COMPARISON OF YIELD, FRUIT QUALITY AND LEAF NUTRIENT CONTENT OF SOME PEAR CULTIVARS

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ABSTRACT

This research was conducted during 2009-2013 on six years old 'Akça', 'Coscia', 'Deveci' and 'Dr. Jules Guyot' trees budded on Pyrus communis rootstock at the Pome Fruit Research Station of the Faculty of Agriculture at Harran University (Sanliurfa, Turkey). The aim of this research was to determine the performance of four pear cultivars under high clay-calcareous soil and semi-arid conditions in terms of fruit yield, fruit weight, yield efficiency, fruit quality parameters, trunk growth and leaf mineral nutrient concentration of the trees. The average fruit weights of the cultivars were determined as 73.78 g (Akça) and 338.26 g (Deveci). Average total soluble solid content ranged between 14.64 % (for Akça) and 15.96 % (for Deveci), while the highest of titratable acidity was observed 0.33 % in Dr. Jules Guyot. Trunk cross-sectional area of four pear cultivars at the end of the 10th year was 103.3 cm2/tree (Coscia) - 151.9 cm2/tree (Akça). Coscia has taken the first row in respect of cumulative yield (129.3 kg/tree) and yield efficiency (1.11 kg/cm2) in ten cropping years. In pear leaves N, P, K, Fe, Zn, and B concentrations from 30 days after full bloom (DAFB)-90 DAFB towards significant decreases while; there have been increases in Ca, Mg and Mn concentrations. On the other hand, leaf N, K, Ca, Mg, Fe, Cu, and B concentrations of Akça, and leaf Zn concentration of Dr. Jules Guyot cultivars were determined to be at a lower level than other pear varieties.

Keywords: Pear, nutrient content, leaf nutrition, yield, cumulative yield, leaf mineral analysis, leaf analysis

BAZI ARMUT ÇEŞİTLERININ VERIM, MEYVE KALITESI VE YAPRAK BESIN İÇERIKLERININ KARŞILAŞTIRILMASI

ÖZET

Bu araştırma, Harran Üniversitesi Yumuşak Çekirdekli Meyveler Araştırma Bahçesi'nde yer alan armut çöğürü (Pyrus communis L.) üzerine aşılı 6 yaşlı 'Akça', 'Coscia', 'Deveci' ve 'Dr. Jules Guyot' armut çeşitlerine ait ağaçlar üzerinde 2009-2013 yılları arasında yürütülmüştür. Araştırmada, yüksek killi-kireçli toprak ve yarı kurak iklim koşullarında dört armut çeşidinin meyve verimi, meyve ağırlığı, verim etkisi, meyve kalite özelikleri, gövde gelişimi ve ağaçların yaprak besin maddesi içeriklerinin belirlenmesi amaçlanmıştır. Armut çeşitlerinin ortalama meyve ağırlıkları 73.78 g (Akça) ile 338.26 g (Deveci) arasında belirlenmiştir. Çeşitlerin suda çözünebilir kuru madde miktarı % 14.64 (Akça) ile % 15.96 (Deveci) arasında değişirken, en yüksek meyve asitliği Dr. Jules Guyot (% 0.33) çeşidinde saptanmıştır. Dört armut çeşidinin 10. yıldaki gövde enine kesit alanı 103.3 cm2/ağaç (Coscia) - 151.9 cm2/ağaç (Akça) arasında değişim göstermiştir. Toplam verim (129.3 kg/ağaç) ve gövde enine kesit alanına düşen verim (1.11 kg/cm2) bakımından en yüksek değer Coscia çeşidinden elde edilmiştir. Tam çiçeklenmeden 30 gün sonra alınan yaprak örneklerindeki N, P, K, Fe, Zn, Cu ve B konsantrasyonlarının, tam çiçeklenmeden 60 ve 90 günde alınan örneklere göre önemli oranlarda azalmasına karşılık; Ca, Mg ve Mn konsantrasyonlarında artışlar meydana gelmiştir. Öte yandan, Akça çeşidinin yaprak N, K, Ca, Mg, Fe, Cu ve B; Dr. Jules Guyot çeşidinin ise Zn elementi içeriğinin diğer çeşitlerden daha düşük olduğu belirlenmiştir.

Anahtar Kelimeler: Armut, besin elementi, yaprak besin içeriği, verim, kümülatif verim, yaprak analizi

Introduction

Pear (Pyrus communis L.), is one of the most important fruit species grown in the temperate climates across the world, and it belongs to the subfamily Pomoideae in the family Rosaceae. One of the gene centers of this fruit species, which is distributed in a wide area in the world from China to Manchuria, Japan, Northwest India, Afghanistan, Uzbekistan, Turkmenistan, Caucasus and Central Europe, is Anatolia. Indeed, it is reported that there are more than 600 pear varieties in Anatolia (Ozbek, 1978; Ozcagiran et al., 2004).

Today, the greatest world pear production (25 203 754 tonnes) is supplied by China, USA, Italy, Argentina, and Turkey countries, etc. (FAOSTAT, 2013). According to recent statistics, an area of 34 800 hectares in Turkey is under pear culture with an average annual production of about 461 826 tonnes (FAOSTAT, 2013).

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Pear trees do not root easily, so the pears are propagated by budding or grafting onto a rootstock. Rootstocks are propagated from seed or from cuttings (Marini, 2009). Pear varieties are produced through the budding and grafting techniques onto non-homozygous rootstocks. On the pear cultivation; pear seedlings, quince seedlings, clonal pear and clonal quince rootstocks are widely used. Domestic or wild pear seedling (Pyrus communis) shows very good compatibility with all pear varieties, quince rootstocks (Cydonia oblonga Mill.) shows compatibility only a part of pear varieties (Lombard and Westwood, 1987). In Europe; to get reduced vigor of the trees, put the trees being early yield and pear varieties grafted on quince rootstock to increase the fruit size, but quince rootstocks are quite sensitive lime-induced chlorosis in calcareous soils (Tagliavini and Rombolá, 2001). Conversely, more resistant to cold and lime-induced chlorosis, which is less sensitive to pear seedling rootstock was used as a rootstock, the scion varieties have shown strong growth (Lombard and Westwood, 1987; Günen and Mısırlı, 2004).

Rootstock effects tree size and vigor (Marangoni and Mazzanti, 1999), tree nutrition (Fallahi and Larsen, 1984), precocity, productivity and yield efficiency (Sugar et al., 1999), fruit size (Jacob, 1998), fruit quality (Garcin et al., 1994), compatibility (Ermel et al., 1997), cold hardiness (Palonen and Buszard, 1997) and pear decline and fire blight sensitivity (Lezec et al., 1997; Lemoine et al., 1998).

Pear rootstocks are produced through seeds, cutting or in vitro culture (Wertheim, 2002). When propagated by seeds of various pear species, plants are not genetically uniform. In Turkey, wild pear seedlings are still used as rootstocks by 97% in pear cultivation (Ercisli et al., 2006).

Leaf analysis is widely used in many other fruit species, as in pear (Stassen and Roth, 2005) and apple (Nachtigall and Dechen, 2006) trees, to determine nutritional status of the trees and to perform optimum fertilizer applications according to specific stages of development by detecting early nutritional needs of the trees

The aim of the present research was to study the performance of four pear cultivars grafted on pear seedling rootstocks in terms of fruit yield, fruit weight, production efficiency, fruit quality parameters, trunk growth and leaf mineral status of the trees.

Materials And Methods

Site description

The experiment was carried out at the Harran University Stone and Pome Fruit Research Station in Sanliurfa, Turkey (37^o 10'N; 38^o 59'E; alt. 536 m) during 2009-2013. Sanliurfa province has a semi-arid climate features with cold and wet during the winter and very hot and dry in the summer seasons. During the experiment, the air temperatures were in average 31.4 ^{o}C in summer and 7.2 ^{o}C in winter, while annual precipitation ranged between 355-447 mm, mainly concentrated between the months of November and April. The average relative humidity is at the level of 52.2%. Relative humidity is the highest (66%) ratio in January and in July is the lowest (36%) level. The seasonal temperature and rainfall patterns of the area of the experimental orchard over a period of 10 years are presented in Figure 1.

The orchard was established in a calcareous (21.5 % total carbonates and 10.7 % active lime), alkaline and clay-loam textured soil. **The physical and chemical characteristics of the soil were clay 58.5 %, silt 18.5 % and sand 21 %, with low level of organic matter (0.96 %), pH 7.92 (in 1M KCl), and optimum concentrations of available P (80 mg kg^{-1}), K (160 mg kg^{-1}), Mg (50 mg kg^{-1}), and** Fe (DTPA-extractable Fe:1.45 mg kg^{-1}) **in the top soil layer (0-40 cm).**

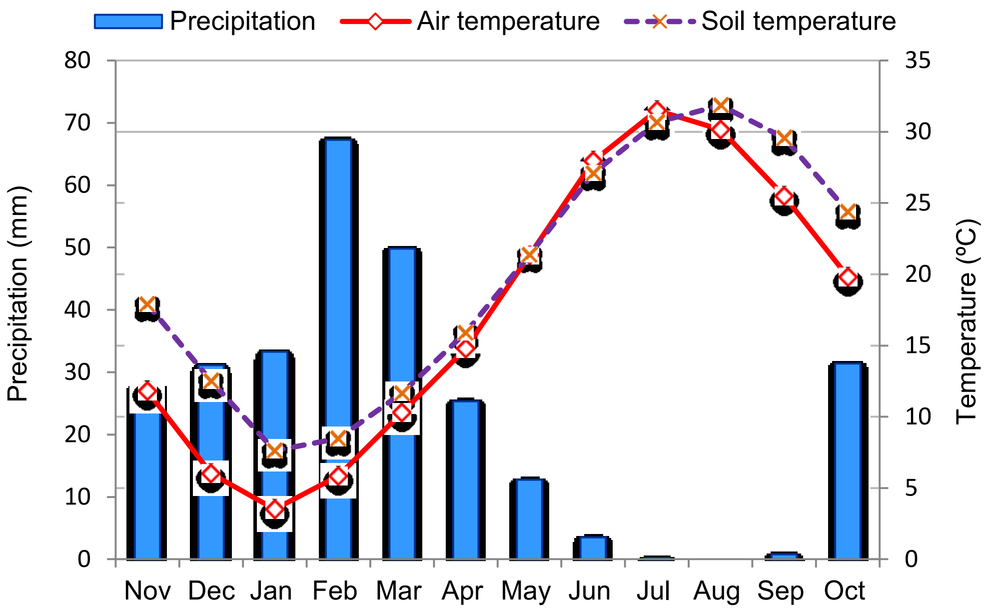

Figure 1: Seasonal Temperature and Rainfall Patterns of the Experimental Orchard

Plant material and experimental design

Akça', 'Coscia', 'Deveci' and 'Dr. Jules Guyot' pear cultivars were grafted on local seedlings (Pyrus communis L.) rootstocks and planted in February 2004 with a 1-year-old scions. The experiment was laid out in a randomized complete-block design with three blocks, each consisting of three trees. Trees on pear seedling rootstocks (hereafter referred to as "seedling rootstocks") were planted at 5 x 5 m (400 trees ha^{-1}) distance and trained in a modified center leader system.

Cultural treatments

The orchard was irrigated with a computerized drip irrigation system twice a week during May to October each season, according to regional recommendations using class-A pan. Each treatment received the same total amount of water each season. All treated trees were similarly fertigated with essential minerals in accordance with soil mineral nutrient analyses. No foliar application of nutrients was done to these trees. Thinning of flowers or fruitless was not carried out during the experiment. Weed, disease, and insect control were managed using the practices that were commonly used for commercial production, and all the treatments were under the identical management. A copper spray was put on at bud break to protect the trees from the firelight.

Data collection on growth, yield, fruit characteristics

Trunk diameter 20 cm above the graft union was measured with digital callipers in December each year. The average of two readings (north-south and east- west) was converted to trunk cross-sectional area (TCSA) for analysis. Annual yields, yield efficiency (yield/TCSA), cumulative yield and cumulative yield efficiency (cumulative yield/TCSA in 2013) were calculated. Cumulative fruit yield efficiency (CYE) was expressed as kg cm^{-2} (Stern and Doron, 2009).

Fruit yield was determined each year by harvesting five central trees from each plot in optimum harvest period. Fruit firmness, soluble solids concentration (SSC), and titratable acidity (TA) of fruits at harvest were determined using a randomly selected sample of 20 fruits for each plot. Fruit yield per tree and average fruit weight were measured at fruit harvest in September. Flesh firmness was measured by an Effegi Penetrometer (8 mm tip) with an 8 mm diameter tip and expressed in terms of lb force. The SSC was determined with an Atago Palette Series Model PR-101a digital refractometer (Atago Co. Ltd., Tokyo, Japan) at 22 °C in the juice squeezed from the fruit homogenate (expressed as %). TA was determined by titrating the fruit homogenate with 0.1 N NaOH to pH 8.1. The TA results represented malic acid content expressed as %.

Data collection on leaf mineral element's content

In each year of the study, five trees of each cultivar were identified. Including 10 pieces of each kind of tree, for a total of 50 leaf samples were taken at each analysis period. Samples of 50 leaflets from the midsection of current year shoots were collected at 30, 60, and 90 DAFB in 2012 and 2013. The leaves were washed with a mild detergent, then rinsed with distilled water and dried in a forced air drying oven at 70°C to constant weight. The leaves were ground to pass a 40 mesh screen. Nitrogen (N) concentration samples was determined according to Kjeldahl method in which 0.5 g sample digested in concentrated H_2SO_4 and distilled with NaOH (40%). The ammonium N was fixed in H_3BO_3 (2%) and titrated with 0.1N H_2SO_4. In order to determine phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) concentrations, 1 g of samples were dry ashed at 550 ^{o}C for 5 h, and the ash was dissolved in 4 mL 3N HCl and filled up with pure water. Phosphorus contents of the samples were determined by vanadate-molybdate colorimetric method. Potassium, Ca, Mg, Fe, Zn, Cu and Mn concentrations were determined using atomic absorption spectrophotometer (Kacar and Inal, 2008). Each determination was replicated three times. The results were expressed on a dry matter basis: % for macro and mg kg^{-1} for microelements.

Statistical analysis

Analyses of variance were performed on all the data collected. Percentage data were subjected to arcsine transformation before analysis, to provide a normal distribution. Differences between the means were ascertained by Duncan's multiple range tests, using the JMP 8.0 software package. The mean values for the combinations labelled with the same letters do not significantly differ at the significance level α=0.05.

Results

The annual yields, cumulative yields and the cumulative yield efficiency values of early (Akça), mid-season (Coscia and Dr. Jules Guyot) and late (Deveci) 4 pear varieties, which were grafted on the pear seedling, between the years 2009-2013 are shown in Table 1. Significant differences were observed between all the varieties in terms of the annual yields, cumulative yields, and the cumulative yield efficiency values. While the highest average yield per tree in terms of yield values among the pear varieties in the 6th year was obtained from Coscia and Akça varieties, the lowest yield value for the same year was obtained from Dr. Jules Guyot variety. In the subsequent years, the highest annual yield per tree was obtained from Coscia variety (Table 1). According to the total yield values of pear varieties between 2009-2013, it was determined that the highest cumulative yield value was obtained from Coscia with 129.3 kg $tree^{-1}$ and the lowest cumulative yield value was obtained from Dr. Jules Guyot variety with 93.6 kg $tree^{-1}$. The highest yield efficiency (1.27 kg cm^{-2}) was recorded on Coscia trees, whereas, the lowest (0.68 kg cm^{-2}) on Akça trees (Table 1).

The results obtained as a result of the pomological analyses performed on the fruits of the pear varieties are shown in Table 2. The differences between the varieties in term of all pomological characteristics investigated were found to be statistically significant. In the pear varieties, we used in the study, fruit diameter values between 52.29 mm (Akça) and 83.83 mm (Deveci), and fruit size values between 69.76 mm (Akça) and 106.31 mm (Dr. Jules Guyot) were obtained. In terms of fruit weight among the varieties, the highest value was obtained from Deveci (338.26 g) and the lowest value was obtained from Akça (73.78 g).

Table 1: Annual Yield, Cumulative Yield, Trunk Cross-Sectional Area (TCSA) and Cumulative Yield Efficiency (kg cm^{-2}) of Some Pear Cultivars Grafted on Pyrus communis Seedling Rootstock

Cultivars	Annual yield (kg $tree^{-1}$)					Cumulative yield (2009-2013) (kg $tree^{-1}$)	Cumulative yield efficiency (kg cm^{-2})^{y}	Cumulative yield (ton ha^{-1}) (2009-2013)
	2009	2010	2011	2012	2013			
Akça	11.4 a^{z}	15.4 b	23.3 c	24.6 b	27.6 b	101.9 bc	0.68 c	40.8 bc
Coscia	13.2 a	20.2 a	31.0 a	31.3 a	33.5 a	129.3 a	1.27 a	51.7 a
Deveci	9.9 ab	16.5 b	22.7 c	27.4 b	28.5 ab	104.9 b	1.02 b	42.0 b
Dr.J. Guyot	7.4 b	14.9 b	26.8 b	20.7 c	23.7 b	93.6 c	0.88 bc	37.4 c
Significance	*	*	**	***	*	***	***	***

^{z}Mean separation within columns by Duncan's multiple range test at P $\leq$0.05.

^{y} kg cm^{-2} final TCSA

*,** and ***Significant at P $\leq$0.05, 0.1 or 0.01, respectively.

Among the pear varieties used in the study, the highest fruit firmness was determined in Deveci (21.71 lb cm^{-2}) and the lowest fruit firmness in Akça (9.1 lb cm^{-2}) variety (Table 2). The variety with the highest amount of water soluble solid content (TSS) was Deveci with a rate of 15.96% and it was followed by Coscia with a ratio of 15.04%. The lowest TSS, on the other hand, was observed in Akça variety with a ratio of 14.64%. In the pear varieties used in the study, the lowest pH value was determined in Deveci with 3.64 and the highest pH value was determined in Dr. Jules Guyot with 4.53. In the pear varieties, the lowest titratable acidity (in malic acid) was determined in Deveci with 0.25% and Akça with 0.27%, the highest value was obtained from Dr. Jules Guyot with 0.33% (Table 2).

Table 2: Fruit Quality Characteristics of Four Pear Cultivars on Pyrus communis Seedling Rootstock (Values are the mean of 2012 and 2013)

Cultivars	Fruit diameter (mm)	Fruit length (mm)	Fruit weight (g)	Fruit firmness (lb)	SSC (%)	pH	TA (%)
Akça	52.29 c[z]	69.76 c	73.78 c	9.1 b	14.64 c	3.83 ab	0.27 bc
Coscia	66.62 b	87.51 b	175.98 b	11.33 b	15.04 b	3.71 b	0.29 b
Deveci	83.83 a	85.55 bc	338.26 a	21.71 a	15.96 a	3.64 b	0.25 c
Dr.J. Guyot	77.76 a	106.31 a	319.87 a	15.60 ab	14.88 c	4.53 a	0.33 a
Significance	**	**	*	**	*	*	***

[z] Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

*,** and ***Significant at $P \leq 0.05$, 0.1 or 0.01, respectively.

Figure 2 demonstrates the concentrations of nutrition elements in leaf samples taken from the pear trees used in the study 30, 60, and 90 days after full bloom. The statistical analysis was applied only to the results of the nutrient analysis conducted on the leaves taken 90 days after full bloom. In all the leaves of the pear varieties used in this study, statistically significant differences were found in the concentrations of nutritional elements that were analyzed. According to the results of the leaf analyses conducted throughout the vegetative cycle of the pear trees, a significant decrease occurred in the N (19%), P (19%), K (12%), Fe (28%), Zn (31%), Cu (16%) and B (40%) concentrations 90 days after full bloom compared to baseline (30 DAFB). In contrast, an increase occurred in the Mn (12%), Ca (15%) and Mg (15%) concentrations in the pear leaves. According to the results of the nutrient analysis performed on the leaves taken 90 days after full bloom, it was determined that the leaves of Akça had a higher concentration of Mn; Coscia had a higher concentration of Fe; Deveci had a higher concentration of N, P, Zn and Dr. Jules Guyot had a higher concentration of Cu and B. On the other hand, it was determined that the leaf nutritional concentrations of Akça (N, K, Ca, Mg, Fe, Cu, and B) and Dr. Jules Guyot (Zn) had lower than other varieties in terms of certain elements.

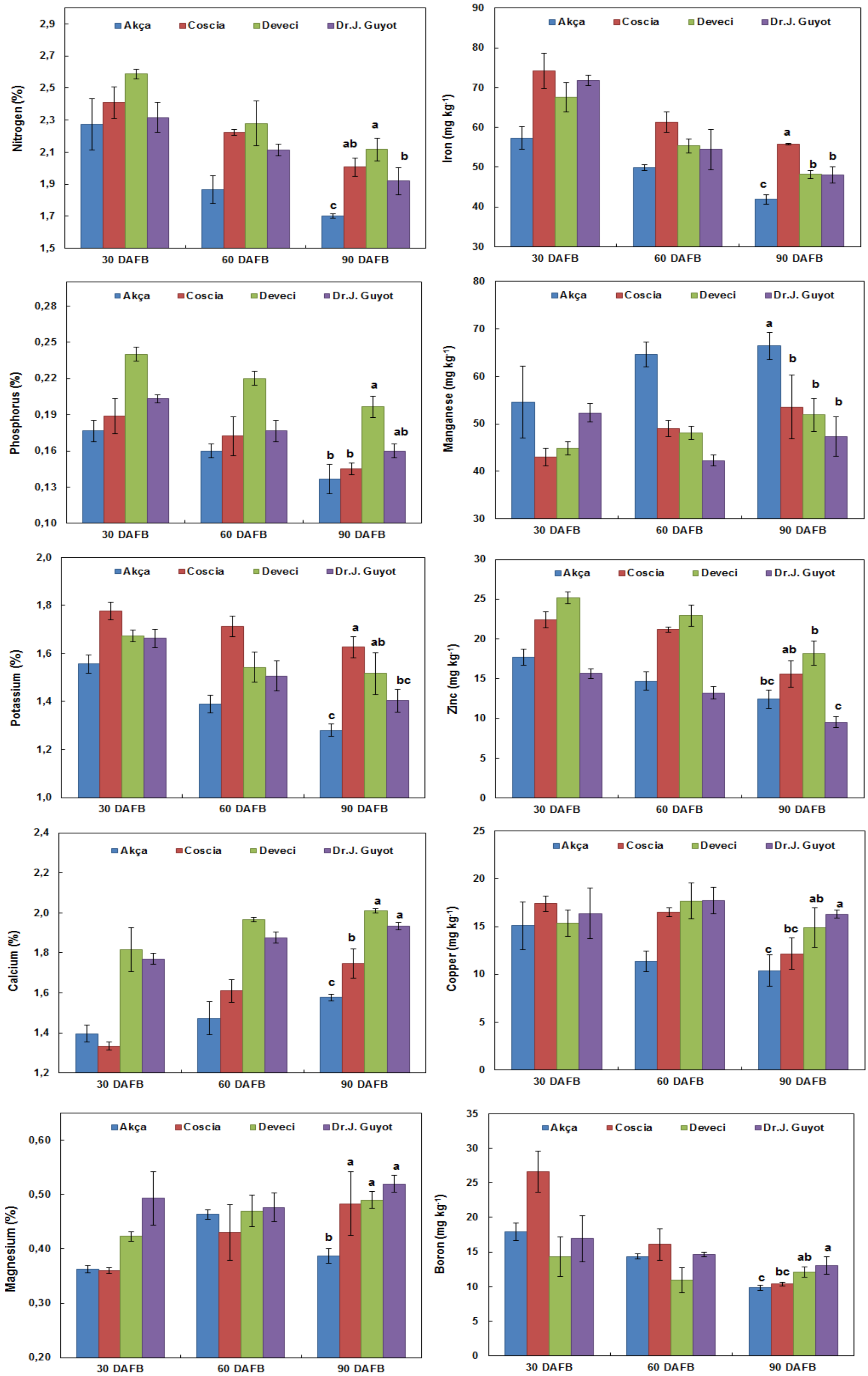

Figure 2: Seasonal nutrient element accumulation (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, and B concentration) in leaves of pear tree cultivars (‘Akça’, ‘Coscia’, ‘Deveci’ and ‘Dr. Jules Guyot’) at the 30, 60 and 90 days after full bloom (average of two years)

Discussion

As the fruit yields of the varieties grafted onto different rootstocks vary from year to year, cumulative yield values are used to compare the efficiency of the varieties. In many studies conducted in various countries in the world, the effects of item types of seedlings and clonal rootstocks on fruit yield and quality were investigated. In this study, 4 different pear varieties grafted on Pyrus communis seedling were compared.

In our study, the genetic structure of each wild pear seedling we used as a rootstock for pear varieties is naturally different. On the other hand, the pear seedlings used in another country will not be similar to the seedlings we use. Therefore, in a study conducted in two different countries (even in close locations), even if the same pear variety is grafted onto rootstocks, it is known that the efficiency of trees in two places and tree growth characteristics of the trees will be different. In a joint research conducted in Lithuania, Latvia and Estonia, where yield and fruit quality characteristics of 'Suvenirs' pear variety grafted on 7 different rootstocks including clonal quince, clonal pear, and pear seedlings were compared, quite different results were obtained in all three countries (Lepsis et al., 2013). In this study conducted by Lepsis et al. (2013), it was determined that while one country 'Suvenirs' tree grafted on one of the clonal quince seedlings was more efficient, in another country the efficiency of the trees grafted on pear seedlings was higher; and similarly while the TCSA development of trees grafted on seedlings was higher in one country, the development of trees grafted on clonal rootstocks was higher in another country.

While a yield between 47-50 kg tree^{-1} was obtained from 10-12 years old Coscia pear tree planted with a distance of 4.5 x 2.5 m and grafted onto 'Quince C' rootstock in Israel (Stern and Flaishman, 2003), which has a semi-arid climate, in this study we conducted, a yield of 28.5 kg tree^{-1} was obtained from 10 years old Coscia pear tree. Therefore, many factors have an impact on yield. It would not be correct to compare the results of studies conducted in different regions of a country or in different countries due to the reasons we mentioned above. In this section of the article, the results obtained in Şanlıurfa (Turkey), which has a semi-arid climate and may not have a very good ecology for pear cultivation, will be discussed.

There are various studies conducted by various researchers (Ercan, 1996; Akçay et al., 2007; Akçay et al., 2009; Canlı et al., 2009; Öztürk et al., 2009; Erdem and Öztürk; 2012) in Turkey's more appropriate ecologies for pear (Aegean and Marmara region) where one, two or all of the varieties that we used in this study were used. In addition to these studies, there is also a study (Kaplan, 1997) which was conducted on Akça and Dr. Jules Guvot varieties in the Diyarbakır province, which is closer to the Şanlıurfa province and has relatively similar climatic characteristics (semi-arid). In the comparisons relating to fruit pomology of the pear varieties, it will be benefitted from the results of these studies.

The fruit diameter (mm), fruit length (mm), fruit weight (g) values, obtained in the studies conducted on pear in the regions of Turkey with temperate (Aegean and Marmara) and semi-arid climatic conditions (Southeastern Anatolia Region), were determined as follows for Akça; 42.61 - 49.07 mm, 56.30 - 61.70 mm and 54.0 - 61.0 g respectively, for Coscia; 54.30 - 68.70 mm, 71.40 - 91.63 mm and 128.2 - 182.19 mm respectively, for Dr. Jules Guyot; 72.86 - 75.40 mm, 80.98 - 88.31 mm and 244.3 - 323.5 g respectively and for Deveci; 76.51 - 85.11 mm, 86.66 - 90.75 mm and 241.0 - 392.30 g respectively. Canlı et al. (2009) determined 6 years old 'Deveci' pear variety grafted onto Quince A rootstock in Egirdir the fruit weight (g), fruit diameter (mm) and fruit length (mm) values as 300.46 g, 82.04 mm and 86.66 mm respectively. The same researchers found the fruit firmness, TSS, pH and titratable acidity content of the 'Deveci' pear variety as 21.87 lb, 14.05%, 4.39 and 0.13% respectively. In the study, we conducted, on the other hand, the fruit weight, fruit diameter and fruit length values of Deveci were determined as 338.26 g, 83.83 mm and 85.55 mm respectively. In our study, the fruit firmness, TSS, pH and titratable acidity content of the Deveci pear were determined as 21.71 lb, 15.96%, 3.64 and 0.25% respectively. As it is seen, very close values were obtained from the Deveci pear variety grown in Sanliurfa, which shows semi-arid climatic conditions, when compared to the fruit quality in Egirdir, which has temperate climatic conditions.

According to the average values of fruit firmness, TSS, pH and titratable acidity content obtained by the researchers mentioned above for each pear variety, it was reported that the variety of the highest fruit firmness and soluble solid content (Brix %) value is Deveci (20.9 lb cm^{-2} and 14.2 % respectively), and the variety of the lowest levels is Coscia (8.5 lb cm^{-2} and 10.0 %). In the research reports conducted before this study, no data were found regarding pH and acidity for the Coscia variety and regarding pH for the Dr. Jules Guyot variety. According to the research results of the researches mentioned above, the highest fruit juice pH value was obtained from Akça with 4.68 and the lowest pH value was obtained from Deveci with 4.34; while the highest titratable acidity was obtained from Dr. Jules Guyot with 0.30% and the lowest titratable acidity was obtained from Deveci with 0.22%.

In the variance analysis, significant differences were observed between the macro and micro nutrient element concentrations in the leaves of all pear varieties. In the leaves of all pear cultivars used in the study (90 DAFB); the average N content was 1.94 %, P content was 0.16 %, K content was 1.46 %, Ca content was 1.81 %, Mg content was 0.47 %, Fe content was 48 ppm, Mn content was 55 ppm, Zn content was 14 ppm, Cu content was 13 ppm, and the B content was 11.4 ppm. Accordingly, it is understood that the pear trees had deficiency in terms of N, at adequate levels in terms P, K, Ca, Mn, and Cu, were rich in terms of Mg, at low levels in term of Zn and at inadequate levels in terms of the B and Fe content (See Appendix 1).

In this study, pear seedlings were used. The differences between scion cultivars as well as the genotypic characteristics of rootstocks that each tree is grafted onto should not be forgotten. Rootstock can favorably influence tree yield, bearing habit, fruit quality, and leaf mineral nutrient concentration and these effects have been reported for commercially important pear cultivars. Sotiropoulos (2006) determined that according to the average leaf nutrient concentrations of the William's BC variety grafted onto 7 different rootstocks in 4-8 years, the trees grafted onto the P. communis rootstock had higher values in terms of N, P, K, Ca, Mg and B. In South Africa, in a study where 6 different rootstocks and leaf nutrient concentrations of the 'Forelle' pear variety grafted on these rootstocks were investigated, it was determined that the trees grafted onto pear rootstocks have higher N and P levels and lower Mg levels compared to quince rootstocks (North and Cook, 2008). In the same study, the leaf nutrient concentrations of the rootstocks were also determined. As a result of this study conducted for two years, it was revealed that pear rootstocks had higher levels of K, Ca, Fe, Mn, Zn, Cu and B, and lower levels of Mg concentrations compared to quince rootstocks. This study has proven that rootstocks have a very important effect on leaf nutrient concentrations of scion cultivars.

Several researchers have shown that scion leaves of trees on more vigorous rootstocks have higher mineral (K, Mg) content than those on size-controlling rootstocks (Amiri et al., 2008). Similarly, many researchers reported that the pear varieties grafted onto the Pyrus communis rootstock had higher leaf nutrient concentrations compared to the varieties grafted on clonal pear or clonal quince rootstocks. One of the possible causes of mineral deficiency seen in the trees grafted onto some dwarfing rootstocks arises from these rootstocks' getting low amounts of minerals from the soil (Amiri et al., 2008).

Among pear varieties, it was determined that especially the Akça variety has lower concentrations than other varieties in terms of some of the leaf nutrient content analyzed. Fruits of the Akça variety, which ripens earlier than other varieties, ripen in mid-July. As it is a variety that ripens its fruits earlier, we can say that the withdrawal of N and other nutrient elements from the tree by the fruits may be one of the main causes for the low levels of leaf nutrient content in the Akça variety. The N deficiency began to be seen in the leaves of Akça during 90 DAFB period (See Figure 2 and Appendix 1). The leaf N concentrations of the other varieties, on the other hand, remained at optimum or low levels at each 3 periods. The concentration of some specific nutrients in leaves varies depending on the differences of withdrawal rates of rootstocks from the soil (Fallahi et al., 2001). As seen in Figure 2, it was determined that the N, P and K concentrations in the pear leaves demonstrated a significant decrease from 30 DAFB to 90 DAFB. Leaf N, P and K concentrations decreased throughout the growing season in deciduous trees (Shear and Faust, 1980; Ryugo, 1988; Sanz et al., 1994; Fallahi et al., 2001; Cheng and Raba; 2009), citrus (Embleton et al., 1973), prunes (Weinbaum et al., 1994), figs (Brown, 1994), avocado (Embleton and Jones, 1966) and olive (Fernandez-Escobar et al., 1999). The seasonal changes in leaf N, P and K concentrations are generally in agreement with those reported for other fruit tree species.

Young leaf tissues of a tree usually present lower water content and higher N, P and K concentrations. On the other hand, old leaves are rich, mainly in Ca, Mn, Fe, and B (Mengel and Kirkby, 2001). Therefore, due to the development of leaves, shoots, branches and fruit development during vegetative cycle and the redistribution of nutrients between the parts of a plant, mainly N, P and K concentrations decreases in pear leaves. In a study conducted in Mid Ebro Basin, one of the most important fruit production regions in Spain, to determine leaf nutrient concentrations 100 pear trees (cultivar was not taken into account), it was reported that the N, P and K levels of the leaves continuously decreased until after 120 days after full bloom (Sanz et al., 1994). From full bloom, fruits on a tree enter the cellular division period first and then the period of cellular expansion. Especially after full bloom, due to rapid growth, metabolism and for transportation of carbohydrates throughout the vegetative cycle, P and K are excessively demanding and this demand reduces the P and K concentrations in the leaves (Hilmelrich and Walker, 1982; Marscher, 1996). Potassium is most needed during the fruit enlargement and during the fruit ripening period (Fallahi et al., 2001).

As opposed to the significant decreases in the N, P, K, Fe, Zn, Cu and B concentrations in the pear leaves during the season from 30 DAFB to 90 DAFB, increases occurred in the Ca, Mg and Mn concentrations. While the leaf Ca concentrations were at normal levels at each 3 sampling periods in all the varieties, the Mg concentrations were found to be at high levels. Sanz et al. (1994) reported a slight increase in the Ca and Mg concentrations in the leaves of the pear trees between full bloom and 120 DAFB. In other research, Nactigall and Dechen (2006) reported that in the apple leaves (Fuji, Gala and Golden Delicious), the Ca and Mg concentrations demonstrated a sharp increase during the first 5 weeks after full bloom, after slowing for several weeks, they entered a steady increase period. In the 6 years old 'Gala' variety growing in sand culture and grafted onto the M26 rootstock, it was reported that the concentrations of most nutrients in the leaves reduced as the growing season progressed and the Ca, Mg and Mn concentrations showed an increase (Cheng and Raba, 2009).

The direction of early seasonal changes in leaf Mg and Mn concentrations is in agreement with the results reported on pear (Sanz et al., 1994), apple (Fallahi et al., 2001; Nactigall and Dechen, 2006; Thomidis et al., 2007; Cheng and Raba; 2009; Kucukyumuk and Erdal, 2011), Pistachio (Picchioni et al., 1997), fig (Brown, 1994) and olive (Fernandez-Escobar et al., 1999).

Fe deficiency began to be seen in the leaves of the Akça variety in the 30 DAFB period. In the following period (60 DAFB), the Fe concentration was at a low level only in the leaves of the Coscia variety, while it was detected that Fe was inadequate in the other 3 pear varieties. During the 90 DAFB period, where some researchers indicated as the most suitable leaf sampling period for apple and pear (Sanz et al., 1994; Cheng and Raba, 2009), on the other hand, the Fe concentrations were observed to be at inadequate levels in the leaves of all pear varieties. Similarly, it was observed that the B concentration in the leaves of the Deveci variety was inadequate (deficient) 30 DAFB and this rate continued 60 and 90 DAFB (Figure 2). In contrast, it was determined that while the B concentration was at low level only in the Coscia variety 60 DAFB, the B concentration was deficient in the leaves of all pear varieties 90 DAFB.

Among the pear varieties, it was determined that the Zn level was inadequate (deficient) only in the leaves of Dr. Jules Guyot in the 90 DAFB; the Zn concentration was at a low or optimum level in the leaf samples taken both in and before this period. Little information is available concerning Zn nutrition of pears. In our study, the change of this element in the early period showed itself in the form of a rapid decrease (Figure 2). However, seasonal trend is typical for this element of deciduous tree species (Ryugo, 1988; Sanz et al., 1994; Fallahi et al., 2001; Nactigall and Dechen, 2006; Cheng and Raba; 2009; Kucukyumuk and Erdal, 2011).

As copper (Cu) is an element included in the composition of fungicides used against many fungal diseases, copper deficiency has not been reported in pear cultivation so far. In our study, while the Cu concentration we determined 30 DAFB was at a higher level, it decreased slowly in later periods. As it is known, in pear cultivation, copper fungicides are used for different diseases, both in the resting period and during the periods after fructification. Fungicide use is more between full bloom and 30 DAFB than 60 and 90 DAFB. In this study, insecticide was applied only 2 times against fire blight (Erwinia amylovora) and scab disease (Venturia pyrina) in the pear. The result, we obtained in our study is consistent with the studies (Sanz et al., 1994; Fallahi et al., 2001; Nactigall and Dechen, 2006; Cheng and Raba; 2009; Kucukyumuk and Erdal, 2011) where the seasonal change of Cu in different deciduous fruit species was determined.

It is known that pear trees have a high B requirement. The B deficiency causes the death of flowers, shedding of dead flowers and as a result a decrease in fructification and yield in trees (Wojcik and Wojcik, 2003). The boron concentration in pear leaves (except Coscia 30 DAFB) was determined to be generally at low or inadequate levels. Any fertilizer application containing the B element was not performed on the trees used in the study through leaves or soil throughout the period of the study. During the period of cell division and cell expansion that begins in the fruits after pollination, B is carried from leaves to fruits. In the studies conducted on apples (Nactigall and Dechen, 2006) and pears (Wojcik and Wojcik, 2003), it was reported that the boron concentration in the fruits increased gradually during the period of fruit growth and B is continuously transported to the fruit via the phloem (Thomidis et al., 2007). The foliar B applications of B-deficient pear trees before full bloom or in the fall were more effective in increasing fruit yield than supplying with B to soil (Wojcik and Wojcik, 2003).

The Fe chlorosis is one of the most important abiotic stresses occurring in fruit trees grown in calcareous or alkaline soils. The most important effect of the Fe chlorosis on high plants is that it decreases photosynthetic pigment concentrations and especially chlorophyll amounts in leaves (Alvarez-Fernandez et al., 2004). It was reported that in soils with high lime, the varieties grafted onto the P. communis rootstock is more resistant to lime-induced Fe chlorosis than other rootstocks (Tagliavini and Rombolá, 2001; Iglesias et al., 2004; Iglesias and Asin, 2005; Alcantara et al., 2012). Standard values have not been established for Fe in the pear. A researcher states that a Fe concentration less than 60 ppm in leaves is inadequate, while another researcher states 25 ppm is inadequate.

As occurs in other species, leaf analysis is not useful for diagnosing Fe deficiency because the inconsistency of leaf, Fe levels in separating chlorotic from non-chlorotic leaves (Korcak, 1987). Visual examination of trees is the best method for diagnosing Fe deficiency, a nutritional problem that negatively affects pear growing in alkaline, calcareous soils (Tagliavini et al., 2000).

APPENDIX 1

Leaf nutrient standard for pears*

Nutrient Element	Deficiency	Low	Optimum	High	Excess
N (%)	< 1.8	1.8 - 2.2	2.3 - 2.7	2.8 – 3.5	> 3.5
P (%)	< 0.10	0.10 – 0.14	0.15 – 0.20	0.21 – 0.30	> 0.30
K (%)	< 0.8	0.8 – 1.0	1.1 – 1.5	1.6 – 2.0	> 2.0
Ca (%)	< 0.7	0.7 – 1.0	1.1 – 2.0	2.1 – 2.5	> 2.5
Mg (%)	< 0.18	0.18 – 0.24	0.25 – 0.35	0.36- 0.50	> 0.50
Fe (mg kg^{-1})		< 60	60 - 200	> 200	
Mn (mg kg^{-1})	< 20	20 - 24	25 - 100	101 - 200	> 200
Zn (mg kg^{-1})	< 10	10 - 15	16 - 50	> 50	
Cu (mg kg^{-1})	< 4	4 - 5	6 - 20	21 - 100	
B (mg kg^{-1})	< 15	15 - 19	20 - 60	61- 200	>200

* It was prepared utilizing from Leece (1976), Jones et al. (1991) and Bright (2005).

References

Akçay, M.E., Büyükyılmaz, M., ve Burak, M. (2007). Bazı armut çeşitlerinin quince - A klon anacı üzerindeki gelişme, verim ve yaşam ilişkileri, V. Ulusal Bahçe Bitkileri Kong., Cilt:1, Erzurum, pp. 417-421.

Alcantara, E., Montilla, I., Ramirez, P., Garcia-Molina, P., ve Romera, F.J. (2012). Evaluation of quince clones for tolerance to iron chlorosis on calcareous soil under field conditions. Sci. Hortic., 138, 50-54.

Alvarez-Fernandez, A., Garcia-Lavina, A.P., Fidalgo, C., Abadia, J., ve Abadia, A. (2004). Foliar fertilization to control iron chlorosis in pear (Pyrus communis L.) trees. Plant and Soil, 263, 5-15.

Amiri M.E., Fallahi, E., ve Golchin, A. (2008). Influence of foliar and ground fertilization on yield, fruit quality, and soil, leaf, and fruit mineral nutrients in apple. Journal of Plant Nutrition, 31, 365-370.

Bright, J. (2005). Apple and pear nutrition. NWS Department of Primary Industries. Primefact Number: 85, First Edition 1 October 2005. Available at: http://ucanr.org/sites/nm/files/76700.pdf (Accessed: 20 April 2016).

Brown, P. H. (1994). Seasonal variations in fig (Ficus carica L.) leaf nutrient concentrations. HortSci., 29, 871-873.

Canlı, F.A., Pektaş, M., ve Kelen, M. (2009). Effects of pre-harvest plant growth regulator sprays on fruit quality of ‘Deveci’ pear (Pyrus communis L.). Journal of Applied Biological Sciences, 3, 81-84.

Cheng, L., ve Raba, R. (2009). Accumulation of macro - and micronutrients and nitrogen demand-supply relationship of ‘Gala’/‘Malling 26’ apple trees grown in sand culture. J. Amer. Soc. Hort. Sci., 134, 3-13.

Embleton, T.W., ve Jones, W.W. (1966). Avocado and Mango. In: Childers, N. F. (Ed.). Fruit Nutrition, Horticultural Publications, Rutgers University, NJ: pp. 51-76.

Ercan, N. (1996). The selection of native and foreign pear cultivars suitable for the Aegean region of Turkey. Anadolu, 6, 58-74.

Ercişli, S., Eşitken, A., Orhan, E., ve Özdemir, O. (2006). Rootstocks used for temperate fruit trees in Turkey: An overview. Sodininkyste ir Darzininkyste, 25, 27-33.

Erdem, H., ve Öztürk, H. (2012). Effect of foliar applied zinc on yield, mineral element contents and biochemical properties of pear varieties grafted to BA 29 rootstock. Süleyman Demirel Üniversitesi, Ziraat Fakültesi Dergisi, 7, 93-106.

Ermel, F.F., Poessel, J. L., Faurobert, M., ve Catesson, A.M. (1997). Early scion/stock junction in compatible and incompatible pear/pear and pear/quince grafts: A histocytological study. Annals of Botany, 79, 505-515.

Fallahi, E., ve Larsen, F. (1984). Rootstock influence on leaf and fruit mineral status of ‘Bartlett’ and ‘D’Anjou’ pear. Scientia Horticulturae, 23, 41-49.

Fallahi, E., Chun, I.J., Neilsen, G.H., ve Michael, W.C. (2001). Effects of three rootstocks on photosynthesis, leaf mineral nutrition, and vegetative growth of “BC-2 Fuji” apple trees. Journal of Plant Nutrition, 24, 827-834.

FAOSTAT (2013). Available at: http://faostat3.fao.org/download/Q/QC/E (Accessed: 17 May 2016).

Fernandez-Escobar, R., Moreno , R., ve Garcia-Creus, M. (1999). Seasonal changes of mineral nutrients in olive leaves during the alternate-bearing cycle. Scientia Horticulturae, 82, 25-45.

Garcin, A., Edin, M., Mathieu, V., ve Hilaire, C. (1994). Poirier: maturité et qualité de William’s en fonction du porte-greffe. Infos-Ctifl, 103, 30-35.

Günen, Y., ve Mısırlı, A. (2004). Armut (Pyrus spp.) yetiştiriciliğinde anaç kullanımı. Anadolu J. of AARI, 14(1), 111-127.

Hilmelrich, D.G., ve Walker, C.E. (1982). Seasonal trends of calcium, magnesium, and potassium fractions in apple leaf and fruit tissues. Journal of the America Society for Horticultural Science, 107, 1078-1080.

Iglesias, I. ve Asin, L. (2005). Performance of 'Conference' pear on self-rooted trees and several Old-Home X Farmingdale, seedling and quince rootstocks in Spain. Acta Horticulturae, 671, 485-491.

Iglesias, I., Asin, L., Montserrat, R., Vilardell, P., ve Carbo, J. (2004). Performance of some pear rootstocks in Lleida and Girona (Catalonia, NE-Spain). Acta Horticulturae, 658, 159-165.

Jacob, H. (1998). Pyrodwarf: A new clonal rootstock for high density pear orchards. Acta Horticulturae, 475, 169-177.

Jones, J.B. Jr., Wolf, B., ve Mills, H.A. (1991). Plant Analysis Handbook. Micro Macro Publishing, Inc.

Kacar, B., ve Inal, A. (2008). Bitki analizleri. Nobel Yayın Dagitim Ltd. Sti., Ankara, 876 pp.

Kaplan, N. (1997). Güneydoğu Anadolu Bölgesi'ne uygun armut çeşitlerinin saptanması. Yumuşak Çekirdekli Meyveler Sempozyumu. 2-5 Eylül 1997. Yalova.

Korcak, R.F. (1987). Iron deficiency chlorosis. Hort. Rev., 9, 133-186.

Küçükyumuk, Z., ve Erdal, I. (2011). Rootstock and cultivar effect on mineral nutrition, seasonal nutrient variation and correlations among leaf, flower and fruit nutrient concentrations in apple trees. Bulg. J. Agric. Sci., 17, 633-641.

Le Lezec, M., Lecomte, P., Laurens, F., ve Michelesi, J.C., 1997. Sensibilité varietable au feu bactérien (1re partie). L'Arboriculture Fruiterie, 44, 57-62.

Leece, D.R. (1976). Leaf compositional standards for stone fruit and pome fruit. Diagnosis of nutritional disorders of fruit trees by leaf and soil analyses and biochemical indices. J. Aust. Inst. Agric. Sci., 42, 3-19.

Lemoine, J., Simon, M., Costard, F., Bossu, V., ve Pradier, B. (1998). Le dépérissement du Poirier ou pear decline. L' Arboriculture Fruiterie, 45, 29-34.

Lepsis, J., Lepse, L., Kviklys, D., ve Univer, N. (2013). Evaluation of pear rootstocks for the cultivar 'Suvenirs' in the Baltic Region. Proceedings of The Latvian Academy of Sciences. Section B. Natural, Exact, and Applied Sciences, 67, 145-150.

Lombard, P.B., ve Westwood, M.N. (1987). Pear rootstocks. In: Rom, C. R., Calson, R. F. (Eds.), Rootstocks for Fruit Crops. Wiley-Interscience Publication, John Wiley and Sons, New York, pp. 145–183.

Marangoni, B., ve Mazzanti, F. (1999). I portinesti del pero. L' Informatore Agrario, 6, 33-38.

Marini, R.P. (2009). Growing pears in Virginia. Virginia Cooperative Extension Publication 422-017, 9 pp. Available at: http://www.ext.vt.edu/pubs/treefruit/422-017. html (Accessed: 08 May 2016).

Marschner, H. (1996). Mineral nutrition of higher plants. Second Edition. Academic Pres Inc. London, G. B., 446 pp.

Mengel, K., ve Kirkby, E.A. (2001). Principles of plant nutrition. 5.ed. Dordrecht: Kluwer Academic Publishers, 849 pp.

Nachtigall, G.R., ve Dechen, A.R. (2006). Seasonality of nutrients in leaves and fruits of apple trees. Sci. Agric. (Piracicaba, Braz.), 63, 493-501.

North, M.S., ve Cook, N.C. (2008). Effect of six rootstocks on 'Forelle' pear tree growth, production, fruit quality and leaf mineral content. Acta Horticulturae, 772, 97-103.

Öztürk, I., Ercisli, S., Kalkan, F., ve Demir, B. (2009). Some chemical and physico-mechanical properties of pear cultivars. African Journal of Biotechnology, 8(4), 687-693.

Özbek, S. (1978). Özel Meyvecilik. Çukurova Üniv., Ziraat Fak. Yay. No: 128, Adana.

Özçagıran, R., Ünal, A., Özeker, E., ve İsfendiyaroglu, M. 2004. Ilıman iklim meyve türleri. Yumuşak çekirdekli meyveler. Cilt- II. Ege Üniv. Yay. No: 556, İzmir.

Palonen, P., ve Buszard, D. (1997). Current state of cold hardiness research on fruit crops. Canadian Journal of Plant Science, 77, 399-420.

Picchioni, G.A., Brown, P.H., Weinbaum, S.A., ve Muraoka, T.T. (1997). Macronutrient allocation to leaves and fruit of mature, alternate-bearing pistachio trees: magnitude and seasonal patterns at the whole-canopy level. J. Am. Soc. Hort. Sci., 122, 267-274.

Ryugo, K. (1988). Fruit Culture, Its Science and Art. Wiley, New York.

Sanz, M., Montañés, L., ve Carrera, M. (1994). The possibility of using floral analysis to diagnose the nutritional status of pear trees. Acta Horticulturae, 367, 290-295.

Shear, C.B., ve Faust, M. (1980). Nutritional ranges in deciduous tree fruits and nuts. Hort. Rev., 2, 143- 163.

Sotiropoulos, T.E. (2006). Performance of the pear (Pyrus communis) cultivar William's Bon Chretien grafted on seven rootstocks. Australian Journal of Experimental Agriculture, 46, 701-705.

Stassen, P.J.C., ve North, M.S. (2005). Nutrient distribution and requirement of 'Forelle'pear trees on two rootstocks. Acta Horticulturae, 671, 493-500.

Stern, R.A., ve Doron, I. (2009). Performance of ‘Coscia’ pear (Pyrus communis) on nine rootstocks in the north of Israel. Scientia Horticulturae, 119, 252-256.

Stern, R.A., ve Flaishman, M.A., 2003. Benzyladenine effects on fruit size, fruit thinning and return yield of ‘Spadona’ and ‘Coscia’ pear. Scientia Horticulturae, 98, 499-504.

Sugar, D., Powers, K.A., ve Basile, S. (1999). Effect of rootstock on fruit characteristics and tree productivity in seven red-fruited pear cultivars. Fruit Varieties Journal, 53, 148-154.

Tagliavini, M., Abadia, J., Rombola, A.D., Abadia, A., Tsipouridis, C., ve Marangoni, B. (2000). Agronomic means for the control of iron deficiency chlorosis in deciduous fruit trees. J. Plant Nutr., 23, 2007-2022.

Tagliavini, M., ve Rombola, A.D. (2001). Iron deficiency and chlorosis in orchard and vineyard ecosystems: A review. Eur. J. Agron., 15, 71-92.

Tagliavini, M., ve Rombolà, A.D. (2001). Iron deficiency and chlorosis in orchard and vineyard ecosystems. European Journal of Agronomy, 15 (2), 71-92.

Thomidis, T., Tsipouridis, C., ve Darara, V. (2007). Seasonal variation of nutrient elements in peach fruits (cv. May Crest) and its correlation with development of Brown rot (Monilinia laxa). Scientia Horticulturae, 111, 300-303.

Weinbaum, S.A., Niederholzer, F.J.A., Ponchner, S., Rosecrance, R.C., Carlson, R.M., Whittlesey, A.C., ve Muraoka, T.T. (1994). Nutrient uptake by cropping and defruited field-grown 'French' prune trees. J. Am. Soc. Hort. Sci., 119, 925-930.

Wertheim, S. (2002). Rootstocks for European pear: a review. Acta Horticulturae, 596, 299-307.

Wojcik, P., ve Wojcik, M., 2003. Effects of boron fertilization on ‘Conference’ pear tree vigor, nutrition, and fruit yield and storability. Plant and Soil, 256, 413-421.