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Seasonal Variations and Different Irrigation Programs on Nutrient Concentrations of 'Starkrimson Delicious' Apple Variety

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Abstract**—**This study was aimed to determine seasonal variations of leaf nutrient concentrations to define nutrient needs related to growing period and to compare irrigation programs in terms of nutrient uptake. In this study,'Starkrimson Delicious' variety grafted onto seedling rootstock was used during 2009-2010 growing seasons. The study was conducted at Eğirdir Fruit Growing Research Station. Leaf samples were taken in five different sample seasons (May, June, July, August and September). Four different pan coefficients (0.50, 0.75, 1.0, 1.25) were applied during drip irrigation treatments in 7 days irrigation interval. Leaf K, Mg, Ca, P, Fe, Zn, Mn and Cu concentrations were determined.

The results showed that among the seasonal changes, the highest concentrations of K, Mg, P and Mn in leaves were recorded in May, followed by a decrease in the other months, while in contrast Ca and Fe showed the lowest concentration in May.

Results of the study demonstrate that among irrigation programs K and Cu concentration in plants was significantly influenced. Cu concentrations decreased with seasonal variations and different irrigation programs. Thus, nutrient needs of 'Starkrimson Delicious' apple trees at different growth stages should be taken into consideration before making effective fertilization program.

Keywords**—**Apple orchard, irrigation programs, seasonal variations, nutrient concentrations.

I. Introduction

TREES absorb water and nutrient by their root system. The root system works not only water and nutrient supplying organ, but also as a plant regulator source which has an effect on the entire physiology of the plant. The size of the root system and its distribution pattern in a given soil are determined to a great extent by irrigation (method, frequency and amount) and its interaction with soil nutrient supply [1]. Low water content amount can be a limiting factor for nutrient delivery to the root surface [2,3]. Water is essential for nutrient uptake by root interception, mass flow and diffusion. Roots intercept more nutrients, especially calcium and magnesium, when they grow in a moisture soil rather than a drier soil because root growth is more extensive [4].

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Leaf mineral analysis is the best diagnostic tool for determining nutritional status of plants and represents an efficient guide for fertilization [5]. The knowledge of seasonal variation in leaf nutrient concentrations is necessary in order to understand the physiology of apple nutrition, and is also helpful in the interpretation of leaf analysis. The nutrient accumulation curves of apple trees are good indicators of nutrient requirement in each plant development stage. They are also a useful tool to evaluate orchard nutritional status and to estimate the amount of soil nutrient removal [6]. It will also use to strengthen the knowledge of seasonal variations in nutrient levels of leaf that would be important to accurate prescription of subsequent fertilizer additions will play theoretical and basic roles in practical steps for production.

Seasonal changes in the distrubition of nutrients in fruit trees have been reported in previous works [6]-[12].

Apple is one of the most important fruits produced in Turkey. Apple production in Turkey is estimated as 3.9% of the world apple production [13]. Isparta, Karaman, Nigde, Antalya and Denizli are the leading apple growing areas. Isparta is a very important apple growing region of Turkey with a production accounting for nearly 22% of the country's total [14].

The aim of this experiment was determining seasonal variations of apple leaf nutrient concentrations to define nutrient needs related to growing period. Determining to evaluate the nutritional status of most suitable irrigation program was another purpose of this work.

II. Material and Methods

The study was conducted at Eğirdir Fruit Growing Research Station 37°49'17.97"N, 30°52'22.44"E, Isparta, Turkey during 2009-2010 growing seasons. The research area has a transition climate between the Mediterranean and Central Anatolia. Apple trees were planted in 1988 (5 m × 4 m spacing). Starkrimson Delicious variety grafted onto seedling rootstock was used in the study. The experimental soil was clay loam having pH 7.6, 7.2% CaCO3, 1.54% organic matter, 48.3 mg kg-1 extractable P, 310.4 mg kg-1 exchangeable K and 508.5 mg kg-1 Mg. The available Fe, Cu, Zn and Mn were 16.99, 10.09, 1.15 and 9.53 mg kg-1, respectively. The experiment was designed according to completely randomized simple factorial design with tree replications. As basal fertilization, 25 kg da-1ammonium nitrate,10 kg da-1 mono ammonium phosphate, 24 kg da-1 K potassium nitrate were used and they were applied by fertigation technique with drip irrigation method.

A.Irrigation Treatments

The orchard was irrigated by drip irrigation. Irrigation water was supplied from an irrigation canal by a pump. Irrigation interval was 7 days and four different pan coefficients (Kcp1 = 0.50, Kcp2 = 0.75, Kcp3 = 1.00, Kcp4 = 1.25) were used for irrigation treatments. Irrigation quantities were based on pan evaporation (Epan) from class-A pan. Evaporation quantities were measured during irrigation interval for drip irrigation treatments. The percentage cover was calculated as 0.60 for drip irrigation treatments. Soil moisture was measured at respectively 30, 60, 90 and 120 cm soil depths with a digital tensiometer before each irrigation. Scheduled irrigations were initiated on May 20, at the time when the soil moisture capacity of the field reached 0-120 cm soil depth.

B.Sampling and Preparation for Analysis

Leaf samples were taken in five different seasons (May, June, July, August and September). Leaves were collected from the medium of branches of the year. Before analysis, samples were washed thoroughly with fountain water, dilute acid (0.2N HCl) and distilled water to remove surface residues, then they were kept at 65±5 0C until they reached stable weight. After than, leaf samples were dried and were grounded for nutrient analysis. In order to determine Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Zinc (Zn), Copper (Cu) and Manganese(Mn) concentrations, 0.25 g of samples were wet digested at 1800C by microwave oven for 15 min. then dissolved in 10 ml HNO3 and filled up with pure water. Phosphorus contents of samples were determined by vanadate-molybdate colorimetricmethod. Potassium, Ca, Mg, Fe, Zn, Cu and Mn concentrations were determined using atomic absorption spectrophotometer [15].

C.Statistical Analysis

Nutritional statues of apple plants were evaluated depending on the values given by Jones et al. (1991). Analysis of variance was performed on the data obtained from the treatments. The level of the significance (LSD at P< 0.05) was used in the SAS to test significance.

III. Results and Discussions

A.Macronutrients

1.Potassium

Seasonal changes of K concentrations were given in Table I. When the results were evaluated, individual effects of irrigation programs and seasonal changes of K concentrations were significant. Potassium concentration of plants decreased from May to September. When irrigation programs evaluated, K concentrations increased by irrigation doses. As seen in Table 1, 0.75 and 1.25 irrigation programs had the highest K concentrations. In a study it was found that the highest concentrations of K in leaves were recorded in May, followed by a decrease in the other months [16]. The fall in K concentrations may have occurred because of dilution effects with the growth and K, which is phloem mobile, being retranslocated to new sinks such developing flowers during winter and spring. This may be because the re-translocation of K from leaves may be largely due to the demand created by sinks such as developing fruits or nuts [17].

TABLE I
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON K CONCENTRATION

Irrigation Programs	Seasons					
	May	June	July	August	September	Mean
0.50	1.87	1.66	1.55	1.67	1.50	1.65 b**
0.75	1.93	1.84	1.71	1.76	1.71	1.79 a
1.00	1.89	1.72	1.57	1.66	1.52	1.67 b
1.25	1.94	1.78	1.83	1.67	1.72	1.79 a
Mean	1.90 A*	1.75 B	1.66 BC	1.69 BC	1.61 C	

*Capital letters shows the difference between sample seasons
**Small letters shows the difference between irrigation programs

2.Calcium

As seen in Table II individual effect of seasonal changes were found significant on Ca concentrations. Calcium concentrations of leaves increased from May to September. Reference [5] found that calcium concentrations increased during the period June–March of the following year in olive trees. Reference [6] found the same increase of Ca in apple trees and the increase can be explained with Ca immobility in plant tissues and no redistribution to other plant organs along the period.

TABLE II
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON CA CONCENTRATION

Irrigation Programs	Seasons					
	May	June	July	August	September	Mean
1	1.22	1.69	2.33	1.95	2.82	2.11
2	1.43	1.71	2.27	2.36	2.80	2.00
3	1.32	1.50	2.16	2.19	2.85	2.00
4	1.19	1.33	1.93	2.25	2.78	1.89
Mean	1.29 D*	1.56 C	2.17 B	2.19 B	2.81 A	

*Capital letters shows the difference between sample seasons

3.Magnesium

Effects of irrigation programs on Mg concentrations were not significant. Seasonal changes were found significant on Mg concentrations. Magnesium concentrations of leaves increased from May to September (Table III). Reference [5] found that Mg concentrations increased during the period June–March of the following year in olive trees.

TABLE III
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON MG CONCENTRATION

Irrigation Programs	Seasons					
	May	June	July	August	September	Mean
1	0.40	0.50	0.55	0.48	0.49	0.49
2	0.32	0.49	0.48	0.50	0.52	0.47
3	0.33	0.48	0.51	0.50	0.56	0.47
4	0.40	0.42	0.45	0.52	0.54	0.46
Mean	0.36 C*	0.47 B	0.50 AB	0.50AB	0.53 A	

*Capital letters shows the difference between sample seasons

4.Phosphorus

Though seasonal variations were significant, different irrigation programs were not. Concentrations of P decreased during May–September (Table IV). Reference [6] found that leaf concentrations of P decreased in apple leaves. Reference [16] found that the highest concentrations of P and K in leaves were recorded in May.

TABLE IV
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON P CONCENTRATION

Irrigation	Seasons					
Programs	May	June	July	August	September	Mean
1	0.31	0.19	0.21	0.20	0.18	0.22
2	0.26	0.23	0.21	0.21	0.19	0.22
3	0.28	0.23	0.20	0.22	0.18	0.22
4	0.28	0.25	0.22	0.22	0.21	0.24
Mean	0.28 A*	0.22 B	0.21 BC	0.21BC	0.19 C	

*Capital letters shows the difference between sample seasons

B.Micronutrients

1.Iron

Although seasonal variations had significant effects on Fe concentrations, irrigation programs did not change by Fe concentrations (Table V). Iron concentrations in apple leaves increased throughout the seasons due to the low or intermediate mobility in phloem of these elements. The same tendency was reported by researchers [6]. In July season Fe concentration had the highest (194 mg kg^{-1}) value.

TABLE V
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON FE CONCENTRATION

Irrigation	Seasons					
Programs	May	June	July	August	September	Mean
1	107	81	216	142	148	139
2	73	102	186	161	163	137
3	75	76	178	167	163	132
4	66	79	195	171	162	135
Mean	80 C*	85 C	194 A	160 B	159 B	

*Capital letters shows the difference between sample seasons

2.Zinc

Zinc had the lowest value in May (44 mg kg^{-1}) than those during the rest of year. Zinc concentrations showed significant differences among sampling dates. In June, Zn concentration had the highest (103 mg kg^{-1}) value.

TABLE VI
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON ZN CONCENTRATION

Irrigation	Seasons					
Programs	May	June	July	August	September	Mean
1	44	87	76	90	83	76
2	41	129	73	87	56	77
3	47	98	85	77	55	73
4	40	100	80	78	56	71
Mean	43 D*	103 A	79 B	83 B	63 C	

*Capital letters shows the difference between sample seasons

3.Manganase

Seasonal variations had significant effect on Mn concentrations. Seasonal variation trends in Mn concentrations were similar to Ca which is also phloem immobile nutrients. Manganase concentrtations increased during May to September seasons. As seen in Table VII, Mn concentration of leaves in May, June, July, August and September were 22, 41, 39, 48 and 38 $mgkg^{-1}$, respectively. As seen there, Mn concentrations had the highest level in August comparing to the other seasons.

TABLE VII
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON MN CONCENTRATION

Irrigation	Seasons					
Programs	May	June	July	August	September	Mean
1	25	35	38	49	46	38
2	20	55	36	49	34	39
3	23	37	46	49	38	39
4	22	35	34	48	32	34
Mean	22 C*	41 AB	39 B	48 A	38 B	

*Capital letters shows the difference between sample seasons

4.Copper

Individual and interaction effects of seasonal changes and irrigation programs were found significant on Cu concentrations. With regard to the micronutrients in leaves, Cu showed significantly lower values in June and July than those observed during the rest of the year. Copper concentrations showed significant differences among sampling dates (Table VIII). Results are comparable to those for apple tree leaves by [17].

TABLE VIII
EFFECT OF SEASONAL CHANGES AND DIFFERENT IRRIGATION PROGRAMS ON CU CONCENTRATION

Irrigation	Seasons					
Programs	May	June	July	August	September	Mean
1	11.06 ABa	10.03 ABa	2.26 Cab	8.18 Bb	11.40 Aa	8.58 a**
2	11.93 Aa	6.97 Bb	1.78 Cb	11.09 Aa	9.25 ABab	8.21 a
3	11.81 Aa	2.50 Cc	3.50 Cab	9.68 ABab	7.18 Bb	6.94 b
4	12.00 Aa	2.44 Bc	5.28 Ba	9.50 Aab	9.00 Aab	7.64 ab
Mean	11.70 A*	5.48 C	3.21 D	9.62 B	9.20 B	

*Capital letters shows the difference between sample seasons
**Small letters shows the difference between irrigation programs

The seasonal variation of mineral elements and different irrigation programs were studied. Looking at the all nutrient concentrations in leaf, it was seen that all nutrients in the plants are between the sufficient ranges under each seasonal changes and irrigation programs [19].

Results showed that, nutrient concentration of 'Starkrimson Delicious' apple trees showed variation depending on the growth stages, generally. Looking at the variation of nutrient concentrations for each growth stage, fertilization programs should be made by taken into consideration nutrient demand of apple. As seen from the results, irrigation levels did not affect nutrient concentration general. This may be due to sufficient rainfall in this growing year, or may be due to increased vegetative biomass resulting in dilution of nutrient due to increased irrigation.

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