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The Effect of Phosphorus Applications on Fruit Yield and Some Quality Characteristics of Sweet Chestnut (*Castanea sativa* Mill.)

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Abstract

Phosphorus is an important plant nutrient fornutrition the plant sand maintaining their metabolic activities. Although chestnut is a plant that makes a profit for the farmers in the world and in our country, the data on fertilization is quite limited. This study was carried out in order to determine the effectiveness of phosphorus applications on fruit yield and quality for two years in Sarıaşılama variety (candy type) chestnut orchards of İnegol (Bursa) district Within this scope, phosphorus doses of 0, 250, 500, 750 and 1000 g P tree^{-1}were applied to the soil of tree scanopy at a depth of 0-30 cm in April.

According to the results of the study, the highest fruit yield was recorded as 29.0 and 30.0 kg tree^{-1} in 750 g P tree^{-1} in both application years respectively. The highest fruit total protein content were determined as 7.5 g 100 g^{-1} in 500 g P tree^{-1}dose in the 2013 year. The star chand total sugar content in fruit was recorded as 41.6 and 9.6 g 100 g^{-1} in 750 g P tree^{-1}dose in second year. According to the results of the study, the amount of phosphorus fertilizer to be applied to the Sarıaşılamavariety of chestnut trees at the age of 20 years were determined as 750 g P tree^{-1}

Keywords: Chestnut (*Castanea sativa* Mill.), phosphorus, yield, quality

Fosfor Uygulamalarının Şeker Kestane (*Castanea sativa* Mill.) Meyve Verimine ve Bazı Kalite Özelliklerine Etkisi

Özet

Fosfor, bitkilerin beslenmesi ve metabolik aktivitelerini sürdürmek için önemli bir bitki besin maddesidir. Kestane, dünyadaki ve ülkemizdeki çiftçiler için kazanç getiren bir bitki olmasına rağmen, gübreleme ile ilgili veriler oldukça sınırlıdır. Bu çalışma, İnegöl (Bursa) yöresinde Sarıaşılama çeşidi (şeker tipi) kestane bahçelerinde iki yıl boyunca fosfor uygulamalarının meyve verimi ve kalitesi üzerindeki etkinliğini belirlemek amacıyla yapılmıştır. Bu kapsamda 0, 250, 500, 750 ve 1000 g P ağaç$^{-1}$ Nisan ayında ağaç taç izdüşümüne 0-30 cm derinlikte toprağa uygulanmıştır.

Çalışmanın sonuçlarına göre, her iki uygulama yılında da en yüksek meyve verimi sırasıyla 750 g P ağaç$^{-1}$ dozunda 29.0 ve 30.0 kg ağaç$^{-1}$ olarak kaydedilmiştir. En yüksek meyve toplam protein içeriği, 2013 yılında 500 g P ağaç$^{-1}$ dozunda 7.5 g 100 g^{-1} olarak belirlenmiştir. Meyvelerdeki nişasta ve toplam şeker içeriği, ikinci yılda 750 g P ağaç$^{-1}$ dozunda 41.6 ve 9.6 g 100 g^{-1} olarak kaydedilmiştir. Çalışmanın sonuçlarına göre, 20 yaşındakiSarıasılama çeşidi kestane ağaçlarına uygulanacak fosforlu gübre miktarı 750 g P ağaç$^{-1}$ olarak belirlenmiştir.

Anahtar Kelimeler: Kestane (*Castanea sativa* Mill.), fosfor, verim, kalite

1. Introduction

Chestnut (*Castanea sativa* Mill.) is one of the most important tree nuts in the world (Ertan et al., 2015). Many species of the genus *Castanea* are grown in several parts of the world for timber and/or edible nut production (Portela et al., 2007). However, some herdsman also cut down wild fruit trees to enlarge their meadowarea, leading to the disappearance of the primary wild chestnut forest (Ercişli et al., 2009).

According to the Food and Agriculture Organization Statistical Database, the world wide chestnut production is 2327500 tons. Chestnut fruits are highly regarded and widely consumed throughout Europe, America, and Asia. In addition, chestnuts are one of the most popular nuts in the oriental world. Chestnuts are mainly cultivated in China (1879000 t), Bolivia (84800 t.), Turkey (64750 t.), and Republic of Korea (56200 t) (Anonymous, 2019).

Phosphorus, like nitrogen, undergoes mineralization and immobilization. The net phosphorus release depends on the phosphorus concentration of the residues undergoing decay and the phosphorus requirements of the activemicrobial population (Alexander, 1977).

Generally, fast-growing, short-season vegetable crop shave higher phosphorus requirements than field and orchard crops. Many deciduous fruit crops infrequently respond to phosphorus fertilization even if soil tests are low (Childers, 1966).

Chestnuts can grow and bear profitable crops of nuts without ever being fertilized, but to get the very highest yields a program of regular fertilization will be necessary. The higher cost can be easily off set by the high value of the crop. If chemical fertilizers are used then regulars oil tests should determine the quantity and type. Regardless of what kind of fertilizer is used, it should be applied in spring and never any later than early June. Fertilizer applied later will result in tender late-season growth which will be subject to winter damage (Wahl, 2002).

Due to the accumulation of potential in nut, nitrogen fertilizers can be expected to affect many quality parameters, primarily protein content in chestnut. It has been reported that low levels of nitrogen in chestnuts while cause poor grow than reduced flowering, low phosphorus levels cause a decrease in the number of developing female flowers. Besides, if the content of boron in the soil is less than 3 ppm and more than 17 ppm, especially in Chinese Chestnuts, it causes the discharge of burrs, and there is a problem of iron deficiency and besides, chestnuts have high zinc needs in calcium-rich soil. (Rutter et al 1990).

Pérez-Cruzado et al. (2011) used wood-bark ash, a product rich in Ca, K, Mg, and to a lesser extent P, as a fertilizer in a young chestnut orchard. They recorded an increase in the diameter and height of the trees and also an improvement in the nutritional status of the plants in terms of K, Ca, and Mg.

However, there are limited cientific data on chestnut management, in particular in the field of mineral nutrition and crop fertilization (Portela et al., 2007). In the past, this species was not fertilized, the soil only be in gamended when farmyard manure was available. Regular application of mineral fertilizers is a recent introduction (Arrobas et al., 2017).

The application of P and K as fertilizers increase the levels of these nutrients in the top soil layer as expected. In addition this, the annual application of P or K significantly increase extractable P_{AL}or K_{AL}, respectively (Arrobas et al., 2017).

In this research, the aim was to determine the effect of phosphorus fertilizer applications on fruit yield and some quality characteristics in mature Sarıaşılama chestnut (Candy type) trees.

2. MaterialandMethod

2.1. Site Characterization

The study was carried out in the chestnut orchards of Inegöl district of Bursa province in the Sarıaşılama cultivar the sweetchest nuttrees of 20 years old. There search was planned as a randomized parcels design with three replications. There are three trees in each parcel. In the study, phosphorus fertilizers were applied in 2012 and 2013. Phosphorus fertilizer applications were adjusted to be P_0: 0, P_1: 250, P_2: 500, P_3: 750 N_4: 1000 g P $tree^{-1}$. However, support fertilizers were applied for phosphorus application treatments as 1500 g N $tree^{-1}$ and 1500 g K $tree^{-1}$.

All fertilizers (treatments and support) were applied to under the canopy of chestnut tree in April mixed in 0-30 cm soil depth. In the experiment, urea (CH_4N_2O) was used as a nitrogen source, triple superphosphate ($Ca(H_2PO_4)_2.H_2O$) as a phosphorus source, and potassium chloride (KCl) as a potassium source.

The region is located in the Marmara and the Aegean climate transitional zone. In the vegetation period (from Marchto October), the total amount of rainfall was 333.8 years in the first year and 396.3 mm in the second year. The average rainfall during the vegetation period in the region for long term years is 342.2 mm. The average temperature during the vegetation period in the region for long term years is 18.2 mm. The average temperature in the period of there searc his consistent with the average temperature long term years, and the total rainfall is consistent with the total rainfall long term years. Climate data for

the experimental sites and periods are shown in Figure 1.

The soil samples of the experimental orchard were taken from 0-30 cm depth in March. The physical and chemical soil properties of the chestnut orchard are shown in Table 1. According to the results of soil analysis, the physical structure of the soil is loamy, the pH is slightly acidic (5.87). Organic carbon and organic matter content were determined as 0.78% and 1.35%, respectively. Soil total salinity is 0.018%. In addition, N, P, K, Fe, Zn, Mn, Cu contents were determined as 0.068%, 6.28, 139.2, 41.3, 0.39, 52.5 and 0.79 ppm, respectively. The lime content of the soil of chestnut orchard was less than 1%.

2.2. Harves tand biochemical analysis in fruit

Chestnuts were harvested during the commercial harvest period in Bursa when fruits reached a physiological maturity stage where the chestnut burrs began to separate and thefruits had grown. To determine the gross yield of each tree, nuts were harvested by shaking trees and collecting by hand. The samples of about 120-150 g fruit that were randomly sampled were squashed with mortar after their outer shells and seed coat (testa) were remove dand analysis was carried out. The dry matter contents of the samples were determined by drying them overnight in the hot-air oven at 105 °C (Ertürk et al 2006).

Total protein quantity was calculated by multiplying the nitrogen content using the Kjeldahl method by the coefficient 5.30 (AOAC 1990). Dinitrophenol method was utilized in the analysis of total carbohydrates and total sugar (Ross 1959) using the BeckmanDu 530 model spectrophotometer. Starch quantity was calculated by multiplying the value obtained by subtracting the total sugars from total carbohydrates by the coefficient 0.94 (Ertürk et al 2006).

2.3. Statistical analysis

Statistical analyses were conducted using analysis of variance (ANOVA) with IBM SPSS 22 Statistics Software. Treatment means were compared with Duncan's multiple range test (*P≤0.05, P≤0.01*).

3. Results

3.1. Fruit yields

Fruit yields in the phosphorus experimental orchard were determined between 20.9- 30.0 kg tree^{-1}. Significant statistical differences were obtained between P fertilization treatments in both years. No significant statistical difference was found between application years. In the experimental orchard, the highest fruit yield was obtained for P_{3+NK} dose (first year: 29, second year: 30 kg tree^{-1}) and the lowest fruit yield for control (first year: 20.9, second year: 21.9 kg tree^{-1}) (Figure 2). Research on cultivated plants has shown that phosphorus fertilizers significantly increase the amount of product (Kacarand Katkat, 1998). A fruit yield increase of 38% was observed in chestnut plants compared to control (P_{0+NK}) in P_{3+NK} (750 g tree^{-1}) treatment. Sustained phosphorus application has stimulating effects on yield (Güneş et al., 2010).

3.2. Fruit total protein contents

The protein content of the fruit is an important criterion for fruit quality. The total protein content of chestnut fruit varies between 4.88 and 10.87 g 100 g^{-1} (Ertürk et al., 2006). The total protein content in the phosphorus application orchard was recorded between4.9 - 7.5 g 100 g^{-1} (Figure 3). The highest protein content was determined for P_{1+NK} (250 g tree^{-1}) and P_{2+NK} (500 g tree^{-1}) doses (first year: 7.3 and 7.5 g 100 g^{-1}, second year: 7.3 g 100 g^{-1}, respectively) and the lowest protein content was recorded for control (first year: 4.9, second year: 5.3 g 100 g^{-1}). In the chestnut fruit, a 46% total protein increase was recorded in P_{1+NK} treatment compared to the control. Significant statistical differences were obtained between P fertilization treatments in both years. No significant statistical difference was found between application years. This was reported between 3.43 and 13.28 g 100 g^{-1}by different researchers in C. sativa Mill. (Pinnavaia et al., 1993; Ferreria -Cardoso et al., 1993; Brighenti et al., 1998; Bounous, 1999; Üstün et al., 1999). This range was narrower in the Chinese chestnuts being between 2.12 and 7.49 g 100 g^{-1} (McCarthy and Meredith, 1988).

3.3. Fruit starch contents

The highest starch content was obtained for P_{3+NK} (750 g tree^{-1}) dose (first year: 41.2, second year: 41.6 g 100 g^{-1}) and the lowest starch content for control (first year: 35.4, second year: 35.6 g 100 g^{-1}). Significant statistical differences were obtained between P fertilization treatments in both

years. No significant statistical difference was found between application years.

The starch content in the experimental orchard was recorded between 35.4- 41.6 g 100 g^{-1} (Figure 4). In addition, the amount of starch may be decreases when there is not sufficient inorganic phosphorus in the fruit (Mohabirand John, 1988; Plaxton and Preiss, 1987). The values found by most researchers were close to these ones, generally ranging from 49.60 to 65.40 g 100 g^{-1} in different species (Pinnavaia et al., 1993; Liu, 1993; Ferreria -Cardoso et al., 1993; Bounous et al., 2000). However, some researchers found the value lower (29.80 g 100g^{-1}) (Üstün et al., 1999) or higher (Demiate et al., 2001) (80 g 100 g^{-1}) than these. A part of starch changes into sugars during storage, thus the ratio of sugars increases and that of starch decreases (Soylu et al., 1987). In the chestnut fruit, a 17% starch increase was recorded in P_{3+NK} treatment compared to the control.

3.4. Fruit total sugar contents

The highest total sugar content was obtained in application orchard, in the P_{2+NK} and P_{3+NK} doses (first and second year: 9.3, second year: 9.5 and 9.6 g 100 g^{-1}, respectively) and the lowest total sugar content was determined for control (first year: 7.0, second year: 7.6 g 100 g^{-1}). Significant statistical differences were obtained between P fertilization treatments in both years. No significant statistical difference was found between applicationyears. The total sugar content in the application orchard was recorded between 7.0 – 9.6. g 100 g^{-1}. At the last dose, the sugar content decreased (Figure 5). In the chestnut fruit, a 30% total sugar increase was recorded in P_{3+NK} treatment compared to the control. Nutrition of plants with phosphorus and potassium positively affects sugar metabolism (Mengel 1991). As a result of the statistical analysis, significant differences were found in among the treatments. This range lower to those obtained by Pinnavaia et al., 1993 and Bounous et al., 2000 which were14.01 - 20.60 g 100 $g^{-1}$and 20.38 g 100 g^{-1}, respectively.

4. Discussion and Conclusions

In this research, significant increases in chestnut fruit yield and quality characteristics have been determined along with balanced fertilization and maintenance processes. The fruit yield in chestnut orchards were increased by approximately 38%. A good fertilization program could increase tree growth rates, health, strength, fruit production and resistance to diseases, insects, cold and drought (Wahl 2002).

According to the results, the highest fruit yield was determined for P_{3+NK} (750 g P $tree^{-1}$) dose as an average of 30.0 kg $tree^{-1}$, highest total starch and total protein content was recordedfor P_{3+NK} (750 g P $tree^{-1}$) and P_{2+NK} (500 g P $tree^{-1}$) dose as an average of 41.6 and 7.5 g 100 g^{-1}respectively and the highest total sugar content was obtained for P_{3+NK} (750 g P $tree^{-1}$) dose as an average of 9.5 g 100 g^{-1}.

When all the results of the study were examined, the amount of phosphorus fertilizer which should be an application to a mature (20 year sold) Sarıaşılama variety chestnut tree was determined for the highest fruit yield and quality characteristics as 750 g P $tree^{-1}$ $year^{-1}$.

Acknowledgement

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Tables

Table 1. Some soil characteristics of chestnut experimental orchard (0-30 cm depth)
Tablo 1. Kestane deneme bahçesinin bazı toprak özellikleri (0-30 cm derinlik)

Soilcharacteristics			
Clay(%)	12.3	Total N (%)	0.068
Silt(%)	27.9	P (ppm)	6.28
Sand(%)	59.8	K (ppm)	139.2
pH	5.87	Fe (ppm)	41.3
Organic matter(%)	1.35	Zn (ppm)	0.39
Organic carbon(%)	0.78	Mn (ppm)	52.5
Total salinity(%)	0.018	Cu (ppm)	0.79

$CaCO_3$: Less than 1%

Figures

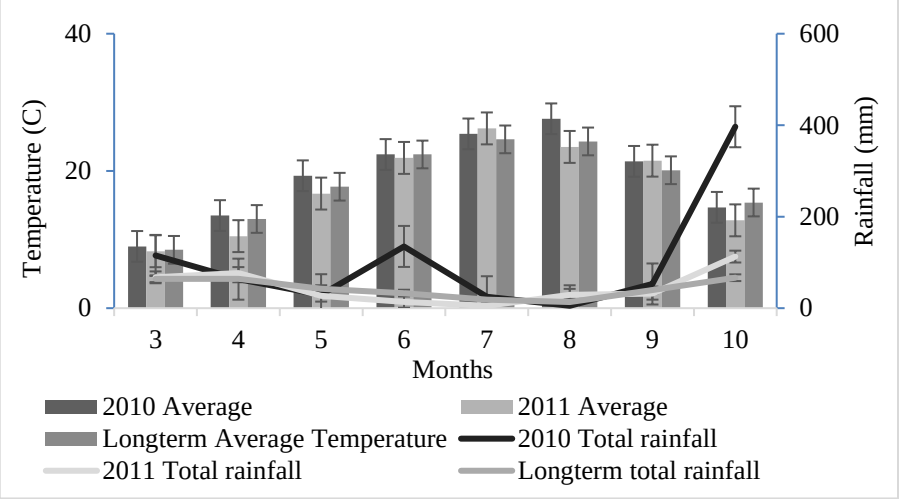

Figure 1. Climate data at there search area over two years (2012 and 2013). The values are shown (on the bars or symbols) as means ± standard deviation (SD).*:Climate data are taken from Inegol Meteorology Station (17670).

Şekil 1. Araştırma alanındaki iki yıllık iklim verileri (2012 ve 2013). Değerler (çubuklar veya sembollerde) ortalama ± standart sapma (SD) olarak gösterilmiştir. *: İklim verileri İnegöl Meteoroloji İstasyonu'ndan (17670) alınmıştır.

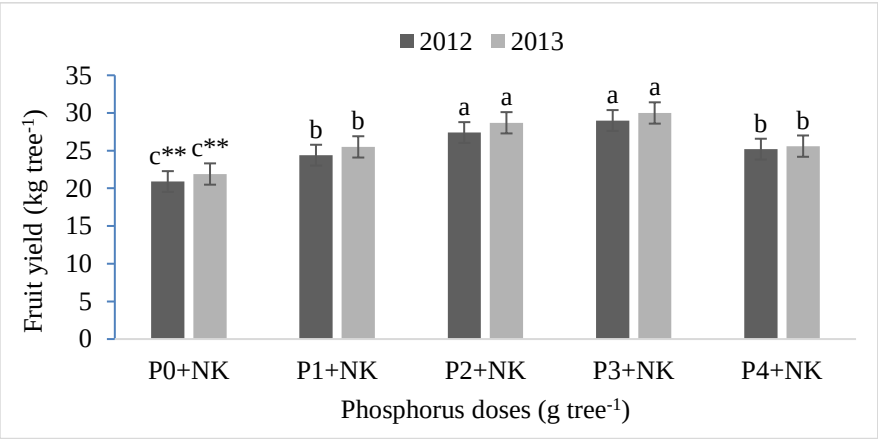

Figure 2. The effect of phosphorus application on the fruit yields in the chestnut. Letters above the columns indicate the results of the Duncan test (**, $P \leq 0.01$) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 10.4, CV_{2013}: 9.5)

Şekil 2. Fosfor uygulamasının kestanedeki meyve verimi üzerine etkisi. Sütunların üzerindeki harfler, deneme bahçesinin meyve verimleri için Duncan testinin (**, $P \leq 0.01$) sonuçlarını göstermektedir. Değerler (çubuklar veya semboller) ortalama ± standart sapmayı (SD) göstermektedir. (CV_{2012}: 10.4, CV_{2013}: 9.5)

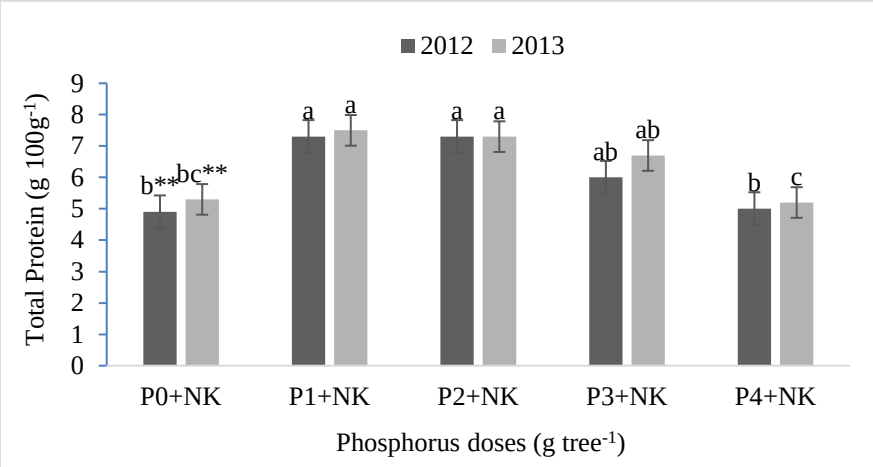

Figure 3. The effect of phosphorus application on the total protein in the chestnut fruits. Letters above the columns indicate the results of the Duncan test (**, $P \leq 0.01$) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 8.3, CV_{2013}: 7.1)

Şekil 3. Fosfor uygulamasının kestane meyvesinin toplam protein üzerine etkisi. Sütunların üzerindeki harfler, deneme bahçesinin meyve verimleri için Duncan testinin (**, $P \leq 0.01$) sonuçlarını göstermektedir. Değerler (çubuklar veya semboller) ortalama ± standart sapmayı (SD) göstermektedir. (CV_{2012}: 8.3, CV_{2013}: 7.1)

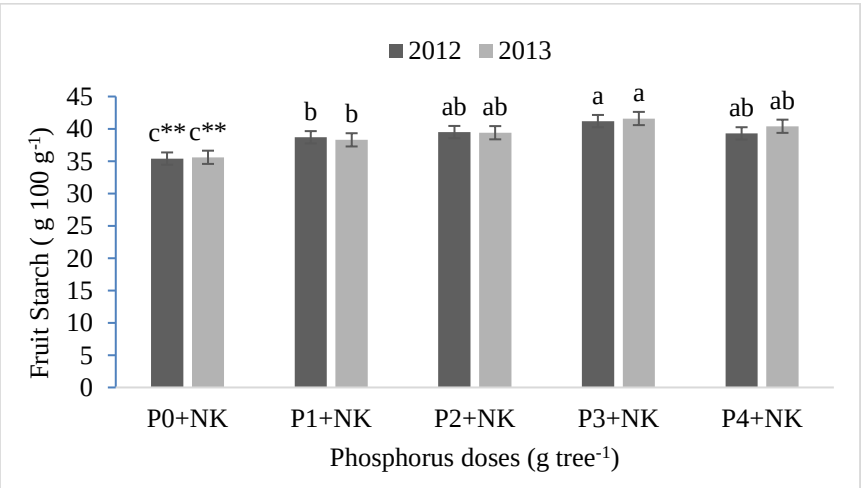

Figure 4. The effect of phosphorus application on the starch content in the chestnut fruits. Letters above the columns indicate the results of the Duncan test (**, $P \leq 0.01$) for thefruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 2.1, CV_{2013}: 3.3)

Şekil 4. Fosfor uygulamasının kestane meyvesinin nişasta içeriği üzerine etkisi. Sütunların üzerindeki harfler, deneme bahçesinin meyve verimleri için Duncan testinin (**, $P \leq 0.01$) sonuçlarını göstermektedir. Değerler (çubuklar veya semboller) ortalama ± standart sapmayı (SD) göstermektedir. (CV_{2012}: 2.1, CV_{2013}: 3.3)

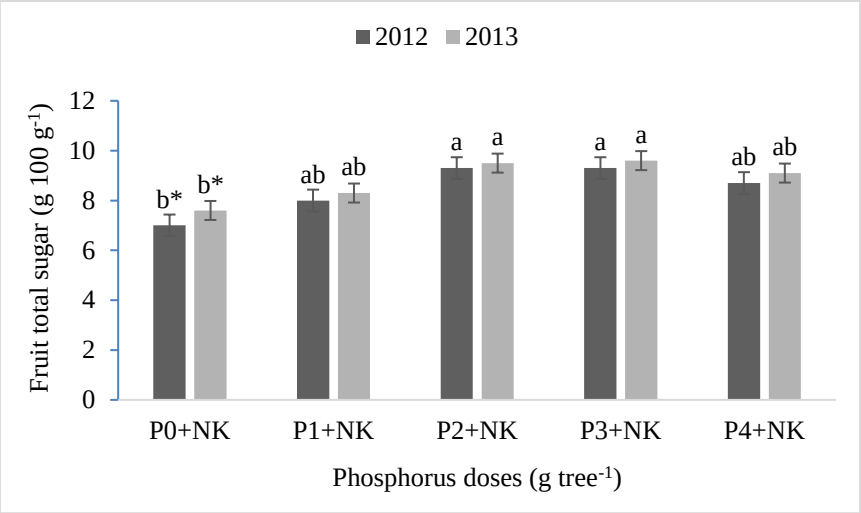

Figure 5. The effect of phosphorus application on the starch content in the chestnut fruits. Letters above the columns indicate the results of theDuncan test (*, $P \leq 0.05$) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 5.6, CV_{2013}: 6.8)

Şekil 5. Fosfor uygulamasının kestane meyvesinin nişasta içeriği üzerine etkisi. Sütunların üzerindeki harfler, deneme bahçesinin meyve verimleri için Duncan testinin (*, $P \leq 0.05$) sonuçlarını göstermektedir. Değerler (çubuklar veya semboller) ortalama ± standart sapmayı (SD) göstermektedir. (CV_{2012}: 5.6, CV_{2013}: 6.8)