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Pruning residuals: their role in the micronutrient budget of Clementine mandarin (*Citrus reticulata* Blanco)

Budama atıklarının Clementine mandarini (*Citrus reticulata* Blanco) mikro element bütçesindeki rolü

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ABSTRACT

Objective: The objective of this study was to determine the micronutrient (Fe, Cu, Mn and Zn) amounts removed with pruning residuals in Clementine mandarin (*Citrus reticulata* Blanco) grafted on bitter orange.

Material and Methods: In order to meet the above objective , at the end of two production seasons (2015 and 2016), measurements and analyses were carried out by collecting pruning residual samples from 50 groves located in the province of İzmir and Aydın (Turkey).

Results: While the biomass value varied between 2.90 and 4.90 kg/tree in the 1st year, it varied in the range of 3.00-5.00 kg/tree in the 2nd year. The concentration (mg kg^{-1}) values for the first year were as Fe: 44-115, Cu: 11-32, Mn: 33-75, Zn: 17-26, while these for the second year were Fe: 48-101, Cu: 16-38, Mn: 40-88 and Zn: 20-30. The yield value was 64-102 kg/tree for the 1st year and 65-94 kg/tree for the 2nd year.

Conclusion: The mean values of the microelement amounts removed with pruning residuals may be listed as Fe > Mn > Zn = Cu for both years. The micronutrient amount removed with pruning residuals (g/tree) was found to be Fe: 0.15-0.41, Cu: 0.04-0.13, Mn: 0.12-0.3 and Zn: 0.05-0.13 for the 1st year and Fe: 0.16-0.44, Cu: 0.06-0.16, Mn: 0.15-0.36 and Zn: 0.07-0.13 for the 2nd year. It is suggested that these amounts should be included in plant fertilization programs.

Keywords: Pruning, microelement concentration in pruning residuals, amount of micro elements in pruning residuals, Clementine mandarin,

ÖZ

Amaç: Bu araştırmada turunç anacına aşılı Clementin mandarininde (Citrus reticulata Blanco) budama atıkları ile kaldırılan mikro besin elementi (Fe, Cu, Mn ve Zn) miktarının belirlenmesi amaçlanmıştır.

Materyal ve Yöntem: Çalışmada, iki üretim sezonu sonunda (2015 ve 2016) İzmir ve Aydın şehirlerinde bulunan toplam 50 adet bahçeden budama atığı örneği alınarak ölçümleme ve analizler yapılmıştır.

Araştırma Bulguları: Biomass değeri 1.yıl (2015) 2.90 ile 4.90 kg/ağaç arasında değişim gösterirken 2.yıl (2016) 3.00-5.00 kg/ağaç arasında değişim gösterdiği belirlenmiştir. Birinci yıl Fe konsantrasyonu (mg kg^{-1}) : 44-115, Cu: 11-32, Mn: 33-75 ve Zn: 17-26 arasında değişim gösterirken; ikinci yıl ise, Fe: 48-101, Cu: 16-38, Mn: 40-88, Zn ise 20-30 arasında değişim göstermiştir. Verim değerinin ise 1.yıl 64-102 kg/ağaç, 2.yıl ise 65-94 kg/ağaç arasında değişim gösterdiği bulunmuştur.

Sonuç: Budama atıkları ile uzaklaştırılan mikro element miktarları ortalama değerler göz önüne alındığında her iki yılda da Fe > Mn > Zn = Cu sırasını izlemiştir. Budama atıkları ile uzaklaştırılan mikro besin elementi miktarı (g/ağaç) 1. yıl Fe: 0.15-0.41, Cu: 0.04-0.13, Mn: 0.12-0.3, Zn: 0.05-0.13 arasında belirlenirken; 2. yıl Fe: 0.16-0.44, Cu: 0.06-0.16, Mn: 0.15-0.36 ve Zn: 0.07-0.13 olarak belirlenmiştir. Bu değerlerin gübreleme programlarına dâhil edilmesi önerilmektedir.

Anahtar sözcükler: Budama, budama atıklarında mikro element konsantrasyonu, budama atıklarında mikro element miktarı, Clementine mandarini.

INTRODUCTION

Citrus plant production is of importance for Turkey and the world. It is also known that the share of mandarin in this production is very high. According to the current data (FAO, 2020), in the last decade (2008-2018), an average of 30 Mts mandarin was produced worldwide, while Turkey contributed to this production with 1 Mt. With the current share it has, Turkey has reached the position of the 3rd largest mandarin producer worldwide following China and Spain. This reveals the significance of mandarin production for Turkey. According to the data of TURKSTAT (2020), while the citrus production in 2019 was 4.3 Mts in Turkey, the production shares were as 40 % for orange, 33 % for mandarin, 22 % for lemon and 6 % for grapefruit. These shares indicate the economic significance of mandarin for both Turkey and the world in general.

In especially products like citrus fruits that have high economic value, studies have been mostly on increasing yield and fruit quality. It is known that fertilizing is a factor that directly affects both yield and quality (Marschner, 2011). While creating fertilization strategies, generally nutrient concentrations in the soil and leaves on annual shoots (<1 years of age) are taken into account. In addition to determine the nutrient concentrations in the soil and leaves, considering remobilization and internal cycling factors in preparation of fertilization programs is another approach (Millard, 1996).

Pruning is performed at the end of the production season for reasons such as improving yield and quality, better utilization of sunlight, making aeration easier and reducing the risk of diseases. In some cases, with pruning, healthy leaves and branches are also removed from the tree (Meade & Hensley, 1998; Lonsdale, 1999; Gilman & Grabosky, 2006; Clark & Matheny, 2010; Ow et al., 2013). This situation creates losses from the total nutrient budget of the tree. This is why it is important to include the nutrient amounts removed from the tree with pruning residuals in the fertilization program in the following production period.

Some researchers emphasize that pruning residuals need to be utilized in various ways, and the society needs to be informed on this issue (FAO, 1997; Jensen, 2000; Close et al., 2001; Kuhns & Reiter, 2007; Kuhns & Reiter, 2009; Velázquez Martí et al., 2011; Badrulhisham &Othman, 2016). However, as most of these studies have been conducted to emphasize the importance of the pruning process or utilization of pruning residuals in different sectors (energy, furniture, etc.) as raw materials, the data on assessing their role in plant nutrition and fertilization are limited. Additionally, considering the current literature, it can be stated that fruits like citrus have been rarely included as material in these studies.

The CIRCE-CERTH collaboration report (2018) stated that pruning residuals obtained from fruit plantations, vineyards and olive groves carry a significant potential for many EU countries. Similarly, it was reported by Magagnotti et al. (2013) that the amount of pruning residuals is on a very significant level, and this amount varies between 1 and 5 tons/ha. In their study on different olive varieties, Velázquez Marti et al. (2011) determined the biomass values in the material obtained as a result of pruning. As a result of the study, they reported that the mean dry biomass ranged between 3.5 and 10 kg/tree in annually pruned varieties.

In their study on utilization of pruning residuals from vineyards in the bioenergy sector, Icka and Damo (2018) found that biomass values varied in the range of 1.6-2.1 t/ha (mean: 1.9 t/ha). Picchi et al. (2018) determined some physical (biomass ash ratio, particle size distribution) and chemical (some nutrients and heavy metal concentrations) properties in the pruning residuals of various fruits (vine, olive, apple, pear and hazelnut). According to their results, while the Mn, Cu and Zn concentrations were determined to be 86, 22 and 9 mg kg^{-1} in olive pruning residuals, respectively, these values were 116, 72 and 78 mg kg^{-1} in pear pruning residual.

Velázquez-Martí et al. (2013) stated that the biomass value of citrus pruning residuals varied based on the variety of fruit and purpose of pruning. In this study, the fresh biomass (wood + leaves) values of the orange varieties of Valencia Late, Naveline and N. Washington were found to be 28, 16 and 12 kg/tree, respectively while for the mandarin varieties such as Clementine, Hybrid and Satsuma, the fresh biomass values were found to be 14, 15 and 14 kg/tree, respectively. In another study on the orange variety of Tarocco, the pruning residual was in the amount of 1.7 t/ha dry weight (DW) (Roccuzzo et al., 2012).

As it differs from the other studies existing in the literature, a study was conducted to contribute to fertilization by utilizing pruning resıduals for plant nutrition. As the study shows differences as compared to many existing studies, and sources on the topic are limited, it is believed that this study will bring a different point of view to fertilization studies to be conducted in the future.

MATERIALS and METHODS

The study was conducted on a total of 50 Clementine mandarin (*Citrus reticulata* Blanco) groves located in the provinces of İzmir (Güzelbahçe, Seferihisar, İnciraltı, Çeşme) and Aydın (Söke, Kuşadası, Davutlar) in Turkey. Mediterranean climate is dominant in these locations, and the groves included in the study had a mainly (65%) sandy-loam texture. The soil characteristics of the groves are shown in Table 1.

Table 1. Some physical and chemical properties of soils (0-30cm) in the studied groves

Çizelge 1. *Araştırma bahçelerine ait toprakların (0-30cm) bazı fiziksel ve kimyasal özellikleri*

Growing Season	Descriptive Statistics	pH	%					mg kg^{-1}								
			Salt	Lime	O.M.*	Texture**	N	P	K	Ca	Mg	Na	Fe	Cu	Mn	Zn
2014-2015	Mean	7.40	0.06	9.19	2.49	Sandy-Loam	0.13	13.4	340	4496	735	40	23	18	36	2.96
	Min	6.30	0.02	5.05	1.87		0.10	7.3	289	3578	493	23	5	1	13	0.70
	Max	7.59	0.08	12.45	4.10		0.27	22.4	388	5318	903	62	43	45	70	4.55
	SD	0.25	0.02	2.06	0.50		0.04	4.8	27	490	107	9	10	12	15	1.13
2015-2016	Mean	7.37	0.05	9.72	2.30		0.12	13.5	349	4528	734	42	23	18	34	3.00
	Min	6.65	0.04	6.23	1.72		0.09	7.3	281	3759	566	23	5	1	14	0.81
	Max	7.60	0.07	12.40	3.06		0.16	21.2	405	5465	893	70	40	40	64	4.50
	SD	0.18	0.01	1.65	0.34		0.02	4.0	31	488	94	12	10	11	13	1.09

***** Organic matter, ** In the groves, sandy loam by 65 %, loam by 17 % and sandy clay loam in the remaining were dominant.

The study material consisted of pruning residuals (wood + leaves) from Clementine mandarin trees aged 15 to 35 grafted on bitter orange (*Citrus aurantium*). The planting intervals (m x m) showed a variation as 5 x 5, 5 x 7 and 7 x 7, all groves were using drip irrigation systems. As main fertilization in the groves, according to calculations based on soil analysis results, 180-350 g N/tree, 40-60 g P/tree and 110-300 g K/tree were applied.

Pruning residuals were collected from 10 trees from each grove at the end of the production seasons (February) of 2014-2015 and 2015-2016 in two consecutive years on pruning days. The pruning residuals were measured and analyzed without separating the wood and leaf parts from each other. The samples whose fresh weights were recorded were washed in distilled water, dried at 65°C, ground with a laboratory-type mill with stainless steel knives (IKA- A 11 basic, Germany) and prepared for analysis (Kacar & İnal, 2008).

Microelement (Fe, Cu, Mn and Zn) concentrations were determined by an atomic absorption spectrophotometer (Spectra AA 220 Fast Sequential) in extracts obtained by wet digestion method with a mixture of concentrated $HCl:HNO_3$ (1:4, v/v) and were expressed on a dry weight basis.

The amounts of removed nutrients were determined from biomass and concentrations. Yield values were determined from the same trees from which the pruning residuals were collected in the harvest period (November).

The statistical analyses were carried out with the IBM SPSS 25.0 software. Pearson's correlation coefficient was used in the normally distributed variables, while Spearman's correlation coefficient was used in the non-normally distributed variables.

In this study, sample size was found by using "G. Power-3.1.9.2" program at 95% confidence level. As a result of the analysis, when ($\alpha = 0.05$) Cohen's (1988) standardized effect size was assumed as 0.60 (high level) with the expert opinion in addition to the lack of any related study, minimum sample size was found as 50 for the Two Independent Pearson correlation with the 0.80 theoretical power.

RESULTS and DISCUSSION

The ranges of the biomass values of the pruning residuals, Fe, Cu, Mn and Zn concentrations, removed amounts and fruit yield values are tabulated in Table 2.

Table 2. Analysis results of pruning residuals

Çizelge 2. *Budama atıklarının analiz sonucu*

Growing Season	Descriptive Statistics	Fruit Yield, kg/ tree	*Biomass, kg dry matter/tree*	Microelement content of pruning residuals, mg kg^{-1}				Uptake of microelements by pruning residue, g/tree			
				Fe	Cu	Mn	Zn	Fe	Cu	Mn	Zn
2014-2015	Mean	78	3.94	70.6	20.5	51.2	21.1	0.28	0.08	0.20	0.08
	Min	64	2.90	44.1	11.0	33.4	16.9	0.15	0.04	0.12	0.05
	Max	102	4.90	115.2	32.4	75.4	26.3	0.41	0.13	0.31	0.13
	SD	8	0.51	17.0	5.7	10.2	2.4	0.06	0.02	0.04	0.001
2015-2016	Mean	79	4.02	77.2	24.5	57.9	25.4	0.31	0.10	0.23	0.10
	Min	65	3.00	48.0	15.7	39.6	20.4	0.16	0.06	0.15	0.07
	Max	94	5.00	101.4	38.1	88.3	30.3	0.44	0.16	0.36	0.13
	SD	7	0.50	14.2	5.0	10.4	2.7	0.06	0.02	0.05	0.01

The mean pruning residual biomass value for both years was found to be 3.98 kg D.M./tree. This value was lower than the value of 14 kg/tree found by Velázquez-Martí et al. (2013) for Clementine and Satsuma mandarin. This may have been caused by the fact that the research material was not homogenous along with the possible differences in regional and cultural practices.

According to these findings the shares in the microelements in the biomass of the pruning residual could be listed as Fe > Mn > Cu = Zn for both years. 0.016 % (1st year) and 0.018 % (2nd year) of the biomass consisted of the removed microelements (Fe, Cu, Mn and Zn). It is thought that the remaining part in the biomass of the pruning residual consisted of other nutrients and organic components (Welker et al., 2015).

As seen from the correlation tables, there was no significant difference between the yield value and pruning amount. In the first year, there was a negative moderate correlation between the biomass amount and Fe concentration, while there were positive correlations between the biomass amount and removed Cu, Mn and Zn amounts (weak, moderate and moderate, respectively). There was a positive moderate correlation between the amount of removed Zn and the amounts of removed Cu-Mn and concentrations of Zn (Table 3).

Table 3. Correlation coefficients between biomass microelement concentration and uptake amounts of pruning residuals for growing season (2014-2015)

Çizelge 3. *Biomass miktarı ile mikroelement konsantrasyon ve uzaklaştırılan miktarlar arasındaki korelasyon katsayıları (2014-2015)*

		Concentration	Uptakes			
		Fe	Fe	Cu	Mn	Zn[a]
Biomass		-.332*		.281*	.449**	.639**
Concentration	Fe		.831**			
	Cu			.890**		
	Mn				.795**	
	Zn[a]					.626**
Uptake	Cu[a]					.313*
	Mn[a]					.422**

[a] Spearman's rho correlation coefficients

In the second year, there was a positive moderate relationship between the biomass amount and removed Fe, Cu, Zn and Mn (Table 4).

Table 4. Correlation coefficients between biomass, microelement concentration and uptake amounts of pruning residuals for growing season (2015-2016)

Çizelge 4. *Biomass miktarı ile mikroelement konsantrasyonu ve uzaklaştırılan miktarlar arasındaki korelasyon katsayıları (2015-2016)*

		Biomass	Uptake			Concentration		
			Fe	Mn	Zn	Mn	Zn	Cu
	Biomass		.414**	.434**				
Concentration	Fe		.774**			.329*		
	Cu					.330*		
	Mn			.751**				
Uptake	Fe			.397**				
	Cu[a]	.484**	.416**	.516**	.481**			.795**
	Zn[a]	.649**		.519**			.503**	

[a] Spearman's rho correlation coefficients

CONCLUSION

As a result of the study, the amounts of micronutrients (g/tree) removed with the pruning residuals were found to be Fe: 0.28; Cu: 0.09; Mn: 0.21 and Zn: 0.09 as averages of the two years. Considering that these amounts were removed from the trees with the pruning process in this study, there would be reductions in the total nutrient budget of the trees. This situation reveals the necessity for assessing pruning residuals in terms of plant nutrition and fertilization strategies, too, as opposed to studies conducted on the topic of bioenergy so far.

It is known that, as pruning residual is not a homogenous material, its content may regionally vary. Thus, for the purpose of optimizing fertilization studies, it is important to conduct regional studies with pruning residuals as preliminary studies.

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