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FOLIAR APPLICATION OF CALCIUM NITRATE, BORIC ACID AND GIBBERELLIC ACID AFFECTS YIELD AND QUALITY OF POMEGRANATE (*Punica granatum* L.)

Nazan Korkmaz[1], Mehmet Atilla Askin[2], Sezai Ercisli[3], Volkan Okatan[4]

[1] Mugla Sitki Kocman University, Ortaca Vocational School, Ortaca, Mugla-Turkey
[2] Suleyman Demirel University, Agricultural Faculty, Department of Horticulture, Isparta-Turkey
[3] Ataturk University, Agricultural Faculty, Department of Horticulture, Erzurum-Turkey
[4] Usak University, Sivasli Vocational School, Usak-Turkey

Abstract. Effect of two doses of calcium nitrate (2 and 4%), boric acid (1.5 and 3%) and GA_3 (50 and 75 ppm) on yield, fruit characteristics, cracking and sunburn of pomegranate cv. Hicaznar was carried out in a commercial orchard. Calcium nitrate, boric acid and GA_3 applications have been done during blossoming period and one month after blossoming. The fruit yield has been increased by both doses of calcium nitrate and the 3% boric acid dose in the first year while GA_3's 50 ppm dose had an improving effect in the second year. In the first year, all treatments increased the average fruit weight while in the second year only the 2% calcium nitrate and 3% boric acid were found to be effective. The 3% boric acid treatments reduced the rate of cracking of the fruits in first year and in the second year all treatments reduced cracking and the best results were obtained in the applications of GA_3 and calcium nitrate. The 4% calcium nitrate application reduced the sunburn in the pomegranate fruits and 2% calcium nitrate application increased the amount of the total soluble solids.

Key words: fruit cracking, L., sunburn, vitamin C

Corresponding author: Sezai Ercisli, Ataturk University, Agricultural Faculty, Department of Horticulture, Erzurum-Turkey, e-mail: sercisli@gmail.com

INTRODUCTION

Horticulture including fruits, vegetables for a long time are used by people for food, either as edible products, or for culinary ingredients, for medicinal use or ornamental and aesthetic purposes. They are genetically very diverse group and play a major role in modern society end economy [Bajpai et al. 2014, Feng et al. 2014, Ruttanapraset et al. 2014, Mlcek et al. 2015].

The pomegranate is native from Iran to the Himalayas in northern India and has been cultivated and naturalized over the Mediterranean region and the Caucasus region of Asia since ancient times. Pomegranate is tolerant to drought, salt, iron chlorosis and active calcium carbonate. It is widely cultivated throughout China, Iran, India, the drier parts of southeast Asia, Malaya, the East Indies, and dry, hot areas of the United States and Latin America. It typically grows below 1000 m in altitude, is mainly confined to the tropics and subtropics and grows well in arid and semi-arid climates. Favorable growth takes place where winters are cool and summers are hot. It has the ability to withstand frosty conditions, but below -10°C will not survive long. A temperature of 38°C and a dry climate during fruit development produces the best quality fruits. Areas with high relative humidity or rain are totally unsuitable for its cultivation, as fruits produced under such conditions tend to taste less sweet and are prone to cracking [Singh et al. 2003, Ramezanian et al. 2009, Gozlekci et al. 2011a, Gozlekci et al. 2011b].

Although, pomegranate is well adapted to a wide range of growing conditions and soils, nutritional disorders caused by Ca^{2+} deficiency can be common, especially in acid soils where Ca^{2+} availability is significantly reduced. While severe symptoms of Ca^{2+} deficiency may not be found frequently, it is known that Ca^{2+} deficiency, even without the appearance of any visible foliage symptoms, can significantly limit the crop yield [Marschner 1995]. Calcium is the most important mineral in ensuring the cell structure stability and mechanical strength. Elmer et al. [2007] indicated that calcium was an important component of plant tissue, taking part in the protection of plant cells and Ferguson [1984] indicated that Ca played an important role in the regular maturity process. The application of calcium to fruits both prior to and after harvesting provides protection against physiological deterioration, retardation of maturity and improvement fruit quality [Hernandez-Munoz et al. 2006, Lanaouskas and Kvikliene 2006, Bonomelli and Ruiz 2010, Chen et al. 2011, Irfan et al. 2013].

Fruit cracking is a serious problem of pomegranate. It is due to boron deficiency in young fruits while in developed fruits it may be caused due to extreme variations in day and night temperatures. Boron, zinc and calcium were highly effective in improving, nutritional status, yield and fruit quality of pomegranate trees. Foliar application of boron reduced the percentage of cracked fruits [Bambal et al. 1991, Khalil et al. 2013]. Singh et al. [2003] stated that the cracking of the pomegranate fruits could be taken under control by means of controlled and systematic watering as well as boron application. However, information on the effects of boron on the cracking of the fruit, sunburn and fruit quality is quite limited.

Among different elite horticultural practices, growth regulators have been advantageously used in the recently to increase the fruit production and to improve the quality of several fruit crops [Cline and Trought 2007, Amezquita et al. 2008, Canli et al. 2015]. The effects of applying GA_3 on the pomegranate plants to improve plant growth, yield, fruit quality parameters and lessening of cracking as well as the retardation of maturity have been studied [Singh et al. 2003, Ameen Al-Imam 2009, Khalil and Aly 2013].

A search of the literature reveals that studies on the effects of applications of Calcium, Boron and Gibberellin on productivity and quality in pomegranate are scarce. In this study, the effects of applying plant nutrition elements and hormones on the productivity and quality of the pomegranate fruit have been examined.

MATERIAL AND METHODS

The study has been conducted on cv. Hicaznar grown in commercial orchard located in Ortaca district of the province of Mugla. The pomegranate plants were 5 years old and planted with 6 × 3 meters between and within rows. The soil samples obtained from the study area obtained at 0–30 and 30–60 cm depths as well as the fruit samples taken from October. The soil samples have been analyzed in conformance to the principles indicated by Kacar [1984]. The physical and chemical properties of the testing soil are provided in Table 1.

Table 1. The physical and chemical properties of the soils taken before the experiment

		Texture			pH	EC (mmhos·cm^{-1})	$CaCO_3$ (%)	Organic matter (%)	Macro- and microelements								
		sandy (%)	clay (%)	silt (%)					N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Mn (ppm)
Depth	0–30	55	24	21	7.85	195	15.06	1.45	0.81	16.06	158	4655	956	4.32	0.71	0.34	4.36
(cm)	30–60	19	55	26	7.87	218	17.12	0.90	0.88	11.78	154	4251	1044	3.90	1.23	0.38	4.51

The experiment has been set in 7 treatments and 3 replications according to randomized design. Control, calcium nitrate (Ca_2NO_3) 2 and 4% (CN1,CN2), boric acid (H_3BO_3) 1.5 and 3% (B1, B2), and GA_3 as 50 and 75 ppm ($GA_3$1, $GA_3$2) have been applied through the leaves on plant during blossoming and 1 month after the blossoming. 3 trees were used in each replication (or experimental plot). The yield per tree (kg), cracking ratio (%), and sunburn fruit ratio (%) were recorded at the end of the harvesting period. The ratios of the cracked and sunburn fruits were determined by dividing the affected fruits to the total number of fruits. The measurements of average fruit weight (g), aril yield (%), fruit juice yield (%) and total soluble solids (TSS, %) were taken on 10 fruits that were obtained from each lot separately. Fruit samples were obtained during harvesting.

In both years of the experiment, NPK 15-15-15 compound fertilizer was applied in the fertilization process. The application of the fertilizer was made at the rate of 1.5 kg per tree in the month of February. In the first year of the experiment, farm manure was applied in September.

The data obtained in the study has been evaluated by using TARIST analysis program, to detect statistically significant differences with at 5% confidence level [Acikgoz et al. 1994]

RESULTS AND DISCUSSION

The yield per tree was higher in the first year in comparison to the second year (tab. 2). The difference is statistically significant ($p < 0.05$). In the first year, the CN1 application yielded the highest yield (38.34 kg·tree^{-1}), and followed by B2 (38.11 kg·tree^{-1}) and CN2 (35.55 kg·tree^{-1}) applications. When the second year of results was evaluated, it has been observed that only $GA_3$1 application yielded (36.60 kg·tree^{-1}) higher than the control (28.24 kg·tree^{-1}).

Table 2. Effect of fertilizer and gibberelic acid applications on yield, fruit weight, cracking and sunburn of pomegranate

	Foliar application	Yield (kg·tree^{-1})	Fruit weight (g)	Cracking (%)	Sunburn (%)
2011	control	32.69ab	515.8	32.55a	7.408 bc
	CN1	38.34a	565.4	29.85ab	7.944 bc
	CN2	35.55a	554.0	22.36bc	6.120 c
	B1	24.48bc	535.4	26.84abc	7.988 bc
	B2	38.11a	580.2	32.55a	6.246 c
	$GA_3$1	22.53bc	569.4	21.60bc	9.984 ab
	$GA_3$2	20.76c	582.4	17.20c	12.843 a
	$LSD_{0.05}$	**10.187	NS	*9.720	*3.626
2012	control	28.24	456.2	23.61a	15.743
	CN1	26.88	481.7	14.76ab	17.607
	CN2	26.18	429.9	15.14bc	9.580
	B1	27.35	428.0	9.54bc	14.047
	B2	25.35	521.1	16.56bcd	13.960
	$GA_3$1	36.60	445.6	5.68cd	17.400
	$GA_3$2	25.75	417.8	6.83d	13.460
	$LSD_{0.05}$	NS	NS	**8.313	NS

NS – non significant

Amezquita et al. [2008] studied the effects of different doses of gibberellin (5, 10 or 15 mg·L^{-1}) and calcium (0.5, 1.0 or 1.5 g·L^{-1}) applied 3, 10, 17 and 24 days after anthesis on the yield, fruit quality and cracking rate of *Physalis perivuana* L. and determined that the application of gibberellin and calcium significantly increases yield. In our study, the yield was lower in comparison to the control in the first year. In the second year, the highest yield was obtained with $GA_3$1 dose. Yeşiloğlu and Cucu Acikalin [2002] obtained a similar result on mandarin and reported that the use of GA_3 in the first year promoted vegetative growth of the trees.

The effects of the applications in both 2011 and 2012 on the fruit weight were determined to be statistically insignificant. In the first year all applications affected the fruit weights positively and fruit weight increased. The highest fruit weight was achieved at 582.4 g in $GA_3$2 application. However, in the second year other than CN1 (481.7 g) and B2 applications (521.1 g) were not able to increase fruit weight in comparison to the control (tab. 2). Ramezani and Shekafandeh [2009] reported significant increases in the fruit weight of the olive fruits following Gibberellic acid application.

In the first year of the experiment, all the applications except the second dose of the boron application were effective in reducing the rate of cracking in comparison to the control. In the second year all the applications were determined to have a reducing effect on the cracking of fruits. Researchers reported that the application of GA_3 could reduce the rate of cracking in mandarin [Yesiloglu and Cucu Acikalin 2002] and pomegranate [Yilmaz and Ozguven 2003].

Sunburn in fruits reduces the quality. When results were examined, CN2 application has revealed itself to be the one with the least sunburn rate. Calcium directly contributes to the strengthening of cell walls in plants [Demarty et al. 1984]. When both of these facts are taken into consideration with the data obtained from our study, it can be deduced that the application of calcium to pomegranate strengthened the cell walls and was effective in reducing the rate of sunburn based on damaging effects of the sunlight.

When the physical and chemical properties examined, no statistically significant difference found between the applications on fruit properties, except Vitamin C in 2011 (tab. 3).

The highest aril yield have been obtained in Control application (51.82%) in the first year, while in the second year CN2 application yielded the highest aril yield (50.11%). Similarly the highest fruit juice yield have been obtained in control fruits (40.83%) in the first year, while in the second year CN2 application yielded the highest fruit juice yield (38.61%) (tab. 3).

Table 3. Effect of fertilizer and gibberelic acid applications on aril yield, fruit juice yield, TSS and Vitamin C

	Foliar application	Aril yield (%)	Fruit juiceyield (%)	TSS (%)	Vitamin C ($mg \cdot 100\ g^{-1}$)
2011	control	51.82	40.83	15.93	5.85 c
	CN1	49.90	39.57	16.01	10.17bc
	CN2	49.66	39.15	16.07	12.33 ab
	B1	45.41	35.20	16.18	16.10 ab
	B2	48.09	36.39	15.80	18.70 ab
	$GA_3$1	50.83	40.47	15.83	20.73 a
	$GA_3$2	45.97	37.01	16.08	19.83 a
	$LSD_{0.05}$	NS	NS	NS	*8.701
2012	control	46.91	36.29	10.80	8.47
	CN1	40.69	32.19	13.60	9.41
	CN2	50.11	38.61	12.23	10.07
	B1	45.16	35.09	12.97	9.29
	B2	49.05	34.40	11.93	9.34
	$GA_3$1	46.90	36.56	12.57	9.43
	$GA_3$2	47.04	37.94	13.03	9.34
	$LSD_{0.05}$	NS	NS	NS	NS

NS – non significant

Yilmaz [2005] indicated that the aril and fruit juice yield increased in pomegranate (*Punica granatum* L.) when the amounts of calcium and magnesium applied through the leaves. In our study, the leaf calcium content (not provided in the article) has been determined to be the highest in the CN2 application (3.098%) in comparison to the others in the second year. In the year 2011, B1 application increased the total soluble solids

(TSS) (16.18%) and in 2012, CN1 application yielded the highest value (13.60%). Cheng [1994] reported that the deficiency of boron led to a decrease in TSS and Vitamin C values in strawberries. Alila and Achumi [2012] examined the effects of calcium chloride (0.5 and 0.69%), calcium nitrate (1, 1.5, and 2%) and boric acid (0.2, 0.4, and 0.6%) preharvest application in Litchi fruit (*Litchi sinensis*) on postharvest fruit quality and determined that the 4% boric acid resulted the highest content of TSS. In our study, TSS was the highest in B1 application in the first year of the experiment and higher than the control application in the second year. Raese and Drake [2000] conducted a study on Golden Delicious apples examined the effects of 7 different calcium applications on the quality of the fruit and reported that 5 calcium applications increased the TSS in comparison to the control. Content of vitamin C increased significantly in the most of treatments in 2011. Vitamin C value was the highest in $GA_3$1 (20.73 mg·100 g^{-1}) application in the first year and in CN2 (10.07 mg·100 g^{-1}) application in the second year. Ramezanian et al. [2009] reported calcium chloride was effective in increasing the Vitamin C levels in the pomegranate fruit.

CONCLUSIONS

The yield and quality characteristics in individual years were increased by foliar applications of Boron, Calcium and GA_3. In the second year all the applications were determined to have a reducing effect on the cracking of fruits. Especially, twice 4% calcium nitrate application can be preferred during blossoming and one month after blossoming would minimize the rate of sunburns in the fruit. The data presented in the study indicate that the maximum TSS was obtained from Boron applications. Vitamin C concentration was increased by Calcium and GA_3 foliar applications. Foliar Boron, Calcium and GA_3 applications could be adopted in commercial pomegranate orchards as a practice to enhance fruit yield and quality.

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WPŁYW DOLISTNEGO ZASTOSOWANIA AZOTANU WAPNIA, KWASU BOROWEGO I KWASU GIBERELINOWEGO NA PLON I JAKOŚĆ GRANATU

Streszczenie. W komercyjnym sadzie badano wpływ dwóch dawek azotanu wapnia (2 i 4%), kwasu borowego (1,5 i 3%) i kwasu giberelinowego (50 i 75 ppm) na plon, cechy owoców, pękanie i poparzenia słoneczne granatu odmiany Hicaznar. Azotan wapnia, kwas borowego oraz GA_3 zastosowano podczas kwitnienia i miesiąc po kwitnieniu. Plon owoców wzrósł przy obydwu dawkach azotanu wapnia i kwasu borowego w pierwszym roku, a dawka GA_3 50 ppm miała pozytywny wpływ w drugim roku. W pierwszym roku wszystkie zabiegi podnosiły średnią masę owoców, natomiast w drugim roku tylko 2% azotan wapnia i 3% kwas borowy okazały się skuteczne. Zabiegi 3% kwasem borowym zmniejszały pękanie owoców w pierwszym roku, a w drugim roku wszystkie zabiegi zmniejszały pękanie, natomiast najlepsze rezultaty osiągnięto po zastosowaniu GA_3 i azotanu wapnia. Zastosowanie 4% azotanu wapnia zmniejszało poparzenie słoneczne owoców granatu, a zastosowanie 2% azotanu wapnia zwiększało całkowitą ilość rozpuszczalnych związków stałych.

Słowa kluczowe: pękanie owoców, oparzenie słoneczne, witamina C

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