Pre−harvest glochid abscission induced by spraying of GA_3 and ethephon on fruits of cactus pear (*Opuntia* spp.)

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Abstract

Glochids are fine, sharp, sclerified thorns composed of pure crystalline cellulose. The presence of these small spines negatively affects harvest, fruit quality and acceptance; therefore, it is necessary to remove them. At present, glochids are removed by placing the fruits on the ground where they are swept with a broom or a bundle of twigs, or by machines. However, these techniques cause mechanical damage and postharvest losses. Another option is the use of growth regulators before harvest, which has had medium success on white cactus pear. However, the particular effect that these regulators may have on glochid abscission and postharvest physiology and quality in other Mexican varieties has not been studied. In this research, the effect of GA_3 and Ethephon on glochid abscission (pre− and post−harvest) and on postharvest fruit quality was evaluated in four cactus pear varieties: Solferino, Rojo 3589, Amarillo 2289, and Rojo Vigor. At anthesis, flowers and fruits were sprayed with 4 or 6 consecutive (weekly) applications of GA_3 (50 or 100 ppm) and, later, 4 or 6 consecutive (weekly) applications of Ethephon (700 to 900 ppm). After harvest, the following variables were measured: fruit weight, peel, pulp seed, juice ºBrix, firmness and color. The varieties showed natural differences in the number of glochids per areole, areole glochid retention force, and as response to the treatments. Before harvest, the highest (82%) and lowest (70%) average glochid abscission were observed in the Amarillo 2289 and Solferino varieties, respectively. After harvest, the highest abscission (97.3%) was observed in the Solferino, Rojo 3589 and Amarillo 2289 varieties, and the lowest abscission (92%) in the Rojo Vigor variety. The high GA_3 concentration (100 ppm) promoted higher abscission of glochids than the lower concentration (50 ppm). An antagonistic effect was observed between the factors GA_3 concentration and number of applications. Before harvest, none of the other factors had a differential effect on this variable, except the variety factor. In general, the treatment that promoted the highest glochid abscission, before (82.25%) and after (97.25%) harvest, was four applications of GA_3 (100 ppm) and four applications of Ethephon (700 ppm). In general, the application of GA_3 and Ethephon improved fruit quality parameters, although in certain varieties, some of the quality parameters were affected negatively by some of the treatments.

Keywords: Growth regulators; Pre− and post−harvest glochid removal; ºBrix; Fruit firmness; Color; Weight and shape.

Abbreviations: GABH, Glochids abscission (%) before harvest; GAAH, Glochids abscission (%) after harvest ; GA_3, gibberellic acid.

Introduction

Cactus pear (*Opuntia ficus−indica* [L.] Mill.) is cultivated for fruit production in both hemispheres and on all continents, except the Antarctic. Mexico is the country that has the largest area under cultivation (54,294.61 ha) and has the largest production (393, 974.61 t) (SIAP, 2010). According to Cantwell (1995), the main factors that affect demand for this fruit, positively or negatively, are (1) seed content, (2) fruit size, (3) ripening season, (4) ripeness, (5) packaging, (6) fruit color, and (7) presence of glochids and spines (requiring appropriate postharvest management to remove glochids). Of these factors, probably color and the presence of glochids are the most important; the yellow, red, purplish red and pink fruits are highly appreciated particularly on the North American market. Studies in Italy show that consumers who are not familiar with this fruit are more attracted by red fruits, which are those they buy first (Ascuito *et al*., 1997). Unlike other cactus pear producing countries, Mexico has the widest range of germplasm variety (Mondragón *et al*., 2009), which includes fruits of several colors: yellow, red, orange, pink and purplish red.

The presence of glochids (small spines) is also very important since it negatively affects harvest, fruit quality and consumer acceptance. Because of the spines, pickers tend to avoid touching them and try picking with only two fingers instead of distributing the necessary force uniformly among all of the fingers causing undesirable damage from the pressure. These are known as 'finger marks', which are not immediately evident until a few days later. It is in these damaged areas where undesirable changes in color, rotting and fruit senescence begin (Corrales−García, 2003). The 'finger mark' affects the light colored varieties to a greater degree (Cantwell, 1995). Corrales and González (2001) found that GA_3 (100 ppm) + Ethephon (500 ppm) sprayed on floral buds first (at anthesis) and later on fruits during their development caused significant abscission of glochids (up to 93%) after the mechanical effect of harvest. However, the study was conducted on *Opuntia amyclaea* T., which is a green cactus pear, highly appreciated in Mexico but little known and demanded by the United States of America market. The objective of the present study was to assess the effect of several concentrations and number of applications of GA_3 and Ethephon on glochid abscission (%) and postharvest quality of red and yellow cactus pears, which are those that are more highly demanded for the export market.

Materials and methods

Plant material and treatments

In the experimental cactus pear orchard 'Facundo Barrientos Pérez' of the Universidad Autónoma Chapingo, 144 mature cactus pear plants with similar age and agronomic management were selected; these were of the Solferino, Rojo 3589, Amarillo 2289 and Rojo Vigor varieties (36 of each variety). On each plant, three producing cladodes were selected and labeled. Aqueous solutions (50 or 100 ppm) of giberelic acid (GA_3) (Biogib™) were sprayed on the floral buds and later on the fruits during their development on four or six consecutive occasions (every week), beginning immediately after the flower opened (anthesis). After this, aqueous solutions (700 or 900 ppm) of 2−chloroethyl phosphoric acid (Ethephon™) were sprayed on the same fruits on four or six consecutive occasions (every week). In the preparation of the two solutions a phosphate buffer solution (Dawson *et al*., 1972) pH 6 was used; to this, 5 mL of a commercial adherent (Resinal™) was added to each L of solution.

In this way, the following treatments were obtained, each of which were replicated four times on each of the four varieties included in the study:

Control: 0 applications of GA_3 and none applications of Ethephon
T1: 4 applications of 50 ppm GA_3 and 4 of 700 ppm Ethephon.
T2: 6 applications of 50 ppm GA_3 and 6 of 700 ppm Ethephon.
T3: 4 applications of 50 ppm GA_3 and 4 of 900 ppm Ethephon.
T4: 6 applications of 50 ppm GA_3 and 6 of 900 ppm Ethephon.
T5: 4 applications of 100 ppm $GA_3$and 4 of 700 ppm Ethephon.
T6: 6 applications of 100 ppm GA_3 and 6 of 700 ppm Ethephon.
T7: 4 applications of 100 ppm GA_3 and 4 of 900 ppm Ethephon.
T8: 6 applications of 100 ppm GA_3 and 6 of 900 ppm Ethephon.

When the fruits reached horticultural maturity, determined by the harvest indexes (size, fruit fill and visual appearance), as suggested by Corrales and Hernández (2005) and Cantwell (1995), they were carefully picked using gloves and knife and immediately taken to the laboratory for assessment.

Determination of dependent variables

Glochid abscission (%) before (GABH) and after harvest (GAAH)

To assess these variables, before picking, a strip of adhesive tape was placed on the peel, covering 3 to 4 areoles to fix the glochids until they were counted to calculate GABH. After, the fruits were harvested and taken to the laboratory where another strip of adhesive tape was placed on another 3 to 4 different areoles to prevent glochids from falling off. Then, glochids were later counted and GAAH was calculated. To count the glochids, both strips of adhesive tape were removed and placed on a microscope slide, and the number of glochids adhered to each tape strip were counted.

After counting, glochids abscission (%) was calculated with the following equations:

$$GABH = \frac{(X_1 - X_2)100}{X_1}, \quad (1)$$

where X_1 = Average number of glochids per areole present on control fruit, and X_2 = Average number of glochids per areole present before harvest on treated fruits.

$$GAAH = \frac{(Y_1 - Y_2)100}{Y_1}, \quad (2)$$

Where Y_1 = Average number of glochids per areole present on control fruits, and Y_2 = Average number of glochids per areole present after harvest on treated fruits.

Weight of fruit (FW), peel (PeW), pulp (PuW) and seed (SW)

These variables were determined with a top loading balance (Shimadzu BX 4200D), and the results were expressed in g.

Fruit firmness

This variable was determined with a universal texturometer (SUMMER & RUNGE KG, Berlin−Friedenau). A conical probe penetrated the fruit; after five seconds of free fall, the distance was determined. The results were expressed as mm penetration.

Total soluble solids (TSS)

TSS was determined in the fruit juice with a manual refractometer (ATAGO, Japan) with a scale of 0−32º. The results were expressed in ºBrix at 20ºC.

Fruit shape (length/diameter ratio)

The polar and equatorial diameter lengths were measured (cm) with a 0.001 cm precision vernier, and later the length/diameter ratio was calculated. The results of this variable are dimensionless.

Peel color

A colorimeter (Hunter Lab™, model MiniScan XE plus Nº 45/O−L) was used to determine L*, a* b* to later calculate Hue and Chroma, taking into account that Hue = arc tan b*/a*, and Chroma = $(a^{*2}+b^{*2})^{1/2}$.

Statistical analysis

The obtained data were analyzed using an analysis of variance (ANOVA) and the Tukey test of comparison of means ($P = 0.05$) by using the statistical software Statistical Analysis System (SAS, version 9.1). The experimental unit was one cactus pear plant, and each treatment was replicated four times. For the variables GABH and GAAH, the experimental design was completely randomized with a factorial arrangement of 4x2x2x2 (four varieties, two GA_3 concentrations, two concentrations of Ethephon, and two application times). For the postharvest quality variables, a completely randomized design was used taking into account the 9 treatments (including the control) for each of the four varieties.

Results and discussion

Effect of treatments on GABH and GAAH

Before harvest, a marked abscission of glochids was observed in all of the treated fruits. Apparently, as proposed by Reid (1992), Ethephon releases ethylene that induces glochid abscission by promoting accelerated ripening and weakening of the tissues and structures (areoles) that support the glochids. For this reason, it appears that all of the treatments weakened the areoles in a like manner; there were no significant differences in glochid abscission among the treatments for most of the varieties (Solferino, Rojo 3589 and Amarillo 2289) under study. Nevertheless, in the variety Rojo Vigor, treatment 5 caused greater glochids abscission than the treatments 3 and 6. The results provide evidence that of the four studied varieties, Rojo Vigor was that which exhibited the lowest response to any of the treatments in terms of percentage of glochids abscission (Table 1).

Table 1 shows that manipulating the fruits of the four varieties during harvest caused a notorious additional abscission of glochids, even on the untreated fruits (control). Similarly, for postharvest, there were no significant differences in glochids abscission among treatments for most of the studied varieties (Solferino, Rojo 3589 and Amarillo 2289).

Only in Rojo Vigor, treatment 5 caused a significantly higher percentage of glochid abscission than that caused by the other treatments. In contrast, untreated fruits (control) had a significantly lower abscission than any of the other treatments.

It deserves to be mentioned that the percentage of glochid abscission (almost 95%) in the Rojo Vigor variety was lower than in the other three varieties. These results could be partly explained due to this variety, according to the counts, had by nature the largest average number of glochids per areole (165). In addition, field observations revealed that it is the variety that most retains its glochids.

Table 1. Effect of treatments on GABH and GAAH on cactus pear fruits from Solferino, Rojo 3589, Amarillo 2289 and Rojo Vigor varieties.

Treatment	Variety							
	Solferino		Rojo 3589		Amarillo 2289		Rojo Vigor	
	GABH (%)	GAAH (%)	GABH (%)	GAAH (%)	GABH (%)	GAAH (%)	GABH (%)	GAAH (%)
Control	DND	68.1 b	DND	73.5 b	DND	52 b	DND	53.6 d
T1	75.2 ab	98.2 a	79.2 ab	95.9 a	78.4 ab	96.5 a	75.6 ab	90.9 bc
T2	77.8 ab	99.2 a	82.7 a	96.3 a	84.3 a	96.1 a	76.4 ab	91.9 bc
T3	83.5 a	97.2 a	77.0 ab	96.8 a	85.3 a	96.3 a	72.0 b	89.8 c
T4	78.7 ab	98.7 a	77.3 ab	97.4 a	79.2 ab	96.0 a	72.5 ab	91.5 bc
T5	80.4 ab	98.8 a	83.1 a	96.8 a	85.7 a	98.7 a	79.8 a	94.5 a
T6	78.3 ab	97.0 a	80.9 a	97.6 a	86.3 a	97.7 a	71.9 b	91.1 bc
T7	79.2 ab	98.6 a	78.6 ab	95.9 a	84.0 ab	98.1 a	75.3 ab	92.6 bc
T8	83.0 a	97.9 a	77.7 ab	97.1 a	82.3 ab	96.1 a	68.9 b	91.5 bc

Means followed by the same letter by column are statistically equal (Tukey; P=0.05). GABH: glochids abscission (%) before harvest. GAAH: glochids abscission (%) after harvest. DND: Data not available. Control: 0 Applications of GA_3+0 Applications Ethephon. T1: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 700 ppm). T2: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications 700 ppm). T3: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 900 ppm). T4: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications, 900 ppm). T5: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 700 ppm). T6: GA_3 (6 Applications, 100 ppm)+Ethepon (6 Applications, 700 ppm). T7: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 900 ppm) T8: GA_3 (6 Applications, 100 ppm)+Ethephon (6 Applications, 900 ppm).

Effect of the factors on GABH and GAAH

The variety was the only factor that had significant effects on GABH and GAAH. Before harvest, glochid abscission in the Solferino variety was significantly lower than in the others. There were no significant differences for this variable between Rojo 3589 and Rojo Vigor varieties (Figure 1).

After harvest, there was a noticeable increase in glochid abscission (%); this suggests that both harvest and transport to the laboratory implicates movement and manipulation, contact with other fruits and the containers used for gathering, all of which contributed to glochid abscission. As observed in Figure 2, the Rojo Vigor variety had significantly lower glochid abscission than the other varieties. Taking into account this dependent variable, there were no differences among the Solferino, Rojo3589 and Amarillo 2289 varieties.

None of the other studied factors were statistically different from the control in terms of their effect on glochid abscission (%). After harvest, besides variety, GA_3 concentration was the only factor that had a significant effect on glochid abscission. At the higher concentration (100 ppm), GA_3 caused significantly greater glochid abscission than the lower concentration (50 ppm) (Figure 3).

The highest glochids abscission caused by the highest concentration of GA_3 was likely due in part to the greater growth of glochids promoted by this regulator. Therefore, glochids were longer and more susceptible to the action of wind, rain, picking, or other source of mechanical movement.

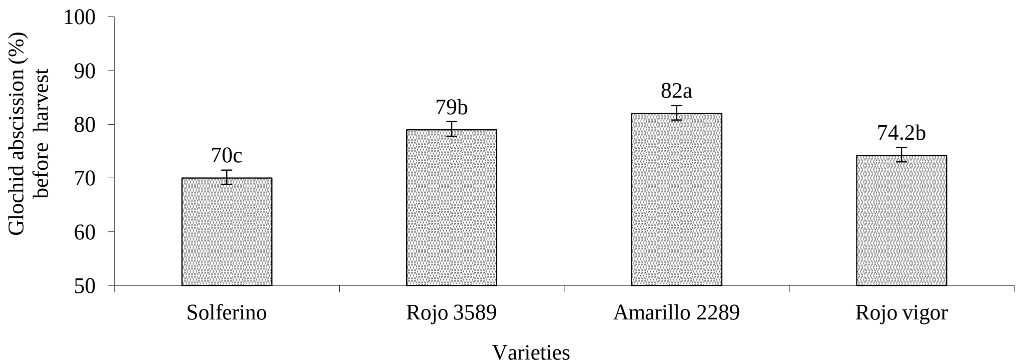

Figure 1. Effect of the factor variety on preharvest glochids abscission (%) in cactus pear subjected to different conditions of GA_3 and Ethephon application. Means followed by the same letter are statistically equal (Tukey; P=0.05). n=32.

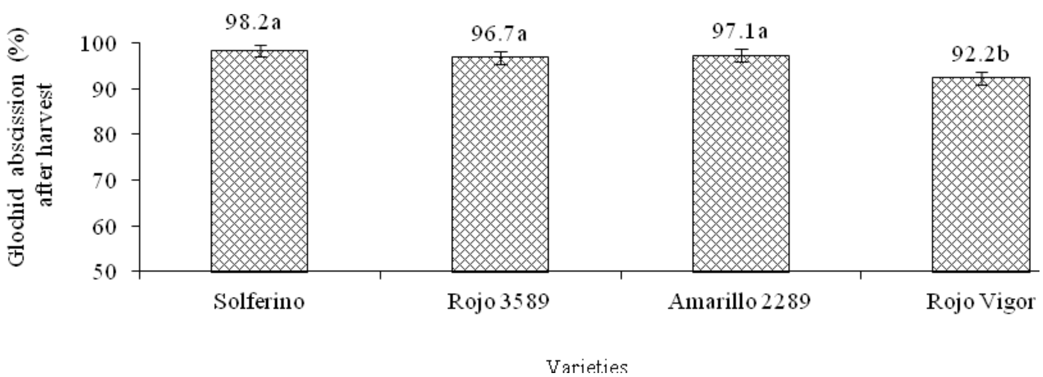

Figure 2. Effect of the factor variety on postharvest glochids abscission (%) in cactus pear subjected to different conditions of GA_3 and Ethephon application. Means followed by the same letter are statistically equal (Tukey; P=0.05). n=32.

Effect of the factor interactions on GABH and GAAH

The statistical analysis of the results showed that, before harvest, no interaction among the studied factors was significant. However, after harvest, there was a significant interaction between the factors GA_3 concentration and number of applications: when GA_3 concentration increased from 50 to 100 ppm and the number of applications was low (4), glochids abscission (%) was greater. Nevertheless, when the GA_3 concentration increased from 50 to 100 ppm and the number of applications was high (6), instead of causing greater glochids abscission, the combination reduced abscission (antagonistic effect) (Figure 4).

The information generated from the results of this study is not sufficient to give a reasonable, precise, reliable explanation for this antagonistic interaction, and further investigation is necessary.

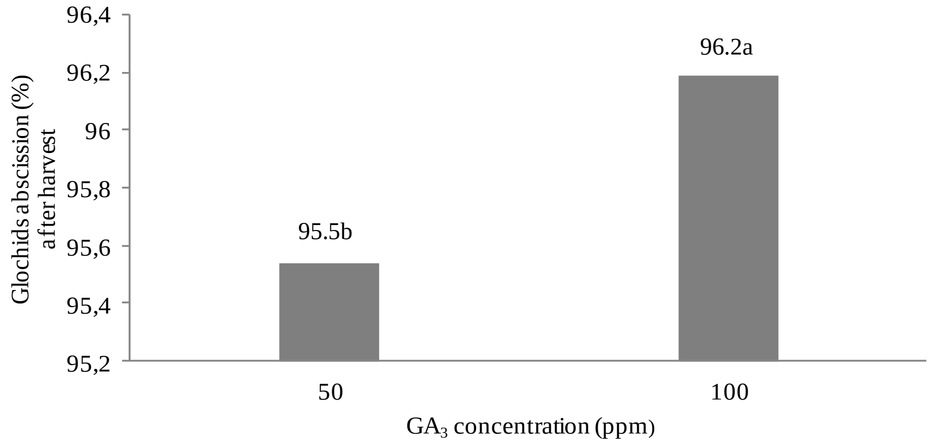

Figure 3. Effect of the factor GA_3 concentration on postharvest glochids abscission (%) in cactus pear fruits of the Solferino, Rojo 3589, Amarillo 2289 and Rojo Vigor varieties subjected to different conditions of Ethephon application. Means followed by the same letter are statistically equal (Tukey; P=0.05). n=64.

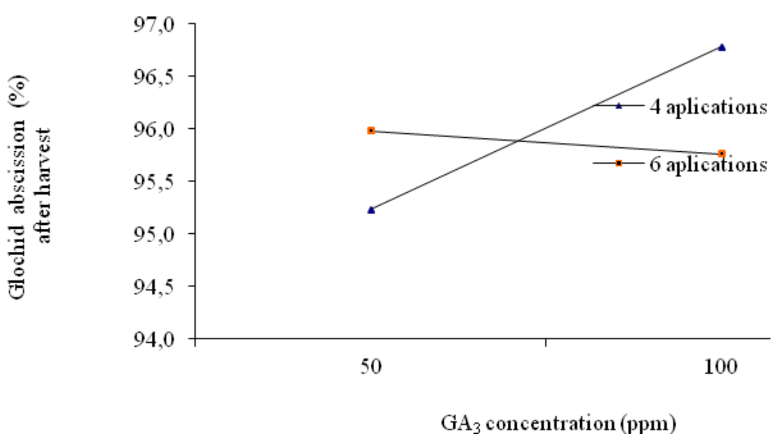

Figure 4. Negative interaction (antagonistic) between the factors GA_3 concentration and number of applications on postharvest glochids abscission in cactus pear of the Solferino, Rojo 3589, Amarillo 2289 and Rojo Vigor varieties. P=0.0076. n=32.

Effect of treatments on fruit quality of the Solferino variety

Fruit weight. Treatments 1 and 7 caused Solferino fruit to be 15.6% and 17.9% heavier, respectively, than the control. The other treatments had little effect on this variable, with the exception of Treatment 4, which reduced fruit weight 11.7% (Table 2). Response to the treatments, especially those with the higher concentration of growth regulator, was positive, but only when there were no more than four applications. The results support the growth promoter effect of GA_3 even with few (four) applications.

Peel weight. Most of the treatments had no negative effects on peel weight. Treatments 2, 4, and 5 had a small effect, and the treatment 3 only that reduced peel's weight (13.9%), while treatments 1, 6, 7 and 8 increased peel's weight significantly (27.8% on average) (Table 2). This can be considered a relatively favorable effect in the sense that a higher peel weight indicates thicker peel. According to Corrales−Corrales *et al*. (2006), cactus pears with thicker peel are favored by shippers since thicker−peeled fruits are more resistant to bruising and, therefore, more tolerant to postharvest handling.

Table 2. Effect of the treatments on some of the fruit quality parameters in Solferino variety.

Treatment	Variable							
	FW (g)	PeW (g)	PuP (g)	SW (g)	ºBrix	Lum	HUE (º)	Chroma
Control	128.0 b	43.0 c	84.0 bc	10.0 c	11.3 b	31.1 bc	22.0 a	16.1 b
T1	148.0 a	51.0 b	96.0 a	9.0 cd	12.6 a	30.6 c	23.0 a	16.3 b
T2	120.0 bc	45.0 bc	74.0 cd	8.0 d	12.0 ab	31.9 bc	23.0 a	15.9 b
T3	126.0 b	37.0 d	89.0 b	10.0 bc	12.3 ab	31.1 bc	23.0 a	16.6 b
T4	113.0 c	44.0 c	69.0 c	9.0 cd	12.2 ab	32.6 b	20.0 ab	15.9 b
T5	125.0 b	42.0 c	82.0 b	12.0 a	12.7 ab	38.4 a	20.0 ab	21.1 a
T6	128.0 b	55.0 b	73.0 bd	13.0 a	12.5 a	39.5 a	22.0 a	14.9 b
T7	151.0 a	66.0 a	86.0 b	12.0 ab	13.4 a	32.1 b	20.0 ab	20.4 a
T8	123.0 bc	48.0 b	75.0 cd	12.0 a	12.5 a	31.8 bc	22.0 a	26.2 b

Means followed by the same letter by column are statistically equal (Tukey; P=0.05). n = 32. Control: 0 Applications of GA_3+0 Applications Ethephon. T1: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 700 ppm). T2: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications 700 ppm). T3: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 900 ppm). T4: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications, 900 ppm). T5: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 700 ppm). T6: GA_3 (6 Applications, 100 ppm)+Ethepon (6 Applications, 700 ppm). T7: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 900 ppm) T8: GA_3 (6 Applications, 100 ppm)+Ethephon (6 Applications, 900 ppm). FW: Fruit weight, PeW: peel weight, PuW: pulp weight, SW: seed weight, Lum: Luminosity.

Pulp weight. None of the treatments affected this variable negatively; rather, treatment 1 (the lowest number of applications and the lowest GA_3 concentration) caused a significant increase (14.2%) in pulp weight, a very desirable trait (Table 2).

Seed weight. Treatments 1, 3 and 4 resulted in seed weight equal to that of the control fruits, while treatment 2 significantly reduced seed weight (20%). However, treatments 5, 6, 7 and 8 increased seed weight by 22.5% on average (Table 2).

Total soluble solids. None of the treatments affected this variable negatively. Fruits of treatments 2, 3, 4 and 5 had the same ºBrix as the control fruits, whereas treatments 1, 6, 7 and 8 increased ºBrix by 12.8% on average, i. e., these fruits were sweeter (Table 2).

Fruit color (Luminosity, Hue and Chroma). Fruit Luminosity associated to treatments 1, 2, 3, 4, 7 and 8 was no different to that of the control, whereas treatments 5 and 6 increased Luminosity 25.2%, which a desirable result is. Both fruit Hue and Chroma were not different among all the treatments, including the control, except treatments 5 and 7, which increased the Chroma about 28.8% on average, improving its appearance (Table 2).

Fruit shape (ratio length/diameter). Treatment 2 caused a significant reduction (12.5) in the length/diameter ratio; that is the fruits were more spherical. The other treatments did not affect this variable, whose average value was 1.5 (data not shown).

Fruit firmness. Firmness of the fruits from all of the treatments was statistically equal to that of the control. This variable had an average value of 3.9 mm penetration (data not shown).

Effect of treatments on fruit quality of the Rojo 3589 variety

Fruit weight. Fruits of all the treatments had average weight that was statistically equal to that of the control, except for treatment 2, which reduced this variable 22.6% (Table 3).

Peel weight. Peel weight of the fruits of all the treatments was not significantly different from that of the control (Table 3).

Pulp weight. Treatment 2 caused lower pulp weight (25%) with respect to the control. It should be mentioned that this treatment also reduced fruit weight; whereas the other treatments had no effect on this variable.

Seed weight. Treatment 2 reduced (10%) seed weight, whereas treatments 5 and 7 increased it (20%). The other treatments had no effect on this variable (Table 3).

Total soluble solids. For this variable, the treatments were statistically equal to the control; that is, they were equally sweet. Only treatment 6 fruits had a ºBrix content lower than the control (Table 3).

Fruit color (Luminosity, Hue and Chroma). For the variable Luminosity, there were no statistical differences between the treatments and the control. For Hue, treatments 1, 2, 4, 5 and 8 were statistically equal to the control, whereas treatments 3, 6, and 7 had a larger (35.2% on average) Hue angle than the control; that is, the fruits were less red, tending toward orange. The color saturation index in fruits of all the treatments was equal to that in control fruits, except for those of treatments 7 and 8, in which it was 33.6% higher than in control fruits, meaning improved appearance of these fruits with a purer, more intense color (Table 3).

Fruit shape (length/diameter ratio). This variable was not affected by any of the treatments. Average value was 1.5 (data not shown).

Fruit firmness. None of the treatments affected this variable, whose average value was 4.3 mm of penetration (data not shown).

Effect of treatments on fruit quality of the Amarillo 2289 variety

*Fruit weight.*Treatment 6 caused a significant increase (35.7%) in fruit weight, with respect to the control. The other treatments did not affect this variable (Table 4).

Peel weight. Treatment 2 caused a reduction (20%) in peel weight, when compared with the control. The other treatments did not affect this variable (Table 4).

Table 3. Effect of treatments on some fruit quality parameters. Rojo 3589 variety.

Treatment	Variable							
	FW (g)	PeW (g)	PuW (g)	SW (g)	ºBrix	*Lum*	HUE (º)	Chroma
Control	128.0a	43.0 ab	84.0 a	10.0 b	12.7 a	30.1 a	17.0 b	49.0 bc
T1	123.0 a	45.0 ab	78.0 ab	10.0 b	11.8 ab	29.6 a	18.0 b	46.0 bc
T2	99.0 b	36.0 b	63.0 b	9.0 c	11.9 ab	32.2 a	21.0 ab	56.0 b
T3	124.0 a	48.0 ab	77.0 ab	10.0 b	12.1 a	29.6 a	23.0 a	57.0 b
T4	122.0 a	44.0 ab	78.0 ab	10.0 b	11.6 ab	31.0 a	20.0 ab	49.0 bc
T5	130.0 a	46.0 ab	83.0 a	12.0 a	12.1 a	29.9 a	18.0 b	54.0 b
T6	132.0 a	50.0 a	82.0 a	10.0 b	11.0 b	31.0 a	22.0 a	57.0 b
T7	144.0 a	53.0 a	90.0 a	12.0 a	12.5 a	29.9 a	24.0 a	63.0 a
T8	125.0 a	44.0 ab	81.0 a	10.0 b	11.7 ab	29.8 a	18.0 b	68.0 a

Means followed by the same letter by column are statistically equal (Tukey; P=0.05). n = 32. Control: 0 Applications of GA_3+0 Applications Ethephon. T1: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 700 ppm). T2: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications 700 ppm). T3: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 900 ppm). T4: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications, 900 ppm). T5: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 700 ppm). T6: GA_3 (6 Applications, 100 ppm)+Ethepon (6 Applications, 700 ppm). T7: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 900 ppm) T8: GA_3 (6 Applications, 100 ppm)+Ethephon (6 Applications, 900 ppm). FW: fruit weight, PeW: peel weight, PuW: pulp weight, SW: seed weight, Lum: Luminosity.

Table 4. Effect of treatments on some fruit quality parameters. Amarillo 2289 variety.

Treatment	Variable							
	FW (g)	PeW (g)	PuW (g)	SW (g)	ºBrix	*Lum*	HUE (º)	Chroma
Control	123.0 b	49.0 ab	74.0 b	8.0 b	15.4 a	44.1 a	64.6 a	51.8 a
T1	117.0 b	46.0 bc	71.0 b	9.0 ab	13.8 b	43.9 a	67.6 a	51.9 a
T2	103.0 bc	39.0 c	64.0 b	8.0 b	14.9 a	44.2 a	62.6 a	46.5 ab
T3	109.0 b	43.0 bc	67.0 b	8.0 b	13.6 b	43.8 a	64.7 a	52.4 a
T4	108.0 b	41.0 bc	68.0 b	9.0 ab	14.5 a	41.8 a	62.8 a	50.0 a
T5	104.0 bc	41.0 bc	63.0 b	9.0 ab	14.8 a	42.1 a	65.1 a	47.3 ab
T6	167.0 a	54.0 a	113.0 a	8.0 b	14.3 a	42.7 a	63.1 a	52.5 a
T7	125.0 b	45.0 bc	79.0 b	10.0 a	14.0 ab	44.3 a	61.7 a	53.2 a
T8	110.0 b	43.0 bc	67.0 b	9.0 ab	14.5 a	43.6 a	64.9 a	51.6 a

Means followed by the same letter by column are statistically equal (Tukey; P=0.05). n = 32. Control: 0 Applications of GA_3+0 Applications Ethephon. T1: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 700 ppm). T2: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications 700 ppm). T3: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 900 ppm). T4: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications, 900 ppm). T5: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 700 ppm). T6: GA_3 (6 Applications, 100 ppm)+Ethepon (6 Applications, 700 ppm). T7: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 900 ppm) T8: GA_3 (6 Applications, 100 ppm)+Ethephon (6 Applications, 900 ppm). FW: fruit weight, PeW: peel weight, PuW: pulp weight, SW: seed weight, Lum: Luminosity.

Peel weight. Treatment 6 significantly increased (52.7%) pulp weight, with respect to the control. The other treatments did not affect this variable (Table 4).

Seed weight. Treatment 7 significantly increased (25%) seed weight, with respect to the control. The other treatments did not affect this variable (Table 4).

Total soluble solids. Treatments 1 and 3 significantly reduced this variable (10.9% on average); i. e., the fruits from this treatment were less sweet. The other treatments did not affect this variable (Table 4).

Fruit color (Luminosity, Hue and Chroma). There were no significant differences in Luminosity, Hue or Chroma between the fruit treatment and the control (Table 4).

Fruit shape. None of the treatments affected this variable. The average value was 1.4 (data not shown).

Fruit firmness. Treatments 1, 2, 4, 5 and 8 increased resistance to penetration (15.9% on average), with the control as reference. The other treatments had little effect on this variable, whose average value was 4.8 mm of penetration (data not shown).

Effect of treatments on fruit quality of the Rojo Vigor variety

Fruit weight. Most of the treatments reduced fruit weight; treatment 2 caused the greatest reduction (15.8%) in this variable. Only treatment 8 had fruits of the same weight as the control (Table 5).

Peel weight. Treatment 8 increased peel weight 22.8%, relative to the control. The other treatments had no effect on this variable (Table 5).

Pulp weight. All of the treatments caused a significant reduction of this variable; treatment 2 had the lowest (21.1%) pulp weight (Table 5).

Seed weight. Although most of the treatments caused lower seed weight (21.6% on average), particularly treatment 2 had a reduction of 30.7%, and treatments 5 and 7 had no effect on seed weight (Table 5).

Total soluble solids. Treatment 6 significantly reduced ºBrix (9.1%) with respect to the control. The other treatments did not affect this variable (Table 5).

Fruit color (Luminosity, Hue and Chroma). None of the treatments significantly affected Luminosity or Chroma of the fruits. Hue was not affected by most of the treatments since the treated fruits had values equal to that of the control. However, treatments 3 and 6 caused a significant increase (26.8% on average) in Hue, meaning that the fruits were less red and more orange (Table 5).

Fruit shape (length/diameter ratio). The length/diameter ratio of the fruits of treatments 1, 2, 3, 5 and 7 was 13.3% lower than that of the control fruits. It was little affected by the other treatments. The average value was 1.4 (data not shown).

Fruit firmness. None of the treatments affected this variable, which had an average value of 3.8 mm of penetration (data not shown).

The treatments had negative effects on Solferino variety: lower fruit weight (treatment 3), lower peel weight (treatment 4), and higher seed weight (treatments 5, 6, 7 and 8). The remaining variables were not affected negatively; instead, some treatments had positive effects on the fruit quality of this variety, particularly in the variables fruit weight (treatments 1 and 7), pulp weight (treatment 1), seed weight (treatment 2), ºBrix (treatments 1, 6, 7), and Luminosity (treatments 5 and 6). Also, Hue decreased with all of the treatments, while Chroma increased with treatments 5 and 7.

For the Rojo 3589 variety, there were also some negative effects, such as reduction of the fruit weight (treatment 2), reduced pulp weight (treatment 2), increased seed weight (treatments 5 and 7), decreased ºBrix (treatment 6) and increased Hue (treatments 3, 6 and 7). None of the treatments had negative effects on the other variables. In contrast, some of the treatments improved quality parameters, with respect to the control: increased fruit weight (treatments 1, 3, 4, 5, 6, 7 and 8), and pulp weight (treatments 1, 3, 4, 5, 6, 7 and 8), reduced seed weight (treatment 2) and Chroma (treatments 7 and 8). All of the treatments increased Luminosity. However, fruit firmness associated to all treatments was equal to that of the control.

Table 5. Effect of treatments (T) on some fruit quality parameters. Rojo Vigor variety.

Treatment	Variable							
	FW (g)	PeW (g)	PuW (g)	SW (g)	ºBrix	*Lum*	HUE (º)	Chroma
Control	120.0 a	35.0 b	85.0 a	13.0 a	12.0 a	30.1 a	17.1 b	18.6 a
T1	105.0 bc	33.0 b	71.0 bc	10.0 bcd	11.4 ab	29.5 a	18.5 ab	17.5 a
T2	101.0 c	35.0 b	67.0 c	9.0 d	11.4 ab	31.6 a	20.5 ab	17.6 a
T3	109.0 b	36.0 b	73.0 bc	11.0 abc	11.5 ab	29.5 a	21.8 a	16.9 a
T4	103.0 bc	33.0 b	71.0 bc	11.0 bcd	11.3 ab	31.0 a	18.7 ab	17.5 a
T5	110.0 b	36.0 b	75.0 b	12.0 a	11.8 a	29.9 a	18.4 ab	19.3 a
T6	106.0 b	34.0 b	73.0 bc	10.0 cd	10.9 b	30.9 a	21.6 a	17.0 a
T7	109.0 b	34.0 b	75.0 b	12.0 a	11.6 ab	29.8 a	18.4 ab	18.9 a
T8	117.0 a	43.0 a	75.0 b	10.0 cd	11.7 a	29.7 a	18.2 ab	18.2 a

Means followed by the same letter by column are statistically equal (Tukey; P=0.05). n = 32. Control: 0 Applications of GA_3+0 Applications Ethephon. T1: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 700 ppm). T2: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications 700 ppm). T3: GA_3 (4 Applications, 50 ppm)+Ethephon (4 Applications, 900 ppm). T4: GA_3 (6 Applications, 50 ppm)+Ethephon (6 Applications, 900 ppm). T5: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 700 ppm). T6: GA_3 (6 Applications, 100 ppm)+Ethepon (6 Applications, 700 ppm). T7: GA_3 (4 Applications, 100 ppm)+Ethephon (4 Applications, 900 ppm) T8: GA_3 (6 Applications, 100 ppm)+Ethephon (6 Applications, 900 ppm). FW: fruit weight, PeW: peel weight, PuW: pulp weight, SW: seed weight, Lum: Luminosity.

For the Amarillo 2289 variety, some negative effects of the treatments included: reduced peel weight (treatment 2), increased seed weight (treatment 7) and reduced ºBrix (treatments 1 and 3). None of the treatments had negative effects on the remaining variables; rather, some of the treatments improved quality parameters, relative to the control: increased fruit weight (treatment 1) increased pulp weight (treatment 6), and fruit firmness was preserved to a greater degree with treatments 1, 2, 4, 5 and 8. All of the treatments increased Luminosity, Hue and Chroma.

For the Rojo Vigor variety, some of the negative effects of the treatments were reduced fruit weight (treatments 1, 2, 3, 4, 5, 6 and 7), reduced ºBrix (treatment 6) and increased Hue (treatments 3 and 5). None of the treatments negatively affected the other variables, but some treatments increased fruit quality parameters: increased peel weight (treatment 8), pulp weight (treatment 2), and decreased seed weight (treatment 2). All of the treatments favored increased Luminosity, increased Chroma, and fruit firmness.

Conclusions

In general, all the treatments promoted greater glochids abscission (%) than the control, especially treatment 5, which promoted glochids abscission of up to 82% before harvest and 97% after harvest.

The four varieties exhibited differences in terms of average number of glochids per areole and the strength of their attachment, similarly for their response to the treatments there are significant differences. Before harvest, Amarillo 2289 variety was that which had the highest glochids abscission average, and Solferino variety had the lowest (70%). After harvest, the Solferino, Rojo 3589 and Amarillo 2289 varieties had a higher response (loss was 97.3% on average) than Rojo Vigor (92.2%).

The GA_3 concentration factor promoted a great glochids abscission in the four varieties at the higher concentration (100 ppm) after harvest than at the lower concentration (50 ppm), but an antagonistic effect between this factor and the number of applications was observed.

In general, the application of GA_3 and Ethephon improved fruit quality attributes. However, in some varieties, these treatments affected negatively some variables. Fruit weight of the Rojo Vigor variety was lower by about 11.5% with all treatments, except treatment 8. Peel weight was 20.4% lower with treatment 2 in the Amarillo 2289 variety and 13.9% lower with treatment 3 in the Solferino variety. This reduction could be considered negative since it means the fruit is more susceptible to bruising during postharvest handling. Rojo 3589 variety pulp weight was 25% lower for treatment 2. Seed weight was an average 22.5% higher in treatments 5, 6, 7 and 8 of the Solferino variety. Treatments 1 and 3 caused 10.3% and 11.6% lower ºBrix, respectively, in the Amarillo 2289 variety, and treatment 6 resulted in 9.1% lower ºBrix in the Rojo Vigor variety. In the red varieties, treatments 3, 6 and 7 inhibited a reduction in Hue by around 32%, i.e. the fruits did not completely develop their typical red color.

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