International Journal of Plant & Soil Science
10(6): 1-13, 2016; Article no.IJPSS.25682
ISSN: 2320-7035

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Tomato Responses to Bioregulators Grown under Greenhouse Conditions

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Authors' contributions

This research was carried out in collaboration among all authors. Authors HR, MGZR, ASL, ALF and PAZ designed the study, wrote the protocol, managed the experimental process, analyses of the study, performed the laboratory analysis and wrote the manuscript. Authors RRG, DJC, AZG, NCA and JAVQ managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/25682
Editor(s):
(1) Dionisios Gasparatos, Soil Science Laboratory, Faculty of Agriculture, Aristotle University of Thessaloniki, Greece.
Reviewers:
(1) Jigna G. Tank, Saurashtra University, India.
(2) P. Rama Bhat, Mangalore University, Karnataka, India.
Complete Peer review History: http://sciencedomain.org/review-history/14325

Original Research Article

Received 15th March 2016
Accepted 19th April 2016
Published 25th April 2016

ABSTRACT

Aims: Greenhouse contemporaneous horticulture demands a permanent use of new technologies directed to improve yield and fruit quality. Although, the use of bioregulators has made an important contribution to agriculture by increasing yield in vegetable and fruit crops grown under open field

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conditions; little is known on their effects on tomato grown in greenhouse. It would be useful to study how they may influence the behaviour of that crop. This approach could be an alternative for improving yield and fruit quality; in particular the one related to increase the antioxidant content. Prohexadione calcium (P-Ca) is a growth retardant which reduces vegetative growth and increases antioxidants content in deciduous fruit species; whereas gibberellins $GA_{4/7}$ and 6-benzyl amino purine (6-BAP) stimulate flowering or fruit growth on temperate fruit crops. The effect of these hormones in tomato crop grown in greenhouse is not clear. Therefore, the aim of this research was to evaluate the effects of P-Ca, $GA_{4/7}$ and 6-BAP on the growth, yield and fruit quality in saladette tomato hybrid "Raptor-F1".

Study Design: A completely randomized statistical design was used with ten replicates per treatment. The results obtained were analyzed with the statistical program R version 2.14.2, for Windows version 8, and for the analysis of variance and comparison of means, the LSD (*P≤0.05*) test was applied.

Place and Duration of Study: The experiment was conducted at the Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, México, during the period April - August 2015.

Methodology: When plants showed floral primordia, a first foliar spray of treatments: control (H_2O), P-Ca (50 mg L^{-1}), $GA_{4/7}$ (50 mg L^{-1}), $GA_{4/7}$ (100 mg L^{-1}), 6-BAP (50 mg L^{-1}), 6-BAP (100 mg L^{-1}), $GA_{4/7}$ (50 mg L^{-1}) + 6-BAP (50 mg L^{-1}) and $GA_{4/7}$ (100 mg L^{-1}) + 6-BAP (100 mg L^{-1}) was applied to run-off using a hand sprayer. A second application of same dosages was performed 15 days later.

Results: P-Ca inhibited the synthesis of gibberellins A_1, A_4 and A_7 at the apex; significantly reduced plant height and increased stem diameter, number of flowers, leaves, fruits, and ratio. $GA_{4/7}$ at 100 mg L^{-1} promoted firmness and sugar content in fruits; whereas, when combined with 6-BAP at 100 mg L^{-1} increased the content of vitamin C and lycopene in ripen fruits. Although, the yield was not increased by bioregulators, improvement in fruit quality compensated this since the benefit : cost (B:C) ratio in these fruits had a value of 1.9, 1.9, 1.84 and 1.74 for P-Ca, $GA_{4/7}$, 6-BAP and $GA_{4/7}$, + 6-BAP respectively against 0.86 in control fruits as a result of a higher market price.

Conclusion: The bioregulators P-Ca, $GA_{4/7}$ and 6-BAP provoke positive effects on growth, yield and fruit quality in saladette tomato hybrid “Raptor-F1” growing under greenhouse conditions.

Keywords: Tomato; prohexadione-ca; gibberellins; cytokinins; lycopene.

1. INTRODUCTION

Cultivated tomato *(Solanum lycopersicon* L.) is considered as one of the most important horticultural crops worldwide, mainly due to its great contribution to human feeding. Globally, it ranks as a second horticultural crop in importance among the vegetable species as a result of its yield potential [1]. In México, tomato is also the second most important horticultural species. Recent statistics show a cultivated area of 81,000 ha with a total yield of 2 millions metric ton [1,2]. The production management and marketing of tomato generate a high number of jobs, making an important contribution to nation´s economy. Therefore, it is obligated the searching for new technologies directed to the improvement on yield and fruit quality of this crop [3].

The use of bioregulators in agriculture is now-a-days a practice to increase yield and quality of several crops [4]. These compounds temporarily modify the gene action. This effect is of a great value since it could meet marketing demand related to yield per ha, early or late fruit ripening and high fruit antioxidants content [5].

Prohexadione calcium (P-Ca) is a growth retardant which has proved to be useful for the control of excessive vegetative growth and to improve fruit quality in temperate fruit species such as pear, peach and apple; and in vegetables such as hot pepper [6,7]. It is well known that P-Ca reduces vegetative growth by inhibiting the synthesis of gibberellins A_1, A_4 and A_7 at the apex [7]. P-Ca also increases the content of cytokinins in the apical meristem which frequently are related to flower formation and fruit set in hot pepper, apple and cherry [8,9]. The effect of P-Ca, gibberellins and cytokinins in tomato grown in greenhouse is little known [8]; therefore, more information is required in this important crop.

On these bases, the objective of this research was to evaluate the effects of prohexadione calcium, gibberellins$_{4/7}$ ($GA_{4/7}$) and 6-benzyl amino purine (6-BAP) on vegetative growth, yield

and fruit quality in tomato "Raptor-F1" hybrid saladette under greenhouse conditions.

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

This study was conducted at the Universidad Autónoma Agraria Antonio Narro in Saltillo, Coahuila, México, in a greenhouse with a metallic overhead structure covered with white plastic (Caliber 720) on the roof and side-plates of polycarbonate. Two months tomato seedlings of the indeterminate growth saladette "Raptor-F1" hybrid were transplanted on 15 April 2015 into a 12 liters black plastic bags using as a substrate, soil, tezontle and perlite (2:1:2 w/w). The bags were distributed at a distance of 50 cm between plants and 75 cm between rows. The climate conditions inside the greenhouse were maintained at 25℃ and 65% RH during the experiment. Treatments with bioregulators were as follows: control (H_2O) , P-Ca (50 mg L^{-1}), $GA_{4/7}$ (50 mg L^{-1}), $GA_{4/7}$ (100 mg L^{-1}), 6-BAP (50 mg L^{-1}), 6-BAP (100 mg L^{-1}), $GA_{4/7}$ (50 mg L^{-1}) + 6-BAP (50 mg L^{-1}) and $GA_{4/7}$ (100 mg L^{-1}) + 6-BAP (100 mg L^{-1}). When plants showed the first floral primordia on May 18, 2015, a first foliar spray of treatments was applied to run-off using a hand sprayer. A second application of same dosages was performed 15 days later. A Completely Randomized Design with 10 replicates per treatment was used. The variables evaluated were: Gibberellins at shoot tips, rate of growth in height and diameter of main stem, number of leaves, flowers and fruits; fruit ratio and yield per plant. The content of sugar, vitamin C, lycopene as well as firmness, color and shelf life were determined in harvested ripen fruits. The results obtained were analyzed with the statistical program R version 2.14.2 for Windows 8. The analysis of variance and comparison of means was performed using the LSD difference test at ($P \leq 0.05$).

2.2 Phenological Parameters

2.2.1 Stem growth rate

Main stem growth was measured between base and apical meristem from date of bioregulator first application until the end of the plant growing season using a Pretul tape scale 0 to 5 m. Measurements were made at 0, 3, 5, 10 and 15 days after first application of treatments and later, successively every 15 days until the end of the growing season.

2.2.2 Stem diameter growth rate

This variable was measured at the middle region of main stem on the same dates as above using a Petrul vernier with a scale of 0-13 cm.

2.2.3 Number of leaves and flowers

The number of leaves and flowers per plant among treatments were recorded on same dates used for the evaluation of stem growth rate using an ENM hand counter.

2.3 Production Parameters

2.3.1 Number of fruits and yield

The number of fruits per plant was recorder during each of the ten cuts performed among treatments using an ENM hand counter; while total yield per plant resulted from the sum of weight from these fruits using a Scout® Pro scale with a capacity of 1000 g.

2.4 Fruit Quality Parameters

2.4.1 Ratio

The polar and equatorial diameter was determined at harvest time from 5 fruits per plant randomly selected from the 10 replicates on each treatment using a Pretul vernier scale 0-13 cm. This was done during the 6 first cuts.

2.4.2 Flesh firmness

The flesh firmness was recorded at harvest time from a five fruits sample per replicate treatment using a penetrometer tester model FT327. This was done during the first 6 cuts.

2.4.3 Total soluble solids (°Brix)

The content of total soluble solids in fruits was determined as above using an ATAGO refractometer model N-8α.

2.4.4 Shelf life

The shelf life was obtained by counting the number of days through which, 5 ripen fruits per treatment from first 6 cuts kept their marketing consistency at room temperature (18℃).

2.4.5 Color

The color was determined in 5 fruits per treatment at each harvest cut using a Minolta 300 CR colorimetric equipment. Fruit samples were washed with distilled water, dried and later placed on the reading zone of equipment which was previously calibrated with a range 0-100 luminosity (L) values corresponding to a chromatic diagram between red (a+) and blue (b-) color area. Two readings were done at the equatorial zone on each selected fruit. The colorimeter values were determined and identified as L* a* b*.

2.5 Antioxidants

2.5.1 Vitamin C

The content of vitamin C was determined using the methodology reported by Padayatt et al. [10]. Ten grams of fresh fruit were grounded in a mortar, placed in a flask, 10 ml of hydrochloric acid (2% v/v) and 40 ml of distilled water were added and mixture was later filtered through gauze. 10 ml of supernatant was titrated with 2.6 - modified dichloro phenol indophenol ($1x10^{-3}$ N). When solution reached a pink color, vitamin C content was determined using the following formula:

$$Vitamin\ C\ (mg\ 100\ g\ fw) = \frac{(ml\ 2.6 - dichlorofenolindofenol\ used\ x\ 0.088\ x\ total\ volume\ x\ 100)}{(sample\ weight\ x\ volume\ of\ the\ aliquot)}$$

2.5.2 Lycopene

The content of fruit lycopene was determined as follows: 3 g of fresh weight taken from pericarp were placed in a frozen mortar containing 3 ml of phosphate buffer (pH 7) and ground, 2 ml of the mixture were transferred into a centrifuge tubes, it was added 4 ml of a solution hexane - acetone (3:2), stirred to separate and dissolve pigments from tissue [11], tubes with samples were later centrifuged at 3,000 rpm for 10 minutes for phase separation, colored phase was identified and quantified at a wavelength of 450 nm on a Varian HPLC model 500-MS.

In order to determine the content of lycopene in the samples, a calibration curve was constructed using lycopene standard (Sigma,Co) with a range of 0 - 0.40 mg ml^{-1}, previously dissolved in the referred solution. Samples were compared with the calibration curve and lycopene content determined using a linear regression equation.

2.6 Content of Endogenous Gibberellins at the Apex

With the purpose to learn on the inhibition of gibberellin synthesis by prohexadione-ca, shoot apex samples from control and P-Ca treated plants were collected four days after the first application of the growth retardant. Removed shoot tips were frozen, freeze-dried and ground in the same manner as described by Ramírez et al. [12].

2.6.1 Identification of gibberellins by GC-MS

The extraction and purification procedure for GAs from 1 g dry weight shoot tips samples prior to GC-MS analysis was performed using the column solvent methodology [12]. Samples with gibberellin activity detected in thin-layer chromatography were prepared for GAs identification [13]. Purified extracts were dissolved in a few drops of methanol and methylated with diazomethane. A portion of the methylated extract was dissolved in pyridine and treated with trimethylchlorosilane and hexamethyldisilazane. Aliquots were examined using a Pye 104 GLC coupled through a silicone membrane separator to an AEI MS30 dual beam mass spectrometer. Silanized glass column (213 x 0.2 cm) was packed with 2 % SE-33 on 80-100 Gas Chrom Q. The He-flow rate was 25 ml•min^{-1} and the column temperature was programmed from 180 to 280℃ at 2℃•min^{-1}. The MS were determined at 24 eV at a source temperature of 210° C and a separator temperature of 190℃ with a scan speed of 6.5 sec per mass decade. The spectra were recorded by a DEC Linc 8 computer.

3. RESULTS AND DISCUSSION

3.1 Vegetative Growth and Gibberellins

The application of bioregulators modified the growth rate on height (Fig. 1) and diameter (Fig. 2) of main stem (see appendix). The growth retardant P-Ca significantly reduced (*P≤0.05*) the longitudinal rate of growth; whereas $GA_{4/7}$ (50 and 100 mg L^{-1}) produced the highest stem growth (Fig. 1). This effect was observed between 4 to 97 days after the first hormones application. Soon after, growth was restored in P-Ca treated plants (Fig. 1). The diameter of main stem was significantly increased (*P≤0.05*) in most bioregulators treatments (Fig. 2). This pattern was observed from the ninth day after first application of bioregulators until the end of

the vegetative cycle. The number of leaves increased in plants sprayed with P-Ca and with the combination of $GA_{4/7}$ + 6-BAP at 50 and 100 mg L^{-1} (Table 2).

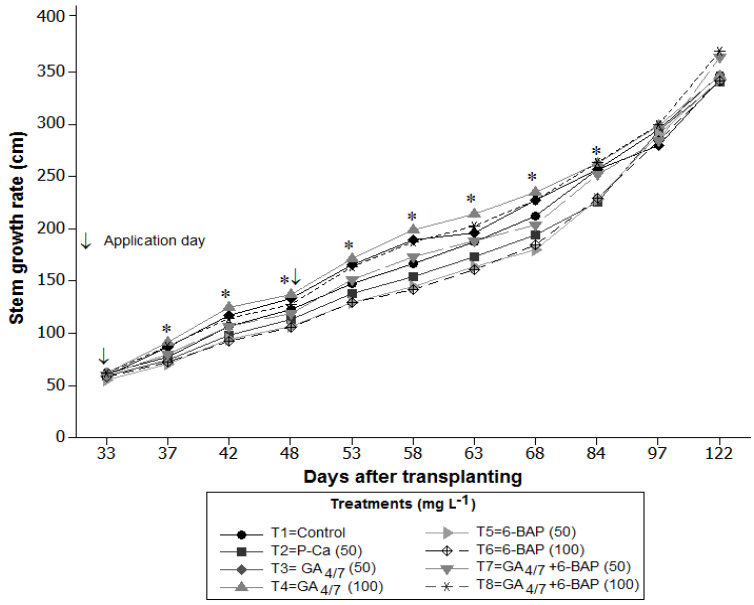

Fig. 1. Main stem growth rate of saladette tomato hybrid "Raptor-F1" after being treated with bioregulators

*Each point represents the mean of ten replicates. * indicates statistically significant difference (P≤0.05)*

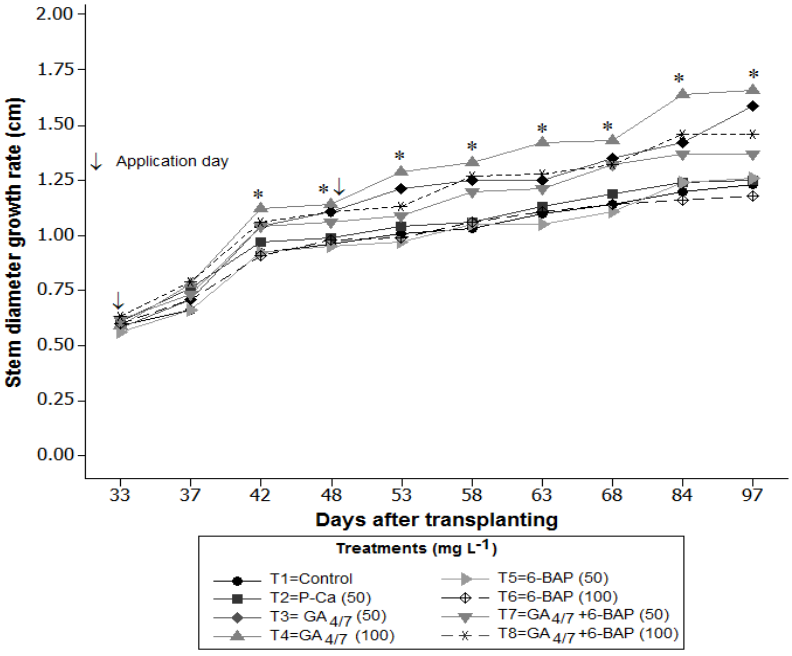

Fig. 2. Growth rate of stem diameter in saladette tomato plants hybrid "Raptor-F1" after being treated with bioregulators

*Each point represents the mean of ten replicates. * indicates statistically significant difference (P≤0.05)*

The effect observed with P-Ca on the reduction in the height of tomato plants is consistently related to the inhibition of the biosynthesis of gibberellins A_1, A_4 and A_7 by this growth retardant at the apex [6,14]. It has been reported that the biosynthesis of these biologically active gibberellins is inhibited within a few hours after P-Ca is taken by the shoot apex; whereas the stem growth reduction appears few days later [6]. Table 1 shows that P-Ca inhibited the production of gibberellins A_1, A_4 and A_7 at the apex four days after the spray took place. Instead, giberellins A_9, A_{20} and A_{53} were detected. These GAs are biologically inactive and therefore the reduction in growth (Fig. 1) is attributable to these conditions. The increment in stem growth seen by the exogenous application of $GA_{4/7}$ (50 and 100 mg L^{-1}) is probably connected to the stimulation of cell elongation at the tissue as it has previously been reported [7]. The increment on stem diameter in plants of most bioregulators treatments (Fig. 2) would be explained as a result of an increase in cell division and cell elongation provoked by cytokinins and gibberellins followed by an increase of assimilate flux moving into that growing tissue originating anatomical changes as a result of an increase in starch synthesis in marrow cells and cortical stem [15,16]. This effect has also been reported in saladette tomato by Ramírez et al. [7] and in jalapeño pepper [17]. The higher number of leaves formed in plants treated with P-Ca and $GA_{4/7}$ + 6-BAP (Table 2) may reflect the stimulation of leaf tissue differentiation caused by cytokinins and gibberellins [18]; hormones which in this study were sprayed (Fig. 1). It is known that P-Ca promotes the synthesis of endogenous cytokinins in immature seeds and apex in several species [7]. This may explain the promotion on leaf formation observed in plants treated with this growth retardant. The presence of gibberellins A_9, A_{20} and A_{53} at the apex of P-Ca treated plants (Table 1) did not alter the formation of leaves since these substances are biologically inactive as it has been demonstrated in other crops such as rice [19] and apple [20,21].

3.2 Number of Flowers and Fruits

It can be seen in table 2 that the number of flowers and fruits was higher (*P≤0.05*) in those plants treated with P-Ca at 50 mg L^{-1}. An increment of 10% in both parameters from these plants was observed when compared to control samples. The treatment with $GA_{4/7}$ at 100 mg L^{-1} resulted in the lower number of fruits per plant which was 21% less than those corresponding to control plants. P-Ca is a growth retardant which promotes flower induction in jalapeño pepper and tomato [7]; and in apple, pear, peach and cherry [6]. These reports support the increments in flower number found in this study (Table 2). The effect caused by P-Ca seems to be mediated through the increment of cytokinins in the meristematic bud at the time flower bud induction is taking place as have been shown in bourse buds of apple trees at the time of flower bud initiation [6]. The higher number of fruits per plant observed in P-Ca treated plant reflects an increase in fruit set. This is true when the growth retardant was sprayed to tomato [7] and Bell pepper [6]. The mechanism through which P-Ca works is not totally clarified; however, it is well known that when it blocks the synthesis of gibberellins A_1, A_4 and A_7 at the apex (Table 1), this condition modifies the translocation of assimilates from that tissue into the fruitlets recently formed, causing more fruit retention [22]. The same effect was reported in tomatillo (*Physalis ixocarpa* Brot.) [23] and in apple [24]. These experiences also may explain the reduction in fruit set seen in plants treated with $GA_{4/7}$ at 100 mg L^{-1}, where the vegetative competition caused by these hormones reduced the flux of assimilates into fruits (Table 2).

Table 1. Effect of P-Ca on endogenous gibberellins in apices of saladette tomato hybrid "Raptor-F1" identified by GC-MS

Hormones	IRK[a]	Pattern of fragmentation and relative intensity (%)
Gibberellins	**Control**	
GA_1	2651	[506(M^+,100), 448(14), 377(15), 375(18)]
GA_4	2488	[418(M^+,21), 403(2), 400(12), 386(25), 284(100)]
GA_7	2416	[416(M^+,10), 193(12), 179(5), 155(13]
	P- Ca 50 mg L^{-1}	
GA_9	2295	[330(M^+,5), 217(37), 183(19), 159(45)]
GA_{20}	2468	[418(M^+,100), 403(17), 387(6), 375(82), 359(19)]
GA_{53}	2507	[448(M^+,7), 403(3), 386(15),371(3), 358(1)]

[a] *Kovats retention index; M^+ = Ion molecule*

Table 2. Effect of bioregulators on the number of leaves, flowers, fruits and yield in saladette tomato hybrid "Raptor-F1"

Treatments	Leaves	Flowers	Fruits	Yield
(mg L^{-1})		(Number per plant)		(Kg/plant)
Control	45 ab [z]	30 ab	19 ab	1.75 a
P-Ca (50)	48 a	33 a	21 a	1.67 a
$GA_{4/7}$ (50)	43 b	25 b	17 b	1.17 bc
$GA_{4/7}$ (100)	45 ab	26 b	15 b	0.89 c
6-BAP (50)	45 ab	29 ab	18 ab	1.57 a
6-BAP (100)	46 ab	29 ab	17 b	1.44 ab
$GA_{4/7}$+6-BAP (50)	47 a	30 ab	17 b	1.15 bc
$GA_{4/7}$+6-BAP (100)	48 a	31 ab	16 b	1.10 c
VC (%)	8.91*	22.72*	23.46*	26.7*

*[z] = values with the same letter are statistically equal in accordance with the LSD to a test P≤0.05; *= significant difference to a P≤0.05; VC= coefficient of variation; Kg= kilograms. Each value represents the average of ten plants*

3.3 Fruit Quality

The polar and equatorial diameter of fruits from P-Ca treated plants were significantly larger than the rest of bioregulators (see appendix); whereas gibberellins $_{4/7}$ at 50 mg L^{-1} produced smaller fruits (Table 3). The increase in fruit size by P-Ca is not frequently seen in horticultural crops such as tomatillo [23] and apple [16]. In the present study a concentration of 50 mg L^{-1} of this bioregulator was applied which is half of that used on these crops. It is possible that P-Ca at a lower concentration could promote enough amounts of cytokinins and auxins at the apex or other plant organs and subsequently transferred to developing tissues such as fruits [25] where cytokinins promote cell division and auxins avoid fruit abscission [18]. The small fruits observed in plants sprayed with gibberellins could be the result of competitive vegetative growth caused by the same hormones as it has been reported in fruit trees [21].

The firmness and °Brix were significantly different in fruits from treatment with $GA_{4/7}$ at 100 mg L^{-1} (Table 3). Both parameters show increments when compared with the rest of bioregulators. Similar effects were found in cherry [26]. Ramirez et al. [7] also reported similar pattern in two hybrids of tomato saladette with determined and undetermined growing habit. It has been proposed that the presence of gibberellins during fruit ripening participate by maintaining rigidness on skin and external membranes; they may also be involved in the event linked to fruit sugar synthesis [12,13]. However more research is need on this topic.

The color and shelf life of experimental fruits were not affected by any bioregulator (Table 3). Although there was a tendency in increasing the shelf life on fruits treated with P-Ca and gibberellins; these hormones never gave statistical difference.

Table 3. Effect of bioregulators on fruit quality in saladette tomato hybrid "Raptor-F1"

Treatments	Polar diameter	Ecuatorial diameter	Firmness	°Brix	Color luminosity	Shelf life
(mg L^{-1})	(mm)	(mm)	(Kg/cm^2)	(%)	(L)	(days)
Control	64.12 ab [z]	50.95 abc	4.16 abc	3.8 abc	43.38 a	31 a
P-Ca (50)	66.84 a	53.06 a	4.14 abc	3.8 bc	44.85 a	37 a
$GA_{4/7}$ (50)	58.54 c	46.59 d	4.48 ab	4.1 ab	44.64 a	36 a
$GA_{4/7}$ (100)	59.73 bc	46.81 cd	4.63 a	4.3 a	43.33 a	31 a
6-BAP (50)	64.07 ab	51.42 ab	3.55 c	3.7 bc	45.04 a	29 a
6-BAP (100)	63.42 ab	50.52 abcd	3.46 c	3.6 c	43.59 a	31 a
$GA_{4/7}$+6-BAP (50)	62.15 abc	49.95 abcd	4.06 abc	3.8 abc	45.45 a	31 a
$GA_{4/7}$+6-BAP (100)	60.23 bc	47.99 bcd	3.7 bc	3.9 abc	45.74 a	32 a
VC (%)	6.5*	7.35*	16.68*	11.67 *	4.96 NS	27.46 NS

*[z]= Values with the same letter are statistically equal in accordance with the LSD to a test P≤0.05; *= Significant difference to a P≤0.05; NS=non-significant difference; VC=coefficient of variation; mm= millimeters. Each value represents the average of ten plants*

The content of vitamin C in tomato fruits is shown in Fig. 3. It was evident that the combination of $GA_{4/7}$ + 6-BAP at 100 mg L^{-1} produced the highest content of this antioxidant (*P≤0.05*). This value was 47% above of control samples. The application of P-Ca and individual gibberellins also showed a tendency in increasing the level of that antioxidant. These findings are supported by the reports in Mirador pepper [13] and in jalapeño pepper [27]. Vitamin C is a compound which has shown to play an important role in detoxification of activated oxygen and reacts directly with reactive oxygen molecules [12]. This antioxidant seems to contribute to a good health in humans and also strengthens the system of protection against diseases such as diabetes, cancer and blood pressure [23,27]. Therefore, increments in vitamin C by bioregulators in fruits of vegetable crops are considered an important contribution in contemporaneous horticulture [17].

The content of lycopene in fruits show a similar pattern on plants where the treatment with $GA_{4/7}$ + 6-BAP at 100 mg L^{-1} was sprayed resulting in a significant increment (*P≤0.05*) on that antioxidant (Fig. 4). The amount of this valuable antioxidant was 55% higher than control fruits. P-Ca, gibberellin alone or in combination with 6-BAP show a tendency to increase the content of lycopene as well. The results on this study fit with those previously reported by Ramirez et al. [28]. Lycopene is now-a- days an important demanding antioxidant which makes an important contribution on human health strengthens [17]. Any technical alternative such as the use of bioregulators for increasing the content of lycopene in tomato fruits will be of great value and therefore more research is need.

3.4 Yield and Economic Impact

Table 2 illustrates that yield in plants sprayed with P-Ca and 6-BAP at 50 mg L^{-1} were similar to control samples. These values were higher than the rest of bioregulator treatments. The lowest yield per plant resulted when $GA_{4/7}$ at 100 mg L^{-1} was applied alone or in combination with 6-BAP at 100 mg L^{-1}. The application of P-Ca and 6-BAP in the range of 100 to 300 mg L^{-1} have proven to increase the yield in temperate fruit species such as apples and pear [6]; however, the contrary occurred when those dosages were sprayed in jalapeño pepper [17]. In the present research, the concentration of both compounds was in most cases lower; condition which may explain these results. The drastic reduction on yield caused by gibberellins may be related to a competition with the vegetative growth seen in stem height and leaf number (Fig. 1, Table 2), as have been observed in apple trees [6]. Table 4 shows that the cost of production is slightly higher in any treatment with bioregulators when compared to control; however, this difference in cost is compensated by the market price, which doubles the price of control as a result of a higher antioxidants content in fruits treated with bioregulators (Figs. 3 and 4). This difference is reflected in the benefit: cost ratio with values of 1.9, 1.9, 1.84 and 1.74 for P-Ca, $GA_{4/7}$, 6-BAP and $GA_{4/7}$, + 6-BAP respectively against 0.86 in control fruits. The improvement in fruit quality could compensate the no effect on yield (Table 2) since fruits from bioregulators should reach higher market price. This statement now-a- days is supported by the increasing demand on vegetable commodities with a high content of antioxidants [12].

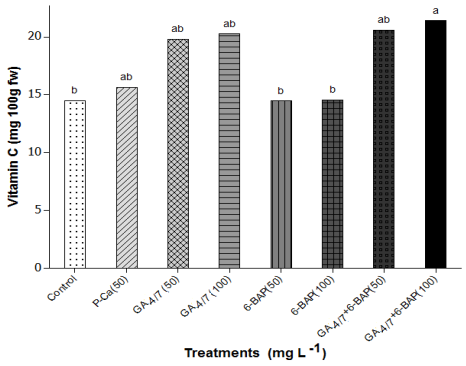

Fig. 3. Influence of bioregulators in vitamin C content in fruits of saladette tomato hybrid "Raptor-F1"

Each bar represents the average of ten replications. Bars with the same letter are equal (P≤0.05)

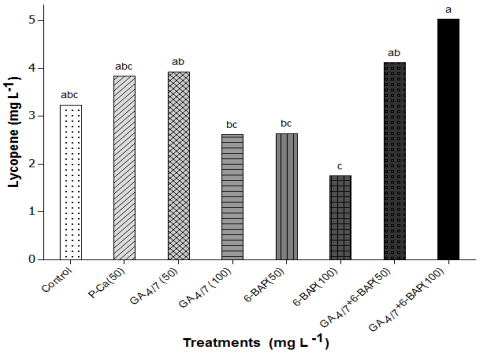

Fig. 4. Influence of bioregulators in lycopene content in fruits of saladette tomato hybrid "Raptor-F1"

Each bar represents the average of ten replications. Bars with the same letter are equal (P≤0.05)

Table 4. Economic impact for saladette tomato hybrid "Raptor-F1" treated with bioregulators

Concept	Control	P-Ca[Z]	$GA_{4/7}$	6-BAP	$GA_{4/7}$ +6-BAP
	> 30 % Lycopene + Vitamin C				
Grower price*/kg.$ USD	0.93			1.48	
Cost/kg. $ USD	0.50	0.51	0.51	0.52	0.54
Benefit:Cost Ratio	0.86	1.9	1.9	1.84	1.74

**SAGARPA, México; [Z]=Mean bioregulator treatments*

4. CONCLUSIONS

Prohexadione-calcium inhibits the synthesis of gibberellins A_1, A_4 and A_7 at the apex; reduces plant height; increases stem diameter, number of leaves, flowers and fruits. $GA_{4/7}$ and 6-BAP increase firmness, sugar level, vitamin C and lycopene in ripen fruits on saladette tomato hybrid "Raptor-F1" grown in greenhouse.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX


9 days after the second application of treatments
$GA_{4/7}$ 100 mg L^{-1}
$GA_{4/7}$ 50 mg L^{-1}
$GA_{4/7}$+6-BAP 100 mg L^{-1}
$GA_{4/7}$+6-BAP 50 mg L^{-1}
Control
PCa 50 mg L^{-1}
6-BAP 50 mg L^{-1}
6-BAP 100 mg L^{-1}

GA4/7+6-BAP (100 mg L^{-1})

GA4/7+6-BAP (50 mg L^{-1})

6-BAP(100 mg L^{-1})

6-BAP (50 mg L^{-1})

$GA_{4/7}$ (100 mg L^{-1})

$GA_{4/7}$ (50 mg L^{-1})

P-Ca (50 mg L^{-1})

Control

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