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Effects of Different Nitrogen Rates on Yield and Leaf Nutrient Contents of Drip-fertigated and Greenhouse-grown Cucumber

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Abstract: The aim of the present study was to investigate the effect of the nitrogen concentrations (0-100-150-200 mg N L^{-1}) and their application frequencies (one and twice per week) on yield and leaf nutrient content of drip-fertigated cucumber on sandy-loam soil under the glasshouse conditions and also to determine whether there was a difference between the application of low nitrogen concentrations (50 and 100 mg N L^{-1}) continuously and high nitrogen concentrations (200 and 250 mg N L^{-1}) twice per week in terms of investigated characteristics. The highest yield (75.2 t ha^{-1}) was obtained with the application of 200 mg N L^{-1} nitrogen twice per week. Irrespective of application frequency, the highest total yield was produced with 200 mg N L^{-1} nitrogen concentration (71.2 t ha^{-1}). Nitrogen application twice per week also resulted in higher early yield compared to once a week application. Nitrogen concentration and application frequency also affected fruit number. The highest fruit number was obtained with 200 mg N L^{-1} nitrogen concentration (59.4 fruit m^{-2}). While the chlorophyll content of the leaf was affected by only nitrogen concentration, the nitrogen (N) and phosphate (P) content of the leaf were affected by both the nitrogen concentration and the application frequency. Whereas potassium (K) content of the leaf was influenced by the application frequency of nitrogen. The N, P and K contents of the leaf were within the sufficiency level. In the study where different nitrogen concentrations were applied at each irrigation (continuously) or at twice per week, the best result obtained with application of 200 mg N L^{-1} nitrogen concentration twice per week (86.6 t ha^{-1}). Based on these results it was concluded that application of 200 mg N L^{-1} nitrogen twice per week irrigation together with 200 mg K L^{-1} +40 mg Mg L^{-1} +2.5 mg Fe L^{-1} once a week was adequate in terms of yield and leaf nutrient contents. Also, application of lower nitrogen concentrations at each irrigation did not produced greater yield when compared to 200 mg N L^{-1} nitrogen applied twice per week. It can be concluded from this result that there is no need to continuous nitrogen supply in fertigation.

Key words: Cucumber (*Cucumis sativus* L.), drip irrigation, yield, nitrogen, application frequency

INTRODUCTION

Fertigation has been widely used by growers all over the world because of leading to increase in yield and quality as well as increase in water and fertiliser use efficiency. Under drip irrigation conditions, crops have restricted root volumes and small reserves of water and nutrient in the soil (Bar-Yosef *et al.*, 1980). In general the smaller soil volume is considered beneficial because of minimising losses of water and agrochemicals, but rapid variations of environment are produced by plant activity in the small rooting volume. Thus, the concentration of nutrients and its application frequency are more important in fertigation than conventional irrigation and fertilisation techniques. Numerous studies have been conducted with different crops on determination of the concentration of the nutrients (Bhella and Wilcox, 1985; Papadopoulos, 1987; Albregts *et al.*, 1996; Locascio *et al.*, 1997), and the quantity of the irrigation water (Horton *et al.*, 1982; Wierenga and Hendrickx, 1985; Locascio *et al.*, 1989; Hartz, 1993) to be applied via drip irrigation system. Also, there have been several studies on determination of application frequency of irrigation water (Bar-Yosef *et al.*, 1980; Locascio *et al.*, 1985; Locascio *et al.*, 1989; Hartz *et al.*, 1994). However information on application frequency of nutrients supplied with irrigation water by drip irrigation system is scarce, especially for soil-grown vegetables (Thomas *et al.*, 2003). Most of the available data have been obtained from soilless culture growing technique. Soil-grown and soilless culture-grown plant are completely different from each other. The latter has to be regularly supplied with water and nutrient in short intervals due to grown on a inert media which has lower water and nutrient holding capacity when compared to soil-grown plant (Özgümüş, 1996). This study was conducted to determine the best nitrogen concentration and application frequency and to find whether there was

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a difference between continuous application of lower nitrogen concentrations and higher nitrogen concentrations twice a week as fertigation.

MATERIALS AND METHODS

Experiments were conducted on a sandy-loam soil (19% clay, 23% silt, 58% sand) in a glasshouse during 2000-2002. The chemical and physical properties of the experimental soil were as follows: pH: 7.00 (1:2.5 soil:water), EC:3.12 dS m^{-1} (1:2.5 soil-water), $CaCO_3$: 0.32%, organic matter 2.93%, $NaHCO_3$- extractable P: 26.4 kg da^{-1} (0.5 N $NaHCO_3$) and extractable K: 89.9 kg da^{-1} (1.0 N ammonium acetate, pH 7.0). Cucumber cv. *Seyhan* was used in the first study (2000 and 2001), cv *Afrodit* in the second study (2002). In the first study, four nitrogen concentrations (0, 100, 150, 200 mg N L^{-1} and two application frequency (once and twice per week) were tested with respect to yield, leaf chlorophyll, N, P and K content. In addition to nitrogen, all plots received potassium, magnesium and iron at concentrations of 200, 40 and 2.5 mg L^{-1}, respectively, once per week which supplied as 0.5, 1.0, 1.5 and 2.0 l $plant^{-1}$ depending on growing stage and environmental conditions. Irrigation water was applied using tensiometer until tensiometer reading at 30 cm depth reached 30 kPa. Urea (46% N), potassium sulphate (50% K_2O), magnesium sulphate (10% Mg) and Fe-EDDHA (6% Fe) were used as N, K, Mg and Fe sources, respectively. Experimental design was randomised complete block design in four replications. Each plot had ten plants having inter row and inter plant spacing were 90 and 50 cm, respectively. Seedlings were transplanted in the first week of April. In each year, phosphorus was applied at a concentration of 28 kg ha^{-1} as triple super phosphate before transplanting. Total amount of nitrogen applied to per plant throughout the growing season was 9.0 L per plant for once a week nitrogen application treatment and 18.0 L per plant for two times per week nitrogen application treatment. Also each plant received 9.5 L K+Mg+Fe containing solution once per week throughout the growing season. During the first experiment, total amount of nitrogen used for once per week nitrogen application was 24.0 kg N ha^{-1} for 100 mg N L^{-1}, 36.0 kg N ha^{-1} for 150 mg N L^{-1} and 48.1 kg N ha^{-1} for 200 mg N L^{-1} level . In the twice per week nitrogen application treatment, these amounts were two fold of nitrogen mentioned above. In addition, 50.7 kg K ha^{-1} potassium, 10.1 kg Mg ha^{-1} magnesium and 0.63 kg Fe ha^{-1} iron were used (Table 1). All nutrients except for P were supplied within irrigation water via drip irrigation system throughout growing season by using proportional injector D 8 R (Dosatron International), beginning three weeks after transplanting and terminating one week before the last harvest. Nutrient solution was supplied as 0.5, 1.0, 1.5 and 2.0 L $plant^{-1}$ depending on growing stage and environmental conditions.

In the second experiment, 50 and 100 mg N L^{-1} were applied at each irrigation (plant did not received water without nitrogen), 200 and 250 mg N L^{-1} were supplied at twice per week. This experiment was carried out using complete block design with four replicates. Planting space, irrigation and fertilisation were the same as the first study. Only ammonium nitrate (%33 N) was used as nitrogen source instead of urea. Total amount of nitrogen solution applied was 27.5 L $plant^{-1}$ for 50 and 100 mg N L^{-1} plots and 19.5 L $plant^{-1}$ for 200 and 250 mg N L^{-1} plots. Also, all plants received 9 L $plant^{-1}$ K+Mg+Fe solution throughout growing period. These amounts were equivalent to 36.7 kg N ha^{-1} nitrogen for 50 mg N L^{-1}, 73.4 kg N ha^{-1} for 100 mg N L^{-1}, 104.1 kg N ha^{-1} for 200 mg N L^{-1} and 130.2 kg N ha^{-1} for 250 mg N L^{-1} nitrogen concentration. Also, all plants were supplied with 48.1 kg K ha^{-1} potassium, 9.6 kg Mg ha^{-1} magnesium and 0.6 kg Fe ha^{-1} iron during the growing season (Table 2). During the experiments early yield, total yield, fruit number, mean fruit weight, leaf chlorophyll, N, P and K contents were recorded. Harvest was made twice or three times per week. Fruit numbers were counted at every harvest. Mean weight were calculated dividing total yield to total fruit number. The cumulative yield of the first three harvests evaluated as early yield. The leaf chlorophyll was measured using minolta SPAD-502 chlorophyll - meter.

Table 1: Details of nitrogen concentration and application frequencies experiment (Exp. I)

Application frequency	Nitrogen concentration (mg N L^{-1})	Nitrogen solution used (L $plant^{-1}$)	K+Mg+Fe[z] solution used (L $plant^{-1}$)	Total nitrogen used (kg N ha^{-1})
Once per week	0	-	9.5	0
	100	9	9.5	24
	150	9	9.5	36
	200	9	9.5	48.1
Twice per week	0	-	9.5	0
	100	18	9.5	48
	150	18	9.5	72
	200	18	9.5	96.2

[z] = This amount solution is equal to 50.7 kg K ha^{-1}, 10.1 kg Mg ha^{-1} and 0.63 kg Fe ha^{-1}

Table 2: Details of continuous and twice per week nitrogen application experiment (Exp. II)

Nitrogen concentration (mg N L^{-1})	Application method	Nitrogen solution used (L $plant^{-1}$)	K+Mg+Fe[z] solution used (L $plant^{-1}$)	Total Nitrogen used (kg N ha^{-1})
50	Continuous supply	27.5	9.0	36.5
100	Continuous supply	27.5	9.0	73.4
200	Twice per week	19.5	9.0	104.1
250	Twice per week	19.5	9.0	130.2

[z] = This amount solution is equal to 48.1 kg K ha^{-1}, 9.6 kg Mg ha^{-1} and 0.6 kg Fe ha^{-1}

Table 3: Effects of nitrogen concentration and application frequency on the total yield, early yield, fruit number and mean fruit weight of cucumber (2000-2001)

Treatments		Total yield (t ha^{-1})	Early yield (t ha^{-1})	Total fruit number (fruit m^{-2})	Mean fruit weight (g $fruit^{-1}$)
Year	2000	60.1	2.87	48.4	124.5
	2001	66.8	1.87	58.2	114.5
LSD		2.60**	0.293**	2.29**	2.99**
Application Frequency	Once per week	60.7	1.85	51.9	117.4
	Twice per week	66.2	2.91	54.6	121.6
LSD		2.60**	0.293**	2.29**	2.99**
Nitrogen Concentrations (mg N L^{-1})	0	53.1c	1.69c	45.4c	117.4b
	100	63.3 b	2.62ab	51.2b	124.1a
	150	66.1 b	2.35b	57.1a	116.6b
	200	71.2 a	2.81a	59.4a	117.4b
LSD		3.68**	0.414**	3.231*	4.24*
Once per week	0	54.4ef	1.12	47.0ef	116.3b
	100	58.9de	2.21	49.7de	118.9b
	150	62.3cd	1.80	54.7c	114.2b
	200	67.2bc	2.23	56.2bc	120.1b
Twice per week	0	51.9f	2.27	43.8 f	118.5b
	100	67.7b	3.04	52.6cd	129.3a
	150	69.9b	2.91	59.5ab	118.9b
	200	75.2a	3.40	62.6a	119.7b
Nitrogen vs Application frequency		5.21**	ns	4.570**	4.48*
Year vs Application frequency		3.68**	ns	ns	ns
Year vs Nitrogen		5.21**	0.586**	4.570**	ns
Year vs Nitrogen vs Application frequency		ns	ns	ns	ns
Cv (%)		6.11	18.22	6.36	3.70

ns, * and ** non significant or significant at p = 0.05 or 0.01, respectively

Leaf samples were collected for determination of N, P and K. Leaf N was determined by micro-kjeldahl method and leaf K by flame emission spectrophotometry. Leaf P was determined spectrophotometrically.

Analysis of variance (ANOVA), LSD Test and regression analysis were performed on each variable using MSTAT program.

RESULTS

Effects of nitrogen concentration and application frequency

Yield parameters: Both nitrogen concentrations and application frequency had significant effect on total yield (Table 3). Total average yield was 60.7 t ha^{-1} for once a week N receiving plants. Whereas it was 66.2 t ha^{-1} twice N receiving plants (Table 3). Irrespective of the application frequency, 200 mg N L^{-1} gave the highest yield (71.2 t ha^{-1}). Nitrogen concentration x application frequency interaction was significant for total yield. The highest yield (75.2 t ha^{-1}) was obtained from the plant supplied with 200 mg N L^{-1} two times per week. The relation between nitrogen concentration and yield was found as $y = 5.3446+0.089x$, where y is total yield and x is nitrogen concentration. There was significant relationship between nitrogen concentration and total yield ($R^2 = 0.509$).

The early yield was also affected by both nitrogen concentration and application frequency (Table 3). Early yield was greater with twice nitrogen application (2.91 t ha^{-1} in average) when compared to single nitrogen application (1.85 t ha^{-1}). Irrespective of application frequency, plant supplied with 200 mg N L^{-1} nitrogen produced significantly higher early yield (2.82 t ha^{-1}) when compared to other nitrogen concentrations (Table 3).

As in the total and early yield, both nitrogen concentration and application frequency affected the total fruit number and the mean fruit weight. Nitrogen concentration x application frequency interaction was significant for both parameters (Table 3). Total fruit number was 51.9 fruit m^{-2} for plants receiving nitrogen once per week, whereas it was 54.6 fruit m^{-2} for plants receiving nitrogen twice per week. Fruit number increased with increasing nitrogen concentration and 200 mg N L^{-1} nitrogen concentration gave the highest fruit number (59.4 No. m^{-2}). Mean fruit weight was significantly higher with application of nitrogen two times per week (121.6 g $fruit^{-1}$). Irrespective of application frequency, bigger fruit was obtained from 100 mg N L^{-1} nitrogen concentration (Table 3).

Leaf chlorophyll, N, P and K contents: Application frequency had no significant influence on leaf chlorophyll. When compared to the control plants, nitrogen receiving plants had higher leaf chlorophyll. But there were no significant differences among nitrogen concentrations in terms of leaf chlorophyll content. Both leaf N and P contents were affected by both nitrogen concentration and application frequency, whereas leaf K was only influenced by nitrogen application frequency (Table 4). The plant received nitrogen two times per week had significantly lower N, P and K than that of received nitrogen one times per week. Leaf N increased with higher nitrogen concentration (Table 4). The leaf N, K and P contents were within the range reported by Locascio (1993).

Results of continuous and twice per week nitrogen application experiment: Total yield was significantly greater (86.6 t ha^{-1}) when applied 200 mg N L^{-1} twice per week than continuous application. The plants supplied with 50 mg N L^{-1} at each irrigation produced the lowest yield (58.7 t ha^{-1}). Treatments had no significant effect on the early yield. But it was higher at 200 mg N L^{-1} supplied at two times per week. Total fruit number was also higher (75.3 fruit m^{-2}) for the same treatment (Table 5). Bigger fruit sizes were obtained from 200 and 250 mg N L^{-1} applied at twice per week when compared other nitrogen concentrations supplied with each irrigation.

In this experiment, only leaf chlorophyll was determined (Table 5). It was significantly higher ($p<0.05$) at plant received 100 mg N L^{-1} nitrogen at each irrigation (SPAD reading value 42.3).

Table 4: Effects of nitrogen concentration and application frequency on the leaf chlorophyll, N, P and K contents of cucumber (2000-2001)

Treatments		Leaf chlorophyll^z	Leaf N (%)	Leaf P (%)	Leaf K (%)
Year	2000	43.6	5.06	0.92	5.10
	2001	44.9	5.16	0.77	3.03
LSD		0.952**	ns	0.030*	0.304**
Application frequency	Once per week	44.2	5.23	0.87	4.29
	Twice per week	44.5	4.99	0.82	3.84
LSD		ns	0.214**	0.030**	0.304**
Nitrogen Concentrations (mg N L^{-1})	0	43.1c	4.76c	0.83ab	4.09
	100	45.4a	5.01b	0.81b	4.07
	150	44.1bc	5.22ab	0.87a	4.19
	200	44.6ab	5.43a	0.87a	3.91
LSD		1.347**	0.304**	0.042**	ns
Once per week	0	43.5	5.11ab	0.86a	4.15
	100	45.8	5.04b	0.87a	4.41
	150	43.3	5.25ab	0.87a	4.42
	200	44.2	5.51a	0.88a	4.18
Twice per week	0	42.7	4.11c	0.79b	4.04
	100	45.1	4.99b	0.76b	3.74
	150	44.9	5.20ab	0.88a	3.95
	200	45.1	5.34ab	0.85a	3.64
Nitrogen vs Application frequency		ns	0.429*	0.061**	ns
Year vs Application frequency		ns	ns	ns	ns
Year vs Nitrogen		ns	0.429*	ns	ns
Year vs Nitrogen vs Application frequency		2.693**	0.454*	ns	ns
Cv (%)		3.18	6.21	5.45	11.07

ns, * and ** non significant or significant at p = 0.05 or 0.01, respectively, ^{Z} SPAD chlorophyll meter reading value

Table 5: Effects of different nitrogen concentrations and application frequencies (at each irrigation or twice per week) on the total yield, early yield, total fruit number and mean fruit weight of cucumber (second experiment in 2002)

Nitrogen concentrations (mg N L^{-1})	Total yield (t ha^{-1})	Early yield (t ha^{-1})	Total fruit number (fruit m^{-2})	Mean fruit weight (g $fruit^{-1}$)	Leaf chlorophyll^z
50^y	58.7c**	11.6^{ns}	51.7c**	113.8b**	39.7bc*
100	64.9bc	13.4	60.5b	107.3c	42.3a
200	86.6a	15.6	75.3a	114.9a	41.7ab
250	71.7b	11.9	62.4b	114.9a	38.6c
Lsd	8.79	ns	5.166	6.520	2.242
Cv (%)	5.43	15.66	3.60	2.52	3.45

^{Z} is SPAD chlorophyll meter reading value ^{y}50 and 100 mg N l-1 applied at each irrigation, 200 and 250 mg N l-1 at two times per week ns, * and ** non significant or significant at p = 0.05 or 0.01, respectively

DISCUSSION

In the nitrogen concentration and application frequency experiment, nitrogen concentration led to significant differences in all investigated characteristics except for leaf K content. No significant differences among nitrogen concentrations in leaf K content might be ascribed to regularly supply of K+Mg+Fe containing solution to all plants including control once per week. Total and early yield were significantly greater for 200 mg N L^{-1} applied at twice per week. This result agreed with the result of Güler and İbrikci (2002), 200 mg N L^{-1} nitrogen was adequate for drip-fertigated cucumber. In another study, the best nitrogen concentration for cucumber grown on perlite was found to be 200 mg N L^{-1} (Altunlu and Gül, 1999; Altunlu *et al*., 1999). This nitrogen concentration was also close to the value mentioned by Papadopoulos (2001) for soil-grown cucumber fertigation. There was a significant relationship between nitrogen concentration and yield ($R^2 = 0.509$). The reason for lower regression coefficient might be attributed to application of K+Mg+Fe containing solution once per week to all plants including control. This conclusion was supported by the leaf data where all plants including control contained adequate N, P and K. Leaf chlorophyll was higher with 100 mg N L^{-1} nitrogen concentration, however differences were not greater among nitrogen concentrations. This might have been resulted from application of K+Mg+Fe in per week. As known Mg and Fe are the key elements for chlorophyll structure (Epstein, 1971). Leaf N and P increased with increasing nitrogen concentration. These results are in agreement with the results of Bhella and Wilcox (1985), Papadopoulos (1988) and Güler and Güzel (1999).

In this study, application frequency of nitrogen gave rise to significant differences in all investigated characteristics except for leaf chlorophyll. Total yield and early yield were 9.11 and 57.6% higher, respectively, on plant received nitrogen twice per week when compared to once per week application. These increases were due to not only increase in fruit number per plant but also increase in fruit size. This result was inconsistent with the result of Locascio and Smajstrla (1989) who worked with tomatoes and found that fruit yields were similar with daily or weekly N+K application. The reason for that might be the difference in the amount of N+K applied by fertigation in the studies. In this study all nitrogen was applied by fertigation, however they applied 40% N+K preplant, 60% N+K by drip irrigation after planting. Another possible reason might be using different crops in their studies. Because tomato and cucumber plants show wide differences in water and nutrient demand (Wittwer and Honma, 1979; Locascio, 1993; Wilcox, 1993).

There was no significant difference between application frequency of nitrogen regarding leaf chlorophyll. The reason for that might be regularly application of K+Mg+Fe solution as explained above. Leaf chlorophyll reading value measured in this study was close the value (43.6 reading value) reported by Shaaban and El-Bendary (1999) for cucumber. Nitrogen, P and K contents of leaf were lower in plants received nitrogen two times per week than those of received nitrogen once a week. This result might be attributed to dilution effects of nutrients (Jarrel and Beverly, 1981). Another reason for that might be accumulation of nutrients in the fruit (Hegde, 1997).

Nitrogen concentration by application frequency interaction was significant for total yield, total fruit number, mean fruit weight, leaf N and P. Application of 200 mg N L^{-1} two times per week gave significantly greater total yield and fruit number when compared to other nitrogen concentration and once a week application frequency.

Results of the continuous and twice per week nitrogen application experiment showed that application of higher nitrogen concentrations two times per week produced higher yield when compared to application of lower nitrogen concentrations continuously at each irrigation. Based on this result it was concluded that soil-grown plants do not need nutrients at each irrigation. Because in fertigation nutrient demand of the soil-grown plant is different from soilless-grown plant. The later needs regularly supplied water and nutrients because of being grown in inert media which has lower water and nutrient holding capacity. Geissler *et al.* (1984) reported that growing on restricted media such as containers, substrate channels and mats which are less than 10 L require continuous daily supply of water and nutrients in accordance with the actual plants requirements. Working with broccoli, Thomas *et al.* (2003) found that on sandy loam or finer soils, fertigation could be applied as infrequently as monthly, without compromising crop yield or quality.

Based on data obtained from both studies it was also concluded that application of 200 mg N L^{-1} nitrogen twice per week together with 200 mg K L^{-1} +40 mg Mg L^{-1} +2.5 mg Fe L^{-1} supplied once per week with irrigation water via drip irrigation system was adequate for soil-grown cucumber.

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