Effects of gibberellic acid, potassium nitrate and calcium sulfate on pomegranate fruit splitting and fruit characteristics

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Summary

Pomegranate fruit splitting is one of the major problems of production which leads to economic and quality losses. Cultivars with thin peel such as 'Kadru' are more susceptible to this disorder. The present study was carried out in a completely randomized block design to evaluate the influence of foliar application of gibberellic acid (GA_3), potassium nitrate (KNO_3) and calcium sulfate ($CaSO_4$) on alleviating fruit splitting of 'Kadru' cultivar in addition to some physical and quality characteristics in an orchard in Farugh region (Fars Province, Iran). Uniform healthy pomegranate trees were chosen for the experiment. Treatments included the foliar application of GA_3 (50, 100 and 200 mg L^{-1}), CaSO4 (2500, 3000 and 3500 mg L^{-1}) and KNO_3 (5000, 10,000 and 15,000 mg L^{-1}) in May and early September in two successive years. The results indicated that most of the treatments significantly increased the number of healthy fruits, however, the application of KNO_3 at 5000 mg L^{-1} concentration did not cause a significant response. Foliar application of GA_3 (100 mg L^{-1}) was evaluated as the most effective treatment in the reduction of the fruit splitting. Also, KNO_3 (10,000 mg L^{-1}) treatment mitigated the percentage of fruit splitting and had a beneficial impact on the weight of 100 arils, percentage of the edible part of the fruits and ascorbic acid concentration. Therefore, foliar application of KNO_3 (10,000 mg L^{-1}) is recommendable for the reduction of the pomegranate fruit splitting.

Key words

cell wall, foliar application, peel, physiological disorders

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Introduction

Pomegranate (*Punica granatum* L.) is a nutrient-dense fruit, rich in phytochemical compounds (Miguel et al., 2010). Market ability and quality of pomegranate depend on peel color, lack of physical defects, juice total soluble solids (TSS), titratable acidity (TA) and taste (Al-Said et al., 2009). Pomegranate fruit splitting is one of the major problems of production that reduces the postharvest life of the product that leads to economic and quality losses (Singh et al., 2017). Cultivars with thin peel such as 'Kadru' are more susceptible to this disorder. Various preharvest treatments such as foliar application of plant growth regulators (PGR) and macro and micronutrients have been studied for increasing peel thickness and elasticity and mitigating this disorder. However, foliar application of different PGR was found to be more effective treatments in comparison to mineral nutrients application (Stander, 2013).

The presence of optimized plant macro and micronutrient concentration within plant tissues and organs is a prerequisite of elevated fruit quality and yield (Marschner, 2011). Li et al. (2009) found that spraying of potassium and calcium could significantly decrease fruit splitting. The deficiency of calcium has been reported to be associated with the splitting of pericarp cells in tomato (Astuti, 2002) and lychee (Huang et al., 2005). The application of potassium nitrate caused the reduction of fruit splitting and higher total soluble solids in lychee (Mishra et al., 2012). The goal of the present study was to evaluate the effects of gibberellic acid, potassium nitrate and calcium sulfate on mitigating pomegranate fruit splitting and improve the quality of the fruit.

Materials and methods

Plant materials and treatments

The present experiment was carried out in a completely randomized blocks design in two consecutive years (2012 and 2013) in an orchard in Farugh region (near Marvdasht City, Fars Povince, Iran), with four replications, each replication had four trees.

Average annual precipitation was 263 mm; maximum relative humidity was 55% and minimum 23%, maximum temperature was 40 and minimum 5°C in the experimental region. The soil of the orchard was sampled at two depths and analyzed for mineral content, organic matter, pH and EC (Table 1). Uniform same-aged (eight- year's old trees) and healthy pomegranate trees of 'Kadru' cultivar, were chosen for this study. The trees were grown on a loamy sand soil under drip irrigation (every six days for 12 hours) with 3 m distance in rows and 4 m distance between rows. Routine cultural practices suitable for commercial fruit production were conducted during the experimental period. Treatments included: 1. control (trees sprayed with distilled water); 2. gibberellic acid (trees sprayed with 50, 100 and 200 mg L^{-1} GA_3); 3. calcium sulfate (trees sprayed with 2500, 3000 and 3500 mg L^{-1} $CaSO_4$) and 4. potassium nitrate (trees sprayed with 5000, 10,000 and 15,000 mg L^{-1} KNO_3). All treatments were foliar applied twice a year: in May (immediately after fruit set) and early September (during this period of year fruit splitting increases due to augmentation of temperature). Pomegranate fruits were harvested in late October.

Data collection

In four trees (i.e. one tree per replication), the total number of fruits (split and healthy) was counted before harvest. Four healthy and four split fruits were sampled from four sides of each tree at the same height for the determination of physical and quality characters. There were 64 fruits per treatment. Average peel thickness (mm) and fruit length/diameter were determined using a digital caliper. Peel weight (g), 100 aril weight (g) and the percentage of the edible part of the fruit (i.e. aril/fruit weight ratio) were measured using a digital scale. The juice was extracted using a manual device and TSS was measured using a refractometer (ATC1E, ATAGO, Japan) and expressed in Brix°. The TA percentage was determined by titrating 5 mL of fruit juice with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator (Khalil and Aly, 2013). Fruits taste (TSS/TA ratio) was calculated. The ascorbic acid concentration in fruits was measured spectrophotometrically. To 100 µl of fruit juice, 10 ml of metaphosphoric acid (1%) was added, then to 1 ml of this mixture, 9 ml of indophenol (50 µM) was added and vortexed and read absorbance with a spectrophotometer (WPA Bioware2, UK) at 515 nm. A calibration curve was prepared with known ascorbic acid concentrations. The results were expressed as $mg.100^{-1}$ ml juice. Dried samples (one gram) were ground and ashed at 450°C in a porcelain crucible for 6 h. The white ash was mixed in 2 N hot HCl, filtered and finally made up to 50 mL with distilled water. The potassium concentration of samples was determined using a flame emission method using a flame photometer. Atomic absorption spectrophotometer (Shimazu AA-670, Kyoto, Japan) was used to determine calcium (Miller-Ihli, 1996).

Statistical Analysis

Data were analyzed by SAS (version 9.1 for Windows) and LSD test was used. Means were compared using LSM (least-squares mean) at a 5% probability level. Logistic regression was used for analyzing fruit splitting percentage and determination of the year and treatment impacts. Percentage parameters were transformed before analysis with the ANOVA method.

Table 1. Basic soil characteristics in the experimental orchard (2012)

Soil depth	Dept (cm)	pH of paste	EC*10^3 dS/m	O.C.† (%)	P_2O_5 ($mg{\cdot}kg^{-1}$)	K_2O ($mg{\cdot}kg^{-1}$)	Cu ($mg{\cdot}kg^{-1}$)	Mn ($mg{\cdot}kg^{-1}$)	Fe ($mg{\cdot}kg^{-1}$)	Zn ($mg{\cdot}kg^{-1}$)
Depth one	0-30	7.8	0.31	0.41	15.8	696	0.58	6.62	4.74	0.34
Depth two	30-60	8.2	0.32	0.02	3	160	3.48	13.40	8.92	3.68

† Organic Carbo

Results

Trees sprayed with GA_3 at a concentration of 50 mg L^{-1} in the first year and 100 mg L^{-1} in the second year produced a higher number of healthy fruits in comparison to the control (Fig. 1). Our results were indicative of the beneficial impact of KNO_3 (especially at concentrations of 10,000 and 15,000 mg L^{-1}) on the reduction of fruit splitting (Fig. 1). In the second year, all treatments had higher healthy fruits (compared to the control in year 2). All treatments significantly increased the number of healthy fruits in comparison to control samples on average. However, the application of KNO_3 at a concentration of 5000 mg L^{-1} did not cause a significant response. Gibberellic acid (100 mg L^{-1}) was evaluated as the most effective treatment in the reduction of the fruit splitting. However this treatment was not significantly different in comparison to foliar application of KNO_3 at a concentration of 10,000 or 15,000 mg L^{-1}, GA_3 at 50 mg L^{-1} and $CaSO_4$ at a concentration of 2500 or 3000 mg L^{-1} (Fig. 1). The healthy fruit weight, peel weight and thickness, 100 arils weight were significantly higher in the second year compared to the first year and the percentage of healthy fruit in second year (90%) was higher than first year (86%). Aril weight did not change significantly in year one or two of the experimental period. Edible part of fruits and fruit length to diameter ratio were higher in the first year in comparison to the second year (Table 2). Fruit length to diameter ratio was significantly higher in split fruits compared to healthy samples (Table 2).

GA_3 at the concentration of 50 mg L^{-1} caused a significant increase in fruit peel weight compared to the control (Table 3). However, GA_3 at a concentration of 100 or 200 mg L^{-1}, $CaSO_4$ at all levels and KNO_3 at 5000 mg L^{-1} were not statistically different. In plants sprayed with KNO_3 (10,000 mg L^{-1}), 100 arils weight (Table 3) and percentage of the edible part of fruits (Table 4) increased significantly. However other treatments did not change this feature statistically in comparison to control. The peel thickness of fruits increased significantly with $CaSO_4$ at concentrations of 2500 and 3000 mg L^{-1} in comparison to control samples (Table 4). All KNO_3 levels decreased fruit length to diameter ratio in comparison to control and other treatments did not change this character (Table 4).

Peel potassium and ascorbic acid concentration, TSS and titratable acidity were higher in the second year, whereas peel calcium concentration and TSS to titratable acidity ratio was significantly higher in year one of the experimental period (Table 5). Fruit splitting did not change TA and taste significantlly although other characteristics were significantly higher in healthy fruits (Table 5).

Peel potassium concentrations were higher in trees sprayed with KNO_3 (concentration of 10,000 or 15,000 mg L^{-1}) in comparison to control samples and other treatments were not statistically different (Table 6). Table 6 demonstrats peel calcium concentration increased in trees that received $CaSO_4$ (concentration of 3000 mg L^{-1}) and TSS increased in trees after foliar application with KNO_3 (15,000 mg L^{-1}). Titratable acidity decreased significantly in plants treated with KNO_3 at a concentration of 5000 or 15,000 mg L^{-1}; other treatments demonstrated no significant difference in comparison to control. Taste increased in samples that received KNO_3 at a concentration of 15,000 mg L^{-1}, other treatments were not statistically different. The highest ascorbic acid concentration was obtained from samples sprayed with KNO_3 (concentration of 10,000 mg L^{-1}), other treatments did not change this character (Table 7).

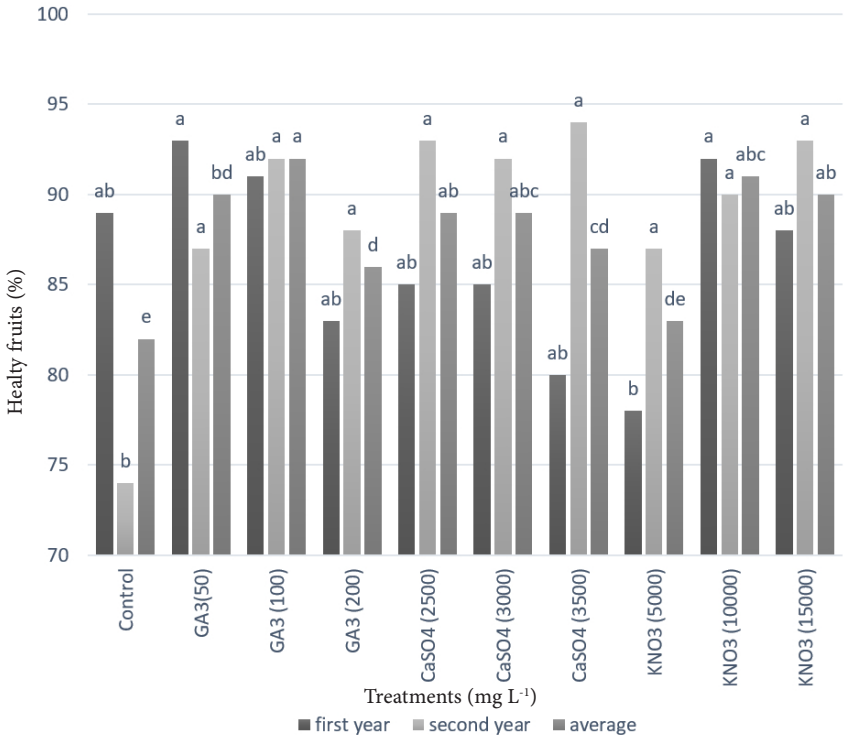

Figure 1. Effect of foliar application of GA_3 (50, 100, 200 mg L^{-1}), $CaSO_4$ (2500, 3000, 3500 mg L^{-1}) and KNO_3 (5000, 10,000, 15,000 mg L^{-1}) on pomegranate fruit splitting during the experimental period

Note: columns marked with the same letters are not significantly different at $P < 0.05$ using LSD test

Table 2. Effect of year and splitting on physical characters of pomegranate fruits

	Fruit weight (g)	Total arils weight (g)	Fruit peel weight (g)	100 arils weight (g)	Aril/Fruit weight (Edible part of fruit) (%)	Fruit peel thickness (mm)	Fruit length/ diameter
				Year			
(2012)	623.28b	445.64a	177.34b	34.76b	8.45a	1.25b	1.17a
(2013)	701.08a	492.61a	207.47a	36.63a	8.13b	1.63a	0.92b
				Fruit status			
Healthy	730.55a	215.63a	531.03a	37.74a	8.45a	1.49a	1.02b
Splitted	593.81b	169.17b	407.23b	33.65b	8.14b	1.39b	1.06a
				Statistical significance			
Year	33.81*	6.22n.s.	91.99**	135.44**	3.81**	5.52**	0.34**
Splitting	136.73**	420.93**	110.66**	642.32**	3.69**	0.37*	1.74**

Note: least-squared means are shown. Means with the same letters in each column are not significantly different at $P < 0.05$ using LSD test; n.s. - non-significan, * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Table 3. Effect of foliar application of GA_3, $CaSO_4$ and KNO_3 on pomegranate fruit physical characters

Treatments	Fruit peel weight (g)			100 aril weight (g)		
	(2012)	(2013)	Average	(2012)	(2013)	Average
Control	142.25a	231.12abc	154.57b	35.39a	31.54b	33.46b
GA_3 50 mg L^{-1}	197.57a	318.27ab	229.37a	33.80a	34.62ab	34.14ab
GA_3 100 mg L^{-1}	179.24a	351.12a	205.82ab	33.04a	35.32ab	34.14ab
GA_3 200 mg L^{-1}	194.87a	238.25abc	207.93ab	35.30a	36.09ab	35.69ab
$CaSO_4$ 2500 mg L^{-1}	176.50a	210.62bc	197.54ab	34.36a	37.29ab	35.82ab
$CaSO_4$ 3000 mg L^{-1}	216.55a	168.50c	187.30ab	35.38a	34.22ab	34.80ab
$CaSO_4$ 3500 mg L^{-1}	183.25a	220.13bc	213.35ab	35.71a	36.40ab	36.14ab
KNO_3 5000 mg L^{-1}	177.25a	223.87bc	188.68ab	36.06a	38.98a	37.52ab
KNO_3 10000 mg L^{-1}	179.25a	174.25c	169.67b	35.01a	43.14a	39.08a
KNO_3 15000 mg L^{-1}	162.37a	176.50c	169.79b	33.91a	38.36ab	36.14ab
			Statistical significance			
Year			91.99**			135.44**
Treatment			16.86**			44.59*

Note: means with the same letters in each column are not significantly different at $P < 0.05$ using LSD test; * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Table 4. Effect of foliar application of GA_3, $CaSO_4$ and KNO_3 on pomegranate fruit physical characters

Treatments	Edible part of fruit (%)			Fruit peel thickness (mm)			Fruit length/ diameter		
	(2012)	(2013)	Average	(2012)	(2013)	Average	1.21a	0.96a	1.11a
Control	67.55a	62.20c	70.59B	1.40a	1.10b	1.25c	1.17a	0.95a	1.05a
GA_3 50 mg L^{-1}	69.04a	61.43c	69.20B	1.47a	1.17ab	1.35abc	1.15a	0.94a	1.02a
GA_3 100 mg L^{-1}	66.12a	59.87c	69.49B	1.52a	1.14b	1.35abc	1.16a	0.94a	1.02a
GA_3 200 mg L^{-1}	83.26a	63.71b	75.44AB	1.46a	1.16b	1.31abc	1.13a	0.93a	1.02a
$CaSO_4$ 2500 mg L^{-1}	70.34a	74.75ab	74.98AB	1.57a	1.65ab	1.61ab	1.15a	0.93a	1.01a
$CaSO_4$ 3000 mg L^{-1}	72.69a	64.66abc	65.54B	1.51a	1.77a	1.64a	1.15a	0.90ab	1.02a
$CaSO_4$ 3500 mg L^{-1}	71.77a	65.83abc	71.30AB	1.56a	1.65ab	1.60abc	1.16a	0.85b	0.70b
KNO_3 5000 mg L^{-1}	71.23a	69.12abc	67.02B	1.41a	1.13b	1.27bc	1,15a	0.91ab	0.70b
KNO_3 10000 mg L^{-1}	75.86a	75.99a	79.83A	1.56a	1.47ab	1.51abc	1.12a	0.91ab	0.68b
KNO_3 15000 mg L^{-1}	71.39a	67.94abc	70.45AB	1.43a	1.58ab	1.50abc			
				Statistical significance					
Year			3.81**			5.52**			0.34**
Treatment			0.90**			0.35**			0.40**

Note: means with the same letters in each column are not significantly different at $P<0.05$ using LSD test; * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Table 5. Effect of year and splitting on quality characters of pomegranate fruit juice and peel potassium and calcium concentrations

	Peel K^+ (%)	Peel Ca^{2+} (mg kg^{-1})	Total soluble solids (Brix°)	Titratable acidity (%)	Total soluble solids/ Titratable acidity (taste)	Ascorbic acid (mg100 mL^{-1} of fruit juice)
				Year		
(2012)	19.66b	8.14a	14.96a	0.71b	5.46a	5.57b
(2013)	22.26a	6.77b	15.39a	0.77a	5.09b	7.65a
				Fruit status		
Healthy	21.4a	8.55a	15.41a	0.74a	5.31a	7.13a
Splitted	20.52b	6.36b	14.94b	0.74a	5.24a	6.09b
				Statistical significance		
Year	260.42**	35.91**	7.37n.s.	0.16**	5.13**	167.52**
Splitting	29.72*	91.04**	8.68*	0.1n.s.	0.21n.s.	42.07**

Note: means with the same letters in each column are not significantly different at $P < 0.05$ using LSD test; n.s. - non-significan, * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Table 6. Effect of foliar application of GA_3, $CaSO_4$ and KNO_3 on pomegranate fruit physical characters

Treatments	Total soluble solids (Brix°)	Peel K^+ (%)			Peel Ca^{2+} (mg kg^{-1})		
	Average	(2012)	(2013)	Average	(2012)	(2013)	Average
Control	14.4b	16.75b	21.49a	19.12b	6.68a	6.36b	5.62b
GA_3 50 mg L^{-1}	15.73ab	19.08ab	21.75a	20.46ab	7.94a	6.15b	7.26ab
GA_3 100 mg L^{-1}	14.7b	19.71ab	22.05a	20.90ab	8.04a	5.85b	6.34ab
GA_3 200 mg L^{-1}	15.32ab	19.16ab	22.46a	20.81ab	9.02a	6.46ab	7.80ab
$CaSO_4$ 2500 mg L^{-1}	15.35ab	19.30ab	22.72a	21.01ab	8.66a	8.07ab	8.06ab
$CaSO_4$ 3000 mg L^{-1}	14.89ab	18.62ab	22.75a	20.69ab	8.57a	8.76a	8.57a
$CaSO_4$ 3500 mg L^{-1}	14.82ab	19.52ab	21.92a	20.70ab	8.15a	7.65ab	7.50ab
KNO_3 5000 mg L^{-1}	14.71b	21.57a	21.47a	21.52ab	7.85a	7.70ab	7.11ab
KNO_3 10000 mg L^{-1}	15.45ab	20.69ab	23.38a	22.04a	8.10a	7.86ab	8.25ab
KNO_3 15000 mg L^{-1}	16.38a	22.04a	22.67a	22.35a	9.01a	7.16ab	8.03ab
				Statistical significance			
Year	7.37ns			260.46**			35.91**
Treatment	5.43**			12.75*			4.82*

Note: means with the same letters in each column are not significantly different at $P < 0.05$ using LSD test; n.s. - non-significan, * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Table 7. Effect of foliar application of GA_3, $CaSO_4$ and KNO_3 on quality characters of pomegranate fruit juice and peel potassium and calcium concentrations

Treatments	Titratable acidity (%)			Total soluble solids/ Titratable Titratable acidity (taste)			Ascorbic acid (mg100 mL^{-1} of fruit juice)		
	(2012)	(2013)	Average	(2012)	(2013)	Average	1.21a	0.96a	1.11a
Control	0.65a	0.68a	0.80A	22.72b	23.54b	4.77b	27.28ab	51.03ab	5.99b
GA_3 50 mg L^{-1}	0.51ab	0.60ab	0.74AB	31.12ab	27.93ab	5.38ab	33.37ab	54.20ab	6.21ab
GA_3 100 mg L^{-1}	0.50b	0.63ab	0.75AB	28.78ab	24.12ab	5.12ab	27.16ab	53.25ab	5.98b
GA_3 200 mg L^{-1}	0.49b	0.58ab	0.73AB	31.46a	26.75ab	5.36ab	40.90ab	43.99b	6.20ab
$CaSO_4$ 2500 mg L^{-1}	0.52ab	0.66ab	0.76AB	29.82ab	23.34b	5.13ab	20.92b	65.55ab	6.32ab
$CaSO_4$ 3000 mg L^{-1}	0.44b	0.60ab	0.72AB	33.03a	25.07ab	5.37ab	34.01ab	75.22ab	7.16ab
$CaSO_4$ 3500 mg L^{-1}	0.49b	0.63ab	0.74AB	30.68ab	23.69ab	5.20ab	32.94ab	56.77ab	6.23ab
KNO_3 5000 mg L^{-1}	0.53ab	0.51b	0.72B	27.53ab	30.66ab	5.35ab	42.35ab	62.99ab	7.03ab
KNO_3 10000 mg L^{-1}	0.46b	0.61ab	0.73AB	23.45a	25.88ab	5.38ab	60.99a	70.72ab	7.97a
KNO_3 15000 mg L^{-1}	0.46b	0.56ab	0.71B	34.09a	31.02a	5.68a	25.78ab	84.19a	7.04ab
				Statistical significance					
Year			0.16**			5.13**			167.52**
Treatment			0.01**			0.91**			6.69*

Note: means with the same letters in each column are not significantly different at $P < 0.05$ using LSD test. n.s. - non-significan, * - significant at $P < 0.05$, ** - significant at $P < 0.01$

Discussion

Fruit splitting

In our study, GA3 mitigated fruit splitting was in agreement with previous works. Cline and Trought (2007), Adnan and Koyuncu (2010) and Butani et al. (2019) reported that GA_3 has alleviating impact on fruit splitting in sweet cherries, lychee, lemon, pomegranate and apple. Gibberellic acid increases elasticity of cell walls which is due to changes in the chemical composition of cell walls. Gibberellic acid increases glucose in the cell wall (Choi et al., 2002). Data were indicative of the beneficial impact of KNO_3 (especially at a concentration of 10,000 and 15,000 mg L^{-1}) on the reduction of fruit splitting which was in accordance with previous studies such as Alva et al. (2006). A similar alleviating effect of potassium on fruit splitting in pomegranate (Yilmaz and Özgüven, 2009) and lychee (Mishra et al., 2012) has been reported. During ripening, fruits are a strong sink for potassium (Tagliavini et al., 2000). The presence of a higher level of potassium leads to a decline in fruit splitting (Jinbao et al., 2002). The mitigating effect of $CaSO_4$ on the reduction of fruit splitting was observed in the present study. This can be attributed to its effect on the cell wall elasticity because the presence of a higher concentration of calcium ions in the cytoplasm increases cell wall elasticity (Facteau, 1982). Previous studies demonstrated the influence of some mineral elements, such as calcium and potassium, on pomegranate fruit splitting (Poovaiah et al., 1988).

Peel thickness

Peel thickness in fruits sprayed with $CaSO_4$ at a concentration of 3000 mg L^{-1} was significantly higher than other treatments. Calcium improves cell wall function and its metabolism (Storey et al., 2002). Also, calcium stabilizes cell membrane as linking component of phosphates, carboxylate groups, phospholipids and membrane proteins (Vicente et al., 2005). Cell wall metabolism and the fruit peel structure have a pivotal role in fruit splitting (Huang et al., 2006). Calcium spraying modifies cell-wall Ca^{2+} content in peel that leads to increase of bound calcium and water-soluble pectin in the peel cell wall that can prevent depreciation of pectin, cellulose, hemicellulose and decrease arabinose and galactose (Blanco et al., 2010). Wen and Shi (2012) reached similar results on 'Jincheng' sweet orange after calcium treatment. This macronutrient is a vital prerequisite for cell division and expansion (Barker and Pilbeam, 2015).

Fruit peel weight, 100 arils weight, percentage of edible part of fruits and fruit form

Comparison of augmentation of aril and peel weight indicated that increase in peel weight and thickness were the reason responsible for rising in fruit weight in the second year. Since 'Kadru' is susceptible to fruit splitting due to fruits thin peel, increase of peel thickness as result of the treatments can be one of the factors mitigating fruit splitting in year two of the experimental period.

Gibberellic acid at a concentration of 50 mg L^{-1} caused an increase in fruit peel weight compared to the control. Due to influences on cell enlargement, exogenously applied GA_3 causes an increase in fruit weight (Li et al., 2011). Spraying of this phytohormone accelerates cell division and expansion in all parts of fruits, including peel, and results in larger and heavier fruits (Li et al., 2015). Khalil and Aly (2013) reported the elevating effect of GA_3 application at a concentration of 75 mg L^{-1} on 'Ganesh' pomegranate fruit weight.

The average weight of 100 arils and the highest percentage of the edible part of fruits increased following KNO_3 treatments in our study. Potassium deficiency leads to a reduction in photosynthesis due to a decline in sucrose loading from leaves and results in lower fruit growth (Cakmak, 2005). Fruit length to diameter ratio was decreased by all levels of KNO_3 treatments. Since increasing in diameter or decreasing in length of fruit is an improvement (from elongated to spherical) of fruit form (Stander, 2013) that can be considered as the beneficial effect of KNO_3 on fruit form. Our results are in agreement with findings of Razzaque and Hanafi (2001) who observed similar effects of potassium on length and diameter of pineapple fruits.

Peel potassium

Potassium concentration increased in fruits peel treated by KNO_3. Similar results have been reported for olive fruits that received potassium treatments (Restrepo-Diaz et al., 2008) and these results agree with study of Li et al., (2009). Potassium can enhance fruit splitting resistance ability due to cell division improvment that leads to developent of thicker peel fruit (Ali et al., 2000). Potassium plays an important role in the synthesis of some amino acids that are essential for photosynthesis and increases plant resistance against physiological disorders (Srivastava and Singh, 2003).

Peel calcium

Foliar application of $CaSO_4$ led to an increase in peel calcium concentration. Similar results reported Holb et al. (2012). Ramezanian et al. (2009) demonstrated an increase in pomegranate peel calcium concentration following calcium foliar application. The presence of optimal calcium concentration in plant tissues decreases senescence and fruit ripening rate and increases resistance against diseases and chilling injury (Joyce et al., 2001).

TSS and taste

Our results are indicative of the elevating effect of KNO_3 application (15,000 mg L^{-1}) on fruits taste and TSS, which is in agreement with Alva et al. (2006) findings. Also, potassium treatment increased tomato TSS under saline and non-saline conditions (Amjad et al., 2014). Improvement of fruit quality can be attributed to the effects of potassium on carbohydrates and/or PGRs in developing fruit. Moderate levels of potassium in the plants increase phloem loading; movement and unloading of sucrose (Lester et al., 2005). Potassium deficiency leads to the accumulation of assimilates in the leaves that are required for balancing the water potential under such conditions (Marschner, 2011).

Ascorbic acid

As a powerful antioxidant, ascorbic acid is one of the most important quality characters of fruits and vegetables. Ascorbic acid concentration is influenced by species, stage of ripening at the harvest and pre and postharvest treatments, such as foliar application of micro and macronutrients and PGRs (Xiao et al., 2005). Potassium had a significant effect on ascorbic acid content and these results are in line with Alva et al. (2006). As mentioned earlier potassium is an essential element for the growth of fruit cells, balancing the carbohydrates and maintenance of quality character (Marschner, 2011).

Conclusion

Our results demonstrated that most of the studied characteristics improved in year two of the experimental period. Healthy fruits had higher quality and physical characters value. Foliar application GA_3 at the concentration of 100 mg L^{-1} was evaluated as the most effective treatment in the reduction of the fruit splitting. Also, KNO_3 (concentration of 10,000 mg L^{-1}) treatment mitigated the percentage of fruit splitting and had a beneficial impact on the weight of 100 arils, percentage of the edible part of the fruits and ascorbic acid concentration. In addition, KNO3 at a concentration of 15,000 mg L^{-1} caused the lowest fruit length/ diameter ratio and the highest TSS, taste and peel potassium concentration. Since KNO_3 had beneficial influence on fruit physical and quality characters, its foliar application can be recommended for the reduction of fruit splitting and improvment of the postharvest life of fruits.

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