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Effect of pollinator cultivars on nutrient content in some Turkish hazelnut cultivars

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ABSTRACT

The main objective of this study was to assess the pollen effects on macro and micro nutrition elements on hazelnut cultivars (*Corylus avellana* L.). Tombul, Palaz, Çakıldak, Foşa and Allahverdi were used as main cultivars while Tombul, Palaz, Çakıldak, Foşa, Allahverdi, Sivri, Kalınkara and Yassı Badem were used as pollinator cultivars. In the study, it was investigated that the pollinator cultivars caused changes in some nutrition elements. The effects of the applications on nitrogen, phosphorus and potassium content were found to be statistically significant. It was determined that the nutrition element with the highest rate in the examined hazelnut cultivars is potassium. It has been observed that the amount of potassium is high in Tombul-pollinator treatments. The potassium content of Foşa and Çakıldak weres found to be higher than other cultivars. In Palaz and Yassı Badem-pollination treatments, it has been observed that the Ca content is generally lower than other treatments. Fe content was found to be significantly higher in Palaz-pollination treatments. The highest Mn and Zn content was obtained from Çakıldak. As a result, it has been revealed that pollinators may have an effect on nutrient content.

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1. Introduction

Anatolia is the place where *Corylus avellana* L. was first cultivated. Turkey, which ranks first in the world hazelnut production. Italy, Azerbaijan, USA and Iran are other important hazelnut producing countries (FAO, 2021). 80-85% of the hazelnuts produced in Turkey are exported and export revenues are obtained from the average $ 1.9 billion (Anonymous, 2021). Hazelnut production in Turkey is mainly in the coast cities of the Black Sea region. Hazelnut production is the main source of income for the eastern Black Sea region and provides a large amount of foreign currency return to our country. Therefore, hazelnut is an important agricultural product in Turkey.

Hazelnut is a very rich food source in terms of mineral substances. The mineral substance in 100 g of hazelnut kernels can easily meet an adult person's daily needs for Fe, Mg, Cu, Mn, K, P, Zn and Ca. Low sodium, high Mg, Ca and K in hazelnuts play a role in regulating of blood pressure in the body. Hazelnuts are particularly rich in Ca maintenance, which is necessary for bone and tooth development. It is also one of the sources rich in Fe, which is necessary to prevent of anemia, digestive and respiratory system disorders. In addition, Mg, which is necessary for the prevention of respiratory and nervous system disorders; Cu, which is necessary for the prevention of anemia, weight loss, reproductive and growth disorders; Mn, which is necessary to prevent growth, growth and reproductive disorders; K, which is necessary for the prevention of disorders in the heart, muscle, nervous system, development and hormonal systems, high blood sugar and strokes; Zn, which is necessary for the prevention of growth, reproduction and immune system disorders, hair loss and loss of appetite; and a good resource for P, which is essential for rickets prevention (Şimşek and Aslantaş, 1999).

Many studies have been conducted to determine the macro-elements and micro-elements levels in hazelnuts (Şimşek, 2004; Köksal et al., 2006; Özenç et al., 2015). However, in some studies, it was emphasized that conditions such as cultivar, climate and soil conditions, fertilization and irrigation, cultivation technique and geographical region might affect the content of mineral matter, protein, oil and ash (Amaral et al., 2006; Köksal et al., 2006; Cristofori, 2008).

100 g of the Tombul hazelnut cultivar meets the requirement of an adult person's 43.5% phosphorus, 13.2% potassium, 19.4% calcium, 37% magnesium, 0.2% sodium, 53.8% iron, and 24.5% zinc (Özenç et al., 2015). It is also stated that the pollinator may have an effect on the nut quality of hazelnut (Fattahi et al., 2014; Balik and Beyhan, 2019; Balik and Beyhan, 2020), walnut (Golzari et al., 2016), almond (Torregrossa et al., 1993; Legave et al., 1997; Dicenta et al., 2002) and pistachio (Ak, 2001; Alhajjar et al., 2015). The effect of pollinators on nut quality occurs due to xenia. Denney (1992) defined xenia as pollen-induced changes in seed and fruit shape, color, ripening time and chemical composition. In this study, it was aimed to determine the changes in macronutrient and micronutrient content of hazelnut depending on the pollinator.

2. Materials and methods

2.1. Area description

This study was conducted under ecological conditions of Giresun province in the Black Sea Region in North of Turkey in 2016. Tombul, Palaz, Çakıldak, Foşa and Allahverdi were used as main cultivar. These cultivars were controlled-pollinated with Sivri, Kalınkara and Yassı Badem cultivars. Self-pollination was done as a control treatment. Experiments were conducted in randomized blocks design with 3 replications and with 3 plants in each replication.

2.2. Emasculation, isolation and pollen collection

In plants of main cultivars to be controlled-hybridized, male flowers (catkins) were removed as specified by Erdoğan and Mehlenbacher (1997). Plants of main cultivars were surrounded by 4 m high and 4 m wide iron constructions and entire plant was encapsulated within this framework and covered with Tyvek®. When the catkins of pollinizer cultivars started to elongate, they were carefully cut together with the shoot bearing catkins, then they were placed in water-filled glass jars and kept at room temperature for 24 hours. Following 24 h, catkins were shaken over a black paper, pollens were sieved through 125 µ sieve and transferred to the preservation cups. Pollens were preserved in a deep freezer at -18 °C until the use.

2.3. Controlled pollinations

When the female flowers of main cultivars become receptive, pollens were used for crossing. Stigmatic styles can accept pollens as soon as they went out of the florets, but it was waited until these styles got a shiny red color for an effective pollination. The artificial pollination was performed through touching to styles of the florets with the index finger.

2.4. Macro and micro elements

The samples have been dried under the sun until the humidity level falls below 6% and it was stored in a deep freezer at -18 ° C until analysis. Analyzes were made in 3 replications. 50 g of hazelnuts are used in each replication. While the nitrogen (N) was determined by the Kjeldahl method, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) elements of hazelnuts, ground hazelnut kernel samples were burned in microwave oven and readings were made at ICP (AOAC, 2000).

2.5. Statistical analysis

Experimental data were subjected to statistical analyses with SAS Version 9.1 software. Significant means were compared with the Duncan's multiple range test at a 5% level ($P<0.05$). No data was obtained in Palaz × Palaz crossings.

3. Results and discussion

3.1. Nitrogen (N)

The effects of the applications on the N amount were found to be statistically significant ($P<0.05$). In Tombul pollinated with Sivri, the N amount was significantly higher than self-pollination. On the other hand, Palaz, Çakıldak, Foşa, Allahverdi and Yassı Badem-pollination treatments on Tombul, the N amount was significantly lower than self-pollination. In Palaz pollinated with Tombul, the amount of N was significantly higher than other applications. In Çakıldak-pollination treatment, the amount of N was found to be significantly lower than other treatments. In Çakıldak, the amount of N in all treatments was determined to be lower than self-pollination and this difference was found to be statistically significant. In Foşa, the significantly higher N content was determined in Sivri-pollination treatment. In Allahverdi, the N amount was determined to be significantly higher than the self-pollination in the Tombul, Palaz, Çakıldak, Foşa, Sivri, Kalınkara and Yassı Badem-pollination treatments (Table 1).

3.2. Phosphorus (P)

The effects of the treatments on the amount of P were found statistically significant ($P<0.05$). The effects of the applications on the amount of P in the Tombul were found to be statistically similar to self-pollination. However, the effects of the treatments have been at different levels. In the Palaz, the amount of P in Sivri-pollination treatment was determined to be significantly higher than other treatments. In Çakıldak, although the P amount in Foşa, Kalınkara and Yassı Badem-pollination treatments was higher than by self-pollination, this numerical difference was not statistically significant.

Table 1. Effect of pollinators on nitrogen (N) content (%) of hazelnut cultivars

Pollinator Cultivars	Main Cultivars				
	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	2.93 b	2.83 a	3.09 b	2.71 c	2.59 d
Palaz	2.67 d	-	2.70 e	2.64 de	2.77 c
Çakıldak	2.79 c	2.32 e	3.23 a	2.67 cd	2.73 c
Foşa	2.63 e	2.45 bc	2.60 f	2.51 f	3.13 a
Allahverdi	2.82 c	2.39 d	2.62 f	2.89 b	2.50 e
Sivri	3.12 a	2.45 bc	2.91 c	3.01 a	2.87 b
Kalınkara	2.91 b	2.44 cd	2.70 e	2.58 ef	2.57 d
Yassı Badem	2.53 f	2.43 cd	2.73 de	2.61 de	2.59 d

The differences among the treatments indicated with the same letter vertically were not significant at $P<0.05$.

Significantly lower amounts of P were detected in Tombul, Çakıldak and Yassı Badem-pollination treatments compared to self-pollination. Şimşek (2004), determined the amount of P as 300 mg $100g^{-1}$ in Tombul, 271.6 mg $100g^{-1}$ in Palaz and 255.9 mg $100g^{-1}$ in Foşa. Köksal et al. (2006) determined the P amount as 288 mg $100g^{-1}$ in Tombul, 370 mg $100g^{-1}$ in Palaz, 335 mg $100g^{-1}$ in Çakıldak and 339 mg $100g^{-1}$ in Foşa. The amount of P obtained in the experiment is similar to the literature. P is found in the structure of enzymes involved in the formation of bones and teeth, in the metabolism of

nutrients along with Ca, and is necessary for cell functioning. In addition, it prevents the transformation of body fluids into an acid environment and ensures that intracellular and extracellular fluids are kept in balance. 90% of the P in the body is found in bones and teeth, and the remaining 10% in body fluids and cells. Daily P need of an adult over the age of 24 is 800 mg (Samur, 2008). In the study, it was determined that average 100 g of hazelnut kernels could meet 38.9% of the daily P need of an adult, depending on the treatments (Table 2).

Table 2. Effect of pollinators on phosphor (P) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	275 abc	290 cd	165 abc	235 abc	195 de
Palaz	280 abc	-	145 c	225 c	255 ab
Çakıldak	257 bc	305 c	205 ab	230 bc	145 f
Foşa	315 ab	220 e	220 a	245 abc	235 bc
Allahverdi	245 c	255 de	205 ab	225 c	240 bc
Sivri	265 abc	740 a	155 bc	220 c	220 cd
Kalınkara	330 a	690 b	210 ab	275 a	275 a
Yassı Badem	260 bc	215 e	210 ab	240 abc	165 ef

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

3.3. Potassium (K)

The effects of the treatments on the amount of K were found statistically significant (P<0.05). Remarkably that the amount of K is high in applications where Tombul is a pollinator. Although the effects on the amount of K in the Tombul are statistically similar, the amount of K in Palaz, Çakıldak, Allahverdi, Sivri, Kalınkara and Yassı Badem-pollination treatments was determined to be significantly lower than self-pollination. The amount of K in Çakıldak pollination treatment in Palaz was determined to be significantly higher than Foşa, Allahverdi, Sivri, Kalınkara and Yassı Badem-pollination treatment. In the Palaz-pollination treatment in Foşa, the amount of K was found to be statistically significantly higher than self-pollination. Köksal et al. (2006) determined the K amount as 814 mg $100g^{-1}$ in Tombul, 1014 mg $100g^{-1}$ in Palaz, 1470 mg $100g^{-1}$ in Çakıldak and 1052 mg $100g^{-1}$ in Foşa. In our research, it has determined that the K values of the Foşa and Çakıldak cultivars are higher than the other cultivars. Şimşek (2004) determined the K amount as 491.7 mg $100g^{-1}$ in Tombul, 469.9 mg $100g^{-1}$ in Palaz and 515.5 mg $100g^{-1}$ in Foşa. Our results were higher than the values reported by Şimşek (2004), but lower than the values determined by Köksal et al. (2006). K constitutes 5% of our body's mineral content. 2-4 g of K per day is sufficient for adults (Samur, 2008). Our research, it was determined that average 100 g of hazelnut kernels can meet 23% of the daily K requirement of an adult, depending on the treatments (Table 3).

Table 3. Effect of pollinators on potassium (K) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	797.61 a	875.99 a	796.74 a	784.79 b	784.57 a
Palaz	743.49 b	-	786.15 a	825.25 a	734.54 c
Çakıldak	697.18 c	899.57 a	769.79 a	743.51 c	722.94 c
Foşa	793.93 a	824.01 b	756.43 abc	798.93 b	798.01 a
Allahverdi	743.84 b	799.00 bc	715.09 d	796.49 b	744.11 bc
Sivri	710.65 c	707.31 d	766.32 ab	801.89 b	789.31 a
Kalınkara	719.99 bc	723.05 d	718.48 cd	813.37 b	778.16 ab
Yassı Badem	714.34 c	812.02 bc	727.93 bcd	816.03 b	795.18 a

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

3.4. Calcium (Ca)

The effects of the treatments on the amount of Ca were found to be statistically significant (P <0.05). It has been determined that the amount of Ca is generally low in Palaz and Yassı Badem-pollination treatments. Çakıldak, Allahverdi, Sivri, Kalınkara and Yassı Badem-pollination treatments were found to be significantly higher than self-pollination in Tombul cultivar. In Palaz and Foşa-pollination treatments, it has been found to be significantly lower than self-pollination. In Palaz cultivar, the amount of Ca was determined to be significantly higher than other applications in Tombul-pollination treatment. In Çakıldak cultivar, the amount of Ca was determined to be significantly higher than self-pollination in Sivri-pollination treatment. In other treatments, the amount of Ca was found to be significantly lower than self-pollination. In Foşa cultivar, the amount of Ca in Yassı Badem-pollination treatment was found to be significantly lower than self-pollination. In Allahverdi cultivar, the Ca amount was determined to be significantly higher in Tombul, Palaz, Çakıldak, Foşa and Sivri-pollination treatments than self-pollination. In Kalınkara-pollination treatment, the amount of Ca was found to be significantly lower compared to self-pollination. Şimşek (2004) determined Ca values 185.6 mg $100g^{-1}$ in Tombul, 179.5 mg $100g^{-1}$ in Palaz and 138.8 mg $100g^{-1}$ in Foşa; Köksal et al. (2006) determined that 217 mg $100g^{-1}$ in Tombul, 328 mg $100g^{-1}$ in Palaz, 224 mg $100g^{-1}$ in Çakıldak and 172 mg $100g^{-1}$ in Foşa. 99% of the Ca in the body is in bones and teeth, and the remaining 1% is in body fluids and cells. In the insufficiency of Ca and vitamin D; rickets in

children, osteomalasia in adult women, and osteoporosis in the elderly. The daily requirement for adults is 1000 mg (Samur, 2008). According to our research, it has been determined that average 100 g of hazelnut kernels can meet 18.8% of the daily Ca need of an adult, depending on the treatments (Table 4).

Table 4. Effect of pollinators on calcium (Ca) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	137.96 d	117.69 a	101.59 f	98.92 c	126.44 a
Palaz	98.93 f	-	93.89 g	98.31 cd	121.70 b
Çakıldak	146.50 c	108.03 c	133.29 b	96.16 d	128.69 a
Foşa	114.02 e	96.94 d	110.62 d	112.99 a	112.99 cd
Allahverdi	161.75 a	114.92 b	104.45 e	98.11 cd	106.96 e
Sivri	147.35 bc	109.16 c	138.82 a	113.89 a	114.92 c
Kalınkara	146.15 c	108.19 c	130.29 c	108.50 b	100.63 f
Yassı Badem	146.70 c	92.29 e	110.92 d	92.14 e	107.76 e

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

3.5. Magnesium (Mg)

The effects of the treatments on the Mg amount were found to be statistically significant (P <0.05). In the Tombul cultivar, the amount of Mg was found to be significantly lower than self-pollination in Allahverdi, Sivri and Kalınkara-pollination treatments. The amount of Mg in Tombul pollination application in Palaz cultivar was determined to be significantly higher than other treatments. In Çakıldak cultivar, the amount of Mg in Kalınkara and Yassı Badem-pollination treatments was determined to be significantly higher than self-pollination. In Tombul and Palaz-pollination treatments are significantly lower in self-pollination. In Foşa cultivar, the amount of Mg in Çakıldak, Allahverdi and Yassı Badem-pollination treatments was determined to be significantly higher than self-pollination. In Palaz-pollination treatment, it was found to be significantly lower than self-pollination. In Allahverdi cultivar, the amount of Mg in Foşa, Kalınkara and Yassı Badem-pollination treatments was determined to be significantly higher than self-pollination.

Table 5. Effect of pollinators on magnesium (Mg) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	235.54 ab	321.44 a	270.80 c	257.68 cd	278.18 c
Palaz	209.10 bcd	-	185.11 e	181.83 e	276.13 c
Çakıldak	239.30 ab	212.58 e	295.81 b	268.75 b	281.05 c
Foşa	209.10 bcd	193.31 f	293.97 b	250.51 d	325.13 a
Allahverdi	198.10 cd	285.36 b	299.91 b	289.05 a	280.44 c
Sivri	190.30 cd	251.94 c	299.91 b	253.38 cd	258.91 e
Kalınkara	177.85 d	285.97 b	307.91 a	249.07 d	297.04 b
Yassı Badem	219.75 abc	169.12 g	310.16 a	260.35 c	300.73 b

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

In the Sivri-pollination treatment, the amount of Mg was found to be significantly lower than sself-pollination. Şimşek (2004) determined the Mg amount as 177.8 mg 100g^{-1} in Tombul, 150.7 mg 100g^{-1} in Palaz and 180.8 mg 100g^{-1} in Foşa; Köksal et al. (2006) determined it as 168 mg 100g^{-1} in Tombul, 200 mg 100g^{-1} in Palaz, 224 mg 100g^{-1} in Çakıldak and 176 mg 100g^{-1} in Foşa. According to our research, Mg values are higher than Şimşek (2004) and similar to Köksal et al (2006). 60% of the average 20-28 g Mg in the human body is found in bones, 27% in muscles, and 13% in other tissues and body fluids. Mg has functions such as energy metabolism in the body, regular functioning of the muscular and nervous system, the formation of bones and teeth, and regulation of blood pressure. The amount to be taken daily is 360 mg for adults (Samur, 2008). In the experiment, it was determined that average 100 g of hazelnut kernels can meet 88% of the daily Mg need of an adult, although it varies according to the treatments (Table 5).

3.6. Iron (Fe)

The effects of the treatments on the amount of Fe were found to be statistically significant (P <0.05). It is remarkable that the amount of Fe is high in Palaz-pollination treatment. Şimşek (2004) determined the Fe amount as 4.80 mg 100g^{-1} in Tombul, 4.17 mg 100g^{-1} in Palaz, 5.90 mg 100g^{-1} in Foşa; Köksal et al. (2006) determined it as 4.2 mg 100g^{-1} in Tombul, 4.9 mg 100g^{-1} in Palaz, 5.1 mg 100g^{-1} in Çakıldak and 4.8 mg 100g^{-1} in Foşa. An adult human body contains an average of 3-5 g of Fe.

The majority of Fe is found in the blood and hemoglobin in red blood cells. The role of the Fe in the structure of hemoglobin is to carry oxygen in the body. It carries oxygen from the lungs to the cells and carbon dioxide from the cells to the lungs. Diet based on foods of animal or plant origin differs in Fe requirement. In our country, since the diet is based on grains, it is recommended that adults consume approximately 15 mg of Fe (Samur, 2008). According to the results, it has been determined that average 100 g of hazelnut kernels can meet 36.3% of the daily Fe need of an adult, although it varies depending on the treatments (Table 6).

Table 6. Effect of pollinators on iron (Fe) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator Cultivars	Main Cultivars				
	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	7.23 b	3.05 bc	7.14 ab	2.81 bc	6.26 b
Palaz	8.94 a	-	8.03 a	3.26 a	6.95 a
Çakıldak	4.80 c	3.50 b	4.25 d	2.91 abc	5.93 bc
Foşa	8.78 a	2.88 c	7.64 ab	3.15 ab	6.24 b
Allahverdi	4.18 c	2.61 c	6.57 b	2.91 abc	6.77 a
Sivri	4.92 c	6.03 a	6.87 ab	3.16 ab	6.13 bc
Kalınkara	4.55 c	6.25 a	5.41 c	3.08 ab	6.82 a
Yassı Badem	4.52 c	3.37 b	6.90 ab	2.41 d	5.70 c

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

3.7. Manganese (Mn)

The effects of the treatments on the amount of Mn were found to be statistically significant (P <0.05). Mn amounts were significantly higher in the Kalınkara- pollination treatment in Tombul, Palaz and Foşa cultivars, and in treatments where Tombul was pollinator in Çakıldak and Allahverdi cultivars. Şimşek (2004) determined the amount of Mn 5.45 mg $100g^{-1}$ in Tombul, 4.70 mg $100g^{-1}$ in Palaz, 10.31 mg $100g^{-1}$ in Foşa; Köksal et al. (2006) determined it as 7.7 mg $100g^{-1}$ in Tombul and Palaz, 10 mg $100g^{-1}$ in Çakıldak and 8.4 mg $100g^{-1}$ in Foşa. As recorded in Köksal et al. (2006), according to our research, the highest amount of Mn was determined in Çakıldak. In the human body, which contains about 20 mg of Mn, it is seen that Mn mostly concentrates in bones, kidneys, liver and pancreas. The average daily need for Mn in adults is 4 mg (Samur, 2008). According to the results, it was determined that average 100 g of hazelnut kernels could meet 125% of the daily Mn need of an adult, depending on the treatments (Table 7).

Table 7. Effect of pollinators on manganes (Mn) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator Cultivars	Main Cultivars				
	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	7.25 cd	8.44 c	14.93 a	5.60 e	19.06 a
Palaz	5.77 e	-	12.68 ab	6.67 c	6.69 c
Çakıldak	7.85 bc	6.92 d	6.98 d	5.47 e	5.53 d
Foşa	6.02 e	4.18 f	10.23 c	7.67 b	6.57 c
Allahverdi	8.13 ab	3.28 g	8.57 cd	6.21 d	18.96 a
Sivri	7.26 cd	11.34 b	6.59 d	5.74 de	5.47 d
Kalınkara	8.54 a	13.31 a	6.94 d	8.68 a	3.58 e
Yassı Badem	6.79 d	4.01 f	10.82 bc	3.61 f	8.72 b

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

3.8. Copper (Cu)

The effect of the treatments on the amount of Cu was found statistically significant in Tombul, Palaz, Foşa and Allahverdi cultivars. There was no statistically significant difference between the treatments in Çakıldak (P <0.05). Şimşek (2004) determined the Cu amount 2.07 mg $100g^{-1}$ in Tombul, 1.93 mg $100g^{-1}$ in Palaz, 2.17 mg $100g^{-1}$ in Foşa; Köksal et al. (2006) determined it as 2.3 mg $100g^{-1}$ in Tombul, 3.2 mg $100g^{-1}$ in Palaz, 2.6 mg $100g^{-1}$ in Çakıldak and Foşa. Our research results differ from the literature. However, in some studies, it was emphasized that conditions such as cultivar, climate and soil conditions, fertilization and irrigation, cultivation technique and geographical region may affect the content of mineral matter, protein, oil and ash (Amaral et al., 2006; Köksal et al., 2006; Cristofori, 2008; Özenç et al., 2015). Cu is necessary for enzymes responsible for regeneration of body tissue and ensuring the strength of bone structure. It takes part in protein synthesis and energy production. It contributes to the formation of red blood cells. Taking an average of 2.5 mg of Cu in adults will meet the daily cupper need (Samur, 2008). In the experiment, it was determined that average 100 g of hazelnut kernels can meet 66.4% of the daily Cu need of an adult, although it varies according to the treatments (Table 8).

3.9. Zinc (Zn)

The effect of the treatments on the amount of Zn was found to be statistically significant (P <0.05). The highest amount of Zn was determined in Çakıldak. The amount of Zn in the Tombul cultivar was determined to be significantly higher in the Allahverdi, Sivri, Kalınkara and Yassı Badem-pollination treatments than self-pollination. While the amount of Zn in Tombul and Kalınkara-pollination treatments in Palaz was statistically similar to the Sivri-pollination treatment, it was found to be significantly higher than the other treatments. The effects of the treatments on the amount of Zn in Çakıldak were at different levels. In the Foşa, the amount of Zn in Allahverdi and Kalınkara-pollination treatments was determined to be significantly higher than self-pollination. In Çakıldak, Sivri and Yassı Badem-pollination treatments, the amount of Zn was recorded to be significantly lower than self-pollination. The amount of Zn in all treatments in the Allahverdi was determined to be significantly higher than self-pollination.

Table 8. Effect of pollinators on copper (Cu) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	0.47 e	1.57 b	1.59	1.52 cd	0.40 bc
Palaz	0.49 e	-	1.50	1.84 a	0.30 c
Çakıldak	2.44 a	1.56 b	1.73	1.45 d	0.30 c
Foşa	0.79 d	1.73 a	1.16	1.45 d	0.84 a
Allahverdi	1.99 bc	1.60 b	1.38	1.54 c	0.53 b
Sivri	1.95 c	0.90 d	1.50	1.85 a	0.87 a
Kalınkara	2.08 bc	1.28 c	1.43	1.51 cd	0.24 c
Yassı Badem	2.18 b	1.62 b	1.73	1.48 cd	0.96 a

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

Şimşek (2004) determined the Zn amount as 3.55 mg $100g^{-1}$ in Tombul, 2.52 mg $100g^{-1}$ in Palaz, 6.11 mg $100g^{-1}$ in Foşa; Köksal et al. (2006) determined it as 2.7 mg $100g^{-1}$ in Tombul, 3.4 mg $100g^{-1}$ in Palaz, 4.4 mg $100g^{-1}$ in Çakıldak and 3.1 mg $100g^{-1}$ in Foşa. It is clear that the values determined in the experiment are similar to the literature. In the human body, Zn is found mostly in the liver, pancreas, kidneys, bones, muscles and other tissues. It takes part in the structure of enzymes that have important metabolic functions in the body. It is active in the growth and development of the sexual organs and the formation of cellular immunity. 15 mg of Zn per day is recommended for adults (Samur, 2008). In the experiment, it was determined that average 100 g of hazelnut kernels can meet 17.5% of the daily Zn requirement of an adult, although it varies according treatments (Table 9).

Table 9. Effect of pollinators on zinc (Zn) content (mg 100 g^{-1}) of hazelnut cultivars

Pollinator	Main Cultivars				
Cultivars	Tombul	Palaz	Çakıldak	Foşa	Allahverdi
Tombul	2.59 d	2.60 a	3.10 bc	2.39 b	2.48 c
Palaz	2.74 cd	-	3.47 ab	2.32 bc	2.52 c
Çakıldak	2.94 bcd	2.30 b	3.22 abc	2.18 de	2.29 d
Foşa	2.73 cd	2.40 b	3.04 c	2.36 b	3.05 a
Allahverdi	3.13 b	2.18 c	2.89 c	2.54 a	2.06 e
Sivri	3.26 b	2.46 ab	3.46 ab	2.21 cde	2.69 b
Kalınkara	3.02 bc	2.59 a	3.51 a	2.53 a	2.55 bc
Yassı Badem	3.17 b	2.24 c	2.83 c	2.15 e	2.92 a

The differences among the treatments indicated with the same letter vertically were not significant at P<0.05.

4. Conclusion

In our study, the effects of the applications on the amount of N, P and K were statistically significant. However, the effects on other elements were indistinguishable. The most abundant element in the hazelnut cultivars examined in the study was K. In Tombul-pollination treatment, the amount of K was significantly higher. It was observed that the K content of the Foşa and Çakıldak was higher than the other cultivars. In Palaz and Yassı Badem-pollination treatments, the amount of Ca was generally lower than in other treatments. However, the amount of Fe was higher in the Palaz-pollination treatment. In our study, the highest Mn and Zn content was obtained from Çakıldak. As a result, it was revealed that hazelnut pollinator can affect the nutritional content of the nuts.

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Authors' Contributions

Huseyin Irfan Balik: Methodology, Investigation, Conceptualization, Validation, Review and editing. **Neriman Beyhan**: Methodology, Investigation, Conceptualization, Validation, Writing - original draft, Visualization.

Conflict of Interest

The authors declare that they have no conflict of interest.

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