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Growth, nutrient uptake and nitrogen use efficiency of *Ficus hawaii* grown by nutrient film techniques (NFT) using different N-sources

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Abstract

Nutrient film technique was designed and used to grow *Ficus hawii* using different nitrogen sources, nitrate (calcium and potassium nitrate (N), urea (U) and ammonium nitrate (AN) in the same dose. Aim of the study was to investigate the most proper form of nitrogen, which gives the highest vegetative growth and nutrients uptake in the early growth of the plants. Results show that in general, AN gave the highest vegetative growth parameters expressed as plant height, number of branches plant^{-1}, leaves plant^{-1}, leaf area, fresh and dry weight. AN favoured apical growth, while U favoured lateral growth. Shoot/root ratio was highest in the AN treatment. Nutrients uptakes by the whole plant was much higher in the case of AN then U and N. Nitrogen use efficiency was highest in AN followed by U (more or less similar) and lowest in case of N.

Key words: *Ficus hawaii*, N use efficiency, N forms, nutrient film technique, nutrient uptake

Introduction

The nutrient film technique (NFT) is considered as a method for production of vegetables and ornamental plants. More than one type of this technique were designed and successfully used. The main differences between them are due to the aim of cultivation and availability of material. Hydroponics is defined as a distinct technique for plant growing where no root-supporting medium is used, whereas the other systems employ a rooting medium, either inorganic or organic.

Hydroponic systems increase the cultivation capacity per unit area. Also, they lead to decrease the cost of pesticides, water and fertilizers as well as infection effects. Successful application of these systems could minimize the pollution by the above mentioned compounds. Nitrate and ammonium are the major forms of N available for plant uptake. Although most plants can use either or both forms as a source of N, the degree of effectiveness of these two forms on plant growth is dependent on plant species and NH_4: NO_3 ratio and the concentration.

Numerous 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. The study was planned to design a (NFT) growth unit as well as to investigate the effect of different nitrogen forms on the growth and development of *Ficus hawii* L. plant.

Materials and methods

The study was carried out in the green house under the project "Micronutrients and other Plant Nutrition Problems in Egypt", National Research Centre (NRC) Dokki, Giza during the season 1999.

Growth unit design: The (NFT) system used for the study is illustrated in Fig. 1. The system was operated under fixed flow rate (45 L min^{-1}). It was made of dark blue plexiglas material. It was positioned with a gentle slope of (1%). Accordingly, the nutrient solution was flowed under the influence of gravity.

The system consisted of: a) trough as growth container or pot carrier, b) experimental pots which contained an inert growth media (peat-moss), c) non-metal pump, d) fixed pipe system, and e) the recommended nutrient solution according to Cooper (1979). Automatic pH, temperature, E.C. and humidity controller and monitoring system were used. The system is described in details below:

Trough (1): The channels were made from 10-mm metal free dark blue Plexiglas with the dimensions of 190 x 20 x 10 cm for length, width and height, respectively as shown in Fig. (1). To prevent growth of algae and other contaminating microorganisms, the channels were coated by black film of polypropylene (plastic mulch 40 micron thickness). This also led to minimize evaporation rate and photo-damage of roots.

Nutrient solution tank (2): Double face tank was made (80 x 40 x 20 cm) to have a final capacity of 60 L. The outer face of the tank was made from polypropylene (6 mm, gray color) to prevent contamination and light effect. The inner face was made from Plexiglas (3 mm, white color). The emerged plastic pump was installed in the tank centre. All connections inside the tank were made of polypropylene. The tank was located under troughs to allow the high flowing rate of drained nutrient solution to be recycled again.

Pump (3): An emerged plastic pump was used to avoid the metal concentration engaged by salt corrosion. The pump was running continuously with a given flow rate of 150 litre per-minute and

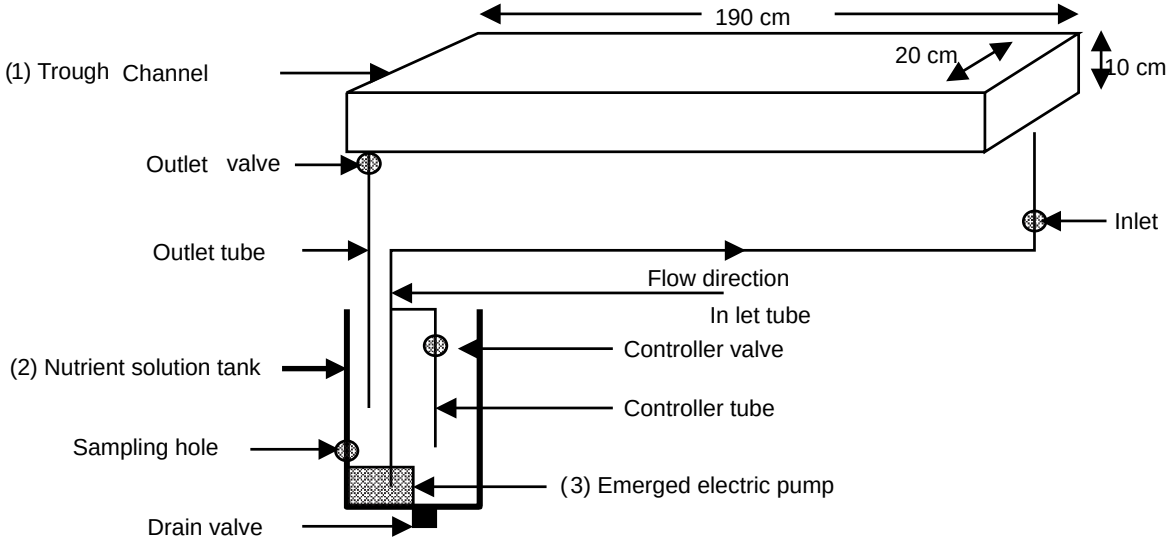

Fig.1. Side view of the plexiglas unit

was adjusted at 54 L minute^{-1}, for the type, carrying the nutrients solution from the tank to the head of channels. Flow rate was adjusted to be parallel with that of drainage rate, and also, to give a shallow solution of about 0.5 cm thickness.

Cultures were supplied by the nutrient solution using emerged centrifugal pump (Eheim 1250-Germany). Technical data of the pump used in the system are listed in Table (1).

Table 1. Technical data of the pump used (Eheim 1250)

Pump-out approx.	1200 (L h^{-1})
Delivery head	2.00 (m.w.c.)
Power consumption	28 (watt hr^{-1})

Pipe system (4): The nutrient solution was supplied through PVC pipe started at the highest end to allow the high flowing of nutrient solution. The drain of the nutrient solution was re-collected in the nutrient tank and re-cycled again by the emerged pump to the upper side. The content of nutrients and their balance were recorded. The feeding pipes were connected from the rear side to prevent the root damage by solution pressure, which is generated from the high flow rate.

Experiment: The experiment was initiated to investigate how various nitrogen sources affect plant growth, plant nutrient concentrations and nutrient uptake of *Ficus hawaii* . The experiment was conducted during January-April 1999 and three nitrogen sources *i.e.* nitrate, urea and ammonium nitrate were examined.

Nutrient solution

Treatment (1) - Nitrate (N): Nutrient solution was prepared according to Cooper (1979), containing the nitrogen as calcium nitrate and potassium nitrate at concentration of 200 mg L^{-1} in equal rates.

Treatment (2) - Urea (U): Nutrient solution contained the nitrogen as urea. K_2SO_4 and CaO were compensated for the initial amount of K and Ca from nitrate salts (treatment1).

Treatment (3) - Ammonium nitrate (AN): Nutrient solution contained the nitrogen as ammonium nitrate and additional equivalent quantity from K_2SO_4 and CaO, to compensate K and Ca in treatment 1.

Day temperature during the experiment ranged from 22 to 32^{O}C, relative humidity from 36 to 56%, and pH of all solutions was adjusted to pH 6.0-6.5, and conductivity of the nutrient solutions was measured two times every week. HCl or NaOH were added to keep pH in the range of 6.0-6.5. All the nutrient solutions were changed every two weeks. Solutions were aerated constantly; meanwhile de-ionized water was added to maintain the volume of the nutrient solution. Each treatment was replicated three times.

Planting: Terminal stem cuttings of *Ficus hawaii* 5-7 cm long were taken on 15 October 1998 and rooted in peat moss under low tunnel in the greenhouse. Four weeks later, selected rooted cuttings were transplanted to grow under green house conditions till the experiment started (January 1999) and then transferred to the solution culture (NFT system).

Growth parameters measured: At the end of the experiment, plant length, stem diameter, number of leaves, number of lateral branches, leaf area, fresh and dry weights for whole plants and their fractions, were measured.

Plant height (cm) was measured from peat-moss surface to the top of the plant at the end of the experimental period. Leaf area (cm^2 plant^{-1}) was measured by getting a disk area, disk dry weight and leaves dry weight (g plant^{-1}). Shoot/root ratio was calculated. The leaves on the main stem and branches were taken to determine fresh and dry weights.

Sampling for chemical analysis: 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 normal HCl followed by distilled water twice. Thereafter, they were air-dried at room temperature under gentle ventilation for 1 h and then, the samples were oven-dried at 70 ^{O}C for 24 hours in drying oven; and finely 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).

Chemicals analysis: The dried parts of the plant were used. Total nitrogen in plant was determined based on micro-Kjeldahl method according to Markaham (1942), using boric acid modification as

Table 2. Chemical composition of the nutrient solution (Cooper, 1979)

Elements	mg L^{-1}	Elements	mg L^{-1}
Nitrogen	200	Manganese	0.1
Phosphorus	60	Boron	0.3
Potassium	300	Copper	0.1
Calcium	170	Zinc	0.1
Magnesium	50	Molybdenum	0.2
Iron	12		

described by Ma and Zuazage (1942), under steam distillation using Buchii 320 unit, and was calculated as nitrogen percent. The wet ashing technique was carried out for extracting the other nutrients from plant tissues by digesting plant material using a mixture of nitric acid, sulphuric acid, perchloric acid (8:1:1) according to the method described by Chapman and Pratt (1978). Concentrations of the microelements Fe, Mn, Zn and Cu were measured by using atomic absorption spectrophotometer Perkin Elemer, 1100 B apparatus. Phosphorus was measured in digested plant material according to the method described by Jackson (1973). Potassium, calcium and sodium were measured in digested plant material using Flame photometer, Eppendorf. Magnesium was measured in digested plant material by using atomic absorption spectrophotometer Perkin Elemer, 1100 B apparatus according to Chapman and Pratt (1978).

Results of analysis were calculated on dry weight basis. Concentrations of N, P, K, Ca, Mg and Na were calculated as (%), whereas, Fe, Mn, Zn and Cu were calculated as ppm.

Statistical analysis: The experimental design was complete block with three treatments. Each treatment contained three replicates. Data were statistically analyzed using COSTAT computer statistical program and means were compared using L.S.D. at P=0.05 and P=0.01. The parameters *viz.*, number of leaves, number of branches, plant height, fresh and dry weights and chemical analysis of macro and microelements were analyzed.

Results and discussion

Morphological characters: Plant height was significantly affected by N-sources. The maximum plant height resulted in plants grew with AN. The increment of plant height with NH_4-NO_3 reached 30% more than that of using nitrates alone (control), or 32% than that of U treatment.

The number of branches per plant was also affected by the N-source. The highest value was obtained in plants supplied with U, followed by those grew in AN and the least value was recorded in N treatment. The differences in number of branches plant^{-1} were significant. The differences in leaf number plant^{-1} were significant. AN treatment increased number of leaves plant^{-1} by 71% over the N treatment and by 30% compared with U treatment.

Leaf area was significantly affected. The largest leaf area resulted for plants which grew in nutrient solution containing AN, being significantly higher than that of the plants grew in U and N alone. The percentage of increment in leaf area reached (81%) for plants grew in AN and 54% for plants grew in U, over the plants grew in a nutrient solution containing only N (Table 3).

In this connection, several authors mentioned that growth of different plants is greatly affected by the nitrogen source in the nutrient solution. Scoggins and Mills (1998) found that leaf area of poinsettias (*Eupliorbia puicherrima* Willd-Ex Klotz) was maximized with 25:75 and 50:50 NH_4: NO_3 treatments, respectively. Errehbi and Wilcox (1990) mentioned that the addition of small amounts NH_4 to NO_3 solution, up to 14 ppm improved plant growth of tomato.

On the other hand, Qasem and Hill (1993) found that the growth of tomato was reduced when ammonium or urea was the only sources of N. In our experiments AN produced plants taller than the other two treatments with more branches and leaves and leaf area plant^{-1}. It is interesting to note that U did not affect plant height compared with N, but produced more branches, leaves and leaf area, which indicates that U encourages the lateral growth more than the apical growth, which is in contrast to the effect of AN.

Fresh weight (g plant^{-1}): Table 4 show that the plant fresh weight was highest in nutrient solution contained AN, followed by U and NO_3. The stem, shoot (aerial growth) and roots fresh weight

Table 3. Effect of N sources on some morphological parameters of *Ficus hawaii* L. (7 days old)

N sources (200 ppm)	Plant height (cm)	Number of		Leaf area (cm^2 plant^{-1})
		Branches plant^{-1}	Leaves plant^{-1}	
Nitrate (N)	25.83	7.67	73.33	197.21
	100%	100%	100%	100%
Urea (U)	25.33	13.67	103.33	249.93
	98%	178%	141%	127%
Ammonium nitrate (AN)	33.67	13.33	125.33	356.15
	130%	174%	171%	181%
LSD (P=0.05)	4.24	1.99	11.53	54.53
LSD (P=0.01)	6.42	3.03	17.84	82.61

Table 4. Effect of N sources on fresh weight (g plant^{-1}) of *Ficus hawaii* L.

N sources (200 ppm)	Fresh weight (g plant^{-1})					Shoot : Root Ratio
	Leaves (L)	Stems (S)	Shoot (L+S)	Root (R)	Whole plant	
Nitrate (N)	14.24	4.49	18.73	4.98	23.71	3.76
	100%	100%	100%	100%	100%	
Urea (U)	18.29	5.08	23.37	4.89	28.38	4.78
	128%	113%	125%	98%	120%	
Ammonium nitrate (AN)	27.91	7.53	35.44	5.92	41.15	6.99
	196%	168%	189%	119%	174%	
LSD (P=0.05)	1.35	0.73	1.64	NS	2.62	1.88
LSD (P=0.01)	2.05	1.10	2.54	NS	3.97	NS

showed the same pattern when comparing growth of plants grown under the three nitrogen forms.

The AN treatment had a higher shoot/root ratio of fresh weight (6.99) than U (4.78) and N treatment (3.76) (Table 4). These differences were highly significant between AN and the other sources. Similar results were reported by Spiers and Braswell (1993) who found that shoot growth of muscadine grapes plants was greatest with NH_4NO_3. Santamaria *et al.* (1998) reported that rocket growth was inhibited by NH_4 nutrition, while it reached the highest values with the NH_4:NO_3 ratio 1:1.

Dry weight (g plant^{-1}): Table 5 indicates that dry weight for whole plant was highest for plants which grew in AN, followed by those grew in U and then N, which is the same pattern as the fresh weight. The highest shoot growth in terms of dry weight was obtained by plants which grew in a nutrient solution containing AN as N-source, as compared when nitrogen nutrient came from urea or from nitrate as sources for nitrogen.

The same trend was obtained for dry weight of shoots and whole plant. This leads to that AN treatment had a high shoot: root dry weight ratio (7.35) as compared to the N treatment (5.14). The average increment in dry weight per whole plant and different organs were: (leaves 78% , stem 46%, root 18%, shoot 69% and whole plant 61%) with AN over the plants received N treatment.

The above-mentioned results indicate that AN application increased plant growth, in terms of dry matter production. Shaviv *et al.* (1990) also reported that tomato plants grew on mixed ammonium and nitrate as N sources produced larger dry matter and protein yields than those grew on nitrate alone. Somda *et al.* (1990) found that the largest shoot and root dry weights were obtained when tomato plants were fed with 1:1 NH_4^+ NO_3^- ratio. Further, Qasem and Hill (1993) found that the growth of all species of tomato plant was reduced when ammonium or urea were the only sources of N. Santamaria *et al.* (1998) found that rocket growth was inhibited by NH_4 nutrition, while it reached the highest values with the NH_4^+ NO_3^- ratio 50:50. On the other hand, Feigin (1990) mentioned that the dry matter production was not significantly affected by the NH_4/NO_3 ratio on crop yield. Ganmore-Neuman and Hagiladi (1990) found that the ratio did not affect cutting yields of Pelargoniurn plants. Also, Aminuddin *et al.* (1991) reported that plant dry weight did not differ significantly between treatments of ammonium or nitrate.

Effect of N-source on nutrient status of Ficus hawaii plants

Nutrient concentration

Leaves: N, P, Ca, Na and Fe concentrations in leaf tissues increased in N compared to U or AN. While K, Mg, Mn Zn and Cu concentration in leaf tissues increased when U was the nitrogen source (Table 6).

Table 5. Effect of N sources on dry weight (g plant^{-1}) of *Ficus hawaii* L plants

N sources (200 ppm)	Dry weight (g plant^{-1})					Shoot / Root Ratio
	Leaves L	Stems S	Shoot (L+S)	Root R	Whole plant	
Nitrate (N)	2.64	1.01	3.65	0.71	4.36	5.14
	100%	100%	100%	100%	100%	100%
Urea (U)	3.21	1.00	4.21	0.69	4.90	6.10
	122%	99%	115%	97%	112%	119%
Ammonium nitrate (AN)	4.69	1.48	6.17	0.84	7.01	7.35
	178%	146%	169%	118%	161%	145%
LSD (*P*=0.05)	0.71	0.32	0.90	NS	0.96	2.04
LSD (*P*=0.01)	1.08	0.48	1.37	NS	1.46	NS

Table 6. Effect of N sources on elemental concentration in *Ficus hawaii* leaf tissues

N sources (200 ppm)	Macronutrient (%)						Micronutrient (ppm)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	3.67	0.29	1.88	0.31	0.51	0.48	521	93	53	6
Urea (U)	2.31	0.28	2.86	0.30	0.59	0.37	478	141	76	11
Ammonium nitrate (AN)	2.40	0.26	2.67	0.27	0.56	0.35	375	125	66	14
LSD (*P*=0.05)	0.47	0.05	1.40	NS	0.09	0.08	115	NS	NS	4
LSD (*P*=0.01)	0.72	NS	NS	NS	NS	0.12	NS	NS	NS	6

Table 7. Effect of N sources on elemental composition in *Ficus hawaii* stem tissues

N sources (200 ppm)	Macronutrient (%)						Micronutrient (ppm)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	2.47	0.31	2.87	0.17	0.77	0.37	327	150	108	12
Urea (U)	3.31	0.30	2.43	0.19	0.81	0.32	511	147	110	9
Ammonium nitrate (AN)	2.80	0.28	2.68	0.34	0.73	0.33	432	178	95	6
LSD (*P*=0.05)	0.28	NS	0.44	0.13	0.06	0.09	137	28	22	3
LSD (*P*=0.01)	0.42	NS	NS	NS	NS	NS	NS	NS	NS	4

Table 8. Effect of N sources on elemental composition in *Ficus hawaii* root tissues

N sources (200 ppm)	Macronutrient (%)						Micronutrient (ppm)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	2.48	0.47	1.49	0.13	0.75	0.43	165	121	83	13
Urea (U)	2.46	0.38	1.89	0.15	0.76	0.35	238	156	88	12
Ammonium nitrate (AN)	2.47	0.35	3.12	0.12	0.75	0.24	318	136	75	11
LSD (*P*=0.05)	NS	0.12	1.09	NS	NS	NS	125	NS	NS	NS
LSD (*P*=0.01)	-	NS	NS	-	-	-	NS	-	-	-

Stem: The highest values of P, K, Na and Cu concentrations were found in plants grown in a nutrient solution containing NO_3 as a sole N-source. While, the highest values of N, Mg, Fe and Zn concentrations were obtained when plants were fed with a solution containing nitrogen either in U or AN forms (Table 7).

Roots: No specific trend could be detected for nutrient concentrations in response to the source of nitrogen in the nutrient solution. Nitrogen, phosphorus, sodium and copper contents recorded the highest values in root tissues of the plants, which were supplied with NO_3, as compared to the other sources. The highest concentration of Ca, Mg, Mn and Zn were found in root tissues of the plants which received U. The highest value of K and Fe was found with AN treatment (Table 8).

Nutrient uptake

Content of leaves: Table 9 indicate different responses of nutrient uptake by leaves of *F. hawaii*. The AN application gave the highest of all nutrient uptakes when compared to U or N treatment. The lowest values of nutrients uptake by leaves (except N) were obtained with N application treatment.

Content in Stems: Table 10 show that the highest values of most nutrient uptake in stems resulted from AN as a nitrogen source in nutrient solution when compared to U and N treatments. The lowest values of Na and Mn nutrient uptake resulted in plants which grew in nutrient solution contained U as nitrogen source. Whereas, the lowest N uptake value was found in plants which were supplied with N treatment,

Content in roots: Table 11 demonstrate different responses of nutrient uptake in roots of *F. hawaii*. The highest nutrient uptake values of N, K, Mg, Fe, Mn and Cu were found in AN treatment, as compared to the other treatments. The lowest uptake values except for K, Fe, Mn and Zn were observed when N was the nitrogen source in nutrient solution.

Content in shoots: Table 12 show that the nutrient uptake of shoots exhibit various responses to different nitrogen sources. The highest uptake of all measured nutrients resulted from AN treatment as compared to the other nitrogen sources. The application of N as nitrogen source resulted in the lowest values of most nutrients uptake, as compared to other sources.

Table 9. Effect of N sources on nutrient uptake by leaf tissues of *F. hawaii* L. plants

N sources (200 ppm)	D.M. (g)	Macronutrient (mg plant^{-1})						Micronutrient (ppm)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	2.64	95	8	49	8	13	12	1400	242	138	16
Urea (U)	3.21	74	9	82	10	19	12	1500	451	243	35
Ammonium nitrate (AN)	4.69	113	12	125	13	26	16	1800	586	310	66
LSD (*P*=0.05)	0.71	9.67	2.83	10.14	3.12	3.46	NS	NS	43.93	27.6	9.30
LSD (*P*=0.01)	1.08	14.66	NS	15.37	NS	5.24			66.56	41.81	14.09

Table 10. Effect of N sources on nutrient uptake by stem tissues *F. hawaii* L. plants

N sources (200 ppm)	D.M. (g)	Macronutrient (mg plant^{-1})						Micronutrient (ppm)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	1.01	25	3	29	2	8	4	327	150	108	12
Urea (U)	1.00	33	3	24	2	8	3	511	147	110	9
Ammonium nitrate (AN)	1.48	42	4	40	5	11	5	648	267	143	9
LSD (*P*=0.05)	0.32	7.11	NS	8.71	1.41	2	NS	30.4	16.2	15.1	NS
LSD (*P*=0.01)	0.48	10.77		13.19	2.14	NS		NS	24.59	22.99	

Table 11. Effect of N sources on nutrient uptake by root tissue *F. hawaii* L. plants

N sources (200 ppm)	D.M. (g)	Macronutrient (mg plant^{-1})						Micronutrient (ppm)			
		N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	0.71	17	3	10	1	5	3	116	85	58	9
Urea (U)	0.69	17	3	13	1	5	2	167	109	62	8
Ammonium nitrate (AN)	0.84	20	3	25	1	6	2	254	109	60	9
LSD (*P*=0.05)	0.33	NS	NS	3.46	NS	NS	NS	5.65	8.71	NS	NS
LSD (*P*=0.01)	0.50			5.24				8.56	13.19		

Table 12. Effect of N sources on nutrient uptake by whole plant *F. hawaii* L. plants

N sources (200 ppm)	Macronutrient (mg plant^{-1})						Micronutrient (ppm)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	137	14	88	11	26	19	1843	477	301	37
Urea (U)	124	15	129	13	32	17	2178	707	415	62
Ammonium nitrate (AN)	175	19	190	19	43	23	2702	964	513	84
LSD (*P*=0.05)	7.74	2.0	7.56	2.0	4.32	2.0	163	19.8	23.4	5.65
LSD (*P*=0.01)	11.72	3.03	11.46	3.03	6.54	3.03	248	30	35.4	8.56

Table 13. Effect of N sources on nutrient uptake by shoot tissue *F. hawaii* L. plants

N sources (200 ppm)	Macronutrient (mg plant^{-1})						Micronutrient (ppm)			
	N	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu
Nitrate (N)	120	11	78	10	21	16	1727	392	246	28
Urea (U)	107	12	116	12	27	15	2011	598	353	44
Ammonium nitrate (AN)	155	16	165	18	37	21	2448	855	453	75
LSD (*P*=0.05)	8.44	2	7.11	2.83	5.29	2	34.9	11.12	8.48	8.16
LSD (*P*=0.01)	12.84	3	10.77	4.28	8.01	3.03	52.8	16.9	12.81	12.36

Table 14. N use efficiency mg dry matter produced/mg N in the plant

N-Sources	Dry weight (g plant^{-1})	N Content (mg plant^{-1})	Use efficiency (mg dry wt g^{-1})
Nitrate (N)	4.360	137	31.8
Urea (U)	4.90	124	39.5
Ammonium nitrate (AN)	7.01	175	40.1

Nutrient uptake by whole plant: Table 13 show that the nutrient uptake of whole plant exhibited the same trend. The highest nutrient uptake of all nutrients was found in AN treatment, as compared to U and N.

Nitrogen use efficiency (NUE): It is clear that AN treatment, which was superior to other treatments in almost all measured parameters showed also a higher use efficiency of nitrogen. The difference between NUE in this treatment and U was very negligible. However, the total fresh and dry weight accumulation in the urea treatment was much lower.

It could be concluded that AN is a better source of nitrogen for *F. hawaii* while urea enhances lateral growth with lower dry matter accumulation.

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