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EFFECTS OF FERTIGATION STRATEGIES ON NITRATE-NITROGEN LEACHING AND YIELD PARAMETERS OF CUCUMBER GROWN IN GLASSHOUSE

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ABSTRACT

In this study, the amount of nitrate leached from the soil and its effects on yield and quality of cucumber plant grown under greenhouse conditions were determined as a result of different fertigation strategies which was formed by changing the application time of the mixture of fertilizer solution during the irrigation cycle. For this purpose, five different fertigation strategies were applied, i.e. feeding of fertilizer solution during the whole irrigation period (F1), feeding of fertilizer solution during the first half of irrigation period (F2), feeding of fertilizer solution during the second half of irrigation period (F3), feeding of fertilizer solution between 1/4'th and 3/4'th irrigation period (F4) and injection of fertilizer solution immediately upon start of irrigation (F5) The highest and least yield was obtained in F1 (16.66 tons da^{-1}) and F3 (15.05 tons da^{-1}) fertigation strategies respectively. It was determined that fertigation strategies did not affect statistically the yield, fruit length, fruit diameter, plant height and stem diameter. On the other hand, it was found that the effect of fertigation strategies on nitrate-nitrogen (NO_3-N) leaching was statistically significant. The highest NO_3-N leaching was observed in F2 and the least in F4 fertigation strategy. It was concluded that the best fertigation strategy to prevent the pollution of groundwater by minimizing NO_3-N leaching, the most appropriate strategy is F4, i.e. feeding of fertilizer solution between 1/4'th and 3/4'th irrigation period.

KEYWORDS:
Greenhouse, Accumulation, Irrigation, Pan Evaporation, Mediterranean

INTRODUCTION

Greenhouse cultivation developed rapidly in the last 30 years [1] is an agricultural sector which is common in countries with the coast to the Mediterranean. According to the Turkish statistical data [2], 99% of the total greenhouse areas of Turkey (691 707 da) are located on the coasts of the Mediterranean, while 40% are in the province of Antalya because of climatic, technological and logistical advantages. Common crops grown widely in greenhouses located in Antalya, Turkey, are tomato (60%), cucumber (14%), pepper (11%), eggplant (4%) and other vegetables, fruit and ornamental plants (11%) are grown [2]. Therefore, the province of Antalya has an important region among intensive agricultural applications especially intensive irrigation. Fertilization is very important in terms of increasing soil productivity and plant yield to meet plant nutrients which are removed from the soil as a result of intensive agricultural activities. It is an indisputable truth that water and plant nutrients, especially N minerals, are the most important inputs in terms of plant growth, quality and yield.

The application of plant nutrient with irrigation water (fertigation) is the most efficient method to enhance crop production and reduce potential environmental damage in comparison to the conventional method [3]. In fertigation applications, it is aimed to accumulate the fertilizer and water in the root zone. Although the loss of plant nutrients is less in the drip irrigation method than in the other irrigation methods, it can reach a significant level as a total loss in irrigation with short intervals [4]. Because of the incorrect fertigation strategies, excessive fertilizer accumulation in the root zone may negatively affect the development of the plant and increase the cost of the input economically. On the other hand, if the plant nutrients reach out of the root zone, plant nutrient deficiency will occur and more fertilization will be required to increase the yield. As a result of excessive fertigation, nitrate having negatively charged ions will be leached out of the plant root zone and cause groundwater pollution.

The World Health Organization [5] has reported a critical value of 50 mg L^{-1} for nitrate (equivalent to 11 mg/L as nitrate-nitrogen) in drinking water for the protection of the health of the most sensitive subpopulation infants. For this reason, numerous simulations based studies [6, 7, 8, 9, 10, and 11] were conducted to determine the effects of fertigation strategies. Bristow et al. [6] investigated two basic strategies for the mixing time of fertilizer with water during irrigation. In the first strategy, the fertigation starts with irrigation and then only water was given until the end of the irrigation period. In

the second one, the fertigation starts near the end of the irrigation cycle. The authors reported that if the first strategy was applied, the accumulation of fertilizer around the dripper prevented and the loss of fertilizer was reduced even further. Cote et al. [7] reported similar results in their study of simulations for highly permeable coarse-textured soils in subsurface trickle irrigation. Contrary to these studies, Gärdenäs et al. [8] and Hanson et al. [12] reported that nitrate leaching was less and nutrient use efficiency was higher with fertigation application initiated at the end of the irrigation cycle. But Phogat et al. [9] did not find any relation between the time of fertilizer and nitrate leaching.

Published studies showed that there is a dilemma about the time of fertigation in terms of nitrate-nitrogen leaching and yield characteristics. Therefore, the aims of this study are 1) to assess the effects of different fertigation strategies on the nitrate distribution in the plant root zone, 2) to determine the amount of nitrate leached from the root zone, and 3) to examine the effects of different fertigation strategies on yield and yield parameters of cucumber plants grown in the glasshouse.

MATERIALS AND METHODS

This study was conducted in a gable-roofed (60×16 m) glasshouse having an area of 960 m^2 located in the north-south direction between September and December 2012 at the Research and Application Farm of Agricultural Faculty at Akdeniz University. The experimental area is located at coordinates of 36°53'53"N and 30°38'15" E and is 54 m above sea level. Some physical properties of the experimental soil are given in Table 1.

The experimental area has a Mediterranean climate and its summers are hot and dry, winters are warm and rainy. The annual average temperature in Antalya is 18.5 °C and the long-term average total rainfall is 1119 mm. Total evaporation, average minimum and maximum temperature during the experiment were measured as much as 245 mm, 14.2 °C, and 36.3 °C, respectively. The maximum and minimum temperature changes measured in the greenhouse during the experimental period are given in Figure 1.

The salinity and pH of the irrigation water used in the irrigation is 0.68 dS m^{-1} and 7.1, respectively. Cucumber (*Cucumis sativus* L.) which was named Yaren variety widely grown in the region was used as plant material in the experiment. The experimental area was prepared for seedling planting on August 31, 2012. Seedlings were planted after 24 kg 15-15-15 compound fertilizers were applied to the seedling beds on September 5, 2012. The monthly fertilization program (kg 240 m^{-2}) applied two times per month in the greenhouse during the experimental time is given in Table 2.

TABLE 1
Physical characteristics of the soil

Soil depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture class	Field capacity (%)	Permanent wilting point (%)	Bulk density (g cm^{-3})
0-20	31.61	39.73	28.66	Clay Loam	30.0	22.0	1.28
20-40	36.28	39.80	23.92	Clay Loam	23.0	16.0	1.52

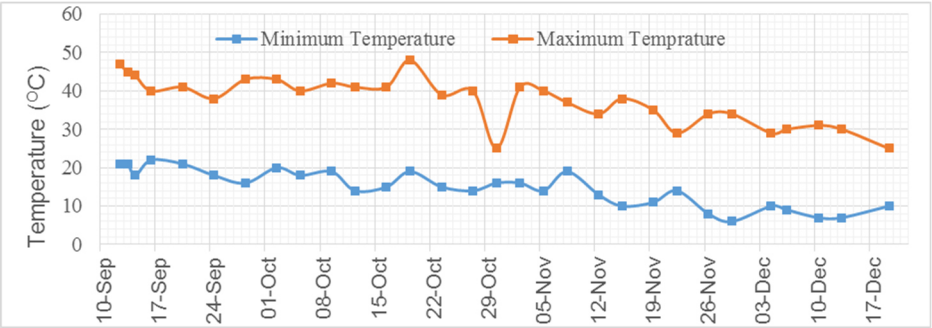


FIGURE 1
Maximum and minimum temperature measured in the greenhouse

TABLE 2
Monthly fertilization program (kg 240 m^{-2})

Month	%33 N Ammonium nitrate	Monoammonium Phosphate	Potassium Nitrate	Magnesium Sulphate	Calcium-Bor (lt)
September	0.36	0.24	0.36	0.24	-
October	0.6	0.48	0.72	0.48	0.5
November	1.44	0.72	1.8	0.48	0.5
December	1.44	0.48	1.44	-	0.5

The study was conducted in 3 replicates, according to randomized block trial design. Cucumber seedling planting was arranged according to the double row planting technique and was performed with 40 cm spacing along the row and 50 cm spacing between the rows and 2 m spacing was left between the treatments. The experimental design is given in Figure 2.

Drip irrigation method is used for irrigating the plots. The amount of water delivered to the plots was measured using a water gauge. One lateral drip line having in-line drippers spaced at 20 cm and discharging 2 L h^{-1} at 100 kPa pressure was laid down along each plant row. In the study, soil water content was monitored with PR2 profile probe (Delta T, USA) which was placed near the dripper and 20 cm away from dripper before and after every irrigation during the growing season in all treatments. The amount of irrigation water was calculated based on the measured amount of evaporation from Class A Pan located in the greenhouse.

Based on the studies conducted by Cemek et al. [13], Ayas and Demirtaş [14] and Wang et al. [15], the amount of irrigation water was determined as much as the amount of evaporation from the Class A Pan in four days. However, from planting (September 2, 2012) until September 16, crops are irrigated 8 times as much as 106 mm without taking pan evaporation into consideration for a homogenous standing. The first and last irrigation based on pan evaporation in the experiment was performed on 20.09.2012 and 19.12.2012 respectively. The plants were irrigated 34 times including the irrigations not based pan evaporation.

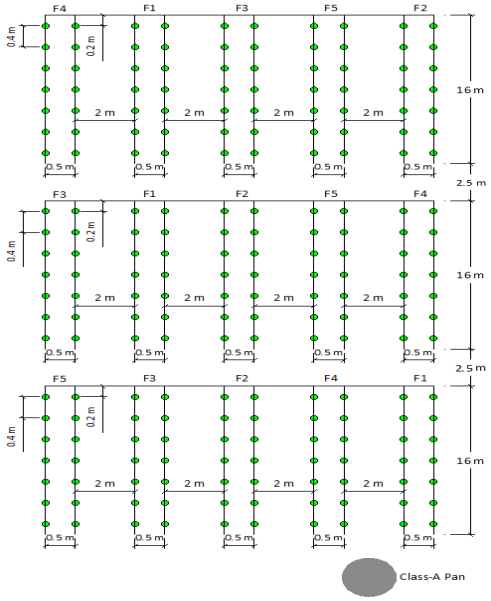


FIGURE 2
The experimental design

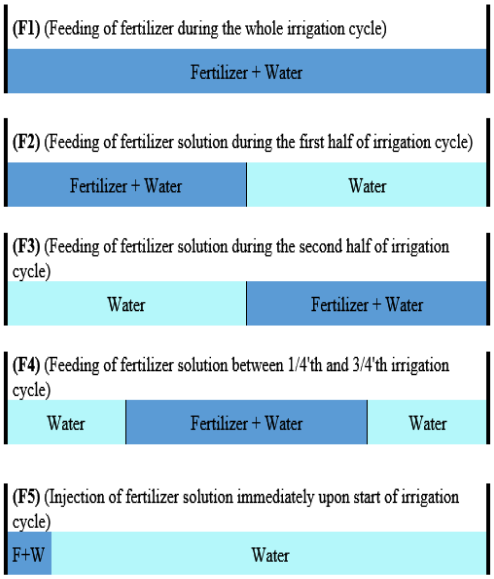


FIGURE 3
Fertigation strategies used in the study

The amount of water use of cucumber was computed based on water budged. The amount of water measured at 45 cm depth was considered deep percolation [16]. Five different fertigation strategies identified, based on changing the timing of feeding in the cycle of irrigation. The strategies are shown in Figure 3.

In order to determine the amount of nitrate-nitrogen (NO_3-N) in the soil, before and after fertigation, soil samples were taken from three different depths (15, 30 and 45) just under the dripper and 20 cm away from the dripper. Previous studies [17] indicated that the root system of the cucumber plant was developed in the upper 30 cm layer of soil and the root density was mostly concentrated at the upper 15 cm depth of the soil. For this reason, the amount of NO_3-N at the depth of 45 cm below the dripper and 20 cm away from the dripper, which was just the edge of wetting front horizontally determined after visual inspection, was considered to be leached.

The amount of NO_3-N was determined using the DR 2800 spectrophotometer (Hach, USA) according to the Cd reduction method [18]. Plant height and plant stem diameter (bottom, middle and top part) were measured every two weeks to determine the response of the cucumber plant to fertilization at different times in the experiment. Four plants were identified from each treatment and a total of 20 plants were used to measure for height and diameter. The plant length was measured by the meter. The stem diameter was measured by digital caliper. Harvesting at the experiment was started on 28 September 2012 after 28 days of planting. Between September 28 and December 20, crops were harvested 21 times. After each harvest, the fruit diameter and length were measured taking samples of 5 fruits from each treatment. The experimental data were analyzed by the General Linear Model (GLM) using Statistical Analysis Software, (SAS/STAT). Duncan's Multiple Range test was used, if necessary, to separate the means of the data at 0.05 level of significance.

RESULTS AND DISCUSSION

Applied Irrigation Water and Crop Water Use. The time course of applied water in each irrigation and cumulative applied irrigation water is shown in Figure 4. As given in materials and methods section, the amount of irrigation was equal to the amount of evaporation in Class A Pan located inside the greenhouse.

The amount of irrigation water declined depending on decreasing evaporation. The amount of evaporation measured in four days was as much as 20 mm in beginning of growing season which is in first half of September while it was measured as much as 5 mm in four days towards to the end of the growing season in the second half of December. The pan evaporation values obtained in the experiment was in agreement with those of Fernández et al. [19] under similar environmental conditions. Pan evaporation values were determined by Fernández et al. [19]. as 2.5 for autumn and 1.1 mm day^{-1} for winter growing season.

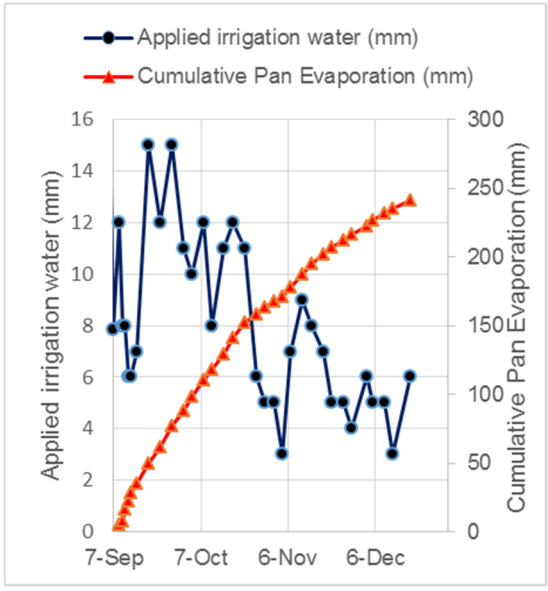


FIGURE 4
Applied irrigation water and cumulative pan evaporation

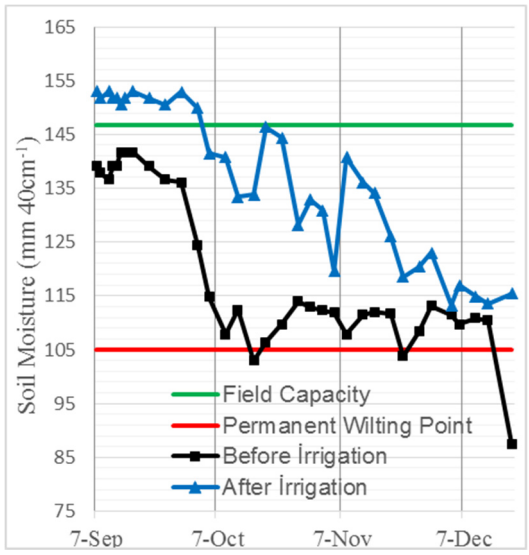


FIGURE 5
Change in soil water content

TABLE 3
Components of water balance during the experiment.

Applied irrigation water (mm)	Soil water depletion (mm)	Deep percolation (mm)	Crop water use (mm)
310	24	64	270

The amount of applied irrigation water, depleted soil water, the amount of percolated water and seasonal water use throughout the experimental period are given in Table 3. The amount of crop water use in the whole growing season which equals 110 days from planting to the time when experiment ended was 270 mm. The average daily water use was equal to 2.45 mm while daily applied water was 2.82 mm. In a study conducted in Cyprus by Nikolaou et al. [20] under greenhouse conditions in spring growing season reported applied water as much as 180 mm in ten week periods which corresponds to daily average applied irrigation water of 2.57 mm.

The change in soil water content at the point 20 cm away from dripper before and after irrigation event during the experiment is presented in Figure 5. The soil water content in the beginning of the experiment when crop is not grown fully was somewhat higher than field capacity resulting percolation of some of the irrigation water. When crop growth is fully completed, soil water content did not reach field capacity after irrigation meaning that the amount of applied water is not enough to meet crop water requirement. In another words, in most of the experimental period, soil water movement occurred under unsaturated conditions which is slower than that of the saturated conditions usually occurred in the beginning of the experimental period.

Yield and Yield Parameters. Cumulative plant height is presented in Figure 6. Year-end plant height, total yield, average fruit diameter, average fruit length, and average stem diameter are statistically analyzed. It was found that the fertigation strategies did not affect statistically all of the parameters mentioned.

The year-end plant height ranged from 359 cm (F1) to 394 cm (F5). The total yield varied between 15.05 ton da^{-1} (F3) and 16.66 ton da^{-1} (F1). Çakir et al. [21] and Alomran et al. [22]) reported cucumber yield of 10.71 and 15.0 ton da^{-1}, respectively, for similar conditions. Fruit diameters ranged from 3.0 (F2) to 3.16 (F3) cm while fruit lengths varied between 16.20 (F2) and 16.67 (F5) cm. In similar environmental conditions and cultural practices, Wang et al. [23] reported for the fruit diameter and the fruit length of 3.23 cm, 20.3 cm, respectively.

Accumulation and Leaching of NO_3-N. The amount of NO_3-N obtained from two different points (under the dripper and 20 cm away from the dripper) and three different soil depths (15, 30, and 45 cm) was given in Table 4. The amount of NO_3-N increased as soil depth increases in soil samples taken from the point under the dripper meaning that NO_3-N moving downwards. In addition, the amount of NO_3-N increased at location 20 cm away from the dripper. This was the result of accumulating the NO_3-N towards the edges of the wetting front. Li et al. [24] reported also that nitrate is accumulated toward the boundary of the wetted volume for different fertigation strategy.

Statistical evaluation of NO_3-N at different depths depending on fertigation strategies is presented in Table 5. It was determined that the effect of different fertigation strategies and the interaction between soil depths and fertigation strategies on average NO_3-N distribution under the dripper is not significant (Table 5a). However, the amount of NO_3-N at different depths was found significant ($P < 0.01$). The highest mean NO_3-N value was determined at 45 cm (4.80 mg kg^{-1}). There was no significant difference in the amount of NO_3-N in other soil depths (15 cm-2.26 mg kg^{-1} and 30 cm 2.80 mg kg^{-1}). The vertical distribution of NO_3-N in F2 and F4 strategies were relatively uniform. However, the amount of NO_3-N at the depth of 45 cm soil layer in F1, F3, and F5 strategies are statistically different. This means that NO_3-N is leaching from those strategies.

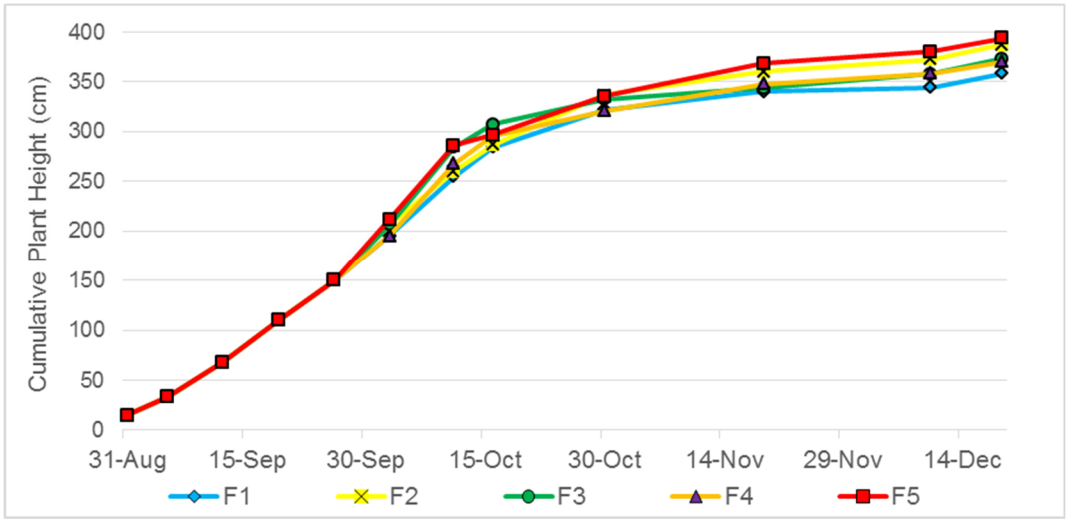


FIGURE 6
Cumulative plant height measured during experiment

TABLE 4
The amount of NO_3-N (mg kg^{-1}) obtained from two different points (under the dripper and 20 cm away from the dripper) and three different soil depths (15, 30, 45 cm)

Date	Depth (cm)	F1		F2		F3		F4		F5	
		Horizontal distance from the dripper (cm)									
		0	20	0	20	0	20	0	20	0	20
	15	0.91	25.17	2.16	16.10	0.91	1.93	1.14	0.91	1.70	12.59
19.09.2012	30	1.59	22.34	1.36	7.94	1.14	4.65	0.57	0.68	1.02	5.11
	45	3.40	16.22	0.91	20.86	2.27	10.21	1.02	1.36	2.16	18.03
	15	0.91	3.06	1.59	20.18	1.36	4.54	0.91	8.73	1.70	6.81
21.09.2012	30	0.23	1.82	1.02	11.11	1.02	3.06	0.91	6.92	0.91	6.92
	45	0.34	1.48	3.40	10.09	3.06	1.93	1.36	8.73	1.70	6.35
	15	1.02	0.68	1.02	1.02	1.14	21.43	0.57	9.98	0.46	4.08
04.10.2012	30	1.48	2.27	1.02	1.14	4.88	15.65	0.91	5.45	0.80	4.65
	45	2.61	3.74	2.04	1.48	14.17	17.46	0.80	11.91	1.59	16.44
	15	1.14	1.14	1.36	2.38	0.80	1.02	2.04	1.59	0.80	1.02
06.10.2012	30	1.14	1.02	1.02	3.06	1.93	1.36	0.80	2.27	0.80	1.25
	45	1.25	1.82	1.48	3.97	1.14	3.74	1.14	4.43	0.80	2.72
	15	0.91	23.70	1.02	26.31	0.80	9.53	4.65	3.74	0.57	6.69
18.10.2012	30	1.36	31.07	1.14	11.79	2.50	4.31	1.02	1.02	0.80	3.29
	45	2.04	22.34	1.14	7.03	4.99	0.80	1.14	6.01	1.02	2.84
	15	0.80	6.81	0.91	10.55	0.91	4.65	1.14	9.98	1.59	15.76
20.10.2012	30	1.02	2.27	1.93	9.64	1.25	1.25	1.36	5.67	2.61	9.98
	45	1.59	4.31	4.65	18.26	1.70	1.82	1.48	13.83	4.88	10.09
	15	0.91	23.81	0.91	13.38	2.50	14.17	0.80	13.15	0.46	3.52
07.11.2012	30	1.02	19.28	3.97	12.25	6.69	15.31	1.48	9.19	1.02	3.40
	45	4.43	20.75	3.18	21.09	18.71	12.47	1.93	10.89	1.93	3.40
	15	3.52	14.86	2.38	29.59	2.95	8.51	8.73	10.43	1.93	23.13
09.11.2012	30	5.67	8.28	2.84	25.17	4.65	4.54	7.15	12.93	2.95	22.90
	45	7.15	7.83	6.01	20.52	10.21	3.97	12.13	10.21	3.63	28.23
	15	1.36	31.63	2.27	2.38	2.04	19.50	0.91	9.19	0.68	1.02
21.11.2012	30	2.27	30.73	3.74	3.86	2.16	16.10	1.70	8.51	0.80	2.84
	45	11.57	22.90	6.01	4.54	2.50	10.43	2.16	6.13	1.02	4.88
	15	6.13	1.93	4.99	8.17	2.27	10.89	4.43	9.07	0.91	22.56
23.11.2012	30	1.82	5.79	4.08	6.47	1.82	12.47	5.33	14.29	2.38	23.24
	45	2.16	1.59	6.24	12.47	2.38	12.93	6.47	10.43	4.43	26.76
	15	2.61	31.07	4.43	13.38	3.52	17.01	1.82	14.06	1.02	13.72
05.12.2012	30	3.52	32.54	4.08	13.04	3.06	17.46	1.25	9.98	2.95	5.11
	45	9.19	23.47	6.47	12.93	20.30	19.16	1.36	18.03	2.27	3.18
	15	2.72	8.39	2.95	21.77	3.29	12.13	3.18	13.04	1.14	5.79
07.12.2012	30	3.86	7.71	4.08	18.94	3.97	8.28	2.72	15.42	1.25	5.11
	45	8.39	6.01	3.29	21.09	2.61	10.32	4.99	16.10	2.16	9.98
	15	4.43	33.22	8.62	31.18	3.18	22.22	1.70	10.89	3.40	20.30
18.12.2012	30	6.13	33.79	7.94	28.23	3.63	23.58	2.72	12.59	3.97	15.31
	45	8.28	24.15	21.32	32.31	3.97	14.06	2.61	9.19	17.80	10.55
	15	5.11	10.55	5.79	21.77	3.74	10.55	5.56	8.85	1.70	11.11
20.12.2012	30	8.51	10.09	12.47	17.35	2.50	9.30	9.87	8.73	4.08	10.89
	45	8.62	8.17	8.28	12.25	2.38	3.74	9.19	9.87	7.26	10.32

Unlike NO_3-N determined under dripper, the effect of different fertigation strategies on NO_3-N distribution at depths 20 cm away from the dripper is statistically significant ($P < 0.01$) (Table 5b). The interaction and vertical distribution of NO_3-N were not significant. However, the mean amount of NO_3-N determined 20 cm away from the dripper is rather higher than that of the values found under the dripper indicating that NO_3-N is moving towards edge of wetting front. The highest NO_3-N was obtained from F1 (14.04 mg kg^{-1}) and F2 (13.98 mg kg^{-1}) strategies.

The amount of NO_3-N leached during the growing season is given in Table 6, while statistical evaluation of total leached NO_3-N at the end of the growing season is presented in Figure 7, and 8, under the dripper and 20 cm away from the dripper, respectively. All of the leached NO_3-N at the depth of 45 cm at the end of the growing season together with the statistical evaluation is depicted in Figure 9. It was found that the effect of fertigation strategies on NO_3-N which was leached is statistically significant. Usually, in the fertigation applications towards the end of the growing season the leaching amount of NO_3-N increased (Table 6). Even between fertigation applications, nitrate continued to move since it is highly mobile.

The highest leached amount of NO_3-N under the dripper was found to be in F3 (fertigation in the second half of irrigation cycle) (Figure 7) while it was in F2 (fertigation in the first half of irrigation cycle) for the point 20 cm away from the dripper (Figure 8). The least leached NO_3-N under the dripper was found to be in F4 (fertigation of fertilizer solution between 1/4'th and 3/4'th irrigation cycle) strategy (Figure 7) while it was in F3 strategy for the point 20 cm away from the dripper (Figure 8). In the F3 strategy, NO_3-N is transported mostly under saturated soil water conditions while in F2, it is

TABLE 5
Statistical evaluation of average NO_3-N (mg kg^{-1}) values obtained during the growing season at different fertigation strategies and depths

(a) Under the dripper

Depth (D) of Sample	Fertigation Strategies (FS) F1		F2		F3		F4		F5		P > F	Mean of Depths	
15	*2.32*	*b*	*2.89*		*2.10*	*b*	*2.68*		*1.29*	*b*	**ns**	**2.26**	**b**
30	*2.83*	*b*	*3.62*		*2.94*	*b*	*2.70*		*1.88*	*ab*	**ns**	**2.80**	**b**
45	*5.07*	*a*	*5.32*		*6.46*	*a*	*3.41*		*3.76*	*a*	**ns**	**4.80**	**a**
P > F	*		**ns**		*		**ns**		*				
Mean of FS	**3.41**		**3.94**		**3.83**		**2.93**		**2.31**				
Significance level	**Fertigation Strategies (FS): ns**						**Depth (D): ****				**FS x D: ns**		

(b) 20 cm away the dripper

Depth (D) of Sample	Fertigation Strategies (FS) F1		F2		F3		F4		F5		P > F	Mean of Depths	
15	*15.43*		*15.58*		*11.29*		*8.83*		*10.58*		**ns**	**12.34**	
30	*14.93*		*12.14*		*9.81*		*8.12*		*8.57*		**ns**	**10.71**	
45	*11.77*		*15.58*		*8.79*		*9.79*		*10.98*		**ns**	**11.10**	
P > F	**ns**		**ns**		**ns**		**ns**		*ns*				
Mean of FS	**14.04**	**A**	**13.98**	**A**	**9.96**	**B**	**8.91**	**B**	**10.05**	**B**			
Significance level	**Fertigation Strategies (FS): ****						**Depth (D): ns**				**FS x D: ns**		

The capital letters show the comparison of the averages given along the horizontal (along the row) at the 5% significance level according to the Duncan test. The small letters are given in vertical (along the column) and the capital letters given in horizontal (along the row) show the comparison of the averages at the 5% significance level according to the Duncan test.
*, **: %5, %1 significance level of probability, respectively. ns: not significant.

TABLE 6
The leaching amount of NO_3-N (mg kg^{-1}) during the growing season

Time	Fertigation Strategies F1		F2		F3		F4		F5	
	Horizontal distance from the dripper (cm) 0	20	0	20	0	20	0	20	0	20
19.09.2012	3.4	16.2	0.9	20.9	2.3	10.2	1.0	1.4	2.2	18.0
21.09.2012	0.3	1.5	3.4	10.1	3.1	1.9	1.4	8.7	1.7	6.4
04.10.2012	2.6	3.7	2.0	1.5	14.2	17.5	0.8	11.9	1.6	16.4
06.10.2012	1.3	1.8	1.5	4.0	1.1	3.7	1.1	4.4	0.8	2.7
18.10.2012	2.0	22.3	1.1	7.0	5.0	0.8	1.1	6.0	1.0	2.8
20.10.2012	1.6	4.3	4.7	18.3	1.7	1.8	1.5	13.8	4.9	10.1
07.11.2012	4.4	20.8	3.2	21.1	18.7	12.5	1.9	10.9	1.9	3.4
09.11.2012	7.2	7.8	6.0	20.5	10.2	4.0	12.1	10.2	3.6	28.2
21.11.2012	11.6	22.9	6.0	4.5	2.5	10.4	2.2	6.1	1.0	4.9
23.11.2012	2.2	1.6	6.2	12.5	2.4	12.9	6.5	10.4	4.4	26.8
05.12.2012	9.2	23.5	6.5	12.9	20.3	19.2	1.4	18.0	2.3	3.2
07.12.2012	8.4	6.0	3.3	21.1	2.6	10.3	5.0	16.1	2.2	10.0
18.12.2012	8.3	24.2	21.3	32.3	4.0	14.1	2.6	9.2	17.8	10.6
20.12.2012	8.6	8.2	8.3	12.3	2.4	3.7	9.2	9.9	7.3	10.3
Total	71.0	164.8	74.4	198.9	90.4	123.0	47.8	137.1	52.7	153.8

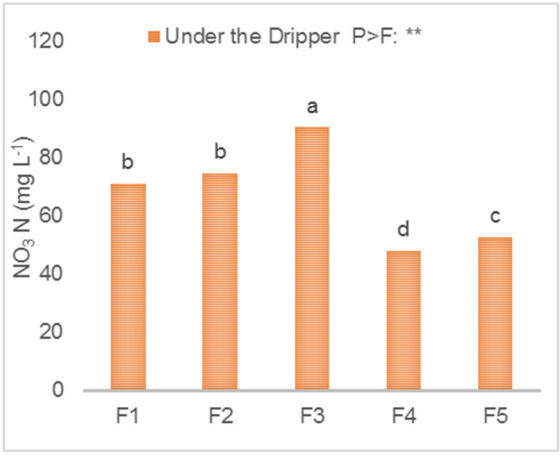


FIGURE 7
Effect of different fertigation strategies on NO_3-N leaching under the dripper

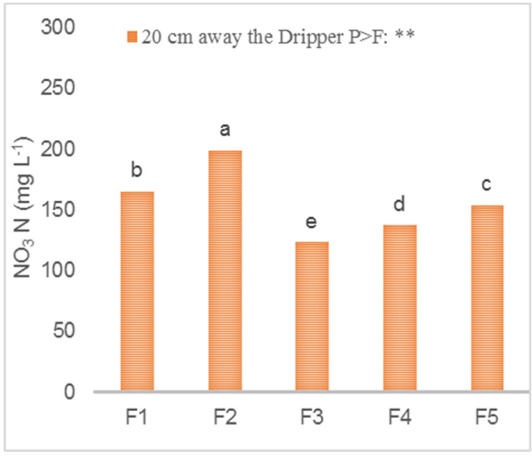


FIGURE 8
Effect of different fertigation strategies on NO_3-N leaching at 20 cm away from the dripper

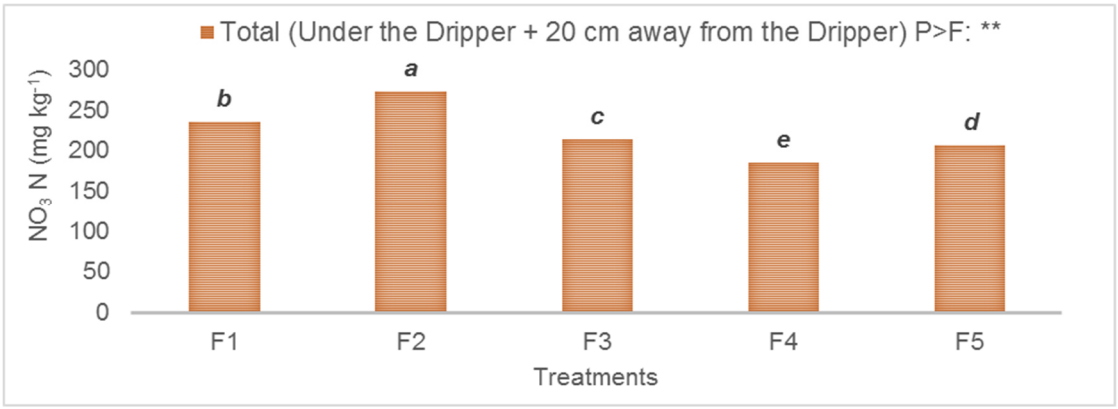


FIGURE 9
Effect of different fertigation strategies on total NO_3-N leaching

conveyed under unsaturated soil water conditions. Since the hydraulic conductivity was high under saturated conditions, the fertilizer carried out by irrigation water very fast and the fertilizer was transported deeper than the targeted root zone.

The total amount of nitrogen leached was significantly affected by the fertigation strategies ($p<0.05$) (Figure 9). The highest amount of leached NO_3-N was observed in F2 strategy while the least was found in F4 strategy. Hanson et al. [25] reported that NO_3-N was more uniformly distributed in the root zone of the plant by fertigation during the irrigation cycle. Also, Hou et al. [26] suggested that fertilizers should be given at the beginning of the irrigation for efficient use of the nitrogen. The results obtained in this study contradicts to the previous studies and shows that fertilizers should be given between 1/4'th and 3/4'th irrigation cycle to obtain relatively more uniform NO_3-N distribution in the root zone to minimize the amount of NO_3-N that was leached.

CONCLUSION

In this study, the amount of NO_3-N leaching in the soil and its effect on yield and yield parameters of cucumber were investigated by differentiating the mixing time of the fertilizer solution in the irrigation cycle under different fertigation strategies under the greenhouse conditions. Five different fertigation strategies, namely feeding of fertilizer solution during the whole irrigation period (F1), feeding of fertilizer solution during the first half of irrigation period (F2), feeding of fertilizer solution during the second half of irrigation period (F3), feeding of fertilizer solution between 1/4'th and 3/4'th irrigation period (F4) and injection of fertilizer solution immediately upon start of irrigation period (F5) were applied. The amount of NO_3-N in the soil was determined by soil samples made in two different zones (under the dripper and 20 cm away from the dripper) and three different depths (15, 30 and 45 cm). In the experiment, it was found that different fertigation strategies did not affect plant yield parameters (cumulative yield, plant height, fruit length, fruit diameter and stem diameter) but it affected the amount of NO_3-N leached from the root zone. The NO_3-N leaching results were determined to be F3> F2=F1= F5> F4, according to analyzes made from soil samples at a depth of 45 cm under the dripper. At the point 20 cm away from the dripper, NO_3-N leaching was determined as F2>F1>F5>F4>F3. When total amount of leached NO_3-N is taken into account, it was found that F2>F1>F3>F5>F4. In order to increase marginal utilization and reduce NO_3-N leaching from cucumber root zone as well as not to cause ground water pollution, fertigation applications should be carried out in the middle of irrigation period (F4 strategy).

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REFERENCES

[1] Baytorun, N. (2016) Greenhouses, Greenhouse Types, Equipment and Air Conditioning. 1st ed. Nobel Academic Publishing Education Consultancy, Ankara, Turkey. (In Turkish).
[2] TUİK (2017) Plant Production Statistics. Turkish Statistical Institute. (In Turkish). Ankara.
[3] Abbasi, F, Rezaee, H.T., Jolaini, M, Alizadeh, H.A. (2012) Evaluation of fertigation in different soils and furrow irrigation regimes. Irrigation and Drainage. 61, 533–541.

[4] Nachmansohn, J. (2016) Minimized nutrient leaching through fertilizer management - An evaluation of fertilization strategies. Swedish University of Agricultural Sciences.
[5] WHO (2016) Nitrate and Nitrite in Drinking - Water. Background document for development of WHO Guidelines for Drinking-water Quality 33.
[6] Bristow, K.L., Cote, C.M., Thorburn, P.J., Cook, F.J. (2000) Soil Wetting and Solute Transport in Trickle Irrigation Systems. In: Rome, Italy: International Commission on Irrigation and Drainage (ICID), 1–9.
[7] Cote, C.M., Bristow, K.L., Charlesworth. P.B., Cook, F.J., Thorburn, P.J. (2003) Analysis of soil wetting and solute transport in subsurface trickle irrigation. Irrigation Science, 22, 143–156.
[8] Gärdenäs, A., Hopmans, J.W., Hanson. B.R., Šimůnek, J. (2005) Two-dimensional modeling of nitrate leaching for various fertigation scenarios under micro-irrigation. Agricultural Water Management. 74, 219–242.
[9] Phogat, V., Skewes, M.A., Cox, J.W., Alam, J., Grigson, G., Šimůnek, J. (2013) Evaluation of water movement and nitrate dynamics in a lysimeter planted with an orange tree. Agricultural Water Management. 127, 74–84.
[10] Zhang, J.J., Li, J.S., Zhao, B.Q., Li, Y.T. (2015) Simulation of water and nitrogen dynamics as affected by drip fertigation strategies. Journal of Integrative Agriculture. 14, 2434–2445.
[11] Qin, W., Heinen, M., Assinck, F.B.T., Oenema, O. (2016) Exploring optimal fertigation strategies for orange production, using soil-crop modelling. Agriculture, Ecosystems and Environment. 223, 31–40.
[12] Hanson, B., Šimůnek, J., Hopmans, J.W. (2006) Evaluation of urea-ammonium-nitrate fertigation with drip irrigation using numerical modeling. Agricultural Water Management. 86, 102–113.
[13] Cemek, B., Kara, T., Apan, M., Taşan M. (2004) Comparative study on evaporation values obtained from class A pan and small-scale evaporation pans in greenhouse. J. of Faculty of Agriculture of Uludag University. 18, 13–24 (In Turkish).
[14] Ayas, S. and Demirtaş, Ç. (2009) Deficit irrigation effects on cucumber (Cucumis sativus L. Maraton) yield in unheated greenhouse condition. Journal of Food, Agriculture and Environment. 7, 645–649.
[15] Wang, Z., Liu, Z., Zhang, Z., Liu, X. (2009) Subsurface drip irrigation scheduling for cucumber (Cucumis sativus L.) grown in solar greenhouse based on 20 cm standard pan evaporation in Northeast China. Scientia Horticulturae. 123, 51–57.
[16] Allen, R.G., Pereira, L.S., Raes, D, Smith, M. (1998) Crop evapotranspiration: Guidelines for computing crop water requirements. Roma: FAO.
[17] Chartzoulakis, K., Michelakis, N. (1990) Effects of different irrigation systems on root growth and yield of greenhouse cucumber. Acta Hort (ISHS). 278, 237–244.
[18] Kurunc, A., Ersahin, S., Uz, B.Y. (2011) Identification of nitrate leaching hot spots in a large area with contrasting soil texture and management. Agricultural Water Management. 98, 1013–1019.
[19] Fernández, M.D., Bonachela, S., Orgaz, F. (2010) Measurement and estimation of plastic greenhouse reference evapotranspiration in a Mediterranean climate. Irrigation Science. 28, 497–509.
[20] Nikolaou, G., Neocleous, N., Katsoulas, N., Kittas, C. (2017) Effect of irrigation frequency on growth and production of a cucumber crop under soilless culture. Emir. J. Food Agric. 29(11), 863-874.
[21] Çakir, R., Kanburoglu-Çebi, U., Altintas, S., Ozdemir, A. (2017) Irrigation scheduling and water use efficiency of cucumber grown as a spring-summer cycle crop in solar greenhouse. Agricultural Water Management. 180, 78–87.
[22] Alomran, A.M., Louki, I.I., Aly, A.A., Nadeem, M.E. (2013) Impact of deficit irrigation on soil salinity and cucumber yield under greenhouse condition in an arid environment. Journal of Agricultural Science and Technology. 15, 1247–1259.
[23] Wang, Z., Liu, Z., Zhang, Z., Liu, X. (2009) Subsurface drip irrigation scheduling for cucumber (Cucumis sativus L.) grown in solar greenhouse based on 20 cm standard pan evaporation in Northeast China. Scientia Horticulturae. 123, 51–57.
[24] Li, J., Zhang, J., Rao, M. (2004) Wetting patterns and nitrogen distributions as affected by fertigation strategies from a surface point source. Agricultural Water Management. 67, 89-104.
[25] Hanson, B., Hopmans, J.W., Simunek, J., Gardenas, A. (2004) Crop nitrate availability and nitrate leaching under micro-irrigation for different fertigation strategies. In: ASAE Annual International Meeting. 2004
[26] Hou, Z, Li, P, Li, B, Gong, J, Wang, Y. (2007) Effects of fertigation scheme on N uptake and N use efficiency in cotton. Plant and Soil. 290, 115–126.

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