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BIOTECHNOLOGY

The application of polyamines and self-incompatibility control substance on yield indices and qualitative traits of apple cv 'Red Delicious'

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ABSTRACT. Among the main problems of some temperate fruit species, such as the apple tree (*Malus domestica*), are the poor set of fruits and low production. Polyamines and Self-Incompatibility Control Substances (SICS), involving mineral nutrients such as manganese and boron, are the major chemical compounds used to reduce these problems. The aim of this study was to use popular polyamines putrescine (Put) at 0.1, 0.25 mM, spermine (Spm) and spermidine (Spd) both at 0.05, 0.25 mM and SICS at 1, 2 mg L^{-1}, alone or with cotton coverage bags and control to show the effects of these chemical compounds on yield indices and qualitative traits of apple (*Malus domestica*) cv 'Red Delicious'. Results showed that Spd (0.25 mM) and SICS (1 mg L^{-1}) had higher effect on yield per weight and per fruit number, final fruit set and ISI, but Spd (0.25 mM) decreased final drop. Put (0.1 mM + ccb), Spd (0.25 mM) and SICS (2 mg L^{-1} + ccb) were the most suitable treatments in order to increase the qualitative characteristics.

Keywords: cotton coverage bags; fruit set; putrescine; spermidine; spermine; yield.

A aplicação de poliaminas e substância de controle de auto-incompatibilidade em índices de produção e características qualitativas da maçã 'Red Delicious'

RESUMO. Entre os principais problemas de algumas espécies frutíferas de clima temperado, como a macieira (*Malus domestica*), está o fraco conjunto de frutos e a baixa produção. As Poliaminas e Substancias de Controle de Auto-Incompatibilidade (*self-incompatibility control substances*-SICS) (envolvendo nutrientes minerais tais como manganês e boro) são os principais compostos químicos usados para reduzir esses problemas. O objetivo deste trabalho foi empregar a poliamina putrescina (Put) em 0,1, 0,25 mM, espermina (Spm) e espermidina (Spd) ambas em 0,05, 0,25 mM e SICS em 1,2 mg L^{-1}, sozinhos ou com sacos cobertos de algodão, para demonstrar o efeito destes elementos químicos nos índices de produção e características qualitativas da maça (*Malus domestica*) 'Red Delicious'. Resultados mostraram que a espermidina (0.25 mM) e SICS (1 mg L^{-1}) tiveram um efeito maior na produção por peso e pelo número de frutos, o conjunto final de frutos e ISI, mas a espermidina (0.25 mM) caiu na produção final. Put (0.1 mM + sca), Spd (0.25 mM) e SICS (2 mg L^{-1} + sca) foram os tratamentos mais adequados para aumentar as características qualitativas.

Palavras-chave: sacos de algodão; conjunto de frutas; putrescina; espermidina; espermina; rendimento.

Introduction

Having suitable yield, percentage of fruit set and qualitative traits are the most important concerns in apple (*Malus domestica*). Alternate bearing is also vigorous in some cultivars of apple and some of them are self-incompatible, which means that they are not capable to pollinate each other. According to these problems, different techniques are used in order to do successful pollination. Some of these techniques are done by bees and artificial pollination. However, these techniques have some limitations; including (1) having adequate quantity of compatible pollen grains with high quality (actually, pollination with semi-compatible pollen resulted in lower fruit-set compared with fully compatible pollen), (2) flowers must be attractive in order to decrease the number of bees visiting the flowers of weeds throughout the orchard, (3) an overlap period of flowering and pollination between pollinizer and pollinator is mandatory. In addition, pollinator must be cultivated along with pollinizer trees. Artificial pollination, which can be done by hand and it is regarded as hand pollination, had also some requirements. When the king flower opens, it is important to place bee colonies, which must be stablished for cross pollination by bees and then the colonies should be removed at petal fall in fruit orchards One of the best techniques, which applied to do pollination, involves chemical one. Some chemical compounds like plant bio regulators be applied to achieve adequate fruit set and high yield in this approach. Plant bio regulators (PBRs) can increase pollen germination and pollen tube length in almond (Maita & Sotomayor, 2015): PBRs activity significantly increased the fruit set percentage at both the bud pink and petal fall phenological stages (Maita & Sotomayor, 2015). Polyamines as plant bio regulators are natural compounds involved in plant growth and development process. Polyamines are ubiquitous, aliphatic polycation class of biogenic amines with essential function in living organisms. The most common plant polyamines are diamine putrescine (Put) and higher polyamines (triamine ones) spermidine (Spd) and spermine (Spm). Polyamines have been involved in many biological processes including flower induction and fruit growth, development, and ripening (Nikfar & Abdoosi, 2013). Polyamines increase pollen tube growth and fruit set by stimulating pollen germination (Liu, Honda, & Moriguchi, 2006) and lengthens pollen tube (Aloisi, Caib, Tumiattic, Minarinid, & Del Duca, 2015). Polyamines reduce flower and fruit drop by competing with ethylene synthesis due to having the same precursor s-adenosyle methionine (Khezri, Talaie, Javanshahb, & Hadavib, 2010). On the other hand, a new chemical compound like self-incompatibility control substance (SICS) which includes selected nutrient elements (the mixture of manganese (between 6.8-13.6 mg L^{-1}) and boron (between 3.5-6.8 mg L^{-1}) can also be useful for this goal (Son, Kim, Rico, & Chung, 2009). Fruit production with high quality is also a necessary factor for consumers, because of high competition in the market. Since fruit quality could be affected by the exogenously applied plant growth regulators, the determination of suitable treatments for promoting the fruit quality are of merit (Asadi, Ardebili, & Abdosi, 2013). In chemical methods of measuring fruit quality in terms of total Carbohydrates, organic acids, pH, phenol, anthocyanin, total soluble solids, etc. are measured (Marandi, 2008). Sugars and organic acids can affect fruit flavor (Marandi, 2008). The ratio of these traits is an indicator for sweet or sour flavor in fruits (Marandi, 2008). Phenolic compounds can also affect fruit color and flavor (Marandi, 2008). They can cause to resist against abiotic and biotic stresses and factors. Fruit ground color is the first index for crop harvest (Marandi, 2008). Being climacteric fruit, apple undergoes rapid ripening and senescence, changes in color, taste, acid and sugars (Ullah & Jawandaha, 2013). Fruit ripening accompanied by fruit softening and ethylene production, so, shelf life period reduced (Marandi, 2008). Application of some compounds like polyamines is necessary in order to decrease fruit ripening and delay senescence stage (Babalar, Hosseini, Askari, & Davarpanah, 2014). These compounds induced to produce healthy crop with high nutritional and medicinal values they are ecofriendly environment and compatible with nature without use of deterious and toxic effects on human life (Azh, Asghari, & Aein, 2014). In the case of fruit quality, polyamines could improve (total soluble solids) (TSS), titratable acidity (TA), color variation and vitamin C (ascorbic acid) content (Asadi et al., 2013).

When the fruit ripens, the free radicals produced, but vitamin C acts as a scavenger for these compounds. Application of Put inhibited cell wall degradation and delay senescence, so this vitamin was preserved (Babalar et al., 2014). Put ascended TSS, but the index of maturity was not significantly different. The effect of Put on delaying color changes has also reported in crops, including apricot and lemon during storage by reducing senescence rate. Higher TSS and lower TA in untreated fruits were observed due to faster maturation process and higher water loss in comparison with Put treated fruits (Barman, Asrey, & Pal, 2011). Put application ascended TSS, index of maturity, vitamin C and acidity at full bloom stage as compared to final fruit set stage (Saleem, Malik, Anwar, & Farooq, 2008). Put increased TA, TSS, the index of maturity (TSS/TA), total carbohydrates and anthocyanin (Khosroshahi & Ashari, 2008). In addition, the effective role of boron and manganese in the SICS compound on increasing the qualitative traits was stated by Liu et al. (2006); Mirdehghan and Rahimi (2016).

There was no literature cited about the effects of SICS or polyamines along with cotton coverage bags on yield, fertility, compatibility indices and fruit quality in order to compare with the application of these compounds without cotton coverage bags in apple or pear. The aim of this study was to increase yield indices and qualitative traits in apple cultivar ‘Red Delicious’, accompanying the decrease of self-incompatibility and fruit drop using polyamines and SICS.

Material and methods

This project was done in a commercial orchard located in Mashhad city with latitude of 36º 20' and altitude 59º 34'. This area had an arid and semiarid climate with the average of annual participation of 255 mm. The foliar application was done with 5 l sprayer on selected branches of *Malus domestica* cv. 'Red Delicious' trees. The compounds include polyamines putrescine (Put) (0.1 and 0.25 mM), spermine (Spm) (0.05 and 0.25 mM), spermidine (Spd) (0.05 and 0.25 mM) and SICS (1 and 2 mg L^{-1}) with cotton coverage bags (+ ccb) or without (- ccb) and control to show the effects these chemical compounds on self-incompatibility and yield indices and qualitative traits in this crop.

Quantitative traits

The traits were measured in this study include: Yield fruit: It was calculated by the dividing the number of fruit into cross sectional shoots (Dehghani, Arzani, & Khani, 2012). Yield weight, P Index: It was calculated by dividing the fruit weights into cross sectional shoots. Compatibility indexes (Dehghani et al., 2012). Fruit set (initial (2 weeks after petal fall) and final drop. IF (Index of fertility) (percentage of initial fruit set of each treatment to percentage of initial fruit set of control ratio). ISI (Index of self-incompatibility) (percentage of final fruit set of each treatment to percentage of final fruit set of control ratio). If the ratio is between 0.2-1, that treatment induced to semi compatibility, if it is lower than 0.2, this leads to incompatibility. If the treatments include ratio higher than 1, full self-compatibility occurs (Moutier, 2002; Quero, Pinillos, & Cuevas, 2002).

Chemical traits of fruit juice

TSS: TSS was measured by refractometer. In this method, one drop of fruit juice extraction poured on prism of this means. Then, it was exposed to light; the interface between light and dark on it was the TSS content (Rabie & Ghasemi, 2013). TA: TA was measured with titration with NaOH 0.1 N and phenol fetalein 1%. The titration continued up to the pink color (Alikhani, Sharifani, Azizi, Hemati, & Zadeh, 2009). The index of browning: The index of browning was achieved by titration of potassium bicarbonate 0.1N. Condensed sulfuric acid was used as a catalyst (Malakouti et al., 2005). Vitamin C: Vitamin C was measured by titration with iodine crystals in KI and starch 1% as a reagent. The titration continues up to dark blue color (Rabie & Ghasemi, 2013). Total soluble sugar contents in pear juice were determined using the anthrone reagent method. 0.5 g of cut fruit mixed with ethanol 75% in mortar. Then, it was centrifuged with 3500 rpm for 15 min and the supernatant was extracted. 0.1 mL of the alcoholic extract was added to three mL of anthrone (150 mg pure anthrone in 100 mL of $H2SO_4$ 72%). The sample was heated for 10 min in boiling water at 70º C, and after cooling at room temperature absorbance was determined at 625 nm using spectrophotometer. The total sugar contents were calculated using glucose standard curve (Zafarinia, Arzani, & Ghasemi, 2010). In all of the measurements with titration, it was mandatory to extract fruit juice and then diluted with distilled water. Anthocyanin: Total anthocyanin was estimated by the pH differential method using two buffer systems: 25 mM K chloride pH 1.0, and 0.4 M Na acetate pH 4.5. Samples were diluted with K chloride buffer until the absorbance of the sample at 510 nm was within the linear range of the spectrophotometer (Cecil Bio Quest, CE 2502). The same dilution factor was used to dilute the sample with the Na acetate buffer later. Readings were performed at 510 and 700 nm in the two different buffers after 15 min of incubation, four times per sample. Total anthocyanin contents were calculated as follows: total anthocyanins = [(A × MW × DF × 100)/MA], where A = (A510 - A700) pH = 4.5; MW: molecular weight (449.2); DF: dilution factor; MA: molar absorptive coefficient of cyanidin-3-glucoside (26.900). Results were expressed as mg cyanidin-3-glucoside 100 g – 1 of juice. Panel test: Three replications of every treatment were selected for assessing the fruit quality. Then, one grade was attributed to every fruit by experienced people between 1 to 5. These grades involve 1: unfair, 2: medium, 3: good, 4: very good, 5: excellent. The average of given grades was achieved and then analyzed (Najafzadeh, Arzani, & Babaei, 2012).

Statistical analysis

The experimental design was used a randomized complete block design with four replications. Data were statistically evaluated by analysis of variance (ANOVA) by SAS 9.1 software and the means were surveyed by LSD test at 0.05.

Results and discussion

Quantitative traits

Spd (0.25 mM) led to the highest yield (per fruit weight and fruit number), final fruit set and ISI and the lowest final drop among all of treatments

(P value < 0.05) (Table 1). SICS (2 mg L^{-1}) had also higher effect on yield (per fruit weight and fruit number), final fruit set and ISI. Treatments with Spd (0.25 mM), SICS (2 mg L^{-1}), Put (0.25 mM) and Spm (0.25 mM) had higher final fruit set than control, respectively. Spd (0.25 mM) had the most ISI and followed by Put (0.25 mM) and led to full compatibility (self+cross compatibility). Although, there was no significant difference between control and other treatments in IF, but IF is the ratio and regardless of significance difference, if the ratio is higher than 1, we confront to full fertility. In our research, some of the treatments such as Spd and Spm both at (0.05 mM + ccb) and SICS (2 mg L^{-1}) led to full self-fertility. Treatments such as Spd and Spm both at (0.05, 0.25 mM and SICS (2 mg L^{-1}) led to full self-compatibility. Spd (0.25 mM), Put (0.25 mM + ccb), Spd (0.05 mM), SICS (1 mg L^{-1} + ccb), Spm (0.05 mM) and Put (0.1 mM) decreased significantly fruit drop in comparison with control, respectively.

Numerous researchers studied about the effects of polyamines on yield indices. Exogenous application of different polyamines at full bloom had influence on increasing fruit set and total yield in apples, olive, litchi and mango. Increase in fruit set and yield by polyamines was due to raising pollination, fertilization and fruit retention (Saleem et al., 2008; Serrano, Zapata, Martinez-Romero, Diaz-Mula, & Valero, 2016). Put increased ovule longevity and EPP (Effective Pollination Period), increased N and B, and might increase the pollen tube growth rate in the styles of pears and could increase fruitset and yield of 'Comice' pear at anthesis (Crisosto, Lombard, Sugal, & Polito, 1988). In another study, it was reported that polyamines significantly increased initial fruit set yield/tree (Saleem et al., 2008). It was also declared that Spm and Spd were more effective than putrescine for increasing fruit set. Putrescine treatments significantly reduced secondary fruit drop on date palm, apple, pear, mango, sweet orange and avocado (Asadi et al., 2013).

Our results about the effects of polyamine on fruit set and yield, was in agreement with Saleem et al. (2008) and Asadi et al. (2013).

High levels of boron in floral organs such as the stigma and style, may aid pollen germination and make pollen tube growth faster down the style and into the ovary. Where (Effective Pollination Periods) EPPs are short, due to rapid ovule senescence, this should help fruitset (Webster, 2002). Application of SICS a day before full bloom at 1 or 2 mg L^{-1} on three pear cultivars increased fruit set especially at 1 mg L^{-1} SICS (Son et al., 2009). Application of SICS (2 mg L^{-1}) on yield per weight and per fruit and fruit set in our study was in accordance with Son et al. (2009).

Chemical traits of fruit juice

Treatment with Put (0.1 mM + ccb) had the best extract volume among all of the treatments (P value < 0.05) (Table 2). SICS (1 mg L^{-1} ± ccb) and Spd (0.25 mM) increased this trait (P value < 0.05). Spd (0.25 ± ccb) and SICS (2 mg L^{-1} + ccb) showed higher TSS as compared to control. Spd (0.25 mM) showed the most total carbohydrate content and followed by Put (0.1 mM+ccb) (P value < 0.05).

Table 1. The effects of polyamines (Putrescine, Spermine, Spermidine) and SICS on yield and fruitset in *Malus domestica* L. cv. 'Red delicious'.

	Treatments								
Cotton coverage bags	Chemical compounds	yield per fruit weight (g)	P index	yield per fruit number	initial fruit set (%)	final fruit se (%)t	IF	ISI	final drop (%)
Without cotton coverage bags	Control	1121.7cde	152.09ef	0.579cde	59.63a-f	10e	1a-e	1c	81.08ab
	Put (0.1 mM)	1290.7bc	478.89a	1.486bc	49.65c-f	21.426b-e	0.837c-f	2.905bc	55.27cdef
	Put (0.25 mM)	1246.4cd	355.13bc	0.689cd	52.89c-g	29.322bc	0.898c-f	5.039ab	65.2a-e
	Spd (0.05 mM)	692.1fgh	91.88f	0.785fgh	40.1fg	20.557b-e	0.666ef	2.411bc	45.34ef
	Spd (0.25 mM)	1697a	343.93f	2.472a	70.48abc	56.337a	1.184abc	6.817a	18.73g
	Spm (0.05 mM)	1402.5abc	201.39de	0.777abc	68.51a-d	18.481b-e	1.124abc	1.638c	49.74def
	Spm (0.25 mM)	1381.9bc	128.87de	0.79727bc	77.86a	27.47bcd	1.3171a	2.379bc	65.2a-e
	SICS (1 mg L^{-1})	545.5gh	68f	0.518gh	65.85a-d	13.26de	1.125abc	1.582c	82.38ab
	SICS (2 mg L^{-1})	1555.2ab	265.41cd	0.60ab	55.06b-g	32.241b	0.923b-e	3.903abc	60.75b-f
With cotton coverage bags	Put (0.1 mM)	455.8h	163.92ef	0.88322h	56.44b-f	12.74e	0.9773a-d	1.404c	78.51ab
	Put (0.25 mM)	1134.3cde	418.89ab	1.13249cde	35.42g	22.2b-e	0.5959f	2.655bc	39.29fg
	Spd (0.05 mM)	844.6efg	164.73bc	0.80817efg	61.77a-e	21.049bcde	1.0379a-d	2.577bc	68.8a-d
	Spd (0.25 mM)	984def	199.42ef	0.450def	54.69b-g	12de	0.938b-f	1.473c	76.19abc
	Spm (0.05 mM)	431h	80.16ef	0.97049h	75.38ab	13.65de	1.2759ab	1.613c	87.1a
	Spm (0.25 mM)	574.1gh	123.04f	0.58245gh	49.31d-g	10.62e	0.833cdef	1.127c	65.48a-e
	SICS (1 mg L^{-1})	668.6gh	151.75ef	0.54365gh	44.2ef	25.73bcde	0.751def	2.709bc	43.33ef
	SICS (2 mg L^{-1})	522h	80.33f	0.75308h	78.23a	16.129cde	1.3056a	1.796c	74.69abc

The means with the same letter was not significantly different in 0.05 level at LSD test. Put = putrescine, Spd = spermidine, Spm = spermine, SICS = self-incompatibility control substance, IF = index of fertility, ISI = index of self-incompatibility.

Polyamine could enhance soluble solid contents via affecting cellular division and metabolism, which polyamines stimulated cellular metabolism in sink tissues and may change the phloem transport. Therefore, the fruit quality is affected (Asadi et al., 2013). Exogenous polyamine application may reduce the TSS of fruits (Tavakoli & Rahemi, 2014). The highest TSS value was found in the control treatment (Tavakoli & Rahemi, 2014). In another study, Treatments with polyamine like Spm and Put had higher TA and vitamin C in kiwi in comparison with control (Fam, Hajilou, & Nahandi, 2015). Spd and Put had lower TSS in comparison with control (Fam et al., 2015). The combination of Put and Spd significantly increased total soluble solids in mango and date palm and decreased total acidity in apricot (Serrano et al., 2016). Spd (8mM) in sweet cherry increased TSS, TSS/TA in comparison with control (Sharifzadegan, Abdoosi, Bojar, & Naeini, 2014). A lower TSS content and higher TA% was observed in Put- and Spd-treated berries of grape at harvest except some concentration, indicating a marked delay in process of maturation and ripening (Mirdehghan & Rahimi, 2016). Treatment with put increased the content of reducing and non-reducing sugars, and reduced TA and tannin concentration (Serrano et al., 2016). Polyamines like Put induced to slow down senescence and respiration processes and decreased the consumption of TSS and organic acids (Asghari, Asghari, & Farrokhi, 2014; Champa, Gilla, Mahajan, & Arora, 2014). So, cell wall degradative enzymes and free radicles, followed by cell requirement to vitamin C decreased and this vitamin preserved (Asghari et al., 2014). In addition, when the respiration process decreased, Organic acids are not consumed TA is kept and TSS does not increase (Babalar et al., 2014). In the case of TA, Spd (0.25 mM + ccb), Spm (0.05 ± ccb) and SICS (2 mg L^{-1}+ccb) had higher content as compared to control in our study (P value < 0.05). Polyamines treatments decreased acidity losses and increased TSS in peach and nectarine (Serrano et al., 2016). Polyamines also retarded the degradation of TSS and TA while maintaining higher total phenol content.

It was reported that boron application increased TSS and TA (Khoshghalb, Arzani, Malakouti, & Barzegar, 2013). Application of boron improved vitamin C and total carbohydrates by boron application due to influence on photosynthesis (Mashayekhi & Atashi, 2012). Boron conjunct to carbohydrate and can translocate as a sucrose and pass through cell membrane faster. Boron spray increased TSS and total carbohydrate in orange. Treatment with Spm at this stage attributed the highest TSS. Application of Put at swollen flower bud had the best effect on anthocyanin (Nikfar & Abdoosi, 2013).

Mn foliar spray increased TSS (Hasani, Zamani, Savaghebi, & Fatahi, 2012). Mn spray had significant effect on juice content of arils and anthocyanin index. Foliar sprays of Mn at both levels (0.3 and 0.6 percent) significantly increased juice content of arils and the 0.6% application of manganese had also significant increase on anthocyanin index. Mn spray had significant positive effects on TSS. TA increased with application of Mn Application of Mn at both levels (0.3 and 0.6%) increased some characters like TSS, anthocyanin index (Hasani, Zamani, Savaghebi, & Fatahi, 2012).

Control had lower vitamin C content when it compared to some treatments like put (0.1 mM), SICS (1 mg L^{-1} + ccb) and Spm (0.05 mM + ccb) in present study (P value < 0.05). The highest pH was seen at SICS (2 mg L^{-1} – P value < 0.05).

The application of Put and Spd led to the elevated pH of fruit juice among the different kinds of applied polyamine treatments (Babalar et al., 2014). Put (0.1 mM) had higher anthocyanin, but this treatment along with cotton coverage bag had the greatest one.

Asghari et al. (2014) reported that Put at 0.2 mM kept TA, vitamin C during storage period. Polyamines keep phenolic compounds via delaying senescence period. The antioxidant characteristic of polyamines attributed to amines groups. Spm, Spd, Put have the highest antioxidant trait due to more amine groups, respectively. Stronger conjunction to cell wall macro molecules in Spm and Spd was related to more cation capacity (Fam et al., 2015). Higher levels of phenolic compounds were observed in Put-and Spd-treated berries of table grape and pomegranate fruits than control (Mirdehghan & Rahimi, 2016). Thus, higher levels of these compounds in grape fruits treated with PAs could be attributed to antioxidant properties of polyamines. Pre-harvest foliar spraying of Put or Spd delayed total anthocyanins concentration after 25 days of storage and improved fruit shelf life, increased ascorbic acid content and retarded fruit skin color changes compared to control. Spm (0.25 mM) had the highest panel test value (P value < 0.05) (Table 2). In addition, treatment with Spd at both concentrations with/without cotton coverage bags showed higher panel test as compared to control.

Table 2. The effects of polyamines and SICS on some qualitative indices of apple (*Malus domestica* L. cv. 'Red delicious') fruit juice with or without cotton coverage.

Treatments											
Cotton coverage bags	Chemical compounds	extract fruit volume (cm^3)	TSS (%)	TA (%)	TSS/ TA	vitamin C (mg 100 g^{-1})	pH	Anthocyanin	Phenol mg GAE g FW^{-1}	total carbohydrates (mg g^{-1} FW)	panel test
Without cotton coverage bags	Control	101.98d-g	10cde	1.249def	8.699abc	19.965de	3.405b-g	35.37b-e	0.039b	78.399cd	2.6gh
	Put (0.1 mM)	105.75c-g	11.875abc	1.169def	10.985a	41.893a	3.4525bcd	60.31a	0.036bcde	71.487de	1.95j
	Put (0.25 mM)	103.03d-g	10.813bcd	1.338b-f	8.423abc	25.856cde	3.4625bc	22.76def	0.033cdef	85.735abc	2.43 75hi
	Spd (0.05 mM)	89fg	8.108e	1.405b-f	5.992c	23.401cde	3.38c-h	18.68def	0.0309efg	29.93g	3.23 33bc
	Spd (0.25 mM)	128.83abc	13a	1.514a-d	8.585abc	28.802b-e	3.28i	23.93def	0.0304fg	94.216a	3.2bc
	Spm (0.05 mM)	126.08a-d	9.25de	1.645abc	5.884c	25.201cde	3.487b	19.47def	0.040b	53.168f	3cde
	Spm (0.25 mM)	97.78fg	9.25de	1.089f	9.735ab	18.983de	3.422b-f	45.37abc	0.0377bcd	82.795bc	3.5a
	SICS (1 mg L^{-1})	128.33abc	10.25bcd	1.484a-e	7.271bc	24.22cde	3.367d-i	22.18def	0.024h	0i	2.75efg
	SICS (2 mg L^{-1})	108.97c-f	10.125cde	1.085f	10.373ab	26.729cde	3.597a	30.74b-e	0.024h	29.817g	3.4ab
With cotton coverage bags	Put (0.1 mM)	147.31a	11abcd	1.275c-f	8.686abc	31.584bcd	3.3hi	66.54a	0.026915gh	90.71ab	2.925def
	Put (0.25 mM)	105.79c-g	11.844abc	1.389b-f	8.534abc	26.642cde	3.33875f-i	6.9f	0.032106d-g	83.954bc	2.25i
	Spd (0.05 mM)	99.61efg	10.875a-d	1.313c-f	8.263abc	18.656de	3.464bc	15.81ef	0.047a	4.883hi	3.1cd
	Spd (0.25 mM)	119.06b-e	13a	1.796a	7.24bc	17.019e	3.33ghi	30.28b-e	0.0379bc	59.953f	
	Spm (0.05 mM)	107.71c-f	9.75cde	1.717ab	5.781c	36.002abc	3.44b-e	38.09bcd	0.035b-f	10.565h	2.6gh
	Spm (0.25 mM)	121.04b-e	10.125cde	1.109ef	9.133abc	27.492b-e	3.425b-f	27.71b-f	0.033b-f	88.449abc	2.825efg
	SICS (1 mg L^{-1})	133.61ab	9.938cde	1.404b-f	7.075bc	39.93ab	3.3575e-i	0.0241h	61.366ef	2.7fg	
	SICS (2 mg L^{-1})	82.56g	12.288ab	1.643abc	7.417bc	20.51de	3.631a	0.0241h	34.736g	3.46ab	

The means with the same letter was not significantly different in 0.05 level at LSD test. Put=putrescine, Spd=spermidine, Spm=spermine, SICS= self-incompatibility control substance, TSS=total soluble solids, TA=titratable acidity, TSS/TA=index of maturity.

The results of our study were in line with (Saleem et al., 2008) on orange, (Khosroshahi & Ashari, 2008) on strawberry, (Ayad, Yousf, & Moursi, 2011) on olive, and (Rahimi, Mirdehghan, & Esmaeilzadeh, 2014) on grape as non-climacteric fruit and (Khattab & Shaban, 2005) on mango and on apricot (Najafzadeh et al., 2012; Nikfar & Abdoosi, 2013) as climacteric fruit. In fact, the effects of polyamine on qualities such as TSS, TA, TSS/TA ratio and vitamin C content depend on the time application. Pre harvest polyamine application at swollen bud might be the highest effect on improving TSS, TSS/TA and vitamin C (Ayad et al., 2011; Asadi et al., 2013; Nikfar & Abdoosi, 2013; Sharifzadegan et al., 2014). Polyamine application induced to reduce TSS, TSS/TA ratio and vitamin C in climacteric fruit like plum (Khan & Singh, 2010) only at final fruit set.

Conclusion

The best treatments were Spd (0.25 mM) in order to raise yield per weight and per fruit number, final fruit set ISI and decrease final drop. Spd (0.25 mM) and SICS (1 mg L^{-1}) had higher effect on yield per weight and per fruit number, final fruit set ISI. Spd (0.25 mM) and SICS (2 mg L^{-1} + ccb) were the most suitable treatments in order to increase the qualitative characteristics. Qualitative traits improved by application of Spd (0.25 mM + ccb) among the applied polyamines and also with SICS (2 mg L^{-1} + ccb).

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