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EFFECTS OF DIFFERENT IRRIGATION METHODS ON LEAF AND FRUIT NUTRIENT CONCENTRATIONS OF YOUNG APPLE VARIETIES GRAFTED ON M9 ROOTSTOCK

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Abstract

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In this study, it was aimed to compare irrigation methods in terms of nutrient uptake of young apple varieties during two consecutive years. According to obtained results, leaf and fruit nutrient concentrations varied with irrigation methods, generally. Looking at the general nutrient status of plants, no nutritional deficiencies were determined between the irrigation methods. Also, nutrient concentrations of leaf and fruit showed variations with the years. Another important result in this study was that nutrient concentrations of leaf and fruit significantly varied with the variety, generally.

Key words: apple, irrigation methods, nutrient uptake, variety

Introduction

Plant nutrient uptake and plant growth are controlled by numerous factors. Plant factors have an important role controlling plant nutrient uptake. Plant species or varieties can show differences for taking soil nutrient even they are grown under same conditions (Marschner 1995, Erdal et al., 2008; Kucukyumuk and Erdal, 2009). Low nutrient availability of nutrients rather than low nutrient content is one of the other major factors for widespread occurrence of nutrient deficiency in plants due to water deficiency. Under many climatic conditions, low water content becomes a limiting factor for nutrient delivery to the root surface (Mackay and Barber, 1985a; Mackay and Barber, 1985b). Water is essential for nutrient uptake by root interception, mass flow and diffusion. Roots intercept more nutrients, especially calcium and magnesium, when they grown in a moisture soil rather than a drier soil because root growth is more extensive (Havlin et al., 1999). Studies concerning irrigation and nitrogen (N) effects on plant growth and plant N uptake showed that biomass production, yield and N concentrations increased with irrigation and N fertilization (Pandey et al., 2000a; Pandey et al., 2000b; Erdal et al., 2006; Timothy and Bottoms, 2009). Dissolved plant nutrients in the soil solution from the bulk of the soil to the root zone (mass flow) are closely related with taking nutrients of plants

(Marshner, 1995; Havlin et al., 1999). And this event depends on soil water content and water movement in the soil. Mass flow is main event especially for N, Ca, Mg, S, B, Zn and Mo for plant uptake. P, K, Mn, Fe and Zn move to the root influence zone mainly with diffusion. Contact Exchange is another mechanism for certain nutrients such as Fe and Cu (Bergmann, 1992). And these nutrients are not needed to dissolve in water solution. Contact Exchange has important relation with plant root growth, root distribution, root intensity and effective root depth and etc. Root cation exchange capacity is also another factor for taking nutrients of plants. Plants, having high root cation exchange capacity can take more nutrients comparing to others. Transpirations rate is very important for transferring nutrients from soil to top of the plant. This rate has specific value for xylem mobile nutrients such as Ca and B. While uptake of xylem mobile nutrients by plant decreases with the factors leading to decrease in transpiration rate, this uptake increases with transpiration increasing factors (Kacar and Katkat, 2007).

The objective of this study was comparing the effect of different irrigation methods on plant nutrient concentrations of apple varieties.

Materials and Methods

Soil and climatic characteristics

This study was conducted during growing seasons of 2007 and 2008, at Suleyman Demirel University, Agriculture Faculty, Research and Application Farm in Turkey (lat. 37^0 50^I 2^{II} N, long. 30^0 32^I 0^{II} E, alt. 1010 m). The experimental soil was clay loam having pH 7.7, 19% $CaCO_3$, 1.3% organic matter, 7.5 mg kg^{-1} extractable P, 150 mg kg^{-1} exchangeable K and Mg. The available Fe, Cu, Zn and Mn were 3.0, 0.9, 0.5 and 3.4 mg kg^{-1}, respectively. Some soil characteristics related to irrigation are presented in Table 1. Isparta region has a transition characteristic between the Mediterranean climate and Middle Anatolian continental climate. Long-term average annual temperature, relative humidity and precipitation are 12^{o}C, 61 %, 520 mm, respectively. The daily weather data were recorded at a meteorological station located near the experiment area. During the experiments (from May to October), values of average monthly air temperature (^{o}C) were 21.0 and 20.4, relative humidity (%) were 49.9 and 48.7 and rainfall (mm) were 45 and 80.6 for 2007 and 2008, respectively.

Experimental Design

Apple cultivars, Williams Pride and Jersey Mac grafted on M9 rootstock were used in this study. Due to their rapid increasing number in the orchards of Isparta Region, an orchard established in April 2006 was used. Trees were planted on rows 3 m apart with 1 m spacing between rows. The plots were consisted of 15 plants in 45 m^2. Irrigation water was obtained from the hydrants on the irrigation network near the orchard and distributed to the pilots by pipes. Discharge rate of the irrigation water taken from the irrigation network was 7 L s^{-1}. Water is class C_3S_1 and can be used for irrigation.

The orchard was irrigated with different irrigation methods during the experimental period. These are the drip irrigation (D), subsurface drip irrigation (SD), under-tree micro sprinkler (MS) and surface irrigation (SF). Engineering principles of irrigation methods are determined from the principles given in Yildirim (2003). Class a pan located in a meteorological station close to the orchard was used to determine amount of applied irrigation water. The amount of water was calculated by the cumulative pan evaporation measured within the irrigation interval of 5 days in a standard Class A pan using Equation 1, whose fundamental are describe in Doorenbos and Pruitt (1977) as follows.

$$I = Kcp \times Epan \times P \qquad (1)$$

where, *I* is the quantity of irrigation water, mm; *Kcp* is plant-pan coefficient (1.0); *Epan* is cumulative evaporation amount in 5 days irrigation intervals, mm and *P* is wetting percent, % (33 % for D and SD; 100 % for MS and SF).

Table 1
Some pyhsical characteristics of the soil of experimental field

Soil depth, cm	Texture	Bulk density, g/cm^3	Field capacity, %	Wilting point, %	Available soil water content, %
0-30	CL	1.46	29.70	13.57	16.13
30-60	CL	1.41	31.81	15.48	16.33
60-90	CL	1.39	27.46	11.70	15.76
90-120	CL	1.36	27.37	11.35	16.02

In the study, experiment was carried out according to the split plots in randomized complete block design with three replications. Statistical analyses were done applying the one way ANOVA analysis method. The Tukey test was used in determining the differences between the averages of the groups and the differences of the treatments were indicated with the Latin letters in the test result.

During the growing season, depending on the soil analysis, all plots were fertigated 40 kg ha^{-1} and 40 kg ha^{-1} phosphorus, 120 kg ha^{-1} and 150 kg ha^{-1}potassium and 80 kg ha^{-1} and 100 kg ha^{-1} nitrogen containing fertilizers in 2007 and 2008, respectively. While the fertilizers were applied by venture as fertigation in D, SD and MS treatments, fertilizers were given by hand as granule in SF treatment.

Leaf samples were collected from current year's terminals from the four sides of trees in July (Bergmann, 1992). Leaf samples were washed thoroughly with dilute acid (0.2 N HCl) and pure water to prevent any contamination. After then, samples were dried at 65°C for 48 h to a constant weight. Dried samples were ground to powder using a mortar and pestle, and stored in polyethylene bottles. Nitrogen content of samples was determined according to Kjeldahl method. For this purpose, 0.5 g of the ground samples were digested using by a block digesting system (KB 8 S Kjeldatherm, Gerhardt) in a digesting tube with 6 ml of concentrated H_2SO_4 in the presence of 5 g a catalyst (K_2SO_4 + $CuSO_4$). After 40% NaOH (w/w) was added, the sample was distilled using an automated unit (VAP2O, Gerhardt). The ammonium N was fixed in 3%H_3BO_3 and was titrated with 0.1 N H in the presence of an indicator (bromo-cresol green and methyl red in 95% ethanol). To determine the P, K, Ca, Mg, Fe, Cu, Zn and Mn content in leaves, 0.4 g ground samples were digested with a microwave digester. The samples were filtered and volume filled up to 50 ml with distilled water. Phosphorus content in the filtrate was determined with a spectrophotometer (Shimadzu UV-1208) at 430 nm according to the vanadomolybdophosphoric acid method. The other elements were measured by an atomic absorption spectrophotometer (Kacar and Inal, 2010). The same procedures given above were applied for the fruit samples for nutrient analysis.

Results

All plots were irrigated up to field capacity in the 0-120 cm soil depth prior to scheduled irrigation. Irrigation treatments were initiated on May. During growing season, treatments were irrigated 29 and 27 times in 2007 and 2008, respectively. The lowest irrigation water amount was applied to the D and SD treatments as 348.3 mm in 2007, the highest irrigation was applied to the SF and MS treatments as 1186 mm in 2008 (Table 2). In the both season, 67 % less water was applied at drip irrigation treatments (D and SD) compared to SF and MS.

Leaf nutrient concentrations

According to the results obtained from experimental years, individual effects of irrigation methods and variety had significant effect on leaf nutrient concentrations of apple trees, generally. Also, irrigation x variety (I x V) interaction had significant effect on N and Mg at first year and on Ca, Mg and Fe at second year (Table 3).

Leaf nutrient concentrations of first year experiment were significantly affected by I x V interaction. Differences in leaf N concentrations depending on varieties, was clearly seen under D and SD drip irrigations, other irrigation systems did not effect on leaf N concentrations. Leaf N concentrations of WP variety, did not change with the irrigation methods. But N concentrations, in the leaf of JM variety, varied with irrigation methods. According to the mean values, WP variety had higher N concentration compared to other

Table 2
Total irrigation number and water amount related to years

Treatments	Irrigation interval, day	2007		2008	
		Irrigation number	Total irrigation water, mm	Irrigation number	Total irrigation water, mm
D	5	29	391.2	27	348.3
SD	5	29	391.2	27	348.3
SF	5	29	1186	27	1056
MS	5	29	1186	27	1056

variety. In 2008 leaf nutrient concentrations were not significantly effected by all factors. Leaf P concentration of WP variety was higher than JM for both years. First year, the highest P concentration obtained from MS method, whereas the lowest P concentration determined from the trees irrigated with D method. Potassium concentration of apple varieties did not change with irrigation methods and variety effect in both years (Table 4).

Leaf Ca concentration showed similarity for each years in terms of irrigation methods. Leaf Ca concentrations collected under two groups. Higher Ca concentration from the plots irrigated with MS and D methods was analyzed. First year, Ca in JM variety was higher, but second year no differences was observed between varieties. Irrigation and variety interaction significantly affected leaf Mg concentrations in 2007 and in 2008. Except for SF in 2007 and SF and MS in 2008, other irrigation methods did not affect Mg concentrations of apple varieties. Effects of irrigation methods for each apple varieties showed differences. For JM variety, the highest Mg concentration was measured from the SF irrigation for 2 years, but for WP variety, the highest Mg concentration was determined from MS in 2007 and D in 2008. According to mean values, only irrigation methods had a significant effect on leaf Fe concentrations at first year. While the highest Fe concentration was determined from D conditions, the lowest Fe concentration was determined from MS in first year. Second year interaction showed significant effect on Fe concentrations. Apple varieties showed different response to each irrigation method, generally. Also, Fe concentration of a variety differed with irrigation methods.

Leaf Cu concentration was not affected by individual factors and their interaction for each year. Mean values showed that irrigation methods had significant effect on leaf Zn concentration in 2007 and 2008. While the highest Zn was determined with MS in 2007, the highest Zn was determined with SF in 2008. In the second year experiment, WP variety had higher Zn concentration (Table 5).

For both years, leaf of JM had higher Mn compared to other variety. According to means of first year results, it was seen that Mn concentration in leaves was the highest under SF, but the lowest under SD. While SD and SF methods did not affect Mn concentrations of varieties, Mn concentration of JM variety under D and MS significantly varied. Response of WP on Mn was found to be similar to irrigation methods. For JM, only the plots irrigated with SD irrigation had different Mn concentrations looking at the other methods (Table 5).

Fruit nutrient concentrations

Analysis of variance of the date obtained from two years results related to effect of irrigation methods on

Table 3
Analysis of variance on data obtained from the experiment

	F values									
	Df	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
First year (2007)										
Irrigation (I)	3	Ns	4.1**	Ns	4.9**	16***	3.5*	Ns	8.6***	8.5***
Variety (V)	1	15.6***	29***	Ns	15.5***	11**	Ns	Ns	Ns	16.5***
IxV	3	6.7**	Ns	Ns	Ns	9***	Ns	Ns	Ns	Ns
Second year (2008)										
Irrigation (I)	3	Ns	Ns	Ns	3.5*	3.2*	Ns	Ns	87***	6.41**
Variety (V)	1	Ns	8.7**	Ns	Ns	30***	Ns	Ns	4.5*	6.35*
IxV	3	Ns	Ns	Ns	Ns	7.5**	12***	Ns	Ns	
Error	16									
Mean	23									

*: p<0.05, **: p<0.01, ***: p<0.001, Ns: not significant

Table 4
Effect of different irrigation methods on N, P and K, Ca, Mg and Fe concentrations in leaf

Irrigation methods	N, %						P, %						K, %					
	2007			2008			2007			2008			2007			2008		
	JM	WP	mean	JM	WP	Mean	JM	WP	Mean	JM	WP	Mean	JM	WP	Mean	JM	WP	Mean
D	2.0 bB	2.6 a**A*	2.3	1.9	2.1	2	0.33	0.37	0.35 b	0.29	0.32	0.31	1.8	1.9	1.9	1.9	1.8	1.8
SD	2.2 abB	2.5 aA	2.4	2.3	2.4	2.3	0.32	0.4	0.36 ab	0.31	0.36	0.33	1.9	1.9	1.9	1.8	1.8	1.8
SF	2.5 aA	2.4 aA	2.4	2.1	2.3	2.2	0.34	0.39	0.37 ab	0.3	0.31	0.3	1.8	1.8	1.8	1.9	1.8	1.9
MS	2.3 abA	2.4 aA	2.4	2.1	2	2.1	0.38	0.41	0.39 a	0.28	0.33	0.31	1.8	1.8	1.8	1.9	1.8	1.9
Mean	2.2	2.5		2.1	2.2		0.34 B	0.39 A		0.30 B	0.33 A		1.8	1.9		1.9	1.8	
	Ca, %						Mg, %						Fe, mg kg^{-1}					
D	1.5	1.4	1.45 a	1.4	1.4	1.40 a	0.28 cA	0.27 cA	0.28	0.27 abA	0.26 aA	0.26	167	116	142 a	212 bB	269 aA	241
SD	1.4	1.3	1.35 b	1.3	1.3	1.30 b	0.34 abA	0.32 abA	0.33	0.24 bA	0.25 abA	0.24	117	123	120 ab	171 bB	241 abA	206
SF	1.5	1.3	1.40 b	1.3	1.4	1.35 b	0.36 aA	0.29 bcB	0.33	0.31 aA	0.23 abB	0.27	112	115	113 ab	295 aA	192 bB	243
MS	1.5	1.5	1.50 a	1.4	1.5	1.45 a	0.32 bA	0.34 aA	0.33	0.28 abA	0.21 bB	0.24	90	107	99 b	223 bA	262 aA	243
Mean	1.48 A	1.38 B		1.35	1.4		0.33	0.31		0.27	0.24		121	115		225	241	

*: Capital letters show the differences in same rows.**: lowercases show the differences in the same column

Table 5
Effect of different irrigation methods on Cu, Zn and Mn concentrations in leaf

Irrigation Methods	Cu, mg kg^{-1}						Zn, mg kg^{-1}						Mn, mg kg^{-1}					
	2007			2008			2007			2008			2007			2008		
	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean
D	9.9	9.1	9.5	11.5	13.3	12.4	62.9	55.6	59.2 ab	43.3	51.1	47.2 c	98	81.8	89.9 ab	84.8 aA	76.8 a**B*	80.8
SD	8.2	9.1	8.6	12.1	13.5	12.8	51.5	50	50.8 b	45.2	46.1	45.7 c	76.7	72	74.3 c	69.0 bA	73.6 aA	71.3
SF	9.4	8.8	9.1	12.8	14.8	13.8	57.5	40.9	49.2 b	89.3	87.2	88.3 a	106	86.6	96.3 a	81.8 aA	81.2 aA	81.5
MS	9.5	9	9.3	14.4	12.9	13.7	63.7	70.7	67.2 a	60.8	72.5	66.7 b	85.7	67.4	76.5 bc	91.5 aA	74.4 aB	82.9
Mean	9.2	9		12.7	13.6		58.9	54.3		59.7 B	64.2 A		91.6 A	76.9 B		81.7	76.5	

*: Capital letters show the differences in same rows.**: lowercases show the differences in the same column

fruit nutrient concentrations are presented in Table 6. According to the ANOVA test, effect of individual factors and their interaction had significant effect on examined parameters, generally. But these effects showed variation depending on the years.

Fruit N concentrations changed with irrigation methods and variety at first year, but no variation was observed in second year. According to mean values, fruit N of JM was significantly higher than WP. Under SF irrigation fruit N level reached up the highest level, on the contrary, the lowest fruit N was analyzed from the D plots. At first year, only irrigation methods and variety effects were significant, but second year, whole factors and interaction effect was not significant. Fruit K concentration was not affected by any factors for two years (Table 7).

Fruit Ca concentrations varied with irrigation methods in both two years. Looking at two years results, a great difference was found in terms of fruit Ca levels between the years. No difference was found between varieties for Ca concentrations. In the first year, fruit Mg concentrations were collected under two groups depending on irrigation methods. In the second year, while the most effective methods were drip irrigation treatments (D and SD), the least effective methods were MS and SF. Fruit Fe concentrations were significantly affected by I x V interaction for both years. Despite irrigation methods were different, the highest fruit Fe was determined from WP variety for both years. According to means, SD was the most effective in 2007, but in 2008, the highest Fe was determined with SF.

Fruit Cu concentrations showed variation depending on irrigation methods and varieties in 2007, but fruit Cu concentrations were not affected by any factors in 2008. Fruit Zn concentrations significantly affected by interactions for both years. Fruit Mn concentrations were affected by only irrigation methods for both years. According to mean values, only MS, having lower effect, showed differences, in terms of fruit Mn concentration in 2007. In 2008, the highest fruit Mn concentration was determined under D, other irrigation methods fell in the last group of the lowest fruit Mn concentration (Table 8).

Discussion

Leaf and fruit nutrient concentrations showed differences depending on the years, generally. We think that variations in climatic conditions and rain fall amount for each growth period are the main factors for having different results. Nutrient concentrations of apple trees had significant differences depending on varieties, generally. As indicated previous studies, plant nutrient uptake can differ if they are grown in the same conditions (Tagliavini et al., 1992; Erdal et al., 2008; Kucukyumuk and Erdal, 2009). This can be explained with genotypic differences such as, effective root depth and width, number of root hair, root cation exchange

Table 6
Analysis of variance on data obtained from the experiment

	F values									
	Df	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
First year (2007)										
Irrigation (I)	3	38***	4*	Ns	25***	6**	56***	9***	Ns	6**
Variety (V)	1	19***	12**	Ns	Ns	8**	10**	5*	7**	Ns
IxV	3	Ns	Ns	Ns	Ns	Ns	7**	6**	15***	Ns
Second year (2008)										
Irrigation (I)	3	Ns	4*	Ns	4*	3*	Ns	Ns	87***	6**
Variety (V)	1	Ns	11**	Ns	Ns	Ns	Ns	Ns	Ns	Ns
IxV	3	Ns	4*	Ns	Ns	Ns	12***	ns	4.5*	Ns
Error	16									
Mean	23									

*: p<0.05, **: p<0.01, ***: p<0.001, Ns: not significant

Table 7
Effect of different irrigation methods on N, P, K, Ca, Mg and Fe concentrations in fruit

Irrigation methods	N, %						P, %						K, %					
	2007			2008			2007			2008			2007			2008		
	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean
D	0.25	0.23	0.24 c	0.30	0.35	0.33	0.21	0.30	0.25 a	0.21 aB	0.30 a**A*	0.25	1.1	1.2	1.2	1.1	1.1	1.1
SD	0.29	0.28	0.29 b	0.38	0.32	0.35	0.23	0.25	0.24 ab	0.20 aB	0.25 abA	0.22	1.2	1.1	1.2	1.1	1.1	1.1
SF	0.37	0.33	0.35 a	0.32	0.31	0.31	0.18	0.24	0.21 ab	0.18 aB	0.26 abA	0.22	1.1	1.1	1.1	1.1	1.1	1.1
MS	0.33	0.28	0.30 b	0.36	0.32	0.34	0.19	0.21	0.20 b	0.20 aA	0.21 bA	0.20	1.1	1.1	1.1	1.0	1.1	1.1
Mean	0.31 A	0.28 B		0.34	0.32		0.20 B	0.25 A		0.20	0.25		1.1	1.1		1.1	1.1	
	Ca, %						Mg, %						Fe, mg kg^{-1}					
D	0.08	0.08	0.08 a	0.03	0.03	0.03 b	0.09	0.08	0.09 a	0.06	0.07	0.07 a	30.0 bA	27.2 cA	28.6	23.7 aA	18.0 bB	20.9
SD	0.04	0.04	0.04 c	0.03	0.05	0.04 a	0.10	0.07	0.09 a	0.05	0.05	0.05 b	61.3 aB	72.3 aA	66.8	19.0 abA	16.5 bA	17.7
SF	0.05	0.06	0.06 b	0.02	0.03	0.03 b	0.07	0.07	0.07 b	0.04	0.05	0.05 b	38.5 bA	36.6 cA	37.5	19.8 abB	34.8 aA	27.3
MS	0.04	0.03	0.04 c	0.02	0.03	0.03 b	0.07	0.06	0.07 b	0.04	0.04	0.04 c	31.8 bB	52.9 bA	42.4	13.8 bA	15.4 bA	14.6
Mean	0.05	0.05		0.03	0.03		0.08 A	0.07 B		0.05	0.05		40.4	47.3		19.1	20.2	

*: Capital letters show the differences in same rows. **: lowercases show the differences in the same column

Table 8
Effect of different irrigation methods on Cu, Zn and Mn concentrations in fruit

Irrigation methods	Cu, mg kg^{-1}						Zn, mg kg^{-1}						Mn, mg kg^{-1}					
	2007			2008			2007			2008			2007			2008		
	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean	JM	WP	mean
D	4.9 abA	5.0 bA	5.0	5.2	5.0	5.1	25.5 bcA	21.8 c**A*	23.7	60.6 aB	67.1 aA	63.9	6.0	5.0	5.5 a	3.8	4.7	4.3 a
SD	6.1 aA	6.4 aA	6.3	5.0	6.0	5.5	35.1 aA	30.2 bA	32.6	63.0 aA	63.3 aA	63.1	6.7	5.8	6.3 a	3.5	3.5	3.5 b
SF	4.4 bB	6.5 aA	5.5	4.8	4.8	4.8	33.1 abA	23.6 bcB	28.4	35.2 bA	25.9 bB	30.6	6.0	5.3	5.7 a	3.7	3.6	3.6 b
MS	4.8 abA	4.3 bA	4.6	3.6	4.8	4.2	23.3 cB	38.5 aA	30.9	23.9 cA	24.2 bA	24.1	3.4	3.3	3.4 b	3.3	3.3	3.3 b
Mean	5.1	5.6		4.6	5.1		29.3	28.5		45.7	45.1		5.5	4.9		3.6	3.8	

*: Capital letters show the differences in same rows. **: lowercases show the differences in the same column

capacity, root excretion, tree canopy, etc. (Levin et al., 1980; Marshner, 1995 ; Wang et al., 2006). However, Kadayifci et al. (2010) indicated that root distribution and effective root depth of apple trees budded on M9 rootstock were similar under different irrigation methods. According to results obtained from both years, leaf N, K and Cu concentrations were not affected by irrigation methods. It means that each irrigation method had the same effect on leaf N, K and Cu concentrations. Looking at the all nutrient concentrations in leaf, it was seen that all nutrients in the plants are between the sufficient ranges (Jones et al., 1991) under each irrigation method. Thus, it can be concluded that, plants did not have nutritional deficiency owing to irrigation methods for both years. So, it can be said that less water applied methods, such as drip irrigation, can be preferred instead of the others. Also, fruit nutrient concentrations were variously affected by different irrigation methods. Results showed that fruit nutrient concentrations were quite lower than leaf nutrient concentrations. In a study conducted by Fadhil (2007), it was found that fruit nutrient concentrations were between 1033.3-1400.0 mg l^{-1} for N, 410-720 mg l^{-1} for Ca and 313.3-403.3 mg l^{-1} for Mg. Due to there is not evaluation scale for apple fruit nutrient concentrations depending on dry matter basis, it was not possible to evaluate nutritional status of fruit.

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