INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 4, No. 12, p. 323-338, 2014

RESEARCH PAPER OPEN ACCESS

Foliar application of Ca and K improves growth, yield, essential oil yield and nutrient uptake of tarragon (*Artemisia dracunculus* L.) grown in Iran

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Key words: Tarragon (*Artemisia dracunculus* L.), Yield, $Ca(NO_3)_2$, KNO_3, nutrient uptake.

http://dx.doi.org/10.12692/ijb/4.12.323-338 Article published on June 28, 2014

Abstract

Artemisia dracunculus L. (tarragon) is a perennial herb in the Asteraceae family, which has a long history of use in culinary traditions. The field experiments was conducted to study the influence of foliar $Ca(NO_3)_2$ and KNO_3 application on vegetative growth, essential oil yield, content and leaf N, P, K and Ca of tarragon in two harvests. The treatments were performed at four level of foliar $Ca(NO_3)_2$ and KNO_3 fertilizers (including control (water spray), 2.5, 5 and 10 g l^{-1}) which was set up in a factorial experiment based on Randomized Completely Block Design with three replications. Results showed that foliar $Ca(NO_3)_2$ application rates significantly increased plant height, plant width, fresh matter yield, dry matter yield, essential oil content and yield, leaf N, P, K and Ca by an average of 36.2, 41.2, 68.3, 68.6, 23, 88.9,7.5, 16.7, 7.2 and 20%, respectively in first harvest and 50.5, 12.1, 42.7, 65.2, 26.3, 91.8, 11.6, 20.8, 10.2 and 26.9%, respectively in second harvest compared with the control. Also, with increasing the foliar KNO_3 rates plant height, plant width, fresh matter yield, dry matter yield, essential oil content and yield, leaf N, P, K and Ca significantly increased by an average of 12.4, 27.6, 121.5, 42.3, 12.4, 75.2, 11.5, 16.7, 9.8 and 21.8%, respectively in first harvest and 26.2, 6.1, 37.8, 49.8, 27, 98.8, 4.2, 16, 42.5 and 6.9%, respectively in second harvest compared with the control. Fresh matter yield, essential oil content, leaf N, P, K and Ca in first harvest and plant height, essential oil yield, leaf N, P, K and Ca in second harvest significantly responded to $Ca(NO_3)_2$ and KNO_3 interaction. It is evident from the results that $Ca(NO_3)_2$ and KNO_3 foliar application improved productivity traits, essential oil yield and content and nutrient uptake of tarragon plants.

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Introduction

Artemisia is one of the important genus of family Asteraceae, widely distributed throughout the world with approximately 800 species. This genus is industrially important due to its insecticidal, antifungal, antibacterial, allelopathic and other properties. The genus is useful in Ayurveda, Homeopathy, Unani, Siddha and Western medicinal system (Ved and Goraya, 2008).

Artemisia dracunculus L. (tarragon) is a perennial herb in the Asteraceae family, which has a long history of use in culinary traditions. It also possesses a wide range of health benefits and has therefore been widely used as a herbal medicine (Obolskiy *et al.*, 2011). Two varieties can be distinguished: (Yaichibe *et al.*, 1997) namely, French tarragon of south European origin and Russian tarragon of Siberian origin (Greger, 1979). French tarragon is mainly used as a culinary herb in oil, sauces, vinegars, mustards and spices, and the French call it the 'king of herbs' (Ribnicky *et al.*, 2004). This research deals with French tarragon. The most important groups of biologically active secondary metabolites in *A. dracunculus* essential oil are coumarins, flavonoids, and phenolic acids (Sayyah *et al.*, 2004; Stubbendieck *et al.*, 2003; Deans and Svoboda, 1988).

In many countries, cultivation and culinary uses of French tarragon are described. It is said to be a tasty, very aromatic, and valuable herb. In Europe it is one of the 20 most commonly grown herbs. In general, all information refers to the essential oil-producing French tarragon, with its main constituent estragole. It is an ingredient in diverse commercial preparations including vinegar, mustard, liqueurs, and perfumes. The essential oil of *A. dracunculus* is included in similar commercial products (Obolskiy *et al.*, 2011).

Foliar nutrition is an option when nutrient deficiencies cannot be corrected by applications of nutrients to the soil (Crabtree, 1999; Sarkar *et al.*, 2007; Cakmak, 2008; Movahhedy-Dehnavy *et al.*, 2009). It is likely therefore, in open-field conditions, where the factors that influence the uptake of the nutrients are very variable, foliar fertilization is a privilege (Movahhedy-Dehnavy *et al.*, 2009).

Plant nutrition is one of the most important factors that increase plant production. It has been shown that application of Ca fertilizers influences the vegetative growth, essential oil content, yield and mineral uptake of plants. Mumivand *et al.* (2010, 2011) in summer savory (*Satureja hortensis* L. cv. Saturn) reported that plant fresh and dry weights were increased by $CaCO_3$ up to 5 t. ha^{-1}. In addition, $CaCO_3$ application positively affected the leaf Ca content and essential oil content and yield, but plant width and leaf N content were negatively affected. In cucumber (*Cucumis sativus* L. cv. AL-Hytham) it was reported that foliar $Ca(NO_3)_2$ application increased plant height, shoot dry weight, N, P, K and Ca content of leaf (Al-Hamzavi, 2010). Yildirim *et al.* (2009) in strawberry (*Fragaria vesca* L.) reported that 10 mM foliar $Ca(NO_3)_2$ application significantly increased shoot dry weight, shoot N, P, K and Ca content. In oregano (*Origanum vulgare* ssp. hirtum), it was reported that foliar application with Ca increased the plant height, dry matter yield, essential oil yield and leaf Ca concentration, but there was no significant effect on essential oil content (Dordas, 2009). Prasad *et al.* (2008) find that the herbage yield and oil content and yield of geranium (*Pelargonium* sp.) significantly increased by the foliar application of calcium chloride. Karaivazoglou *et al.* (2007) reported that liming significantly increased plant height, leaf fresh weight, total gross yield, Ca and P concentrations but decreased K concentration in Virginia tobacco (*Nicotiana tabacum* L.) leaves, whereas it did not significantly affect total N. It has been shown that application of $CaCO_3$ increased significantly total plant yield, stem diameter, flower P content and essential oil content and yield of *Chrysanthemum boreale* M. up to 1.5 t ha^{-1}, whereas the Ca content and uptake by the flowers significantly increased with increasing Ca application rates. In addition, $CaCO_3$ there was no significant influence on total flower N and K content (Lee and Yang, 2007). In *Chrysanthemum coronarium* L. it was reported that total dried weight, plant height, essential oil content and yield increased significantly by increasing lime up to 2 t ha^{-1}. Whereas, total leaf N and Ca content increased with increasing lime up to 5 t ha^{-1} and the higher leaf K content obtained from 3 t ha^{-1} lime application (Supanjani *et al.*, 2005).

Several studies have been shown that K fertilization, particularly K applied by foliar spraying can significantly increase the vegetative traits, essential oil content and yield and mineral uptake of treated plants. Hoda *et al.* (2011) reported that foliar KNO_3 (1 and 2%) spraying significantly increased plant length, fresh and dry weight, leaf N, P, K and Ca content on potato plants (*Solanum tuberosum* L.). Ezz El-Din *et al.* (2010) found that K application increased plant height of caraway plant (*Carum carvi* L.) in first season, whereas it was decreased in second season. Also, increasing K from 30 to 60 then 90 kg fed^{-1} gradually decreased the percentage of essential oil in the first season, but it was higher at 60 kg fed^{-1} in second season. Al-Hamzawi *et al.* (2010) stated that foliar KNO_3 (10 and 15 mM) application significantly increased plant height, shoot dry matter, total yield, leaf N, P, K and Ca content of cucumber plants. Zaghloul *et al.* (2009) and Said-Al Ahl *et al.* (2009) reported that potassium-humate application was increased essential oil content and yield of *Thuja orientalis* and oregano, respectively. In wormwood (*Artemisia annua* L.) it was reported that increasing K concentration from 53 to 155 mg l^{-1} significantly increased total dry weight, leaf dry weight and leaf K concentration, whereas leaf mineral concentrations of N, P, Ca decreased with increasing K application. In addition, there were no significant K treatment differences in stem height throughout the experiment (Davies *et al.*, 2009). Singh and Ganesha Rao (2009) found that K application significantly increased plant height, fresh plant weight, total herbage yield, essential oil yield, N, P and K uptake of patchouli (*Pogostemon cablin* (Blanco) Benth.) with the application of 83 kg K ha^{-1} and N uptake with the application of 41.5 kg K ha^{-1}. In strawberry it was reported that 10 mM foliar KNO_3 significantly increased shoot dry weight, shoot N, P, K and Ca concentration (Yildirim *et al.*, 2009). Singh (2008) in palmarosa (*Cymbopogon martinii* [Roxb.] Wats. var. motia Burk), Singh *et al* (2005, 2007) in lemongrass (*Cymbopogon flexuosus* [Steud.] Wats.) and rosemary (*Rosmarinus officinalis* L.) reported that addition of K at 123, 66.4 and 83 kg ha^{-1}, respectively enhanced the plant height, total herbage yield and essential oil yield, whereas did not significant effect on essential oil content. Nadia (2006) found that application of different K rates resulted in significant increases in plant height, straw and grains yield, N, P, K and Ca uptake of barley (*Hordum vulgare* cv. Giza 123).

Since climatic condition in Iran is arid and semiarid and soil alkaline condition prevent fin absorption of essential nutrient element, foliar application of fertilizers would improve growth and yield production. There was no information about effects of foliar $Ca(NO_3)_2$ and KNO_3 application on growth, essential oil production and mineral uptake of tarragon. Therefore, the present experiment was conducted to study in detail the effect of foliar application of $Ca(NO_3)_2$ and KNO_3 on yield attributes, essential oil content and yield and leaf N, P, K and Ca content of tarragon plant. On the other hand, since foliar application is more effective than soil supplementation therefore, we carried out the present study to investigate effects of foliar spray of $Ca(NO_3)_2$ and KNO_3 on the yield and quality of tarragon.

Materials and methods

Experimental set-up

The experiment was conducted in the Research Center of Horticultural Sciences Department, University of Tehran, Karaj, (35° 46′ N, 50° 55′ E and 1251 masl) Iran.

The meteorological data recorded during the trial period are given in Table 1. Before planting, soil and water samples were taken in order to determine the physical and chemical properties (Table 2). A composite soil sample was collected at a depth of 30–45 cm.

The plots were 150 x 150 cm (16 treatments×3 replications = 48 plots of 22500cm^2 size with 9 plants in each plot). Tarragon plantlets were transplanted at 50cm×50cm (50cm inter-row and 50cm intra-row) spacing and cut to 5 cm above ground in the first week of May 2011.

The experimental design was a factorial in a randomized complete block with three replications. The treatments were performed at four level of foliar applications of $Ca(NO_3)_2$ and KNO_3 fertilizers (including control (water spray), 2.5, 5 and 10 g l^{-1}). Spraying was done three times every 20 days intervals when tarragon plants had 10 cm height. During the growing period, the plants were irrigated and kept based on standard methods. The crop was harvested manually employing sharp sickles before flowering stage, 5cm above the ground level. Two harvests were taken in mid-August and mid-November.

Growth measurements

The harvested plants dried under the shade at room temperature with humidity of 10%. Some yield attributes of *A. dracunculus* L. such as plant height, plant width and stem diameter were measured in the field before harvest. Immediately after each harvest, yield of fresh matter was determined. In dried plant materials, dry matter yield was also calculated.

Essential oil isolation

Chopped air dried leaf samples from each treatment with three replicates were submitted to hydrodistillation using Clevenger type glass apparatus for 2.5h (European Pharmacopoeia, 1996), and essential oil contents (%, leaf dry weight basis) were determined. Essential oil yield per unit area was calculated by multiplying the dry leaf yield with essential oil concentration and weight of the essential oil.

Determination of mineral concentration of leaf

Leaf samples were repeatedly rinsed three times in demineralized water then dried in a forced-air oven at 70 °C for 72 h. Dried leaves were ground and digested in H_2SO_4 for total N or in a ternary solution (HNO_3: H_2SO_4: $HCLO_4$ = 10:1:4 with volume) for the determination of P, K, Ca. Total N was determined using the Kjeldahl method (Helrich, 1990b). K was assayed using Flame photometric method (Helrich, 1990d). Phosphorous content was measured spectrophotometrically with molybdovanadate according to Helrich (1990c). Leaf Ca content was determined according to an atomic absorption spectrophotometric method (Helrich, 1990a).

Statistical analyses

Data analysis was carried out by using SAS 9.1 software and Duncan's multiple range tests were used to detect differences between means at probability level of 0.05.

Results and discussion

Vegetative growth

Plant height

Results showed that $Ca(NO_3)_2$ significantly increased plant height of tarragon in first and second harvest by an average of 36.2 and 50.5%, respectively compared with the control. However, in second harvest there was no difference between 2.5 and 5 g l^{-1} treatments (Table 3). This finding is supported by the reports of Dordas (2009) in oregano, Supanjani *et al.* (2005) in *Ch. Coronarium* and Karaivazoglou *et al.* (2007) in tobacco, which reported that lime treatments increased significantly plant height. On the other hand, Mumivand *et al.* (2011) in summer savory and Lee and Yang (2007) in *Ch. boreale* M. reported that $CaCO_3$ did not significant effect on plant height of treated plants. The increase in plant height might be attributed to increased cell division and cell elongation induced by the interaction between $Ca(NO_3)_2$ and auxin (Al-Hamzawi *et al.*, 2010; Barker and Pilbeam, 2006). In addition, when the calcium level is too low to sustain plant growth, the plants become shorter and the total biomass is lower compared with the plants with sufficient calcium (Marschner, 1995; Dordas, 2009).

Similar trend was found at the KNO_3 foliar application as plant height were increased by an average of 12.4 and 26.2 in first and second harvests, respectively compared with the control. However, there were no significant differences between 2.5 with 5 g l^{-1} and 5 with 10 g l^{-1} treatments in first harvest and control with 2.5 g l^{-1} treatments in second harvest (Table 3). These findings are supported by Hoda *et al.* (2011) in potato, Al-Hamzawi *et al.* (2010) in cucumber, Singh and Ganesha Rao (2009) in patchouli and Singh (2008) in palmarosa. On the other hand, it was reported that K application increased plant height of caraway in first season, whereas it was decreased in second season (Ezz El-Din *et al.*, 2010). Favorable effect of potassium fertilizer on plant growth may be due to that potassium element is very important in the overall metabolism of plant (Mengel and Kirkby, 1978). On the other hand, nitrogen being the main constituent of protein and nucleic acid, which greatly influenced the cell division, cell enlargement and thereby it could increase the shoot length (Kumar *et al.*, 2009).

Table 1. Monthly temperature, precipitation and Minimum average humidity during the growing season.

Harvest	Month	Average temperature (°C)			Total precipitation (mm)	Minimum average humidity (%)
		Minimum	Mean	Maximum		
First	May	12.81	18.92	25.03	1.1655	28.52
	June	17.58	25.06	32.55	0.0516	16.87
	July	20.10	28.08	36.06	0.0714	15.38
	August	21.06	28.82	36.58	0.0889	14.04
Second	August	21.06	28.82	36.58	0.0889	14.04
	September	18.64	25.34	32.05	0.0016	15.70
	October	14.90	21.05	27.20	1.0266	18.91
	November	7.20	12.11	17.03	1.8628	33.28

The interaction effect of $Ca(NO_3)_2$ and KNO_3 was significant in second harvest. The higher plant height obtained from 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 by an increase average of 110.9% compared with the control (No treated with $Ca(NO_3)_2$ and KNO_3) treatment (Table 3).

Plant width

Foliar application of $Ca(NO_3)_2$ there was an increase in plant width by an average of 41.2 and 12.1% at first and second harvests, respectively compared with the control treatment. Also, there were no differences between control and 2.5 g l^{-1} treatments in both harvests (Table 3). In contrast with our result, it is reported that summer savory plant width decreased with increasing $CaCO_3$ levels (Mumivand *et al.*, 2011). This contrast could be due to the use of different sources and application methods of Ca fertilizers. The increments in plant growth characters as a result of spraying $Ca(NO_3)_2$ fertilization may be due to the role of such macro nutrients in the physiological process and cell division and elongation which indirect affect tissue formation and consequently vegetative growth of plant (Hoda *et al.*, 2011).

Plant width in first and second harvests had an average increase of nearly 27.6 and 6.1%, respectively with 10 g l^{-1} KNO_3 rates compared with the control treatment. However, there were no significant differences between control with 2.5 g l^{-1}, 2.5 with 5 g l^{-1} and 5 with 10 g l^{-1} in first harvest and 2.5 with 10 g l^{-1} in second harvest (Table 3). The obtained results might be due to the role of this element on metabolism processes in the plant and consequently on plant growth. In this concern, potassium plays an important role in functions of enzymes needed for the vital processes and growth (Fawzy *et al.*, 2007).

The interaction effect on plant width was not significant in both harvests (Table 3).

Stem diameter

Foliar application of $Ca(NO_3)_2$ and KNO_3 and their interaction did not significant effect on stem diameter in both harvests. Nevertheless, there was an increase in first and second harvests with $Ca(NO_3)_2$ by an average of 15.6 and 6.5%, respectively compared with the control treatment (Table 3). These results are in good accordance with those obtained by Dordas (2009) and Mumivand *et al.* (2011) that stated Ca application did not significant effect on stem diameter of oregano and summer savory, respectively. On the other hand, it is reported that $CaCO_3$ fertilizer rates up 1 and 1.5 t ha^{-1} increased stem diameter in *Ch. coronarium* L. and *Ch. Boreale* M. (Supanjani *et al.*, 2005 and Lee and Yang, 2007, respectively), after which any further increase decreased stem diameter. This result might be due to the increased vegetative growth under abundance of nitrogenous fertilizers for photosynthesis activity (Chaurasia *et al.*, 2005).

Table 2. Physico-chemical properties of the soil and characteristics of water used for irrigation and foliar spraying.

Soil properties	Values	Water characteristics	Values
EC (dS m^{-1})	4.08	EC (dS m^{-1})	0.55
pH	8	pH	7.6
Organic carbon (%)	0.93	K^+	0.02
Total N (%)	0.12	Na^+	0.88
Available P ($meql^{-1}$)	41.2	Ca^{2+}	3.6
Available K ($meql^{-1}$)	334	Mg^{2+}	1.7
Ca ($meql^{-1}$)	11.3	Cl^-	1.1
Mg ($meql^{-1}$)	9.7	CO_3^{2-}	0
Available Fe ($meql^{-1}$)	4.64	H CO_3^{2-}	4.2
Available Zn ($meql^{-1}$)	1.96	SO_4^{2-}	0
Available Mn ($meql^{-1}$)	6.59	SAR†	0.54
Available Cu ($meql^{-1}$)	0.38	TDS†	350
Soil texture	Clay loam		

† Sodium Adsorption Ratio

† Total Dissolved Solids.

KNO_3 rates also increased stem diameter 9.2 and 8.5% in first and second harvests, respectively compared with the control treatment (Table 3). Melton and Dufault (1991) found that K did not significantly influence on stem diameter in tomato plant (*Lycopersicon esculentum*), which is in agreement with our results. Such promoting effect proved the role of potassium as an important nutrient in plant metabolism, enhancing carbohydrates synthesis, positively affecting water transport in the xylem and cell elongation (Ezz El-Din *et al.*, 2010).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on stem diameter was not significant in both harvests (Table 3).

Fresh matter yield

Foliar application of 5 g l^{-1} $Ca(NO_3)_2$ significantly increased fresh matter yield by an average of 68.3 and 42.7% in first and second harvests, respectively compared with the control treatment. However, did not significant difference between 5 and 10 g l^{-1} rates in second harvest (Table 3). Similar response reported by Mumivand *et al.* (2011). They found that the fresh weight was greater in the plants fertilized by 5 t ha^{-1} $CaCO_3$ compared with the control, but no further increase was observed in the plants fertilized by higher levels. On the other hand, Karaivazoglou *et al.* (2007) was found that lime application in highest level (3 t ha^{-1}) increased leaf fresh weight and total gross yield of Virginia tobacco. In addition, it was reported that foliar application of calcium chloride increased herbage yield in rose-scented geranium compared with the control (Prasad *et al.*, 2008). These results may be due to effect of calcium on membranes, enzymes, cell walls and interactions with phytohormones (Barker and Pilbeam, 2006; Clarkson, 1988).

Table 3. Effects of foliar $Ca(NO_3)_2$ and KNO_3 application treatments on some vegetative traits, essential oil content and yield of tarragon in two harvest.

Ca (g l⁻¹)	K (g l⁻¹)	Plant height (cm)		Plant width (cm)		Stem diameter (mm)		Fresh matter yield (t ha⁻¹)		Dry matter yield (t ha⁻¹)		Essential oil content (%w/w)		Essential oil yield (kg ha⁻¹)	
		First	Second	First	Second	First	Second	First	Second	First	Second	First	Second	First	Second
0		46.77 d †	39.73 c	41.15 c	57.40 c	2.37	2.61	2.30 d	2.88 c	1.05 c	1.84 c	1.87 c	1.60 c	11.77 c	19.47 d
2.5		53.27 c	48.56 b	45.55 c	57.97 c	2.44	2.62	2.86 c	3.24 b	1.58 b	2.57 b	2.08 b	1.83 ab	19.47 a	22.94 c
5		56.73 b	49.62 b	51.50 b	59.63 b	2.47	2.64	3.38 a	4.11 a	1.77 a	3.04 a	2.30 a	2.02 a	22.23 a	37.35 a
10		63.68 a	59.79 a	58.11 a	64.32 a	2.74	2.78	3.20 b	4.00 a	1.56 b	2.66 b	2.03b	1.78 bc	15.55 b	30.80 b
						NS ‡	NS								
	0	51.43 c	44.05 c	42.87 c	57.77 b	2.38	2.59	1.77 d	2.96 c	1.23 c	2.07 c	1.94 c	1.63 b	12.74 c	18.90 c
	2.5	54.72 b	45.61 c	47.51 bc	59.88 a	2.55	2.62	2.79 c	3.58 b	1.45 b	2.25 c	2.05 b	1.70 b	16.01 bc	21.70 c
	5	56.46 ab	52.45 b	51.23 ab	60.38 a	2.49	2.64	3.26 b	3.61 b	1.54 b	2.70 b	2.12 ab	1.83 b	17.94 b	32.39 b
	10	57.82 a	55.59 a	54.70 a	61.29 a	2.60	2.81	3.92 a	4.08 a	1.75 a	3.10 a	2.18 a	2.07 a	22.32 a	37.58 a
						NS	NS								
0	0	34.67	33.73 i	41.48	33.73	2.17	2.44	1.54 h	2.27	0.76	1.35	1.65 f	1.40	7.52	12.26 g
	2.5	39.93	36.38 ghi	48.37	36.38	2.49	2.57	2.20 g	3.05	1.06	1.78	1.64 f	1.43	9.97	15.86 fg
	5	45.13	44.95 defgh	48.36	44.95	2.32	2.61	2.74 ef	2.94	1.11	2.00	1.98 de	1.71	13.59	24.26 cd
	10	44.87	43.87 cdefgh	48.86	43.87	2.51	2.81	2.72 f	3.25	1.29	2.24	2.22 b	1.85	16.01	25.51 cd
2.5	0	40.33	43.41 hi	51.55	43.41	2.31	2.55	1.55 h	2.78	1.33	2.27	2.02 bcde	1.61	15.23	16.84 efg
	2.5	44.93	46.14 fghi	52.28	46.14	2.59	2.68	2.86 ef	3.19	1.39	2.20	2.20 bf	1.92	17.44	21.29 cdef
	5	48.67	51.10 fgh	53.67	51.10	2.47	2.60	3.47 cb	3.34	1.71	2.79	2.03 bcde	1.82	19.37	25.96 cd
	10	48.27	53.60 bcdefg	55.58	53.60	2.38	2.66	3.58 b	3.64	1.87	3.03	2.06 bcde	1.96	25.82	27.65 cd
5	0	48.33	46.00 efgh	51.99	46.00	2.35	2.56	2.23 g	3.39	1.40	2.48	2.04 bcde	1.75	14.45	23.38 cde
	2.5	49.07	46.16 bcde	57.30	46.16	2.49	2.55	3.11 cde	4.02	1.75	2.64	2.19 bc	1.99	20.27	28.62 c
	5	53.27	52.54 bcdef	58.70	52.54	2.44	2.59	3.61 b	4.06	1.73	3.12	2.53 a	1.97	23.74	43.01 b
	10	55.35	53.77 fghi	58.91	53.77	2.59	2.84	4.56 a	4.94	2.20	3.93	2.45 a	2.38	30.46	54.40 a
10	0	48.13	53.05 bcd	60.71	53.05	2.70	2.80	1.78 h	3.38	1.44	2.18	2.03 bcde	1.75	13.78	23.11 cde
	2.5	56.10	53.78 bc	60.93	53.78	2.63	2.66	3.00 def	4.05	1.58	2.37	2.15 bcd	1.45	16.34	21.02 def
	5	57.87	61.20 b	65.11	61.20	2.74	2.76	3.24 bcd	4.12	1.59	2.89	1.93 e	1.83	15.07	36.33 b
	10	70.33	71.14 a	67.95	71.14	2.89	2.92	4.79 a	4.47	1.64	3.18	2.01 cde	2.08	17.00	42.74 b
		NS		NS	NS	NS	NS		NS	NS	NS		NS	NS	

† Means in the same column and year followed by the same letter do not differ significantly according to the Duncan's multiple range test (P = 0.05).

‡ NS: not significant.

Fresh matter yield also significantly increased with KNO_3 treatments by an average of 121.5 and 37.8% in first and second harvests, respectively compared with the control treatment. However, there was no significant difference between 2.5 and 5 g l⁻¹ treatments in second harvest (Table 3). These results are agreement with those of Hoda *et al.* (2001) in potato, Singh and Ganesha Rao (2009) in patchouli and Singh (2008) in palmarosa. Regarding to obtained results, it was clear that potassium is considered as one of the most essential elements for growth and development of plant. Many studies proved that potassium plays a major role in many physiological and biochemical processes such as cell division and elongation; enzyme activation; stabilization of the native conformation of enzymes and possibly turgor, stomata movement, metabolism of carbohydrates and protein compounds (Marschner, 1995; Fawzy *et al.*, 2007).

Table 4. Effects of foliar $Ca(NO_3)_2$ and KNO_3 application treatments on contents (mg kg^{-1} leaf dry weight) of N, P, K and Ca tarragon leaves in two harvest.

Ca (g l^{-1})	K (g l^{-1})	N (%)		P (%)		K (%)		Ca (%)	
		First	Second	First	Second	First	Second	First	Second
0		3.61 b †	4.15 c	0.42 d	0.24 c	3.04 c	0.88 c	1.95 c	2.34 c
2.5		3.66 b	4.30 b	0.46 b	0.28 a	3.21 b	0.94 b	2.01 bc	2.35 bc
5		3.72 b	4.31 b	0.49 a	0.29 a	3.24 a	0.97 a	2.09 b	2.47 b
10		3.88 a	4.63 a	0.44 c	0.27 b	3.26 a	0.94 b	2.34 a	2.97 a
	0	3.56 c	4.26 c	0.42 c	0.25 c	3.07 d	0.80 c	1.88 c	2.45 c
	2.5	3.61 c	4.26 c	0.44 c	0.27 b	3.13 c	0.80 c	2.08 b	2.48 bc
	5	3.73 b	4.43 b	0.47 b	0.27 b	3.17 b	0.99 b	2.14 b	2.60 ab
	10	3.97 a	4.44 a	0.49 a	0.29 a	3.37 a	1.14 a	2.29 a	2.62 a
0	0	3.54 de	4.14 j	0.41 fg	0.23 hi	2.92 h	0.77 k	1.70 h	2.60 cde
	2.5	3.48 e	4.26 g	0.42 efg	0.22 i	3.06 g	0.65 m	1.80 gh	2.50 def
	5	3.68 bcde	4.03 k	0.43 defg	0.24 gh	3.06 g	1.01 e	2.10 def	1.97 i
	10	3.74 bcde	4.16 ij	0.43 defg	0.26 ef	3.12 fg	1.08 d	2.20 bcde	2.30 fgh
2.5	0	3.57 cde	4.29 f	0.44 def	0.25 fg	3.06 g	0.78 k	1.90 fgh	2.40 efg
	2.5	3.60 cde	4.41 d	0.45 def	0.29 bc	3.09 fg	0.89 h	2.00 efg	2.40 efg
	5	3.64 bcde	4.18 hi	0.46 cd	0.29 bc	3.14 ef	0.92 g	2.07 def	2.21 ghi
	10	3.81 bcd	4.31 f	0.50 b	0.30 b	3.54 a	1.16 b	2.07 def	2.40 efg
5	0	3.55 cde	4.20 h	0.43 defg	0.28 cd	3.10 fg	0.81 j	1.70 h	2.10 hi
	2.5	3.64 bcde	4.03 k	0.46 cde	0.28 cd	3.18 e	0.98 f	2.17 cde	2.20 ghi
	5	3.81 bc	4.98 b	0.53 ab	0.27 de	3.20 e	0.98 f	2.10 def	3.01 ab
	10	3.88 b	4.03 k	0.55 a	0.32 a	3.47 b	1.11 c	2.40 a	2.59 cde
10	0	3.59 cde	4.41 d	0.40	0.23 hi	3.20 e	0.84 i	2.23 bcde	2.70 cd
	2.5	3.70 bcde	4.34 e	0.42 defg	0.27 de	3.20 e	0.69 l	2.33 abc	2.80 bc
	5	3.78 bcd	4.51 c	0.46 cde	0.27 de	3.27 d	1.06 d	2.30 abcd	3.21 a
	10	4.44 a	5.27 a	0.49 bc	0.29 bc	3.35 c	1.19 a	2.50 a	3.19 a

† Means in the same column and year followed by the same letter do not differ significantly according to the Duncan's multiple range test (P = 0.05).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on fresh matter yield was significant in first harvest. The highest value (4.79 t ha^{-1}) obtained from 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 that increased fresh matter yield 211% compared with the control treatment. However, there was no difference between 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 and 5 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatments (Table 3).

Dry matter yield

Tarragon dry matter yield was increased by $Ca(NO_3)_2$ foliar application and was higher at 5 g l^{-1} rate by an average of 68.6 and 65.2% in first and second harvests, respectively compared with the control. Moreover, in both harvest there were no significant differences between 2.5 and 10 g l^{-1} $Ca(NO_3)_2$ rates (Table 3). This present finding is in agreement with those reported by Al-Hamzawi *et al.* (2010) in cucumber that state the highest shoot dry weight was observed due to the spray with $Ca(NO_3)_2$ at 15 mM. In addition, Yildirim *et al.* (2009) in strawberry reported that the highest shoot dry weight obtained from 10 mM $Ca(NO_3)_2$ spray treatment. According to the results of Dordas (2009) in oregano, dry matter yield increased with Ca during the 2 year study and at both locations compared with the control treatment. In other study, $CaCO_3$ treatment up to 5 t ha^{-1} increased dry weight in Summer savory, after which any further increase (10 t ha^{-1}) decreased the plant dry weight (Mumivand *et al.*, 2011). Also, Lee and Yang (2007) and Supanjani *et al.* (2005) were reported that $CaCO_3$ treatments up to 2 and 1.5 t ha^{-1}, respectively increased *Ch. coronarium* L. total dry weight and *Ch. boreale* M. total dry matter yield. Since enhanced dry matter production induced by elevated plant nitrogen is extremely well documented and probably driven by increases in photosynthetic efficiency (Davies *et al.*, 2009) and on the other hand, calcium has an important role in nitrogen metabolism, therefore proper concentration of this element can increase photosynthesis and as a result increased plant dry matter (Burton *et al.*, 2000).

Increasing in KNO_3 concentrations significantly increased dry matter yield by an average of 42.3 and 49.8% at first and second harvests, respectively compared with the control. Moreover, there were no significant differences between 2.5 and 5 g l^{-1} rates in first harvest and control and 2.5 g l^{-1} treatments in second harvest (Table 3). Similar responses of K applications were reported by Hoda *et al.* (2011) and yildirim *et al.* (2009). The role of potassium in an increasing the yield would can be attributed to its function in plants which include cation transport across membranes water economy, energy metabolism and enzyme activation on exchange rate and nitrogen activity as well as enhanced carbohydrate movement from the shoot to storage organs (Fawzy *et al.*, 2007).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on tarragon dry matter yield did not significant in both harvests (Table 3).

Essential oil

Essential oil content

Essential oil content significantly affected by $Ca(NO_3)_2$ foliar application at both harvests. The higher increase related to 5 g l^{-1} rate by an average of 23 and 26.3% in first and second harvests, respectively compared with the control treatment. Moreover, there were no differences between 2.5 and 10 g l^{-1} treatments in first harvest and 2.5 and 5 g l^{-1} treatments in second harvest (Table 3). According to the results of Prasad *et al.* (2008) in rose-scented geranium essential oil content increased by calcium chloride application compared with the control, which is in agreement with our results. However, Dordas (2009) reported that Ca foliar spraying did not significant influence on the essential oil content of oregano. On the other hand, the higher essential oil content of *S. hortensis* L. (Mumivand *et al.*, 2011), *Ch. boreale* M. (Lee and Yang, 2007) and *Ch. coronarium* L. (Supanjani *et al.*, 2005) obtained from 5, 1.5 and 2 t ha^{-1} $CaCO_3$ applications, respectively and after which any further increase decreased essential oil content. Suh and Park (2000) found that Ca content has the higher correlation with essential oil in plant tissue of basil (*Ocimum basilicum* L.) than N content. Lee and Yang (2007) also reported similar results in *Ch. boreale* M. on the other hand, both essential oil yield and sesquiterpene lactone content of *Ch. coronarium* have quadratic relation with lime concentration. Similarly, quadratic relation also occurs between Ca concentration in leaf and essential oil content (Supanjani *et al.*, 2005). According to this reason, calcium should have a role in terpene biosynthesis in plants.

Foliar application of KNO_3 significantly increased essential oil content by an average of 12.4 and 27% in first and second harvests, respectively compared with the control. Moreover, there were no differences between 5 with 10 and 2.5 with 5 g l^{-1} treatments in first harvest and control, 2.5 and 10 g l^{-1} in second harvest (Table 3). Zaghloul *et al.* (2009) and Said-Al Ahl *et al.* (2009) reported that potassium-humate lead to increase essential oil content in *Thuja orientalis* and oregano, respectively which is in agreement with our results. In addition, it was reported that the maximum value of caraway essential oil content was achieved from 60 kg k fed^{-1} treatment in second season (Ezz El-Din *et al.*, 2010). In contrast, Ezz El-Din *et al.* (2010) was reported that increasing K from 30 to 60 then 90 kg fed^{-1} gradually decreased the essential oil percent of caraway fruits in first season. On the other hand, findings of some researchers showed that applying of K fertilization did not influenced the essential oil contents of patchouli (Singh and Ganesha Rao, 2009), palmarosa (Singh, 2008), rosemary (Singh *et al.*, 2007) and lemongrass (Singh *et al.*, 2005).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on essential oil content was significant in first harvest. The higher value (2.53%) obtained from 5 g l^{-1} $Ca(NO_3)_2$ with 5 g l^{-1} KNO_3 treatment that increased 53.3% compared with the control. However, did not significant difference between 5 g l^{-1} $Ca(NO_3)_2$ with 5 g l^{-1} KNO_3 and 5 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatments (Table 3).

Essential oil yield

In first and second harvests, essential oil yields were higher by 88.9 and 91.8%, respectively at 5 g l^{-1} $Ca(NO_3)_2$ compared with the control and higher rate (10 g l^{-1}) significantly decreased yield of essential oil. However, there was no significant difference between 2.5 and 5 g l^{-1} treatments (Table 3). According to the results of Dordas (2009) in oregano and Prasad *et al.* (2008) in rose-scented geranium essential oil yields increased after the Ca application compared with the control, which in agreement with our results in both harvests. In addition, Mumivand *et al.* (2011) in *S. hortensis* L., Lee and Yang (2007) in *Ch. boreale* M. and Supanjani *et al.* (2005) in *Ch. coronarium* L. were reported that 5, 1.5 and 2 t ha^{-1} $CaCO_3$ rates, respectively caused the higher essential oil yield, after which any further increase decreased essential oil yield.

KNO_3 foliar application was increased essential oil yield by an average of 75.2 and 98.8% in first and second harvests, respectively compared with the control. Moreover, did not significant differences between control with 2.5 g l^{-1} treatments in both harvests and 2.5 with 5 g l^{-1} treatments in firs harvest (Table 3). The obtained results agree with those of Zaghloul *et al.* (2009) and Said-Al Ahl *et al.* (2009) that reported potassium-humate lead to increase essential oil yield in *Thuja orientalis* and oregano, respectively. On the other hand, it was reported that rising K rate did not statistically affect fruits essential oil yield of caraway (Ezz El-Din *et al.*, 2010). In addition, similar positive effects of K fertilization on essential oil yield were reported by several investigators such as Singh and Ganesha Rao (2009) in patchouli, Singh (2008) in palmarosa, Singh *et al.* (2007) in rosemary, Singh *et al.* (2005) in lemongrass.

Existing variations in oil content and composition can be attributed to factors related to ecotype, chemotype, phenophases and the environment including temperature, relative humidity, irradiance and photoperiod (Fahlen *et al.*, 1997). Among the environment factors, nutrients have important roles in essential oil content, yield and constituents (Bars and Koster, 1981).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on essential oil yield was significant in second harvest. 5 g l^{-1} $Ca(NO_3)_2$ with 5 g l^{-1} KNO_3 treatment registered the higher value (54.40 kg ha^{-1}) that increased 343.7% compared with the control (Table 3).

Nutrient uptake

Leaf N content

Table 4 demonstrates that there was significant increase in the leaf N content by an average of 7.5 and 11.6% compared with the control due to foliar spray with $Ca(NO_3)_2$ in first and second harvests, respectively. Moreover, no marked differences between control, 2.5 and 5 treatments in first harvest and control with 2.5 in second harvest, were observed. These results are in good accordance with those obtained by Al-Hamzavi (2010) and Yildirim *et al.* (2009) that reported foliar $Ca(NO_3)_2$ application rates increased N content of cucumber and strawberry, respectively. Nevertheless, Mumivand *et al.* (2010) and Supanjani *et al.* (2005) increasing in $CaCO_3$ levels significantly decreased N content of *S. hortensis* L. and *Ch. coronarium* L., respectively. On the other hand, it was reported that $CaCO_3$ levels did not significant effect on total N content of *Ch. boreale* M. (Lee and Yang, 2007).

Leaf N content significantly increased with increasing KNO_3 rates up to 10 g l^{-1} as higher values by an average of 11.5 and 4.2% compared with the control in first and second harvests, respectively. Moreover, did not significant difference between control and 2.5 g l^{-1} treatments in both harvests (Table 4). Similar responses were reported by Al-Hamzavi (2010) and Yildirim *et al.* (2009) that stated foliar KNO_3 application at 10 and 15 mM cause to highest N content in cucumber and strawberry, respectively. In addition, similar positive effects of K application on N content were reported in several studies (Hoda *et al.*, 2011; Singh and Ganesha Rao, 2009; Yildirim *et al.*, 2009; Singh *et al.*, 2007 and Nadia, 2006). On the other hand, Davies *et al.* (2009) reported that leaf N concentration of wormwood decreased with increasing K application rates.

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on leaf N content was significant in both harvests. The higher value (4.44 and 5.27% in first and second harvests, respectively) obtained from 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatment that increased 25.4 and 27.3% compared with the control (Table 4).

Leaf P content

Leaf P content significantly increased with increasing foliar application rates up to 5 g l^{-1} $Ca(NO_3)_2$ by an average of 16.7 and 20.8% in first and second harvests, respectively compared with the control, after which any further increase decreased P content. However, there was no significant difference between 2.5 and 5 g l^{-1} rates (Table 4). In cucumber and strawberry, it was reported that the higher P content obtained by 10 mM foliar $Ca(NO_3)_2$ application (Al-Hamzavi, 2010; Yildirim *et al.*, 2009). On the other hand, Mumivand *et al.* (2010) reported that $CaCO_3$ levels decreased P content of summer savory plant, while Lee and Yang (2007) and Supanjani *et al.* (2005) reported that higher $CaCO_3$ levels decreased P content of treated plants.

Foliar KNO_3 application significantly increased leaf P contents by an average of 16.7 and 16% in first and second harvests, respectively compared with the control. Moreover, did not significant difference between control with 2.5 g l^{-1} in first harvest and 2.5 with 5 g l^{-1} in second harvest (Table 4). In agreement with the results of this study, increasing foliar KNO_3 application up to 10 and 15 mM increased P content in cucumber (Al-Hamzavi, 2010) and strawberry (Yildirim *et al.*, 2009), respectively. In addition, Hoda *et al.* (2011), Singh and Ganesha Rao (2009) and Nadia (2006) found that increasing levels of K applications increased P content in potato, patchouli and barley plants, respectively. In contrast, Davies *et al.* (2009) reported that K application rates decreased P content of wormwood.

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on leaf P content was significant in both harvests. 5 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatment in first and second harvests caused the higher P content (0.55 and 0.32%) that increased 34.1 and 39.1%, respectively compared with the control (Table 4).

Leaf K content

Leaf K content was increased by $Ca(NO_3)_2$ foliar application and was higher at 10 g l^{-1} rate in first harvest and 5 g l^{-1} rate in second harvest by an average of 7.2 and 10.2%, respectively compared with the control. Moreover, there were no significant differences between 5 with 10 g l^{-1} rates in first harvest and 2.5 with 10 g l^{-1} in second harvest (Table 4). The obtained results agree with those of Al-Hamzavi (2010) and Yildirim *et al.* (2009) that stated 15 and 10 mM foliar $Ca(NO_3)_2$ resulted the higher K content in cucumber and strawberry plants, respectively. On the other hand, K content of *S. hortensis* L. and *Ch. coronarium* L. increased with increasing $CaCO_3$ levels up to 5 and 3 t ha^{-1}, respectively, after which any further increase decreased K content (Mumivand *et al.*, 2010; Supanjani *et al.*, 2005). However, these results were not in agreement with those of Karaivazoglou *et al.* (2007), which reported a considerable decrease in K content of Virginia tobacco due to lime application.

There was an increase in leaf K content by an average of 9.8 and 42.5% in first and second harvests, respectively compared with the control by foliar application of KNO_3. Moreover, did not significant difference between control and 2.5 g l^{-1} rates in second harvest (Table 4). A similar response was reported in cucumber and strawberry where the K content was increased with the foliar KNO_3 application. In addition, this finding is supported by the reports of Hoda *et al.* (2011), Singh and Ganesha Rao (2009), Davies *et al.* (2009), Singh *et al.* (2007) and Nadia (2006). They reported that K fertilization significantly increased K content of potato, patchouli, wormwood, rosemary and barley, respectively.

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on leaf K content was significant in both harvests. The higher value (3.54 and 1.19% in first and second harvests, respectively) obtained from 2.5 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatment in first harvest and 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatment in second harvest that increased 21.2 and 54.5% compared with the control (Table 4).

Leaf Ca content

With increasing foliar $Ca(NO_3)_2$ application rates leaf Ca content significantly increased by an average of 20 and 26.9% compared with the control in first and second harvests, respectively. Moreover, there were no significant differences between control with 2.5 g l^{-1} rates and 2.5 with 5 g l^{-1} rates in both harvests (Table 4). A similar response was reported by Al-Hamzavi (2010) and Yildirim *et al.* (2009) where the Ca content was increased with the foliar $Ca(NO_3)_2$ application. In addition, it was reported that $CaCO_3$ application significantly increased Ca uptake of treated plant (Mumivand *et al.*, 2010; Lee and Yang, 2007; Supanjani *et al.*, 2005).

There was an increase in leaf Ca content by an average of 21.8 and 6.9% in first and second harvests, respectively compared with the control by foliar KNO_3 application. Moreover, did not significant differences between 2.5 with 5 g l^{-1} rates in both harvests and control with 5 g l^{-1} and 5 with 10 g l^{-1} rates in second harvest (Table 4). A similar result was reported in cucumber and strawberry where the Ca content was increased with the foliar KNO_3 application. In addition, these results are in agreement with the reports of Hoda *et al.* (2011) and Nadia (2006) that found K compounds significantly increased Ca content of potato and barley, respectively. In contrast, it was reported that increase level of K fertilization decreased Ca content of wormwood plant (Davies *et al.*, 2009).

The interaction effect of $Ca(NO_3)_2$ and KNO_3 on leaf Ca content was significant in both harvests. 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatment in first harvest and 10 g l^{-1} $Ca(NO_3)_2$ with 5 g l^{-1} KNO_3 treatment in second harvest registered the higher Ca content (2.50 and 3.21%) by 47.1 and 23.5%, respectively compared with the control. Moreover, there were no significant differences between 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 and 5 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatments in first harvest and 10 g l^{-1} $Ca(NO_3)_2$ with 5 g l^{-1} KNO_3 and 10 g l^{-1} $Ca(NO_3)_2$ with 10 g l^{-1} KNO_3 treatments in second harvest (Table 4).

In general, foliar application of $Ca(NO_3)_2$ and KNO_3 improved mineral elements content of tarragon leaves. This increase was expected since both nutrients were given in the form of foliar applications. These applications have a direct effect on the mineral concentration of the elements used and have a more direct effect on growth parameters and in the response of the crop to fertilizer application compared with the soil application (Dordas *et al.*, 2007). In the soil application, the nutrients can be bound and therefore cannot be available for the plants. Also, since most nutrients are taken up with water, their uptake is restricted during water stress (Dordas, 2009). In fact, it was determined that foliar fertilization does not replace soil-applied fertilizer completely but it does increase the uptake and hence the efficiency of the nutrients applied to the soil (Tejada and Gonzalez 2004).

Conclusion

In general, foliar $Ca(NO_3)_2$ and KNO_3 application significantly increased plant height, plant width, fresh and dry matter yield of tarragon plant. The higher essential oil content and yield obtained from 5 g l^{-1} $Ca(NO_3)_2$ and 10 g l^{-1} KNO_3 rates. In conclusion, it is evident from the results that $Ca(NO_3)_2$ and KNO_3 foliar application improved N, P, K and Ca content of tarragon leaves, so can use this plant as a good source of mineral nutrition. In this study we demonstrate that foliar application of main fertilizers for plants make favor condition to produce high yield with higher quality.

Acknowledgements

We thank staffs and kindness and financial support of the Department of Horticultural Sciences, College of Agriculture & Natural Resources, University of Tehran, Karaj, Iran.

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