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Effects of Different Sweet Cherry Rootstocks and Drought Stress on Nutrient Concentrations

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ABSTRACT

Relation between drought stress, genotypic differences and nutrients are important in plant growth. The aim of the study was to determine the effects of different sweet cherry rootstocks grown in 50-liter pots and drought stress on nutrient (N, P, K, Ca, Mg, Zn, Mn, and Cu) concentrations of leaves. In this study 0900 Ziraat sweet cherry variety grafted on five different rootstocks (*P. mahaleb*, Mazzard, Gisela-6, MaxMa 14, CAB 6) were used. Four irrigation treatments (control or 100%, 75%, 50%, and 25% and of the field capacity) were used and irrigation intervals were four days in the study. As a result, mineral concentrations of leaves were changed with both rootstocks and drought stress treatments. In general, “Mazzard and Gisela 6” sweet cherry rootstocks had higher nutrient concentrations than “MaxMa 14” under drought stress conditions. The results showed that drought stress reduced the concentration of N, P, K, Ca, Mg, Zn, Mn, and Cu concentrations. CAB 6 rootstock was not affected by water deficiencies and had higher performance on nutrition than the other rootstocks under drought stress conditions. In conclusion, drought stress and rootstocks have substantial effects on nutrient concentrations of sweet cherry leaves.

Keywords: Drought stress; Nutrient concentrations; Sweet cherry rootstocks

Kirazın Mineral Beslenmesi Üzerine Farklı Anaçlar ve Kuraklık Stresinin Etkisi

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ÖZET

Bitki yetiştiriciliğinde, kuraklık stresi, genotipik farklılık ve besin elementleri arasındaki ilişkiler önemlidir. Bu çalışmada 50 litrelik saksılarda yetiştirilen kirazın mineral beslenmesi (N, P, K, Ca, Mg, Zn, Mn, Cu) üzerine farklı anaçlar ve kuraklık stresinin etkilerini belirlemek amaçlanmıştır. Çalışmada, beş farklı (*P. mahaleb*, Mazzard, Gisela-6, MaxMa 14, CAB 6) anaç üzerine aşılı 0900 Ziraat kiraz çeşidi kullanılmıştır. Denemede kontrol (her sulamada eksik

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nem tarla kapasitesine getirilene kadar sulama) ve 3 farklı su seviyesi (tarla kapasitesinin % 25, % 50 ve % 75'i) olmak üzere dört farklı sulama uygulaması yer almıştır. Denemede evapotraspiraasyonla eksilen su dört günde bir tamamlanmıştır. Sonuç olarak, bitkilerin mineral beslenmeleri farklı anaç ve kuraklık stresinden etkilenmiştir. Genellikle kuraklık stresi koşullarında "Mazzard ve Gisela 6" anaçları "MaxMa 14" anacına göre daha fazla besin elementi konsantrasyonuna sahip olmuştur. Sonuçlar, kuraklık stresinin N, P, K, Ca, Mg, Zn, Mn ve Cu konsantrasyonlarını düşürdüğünü göstermiştir. Kuraklık stresinde, CAB 6 anacının beslenme performansına etkisi diğer anaçlara göre daha yüksek bulunmuş ve kısıtlı sulamadan etkilenmemiştir. Sonuç olarak, kuraklık stresi ve farklı anaçların kiraz yaprakları besin elementi konsantrasyonları üzerine etkisi önemli bulunmuştur.

Anahtar Kelimeler: Kuraklık stresi; Besin elementi içeriği; Kiraz anaçları

1. Introduction

Sweet cherry is an important and common economic fruit tree in the world and in Turkey. Besides having 403.128 tonnes production, Turkey is the leader of the sweet cherry production in the world (FAO 2013). Rootstock-scion relations affect plant growth by influencing the nutritional status and adaptation ability of scion to changing environment. Despite they are grown in the same conditions, mineral concentrations of plants may change (Bergmann 1992; Kacar 1995; Marshner 1995). Studies have shown that rootstocks can affect root and tree growth, yield and quality of sweet cherry fruits (Betran et al 1997; Sitarek et al 1998; Roversi et al 2010; Jimenez et al 2007; Sotirov 2011). Since these differences may change yield and mobility of nutrient concentrations, using different rootstocks should be taken into consideration for obtaining better performance in changing growth environment (Kucukyumuk & Erdal 2011).

Increasing world population threatens the amount of water used in agriculture in the future (Yurtseven et al 2014). Decrease in water used in agriculture may lead the drought stress in plant production which may cause decrease in photosynthesis and transpiration of mechanisms for the regulation to drought stress depending on plant variety (Mengel & Kirkby 2001; Sarker et al 2005). Relations among drought stress, nutrients and genotypic variability in nutrient use of sweet cherry rootstocks are important in sweet cherry growth. Since root growth, nutrient transport to rhizophere and solubility of nutrients in soils are inversely related to water deficiency in the soils, nutrient uptake and transport in the plants are negatively affected under water scarcity (Güneş et al 2006).

The use of drought tolerant rootstocks can have positive effects on fruit yield and quality under stress conditions. Rootstocks can show different ability to use available water in the soil profile depending on the root structure and density (Romero et al 2006). However, there are very limited numbers of research dealing with the effect of rootstock-scion relation on nutritional status of sweet cherry under water stress. Güneş et al (2006) reported that drought stress reduced growth of plant and enhanced nutrient uptake in drought resistant rootstocks.

For economically feasible and environmentally friendly fertilization program, using drought resistant rootstocks should be taken as a practical agricultural approach. Therefore, the aim of this study was to test the effects of five commonly used rootstocks-scion relations for nutritional status of scion under drought stress in a greenhouse study.

2. Material and Methods

2.1. Plant material

In this study 0900 Ziraat sweet cherry variety grafted on five different rootstocks (*P. mahaleb*, Mazzard, Gisela-6, MaxMa 14, CAB 6) were used. These rootstocks and the variety are commonly used in sweet cherry orchards in either Turkey or in the world. One year old sweet cherries budded on the rootstocks were planted in 50-liter pots containing 40 kg of soil:peat:farmyard manure:sand mixture at the rate of 2:1:0.5:1 (on weight base) on 15th of February. The experiment was conducted in completely randomised design under greenhouse conditions in 2012 vegetation season.

Some characteristics of the experimental growth media were: pH 7.4, organic matter 34.0 g kg^{-1}, $CaCO_3$ equivalent 88.0 g kg^{-1}, $NaHCO_3$ extractable P 44.1 mg kg^{-1}, molar ammonium acetate exchangeable K 401 mg kg^{-1}, Ca 2908 mg kg^{-1}, and Mg 239 mg kg^{-1}.

By considering the fertilization requirement of the growth media the following fertilization program were made: 124 mg kg^{-1} N (ammonium nitrate), 23.0 mg kg^{-1} N, 105 mg kg^{-1} (mono ammonium phosphate), 163 mg kg^{-1} K_2O (potassium sulphate) and 98.2 mg kg^{-1} MgO (magnesium sulphate). After fertilization the growth media was thoroughly mixed to maintain the homogeneity.

2.2. Irrigation treatments

Four irrigation schemes were used in order to induce different degrees of drought stress. They are: I) field capacity (T1, control), II) 75% of field capacity (T2), III) 50% of field capacity (T3), and IV) 25% of field capacity (T4). The first irrigation was made in the middle of May and then the evapo-transporated water was added by weighting in four days interval. The irrigation water was supplied from a ground water well by pumping. Some chemical properties of the irrigation water were given in Table 1.

2.3. Sampling and plant analysis

Sweet cherry leaf samples were collected on 15th August. Samples were washed and dried at 65±5 ˚C until a constant weight. Leaf samples were grounded and 0.25 g of samples was wet-digested with 10 mL HNO_3 at 180 ˚C by microwave oven for 15 min. (CEM Mars X-press). Then the digest filled up to 50 ml with de-ionised/distilled water. Phosphorus concentrations were analysed colorimetrically by vanadate-molybdate reagent (Shimadzu UV/VIS 1208); K, Ca, Mg, Zn, Mn and Cu concentrations were analysed by using atomic absorption spectrophotometer (Varian AAS 240 FS). Total nitrogen was analysed according to Kjeldahl method (Kacar & İnal 2008).

2.4. Experiment design and statistical analysis

The pot experiment was set up in completely randomized design with factorial arrangement in triplicates. Statistical analyses were conducted using analysis of variance (ANOVA) using SAS programme (Statistical Analysis Software). The mean separation between the treatments' averages was made by Duncan's Multiple Range Test ($P \leq 0.05$).

3. Results and Discussion

Rootstocks and drought stress had significant effects on total N concentrations of leaves (Table 2). Trees on "Mazzard and Gisela 6" had significantly higher leaf-N concentrations than the other rootstocks. As previously reported, rootstocks influenced the N nutrition status of sweet cherry trees and the differences among the rootstock-scions were attributed to mineral uptake capacity of rootstocks due to their changing root structure (Abrisqueta et al 2011). The main effects of irrigation treatments on leaf-N concentrations were significant and N concentration decreased with increasing water stress. The highest N concentration was obtained for the control treatment (33 g kg^{-1}) and it decreased down to 27 g kg^{-1} for 25% irrigation of field capacity (T4). Similar effects of water scarcity or drought

Table 1- Some chemical properties of irrigation water

Çizelge 1- Sulama suyunun bazı kimyasal özellikleri

Class of irrigation water	*µmhos cm^{-1}*	*pH*	*Cations (mg L^{-1})*				*Anions (mg L^{-1})*				*Na (%)*	*SAR*
			Na^+	*K^+*	*Ca^{2+}*	*Mg^{2+}*	*CO_3^-*	*HCO_3^-*	*Cl^-*	*SO_4^{2-}*		
C_2S_1	310	7.8	7	4	44.1	46.2	-	20.2	48.6	32.5	6.9	1.04

Table 2- Effect of different rootstocks and drought stress on N and P concentrations of leaves (g kg^{-1})

Çizelge 2- Farklı anaç ve kuraklık stresinin yaprağın N ve P içeriklerine etkisi (g kg^{-1})

Rootstocks	*Irrigation treatments*									
	T1		*T2*		*T3*		*T4*		*Mean*	
	N	***P***	***N***	***P***	***N***	***P***	***N***	***P***	***N***	***P***
P.Mahaleb	30	2.9	30	2.9	26	2.8	26	2.9	28C*	2.9
Mazzard	38	3.0	34	2.8	32	2.9	28	2.8	33B	2.9
Gisela 6	45	2.7	36	2.8	36	2.9	34	3.0	38A	2.9
MaxMa 14	28	3.1	28	2.9	24	2.8	20	2.6	25C	2.9
CAB 6	26	2.6	26	2.9	24	3.0	26	2.9	26C	2.9
Mean	33a**	2.9a**	31ab	2.9b	28bc	2.9b	27c	2.8b		

*, capital letters indicates rootstocks differences (P<0.01); **, small letters indicates drought stress differences (P<0.05)

Table 3- Effect of different rootstocks and drought stress on K and Ca concentrations of leaves (g kg^{-1})

Çizelge 3- Farklı anaç ve kuraklık stresinin yaprağın K ve Ca içeriklerine etkisi (g kg^{-1})

Rootstocks	*Irrigation treatments*									
	T1		*T2*		*T3*		*T4*		*Mean*	
	K	*Ca*	*K*	*Ca*	*K*	*Ca*	*K*	*Ca*	*K*	*Ca*
P.Mahaleb	35Aa*	19Ad**	33Bab	18ABc	31Ca	17Bcd	31Ca	15Cd	33	17
Mazzard	36Aa	17Ae	34Ba	16ABd	32Ca	16ABd	32Ca	15Bd	33	16
Gisela 6	33Ab	32Aa	32Ab	31Aa	32Aa	25Ba	32Aa	25Ba	32	28
MaxMa 14	28Ac	27Ab	25Bc	19Bc	25Bb	18BCc	25Bc	17Cc	26	20
CAB 6	35Aa	23Ac	32Bb	22Ab	31Ba	22Ab	28Cb	22Ab	31	22
Mean	33	24	31	21	30	20	30	19		

Capital letters indicates drought stress and small letters indicates rootstocks differences; *, K (P<0.05); **, Ca (P<0.01)

stress were also reported in the previous studies (Yl et al 2009; Abrisqueta et al 2011).

The main effect of irrigation treatments on P concentration of leaves was significant whereas the main effects of rootstocks were non-significant (Table 2). Duncan's multiple range test revealed two homogenous groups. The highest P concentrations were determined at the control treatment (3.0 g kg^{-1}) and drought stress induced decreases in P concentrations were observed in this study. Results are also in agreement with those reported by Getachew (2014). In the study, P concentrations decreased with increase in water deficit level. The highest P concentration was obtained from control conditions (0%) and 25% deficit levels while the lowest was recorded from the highest (75%) water deficit level.

Table 3 shows the effects of different rootstocks and drought stress on K concentrations. İnteraction of drought stress and rootstocks were found significant. Under control conditions Mazzard (36 g kg^{-1}), Mahaleb (35 g kg^{-1}) and CAB 6 (35 g kg^{-1}) rootstocks had the highest K concentrations, the lowest K concentrations determined with MaxMa rootstock (28 g kg^{-1}). Except Gisela 6 rootstock, with decreasing amount of water all rootstocks concentrations decreased. Higher K concentrations were found in Mahaleb and Mazzard rootstocks (33.0 g kg^{-1}). In a similar manner, Roversi et al (2010) reported a genotype dependency in leaf K concentration and K nutritional status for sweet cherry. As the main effect of irrigation treatments regarded, maximum K concentration (33.0 g kg^{-1}) was found at control treatment and the minimum was found at T3 and T4 treatments (30.0 g kg^{-1}). Other researchers found drought stress influence K concentrations and K nutritional status of plants (Sanchez-Rodriguez et al 2012; Nakojima et al 2004). The decrease of K concentrations can be related to reduction of in-flow water in plant. Potassium had important roles on osmoregulation, enzyme activation, neutralization, transport process (Reddy et al 2004). Sufficient K concentrations increase the control over osmotic adjustment which keeps turgor pressure under osmotic stress conditions (Wang et al 2013). Therefore, increased K concentration in leaves could be an indication of drought stress resistance for any rootstock-scion pair.

As seen in Table 3, Ca concentrations of sweet cherry were influenced by drought stress x rootstock interaction. The highest Ca concentration (32.0 g kg^{-1}) was found from T1 x Gisela 6 interactions while the lowest (15.0 g kg^{-1}) was obtained from T4 x *P. Mahaleb*. The rootstocks of Mahaleb and Mazzard had the lowest (17.0 and 16.0 g kg^{-1}) Ca concentrations compared to the other rootstocks. While the highest Ca concentration was determined at T1, leaf Ca levels decreased with increasing water deficit. Also limited movement of Ca through the roots due to deficit mass flow may result Ca deficiency under water deficit conditions (Kacar & Katkat 1998). Mean values of Ca concentrations decreased with irrigation treatments and varied with different rootstocks. While Gisela 6 had the highest (28.0 g kg^{-1}) Ca concentrations Mazzard had the lowest (16 g kg^{-1}) Ca concentrations.

The lesser amount of irrigation water resulted in the lower Mg concentration in leaves. The concentrations of Mg in descending order were 5.2, 4.8, 4.7, and 4.5 g kg^{-1} for T1 > T2 > T3 > T4 treatments, respectively. Romero et al (2006) reported that Mg concentrations decreased with increasing water deficiency. While Gisela 6 rootstock had the highest Mg concentrations (6.0 g kg^{-1}), Mahaleb and Mazzard rootstocks had the lowest (3.9 and 3.8 g kg^{-1}).

Different rootstocks-scion combinations resulted in significant variation in leaf-Cu concentrations, whereas there were no significant effects of irrigation treatments (Table 4). Mazzard rootstock had the highest (12 mg kg^{-1}) Cu concentrations and followed by CAB 6 and Mahalep. Rootstock x drought stress interaction significantly influenced Zn concentrations (Table 5). Drought stress decreased Zn concentrations of plants. The highest Zn concentration was obtained for the control treatment (14 mg kg^{-1}) and increasing water scarcity steadily decreased Zn levels as 13, 12 and 11 mg kg^{-1} for T2, T3, and T4 treatments, respectively.

Drought stress and rootstocks-scion interaction affected Mn concentrations (Table 5). Differing drought stress resulted in a Mn concentration range of 42 to 50 mg kg^{-1}. Besides CAB 6 rootstock, Mn concentrations of all rootstock-scion combinations used in this study were inversely affected by increasing drought stress. Although Mazzard and Gisela 6 rootstocks-scion combinations better performed in uptake of Mn with 53 mg kg^{-1} and 51 mg kg^{-1} Mn concentrations whereas Mahaleb and Max Ma 14 rootstocks showed poor performance (40 mg kg^{-1}).

Mineral concentration of leaves was varied by both rootstocks and drought stress treatments. Rootstock-scion combinations were differently influenced from the degrres of drought stress. Such differences can be attributed to variation in nutrient uptake abilities of rootstocks (Marschner et al 1986a, b; Kayan 2008). Result revealed that in general, “Mazzard and Gisela 6” rootstocks-scion combinations have higher nutrient uptake ability than “MaxMa 14”.

Results showed that drought stress reduced the concentration of N, P, K, Ca, Mg, Mn, Zn, and Cu concentrations. Similar results were reported for concentrations of N, K, Ca and Mg upon increasing drought stress (Nahar & Gretzmacher 2002). Sivritepe et al (2008) found that K, Ca and Mn concentrations of Gisela 5 rootstock shows

Table 4- Effect of different rootstocks and drought stress on Mg (g kg^{-1}) and Cu (mg kg^{-1}) concentrations of leaves

Çizelge 4- Farklı anaç ve kuraklık stresinin yaprağın Mg (g kg^{-1}) ve Cu (mg kg^{-1}) içeriklerine etkisi

	Irrigation treatments									
Rootstocks										
	T1		*T2*		*T3*		*T4*		*Mean*	
	Mg	*Cu*	*Mg*	*Cu*	*Mg*	*Cu*	*Mg*	*Cu*	*Mg*	*Cu*
P.Mahaleb	4.3	11	4.0	12	4.0	10	3.3	13	3.9C*	11B*
Mazzard	4.0	13	4.0	12	3.7	12	3.5	16	3.8C	12A
Gisela 6	6.9	10	5.7	10	5.7	10	5.6	9	6.0A	10BC
MaxMa 14	5.2	10	5.1	10	5.1	9	4.9	8	5.1B	9C
CAB 6	5.7	11	5.2	11	5.2	11	5.2	13	5.3B	11B
Mean	5.2a**	11	4.8b	11	4.7b	10	4.5c	10		

*, capital letters indicates rootstocks differences (P<001 (Mg); P<0.05 (Cu)); **, small letters indicates drought stress differences (P<0.01)

***Table 5- Effect of different rootstocks and dr*ought stress on Zn and Mn concentrations of leaves (mg kg^{-1})**

Çizelge 5- Farklı anaç ve kuraklık stresinin yaprağın Zn ve Mn içeriklerine etkisi (mg kg^{-1})

	Irrigation treatments									
Rootstocks										
	T1		*T2*		*T3*		*T4*		*Mean*	
	Zn	*Mn*	*Zn*	*Mn*	*Zn*	*Mn*	*Zn*	*Mn*	*Zn*	*Mn*
P.Mahaleb	16Aa*	42Ad**	15Aa	41Ab	11Bb	41Ab	11Bb	36Bc	13	40
Mazzard	17Aa	56Aa	17Aa	53ABa	16Aa	52ABa	16Aa	50Ba	17	53
Gisela 6	12Ab	54Aab	10ABb	52Aa	8Bc	52Aa	8Bc	45Bb	10	51
MaxMa 14	10Ab	49Ac	9Ab	41Bb	8Ac	41Bb	8Ac	31Cd	9	40
CAB 6	10Cb	50Abc	17Aa	50Aa	17Aa	51Aa	13Bb	50Aa	14	50
Mean	14	50	13	47	12	47	11	42		

Capital letters indicates drought stress and small letters indicates rootstocks differences; *, Zn (P<0.01); **, Mn (P<0.05)

significant decreases under drought stress. The findings of Brito et al (2003) and Molassiotis et al (2006) showed a decrease in leaf-K and Mn concentrations of sweet cherry under deficit irrigation.

Nutrient concentrations obtained for different rootstock-scion combinations showed a decreasing tendency to increasing water deficiency, but N, P, Ca, Mn, Zn and Cu concentrations of sweet cherry budded on CAB 6 rootstock were not affected from the irrigation treatments. By considering mineral composition of leaves, it can be said that CAB 6 rootstock had higher performance on drought stress than the other rootstocks.

MaxMa 14, Gisela 6, and CAB 6 are the most preferred rootstocks by sweet cherry producers in newly established orchards in the last decade. The reasons of the preference of the rootstocks are earlier yield, higher tree density per ha, ease of cultivation practices such as pruning, harvesting, etc.

4. Conclusions

Nutrient concentrations of leaves were affected by rootstocks and drought stress. Result pointed out that in general, “Mazzard and Gisela 6” rootstocks-scion combinations had higher nutrient uptake ability than “MaxMa 14”. On the other side, drought stress reduced N, P, K, Ca, Mg, Mn, Zn, and Cu concentrations. Results revealed that the lowest nutrient concentration changes of leaves was determined from CAB 6 rootstock. Furthermore, it can be said that CAB 6 rootstock had higher performance on drought stress than the other rootstocks.

Due to increasing global desertification or warming and water scarcity in the last decades, deficit irrigation practice along with drought resistant rootstock-scion combination with minimum yield and quality lost could be considered as economically feasible and environmentally friendly agricultural practice. Therefore, this study supports this idea and results can be used practically by producers. This study has significant attributes for selecting the most tolerant rootstock for water deficit conditions to minimize nutritional disorders of sweet cherry orchards.

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