Soil Studies 11(2), 51-61
*http://doi.org/*10.21657/soilst.1218368

RESEARCH PAPER

Influence of some plant nutrients on sweet cherry cultivars grafted on plum rootstocks (*Prunus cerasifera*) in soil with high pH

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How to cite

Yılmaz, C. H. & Uğur, R. (2022). Influence of some plant nutrients on sweet cherry cultivars grafted on plum rootstocks (*Prunus cerasifera*) in soil with high pH. *Soil Studies, 11*(2), 51-61. http://doi.org/10.21657/soilst.1218368

Article History
Received 07 April 2022
Accepted 08 August 2022
First Online 13 December 2022

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Keywords
High soil pH
Leaf nutrients
Macro and microelements
Nutrient uptake
Plum rootstock

Abstract

This study was aimed to investigate the ability of the plums belonging to Prunus cerasifera species to be rootstock to some cherry cultivars and to examine the effect of rootstock, variety and their combinations on mineral nutrition. Rootstock-scion relationship and plant nutrient transmission were investigated in Napoleon, Starks Gold and Lambert cherry cultivars grafted on 10 selected rootstocks. As a result of the investigations, it was determined that the selected rootstocks were quite effective in transmitting the macro and micro plant nutrients to the cherry cultivars. It was noteworthy that the foliage phosphorus (0.15-0.52%) and potassium (1.65-4.00%) contents of the rootstocks were high. Although the leaf iron contents of rootstocks (49.11-74.42 mg kg-1) remained relatively below the reference values, deficiency symptoms such as chlorosis were not observed in the leaves. A strong correlation (r = 0.780**) was found between leaf chlorophyll contents and Cu. Translocated graft incompatibility was observed in some rootstocks. In combinations with not good graft compatibility, decreases in the transmission of plant nutrients were determined in general. At the end of the study, the idea that Prunus cerasifera wild plum species can be a good clone rootstock alternative for sweet cherry growing in high pH soils has emerged.

Introduction

According to the data of 2019, the world sweet cherry production is approximately 2.595.812 tons. Within this production amount, Türkiye ranks first in the world with 664,224 tons (FAOSTAT, 2020). As in other countries in the Mediterranean zone, soils in Turkey are also mostly calcareous and have a high pH. For this reason, mostly classical wild cherry (Prunus avium), mahaleb (Prunus mahalep) and a little wild cherry (Prunus cerasus) are used as rootstocks in sweet cherry cultivation in the country. Since Prunus avium rootstocks are not suitable for intensive cultivation due to their excessive strong grew, Prunus mahalep and Prunus cerasus rootstocks have excessive bottom suckering, irregularities in nutrient transmission (Jimenez et al., 2007), drying in high ground water and irrigation applications and Its use remains limited, as it carries a risk of delayed graft incompatibility. In recent years, the use of clonal hybrid rootstocks cultivated by different methods brought from outside the country has also increased. However, although some of these rootstocks have received positive results, serious problems occur in some of their adaptation to the high pH soils of the Anatolia. Therefore, it has become more important to carry out rootstock breeding studies in other Prunus species in order to use suitable rootstocks. Among these species, Prunus cerasifera is an important and suitable alternative. However, this species adapts easily to different climatic and soil conditions (Topp et al., 2012). In the breeding programs for the use of Prunus cerasifera as rootstock for stone fruits, it has been determined that this species is quite compatible with the calcareous and high pH soils of the typical Mediterranean region where root rot and chlorosis problems are intense (Moreno, 2004). Failure of a developed rootstock to adapt well to different soil conditions could be difficulties in the transmission of plant nutrients, as well as problems in the graft compatibility rate and post-grafting development.

There are three main factors that affect plant nutrition and the nutritional situations of a plant: Soil, rootstock and environment. Soil texture, pH, salinity, lime, organic matter, cation exchange capacity, available nutrient concentrations, depth and balance are among the soil factors. Species, variety, root structure, age, growth period and other genotypic characteristics of a plant play different important roles on nutrients uptake ability of a plant (Erdal et al., 2008; Marschner, 2012). Factors such as humidity, temperature, precipitation and its characteristics, lighting duration also play a role as environmental factors in soil fertility and plant nutrition. Plant factors are the basic characteristics in determining the degree of influence of these factors. Nutrient uptake capacity of a plant still varies from plant to plant, even if there are different genotypes of that plant species (Clark & Gross, 1986). These variations can be seen even if grown in the same soil and under the same conditions (Küçükyumuk & Erdal 2011; Marschner, 2012; Küçükyumuk et al.2015). In the science of horticulture, rootstock and variety are two important basic factors affecting the performance and survival of a variety against negatory conditions. In order to obtain better plant growth and quality yield, nutrients uptake and transport capacities of plant cultivars and its rootstocks should be taken into consideration (Tsipouridis et al., 1990; Küçükyumuk & Erdal 2011).

In this study, Napoleon, Starks Gold and Lambert sweet cherry cultivars grafted on Prunus cerasifera, the most important goal was to shed light on similar studies to be done after that by revealing how nutrient transfer, rootstock scion match, and sweet cherry cultivars will develop forces. The study was carried out in the greenhouses, laboratories and land of Kahramanmaraş Eastern Mediterranean Transitional Zone Agricultural Research Institute between 2019-2020.

Materials and Methods

This research was carried out between 2019-2020 in the greenhouses and laboratories of Eastern Mediterranean Transition Zone Agricultural Research Institute in Kahramanmaraş province of Türkiye.

Soil Material

In greenhouse studies, the soil obtained with a

Table 1. Some physical and chemical properties and evaluation of the prepared greenhouse soil.

Soil Properties	Greenhouse soil values	Evaluation	By whom
Saturation (%)	67	Clay-Loam (CL)	Ülgen and Yurtsever (1995)
pH	8.45	Moderately alkaline	USDA (1998)
EC (dS m^{-1})	0.94	Slightly saline	FAO (2006)
Lime (%)	4.82	Moderately calcareous	FAO (2006)
Organic matter (%)	7.12	High	Ülgen ve Yurtsever (1995)
Available phosphorus (mg kg^{-1})	58.74	Very high	Rehm et al. (1996)
Available potassium (mg kg^{-1})	566	Very high	Rehm et al. (1996)
Available calcium (mg kg^{-1})	5499	Good	Loue (1968)
Available magnesium (mg kg^{-1})	550	High	Loue (1968)
Available iron (mg kg^{-1})	20.49	Good	Lindsay ve Norvell (1978)
Available manganese (mg kg^{-1})	4.60	Sufficient	Lindsay ve Norvell (1978)
Available copper (mg kg^{-1})	4.69	Sufficient	Lindsay ve Norvell (1978)
Available zinc (mg kg^{-1})	2.97	High	Lindsay ve Norvell (1978)

mixture of garden soil, sand and peat (3:2:1, respectively) and the content of which can be seen in Table 1 was used.

Plant Material

Napoleon, Starks Gold and Lambert sweet cherry cultivars were grafted on 11 rootstocks plants, including 10 selected clonal Prunus cerasifera and 1 control plant Adara (Prunus cerasifera) as material in the study. The number of grafting was set to be 15 from each rootstock-scion combination. In the fall of 2019, chip budding was applied. Those that got the graft incompatibility were eliminated. In the experiment, 6 dm^3 pots with suitable soil mixture were used.

Greenhouse studies

After the application of the graft, the pots where the saplings were located were placed in a fully controlled greenhouse. During the vegetation period, irrigation was applied to all plants by drip irrigation method, on average, once a week according to temperature values. The drip irrigation application was terminated as of the end of October 2020. Sapling growth status in the vegetation period of 2020 was also examined.

Sapling Growth Status

Growing cases and diameters of rootstock and scion were realized with a digital caliper with a sensitivity of 0.01 mm (0.01 mm Gomax GMX1017020) from 5 cm above and below the grafting point. The height of the saplings was measured with the help of strip meters from the graft point (Tekintaş et al., 2006).

Chlorophyll Analysis

The amount of chlorophyll (Chl) per unit area of the leaves that have completed their development in the greenhouse was carried out with the help of SPAD 502 (Minolta Co., Osaka, Japan) chlorophyll measuring device. After adjusting the calibration of the device, the chlorophyll amount of ten leaves taken from each sapling from different ways and from the outward-facing directions was measured in nmol Chl cm2 and the average of all values was found. Chlorophyll measurements were performed monthly from May 2020, when the leaves were fully grown, to the end of October 2020 (Reig et al., 2018a). The obtained values were evaluated in accordance with the experimental plan.

Plant Nutrient Analysis

As reported by Kacar & İnal (2010), leaf samples were collected, dried, ground. Milled samples were wet-digested in a CEM Mars 6 brand microwave oven, and then the total amounts of P, K, Ca, Mg, Fe, Mn, Cu, and Zn of leaves in an Agilent 5100 brand ICP-OES device determined. The accuracy of the results was also checked with certified values of relevant minerals in reference plant materials obtained from the National Institute of Standards and Technology (NIST, Gaithersburg, MD, USA).

Histological Analysis

These analyzes were performed by Moreno et al. (1993) and Reig et al. (2019) was made according to the recommendations.

Evaluation of Data

The experiment was established in a randomized plot design with three replications, with 5 pots in each plot. The analysis of variance on the data obtained from the study was performed using the Jmp 5.0 statistical program (Sall et al., 2017), and the comparison of the means was performed using the LSD ($P < 0.05$) test.

Results and Discussion

Sapling Growth Status

It was observed that the selected rootstocks significantly affected the growth vigor of sweet cherry cultivars. It was determined that the greatest scion diameter development occurred in all sweet cherry cultivars grafted on KL-38 rootstock, with values varying between 15.00-15.46 mm. It was observed that the smallest scion diameter was in the Lambert variety grafted on KL-60. In general, the diameters of the scion ranged between 11-15 mm in the rootstock scion combinations, and the rootstocks were significantly effective in the development strength of the scion (Table 4). As well as the differences in scion-caliber development, the development status in sapling sizes showed a similar distribution, and it was determined that the same combinations had similar results.

Chlorophyll Contents

It was revealed that leaf chlorophyll contents of sweet cherry cultivars were significantly affected by rootstocks (Table 4). Leaf chlorophyll contents are highest in Lambert/KL-54 (47.44 nmol cm2) and Napoleon/KL-60 (47.13 nmol cm2) combinations, the lowest is in Napoleon/KL-47 (36.08 nmol cm2) and Napoleon/KL-33 (36.02 nmol cm2) combinations were found.

Leaf Nutrient Concentrations

Leaf macro and microelement contents of three sweet cherry cultivars were statistically significantly affected by rootstocks. Leaf phosphorus contents of sweet

Table 2. Leaf macronutrient contents of Napoleon, Starks Gold and Lambert sweet cherry cultivars grafted on rootstocks.

Variety	**Rockstock**	**P (%)**		**K (%)**		**Ca (%)**		**Mg (%)**	
	KL-11	0.25 ±hıj		2.17 ±0.05 ıj		0.76±0.01op		0.25 ±0.01 st	
	KL-15	0.33 ±0.01 de		2.64 ±0.06 efg		1.39±0.01 kl		0.35 ±0.01 op	
	KL-29	0.23 ±0.01 lm		2.29 ± 0.06 hı		2.53±0.03 b		0.50 ±0.01 g	
	KL-30	0.20 ±0.01op		2.31 ±0.06 h		1.00±0.02 m		0.31 ±0.01 q	
	KL-33	0.32 ±0.01 e		4.00 ±0.10 a		1.94±0.02 fg		0.52 ±0.01 ef	
Napoleon	KL-38	0.26 ±0.01 gh	0.31 ±0.09 A	2.72 ±0.07 e	2.88 ±0.54 A	2.58±0.03 b	1.97±0.31 A	0.61 ±0.01 a	0.46 ±0.11 A
	KL-47	0.26 ±0.01 hı		3.45 ±0.08 b		2.03±0.02 e		0.40 ±0.01 kl	
	KL-54	0.45 ±0.01 b		2.98 ±0.07 cd		2.62±0.03 b		0.62 ±0.02 a	
	KL-59	0.52 ±0.01 a		3.49 ±0.09 b		2.62±0.03 b		0.57 ±0.01 b	
	KL-60	0.33 ±0.01 d		2.90 ±0.07 d		2.31±0.03 c		0.51 ±0.01 fg	
	ADARA	0.28 ±0.01fg		2.69 ±0.07 ef		1.85±0.02 g		0.42 ±0.01 ıj	
	KL-11	0.19 ±0.01qr		1.65 ±0.04 o		0.58±0.01 o		0.19 ±0.00 v	
	KL-15	0.25 ±0.01ıjk		2.00 ±0.05 kl		1.06±0.01 m		0.26 ±0.01 rs	
	KL-29	0.18 ±0.00 qr		2.53 ±0.06 g		1.61±0.02 ı		0.34 ±0.01 p	
	KL-30	0.15 ±0.01 s		1.76 ±0.04 no		0.76±0.01 op		0.23 ±0.01 tu	
	KL-33	0.24 ±0.01 kl		3.04 ±0.07 c		1.47±0.02 jk		0.40 ±0.01 lm	
Starks Gold	KL-38	0.20 ±0.01 op	0.23 ±0.06 C	1.84 ± 0.05 mn	2.27 ±0.42 C	3.26±0.03 a	1.52±0.35 C	0.56 ±0.01 bc	0.35 ±0.10 C
	KL-47	0.20 ±0.01 op		2.62 ±0.06 efg		1.54±0.02 ıj		0.31 ±0.01 q	
	KL-54	0.34 ±0.01 d		2.27 ±0.06 hı		1.99±0.02 ef		0.47 ±0.01 h	
	KL-59	0.40 ±0.01 c		2.65 ±0.07 efg		1.99±0.02 ef		0.43 ±0.01 ıj	
	KL-60	0.22 ±0.01 mn		2.56 ±0.06 fg		1.07±0.01 m		0.31 ±0.01 q	
	ADARA	0.21 ±0.01 mn		2.04 ±0.05 k		1.41±0.02 kl		0.32 ±0.01 q	
	KL-11	0.22 ±0.01 m		1.91 ±0.05 lm		0.67±0.01 q		0.22 ±0.01 u	
	KL-15	0.24 ±0.01 ıjkl		1.83 ±0.04 mn		0.77±0.01 o		0.22 ±0.01 u	
	KL-29	0.20 ±0.01 op		2.01 ±0.05 kl		2.23±0.03 d		0.44 ±0.01 ı	
	KL-30	0.18 ±0.01 r		2.03 ±0.05 kl		0.88±0.01 n		0.27 ±0.01 rs	
	KL-33	0.28 ±0.29 f		3.57 ±0.09b		1.73±0.02 h		0.47 ±0.01 h	
Lambert	KL-38	0.23 ±0.01 lm	0.27 ±0.08 B	2.39 ±0.06 h	2.50 ±0.60 B	2.27±0.01 d	1.64±0.30 B	0.53 ±0.01 de	0.38 ±0.10 B
	KL-47	0.29 ±0.01 f		3.56 ±0.09 b		1.91±0.02 fg		0.38 ±0.01mn	
	KL-54	0.40 ±0.01 c		2.62 ±0.06 efg		2.30±0.03 cd		0.54 ±0.01cd	
	KL-59	0.46 ±0.01 b		3.07 ±0.08 c		2.31±0.03 cd		0.50 ±0.01fg	
	KL-60	0.17 ±0.00 r		2.12 ±0.05ıj		1.36±0.02 l		0.30 ±0.01q	
	ADARA	0.24 ±0.01 jkl		2.36 ±0.06 h		1.63±0.02 ı		0.37 ±0.01no	
$LSD_{0.05}$		**0.01****	**0.01****	**0.07****	**0.04****	**0.08****	**0.04****	**0.02****	**0.01****

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*http://doi.org/*10.21657/soilst.1218368

Table 3. Leaf micronutrient contents of Napoleon, Starks Gold and Lambert sweet cherry cultivars grafted on rootstocks.

Variety	Rockstock	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})	
Napoleon	KL-11	67.06 ±0.51 e	67.19 ±4.31A	38.65 ±0.95 ıj	43.77 ±7.66 A	13.97 ±0.10 l	20.83 ±8.13 A	15.58 ±0.38 lm	18.78 ±4.66 A
	KL-15	72.84 ±0.30 b		37.43 ±0.92 j		10.58 ±0.13 n		24.61 ±0.85 a	
	KL-29	63.87 ±0.31 g		48.35 ±1.18 c		18.73 ±0.46 j		15.42 ±0.38 m	
	KL-30	61.13 ±0.12 lm		34.89 ±0.85 k		1.89 ±0.22 n		10.82 ±0.27 p	
	KL-33	62.27 ±0.28 ıjk		46.66 ±0.24 d		14.34 ±0.11 l		20.74 ±0.51 cd	
	KL-38	65.19 ±0.16 f		34.54 ±0.85 k		26.43 ±0.65 f		21.70 ±0.53b	
	KL-47	62.61 ±0.22 hıj		34.33 ±0.84 k		13.99 ±0.07 l		10.83 ±0.27 p	
	KL-54	69.66 ±0.14 d		54.40 ±0.80 a		30.36 ±0.50 d		23.95 ±0.46 a	
	KL-59	70.29 ±0.21 d		54.92 ±0.56 a		31.87 ±0.53 c		20.19 ±0.37 de	
	KL-60	74.42 ±0.56 a		47.12 ±0.86 cd		30.63 ±0.26 d		21.29 ±0.40 bc	
	ADARA	69.76 ±0.20 d		50.16 ±0.86 b		27.34 ±0.30 e		21.50 ±0.40 bc	
Starks Gold	KL-11	54.72 ±0.17 r	58.15 ±4.62 C	29.37 ±0.72 mno	35.35 ±7.15 B	3.01 ±0.07 q	17.02 ±9.42 C	11.84 ±0.29 o	15.54 ±4.20 C
	KL-15	53.12 ±0.26 s		28.44 ±0.70 o		14.24 ±0.10 l		21.30 ±0.64 bc	
	KL-29	63.27 ±0.04 gh		32.63 ±0.80 l		18.59 ±0.46 j		16.28 ±0.40 jkl	
	KL-30	55.25 ±0.42 qr		26.51 ±0.65 p		6.76 ±0.17 p		8.22 ±0.20 r	
	KL-33	62.66 ±0.42 hıj		48.26 ±0.61 c		13.30 ±0.08 m		15.76 ±0.39 klm	
	KL-38	62.95 ±0.21 hı		33.46 ±0.94 kl		19.01 ±0.47 j		16.01 ±0.39 jklm	
	KL-47	49.11 ±0.32 t		26.09 ±0.64 p		2.22 ±0.06 r		8.23 ±0.20 r	
	KL-54	55.77 ±0.42 pq		40.63 ±0.60 gh		30.47 ±0.38 d		19.40 ±0.35 ef	
	KL-59	62.23 ±0.60 ıjk		39.42 ±0.43 hı		31.62 ±0.41 c		16.54 ±0.28 jk	
	KL-60	58.81 ±0.31 n		42.27 ±0.62 ef		23.59 ±0.21 ı		19.81 ±0.60 ef	
	ADARA	61.81 ±0.24 jk		41.72 ±0.66 efg		24.38 ±0.23 h		17.67 ±0.31 ı	
Lambert	KL-11	56.06 ±0.24 p	59.31 ±4.95 B	29.01 ±0.84 no	35.07 ±6.76 B	3.49 ±0.09 q	18.21 ±10.45 B	13.71 ±0.34 n	16.18 ±3.86 B
	KL-15	55.14 ±0.19 qr		24.06 ±0.59 q		14.11 ±0.10 l		17.67 ±0.43 hı	
	KL-29	52.40 ±0.47 s		42.55 ±1.04 e		16.48 ±0.40k		13.57 ±0.33 n	
	KL-30	63.19 ±0.61 gh		30.70 ±0.75 m		7.82 ±0.19 o		9.52 ±0.23 q	
	KL-33	54.88 ±0.55 r		38.44 ±0.84 ıj		13.87 ±0.09 lm		18.52 ±0.45 g	
	KL-38	57.97 ±0.33 o		30.40 ±0.74 mn		23.26 ±0.57 ı		19.09 ±0.47 fg	
	KL-47	57.88 ±0.33 o		26.02 ±0.64 p		3.01 ±0.07 q		9.62 ±0.24 q	
	KL-54	61.92 ±0.58 jk		40.51 ±0.70 gh		32.92 ±0.44 b		21.68 ±0.41 b	
	KL-59	71.28 ±0.15 c		42.17 ±0.49 ef		34.24 ±0.47 a		18.37 ±0.33 gh	
	KL-60	60.90 ±0.27 m		41.01 ±0.71 fg		25.20 ±0.25 g		16.73 ±0.29 j	
	ADARA	60.78 ±0.12 m		40.94 ±0.76 fg		25.86 ±0.27 f		19.52 ±0.36 ef	
$LSD_{0.05}$		**0.75****	**0.21****	**1.49****	**0.44****	**0.63****	**0.19****	**0.79****	**0.24****

Table 4. Chlorophyll concentrations and seedling growth status of Napoleon, Starks Gold and Lambert sweet cherry cvs. grafted on rootstocks

Variety	Rockstock	Mean Chlorophyll (nmol cm²)		Rootstock Diameter (mm)		Scion Diameter (mm)		Sapling Height (cm)	
	KL-11	36.81 ±1.45 jk		12.12 ±0.11 ghı		7.69 ±0.31 jkl		67.99 ±2.45 o	
	KL-15	36.77 ±0.64 jk		12.00 ±0.11 g-j		7.61 ±0.30 kl		67.32 ±2.42 o	
	KL-29	41.37 ±1.06 def		11.60 ±0.56 h-k		12.58 ±0.50 b		134.33 ±1.89 cd	
	KL-30	36.45 ±1.44 jk		8.13 ±0.21 n		9.34 ±0.30 ghı		102.19 ±2.80 j	
	KL-33	36.02 ±1.42 k		12.12 ±0.11 ghı		7.69 ±0.31 jkl		68.00 ±2.45 o	
Napoleon	KL-38	37.91 ±0.97 ıjk	40.03 ±4.17	12.76 ±0.70 d-g	11.95 ±2.02 A	15.46 ±0.90 a	10.61 ±2.54	145.66 ±2.49 a	106.88 ±28.43B
	KL-47	36.08 ±1.42 jk		8.12 ±0.17 n		8.93 ±0.50 hıj		96.05 ±4.78 k-n	
	KL-54	46.51 ±1.11 a		14.02 ±0.54 ab		12.81 ±0.56 b		135.66 ±1.70 bcd	
	KL-59	43.16 ±0.56 cde		13.56 ±0.82 a-d		10.97 ±0.98 ef		101.50 ±4.30 jk	
	KL-60	47.13 ±0.95 a		12.91 ±0.46 c-g		12.45 ±0.47 bc		131.00 ±4.32 def	
	ADARA	42.08 ±0.94 c-f		14.14 ±0.58 a		11.19 ±1.13 c-f		126.00 ±2.16 efg	
	KL-11	37.95 ±1.31 ıjk		11.64 ±0.15 h-k		8.99 ±0.21 hıj		93.74 ±1.43 n	
	KL-15	37.92 ±1.31 ıjk		11.52 ±0.15 h-k		8.91 ±0.20 ıj		118.28 ±1.80 ı	
	KL-29	40.96 ±1.04 efg		11.29 ±0.52 ıjkl		12.15 ±0.52 b-e		131.94 ±4.92 d	
	KL-30	37.58 ±1 30 ıjk		8.05 ±0.21 n		9.25 ±0.30 ghı		101.17 ±2.77 jkl	
	KL-33	37.14 ±1.28 ıjk		11.64 ±0.15 h-k		9.00 ±0.21 hı		94.05 ±1.05 n	
Starks Gold	KL-38	39.09 ±1.35 ghı	40.37 ±3.43	12.38 ±0.68 fgh	11.34 ±1.99 B	15.00 ±0.88 a	10.42 ±2.06	138.06 ±3.49 bc	106.79 ±20.34B
	KL-47	37.21 ±1.29 ıjk		8.04 ±0.16 n		8.84 ±0.49 ıjk		95.08 ±3.92 mn	
	KL-54	46.04 ±1.10 ab		13.59 ±0.53 a-d		12.42 ±0.55 bc		131.60 ±de	
	KL-59	42.73 ±0.55 c-f		13.15 ±0.80 b-f		10.64 ±0.95 f		98.45 ±3.20 j-n	
	KL-60	46.18 ±0.93 ab		9.49 ±0.26 m		8.37 ±0.09 ıjkl		72.66 ±1.25 o	
	ADARA	41.66 ±0.92 def		13.99 ±0.57 ab		11.08 ±1.12 def		124.74 ±2.22 gh	
	KL-11	37.18 ±0.65 ıjk		11.15 ±0.24 jkl		10.30 ±0.69 fg		119.48 ±1.22 hı	
	KL-15	37.14 ±1.47 ıjk		11.04 ±0.23 kl		10.20 ±0.68 fgh		118.28 ±1.93 ı	
	KL-29	40.96 ±1.05 efg		11.45 ±0.54 ıjk		12.36 ±0.51 bcd		133.17 ±3.06 cd	
	KL-30	36.81 ±1.45 jk		8.09 ±0.21 n		9.29 ±0.30 ghı		101.68 ±2.78 jk	
	KL-33	36.51 ±0.69 jk		11.16 ±0.24 jkl		10.30 ±0.69 fg		119.50 ±2.86 hı	
Lambert	KL-38	38.29 ±1.51 hıj	40.43 ±4.19	12.57 ±0.69 efg	11.39 ±1.98 B	15.23 ±0.89 a	10.75 ±2.16	140.12 ±2.38 ab	113.41 ±22.02A
	KL-47	36.44 ±1 29 jk		8.08 ±0.16 n		8.88 ±0.49 ıjk		95.57 ±3.96 lmn	
	KL-54	47.44 ±1.13 a		13.80 ±0.53 abc		12.62 ±0.56 b		133.96 ±1.53 cd	
	KL-59	44.03 ±0.57 bc		13.35 ±0.80 a-e		10.81 ±0.97 f		100.31 ±3.85 j-m	
	KL-60	46.64 ±0.94 a		10.53 ±0.10 l		7.09 ±0.02 l		60.00 ±2.94 p	
	ADARA	43.26 ±0.91 cd		14.06 ±0.57 a		11.37 ±1.12 def		125.37 ±2.19 fg	
LSD$_{0.05}$		**2.24****	**N.I.**	**0.89****	**0.27****	**1.27****	**N.I.**	**5.67****	**1.71****

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Table 5. Graft compatibility status among rootstocks and Napoleon, Starks Gold and Lambert sweet cherry cultivars

Variety	Rockstock	Translocated İncompatibility Symptoms	A	B	C	D	E
Napoleon	KL-11	Ab	—	—	—	—	6
	KL-15	Ab	—	—	—	—	5
	KL-29	N	—	2	12	—	—
	KL-30	N	—	—	—	10	—
	KL-33	Ab	—	—	—	—	9
	KL-38	N	—	—	1	14	—
	KL-47	N	—	—	—	8	—
	KL-54	N	14	1	—	—	—
	KL-59	N	15	—	—	—	—
	KL-60	N	13	2	—	—	—
	ADARA	N	15	—	—	—	—
Starks Gold	KL-11	Ab	—	—	—	—	7
	KL-15	Ab	—	—	—	—	5
	KL-29	N	—	—	10	—	—
	KL-30	N	—	—	—	9	—
	KL-33	N	—	—	—	—	8
	KL-38	N	—	—	—	15	—
	KL-47	N	—	—	—	6	—
	KL-54	N	12	3	—	—	—
	KL-59	N	11	4	—	—	—
	KL-60	N	15	—	—	—	—
	ADARA	N	15	—	—	—	—
Lambert	KL-11	Ab	—	—	—	—	6
	KL-15	Ab	—	—	—	—	5
	KL-29	N	—	—	11	—	—
	KL-30	N	—	—	—	7	—
	KL-33	Ab	—	—	—	—	8
	KL-38	N	—	—	3	12	—
	KL-47	N	—	—	—	—	—
	KL-54	N	15	—	—	7	—
	KL-59	N	15	—	—	—	—
	KL-60	N	15	—	—	—	—
	ADARA	N	15	—	—	—	—

cherry cultivars were found the highest in Napoleon/KL-59 and Lambert/KL-59 (0.52% and 0.46%, respectively). The lowest leaf K contents were found in Starks Gold sweet cherry cultivars grafted on KL-30 and KL-11 rootstocks (1.76% and 1.65%, respectively). Ca contents showed a very wide distribution. Starks Gold/KL-38 had the highest Ca content (1.63%), while Starks Gold/KL-11 had the lowest content (0.29%) (Table 2). In rootstock-scion combinations, leaf Fe contents ranged between the highest Napoleon/KL-60 (74.42 mg kg-1) and the lowest Starks Gold/KL-47 (49.11 mg kg-1). The lowest Mn contents were found in Lambert sweet cherry cultivar grafted on KL-47 and KL-15 rootstocks (26.02 mg kg-1 and 24.06 mg kg-1, respectively) (Table 3).

Histological Analyses

In the study, as a result of the longitudinal microscopic observations made in the combinations from which tissue samples were taken, cambial continuity was ensured at the junction point of rootstock and scion in the sweet cherry cultivars grafted on 4 rootstocks, including the control plant, there was no bending in the graft axis, and no thickening or deformation was observed in the phloem of the rootstock and scion. In the dyeing process with potassium iodide, homogeneous staining occurred in rootstock and scion regions (Figure 1). It was decided to classify these combinations as category A. In sweet cherry cultivars grafted on KL-11, KL-15 and KL-33 rootstocks, growth disorders and smaller than normal leaves occurred. In the cross-section analyses, thickening and deformations were observed in the phloem, and necrotic areas were determined also at the graft junction point. In the external examination of the wood tissue, thick black lines were observed along the graft junction line. Some saplings were also seen drying in the middle of the growing period. As a result of these observations, it was concluded that there is a translocated graft incompatibility with the cultivars grafted on these rootstocks (Table 5).

Rootstocks, statistically significantly affected the growth strength, leaf nutrients and chlorophyll contents of Napoleon, Starks Gold and Lambert sweet cherry cultivars grafted on them ($P < 0.05$). It was determined that three selected cultivars showed strong growth with Adara (Prunus cerasifera) rootstock (Table 4). It has been stated that rootstocks that show strong growth can perform well in soils poor, water-scarce, calcareous and with high pH (Gainza-Cortés et al., 2015).

Leaf chlorophyll contents are generally seen to be at medium and high levels (Table 4). It is thought that there is no problem in leaf chlorophyll contents due to the fact that rootstocks belonging to this species adapt well to soils with high lime and pH and areas with high ground water. Jimenes et al. (2007) measured the leaf chlorophyll contents of Stark Hardy Giant sweet cherry variety grafted on Adara (Prunus cerasifera) rootstock and reported that the leaves did not turn yellow in the following years and the yield was high.

Rootstocks and cultivars individually or combinations of these significantly affected leaf nutrient concentrations. Although some rootstock x cultivar combinations were in the same statistical group in terms of leaf nutrient amounts, some of the

Table 6. Correlation status of leaf nutrient contents of rootstocks

	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Klorofil (nmol Chl cm^2)
P (%)									
K (%)	0.574**								
Ca (%)	0.514**	0.439**							
Mg (%)	0.621**	0.551**	0.942**						
Fe (ppm)	-0.143**	0.352**	-0.398**	-0.458**					
Mn (ppm	-0,560**	0.437**	0.495**	0.592**	-0.616**				
Cu (ppm)	0.626**	0.201	0.604**	0.654**	-0.525**	-0.657**			
Zn (ppm)	-0.565**	0.256*	0.390**	0.521**	0.506**	0.563**	0.684**		
Klorofil (nmol Chl cm^2)	0.433**	0.006	0.376**	0.373**	0.310**	0.567**	0.780**	0.475**	

**: $P < 0.01$, significant at the 1% level
*: $P < 0.05$, significant at the 5% level

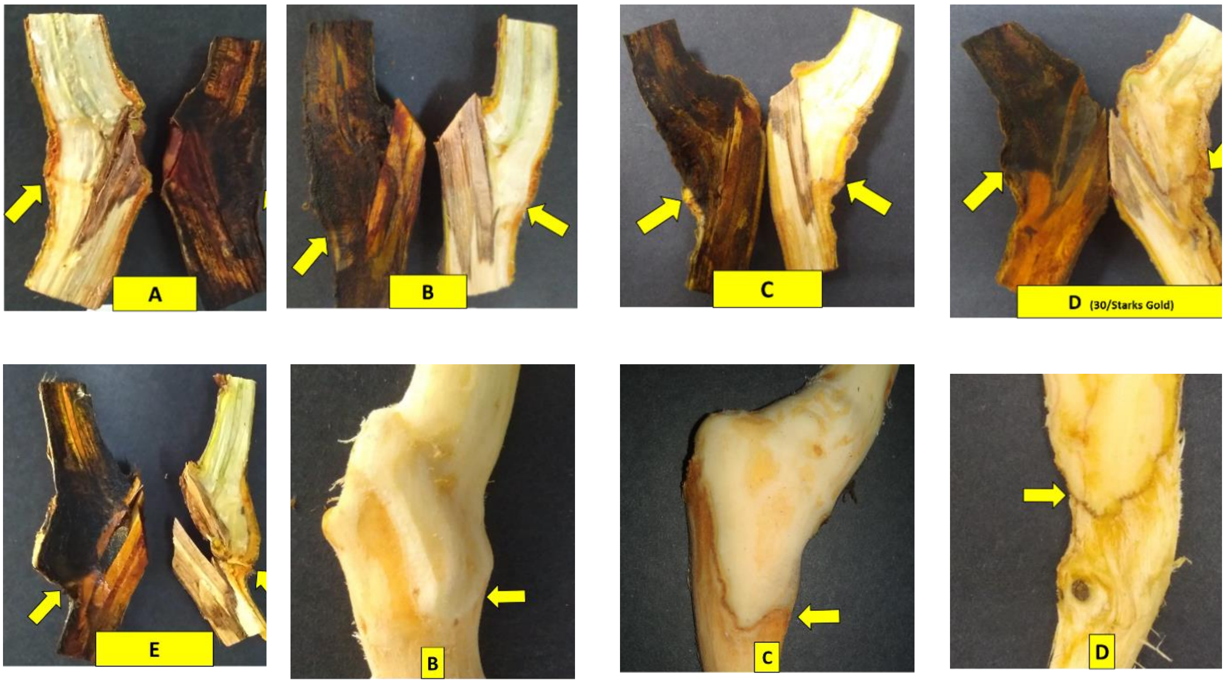

Figure 1. Images of different categories (A, B, C, D and E) from samples taken from the graft junction, accord

combinations contained quite different nutrient amounts. When looking at the individual effects of rootstocks and cultivars on nutrient concentrations of cherries, it is seen that they give variable responses to the different nutrients. The best rootstock x cultivar effect was observed in the rootstocks containing the most P (0.31±0.09 A), K (2.88±0.54 A), Ca (1.97±0.31 A) and Mg (0.46±0.11 A) in the Napoleon sweet cherry cultivar. It was determined that the most productive of these rootstocks were KL-59 in terms of P, KL-33 in terms of K, KL-59, KL-54 and KL-29 in terms of Ca and KL-54 and KL-38 in terms of Mg. The weakest rootstock x cultivar effect was observed in Starks Gold sweet cherry cultivar, in rootstocks containing P (0.23±0.06 C), K (2.27±0.42 C), Ca (1.52±0.35 C) and Mg (0.35±0.10 C).

Also among these rootstocks, it was determined that the most unproductive ones were KL-30 in terms of P and KL-11 in terms of K, Ca and Mg (Table 2). In microelements, the best rootstock x variety effect was observed in the rootstocks containing the most Fe (67.19 ±4.31 A), Mn (43.77 ±7.66 A), Cu (20.83 ±8.13 A) and Zn (18.78 ±4.66 A) in the Napoleon sweet cherry cultivar again. KL-60 (74.42 ±0.56 a) for Fe, KL-59 (54.92 ±0.56 a) and KL-54 (54.40 ±0.80 a) for Mn, KL-59 (31.87 ±0.53 c) for Cu, KL-15 (24.61 ±0.85 a) and KL-54 (23.95 ±0.46 a) for Zn were determined to be the most productive rootstocks.

The weakest rootstock x cultivar effect was observed in Starks Gold sweet cherry cultivar, in rootstocks containing Fe (58.15 ±4.62 C), Cu (17.02 ±9.42 C), and Zn (15.54 ±4.20 C). In terms of microelements, it was determined that the most inefficient rootstocks were KL-47 for Fe, KL-30 and KL-47 for Mn, KL-47 for Cu, and KL-30 and KL-47 for Zn (Table 3). It was determined that leaf Fe contents of three sweet cherry cultivars grafted on rootstocks were within the proficiency reference values determined by Leece and Van Den Ende (1975), but not at the desired level. Zn concentrations were also below the sufficiency level in some rootstocks. This is due to the fact that the P level is quite high. Because iron is in an antagonistic relationship with elements such as P (Aktaş & Ateş, 1998). It has also been reported that Mn can also negatively affect the uptake of Fe by rootstocks (Mengel & Kirkby, 2001). However, no obvious signs of chlorosis were observed.

Similar variable findings were also obtained in cultivars. Differences in leaf nutrient contents among cultivars and rootstocks can be attributed to the connatural nutrient uptake capacity of cultivars and rootstocks and their translocation in plants (Meland, 2010; Mestre et al., 2015). Clark & Gross (1986) reported that even plants grown under the same conditions can take in different amounts of nutrients. Again, the structure of the root system, density, surface area, cation exchange capacities, etc. affects the nutrient absorption capacity of the plant (Marschner, 2012). The diversity of root secretions and their properties depending on the rootstocks, and acidification and chelating properties of the rhizosphere region, might explain the presence of different amounts of nutrients in plants (Dakora & Phillips, 2002; Marschner, 2012). In addition, the resistance of a rootstock or cultivar against to biotic and abiotic stresses may provide an advantage for the plant to absorb more nutrients from the soil (Fazio et al., 2015). Another reason why the nutrient contents is different in the study may be differences in the plant size of the cultivars. Nutrient request and absorb usually increase with plant size and biomass (Mugasha et al., 2013; Peng et al., 2019). Again, the physiological requirement of the cultivars may also have had a significant impact on the nutrient demand.

Although there were significant differences between rootstock and cultivar and their combinations for some nutrient contents in leaves, we could not prominently see rootstock or cultivar or their combination on sweet cherry nutrient concentration. The reason may be the capacity of the greenhouse soil used in the experiment to provide nutrients. Because the nutrient concentrations of the soil were sufficient (Table 1). Almost all of the nutrients in the leaves were within the sufficiency limits (Jones et al., 1991) (Tables 2 and 3). This situation may have prevented the effect of rootstock x cultivar combinations on nutrient uptake capacity.

Positive and significant relationships were determined between plant nutrients and chlorophyll contents in all cultivars. The highest correlation value between chlorophyll and plant nutrient contents was found in Cu (r= 0.780**) (Table 6). Jimenes et al. (2007) also reported this important and strong correlation between chlorophyll content and Cu.

Rootstock-scion incompatibility between the selected and control rootstocks with sweet cherry cultivars gave different results (Table 5; Picture 1). While translocated incompatibility symptoms were found in some rootstocks, localized incompatibility symptoms were found in the majority (Reig et al., 2018b). While a sharp indication of incompatibility was observed in cultivars grafted on some rootstocks, Adara (P. cerasifera) and some selected rootstocks were observed to form a compatible combination with the variety (Figure 1). It can be said that there is no growth in the level of stunting in cherries grafted on rootstocks, but there is a moderate growth when compared to control rootstocks (Table 4).

Conclusion

It can be considered that it is necessary to work with nutrient-poor soils in order to reach definite conclusions about which rootstock and cultivar or their combinations are effective on the mineral nutrition of plant. Prunus cerasifera is a plum species that is closely related to Prunus avium or Prunus cerasus, which is good ability to be produced vegetatively, and can form healthy individuals in saturated with water and calcareous soils. It has been also concluded that this species has the potential to be used as an alternative to P. mahalep rootstock, especially in calcareous and with high pH soils where intensive sweet cherry cultivation cannot be done. This species, which spreads over a wide geography, will make a significant contribution to sweet cherry cultivation with larger capacity rootstock selection breeding programs.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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