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ORIGINAL ARTICLE / ORIGINALBEITRAG

The Effects of Different Micronutrient Fertilizers on cv. Tombul Hazelnut Yield and Certain Nut Properties

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Abstract
Turkey is the leading producer of hazelnuts of global production. Hazelnuts are generally used in the food industry (e.g. by confectioneries, bakeries, ice-cream manufacturers; in dairy, candy, and chocolate products). They are also a part of a wide range of food including cereals, bread, yogurt, soups, and salads. This study was conducted in the Central Black Sea Region of Northern Turkey, which is the largest hazelnut cultivation area in Turkey. The study aims to investigate the effects of different foliar fertilizers on hazelnut yield and nut properties in terms of human nutrition and health. We tried to determine the effects of different characteristics of foliar fertilizers such as Suryamin BZn (B = 9% B, 4% Zn EDTA chelate), Suryamin 1 of chelate (S = 10:7:6+Micro nutrients; 10% N, 7% P, 6% K, 0.04% B, 0.2% Cu, 0.002% Co, 0.6% Fe, 0.07% Mn, 0.4% Zn, 0.002% Mo) and Suryamin Micro (M = 3% Fe, 3% Mn, 3% Zn, 0.5% Cu, 0.7% B) on cv. Tombul hazelnut yield and certain nut properties. During the years, B and Zn were applied as 300 mg kg^{-1}. All other nutrients were applied as 50 mg kg^{-1}. The highest yield and the average results for certain nut properties such as number of nuts in cluster, nut size, kernel weight, and clove/shoot rates were obtained with the B (Suryamin BZn) applications. The highest rates of kernel and shoot length were obtained with the S (Suryamin 1 of chelate) applications. The highest amounts of healthy and the lowest amounts faulty kernel were obtained from M (Suryamin Micro) fertilizer applications.

Keywords Hazelnut · Yield · Nut properties · Foliar fertilizer · Micro nutrient

Einfluss verschiedener Mikronährstoffdünger auf den Ertrag und spezifische Fruchteigenschaften der Haselnuss-Sorte 'Tombul'

Schlüsselwörter Haselnuss · Ertrag · Fruchteigenschaften · Blattdünger · Mikronährstoff

Introduction

The hazelnut (*Corylus avellana* L.) is a member of the *Betulaceae* family. Hazelnut trees are generally distributed along the coasts of the Southern Europe and Black Sea region of Turkey (The Turkish Hazelnut Exporter's Union 2008).

Turkey is the world leader and command world markets in hazelnut production. These facts demonstrate that hazelnut really have a very impressive heritage and a unique location in Turkey. Despite of production is condensed in the Black Sea region, it has shifted from east to west re-

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gion, increasing the production share from 36% to 45% (FAO 2004).

Hazelnuts are widely used in the food industry (e.g. by confectioneries, bakeries, ice-cream manufacturers; in dairy, candy and chocolate products). They are used in a broad range of food including cereals, bread, yogurt, soups, and salads. They are famous for adding flavor to pies and chocolate. Hazelnuts are also popular among vegetarians, who eat nut loaves, nut bread, and rissoles (a French pastry rolled in bread crumbs and filled with a sweet and savory filling). Many different products can be made from hazelnuts such as nut butter (Ackurt et al. 1999; Simsek and Aslantas 1999; Simsek and Aykut 2007). Hazelnuts are generally considered as a rich power supply, vitamins and minerals for human consumption (Souci et al. 2000; Koksal et al. 2006).

Hazelnuts are known to be a concentrated food with their nutrients and they have the potential to be an essential food in the human diet with trace elements. Hazelnut oil decreases the cholesterol level in blood (Durak et al. 1999). Besides their rich mineral content, nut kernels are among valuable sources of such as vitamins B1, B6, and a-tocopherol. Health conscious consumers prefer supplementary foods with rich nutrients. Therefore, trace elements have been increasingly used in recent years in medical treatment to prevent various diseases (Reilly 1998; Rayman 2000; Iannuzzi et al. 2002). Evaluating plant type and growth conditions with respect to human health standards becomes crucial. So, this study aims to investigate the effects of different fertilizers on hazelnut yield and nut properties.

Materials and Methods

This study was conducted in the hazelnut orchard, located at 225 m altitude, having Tombul nut cultivars over two years in 2001 and 2002 at Fatsa district of Ordu city (latitude 41°03″33 and longitude 37°71″0.5) in the Central Black Sea Region of Turkey. Tombul nut cultivar used in the study was established with traditional bushy forms (ocak training system) in space of 4 × 4 m in 1955. They had 5–7 stems with 26.7 ± 6.7 cm diameter.

Micro nutrient fertilizer characteristics were such as Suryamin BZn (***B*** = 9% B, 4% Zn EDTA chelate), Suryamin I of chelate (***S*** = 10:7:6+Micro nutrients; 0.04% B, 0.2% Cu, 0.002% Co, 0.6% Fe, 0.07% Mn, 0.4% Zn, 0.002% Mo) and Suryamin Micro (***M*** = 3% Fe, 3% Mn, 3% Zn, 0.5% Cu, 0.7% B) foliar fertilizers on hazelnut yield and some nut properties. B and Zn application rates were 300 mg kg^{-1} and all other nutrients were applied with the rate of 50 mg kg^{-1} doses under randomized complete block design with three replications. These foliar fertilizers were applied to the hazelnut trees in a two-liter solution and in the form of 1. Control (H_2O), 2. B (Suryamin BZn), 3. S (Suryamin I) 4. M (Suryamin micro), 5. BS, 6. BM, 7. SM, 8. BSM. The soil type of field area was classified as alfisol (Soil Survey Staff 1992). Mean annual temperature were 13.8 °C, precipitation were 1183 mm and relative humidity were 74.7%. Nut samples were taken during the August harvest every two years from 24 trial areas located at Fatsa. Ten plant samples (100 gr of nuts per tree) for cv. Tombul (total 24 trial areas) were randomly collected from different sections of the hazelnut trial areas.

The soil samples in trial orchard were taken from a depth of 0–30 cm in October 2000. They were air-dried and passed through 2 mm sieve for chemical and physical analyses. The pH and EC (electrical conductivity) of the orchard soil used in the experiment were determined in saturation mud (Soil Survey Laboratory 1992), and the texture was determined according to the Bouyoucos hydrometer method (Bouyoucos 1951). The organic matter (OM) level was determined with a modified Walkley-Black method (Nelson and Sommer 1996). Cation exchange capacity (CEC) was determined with barium saturation method (Pratt and Holowaychuk 1954), and available K, Ca, Mg and Na were determined with 1 N ammonium acetate (NH_4OAc) extraction method (Sumner and Miller 1996). The available phosphour determined Bray and Kurt No. 1 method (Bray and Kurtz 1945), The available Fe, Mn, Zn and Cu were determined with 0.005 M diethylenetriamine pentaacetate (DTPA) by Atomic Absorption Photometer (Perkin Elmer AA-200), and available B was determined according to the Azometin-H method (Kacar 2009). The physical and chem-

Table 1 The chemical and physical soil characteristics of trial orchard

Soil properties		Value
pH	Paste	6.60
EC	dS m^{-1}	0.32
Sand	%	24.40
Mil		38.00
Clay		37.60
Texture	–	Clay loam
OM	%	1.84
CEC	cmol kg^{-1}	52.50
Exchangeable K		0.27
Exchangeable Ca		46.70
Exchangeable Mg		5.50
Exchangeable Na		0.01
Available P	mg kg^{-1}	7.24
Available Fe		17.70
Available Mn		14.70
Available Zn		2.05
Available Cu		1.40
Available B		1.11

ical soil characteristics of the trial orchard are given in Table 1.

Results

Hazelnut Yield

As results of this study, different characteristics of fertilizers affected yield and certain nut properties significantly in two-year treatments. Hazelnut yields increased with different fertilizer treatments depending on the properties of fertilizer treatment. The yield of the control application treatment was 2.55 kg $tree^{-1}$ while the highest yield, 3.73 kg/tree, was acquired from the *B* (Suryamin BZn) application (Table 2). Analysis of variance indicated that hazelnut yield was significantly ($P < 0.05$) affected by different foliar fertilizers. In 2001, it was found that fertilizer application was more effective than in 2002, according to the control yield. The effectiveness of the fertilizers ranged in the form of B>M>BSM>S>BM>SM>BS in 2002, while they were ranged in the form of B>M>S>BSM>BS>SM>BM in 2001. Averaged over the two years, it ranged in the form of B>M>S>BSM>BM>SM>BS. The highest nut yield was obtained from the B fertilizer application in both years whereas those under M fertilizer application were monitored as second highest.

Certain Properties of Hazelnut

Different characteristics of fertilizers affected certain nut properties. These properties showed different values in two years (Table 1). Number of nut in cluster (NNC) was significant ($P<0.05$) in 2001 fertilizer application according to control, while it was not found a statistically significant in 2002. Fertilizer applications in both years increased number of nut fruit in cluster. The highest NNC obtained from B fertilization in 2001 and BS fertilization in 2002, and averaged B fertilization, it provided an increase in rates of 22.10%, 10.87% and 15.70% respectively, compared to the control.

Hazelnut kernel percent (HKP) also significantly supplied ($P < 0.05$) an increase in both years of fertilizer applications. The highest kernel percent obtained from BS fertilizer application in 2001, SM fertilization in 2002 and averaged S fertilization, it provided an increase at rates of 8.30%, 2.73% and 3.72% respectively, compared to the control rate.

The NS (nut size) was increased by different fertilizer applications in both years but it was not statistically significant. The largest nut size was obtained from BM and B fertilizer applications according to the control in 2001/02, and averaged B fertilization, it provided an increase at rates of 4.96%, 3.65% and 4.21%, respectively, compared to the control.

Nut weight (NW) was significantly ($P < 0.05$) affected from fertilizer applications in 2001, whereas there were not significant differences in their application in 2002. But nut weight increased also in the fertilizer applications in both years according to the control. The highest nut weight was obtained from BM fertilizer application in 2001, B fertilizer application in 2002 and averaged BM fertilization, it provided an increase at rates of 39.20%, 10.31% and 19.35% respectively, compared to the control.

Kernel weight (KW) showed that it increased with fertilizer applications according to the control for both years, but these increments were not statistically significant. The highest kernel weight obtained from BSM fertilizer application in 2001, SM fertilization in 2002, and averaged B fertilization, provided an increase at rates of 23.31%, 9.97% and 15.19%, respectively, compared to the control.

Blank nut rate (BNR) was not found statistically significant in both year fertilizer applications according to the control. Blank not rate was decreased by the fertilizer applications in 2001. In 2002, while it was decreased by B, BS, BM and BSM fertilizer applications, the other fertilizer applications increased the blank nut rate. The largest decrease in blank nut rate was at –55.60% with M fertilizer in 2001, and decrease of –36.02% with BSM fertilizer in 2002. The two-year average showed it decreased at a rate of –40.86% with BSM fertilizer.

Healthy kernel rate (HKR) was not found statistically significant in the 2002 fertilizer application, However, it was significant ($P<0.05$) in 2001. The highest HKR obtained from BSM fertilizer in 2001, M fertilizer in 2002, and BSM fertilizer averaged over both years, it provided an increase at rate of 14.36%, 3.06% and 6.12%, respectively, compared to the control.

Faulty kernel weight (FKR) was not found statistically significant in 2002 fertilizer application, However, it was significant ($P<0.05$) in 2001. The lowest FKR obtained from BSM fertilizer in 2001, was obtained from M fertilizer in 2002, and M fertilizer averaged the both years, it provided a decreasing at rate of –72.40%, –33.96%, and –48.83%, respectively, compared to the control. Furthermore, it was showed that the decreasing FKR in 2001 was much more than in 2002.

Shoot length (SL) increased with fertilizer applications in both years, but not statistically significant compared to the control. The highest SL obtained from M fertilizer application in 2001, B fertilizer in 2002 and averaged S fertilizer, provided increased rates of 18.37%, 42.36%, and 16.39%, respectively, compared to the control. There was more of an increase in 2001 then 2002.

Bud number (BN) decreased in B, S, BS and SM fertilizer application, while it increased in M, BM and BSM

Table 2 The effects of different characteristic of fertilizers on hazelnut yield and certain nut properties in two years

Years	Fertilizers	Hazelnut Yield (kg tree^{-1})	NNC	Hazelnut kernel (%)	Nut large-ness (mm)	Nut weight (g)	Kernel weight (g)	BNR (%)	HKR (%)	FKR (%)	Shoot length cm	Bud number	Clove number	CN/SR
2001	Control	2.55^{f}	3.27^{b*}	50.3^{b}	15.7	1.18^{b}	0.68	13.7	83.4^{d}	16.6a	10.79	3.29	0.67	20.1
	B	3.73^{a}	3.99^{a}	52.4^{ab}	16.5	1.45^{ab}	0.84	6.96	90.4^{cd}	9.60^{cd}	8.50	2.87	0.93	32.4
	S	3.29^{c}	3.44^{ab}	52.7^{ab}	16.2	1.46^{ab}	0.83	7.25	93.1^{ab}	6.87^{cd}	11.39	3.23	0.77	23.9
	M	3.53^{b}	3.78^{ab}	52.5^{ab}	16.1	1.36^{ab}	0.76	6.06	92.8^{abc}	7.24^{bcd}	12.77	3.33	1.05	31.4
	BS	2.91^{de}	3.85^{ab}	54.5^{a}	16.0	1.37^{ab}	0.84	11.6	92.4^{abc}	7.57^{bcd}	10.30	3.21	0.90	28.4
	BM	2.78^{e}	3.72^{ab}	51.2^{ab}	16.5	1.64^{a}	0.84	7.53	84.6^{cd}	15.4^{ab}	12.4	3.52	0.91	25.9
	SM	2.85^{e}	3.51^{ab}	51.8^{ab}	16.2	1.33^{ab}	0.80	8.28	85.5^{bcd}	14.5^{abc}	11.7	3.08	0.97	31.7
	BSM	3.06^{d}	3.58^{ab}	53.1^{ab}	16.1	1.48^{ab}	0.84	7.62	95.4^{a}	4.57^{d}	11.1	3.31	0.94	28.4
2002	Control	1.63^{b}	3.16	54.0^{ab}	16.6	1.54	0.89	6.71	91.7	8.25	7.87	2.58	0.50	19.5
	B	3.24^{a}	3.45	52.8^{b}	17.2	1.70	0.98	6.56	89.5	10.54	11.21	3.22	0.71	22.6
	S	2.78^{ab}	3.31	55.4^{a}	17.0	1.63	0.97	9.13	92.6	7.39	10.2	3.09	0.78	25.3
	M	3.29^{a}	3.37	55.0^{ab}	16.9	1.64	0.95	8.44	94.5	5.45	8.70	2.92	0.59	20.4
	BS	2.14^{ab}	3.51	53.5^{ab}	16.9	1.57	0.93	6.04	88.8	11.2	9.35	2.70	0.67	24.8
	BM	2.64^{ab}	3.36	53.8^{ab}	16.9	1.61	0.94	6.44	90.7	9.32	8.91	2.89	0.58	20.4
	SM	2.47^{ab}	3.48	55.5^{a}	17.1	1.65	0.98	8.10	91.1	8.89	9.13	3.06	0.45	14.7
	BSM	2.95^{ab}	3.42	53.6^{ab}	16.7	1.66	0.97	4.42	90.5	9.54	9.98	3.10	0.81	26.5

NNC Number of nut in cluster, *BNR* Blank nut rate, *HKR* Healthy kernel rates, *FKR* Faulty kernel rates, *CN/SR* Clove number/shoot rate

*Means followed by the same letters in a year are not significantly different at the 0.05 level fertilizer application compared to the control in 2001. The highest BN obtained from BM fertilizer application in 2001, B fertilizer in 2002 and averaged BM fertilizer, it provided an increase at rate of 6.71%, 24.99%, and 8.84%, respectively, compared to the control.

Clover number (CN) was increased by all fertilizer applications in both years except from SM fertilizer in 2002. The highest CN obtained from the M fertilizer application in 2001, BSM fertilizer in 2002 and averaged BSM fertilizer, it provided an increase at a rate of 57.81%, 61.06% and 44.83% respectively, compared to the control.

Clover/shoot rate (C/SR) increased in both years in all fertilizer applications except for SM fertilizer in 2002. The highest C/SR obtained from the B fertilizer application in 2001, BSM fertilizer in 2002 and averaged B fertilizer, provided an increase at a rate of 61.02%, 29.64% and 38.94% respectively, compared to the control.

Discussion

The Effects of Different Fertilizers On Hazelnut Yield

Compared to the control, hazelnut yields increased by 46.35% with the *B* (Suryamin BZn) application in 2001. Similar results were obtained by the end of 2002 and the highest yields obtained were 3.24 kg tree^{-1} and 3.29 kg tree^{-1} with the fertilizer *B* (Suryamin BZn) and *M* (Suryamin Micro) applications, respectively (Table 1). The highest average hazelnut yield was obtained with the *B* (Suryamin BZn) applications with a 66.70% increase compared to the control (Fig. 1).

Other studies revealed similar results. The applications of compost over a long time may increase hazelnut yield and have the effects of improving the nut quality (Ozenc and Caliskan 2001). Umit et al. (2005) discovered that nut traits and the best yield were obtained with the 150-g dose when the BZn fertilizer was applied to the ground Tombul cv.

The Effects of Different Fertilizers on Certain Properties of Hazelnut

According to the results, the highest values were obtained with the *B* (Suryamin BZn) application (Fig. 1) when the average results of these properties such as the number of nuts in cluster, nut size, kernel weight, and clove/shoot rates were investigated. The highest rates of kernel and shoot length were obtained with the *S* (Suryamin 1 of chelate) applications. The highest amounts of healthy and the lowest faulty kernel were obtained from *M* (Suryamin Micro) fertilizer applications (Fig. 1).

Hazelnuts have the potential to be an essential food in the human diet because of its trace elements (Tannenbaum et al. 1985; Ladipo 2000). The toxic value of hazelnuts for humans mainly depends on plant types and plant growth conditions. Thus, evaluating plant type and growth conditions with respect to human health standards becomes crucial.

Hazelnuts are one of the best sources among tree nuts for essential elements, amino acids, vitamins and they serve as a good source of antioxidants (Ackurt et al. 1999; Bonvehi and Coll 1997; Yurttas et al. 2000; USDA 2008). These antioxidants are very effective to prevent the destructive processes caused by oxidative stress. Because these antioxidants can prevent from reactive oxygen species (ROS) and other oxidants in causing numerous disorders and diseases (Thompson 1994). Various researchers recommend leafy vegetables, sour cherries, fruits such as grapes, and nuts and walnuts as good sources of Vitamin B (Souci et al. 2000; Simsek et al. 2003a, 2003b).

Iron is a constituent of hemoglobin and several enzymes. İron is an essential nutrient (Bothwell et al. 1979). As much as 30% of iron in the body is found in storage forms such as ferritin and hemosiderin and a small amount is associated with transport protein transfer in blood. Absorption of dietary iron-increases as menstrual losses deplete iron stores (Bothwell and Finch 1968).

Zinc, a constituent of enzymes involved in most major metabolic pathways, is an essential element for plants, animals, and humans (Hambidge et al. 1986). Zinc enzymes are involved in a wide variety of metabolic processes including carbohydrate, lipid and protein synthesis or degradation. Large amounts of zinc are deposited in bone but these stores are not in rapid equilibrium with the other organisms. Zinc is required for deoxyribonucleic and ribonucleic acid synthesis; play a role in stabilizing plasma membranes (Shils et al. 1994). A single enzyme function that can explain the rapid onset of physiological and biochemical changes is not yet defined but the requirement for zinc by many enzymes involved in gene expression (Chesters 1982) could explain the effect of deficiency. Zinc has been accepted as an auxiliary factor of superoxide dismutase which provides protection against oxidative processes (Shils et al. 1994). The zinc content of typical mixed diets of adults has been reported to furnish between 10 and 15 mg day^{-1}. In a survey of U.S. foods, found 13.2 mg of zinc in a 2850 kcal diet and the ortehr study show that at least 12 mg of zinc in a mixed diet is required to maintain the existing zinc status of healthy (Pennington et al. 1984; Sandstead 1985; Greger 1989).

It has been demonstrated with a lot of work. manganese is an important element in many animal and human nutrition. Deficiency symptoms, poor reproductive performance, growth retardation, congenital malformations in the off-

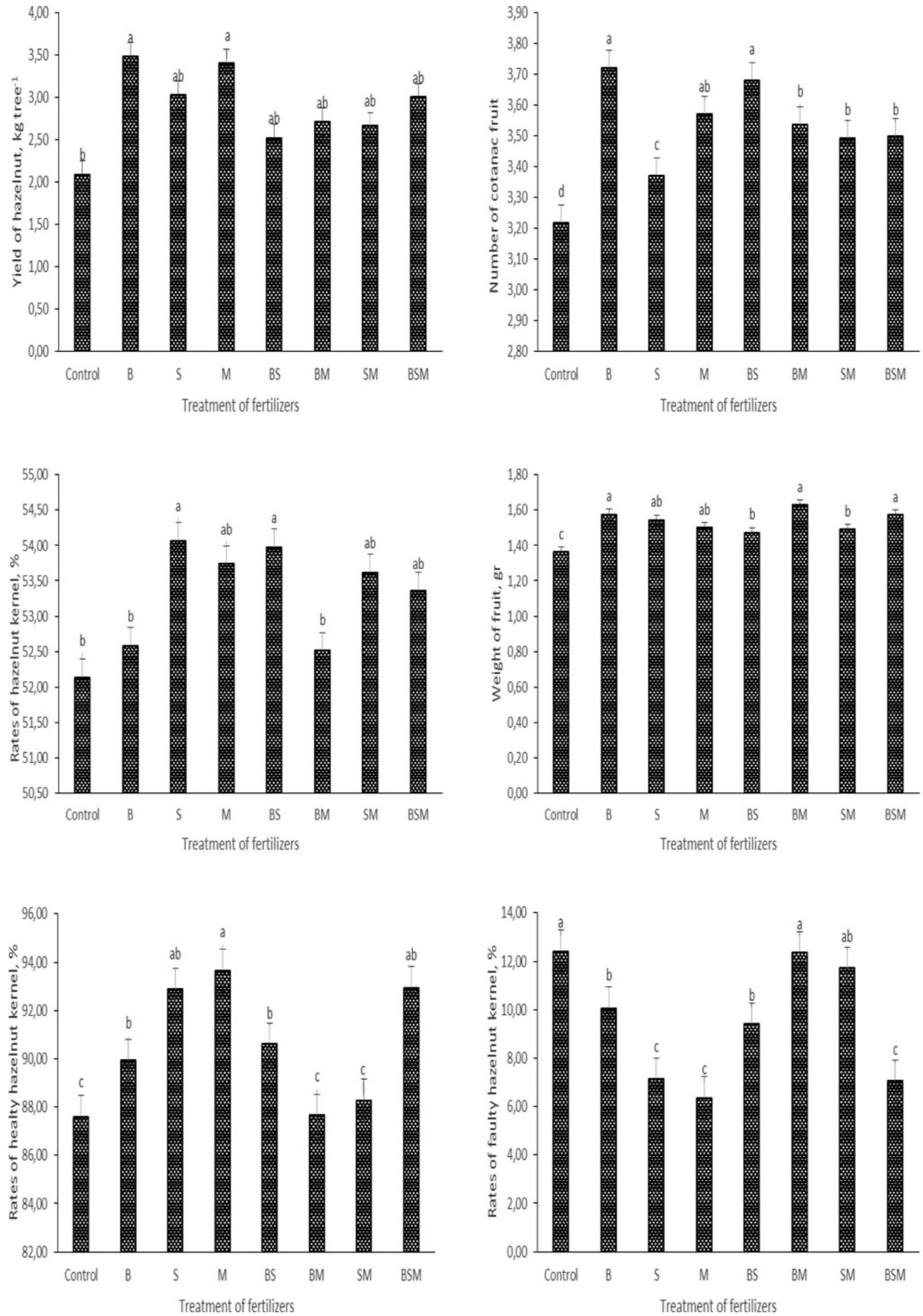

Fig. 1 The effects of different characteristic of fertilizers on certain nut properties as a mean of two-years

spring, abnormal bone and cartilage formation, and impaired glucose tolerance (Hurley and Keen 1987). Under in vitro conditions, several enzymes such as decarboxylases, hydrolases, kinases, and transferases have been non-specifically activated by manganese. There are two manganese metal-enzymes known as pyruvate carboxylase and superoxide dismutase and these have been localized in mitochondria. All grains and cereals are the richest sources of manganese. However, the amount of manganese in vegetables and nuts is slightly less. The Total Diet Study conducted in the United States indicated that the mean daily dietary manganese intake was 2.2–2.7 mg for adult human (Pennington et al. 1989).

In humans, manganese toxicity has been observed only in workers exposed to high manganese dust or smoke concentrations in the air. It is very difficult for people to reach to toxic level in people who consume 8–9 mg manganese per day in their diet depending on their diet program (Schroeder 1966; WHO 1973).

Most enzymes required for iron metabolism contain copper. Copper deficiency is usually rare. However, some studies have reported a direct correlation between the dietary Zn/Cu ratio (Davis and Mertz 1987). Under normal circumstances, dietary copper deficiency is not known to occur in adults. Due to the difficulties in providing Cu's recommended nutrient intake, the National Research Council (1989) published a safe range of 1.5 to 3 mg/day in adults (Cabrera et al. 2003). Older analytical data indicating that most U.S. diets provide a daily copper intake 2–5 mg (Klevay 1984). The Total Diet Study showed that the daily intake of copper for adult males and females averaged about 1.2 mg and 0.9 mg, respectively, (Pennington et al. 1989; Turnlund et al. 1989). The other balance studies suggested that the adult requirement for copper ranged 2.0–2.6 mg day^{-1}, whereas later studies indicated that intakes less than 2.0 mg day^{-1}, and often not much more than 1.0 mg day^{-1} (Mason 1979).

Conclusions

The effects of different characteristics of fertilizers on hazelnut yield and certain nut properties are found to be significant according to variance analysis. The highest yield of 3.73 kg $tree^{-1}$ was acquired with the *B* (Suryamin BZn) application whereas the average results of certain nut properties such as the number of nuts in cluster, nut size, kernel weight, and clove/shoot rates were obtained with the *B* (Suryamin BZn) application. The highest kernel rates and shoot length were obtained with the S (Suryamin 1 of chelate) applications. The highest amounts of healthy and faulty kernel were obtained from M (Suryamin Micro) fertilizer applications.

Difference related to levels of certain nut properties and yield may have resulted from using different fertilizers. Data obtained from hazelnut plants show that applying different fertilizers brought a very high yield potential and increased certain nut properties.

Conflict of interest A. Horuz, A. Güneş, M. Turan, T. Demir, Ü. Serdar, E. Ozlu, M. R. Karaman and G. Fırıldak declare that they have no competing interests.

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