arid region conditions in Egypt. Nusantara Bioscience 5: 15-21.* Arid regions in Egypt are characterized by poor nutrients content and unfavorable environmental conditions which negatively affect growth and productivity of medicinal and aromatic plants including anise, coriander, and sweet fennel. So the main objective of the present investigation was to study the effect of different levels of N, namely 0 (control), 100, 150 and 200 kg ha^{-1} used as ammonium sulphate [$(NH_4)_2SO_4$] (20% N), on selected morphological and biochemical characteristics of anise, coriander and sweet fennel plants cultivated under arid regions conditions during two successive seasons. The most effective dose of nitrogen was 200 kg ha^{-1} of N, resulting in a positive increase in vegetative growth characters and content of essential oil, fixed oil, total carbohydrates, soluble sugars, protein and nutrients (NPK).

Key words: Anise, coriander, sweet fennel, essential and fixed oil, carbohydrates, protein

Abstrak. *Khalid KA. 2013. Pengaruh pemupukan nitrogen pada sifat morfologi dan biokimia dari beberapa tanaman Apiaceae di kondisi daerah kering di Mesir. Bioscience Nusantara 5: 15-21.* Daerah kering di Mesir yang ditandai dengan kandungan hara yang buruk dan kondisi lingkungan yang tidak menguntungkan yang berpengaruh negatif terhadap pertumbuhan dan produktivitas tanaman obat dan aromatik termasuk adas, ketumbar, dan adas manis. Tujuan utama penelitian ini adalah mempelajari pengaruh berbagai tingkat nitrogen, yaitu 0 (kontrol), 100, 150 dan 200 kg ha^{-1} yang digunakan sebagai sumber amonium sulfat [(NH4) 2SO4] (20% N), pada karakteristik morfologi dan biokimia tertentu dari tanaman adas, ketumbar dan adas manis yang dibudidayakan di bawah kondisi daerah kering selama dua musim berturut-turut. Dosis nitrogen yang paling efektif adalah 200 kg ha^{-1}, mengakibatkan peningkatan positif dalam karakter pertumbuhan vegetatif serta kangdungan minyak atsiri, minyak tetap, karbohidrat total, gula larut, protein dan nutrisi (NPK).

Kata kunci: Adas, ketumbar, adas manis, minyak atsiri, minyak tetap, karbohidrat, protein

INTRODUCTION

Plant nutrition is one of the most important factors that increase plant productivity. Nitrogen (N) is the most recognized in plants for its presence in the structure of the protein molecule. In addition, N is found in such important molecules as purines, pyrimidines, porphyrins, and coenzymes. Purines and pyrimidines are found in the nucleic acids RNA and DNA, which are essential for protein synthesis. The porphyrin structure is found in such metabolically important compounds as the chlorophyll pigments and the cytochromes, which are essential in photosynthesis and respiration. Coenzymes are essential to the function of many enzymes. Accordingly, nitrogen plays an important role in the synthesis of the plant constituents through the action of different enzymes (Jones et al. 1991). Nitrogen limiting conditions increase volatile oil production in annual herbs. Nitrogen fertilization has been reported to reduce essential oil content in creeping juniper *(Juniperus horizontalis*) (Robert 1986), although it has been reported to increase total essential oil yield in thyme (*Thymus vulgaris* L.) (Baranauskienne et al. 2003). Munsi 1992 indicated that for improvement in production of essential oil from a crop like Japanese mint (*Mentha arvensis* L), a judicious application of nitrogen is required. Each increase in N level increased the dill seed (*Anethum graveolens* L.) up to 90 kg ha^{-1} but further increase did not affect the seed yield significantly (Randhawa et al. 1996). Nitrogen fertilization increased the vegetative growth, essential oil, fixed oil, total carbohydrates, soluble sugars and NPK content of some Apiaceae (Anis, coriander and sweet fennel) and *Nigella sativa* L. plants (Khalid 1996; Khalid 2001). Zheljazkov and Margina (1996) established that plant height, branching, and essential oil content of mint (*Mentha piperita* and *Mentha arvensis*) increased with increasing N fertilizer rates. However, plant vegetative growth was not significantly affected by the increase of N fertilizer rates. With the increased N fertilizer rates, the fresh herbage yield from the first cut increased by 13 to 72%, and that from the second cut by 23 to 78% compared to the control. Nitrogen fertilization has been shown not only to improve vegetative growth, but also to alter the

Figure 1. A. Anise (*Pimpinella anisum* L), B. Coriander (*Coriandrum sativum* L.), C. Sweet fennel (*Foeniculum vulgare* Mill.) (Photo: from many sources)

essential oil yield and composition of Japanese mint (*Mentha arvensis*) (Saxena and Singh 1998). The influence of N fertilizers on the yield of crop, as well as on the production and composition of the essential oil and some other chemical characteristics of thyme was investigated by Baranauskienne et al. 2003. It was found that N fertilizer increased thyme crop, but differences in the yield of essential oil were not remarkable. However, the use of certain amounts of nitrogen fertilizers resulted in higher yields of essential oil obtainable from the cultivation area unit (dm^3 ha^{-1}). The effects of N fertilizer on yield and quality of basil (*Ocimum basilicum* L.) were investigated by Arabaci and Bayram (2004) and they found that intensive N fertilization increased the amount of green herb yield, essential oil concentration, and essential oil yield. According to Ashraf et al. (2006), a field experiment was conducted to study the effect of N fertilization level on the content and composition of oil, essential oil and minerals in black cumin (*Nigella sativa* L.) seeds. Sixty-three-day-old plants were supplied with varying levels of N, i.e., 0, 30, 60, and 90 kg N ha^{-1}. The fixed oil content of the seeds ranged from 32.7% to 37.8% and it remained almost unchanged at the two higher external N regimes, i.e., 60 and 90 kg N ha^{-1}, but at 30 kg N ha^{-1} the oil content increased significantly; Increasing N rate did not affect the content of nutrient content in the cumin seeds. Akbarinia et al. (2007) indicated that with increasing of N to 60 kg ha^{-1}, there was a significant increase in coriander (*Coriandrum sativum* L.) seed yield, but the highest essential oil and fatty acids content were obtained with 90 kg N ha^{-1}. Senthil Kumar et al. (2009) revealed that application of N at 93.75 kg ha^{-1} gave the highest plant height, number of laterals, fresh and dry weight of shoot, dry matter production, fresh herbage yield and essential oil yield of Davana (*Artemisia pallens* Wall.). Nitrogen fertilization had different effects on mint chemotypes, with *M.* x *piperita*, linalool chemotype, being the only genetic material where nitrogen fertilization resulted in higher total dry mass (Luciana et al. 2010). Hellal et al. (2011) indicated that applying N fertilizer increased the growth, yield and chemical constituents of dill (*Anethum graveolens* L.) plant compared to the untreated control, the highest values of vegetative growth, oil yield, and NPK content were recorded by the treatment of 100 kg N ha^{-1}.

Anise (*Pimpinella anisum* L., Apiaceae) has been used as an aromatic herb and spice since Egyptian times and antiquity and has been cultivated throughout Europe (Hänsel et al. 1999). In folk medicine, anise is used as an appetizer, , and diuretic drug (Tyler et al. 1988; Lawless 1999). The traditional use of Pernod, Ouzo, Anisette, Raki, and many other anise-flavored drinks after a heavy meal is a familiar example of its antispasmodic effect, especially in the digestive tract (Hänsel et al. 1999). Dried ripe fruits of anise, commercially called aniseeds (*Anisi fructus*), contain the whole dry cremocarp of anise (*P. anisum*). For medical purposes, they are used to treat dyspeptic complaints and catarrh of the respiratory tract, and as mild expectorants. It was also reported that extracts from anise fruits have therapeutic effects on several conditions, such as gynecological and neurological disorders (Czygan and Anis 1992; Lawless 1999). Ethanolic extract of anise-fruits contains *trans*-anethole, methyl chavicol (estragole), eugenol, psedoisoeugenol, anisaldehyde, coumarins (umbelliferone, scopoletin), caffeic acid derivatives (chlorogenic acid), flavonoids, fatty oil, proteins, minerals, polyenes, and polyacetylenes as its major compounds (Hänsel et al. 1999).

Coriander (*Coriandrum sativum* L.) is a culinary and medicinal plant and belongs to the Apiaceae family. This plant has economic importance since it has been used as flavoring agent in food products, perfumes, and cosmetics. As a medicinal plant, *C. sativum* L. has been credited with a long list of medicinal uses. Powdered seeds or dry extract, tea, tincture, decoction or infusion have been recommended for dyspeptic complaints, loss of appetite, convulsion, insomnia, and anxiety (Emamghoreishi et al. 2001). Moreover, the essential oils and various extracts from coriander have been shown to possess antibacterial (Burt 2004**)**, antioxidant (Wangensteen et al. 2004), anticancerous and antimutagenic (Chithra and Leelamma 2000) activities. Many phytochemical studies so far investigated the chemical composition of the essential oil from *C. sativum* L. fruits from different origins (Steinegger and Hänsel 1988). Evaluations of the essential oil composition extracted from leaves have also been reported (Eyres et al. 2005). The coriander (*Coriandrum sativum* L.) fruit essential oil yields showed marked increase during maturation process and linalool was the main compound at the fruiting stage (Kamel et al. 1994).

Due to their unique and preferred flavor and aroma, the swollen bases of sweet fennel (*Foeniculum vulgare* var. dulce, Apiaceae) are freshly consumed in salads or cooked as a kitchen vegetable. The major constituents of fennel essential oil such as anethole and limonene are also used as essence in cosmetics and perfumes and for some medicinal purposes (Marotti et al. 1993; Stuart 1982).

Sandy soils generally have fine-grained texture. They retain very little water, fertilizers or nutrients which means they are extremely poor. They are prone to over-draining and summer dehydration, and in wet weather can have problems retaining moisture and nutrients and can only be revitalized by the addition of organic matter. Sandy soils are light and easy to dig, hoe and weed. In addition, arid regions in Egypt are characterized by low nutrient contents (especially N) which negatively affect growth and productivity of medicinal and aromatic plants including anise, coriander and sweet fennel (Abd-Allah et al. 2001). The main objective of the present investigation was to study the effect of different levels of N fertilizers on the morphological and biochemical contents of anise, coriander and sweet fennel plants under arid regions conditions.

MATERIALS AND METHODS

Experiments were carried out in the arid region at the Experimental Farm of the Desert Development Center (DDC) in Sadat City, American University, Egypt, during two successive seasons, 1992/93 and /1993/94. The area of DDC had been recently reclaimed and had not been cultivated before. Physical and chemical properties of the Typic Torrifluvents soil (USDA 1999) used in this study (0-50 cm depth) were determined according to Jackson (1973) and Cottenie et al. (1982); and are presented in Table 1. Seeds of coriander and anise were provided by the Department of Medicinal and Aromatic Plants, Ministry of Agriculture, Giza, Egypt as follows: fertilizers were added to all plots as follows: cattle manure (50 m^3 ha^{-1}), phosphorus (500 kg ha^{-1}) as calcium superphosphate (15.5% P_2O_5) and potassium (375 kg ha^{-1}) as potassium sulphate (48% K_2O); whereas sweet fennel seeds were imported from France. Sweet fennel seeds were sown in the third week of October during both seasons. The seedlings of sweet fennel were transplanted into the open field 45 days after sowing. At the same time, the seeds of coriander and anise were sown directly in the open field. The experimental design was a complete randomized block with four replicates. The experimental area (plot) was 30 m² (4 m x 7.5m) containing 15 rows; the distance between hills was 25 cm and 50 cm between the rows. Thinning for two plants per hill was made 45 days after cultivating the plants in the open field. The sprinkler irrigation system was used in this experiment. All agriculture practices other than experimental treatments were performed according to the recommendations of the Ministry of Agriculture, Egypt. Plots were divided into four groups subjected to N application to soil as ammonium sulfate [$(NH_4)_2SO_4$] (20% N) with the rates of 0, 100, 150 and 200 kg ha^{-1}.

Table 1. Mechanical and chemical analyses of the Typic Torrifluvents soil

Sand		**Silt %**	**Clay**	**Gravel**	**pH**	**EC_e (dS m^{-1})**	
79.7		13.0	7.3	18.7	8.7	2.0	
Ca^{++}	**Mg^{++}**	**Na^{++}**	**K^+**	**CO_3**	**HCO_3^-**	**Cl^-**	**SO_4^{--}**
			mg g^{-1}				
4.9	5.6	1.9	0.6	0.8	1.9	18.6	0.2
K			**Fe**	**Cu**	**Zn**	**Mn**	
mg g^{-1}					ug mg^{-1}		
0.5			5400	400	300	1600	

Harvesting

At fruiting stage, the plants were harvested during the two seasons. Vegetative growth characters measurements [Plant height (cm), Leaf number ($plant^{-1}$), Branch number ($plant^{-1}$), Umbel number ($plant^{-1}$), Herb fresh weight (g $plant^{-1}$), Herb dry weight (g $plant^{-1}$) and Fruit yield (g $plant^{-1}$)] were recorded.

Essential oil isolation

Ripening fruits were collected from each treatment during the first and second season, and then 100 g from each replicate of all treatments was subjected to hydro-distillation for 3 h using a Clevenger type apparatus (Clevenger 1928). The essential oil content was calculated as a weight/volume percentage. In addition, total essential oil yield (g $plant^{-1}$) was calculated by using the dry weight of the fruits.

Total carbohydrates and soluble sugars

Total carbohydrates (TC) and soluble sugars concentrations in leaves (collected at the end of the first and second season of each treatment) were determined according to Ciha and Brun (1978) with some modifications. Samples of 100 mg were homogenized with 10 mL of extracting solution [glacial acetic acid: methanol: water, 1:4:5, v/v/v for soluble sugars or glacial acetic acid: H_2SO_4 (1N): water, 1:4:5, v/v/v for TC]. The homogenate was centrifuged for 10 min at 3,000 rpm and the supernatant was decanted. The residue was resuspended in 10 mL of extracting solution and centrifuged another 5 min at 3,000 rpm. The supernatant was decanted, combined with the original extract and made up to 50 mL with water. For measurement of total carbohydrates and soluble sugars, a phenol-sulfuric acid assay was used (Dubois et al. 1956). A volume of 0.5 mL of 5% (v/v) phenol solution and 2.5 mL of concentrated sulfuric acid were added to 0.5 mL aliquots. The mixture was shaken, heated in a boiling water bath for 20 min and cooled to room temperature. The absorption was then determined by spectrophotometry at 490 nm.

Fixed oil, nutrients and crude protein determination

Fixed oil Extraction: Fifty grams of fruits were crushed to coarse powder and extracted with petroleum ether (40-60 ^{o} C) in a Soxhlet apparatus (AOAC 1970). N, protein, P, and K (in the leaves) of both seasons of each treatment were determined using the methods described by the AOAC (1970) as follows:

The washed and dried materials were ground to fine powder with mortar and pestle and used for dry ashing.

For analysis of K, the powdered plant material (0.2 g) was taken in precleaned and constantly weighed silica crucible and heated in muffle furnace at 400 ^{0}C till there was no evolution of smoke. The crucible was cooled in desiccators at room temperature. The ash, totally free from carbon was moistened with conc. H_2SO_4 and heated on hot plate till fumes of sulphuric acid were evolved from the silica crucible, with sulfated ash was again heated at 600 ^{0}C in muffle furnace till weight of sample was constant (3-4 hrs). One gram sulfated ash was dissolved in 100 ml 5 % conc. HCl in a beaker to obtain solution for determination of K through flame photometry. Standard solution of each mineral was prepared and calibration curve was drawn for K element using flame photometry (Alexander 1963).

For the determination of protein and nitrogen using Micro Kjeldahl method, 1 g of plant sample taken in a Pyrex digestion tube and 30 ml of conc. H_2SO_4 carefully added, then 10 g potassium sulfate and 14 gm of copper sulfate, mixture was placed on sand both on a low flame just to boil the solution. It was further heated till the solution became colorless and clear, allowed to cool, diluted with distilled water and transferred to 800 ml Kjeldahl flask, washing the digestion flask, three or four pieces of granulated zinc and 100 ml of 40 % caustic soda were added and the flask was connected with the splash heads of the distillation apparatus. Next 25 ml of 0.1 N sulphuric acids was taken in the receiving flask and distilled; it was tested for completion of reaction. The flask was removed and titrated against 0.1 N caustic soda solution using Methyl Red indicator for determination of nitrogen, which can be calculated to give the protein content (Lynch and Barbano 1999).

For determination of phosphorous, a 2 g sample of plant material was brought into a 100 ml conical flask, two spoons of Darco-G-60 were added followed by 50 ml of 0.5 M $NaHCO_3$ solution. Next, the flask was corked and shacked for 30 min on a shaker. The content was filtered and the filtrate was collected in a flask from which 5 ml filtrate was taken to a 25 ml volumetric flask. To this solution, 2 drops of 2, 4- paranitrophenol and 5 N H_2SO_4 drops were added with intermittent shaking till the yellow color disappeared. The content was diluted to 20 ml with distilled water and then 4 ml ascorbic acid was added. Then the mixture was well shaken and the intensity of blue color at 660 nm on colorimeter was measured and compared to phosphorus standards to obtain P concentrations (King 1932).

Statistical analysis

In this experiment, one unique factor was considered: nitrogen application as ammonium sulfate (0, 100, 150 and 200 kg ha^{-1}). For each treatment, there were four replicates. The experimental design followed a complete random block design. The averages of data for both seasons were statistically analyzed using one-way analysis of variance (ANOVA-1) using the STAT-ITCF program (Foucart 1982). The least of significant differences between means were calculated using least significant difference (LSD) at 5% according to Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

Effect of N fertilization on plant growth and development

Data in Table 2 shows the response of anise, coriander and sweet fennel plants to the different rates of N. All Nitrogen treatments produced significantly higher values than the control and significantly improved plant growth characters [plant height (cm), leaf number (plant^{-1}), branch number (plant^{-1}), umbel number (plant^{-1}), herb fresh weight (g plant^{-1}), herb dry weight (g plant^{-1}) and fruit yield (g plant^{-1})]. Their highest values were recorded when plants were treated with 200 kg N ha^{-1}. The highest values of plant growth characters (respectively) were 44.5, 32.6, 8.5, 29.7, 19.8, 9.4 and 5.9 for anise; 80.0, 66.0, 7.1, 29.9, 15.9, 12.3 and 5.9, for coriander; 98.9, 21.3, 5.3, 10.4, 118.4, 90.4 and 21.3, for sweet fennel. The ANOVA indicated that the increases in vegetative growth characters were significant for N treatments (Table 2). The positive effects of N fertilization may be due to the important physiological role of N in molecule structure as porphyrin. The porphyrin structure is found in such metabolically important compounds as the chlorophyll pigments and the cytochromes, which are essential in photosynthesis and respiration. Coenzymes are essential to the function of many enzymes. Accordingly, nitrogen plays an important role in synthesis of the plant constituents through the action of different enzymes activities and protein synthesis (Jones et al. 1991) that reflected in the increase in growth parameters of plants such as anise, coriander, and sweet fennel plants. Also, these results are in accordance with those obtained by Khalid (1996, 2001) on some Apiaceae and *Nigella sativa* L. plants; Ashraf et al. (2006) on cumin; Akbarinia et al. (2007) on coriander*;* Hellal et al. (2011) on *dill* (*Anethum graveolens* L.), all of whom reported that N fertilizer treatments were superior to the control treatment and significantly improved the vegetative growth characters of family Apiaceae.

Effect of N fertilization on the essential oil content

The effects of different treatments of N on the essential oil content (% or ml plant^{-1}) extracted from anise, coriander, and sweet fennel fruits are represented in Table 3. Generally, all levels of N as soil application progressively increased the essential oil of anise, coriander, and sweet fennel plants compared to the control. The last level of N (200 kg N ha^{-1}) seemed to be optimal for obtaining a higher concentration of essential oil than the control and other treatments: 0.6, 0.1 and 0.7% more than the control for anise, coriander, and sweet fennel, respectively. The ANOVA indicated that the increase in essential oil (%) was significant ($P<0.05$) in anise and not significant in coriander and sweet fennel. The increase in essential oil yield (g plant $^{-1}$) was not significant in anise and coriander but was significant in sweet fennel (Table 3). The effect of different N treatments on essential oil may be due to its effect on enzyme activity and metabolism of essential oil production in peppermint plant (Burbott and Loomis 1969). These results were in accordance with those obtained by Khalid (1996, 2001) on some Apiaceae and *Nigella sativa* L. plants; Ashraf et al. (2006) on cumin; Akbarinia et al. (2007) on coriander; Hellal et al. (2011) on *dill* (*Anethum graveolens* L.), who reported that N has a positive effect on the quantity of essential oil extracted from Apiaceae plants.

Table 2. Effect of N fertilization on growth characters (at fruiting stage) and fruit yield

Nitrogen treatments (kg ha^{-1})	Growth characters						
	Plant height (cm)	Leaf number (plant $^{-1}$)	Branch number (plant $^{-1}$)	Umbel number (plant $^{-1}$)	Plant fresh weight (plant^{-1})	Plant dry weight (plant $^{-1}$)	Fruit yield (g plant $^{-1}$)
Anise (*Pimpinella anisum*)							
0	31.0	15.7	4.6	12.0	5.2	2.9	1.1
100	40.7	31.5	7.5	24.0	12.4	6.4	3.9
150	42.3	31.6	7.7	25.6	19.7	9.0	5.8
200	44.5	32.6	8.5	29.7	19.8	9.4	5.9
LSD:							
0.05	2.1	8.3	0.6	3.9	5.8	2.4	0.8
Coriander (*Coriandrum sativum*)							
0	41.2	14.2	2,8	7.5	4.3	2.8	1.2
100	68.8	46.1	6.5	29.3	13.0	8.7	3.1
150	69.3	63.8	6.7	29.7	13.9	8.8	3.8
200	80.0	66.0	7.1	29.9	15.9	12.3	5.9
LSD:							
0.05	7.5	10.7	0.9	3.6	2.9	2.4	0.9
Sweet fennel (*Foeniculum vulgare* var. dulce)							
0	62.4	8.8	1.5	1.4	66.8	44.6	10.6
100	83.8	16.9	4.3	10.1	106.7	77.7	19.7
150	95.2	19.4	4.6	10.2	114.1	77.9	19.9
200	98.9	21.3	5.3	10.4	118.4	90.4	21.3
LSD:							
0.05	6.2	4.2	0.7	1.3	18.5	10.1	3.2

Effect of N fertilization on the fixed oil content

Data presented in Table 3 shows that the intensive N fertilization produced an increase in the accumulation of fixed oil (% or ml plant^{-1}) extracted from anise, coriander, and sweet fennel fruits, with the highest content of fixed oil obtained with the highest N dose of 200 kg ha^{-1}. Fixed oil contents were 8.1, 2.7 and 0.4% higher than the control for anise, coriander, and sweet fennel, respectively. The ANOVA indicated that the increase in fixed oil (%) of anise, coriander, and sweet fennel was significant. The increase in fixed oil yield (ml plant^{-1}) was significant for anise and coriander while not significant for coriander. These results were similar to those of Khalid (1996) on some *Apiaceae* plants; Khalid (2001) ana Ashraf et al. (2006) on *Nigella sativa* L.; and Akbarinia et al. (2007) on coriander (*Coriandrum sativum* L.)

Table 3. Effect of N fertilization on chemical composition

Nitrogen treatments (kg ha^{-1})	Chemical constituents									
	Essential oil		Fixed oil		Total car. (%)	Soluble sugars (%)	Protein (%)	N (%)	P (%)	K (%)
	(%)	ml plant^{-1}	(%)	ml plant^{-1}						
Anise (*Pimpinella anisum*)										
0	2.6	0.11	7.0	0.1	23.7	2.7	14.4	2.3	0.7	1.5
100	2.7	0.14	9.0	0.2	28.8	3.0	15.5	2.6	0.8	1.6
150	2.8	0.18	10.7	0.2	24.1	3.3	16.6	2.7	0.9	1.9
200	3.2	0.21	15.1	0.2	24.3	3.5	16.8	2.9	1.0	2.0
LSD:										
0.05	0.1	NS	1.5	NS	2.6	NS	0.2	0.3	NS	NS
Coriander (*Coriandrum sativum*)										
0	0.2	0.01	5.5	0.1	15.3	1.9	9.4	1.6	0.3	2.9
100	0.2	0.02	6.9	0.2	17.0	4.3	9.7	1.8	0.4	3.1
150	0.2	0.02	7.5	0.3	17.3	4.4	11.8	1.9	0.5	3.2
200	0.3	0.03	8.2	0.5	22.4	5.1	14.3	2.8	0.5	3.3
LSD:										
0.05	NS	NS	1.2	0.1	1.0	0.6	0.9	0.1	NS	NS
Sweet fennel (*Foeniculum vulgare* var. dulce)										
0	1.3	0.11	1.2	0.1	18.4	1.7	12.9	1.8	0.6	2.1
100	1.9	0.41	1.3	0.3	18.5	1.8	13.0	1.9	0.7	2.3
150	2.0	0.41	1.6	0.3	18.6	2.0	13.3	2.0	0.8	2.5
200	2.0	0.42	1.6	0.4	18.8	2.1	13.3	2.1	0.9	2.6
LSD:										
0.05	NS	0.11	0.1	0.1	NS	NS	NS	NS	NS	0.1

Effect of N fertilization on the total carbohydrates and soluble sugars contents

Table 3 shows that total content of carbohydrates and soluble sugars in anise, coriander, and sweet fennel increased with increasing N rates. The highest contents of total carbohydrates and soluble sugars were recorded when plants were treated with 200 kg ha^{-1} compared with the control or other treatments. Total carbohydrates were 0.6%, 7.1%, and 0.4% higher than the control and total soluble sugars, 0.8%, 3.2%, and 0.4%) for anise, coriander and sweet fennel, respectively. The ANOVA indicated that the increase in total carbohydrates in anise and coriander was significant, while it was not significant for sweet fennel. The increase in soluble sugars in anise and sweet fennel was not significant, but it was significant in coriander. These results may be due to the increase in chlorophyll content, and consequently, photosynthesis efficiency, induced by N. So it showed that total carbohydrates and soluble sugars contents increased with application of N (Jones et al. 1991).

Effect of N fertilization on the total protein content

Protein content was positively affected by soil application of N (Table 3). The treatment of 200 kg ha^{-1} resulted in the highest protein content in anise, coriander, and sweet fennel plants: 2.4%, 3.9% and 0.4% higher than the control, respectively. The ANOVA indicated that the increase in total protein content was significant for anise and coriander while not significant for sweet fennel. These results may be due to the influence of N on the ribosome structure and the biosynthesis of some hormones (gibberellins, auxins, cytokinins) involved in protein synthesis (Jones et al. 1991; El-Wahab and Mohamed 2007).

Effect of N fertilization on the mineral content

It is evident from Table 3 that NPK content gradually increased in all treatments as compared with the control treatment. With respect to the effect of the N levels, data indicated that applying 200 kg ha^{-1} brought about the highest values of NPK content in anise, coriander and sweet fennel plants: 0.6%, 0.3% and 0.5% for anise; 1.2%, 0.2 % and 0.4% for coriander; 0.3%, 0.3%, and 0.5% for sweet fennel higher N, P and K than the control respectively. The ANOVA indicated that the increase in N content of anise and coriander was significant while it was not significant for sweet fennel. The increase in P content of anise, coriander, and sweet fennel was not significant. The increase in K content of anise and coriander was not significant, but the increase in sweet fennel was. The increase in the essential minerals according to the N treatments may be due to the increase in the dry matter of plant materials (El-Wahab and Mohamed 2007).

CONCLUSION

It may be concluded that N treatments resulted in positive increase in plant growth characters, and content of essential oil, fixed oil, total carbohydrates, soluble sugars, protein, and nutrients. The highest values were recorded when plants were treated with 200 kg ha^{-1} for anise, coriander, and sweet fennel.

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