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The effect of potassium applications on fruit yield and some quality characteristics of sweet chestnut (*Castanea sativa* mill.)

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Abstract
This research was performed to determine the effects of potassium applied on the soil to different doses on the yield and yield components of sweet chestnut grown in conditions in the Bursa province in 2012 and 2013. In this context, 0, 500, 1000, 1500 and 2000 g K tree^{-1} doses were applied to the tree canopy soil at 0-30 cm depth in April. According to the results of the study, the highest fruit yield, total protein, and sugar were recorded averagely 26 kg tree^{-1}, 10.7 and 13.7 g 100 g^{-1} respectively in 1500 g K tree^{-1} dose in application years. The highest starch content in fruit was determined as average 34.5 g 100 g^{-1} in 1000 g K tree^{-1} dose. As a result of this research, the amount of potassium fertilizer to be applied to the Sarıaşılama variety of chestnut trees at the age of 20 years were determined as 1500 g K tree^{-1}

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

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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). According to the Food and Agriculture Organization Statistical Database, the worldwide 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) (FAO 2019).

Potassium is one of the important macronutrients required for the growth, development of plants and it also plays a key role in the plant. Many studies have examined the effects of potassium on the growth and yield of a different fruit species. These investigations indicate that potassium has a very significant effect on the yield and quality of fruits. (Gundesli et al. 2018).

Huvely and Vojnich (2016) investigated the effects of potassium chloride and potassium sulfate fertilizers on the development of pepper plants in increasing doses (10, 20, 40, 80 and 160 kg K_2O da^{-1}) in sandy soils. Half of the fertilizers were applied before planting and the other half as aqueous solution after flowering. As a result, when potassium sulfate and potassium chloride were compared, the highest yield (9.83 ton da^{-1}) was obtained from 20 kg K_2O da^{-1} of potassium sulphate and 40 kg K_2O da^{-1} of potassium chloride (8.19 ton da^{-1}). Kubar et al. (2016) investigated the effects of potassium sulfate fertilizer and 0, 5, 10, 15, 20 and 25 kg K2O da^{-1} doses on growth, biomass and K accumulation in tomato plants grown in pots. As a result, it has been seen that K applications significantly increase the growth, biomass and K accumulation in the plant. Genç (1997), studied the effect of potassium on the yield and quality of Tombul hazelnut variety and found that potassium increases fruit yield by 25 percent. Eryüce and Çokuysal (1993), in their study, foliar KNO_3 applications at 1% level in the vineyards have determined that the weight of 100-grain increases by 30%. Shamir and Israeli (1981), in their research, during irrigation by 4% KNO_3 application, have determined that the pomegranate fruit yield increased by 18%.

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 offset by the high value of the crop. If chemical fertilizers are used then regular soil tests should determine the quantity and type.

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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). 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 scientific 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 being amended when farmyard manure was available. Regular application of mineral fertilizers is a recent introduction (Arrobas et al. 2017).

Potassium increases the nutritional value of food and forage crops by increasing protein scopes and helps feed crops in the pastures to be of higher quality. In corn and other grain crops, they ensure that the grains are full and mature in a uniform manner. While decreasing the weight loss during storage while increasing the color, size, taste, and aroma of various fruits, it increases the quality by minimizing the loss in the marketing rate and loss in the transportation to the places to be marketed (Kacar and Katkat 1998).

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

Materıal and Method

Site Characterization

The study was carried out in the chestnut orchards of Inegöl district of Bursa province in the Sarıaşılama cultivar the sweet chestnut trees of 20 years old. The research was planned as a randomized parcels design with three replications. There are three trees in each parcel. In the study, potassium fertilizers were applied in 2012 and 2013. Potassium fertilizer applications were adjusted to be K_0: 0, K_1: 500, K_2: 1000, P_3: 1500 K_4: 2000 g K tree^{-1}. However, support fertilizers were applied for potassium application treatments as a 1500 g N tree^{-1} and 750 g P 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 March to October), the total amount of rainfall was 333.8 years in the first year and 396.3 mm in the second year. The average temperature in the period of the research is 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.

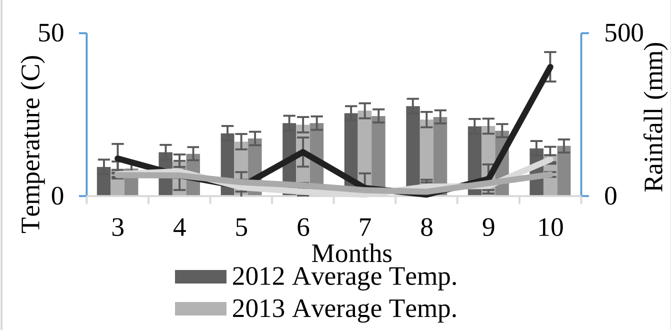

Figure 1. Climate data at the research area over two years (2012 and 2013). The values shown (bars or symbols) are means ± standard deviation (SD). * : Climate data are taken from Inegol Meteorology Station (17670).

The soil samples of chestnut orchards were taken in March month. The physical and chemical soil properties of the three chestnut experiment orchards are shown in Table 1. According to the results of soil analysis, it was determined that the physical structure of the soil was loamy, the pH was slightly acidic and (5.77). Organic carbon contents (1.10%) and organic matter contents (1.75%) were insufficient. It was found that the total salinity of the soil (0.027%) was low levels. Also, the macro (N, P, K) and micronutrient (Fe, Zn, Mn, Cu) contents were found to be insufficient in the soil. The lime content of the soils was below 1% (non calcareous soil).

Table 1. Some soil characteristics of research area (0-30 cm depth)

Soil characteristics	Value
Clay %	11.7
Silt %	29.2
Sand %	59.1
pH	5.77
Organic matter %	1.75
Organic carbon %	1.18
Total salinity %	0.027
Total N %	0.088
P (mg kg^{-1})	8.38
K (mg kg^{-1})	127.1
Fe (mg kg^{-1})	49.5
Zn (mg kg^{-1})	0.49
Mn (mg kg^{-1})	51.5
Cu (mg kg^{-1})	0.86

CaCO3 is less than 1%

Harvest and 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 the fruits 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 removed and 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 Beckman Du 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).

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*).

Results and discussion

Fruit yields

In the research area, statistically significant increases in fruit yields were determined with applied potassium doses. Potassium has metabolic, physiological and biochemical functions that are vital in plants. The effect of these functions increases the quantity and quality of crops in plants (Kacar and Katkat, 1998). Fruit yields in the potassium experimental orchard were determined between 17.3-26.3 kg tree^{-1}. Significant statistical differences were obtained between K 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 K_{2+NP} (1000 g tree^{-1}) and K_{3+NP} (1500 g tree^{-1}) dose (first year: 24.2 and 25.8, second year: 24.9 and 26.3 kg tree^{-1} respectively) and the lowest fruit yield for control (first year: 17.3, second year: 17.9 kg tree^{-1}) (Figure 2). A fruit yield increase of 51% was observed in chestnut plants compared to control (K_{0+NP}) in K_{3+NP} (1500 g K tree^{-1}) treatment. Potassium applications increase fruit size and yield (Bhargava et al 1993)

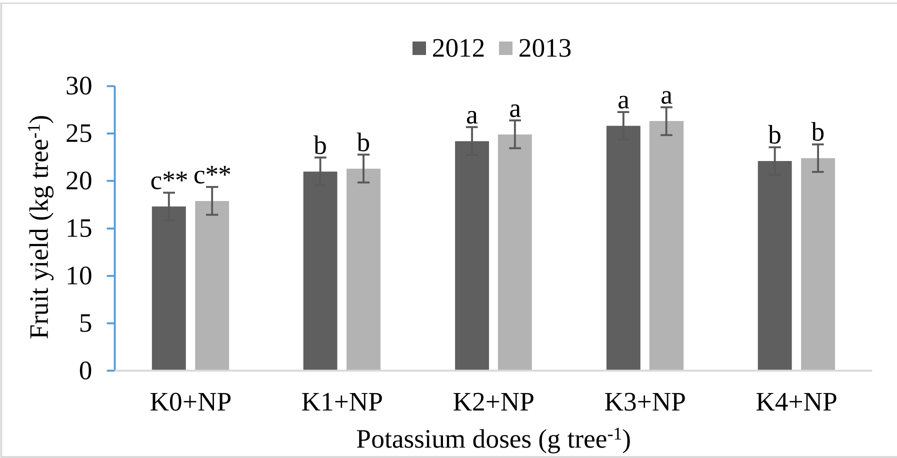

Figure 2. The effect of potassium applications on the fruit yields in the chestnut. Letters above the columns indicate the results of the Duncan test (**, *P ≤ 0.01*) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 11.2, CV_{2013}: 9.7)

Fruit total protein contents

Potassium is involved in protein synthesis in plant growth and required for the production of high energy molecules such as ATP (Imas 1999). The total protein content of chestnut fruit varies between 6.88 and 10.87 g 100 g^{-1} (Ertürk et al., 2006). The total protein content in the potassium application orchard was recorded between 6.3 - 10.7 g 100 g^{-1} (Figure 3). The highest protein content was determined for K_{3+NP} (1500 g K tree^{-1}) dose (first year: 10.7 second year: 10.6 g 100 g^{-1}, respectively) and the lowest protein content was recorded for control (both year: 6.3 g 100 g^{-1}). In the chestnut fruit, a 70% total protein content increase was recorded in $K3_{+NP}$ treatment compared to the control. Significant statistical differences were obtained between K 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).

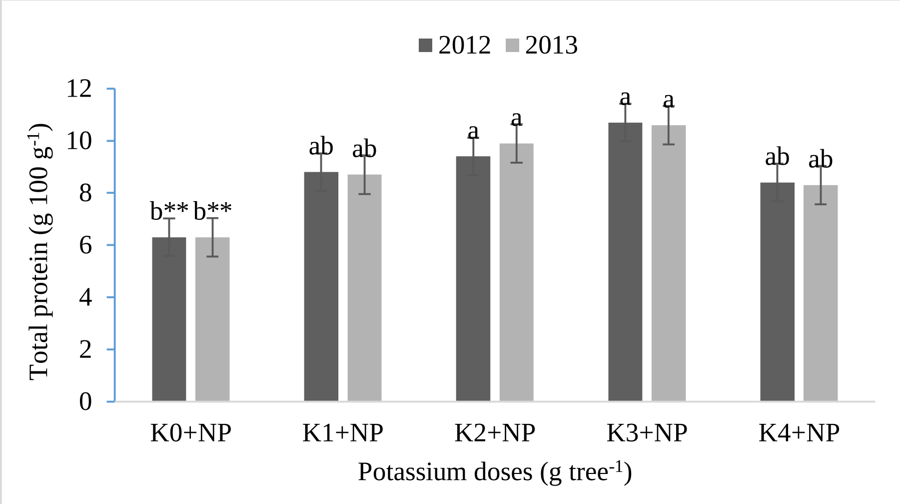

Figure 3. The effect of potassium applications on the total protein in the chestnut fruits. Letters above the columns indicate the results of the Duncan test (**, *P ≤ 0.01*) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 9.6, CV_{2013}: 8.7)

Fruit starch contents

The starch content in the experimental orchard was recorded between 27.4- 34.7 g 100 g^{-1} (Figure 4). The highest starch content was obtained for K_{2+NP} (1000 g K $tree^{-1}$) dose (first year: 34.4, second year: 34.7 g 100 g^{-1}) and the lowest starch content for control (first year: 27.4, second year: 27.7 g 100 g^{-1}). Significant statistical differences were obtained between K fertilization treatments in both years. No significant statistical difference was found between application years. The values by most researchers were found higher than these species, usually 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 values. In the chestnut fruit, a 25% starch increase was recorded in K_{2+NP} treatment compared to the control. Potassium activity in starch synthetase enzyme activity is very high up to a certain level (Preusser et al. 1981). The starch is transport to the storage organs especially in the presence of sufficient potassium (Kacar & Katkat 1998).

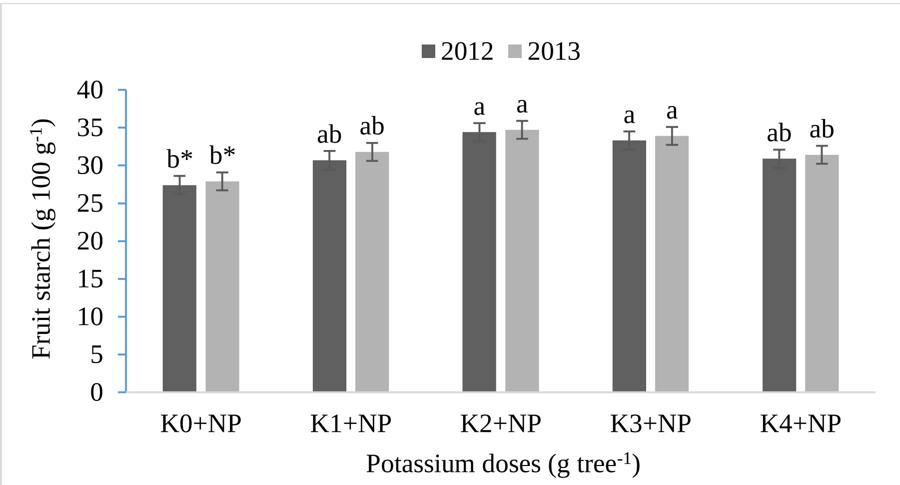

Figure 4. The effect of potassium applications on the starch content in the chestnut fruits. Letters above the columns indicate the results of the Duncan test (*, *P ≤ 0.05*) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 4.7, CV_{2013}: 5.6)

Fruit total sugar contents

Nutrition of plants with phosphorus and potassium positively affects sugar metabolism (Mengel 1991). The highest total sugar content was obtained in application orchard, in the K_{3+NP} (first year: 13.8, second year: 13.6 g 100 g^{-1}) and the lowest total sugar content was determined for control (first year: 9.6, second year: 10.1 g 100 g^{-1}). Significant statistical differences were obtained between K fertilization treatments in both years. No significant statistical difference was found between application years. The total sugar content in the application orchard was recorded between 9.6 - 13.8. g 100 g^{-1}. At the last dose, the sugar content decreased (Figure 5). In the chestnut fruit, a 40% total sugar increase was recorded in K_{3+NP} treatment compared to the control. 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 were 14.01 - 20.60 g 100 g^{-1} and 20.38 g 100 g^{-1}, respectively. Although potassium does not form part of the structure of plant constituents, it regulates the improving quality of the fruits by maintaining desirable sugar to acid ratio, ripening of fruit (Kumar et al 2006).

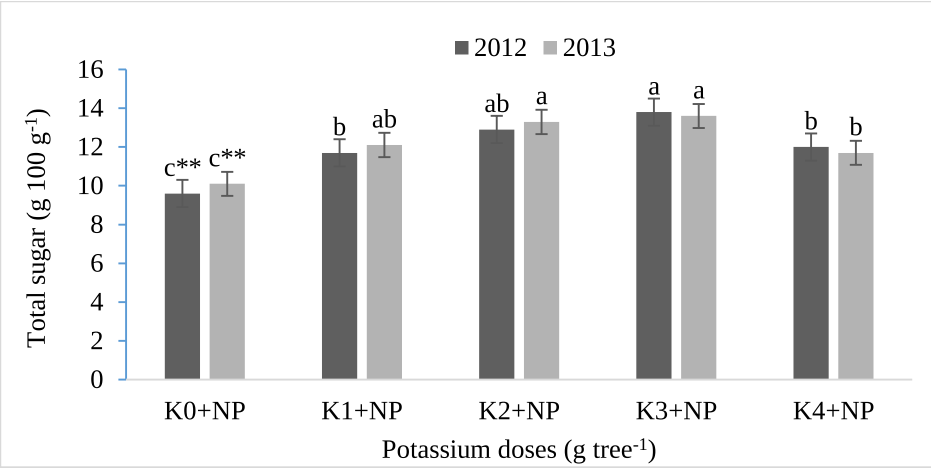

Figure 5. The effect of potassium applications on the sugar content in the chestnut fruits. Letters above the columns indicate the results of the Duncan test (**, $P \leq 0.01$) for the fruit yields of the experimental orchard. The values are shown (bars or symbols) are means ± standard deviation (SD). (CV_{2012}: 6.1, CV_{2013}: 5.1)

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 51%. 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 K_{3+NP} (1500 g K $tree^{-1}$) dose as an average of 26 kg $tree^{-1}$, highest total sugar and protein content was recorded for K_{3+NP} (1500 g P $tree^{-1}$) dose as an average of 10.7 and 13.8 g 100 g^{-1} respectively and the highest fruit starch content was obtained for K_{2+NP} (1000 g P $tree^{-1}$) dose as an average of 34.7 g 100 g^{-1}.

When all the results of the study were examined, the amount of potassium fertilizer which should be an application to a mature (20 years old) Sarıaşılama variety chestnut tree was determined for the highest fruit yield and quality characteristics as 1500 g K tree $^{-1}$ $year^{-1}$. Also, nitrogen and phosphorus should be applied as a 1500 g N $tree^{-1}$ and 750 g P $tree^{-1}$ every year also to improve product yield and quality, and to increase the function of potassium in the plant.

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