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Effect of N-sources on nitrogen use efficiency and nutrient content of *Ocimum canum* plants grown using nutrient film technique (NFT)

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Abstract

The aim of the study was to investigate which nitrogen source gives the highest vegetative growth, nutrient uptake and highest nitrogen use efficiency of *Ocimum canum* plant. Nutrient film technique was used to grow *O. canum* using different nitrogen sources; Nitrate (calcium and potassium nitrate) (N), urea (U) and Ammonium nitrate (AN) in the same dose. Results showed that in general, growth parameters and nutrient uptake by whole plant and different plant organs were significantly higher in nitrate treatment in comparison with the other sources. The nutrient solution containing ammonium nitrate gave the highest number of leaves, number of branches, height and leaf area per plant, as well as fresh and dry weights. Nitrogen use efficiency of N treatment (57 %) was a little bit higher than of AN (53 %), while U nitrogen utilization was much lower (NUE = 31). In conclusion, when growing *O. canum* using NFT, it is recommended that N should be supplied as ammonium nitrate.

Key words: *Ocimum canum,* nutrient film technique (NFT), nitrogen utilization, uptake

Introduction

The nutrient film technique (NFT) is considered as a method for production of vegetables and ornamental plants. Hydroponic systems, increase the cultivation capacity per unit area. It also lead to decrease in cost of herbicides, fungicides, insecticides, water and fertilizers. Successful application of the system could minimize the pollution. Nitrate and ammonium are the major forms of N available for plant growth and nutrients uptake. Although most plants can use both forms as source of N, the degree of effectiveness of these two forms on plant growth is dependent on plant species, NH_4:NO_3 ratio and the concentration. N content of leaves of plants grown with ≥ 50 % NH_4^+ was 1.3 times more than in plants provided only with NO^-_3, (Aiello and Graves, 1997). Studies have shown that NH_4 as the sole source of N, was deleterious to the growth of many plant species. However, addition of small amounts of NH_4 to NO_3 culture has been reported to increase growth of many plant species over that of NO_3 alone (Lee *et al.,* 1991). Nitrogen concentrations and uptake were higher in the plants supplied with NH_4^+ or NO_3^- + NH_4^+ than that in the plants provided with NO_3^- alone. The supply of a combination of 50:50 NO_3^- + NH_4^+ improved the nitrogen use efficiency (NUE) (Becker *et al.*, 2008).

The study was carried out to investigate the effect of nitrogen sources on N-use efficiency and nutrient content of *Ocimum canum* plants grown using nutrient film technique (NFT).

Material and methods

Experiments: The study was carried out in the green house of National Research Centre (NRC). The (NFT) system used for growing plants has been described by El-Fouly *et al.* (2009). The experiment duration was from September to December, plant used was *O. canum*. Three nitrogen sources *i.e.* nitrate, urea and ammonium nitrate were examined.

Nutrient solution: Nutrient solution was prepared according to Cooper (1979) containing the nitrogen as calcium nitrate and potassium nitrate at concentration of 200 mg/L in equal doses.

Treatments: The above mentioned solution was used as Nitrate (N) treatment. Urea (U) was used as nitrogen source in second treatment. Potassium sulfate and calcium oxide, were added to adjust the initial amount of K and Ca from nitrate. Ammonium nitrate (AN) was used as nitrogen source in the third treatment.

Experimental conditions: Day temperature ranged from 22 to 32 ^oC. Relative humidity from 36 to 56 %. pH of all solutions was adjusted to be 6.0-6.5 by adding HCl or NaOH. Conductivity of the nutrient solutions was measured two times every week. All the nutrient solutions were changed every two weeks. Solutions were aerated constantly. De-ionized water was added to maintain the volume of the nutrient solution according to need.

Planting: Selected seedlings, with 9 leaves and uniform length were planted each in a plastic pot of 8 cm diameter, containing peat moss.

Growth parameters: At the end of the experiment following parameters were measured. Plant height (cm) was measured from peat-moss surface to the top of the plant. Number of leaves was counted per plant. For number of branches, lateral branches were counted. Leaf area/plant (cm^2) was measured by getting disk area, disk dry weight and leaves dry weight (g/plant). Shoot/root ratio was calculated per plant. The number of leaves on the main stem, branches on stem and root were determined.

Sampling: Three plants from each replicate of each treatment were sampled at the end of the experiment for chemical analysis. Plants were divided to roots, stems and leaves. Each part was sequentially washed with running tap water then with 0.001 N HCl followed by two times in distilled water. Thereafter, they were air-dried at room temperature under gentle ventilation for one hour and then the samples were oven-dried at 70 ^oC for 24 hours in drying oven; and finally ground using a stainless steel mill with 0.5 mm mesh sieves, homogenized and kept in sealed polythene containers till analysis according to Chapman and Pratt (1978) and Walinga *et al.* (1989).

Nutrient determination: Total nitrogen in plant was determined based on micro-kieldahl method according to Markahem (1942) using boric acid modification as described by Ma and Zuazage (1942), phosphorus according to the method described by Jackson (1973) and K, Ca, Mg, Na and micronutrients according to the method described by Chapman and Pratt (1978). Concentrations of N, P, K, Ca, Mg and Na were calculated as %, whereas Fe, Mn, Zn and Cu were calculated as ppm.

Nitrogen use efficiency (NUE): NUE was determined as as per following relationship:

$$NUE= \frac{\text{Dry wt./whole plant (g)}}{\text{N uptake by whole plant}} \times 100$$

Statistical analysis: The experimental design was complete block with three treatments. Each treatment contained three replicates. Data were statistically analyzed using CO-STAT-computer statistical program and means were compared using LSD (P=0.05).

Results and discussion

Morphological characters: The presented data in Table 1 show that plants that were grown in nutrient solution containing AN formed the highest number of leaves/plant, number of branches/ plant, plant height and leaf area.

Differences in morphological characters *i.e.* leaf number/ plant, plant height and leaf area were significant. However, difference in branch number/plant was not significant.

Cruz *et al.* (1993) reported that the presence of ammonium in the nutrient solution enhanced plant growth rates of carob plants. Scoggins and Mills (1998) found that leaf area of poinsettias (*Euphorbia pulcherrima* Wild. Ex Klotz) was maximized with NH_4 - NO_3 treatment.

Fresh weight (g/plant): Data in Table 2 show that the highest whole plant fresh weight resulted from plants which grew with nutrient solution containing AN as nitrogen source. The results also show that the use of AN had a highly significant positive effect on fresh weight of leaves and roots.

Table 1. Effect of N-sources on some vegetative growth parameters of *O. canum*

N source 200 ppm	Number of		Plant height (cm)	Leaf area/plant (cm^2)
	Leaves/ plant	Branches / plant		
N	539(100%)	27(100%)	64(100%)	2281(100%)
U	420(78%)	29(107%)	55(86%)	1050(46%)
AN	1021(189%)	29(107%)	67(105%)	2728(120%)
$LSD_{0.05}$	74	NS	4	6

Nitrate treatment produced the highest shoot:root ratio of fresh weight (12.0) when compared to the U treatment (9.2) and AN treatment (8.2). Increase in root growth by AN were much higher than those of shoot when compared with N and U treatments.

Table 2. Effect of N sources on fresh weight (g/plant) of *O. canum*

N source 200 ppm	Fresh weight (g/plant)					Shoot: root ratio
	Leaves	Stems	Shoots	Roots	Whole plant	
N	83(100%)	97(100%)	180(100%)	15(100%)	195(100%)	12.0(100)
U	36(43%)	47(48%)	83(46%)	9(60%)	92(47.%)	9.2(77%)
AN	94(113%)	94(97%)	188(104%)	23(153%)	211(108%)	8.2(68%)
$LSD_{0.05}$	6	8	6	2	7	1

In this connection, Feng and Barker (1990) mentioned that shoots and roots fresh weight of radish plants growing at NO_3 and NH_4 increased. Also, Somda *et al.* (1990) mentioned that vegetative growth of tomato was greatest when plants were grown in the 1:1 (NH_4: NO_3) treatment. From the above-mentioned results it may be suggested that *O. canum* needed AN for producing their maximum fresh weight.

Dry weight (g/plant): Data in Table 3 show that the highest whole plant, shoot dry weights of *O. canum* were produced by plants which grew with nutrient solution contained AN, followed by N treatment and U treatment. There were no significant differences between AN and N treatments, while there was a high significant positive difference between AN and U treatments, or N and U treatments.

Results show that the use of AN increased plant growth, in terms of dry matter production. Other authors pointed out this effect, where Shaviv *et al.* (1990) mentioned that mixed ammonium and nitrate produced more dry matter than nitrate alone in wheat plants. Somda *et al.* (1990) found that in tomato dry weights of shoots and roots, were significantly restricted when NH_4-N was the sole form of N. Also, root dry weights were greatest when both N forms (1:1 N ratio) were provided.

Lasseigne *et al.* (1997) reported that root dry weight significantly decreased with increasing NH_4 concentration in nutrient solutions. Santamaria *et al.* (1998) also found that rocket plants growth was inhibited by NH_4 nutrition, while it reached the highest values when the NH_4: NO_3 ratio was 1:1.

Nutrient concentration

Leaves: Table 4 shows that N, P, K, Mn and Cu concentrations

Table 3. Effect of N sources on dry weight (g/plant) of *O. canum*

N source 200 ppm	Dry weight (g/plant)					Shoot: root ratio
	Leaves	Stems	Shoots	Roots	Whole plant	
N	8.5(100%)	12.2(100%)	20.7(100%)	1.4(100%)	22.1(100%)	14.8(100%)
U	4.8(57%)	6.0(49%)	10.9(53%)	1.0(75%)	11.9(54%)	10.4(70%)
AN	8.6(102%)	11.8(97%)	20.5(99%)	2.3(167%)	22.9(104%)	8.8(59%)
$LSD_{0.05}$	1.0	2.0	2.0	0.4	2.0	2.0

in leaf tissues increased as a result of the application of U when compared with N or AN.

Stems: Data in Table 5 show that the concentrations of N, P, Ca, Mg, Na, Fe and Zn in stems of plants which were grown with U were higher than that of AN or N treatments The concentration of Cu resulted from plants fed with N as nitrogen source for *O. canum.* On the other hand, nutrient concentration of K and Mn increased as a result of AN treatment The uptake of Na and Zn increased in plants, which were grown with N treatment when compared to the other nitrogen sources. The lowest values of all nutrient uptake resulted from plants which were grown with U as nitrogen source.

Nutrient distribution

Leaves: Data in Table 8 illustrate that there were marked variations in the nutrients uptake by leaves of *O. canum* as affected by the application of different N-sources, *i.e.* AN, U and N.

Roots: The highest nutrient concentration of P, Ca, Mn and Zn in the root tissues were produced by plants, which were fed with AN (Table 6). The highest nutrient uptake of N, K, Na, Fe and Zn by leaves was found in plants which had nitrate feeding, when compared to other sources. Nutrient concentrations of N, K, Ca, Fe and Cu increased in the root tissues by the application of U as compared to the other nitrogen sources.

Nutrient uptake

Whole plants: The highest uptake of most of the nutrients found in plants which were fed with AN treatment as compared to the other treatments. Nutrient uptake of P, Ca, Mg, Mn and Cu increased with AN treatment. Data also show the lowest nutrient uptake in leaves produced by plants which were grown in nutrient solution containing U.

Table 4. Effect of N sources on dry matter accumulation and nutrient concentration in leaf tissues of *O. canum*

N source (200 ppm)	DM (g)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	8.5	2.65	0.38	5.33	1.49	0.42	0.09	287	117	121	24
U	4.87	3.84	0.50	5.67	1.34	0.42	0.07	232	151	92	27.3
AN	8.68	2.25	0.48	4.46	1.86	0.47	0.06	253	137	65	26.6
$LSD_{0.05}$	1.21	0.81	NS	NS	NS	NS	0.02	NS	14.3	14	5.2

Table 5. Effect of N sources on dry matter accumulation and nutrient concentration in stem tissues of *O. canum*

N source (200 ppm)	DM (g)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	12.21	1.20	0.35	3.60	0.62	0.21	0.11	118	122	30	5.3
U	6.04	2.71	0.49	3.42	0.92	0.31	0.14	181	135	34	4.1
AN	11.88	1.56	0.43	4.25	0.89	0.25	0.10	145	170	33	4.3
$LSD_{0.05}$	1.62	0.33	0.12	NS	0.21	0.04	NS	16	17	NS	1.0

Table 6. Effect of N sources on dry matter accumulation and nutrient concentration in root tissues of *O. canum*

N source (200 ppm)	DM (g)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	1.40	1.38	0.12	0.52	0.36	0.17	0.17	109	162	25	10.7
U	1.05	3.0	0.14	1.02	0.53	0.06	0.17	151	174	69	16.7
AN	2.34	2.09	0.37	0.84	0.53	0.14	0.17	113	256	72	13.9
$LSD_{0.05}$	0.36	0.80	0.06	0.14	NS	0.14	NS	28	44	15	2.4

Table 7. Effect of N sources on nutrient uptake by whole plant of *O. canum*

N source (200 ppm)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	391	77	900	208	63	22	4034	2572	1430	284
U	384	57	496	128	41	14	2389	1738	729	177
AN	430	102	913	280	74	21	4188	2738	1127	315
$LSD_{0.05}$	20	13	60	60	17	3	168	136	25	20

Table 8. Effect of N sources on nutrient uptake by leaf tissues of *O. canum*

N source (200 ppm)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	225	32	453	127	36	8	2440	995	1029	204
U	188	24	276	65	20	3	1130	735	448	133
AN	196	42	387	161	41	5	2196	1189	564	231
$LSD_{0.05}$	10	5	14	6	4	1.7	129	58	35	7

Table 9. Effect of N sources on nutrient uptake by stem tissues of *O. canum*

N source (200 ppm)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	147	43	440	76	26	13	1441	1490	366	65
U	164	30	207	56	19	9	1093	815	205	25
AN	185	51	505	106	30	12	1723	2020	392	51
$LSD_{0.05}$	8	4	5	4	3	2	62	54	9	7

Table 10. Effect of N sources on nutrient uptake by root tissues of *O. canum*

N source (200 ppm)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	19	2	7	5	1	2	153	87	35	15
U	32	2	11	6	1	2	159	183	73	18
AN	49	9	20	12	3	4	264	599	169	33
$LSD_{0.05}$	4	1	2	1	0.7	0.8	7	4	6	2

Stems: Variable response of nutrient uptake by stem due to different nitrogen sources was recorded (Table 9). Nutrient uptake of N, P, K, Ca, Mg, Fe, Mn and Zn by stems increased as a result of applying AN to the nutrient solution when compared with N or U treatments. The nitrate application gave the highest values of Na and Cu in the stems as a result of the application of N when compared to U or AN. The lowest values of uptake of most of the nutrients obtained with the stem which were, grown in nutrient solution contained U (Table 9). Magnesium uptake value were slightly increased

Roots: Data in Table 10 indicate that the highest values of all nutrients uptake resulted from plants grown with AN when compared to the N or U treatments. The values of all nutrient uptakes by shoots had the same trend of that of leaves and stems, the lowest values produced by plants grown with nutrient solution containing U.

Nitrogen use efficiency (NUE): The nitrogen sources in *Ocimum* at harvest was found to be correlated with estimated plant N loss. This may serve as a method of identifying potential plant N loss in order to increase NUE efficiency via alternative management strategies.

The lowest values of most nutrients uptake by root tissues obtained with the application of N. But the uptake of P, Mg and Na had equal values for N or U application.

Table 11. Effect of N sources on nutrient uptake by shoots tissues of *O. canum*

N source (200 ppm)	Macronutrient (mg/plant)						Micronutrient (µg/plant)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
N	372	75	893	203	62	20	3881	2485	1395	269
U	352	55	485	122	40	12	2230	1555	656	159
AN	381	93	893	268	71	17	3924	2139	958	282
$LSD_{0.05}$	12	5	8	4	4	2	31	13	13	7

Table 12. Effect of N-sources on nitrogen use efficiency of *O. canum* plant

N-sources	D.W. (g/plant)	N-content mg/plant	N use efficiency
N	22.11	0.391	57
U	11.96	0.384	31
AN	22.90	0.430	53

Shoots: The highest nutrient uptake of N, P, K, Ca, Mg, Fe and Cu by shoots produced by plants which were grown with AN as compared to U or N treatments (Table 11). Data also showed that the highest nutrient uptake of Na, Mn and Zn resulted by plants which were grown with nitrate treatment, as compared to the other sources. While the lowest uptake values of all nutrients were recorded under U treatment. Data in Table 12 illustrate that the AN treatment was superior source compared with the other treatments in almost all measured parameters but N treatment showed a higher nitrogen use efficiency (NUE). The difference between NUE in N and AN treatment was negligible. The highest (NUE) of all treatment formed by N treatment, as compared to U or AN treatment. However, the total fresh and dry weight accumulation in AN treatment was much higher followed by N and U treatment.

Bsaed on the study it can be concluded that application of ammonium nitrate to the nutrient solution for *O. canum* significantly increased their growth in terms of number of leaves, number of branches, plant height, leaf area, fresh and dry weight per plant as compared to other N-sources. The application of ammonium nitrate also gave the highest content of most nutrient uptake by leaves, stem, shoot and whole plant. Ammonium nitrate treatment was superior source compared to the other treatments in almost all measured parameter but N treatment showed a higher NUE of nitrogen.

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