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Original Article

Effects of Nitrogen and Potassium Fertilization on Nutrient Content and Quality Attributes of Sweet Cherry Fruits

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Abstract

Fertilizers are commonly applied to improve the yield and quality in orchards. But unbalanced fertilization negatively affects the nutrient contents of the fruits. Fruits with low energy and high mineral and vitamin contents are significant foods for human nutrition and human health. This study was carried out with '0900 Ziraat' sweet cherry cultivar grafted on 'Gisela 5' rootstock in two consecutive years. The effects of different nitrogen (N) and Potassium (K) doses on nutrient content of fruits were investigated. Different doses of N (0, 50, 125 and 250 g N tree^{-1}) and K (0, 50, 125 and 250 g K_2O tree^{-1}) were applied beneath the tree canopy in 6 replications and 1 tree in every replication in two consecutive years. Fruit samples were harvested from each tree and fruit colour, firmness, cracking index and nutrient contents (N, P, K, Ca, Mg, Fe, Zn and B) were determined. Fruit N content, N:K ratio, L*, a*, C* and firmness values increased with increasing N doses. While K fertilization did not have significant effects on K content and N:K ratio, it negatively influenced the N content of the fruits. It was concluded that N fertilization directly influenced fruit quality attributes, but K fertilization did not have any significant effects on fruit quality parameters.

Keywords: colour; cracking index; fertilizing; flesh firmness; fruit tree; *Prunus avium* L.; '0900 Ziraat'

Introduction

Sweet cherry (*Prunus avium* L.) has an important place in fruit culture of Turkey (Sarisu and Demirtas, 2015). In recent years, Turkey has gained a significant role in sweet cherry exports. Now, the concept of "Turkish Sweet Cherry" has been formed abroad. The cultivar '0900 Ziraat' has played an important role in forming this concept. With large, firm, and sweet fruits, '0900 Ziraat' has become one of the most popular cherry cultivars of the world (Kaska, 2001). About 440.000,00 tons of world sweet cherry production, which is 2.240.000,00 tons, is produced in Turkey and such an amount corresponds to about 20% of total world production. Turkey with this production is the leading producer of the world (TUIK, 2014) and about 20% of its production takes place in the province of Isparta.

Sweet cherry is a fruit crop with a high economic importance, due to the nutritional, technological and commercial values. Because their regular consumption was reported to decrease the risk of arthritis, gout and headaches, cherries have recently received increased interest as a healthy fresh fruit. The health benefits of cherry fruits are usually attributed to their chemical composition, since they are a good source of antioxidant compounds and other phytochemicals besides sugars, organic acids, minerals, etc. (Sezgin, 2014; Milosevic *et al.*, 2015).

Sweet cherry trees require various nutrients to grow and achieve high yields (Stasiak, 2014). Nitrogen and K are among the most important nutrients. Use of mineral fertilizer is the quickest way to increase crop production. It is well known that the amount of fertilizer applied by farmers is influenced by fruit quality (Bybordi, 2013) and physiological disorders (Fallahi *et al.*, 2010). Fruit quality problems are directly related to fruit mineral deficiencies (Aktas and Ates, 1998; Spectrum Analytic Inc., 2006). However, increasing N doses are thought to negatively influence fruit quality (Souza *et al.*, 2013). In a study, the firmness of apricots was significantly reduced as the rate of applied nitrogen increased from the recommended dose for the crop (Rettke *et al.*, 2006). High K levels in leaves and fruits, similar to N, negatively affect fruit quality and storage characteristics because of antagonistic effects between K and Ca-Mg (Bergmann, 1992). Plant nutrition also influences fruit appearance, texture, and taste (Cuquel *et al.*, 2011). In stone fruits, appearance, texture and flavor, and nutritional value of fruits are defined as postharvest quality and in terms of consumer satisfaction. Beside fertilization, fruit quality attributes are influenced by various factors including the site and cultivar selection, and extending to cultural practices and all the stages of postharvest handling (Crisosto *et al.*, 1995).

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Fertilization also has an effect on diseases and pests (Huber and Graham, 1999) as plants were more prone to pathogen attacks when they had high N and low K contents (Bergmann, 1992).

The present study was conducted to investigate the effects of mineral fertilizers (N and K) on quality attributes of sweet cherry fruits.

Materials and Methods

Biological material and study site

This study was carried in 2015-2016 in a sweet cherry orchard at Egirdir district of Isparta province located in the Lakes Region of Turkey. The province is a transitional zone between Central Anatolia and Mediterranean. The altitude is about 950 m, average annual precipitation is 650 mm and temperature is 13.0 °C (Ucgun *et al*., 2016). The orchard was established with '0900 Ziraat' grafted on 'Gisela 5' rootstock in 2008. The spacing was 2 m between trees in a row and 5 m between rows. Full yield was reached in 2014. Irrigation has been made by drip irrigation. '0900 Ziraat' grows strong and broad. It blooms late. The fruit has a long stem, hard, crisp, broad heart-shaped, large, bright dark red colour and resistant to cracking. Its core is large. It is self-incompatibility and needs a fertile cultivar in the orchards (Sarisu *et al*., 2016). 'Gisela 5' is a semi-dwarf rootstock. It is a hybrid of *Prunus cerasus* × *Prunus canescens*. It was reported that crown width of 'Gisela 5' was about 50% of F12/1 in 5 years after planting (Webster and Schmidt, 1996).

Experimental procedures

Experiments were conducted in randomized blocks design with 6 replications and 1 tree in each replication. Different doses of N (0, 50, 125 and 250 g N tree^{-1}) and K (0, 50, 125 and 250 g K_2O tree^{-1}) were applied to experimental trees. In N treatments, K (125 g K_2O tree^{-1}) and P (50 g P_2O_5 tree^{-1}) fertilizers were applied. In K treatments, N (125 g N tree^{-1}) and P (50 g P_2O_5 tree^{-1}) fertilizers were applied. Fertilizers were applied beneath the canopy in 6 equal portions (dissolved in water) between full bloom and harvest periods. Fruits were harvested for pomological and mineral analyses.

Flesh firmness (FF) was determined with a Fruit Texture Analyzer (Guss, model GS14, South Africa) with a 5.0 mm diameter probe. Two measurements were taken on opposite faces of each fruit with skin, and the results were expressed in Newton (N). Fruit skin color was measured by chroma meter model Minolta CR 400 (Konica Minolta, Inc., Japan). For evaluation of the color CIE, L* (brightness), a* [red (+) – green (-)], b* [yellow (+) – blue (-)], h° (hue angle) and C* (chroma) values were used. Cracking index (CI) of cherries was determined by the method of Christensen (1996). Fifty fruits were randomly selected from each replicate and immersed into 2 L plastic containers filled with water (20 ± 1 °C). Examination of fruits was carried out 2, 4 and 6 hours after immersion into water. Fruits were then removed from the water; cracked fruits were counted and separated and uncracked fruits were quickly immersed again into the water. Cracking index was calculated according to the following formula: $CI = (5a + 3b + c) \times 100/250$; where a, b, and c represent the number of cracked fruits after 2, 4, and 6 h, respectively. Total number of fruits immersed = 50; maximum cracking = 50 × 5 = 250.

Work protocol

Fruit samples were brought to laboratory and immediately washed through tap water, then they were washed through 0.1 N HCl and finally they were washed through deionized water and roughly dried out with drying papers. They were divided into small portions as whole fruits, placed in paper bags and dried at 65-70 °C in a drying chamber until a constant weight (for about 96 hours). Dried samples were then ground and made ready for N, phosphor (P), K, Calcium (Ca), magnesium (Mg), iron (Fe), Manganese (Mn), zinc (Zn) and boron (B) analyses (Kacar and Inal, 2008). Nitrogen content was determined through Kjeldahl wet digestion method. Dry ashing method was carried out for P, K, Ca, Mg, Fe, Mn, Zn and B (Ryan *et al*., 2001). Readings were performed in Inductively Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES) device. NIST-brand reference apple leaf (1515) was used to check the accuracy of fruit analyses.

Statistical procedures

Resultant data were analyzed using one-way ANOVA with "JMP© 8.0" (SAS Institute, Inc.). Least Square Difference (LSD) test and probabilities of $P<0.05$ and $P<0.01$ were used for assessing statistical differences.

Results and Discussion

Experiments were conducted in a cherry orchard with unsaline, slightly alkaline clay-loam soils with medium lime and organic matter content (Table 1). Irrigation water had a quality class of C_2S_1 according to the US Salinity Laboratory Graphical System and it was suitable for irrigation (Table 2). Phenological observations were performed in both years of the study. In 2015, the first bloom was observed on 20 April, full bloom on 24 April, end of flowering on 28 April, bud burst on 4 May and harvest on 2 July. In 2016, vegetation started about 15 days earlier and the dates were respectively observed as 7 April, 10 April, 15 April, 20 April and 20 June. Fertilization did not have any significant effects on phenological observations.

Different N doses had significant effects on fruit N and B contents and N:K ratios. N content and N:K ratios linearly increased with increasing N doses, but B was negatively influenced by N doses. N treatments did not have significant effects on other nutrients. The N content of control treatment was 0.75% and the value increased to 1.15% at the highest N dose (250 g N tree^{-1}). Parallel to increases in N contents, N:K ratios also increased from 0.67 to 0.99. B contents decreased from 23.12 mg kg^{-1} to 19.04 mg kg^{-1} with increasing N doses (Table 3). K fertilizations did not have significant effects on fruit K contents, but negatively influenced N contents and positively influenced B contents. The greatest fruit N contents were obtained from the control and the lowest K doses (50 g K_2O tree^{-1}) (Table 4). While N fertilization had direct positive effects on fruit N contents, K fertilizations did not have significant effects on fruit K contents.

N fertilizations had positive effects on fruit color parameters. Red color formation (a*), brightness (L*) and color intensity (C*) increased with increasing N doses. Flesh firmness (FF) was also positively influenced by N treatments and the greatest values were obtained from 125 and 250 (g N tree^{-1}) doses. Cracking index (CI) values revealed that the fruits from 50 and 125 (g N tree^{-1}) doses were more prone to cracking (Table 5). In N treatments, a correlation was not observed between FF and CI. K fertilization did not have significant effects on FF and color parameters. Contrary to expectations, K fertilization had negative effects on CI. In other words, fruits were found to be more sensitive to cracking at higher K doses (Table 6).

N fertilization altered N and B contents of the fruits. Nutrients play a great role in fruit quality and fertilization directly influences nutritional composition of the fruits. Souza *et al.* (2013) reported increasing N contents of apples with increasing N doses. Yang *et al.* (2015) reported significant negative correlations between N and B contents of litchi leaves. Fallahi *et al.* (2010) also reported significant effects of nutrients on fruit quality and physiological disorders and indicated N, P, K, Ca and B as the most significant nutrients. There may not be linear relationships always between leaf and fruit nutrient contents. Fruit quality problems are directly related to fruit nutrient contents (Aktas and Ates, 1998; Spectrum Analytic Inc., 2006).

Increasing N doses resulted in positive changes in fruit color and flesh firmness. Normally increasing N doses are thought to negatively influence fruit quality. It was reported in previous studies that high N levels generally reduced color development (in red and yellow apple cultivars) and flesh firmness in yield-age trees (Hoying *et al.*, 2004; Nava *et al.*, 2007; Souza *et al.,* 2013). Considering all the other factors as equal, 0.1% increase in N level results in 5% decrease in fruit color (Hoying *et al.*, 2004; Spectrum Analytic Inc., 2006). Rettke *et al.* (2006) also reported that firmness of apricots was significantly reduced as the rate of applied nitrogen increased. In fact, both the deficiency and abundance of N may create problems for plant growth. For instance, insufficient N nutrition resulted in periodicity (Biennial Bearing) in apples (Spectrum Analytic Inc., 2006; Raese *et al.* 2007) and excessive N nutrition also resulted in excess vegetative growth and thus less yield (Herrera, 2001). Since experimental soils were rich in K, increasing N doses did not result in negative outcomes, but had positive influences. Present findings revealed that current N doses were not as much as to create a problem. Maximum quality values were observed at 125 g N tree^{-1} treatment and the same quality parameters were also continued at 250 g N tree^{-1} dose.

N fertilization had significant effects on fruit N:K ratios. Huber and Graham (1999) indicated that diseases and pests may be effective in plants when the plants provided proper ambient for such disease and pests. Accumulation of amino acids and sugars may result in some diseases in plants. Bergmann (1992) indicated that plants were more prone to pathogen attacks when they had high N and low K contents, in other words when they had sugar and amino acid contents higher than normal levels.

Table 1. Soils characteristics of trial orchard

EC (mS/cm)	pH	Total lime (%)	Organic matter (%)	Saturation (%)	P (mg kg^{-1})	K (mg kg^{-1})
0.45	7.87	7.16	2.86	71	22	371
Ca (mg kg^{-1})	Mg (mg kg^{-1})	Na (mg kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})
5143	578	10.94	9.33	7.11	1.78	0.43

Table 2. Characteristics of irrigation water used in trial orchard

EC (mS cm^{-1})	B (mg L^{-1})	pH	Na (me L^{-1})	K (me L^{-1})	Ca (me L^{-1})	Mg (me L^{-1})
0.72	0.05	7.64	0.81	0.05	5.64	2.96
$CO_3^{=}$ (me L^{-1})	HCO_3^- (me L^{-1})	Cl^- (me L^{-1})	$SO_4^{=}$ (me L^{-1})	SAR	Irrigation water class	
-	7.80	1.40	0.26	0.39	C_2-S_1	

Table 3. Effect of N treatments on fruit nutrient content of sweet cherry (mean of consecutive years)

N doses (g tree^{-1})	N (% DW)	P (% DW)	K (% DW)	Ca (% DW)	Mg (% DW)
0	0.75 ± 0.048 c	0.11 ± 0.004	1.10 ± 0.045	0.091 ± 0.008	0.063 ± 0.002
50	0.87 ± 0.037 b	0.11 ± 0.004	1.12 ± 0.041	0.083 ± 0.005	0.064 ± 0.002
125	1.05 ± 0.052 a	0.10 ± 0.003	1.08 ± 0.034	0.077 ± 0.006	0.061 ± 0.001
250	1.15 ± 0.056 a	0.11 ± 0.004	1.15 0.048	0.083 ± 0.004	0.068 ± 0.001
P value	P<0.01	NS	NS	NS	NS
N doses (g tree^{-1})	Fe (mg kg^{-1} DW)	Mn (mg kg^{-1} DW)	Zn (mg kg^{-1} DW)	B (mg kg^{-1} DW)	N:K
0	17.25 ± 2.10	0.97 ± 0.17	3.18 ± 0.31	23.12 ± 1.01 a	0.67 ± 0.036 c
50	17.65 ± 1.51	1.11 ± 0.22	3.62 ± 0.31	22.22 ± 0.90 ab	0.79 ± 0.042 b
125	17.62 ± 2.19	1.23 ± 0.32	3.29 ± 0.26	19.04 ± 0.99 c	0.97 ± 0.056 a
250	16.71 ± 2.01	1.29 ± 0.37	3.33 ± 0.37	20.38 ± 0.75 bc	0.99 ± 0.040 a
P value	NS	NS	NS	P<0.01	P<0.01

DW: dry weight, NS: non-significant, ±: standard error mean

Table 4. Effect of K treatments on fruit nutrient content of sweet cherry (mean of consecutive years)

K_2O doses (g tree^{-1})	N (% DW)	P (% DW)	K (% DW)	Ca (% DW)	Mg (% DW)
0	1.20 ± 0.040 a	0.11 ± 0.003	1.00 ± 0.023	0.077 ± 0.006	0.064 ± 0.002
50	1.23 ± 0.044 a	0.11 ± 0.003	1.02 ± 0.023	0.076 ± 0.005	0.065 ± 0.002
125	1.13 ± 0.040 ab	0.11 ± 0.005	1.02 ± 0.045	0.076 ± 0.006	0.063 ± 0.002
250	1.07 ± 0.037 b	0.10 ± 0.004	1.03 ± 0.030	0.078 ± 0.004	0.063 ± 0.002
P value	P<0.05	NS	NS	NS	NS
K_2O doses (g tree^{-1})	Fe (mg kg^{-1} DW)	Mn (mg kg^{-1} DW)	Zn (mg kg^{-1} DW)	B (mg kg^{-1} DW)	N:K
0	18.14 ± 2.23	0.83 ± 0.26 bc	3.54 ± 0.33	24.06 ± 0.96 a	1.20 ± 0.059
50	16.08 ± 1.70	1.08 ± 0.36 a	3.55 ± 0.32	21.76 ± 0.88 b	1.14 ± 0.080
125	16.59 ± 2.37	0.81 ± 0.26 c	3.33 ± 0.30	20.88 ± 1.34 b	1.12 ± 0.047
250	15.76 ± 2.45	1.02 ± 0.32 ab	3.49 ± 0.31	22.13 ± 1.16 ab	1.10 ± 0.040
P value	NS	P<0.05	NS	P<0.05	NS

DW: dry weight, NS: non-significant, ±: standard error mean

Table 5. Effect of N treatments on fruit quality attributes of sweet cherry (mean of consecutive years)

N doses (g tree^{-1})	a*	b*	C*	L*	*h*°	CI	FF
0	15.86 ± 0.73 b	5.17 ± 0.53 b	16.78 ± 0.76 b	28.24 ± 0.41 c	18.28 ± 1.82 b	36.50 ± 1.53 b	10.46 ± 0.12 b
50	17.22 ± 0.67 b	5.83 ± 0.74 b	18.28 ± 0.82 b	28.93 ± 0.46 bc	18.11 ± 1.85 b	44.73 ± 3.02 a	10.99 ± 0.24 ab
125	19.52 ± 0.53 a	6.99 ± 0.70 a	20.82 ± 0.67 a	29.72 ± 0.48 ab	19.28 ± 1.65 a	44.50 ± 2.95 a	11.52 ± 0.28 a
250	20.59 ± 0.62 a	7.46 ± 0.68 a	21.99 ± 0.75 a	30.04 ± 0.44 a	19.33 ± 1.42 a	34.10 ± 3.41 b	11.62 ± 0.25 a
P value	P<0.01	P<0.01	P<0.01	P<0.01	P<0.05	P<0.05	P<0.01

±: standard error mean, CI: cracking index, FF: flesh firmness

Table 6. Effect of K treatments on fruit quality attributes of sweet cherry (mean of consecutive years)

K_2O doses (g tree^{-1})	a*	b*	C*	L*	*h*°	CI	FF
0	21.01 ± 0.66	7.66 ± 0.59	22.43 ± 0.75	30.15 ± 0.42	19.54 ± 1.28	37.60 ± 4.22 b	11.62 ± 0.19
50	20.17 ± 0.83	7.22 ± 0.64	21.50 ± 0.94	29.97 ± 0.40	19.29 ± 1.26	37.26 ± 4.41 b	12.03 ± 0.32
125	19.55 ± 0.53	6.88 ± 0.56	20.80 ± 0.62	29.74 ± 0.35	18.92 ± 1.30	41.50 ± 4.59 ab	11.68 ± 0.32
250	20.79 ± 0.43	7.43 ± 0.60	22.15 ± 0.55	30.13 ± 0.35	19.16 ± 1.31	46.33 ± 4.89 a	11.59 ± 0.24
P value	NS	NS	NS	NS	NS	P<0.05	NS

NS: non-significant, ±: standard error mean, CI: cracking index, FF: flesh firmness

Increasing N levels also reduce phenolic compounds which have toxic impacts on pathogens. Therefore, a balance should be considered between N and K in fertilization practices for fruit trees. For instance, N:K ratio should be between 1-1.5 in apple leaves (Spectrum Analytic Inc., 2006). Although a special ratio hasn't been indicated for fruits, such a ratio was considered to be a significant quality parameter for fruits. The present N:K ratios increased with increasing N doses, but were mostly below 1. The ratio decreased with increasing K doses, but the changes were not found to be significant.

K fertilizations did not have significant effects on fruit color and flesh firmness. High K contents (371 mg kg^{-1}) of experimental soils (Stiles, 2004; OMAFRA, 2004) might have resulted in such outcomes. Under normal conditions, optimal K fertilization improves fruit quality by enhancing leaf photosynthesis and the reallocation of sugars and organic acids to fruit (Crisosto and Costa, 2008). Nava *et al.* (2007) reported positive effects of K fertilization on fruit colour and total soluble solid content, but negative effects on flesh firmness of apples. In K-deficient fruit trees, fruits will be smaller than normal size, have dull colours and be tasteless because of insufficient acid levels and be thick skinned (Stiles, 1994; Hoying *et al.*, 2004). In general, high K levels in leaves and fruits negatively affect fruit quality and storage characteristics because of antagonistic effects between K and Ca-Mg (Bergmann, 1992). Yang *et al.* (2015) also reported highly significant negative correlations of K contents with Ca and Mg contents and significant negative correlations with Zn content in litchi leaves. But, Saykhul *et al.* (2014) indicated that there were not any significant variations in Ca, Mg and micronutrient concentrations in different plant parts of olive plants with K treatments.

Conclusions

N fertilization directly influenced fruit N contents. Increasing N doses had positive effects on desired fruit quality attributes like fruit color and flesh firmness and optimum values were obtained from 125 g N tree^{-1} treatment. Such effects were not observed in K fertilization. Sweet cherry trees did not respond to K fertilization under the same conditions. Organic matter is the greatest source of N in soils. Although experimental soils had quite high organic matter content (2.86%), sweet cherry trees exhibited positive responds to N fertilization. In this study, it was observed that trees did not respond to K fertilization when the soils had a K levels higher than certain values. Therefore, soil K levels should be taken into consideration while making K fertilization. The antagonistic effect between N and K should also be taken into consideration in K fertilizations. It was concluded in present study that excessive K fertilization did not have positive impacts on fruit quality and might even have negative influences.

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