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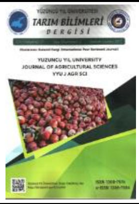

Araştırma Makalesi (Research Article)

Changes in Qualitative and Quantitative Traits of Anatolian Chestnuts (*Castanea sativa* Mill.) Fruit Due to Balanced Macro Fertilization

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Abstract: The aim of this study was to determined effect of different doses of N: P: K applications on fruit yield and some quality traits in Anatolian chestnut in Bursa (Turkey) ecological condition during 2013 and 2014. In the research, triple experimental zones were determined in a 20-year-old chestnut orchard. Each of these experimental zones consisted of 30 trees. As experimental treatments, 1.1, 2.2, 3.3, and 4.4 lb N tree^{-1} (N application zone; NAZ), 0.55, 1.1, 1.65, and 2.2 lb P tree^{-1} (P application zone; PAZ), 1.1, 2.2, 3.3, and 4.4 lb K tree^{-1} (K application zone; KAZ) were applied except for the control dose. The fertilizer doses were applied by mixing to 30 cm depth of tree canopy soil in April. According to analyses of collected, nitrogen, phosphorus, and potassium affected fruit yield by 30, 31, and 27%, respectively. Total protein increased the fastest at the nitrogen application's zone (NAZ) at an average of 14% rate. The highest increasing in carbohydrate, starch, and invert sugar was recorded as 20, 24, and 18%, respectively at N: P: K application's zone.

Dengeli Makro Gübrelemeye Bağlı Olarak Anadolu Kestanesi (*Castanea sativa* Mill.) Meyvelerinin Kalitatif ve Kantitatif Özelliklerinde Değişimler

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Anahtar kelimeler
Kestane,
Gübreleme,
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Kalite.

Öz: Bu çalışmanın amacı, Bursa (Türkiye) ekolojik koşullarında 2013 ve 2014 yıllarında Anadolu kestanesinde farklı dozlarda N: P: K uygulamalarının meyve verimi ve bazı kalite özellikleri üzerindeki etkisinin belirlenmesidir. Araştırmada, 20 yıllık bir kestane bahçesinde örneklenen üçlü deneme bölgelerinde gerçekleştirilmiştir. Bu deneme bölgelerinin her biri 30 ağaçtan oluşmaktadır. Deneme konuları olarak, kontrol dozu haricinde 1.1, 2.2, 3.3 ve 4.4 lb N ağaç$^{-1}$ (N uygulama bölgesi; NAZ), 0.55, 1.1, 1.65 ve 2.2 lb P ağaç$^{-1}$ (P uygulama bölgesi; PAZ), 1.1, 2.2, 3,3 ve 4,4 lb K ağaç$^{-1}$ (K uygulama bölgesi; KAZ) uygulanmıştır. Gübre dozları Nisan ayında 30 cm derinliğindeki ağaç taç izdüşümü toprağına karıştırılarak uygulanmıştır. Elde edilen verilere göre azot, fosfor ve potasyum meyve verimini sırasıyla % 30, % 31 ve % 27 oranında etkilemiştir. Toplam protein, en hızlı nitrojen uygulama bölgesinde (NAZ) ortalama % 14 oranında artmıştır. Karbonhidrat, nişasta ve invert şekerde en yüksek artış N, P, K uygulama bölgelerinde sırasıyla % 20, 24 ve 18 olarak kaydedilmiştir.

1. Introduction

Generally, macro fertilization defines the three essential nutrients nitrogen, phosphorus, and potassium needed by cultivated plants. It has direct effects on the vegetative and generative development of plants as well as fruit yield and quality. Chestnuts are wealthy in starch and sugars, principally monosaccharides, and disaccharides such as glucose, fructose, sucrose, and raffinose. Besides, chestnuts diverge from other nuts for their low-fat content which makes them an ideal fit for high complicated carbohydrates and they have an inimitable taste (Vasconcelos et al., 2010). Chestnut fruits are highly esteemed and widely consumed throughout Europe, America, and Asia. Worldwide chestnut production is 2 327 500 tons. Chestnuts are mainly cultivated in China (1 879 000 tons), Bolivia (84 800 t.), Turkey (64 750 t.), and the Republic of Korea (56 200 tons) (FAO, 2019).

A fertilizer program is needed to make fertilizer product profitability and get products of high quality in chestnut production. If chemical fertilization is to be applied, fertilizers of the appropriate type and quantity can be determined by a regular soil analysis. Regardless of the type of fertilizer, applications have to be passed in spring and never fertilization after June (Wahl, 2002). Because of the gathering of potential in fruit, nitrogen fertilizers could be expected to affect plenty of quality properties, primarily protein content in chestnut. It has been reported that low levels of nitrogen in chestnuts while cause poor growth and reduced flowering, low phosphorus levels cause a decrease in the number of developing female flowers (Rutter et al., 1990).

The goal of this study is to determine the effect of N: P: K mineral fertilizer applications on fruit qualitative and quantitative properties in mature Anatolian chestnut trees. Also, this study is to prove the change of some nutritional values of sugar chestnuts with macro fertilization.

2. Materials and Methods

2.1. Site properties

The experiment was carried out in a chestnut orchards of Bursa in the Osmanoğlu cultivar the sweet Anatolian chestnut trees of 20 years old during 2013 and 2014. Chestnut orchard was divided into three fertilization zones as nitrogen application zone (NAZ), phosphorus application zone (PAZ), and potassium application zone (KAZ). The study was prepensed as a randomized parcel design with three replications and two trees in each parcel. Fertilization was applied to a total of 90 trees.

Nitrogen fertilizer applications were adjusted to be N_0: 0, N_1: 1.1, N_2: 2.2, N_3: 3.3, N_4: 4.4 lb tree^{-1}, phosphorus fertilizer applications, P_0: 0, P_1: 0.55, P_2: 1.1, P_3: 1.65, P_4: 2.2 lb tree^{-1} and potassium fertilizer applications, K_0: 0, K_1: 1.1, K_2: 2.2, K_3: 3.3, K_4: 4.4 lb tree^{-1}. Moreover, support fertilizers were applied for nitrogen application treatments as 1.65 lb P tree^{-1} and 3.3 lb K tree^{-1}, for phosphorus application treatments as 3.3 lb N tree^{-1} and 3.3 lb K tree^{-1}, for potassium application treatments as 3.3 lb N tree^{-1} and 1.65 lb P tree^{-1}. Treatments and support fertilizers were applied to the canopy of the chestnut tree in April month mixed in 0-30 cm soil depth. In the research, urea (CH_4N_2O) was used as a nitrogen origin, triple superphosphate ($Ca(H_2PO_4)_2.H_2O$) as a phosphorus origin, and potassium chloride (KCl) as a potassium origin.

The territory is located in the Marmara and the Aegean climate transitional zone. In the vegetation period (from March to October), the total amount of annual rainfall was 364.4 mm in the first year and 398.9 mm in the second year. The average temperature throughout the study was consistent with the long-term average temperature (18.3 C). Also, the total rainfall was coherent with the total rainfall long term years. Climate data for the experimental orchard and periods were shown in Figure 1.

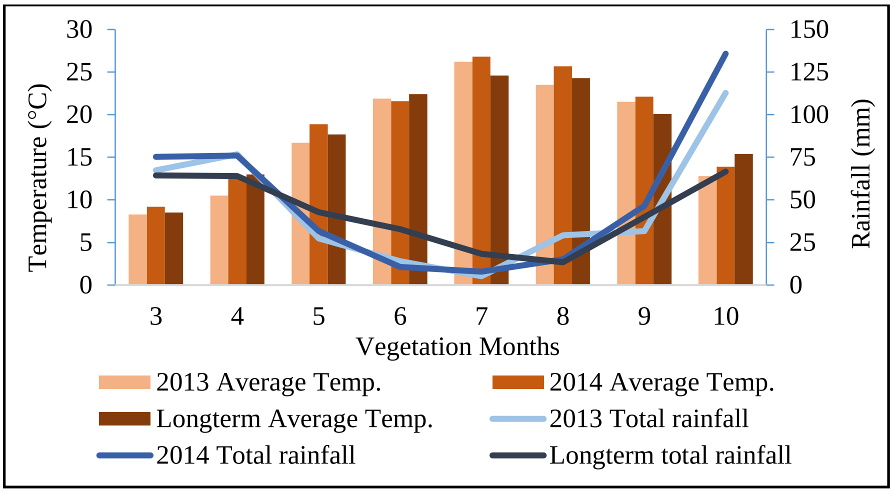

Figure 1. Climate data of the research site during the chestnut vegetation period over two years.

The soil samples of the research site were taken in March. Some physical and chemical analyses of soils concerning to the chestnut orchard were presented in Table 2. According to results, when the soil properties of the chestnut orchard were examined, it was determined that the soil's physical structure was loamy, the soil pH was slightly acidic (5.65), and organic matter (1.51 %) were insufficient. It was found that the total salt (0.04 %) and CaCO3 (0.38%) content of the soil were low levels. Also, the macronutrient contents were determined to be insufficient and micronutrient contents were found to be sufficient in the soil.

Table 1. Some soil physicochemical characteristics of the research orchard (0-30 cm depth)

Soil characteristics		Methods	Soil characteristics		Methods*
Soil texture	Loamy	Bouycous	Potassium (mg kg^{-1})	124.2	NH_4OAc
Total Salt (%)	0.04	Saturation sludge	Calcium (mg kg^{-1})	620.8	NH_4OAc
pH; 1:1 (w/v)	5.65	Saturation sludge	Magnesium (mg kg^{-1})	152.3	NH_4OAc
$CaCO_3$ (%)	0.38	Scheibler	Iron (mg kg^{-1})	42.15	DTPA
Organic matter (%)	1.51	Walkley-Black	Zinc (mg kg^{-1})	1.26	DTPA
Total nitrogen (%)	0.05	Kjendahl	Manganese (mg kg^{-1})	51.24	DTPA
Phosphorus (mg kg^{-1})	7.36	Olsen	Cupper (mg kg^{-1})	0.76	DTPA

*NH_4OAc: Amonium Acetate, DTPA: Diethylenetriaminepentaacetic acid.

2.2. Harvest and biochemical analysis in fruit

Chestnuts were harvested during the mercantile harvest period (mid-October) in Bursa when fruits reached a physiological maturity stage where the chestnut burs began to separate and the fruits had grown and brown color. To determine the gross yield of each tree, nuts were harvested by vibrating trees and picking by hand. The fruit samples of randomly sampled 120-150 gr nuts were analyzed by crushing them with mortar after removing their outer shell and seed shell (testa). Dry matter contents of the samples were determined by drying them in a hot air oven at 105 °C overnight (12 h) (Ertürk et al., 2006).

The total protein content was calculated by multiplying the nitrogen content by the Kjeldahl method with a coefficient of 5.30 (AOAC, 1990). The dinitrophenol method was used in the analysis of total carbohydrate, total and invert sugar (Ross, 1959) using a Beckman Du 530 model spectrophotometer. The amount of starch was calculated by multiplying the value obtained by subtracting total sugars from total carbohydrates by a factor of 0.94.

2.3. Statistical analysis

The data was analyzed by JMP according to the randomized parcels design. The differences between the average values and application years were determined by the LSD test and the relationships between the features examined were also estimated in the same statistic package. The means were grouped by the Duncan test.

3. Results and Discussion

3.1. Fruit yield

Fertilizers applied in a certain balance contributed significantly to chestnut yields at statistical levels ($p<0.05$) in all fertilizer application zones (Table 2). The fastest yield increasing was achieved in the nitrogen application zone (NAZ). In the first year, the yields increased by about 25% compared to the control, while the yields increased by about 37% in the second year. Statistical significance was showed at both the year and the dose level. Besides, year x fertilizer dose interaction was found to be statistically significant. The N_3PK dose of average fruit yields came to the fore and the highest yield was recorded at this dose of balanced fertilizer. As it is known, when nitrogen is applied to plants, it causes an increase in nutrients in leaf tissues and thus an increase in yield (Centeno and Campo, 2011; Yağmur et al., 2019).

Table 2. Chestnut yields (lb tree^{-1}) after balanced N:P:K applications.

	Nitrogen Application Zone (NAZ)				
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	60.5 ^{def*}	58.7 ^{f}	63.6 ^{cd}	75.5 ^{a}	63.8 ^{cd}	64.4 ^{A*}
2014	51.5 ^{g}	59.2 ^{ef}	66.2 ^{c}	70.4 ^{b}	62.7 ^{cde}	62.0 ^{B}
Average	56.0 ^{D*}	59.0 ^{C}	64.9 ^{B}	73.0 ^{A}	63.3 ^{B}	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	48.6	54.1	59.0	60.3	49.5	54.3 ^{B*}
2014	47.1	54.8	61.6	64.9	55.9	56.8 ^{A}
Average	47.9 ^{C*}	54.5 ^{B}	60.3 ^{A}	62.6 ^{A}	52.7 ^{B}	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	47.4	47.4	56.0	60.6	58.1	53.9
2014	49.4	53.9	55.2	62.5	62.8	56.8
Average	48.4 ^{D*}	50.7 ^{CD}	55.6 ^{BC}	61.5 ^{A}	60.5 ^{AB}	

The capital letters represent the results of the Duncan test (*, $P<0.05$) for averages, and lower case letters show the results of the Duncan test (*$P<0.05$) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

In the balanced fertilization in the phosphorus application zone (PAZ), the highest yield was found at the P_3NK dose. Statistically significant differences were obtained in both the years and the fertilizer dose level. But, Year x Fertilizer interaction was not significant. Fruit yields increased by an average of 35% in this zone. The most obvious reason for this situation is the nitrogen and potassium applications applied together. In the first year, the fruit yield increased by 24% compared to the control level, while in the second year it increased by approximately 33%. Studies on cultivated plants have shown that phosphorus fertilizers significantly increase the amount of crops and continuous phosphorus application has stimulating effects on yield (Güneş et al., 2010).

Fruit yield increased by an average of 27% with a balanced fertilization in the potassium application zone (KAZ). Although there was no statistically significant difference between the application years, significant differences were obtained between the fertilizer doses. Besides, year x fertilizer interaction was not significant. In the first year, while fertilizer balanced potassium fertilizer applications increased the yield of approximately 28%, in the second year, 27% yield increase was recorded. The highest fruit yield was detected in K_3NP balanced fertilizer application. Potassium applications increase the size, yield, and quality of the fruit (Kacar and Katkat, 2011).

3.2. Total protein

According to the protein analysis results, no statistically significant ($p<0.05$) difference was found between the application years in all application zones. Despite, important differences have been obtained between the application levels. Also, year x fertilizer interaction was found to be statistically insignificant in all fertilizer application zones (Table 3). The fastest fruit protein content increase was obtained in NAZ (N_3PK: 10.64 mg 100 g^{-1}). An increase of approximately 14% has been determined in this application compared to the control dose. The amount of nitrogen in the soil and many cultural practices could be effective on the protein ratio and quality (Fageria et al., 2011).

Table 3. Chestnut total protein (g 100 g^{-1}) contents after balanced N:P:K applications

	Nitrogen Application Zone (NAZ)					
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	9.20	9.56	10.51	10.61	10.13	10.00
2014	9.42	9.61	10.54	10.66	9.86	10.02
Average	9.31 ^{C*}	9.59 ^{C}	10.52 ^{A}	10.64 ^{A}	10.00 ^{B}	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	6.05	6.61	6.03	6.04	6.11	6.17
2014	6.19	6.43	6.76	6.34	5.81	6.31
Average	6.12 ^{BC*}	6.52 ^{A}	6.40 ^{AB}	6.19 ^{ABC}	5.96 ^{C}	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	6.68	6.87	6.98	7.25	7.24	7.01
2014	6.85	6.98	7.03	7.33	7.27	7.09
Average	6.77 ^{C*}	6.92 ^{BC}	7.01 ^{ABC}	7.29 ^{A}	7.26 ^{AB}	

The capital letters represent the results of the Duncan test (*, P <0.05) for averages, and lower case letters show the results of the Duncan test (*P<0.05) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

However, the highest fruit protein content in PAZ was recorded as 6.52 mg 100 g^{-1} for P_1NK dose. An increase of 6.5% was achieved compared to the control level with this application. In addition, the lowest fruit protein content at the highest P level was determined as 5.96 mg 100 g^{-1}. So, when N and K were in equilibrium, increasing of P were decreased the protein content of fruit. This perhaps due to the negative interaction of nitrogenous and potassium fertilizers given in basic fertilization with the final phosphorus dose. As known, fertilization with high amounts of phosphorus causes the plants are not to benefit from sufficient nitrogen and potassium (Kacar and Katkat, 2011).

Potassium plays a role in protein synthesis in plant growth and is essential for the production of high-energy molecules such as ATP (Imas, 1999). The highest fruit protein content in KAZ was recorded as 7.29 mg 100 g^{-1} for K_3NP. Unlike P, fruit protein content increased as K levels increased. A 7.7% increase was detected at this dose compared to the control dose. The protein contents was reported between 3.43 and 13.28 g 100 g-1 by researchers on chestnut. (Ertürk et al., 2006).

3.3. Carbohydrate

Statistically significant differences were obtained in fruit carbohydrate contents only in NAZ and KAZ both between years and between doses. In PAZ, on the other hand, no statistically significant difference was detected only between application doses. In addition, year x fertilizer interactions were found important in all regions. The second dose of fertilizers applied in NAZ and PAZ achieved the highest carbohydrate content. A decrease was noted with subsequent doses. However, in KAZ, the highest carbohydrate content was detected in the third application dose (Table 4). The highest carbohydrate content in NAZ was recorded as 45.9 mg 100 g^{-1} at the N_2PK dose. In this balanced nitrogen application, an increase of 17.4% was achieved compared to the control dose. A decrease in the carbohydrate content of the fruit was noted at doses after this dose. As the amount of nitrogen applied to plants increases, the content of carbohydrates decreases (Rodrigues et al., 2006).

Table 4. Chestnut carbohydrate (g 100 g^{-1}) contents after balanced N:P:K applications

	Nitrogen Application Zone (NAZ)					
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	40.0 ^{ef*}	40.3 ^{de}	41.9 ^{cd}	39.1 ^{ef}	42.6 ^{c}	40.8 ^{B*}
2014	38.2 ^{f}	46.1 ^{b}	49.9 ^{a}	44.5 ^{b}	40.1 ^{e}	43.8 ^{A}
Average	39.1 ^{D*}	43.2 ^{B}	45.9 ^{A}	41.8 ^{C}	41.3 ^{C}	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	51.8 ^{cd*}	52.9 ^{cd}	52.6 ^{cd}	51.1 ^{d}	51.4 ^{cd}	52.0 ^{B*}
2014	52.6 ^{cd}	53.6 ^{bc}	55.8 ^{a}	57.0 ^{a}	55.5 ^{ab}	54.9 ^{A}
Average	52.2	53.3	54.2	54.1	53.5	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	35.3 ^{e*}	40.6 ^{c}	40.5 ^{c}	40.6 ^{c}	39.8 ^{cd}	39.4 ^{B*}
2014	38.1 ^{d}	42.7 ^{b}	46.7 ^{a}	47.4 ^{a}	43.9 ^{b}	43.8 ^{A}
Average	36.7 ^{C*}	41.7 ^{B}	43.6 ^{A}	44.0 ^{A}	41.9 ^{B}	

The capital letters represent the results of the Duncan test (*, P <0.05) for averages, and lower case letters show the results of the Duncan test (*P<0.05) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

Besides, compared to the first application year, the carbohydrate increase was 7.3% in the second year. Carbohydrate content was recorded as 54.2 g 100 mg^{-1} for the highest P_2NK dose in PAZ. Compared to the control level, this dose increased by a 3.8% rate. Furthermore, compared to the first year, the fruit carbohydrate content increased by 5.6% in the second year. Moreover, when there was enough phosphorus in the fruit, the amount of starch could be increase (Fageria et al., 2011). The fastest increase in carbohydrate content occurred a 19.9% increase in the K_3NP dose was noted compared to the control dose in KAZ. Potassium was very effective on carbohydrate mechanism. In addition, continuously applied potassium increases the quality of cultivated plants (Kumar et al., 2006). In addition, the fastest carbohydrate increase among the years has been determined in KAZ. Carbohydrate content increase in the second year was recorded at approximately 11.1% compared to the first year.

3.4. Total starch

Starch content of chestnut fruit gave positive responses to balanced macro fertilization in all fertilizer application zones. The applied fertilizers were found to statistically significant contributions to the fruit starch content. However, significant statistical differences have been obtained in NAZ and KAZ both between years and between applications. Starch contents were found to be statistically significant in PAZ only between years. In addition, statistical differences in year x fertilizer interactions of all applications were recorded (Table 5).

The highest starch content in NAZ was determined as 35.7 mg 100 g^{-1} at N_2PK application. According to the control level, the starch content increased by about 20% in this application. Also, compared to the first year, the fruit starch content increased by 6% in the second year. In PAZ that another application zone, the highest starch content was recorded as 43.3 mg 100 g^{-1} for P_2NK application. Compared to the first year, the starch content in the fruit increased by 6.5% in the second year. However, after the second dose applied in both NAZ and PAZ, the starch content decreased despite the increased fertilizer applications. Also, when there was excessive phosphorus in fruit, the amount of starch perhaps decreased (Kumar et al., 2006).

Table 5. Chestnut total starch (g 100 g^{-1}) contents after balanced N:P:K applications

	Nitrogen Application Zone (NAZ)					
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	30.6 ^{ef*}	31.1 ^{de}	32.6 ^{cd}	29.1 ^{f}	33.2 ^{c}	31.3 ^{B*}
2014	29.0 ^{f}	35.5 ^{b}	38.9 ^{a}	33.3 ^{c}	29.4 ^{ef}	33.2 ^{A}
Average	29.8 ^{D*}	33.3 ^{B}	35.7 ^{A}	31.2 ^{C}	31.3 ^{C}	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	41.9 ^{de*}	42.2 ^{de}	41.8 ^{de}	40.4 ^{e}	40.7 ^{de}	41.4 ^{B*}
2014	42.5 ^{cde}	42.8 ^{bcd}	44.8 ^{ab}	45.9 ^{a}	44.5 ^{abc}	44.1 ^{A}
Average	42.2	42.5	43.3	43.2	42.6	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	24.8 ^{f*}	29.4 ^{cd}	28.9 ^{de}	29.0 ^{de}	28.1 ^{de}	28.0 ^{B*}
2014	27.2 ^{e}	31.1 ^{bc}	34.8 ^{a}	35.3 ^{a}	32.1 ^{b}	32.1 ^{A}
Average	26.0 ^{C*}	30.3 ^{B}	31.8 ^{A}	32.2 ^{A}	30.1 ^{B}	

The capital letters represent the results of the Duncan test (*, P <0.05) for averages, and lower case letters show the results of the Duncan test (*P<0.05) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

Furthermore, the fastest increasing in fruit starch content was determined in KAZ. Approximately 24% increasing was determined for K_3NP application compared to the control. In addition, a very fast increasing in sugar was found over the years. Fertilizers applied in the second year compared to the first application year increased the fruit sugar ratio by approximately 15%. Potassium action in starch synthetase enzyme activity is quite high up to a certain grade (Fageria et al., 2011). Starch was transported to the storage organs especially in the entity of adequate potassium (Kacar and Katkat, 2011).

3.5. Total sugar

Significant statistical differences were recorded between total sugar content and all fertilizer applications in NAZ, PAZ, and KAZ. However, statistically, significant differences were detected between years and year x fertilizer interactions only in NAZ (Table 6).

Table 6. Chestnut total sugar (g 100 g^{-1}) contents after balanced N:P:K applications

	Nitrogen Application Zone (NAZ)					
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	8.17 ^{c*}	7.93 ^{c}	7.94 ^{c}	8.85 ^{b}	7.97 ^{c}	8.17 ^{B}
2014	8.00 ^{c}	9.08 ^{b}	9.41 ^{ab}	9.79 ^{a}	9.44 ^{ab}	9.14 ^{A}
Average	8.09 ^{C*}	8.50 ^{BC}	8.67 ^{B}	9.32 ^{A}	8.71 ^{B}	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	7.25	8.01	8.09	8.12	8.15	7.92
2014	7.37	8.09	8.12	8.19	8.11	7.98
Average	7.31 ^{B*}	8.05 ^{A}	8.11 ^{A}	8.16 ^{A}	8.13 ^{A}	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	8.98	9.27	9.75	9.78	9.94	9.54
2014	9.14	9.64	9.70	9.87	9.73	9.62
Average	9.06 ^{C*}	9.46 ^{B}	9.73 ^{AB}	9.83 ^{AB}	9.84 ^{A}	

The capital letters represent the results of the Duncan test (*, P <0.05) for averages, and lower case letters show the results of the Duncan test (*P<0.05) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

Total sugar content in fruit was recorded as 9.32 mg 100 g^{-1} at the highest N_3PK dose in NAZ. Against the control dose, a 15% increase in the fruit sugar content was determined at the N_3PK dose. However, compared to the first year, the total sugar rate in the second year increased by approximately 12%. But, the sugar content decreased at the final N dose. The sugar content decreases at increasing nitrogen doses (Kumar et al., 2006). The excess of nitrogen is elongated the vegetative progress term of the plant, delays blooming, and decreases sugar synthesis (Fageria et al., 2011). The total sugar content was found to be 8.16 mg 100 g^{-1} at the P_3NK dose and an increase of approximately 12% was determined compared to the control in PAZ. There was no statistical difference between years in the PAZ. However, the sugar content was noted as the highest in KAZ, with an average of 9.84 mg 100 g^{-1} in K_4NP. Despite the increasing potassium doses, there was an increase in the total sugar content of the fruit. An increase of about 9% was obtained in the last dose compared to the control level. Plant nutrition with phosphorus and potassium contributes positively to sugar metabolism (Mengel, 1991).

3.6. Invert sugar

The invert sugar content in chestnuts was found to be very low compared to total sugar. The total sugar ratio of invert sugar was determined as 6.5, 6.2, and 12.6% in NAZ, PAZ, and KAZ, respectively. Year x fertilizer interaction was found to be statistically insignificant in all fertilizer application zones. Nevertheless, significant statistical differences were obtained both year and fertilizer doses in PAZ. However, K doses also made statistically significant contributions to the amount of invert sugar in the fruit (Table 7).

Table 7. Chestnut invert sugar (g 100 g^{-1}) contents after balanced N:P:K applications

	Nitrogen Application Zone (NAZ)					
Years	N_0PK	N_1PK	N_2PK	N_3PK	N_4PK	Average
2013	0.573	0.550	0.590	0.580	0.583	0.575
2014	0.543	0.553	0.570	0.577	0.497	0.548
Average	0.558	0.552	0.580	0.578	0.540	
	Phosphorus Applications Zone (PAZ)					
Years	P_0NK	P_1NK	P_2NK	P_3NK	P_4NK	Average
2013	0.477	0.514	0.507	0.443	0.450	0.478 ^{B*}
2014	0.523	0.527	0.496	0.499	0.490	0.507 ^{A}
Average	0.500 ^{AB*}	0.520 ^{A}	0.501 ^{AB}	0.471 ^{B}	0.470 ^{B}	
	Potassium Applications Zone (KAZ)					
Years	K_0NP	K_1NP	K_2NP	K_3NP	K_4NP	Average
2013	0.537	0.611	0.690	0.640	0.610	0.618
2014	0.560	0.607	0.610	0.557	0.610	0.589
Average	0.548 ^{B*}	0.609 ^{A}	0.650 ^{A}	0.599 ^{AB}	0.610 ^{A}	

The capital letters represent the results of the Duncan test (*, $P < 0.05$) for averages, and lower case letters show the results of the Duncan test (*$P<0.05$) for interaction between years and treatments. There is no statistical difference between values not shown with letters.

Increasing nitrogenous fertilizer applications showed a situation that did not affect invert sugar among all fertilizer applications. However, the highest fruit invert sugar content was detected at the N_2PK application dose (0.580 mg 100 g^{-1}). Compared to the first year, the invert sugar content decreased by 5% in the second year. This situation paralleled the increase in nitrogen doses. But, the invert sugar content in the fruit decreased by 7.4% in the last two doses. The invert sugar content decreases in excess nitrogen doses (Fageria et al., 2011).

Phosphorus applications also affect showed similarly to NAZ. The highest invert sugar content for P_1NK averaged 0.520 mg 100 g^{-1}, while it tended to decrease as increasing phosphorus doses. There was a 10.6% rate decline in the final P dose. Yet, against the first year, invert sugar increased by 6% in the second year in PAZ. The invert sugar content in the fruit gave positive responses to increasing K doses. The fastest increase occurred in this application zone. Compared to the control level, the K_2NP dose increased the fruit invert sugar content by about 19%. Whereas, there was a 5% decrease in the second year compared to the first year between the implementation years. In spite of potassium does not constitute a part of the structure of plant components, it increases the quality of fruits by providing the desired sugar-acid balance and maturing of the fruit (Kumar et al., 2006).

3.7. Correlation analyses

According to correlation analyses, a statistically significant strong positive relationship was found between chestnut fruit yield and all fertilizer application doses (Table 8). While there was a strong positive correlation between N and K applications on total protein content, P doses had no significant effect on fruit protein content. A statistically significant and strong correlation was noted between carbohydrate and starch contents and P and K applications. In addition, it has been determined that N has no effect on both carbohydrate and starch mechanisms. All applications made statistically significant and positive contributions to the total sugar ratio. A negative correlation was found between fruit invert sugar content P applications. However, statistically insignificant relationships were estimated between invert sugar in fruit and N and K applications.

Table 8. Relationship of chestnut yield and some quality properties due to balanced N: P: K applications according to Pearson's correlation model

Qualitative and quantitative parameters	Fertilizer Application Zones		
	NAZ	PAZ	KAZ
Yield (kg tree^{-1})	0.620**	0.424*	0.752**
Total protein (g 100 g^{-1})	0.599**	-0.239^{ns}	0.617**
Carbohydrate (g 100 g^{-1})	0.122^{ns}	0.415*	0.492**
Total starch (g 100 g^{-1})	0.041^{ns}	0.505*	0.439*
Total sugar (g 100 g^{-1})	0.385*	0.729**	0.678**
Invert sugar (g 100 g^{-1})	-0.026^{ns}	-0.424*	0.289^{ns}

**. Correlation is significant at the 0.01 level, *. Correlation is significant at the 0.05 level, ns: not significant

4. Conclusions

The results of this study proved that balanced macro fertilization has an effect on the yield and some quality characteristics of chestnuts. However, chestnut tree is still accepted in the world as a forest tree. Therefore, the chestnut plant does not sufficiently care and cultural processes. Yet, as in other cultivated plants, chestnut needs some cultural processes such as soil cultivation, fertilization and irrigation. Although this study is a regional study, it seems effective in revealing the nutrients that affect the yield and quality of a mature chestnut tree and drawing a certain road map. Also, different regional macro plant nutrients applied in the same garden presented various evidence for the parallelism of the study.

In the light of all the data, the most appropriate N dose to be applied to the soil per tree in mid-April was determined as 3.3 lb, P dose 1.65 lb and K dose 3.3 lb. In addition to this situation, it is necessary to make organic fertilization in order to increase the organic matter in chestnut orchards. Thus, the effectiveness of other chemical fertilizers applied to the soil will increase and some physical and biological properties of the soil will be enriched in chestnut orchards.

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