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Improving Quality of Prickly Pear Fruits and Reducing Seed Rigidity by NAA, GA_3 and Calcium Borate

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Abstract: Since prickly pear fruits are very popular, demanded by many consumers, nutritious and their plants have the potential to grow and adopted to many stressful conditions. This study was conducted during the two consecutive seasons 2015 and 2016 on "Shamiya" prickly pear cactus plants grown in a private orchard at Badr Center region, Behira governorate, Egypt. The research aimed at improving fruit quality at harvest while reducing seeds rigidity by frequent applications of gibberellic acid formulations, boron andthe auxin NAA. Thus, the preharvest applications, starting at full blooming, included the control (water), the individual spray of either NAA at 50 ppm, GA_3 at 100 ppm, calcium borate at 500 ppm or their combinations at the same above concentrations such NAA plus GA_3, calcium borate plus GA_3, calcium borate plus NAA and finally the formulation containing calcium borate plus both GA_3 and NAA. Three sprays were done by using a hand sprayer at four days intervals, at maturity. The data revealed that there was an increase in fruit weight by many treatments, especially with the combination of NAA plus GA_3 followed by the additions of calcium borate to both growth regulators. Meanwhile, the most reduction in seed weight was found with calcium borate, followed by GA_3 alone or when combined with NAA in a consistent manner in both seasons. Further evidence was found with the data of seed viability assay that gave similar trend to that reported with seed weight. Furthermore, electrolyte leakage of seeds was greater than that of the control with the above three treatments (calcium borate, GA_3 alone or combined with NAA). However, electrolyte leakage at the stem end of the fruit was significantly reduced by calcium borate alone or when combined with GA_3 or with both applied growth regulators, NAA and GA_3 in both seasons. Total soluble solids were slightly reduced by various applied treatments relative to the control. Thus, this study provided evidences about the possibility of improving prickly pear fruit quality while reducing the seed rigidity by frequent applications of calcium borate or the combination of NAA plus GA_3.

Key words: Prickly pears · Cactus · Seed rigidity · Empty seeds · Fruit quality · Electrolyte leakage · NAA · GA_3 · Calcium borate

INTRODUCTION

Prickly pear is one of the most popular fruits in arid and semi- arid regions. It originates from Mexico, that still witnessed by the impressive genetic diversity of 400 species and a great number of varieties [1]. The fruit has been favored for taste and flavor in many ingredients that add to its nutritional values such as amino acids content, readily absorbable sugars, high content of magnesium and calcium as well as technologically interesting fibers that make such fruits very special. The plant has also many adaptive mechanisms and capacity to produce biomass under arid conditions. Furthermore, in many cultures around the world, the true stems called nopal cladodes have been utilized and used for their medicinal values such as reducing serum cholesterol levels, regulating blood pressure, controlling gastric acidity, treating several pathologies such as ulcer, fatigue, dyspnea, glaucoma, capillary fragility, liver conditions, rheumatic pain and wounds [2, 3].

In addition to some -relatively new treatments of gastritis and diabetes [4, 5]. There are even more opportunities to increase prickly pear consumption world wide due to its nutritional, medicinal and human health

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properties [6]. Meanwhile, the natural colorant, as the red carmine has been permitted in the European low in food industry. This carminic acid is extracted, after milling and desiccation from the females of a parasite worm named "Cochinilla" which grows on the surface of the succulent branches of these plants [7]. Eventhougth, the seed percentage of prickly pears only represents about 5 -6 % of the total pulp whether greenish or ripe but still this considered a large number and one of the main undesired fruit properties [7].

In general, little attention has been paid to the research that is concerned with improving properties of the edible part of prickly pear fruit. There has been almost an absence of studies regarding reducing the seeds rigidity before picking the fruits. Such change in the seed property must be induced early during or right after the embryo formation inside the seeds which should increase the demand for prickly pear consumption. Some rare studies were done to study the functional properties of prickly pear seed flour in order to utilize it in food formulations [8]. In spite of the urgent need to face desertification, especially in many Arab countries, the prickly pear plantation still mixed with typical vegetations or cultivated on a small scale to fix the soil to reduce erosion. Little consideration is made to the climacteric nature of the fruit whether during picking or its mishandling following harvest, transportation or display in the Egyptian -local market which further increases the fruit decay and losses.

Moreover, the increase in gibberellic acid content during flowering of prickly pear can result in forming seedless fruits while their size and sugar content remarkably increased [9, 10]. Meanwhile, the increase of auxins or boron during flowering or post ovule fertilization, respectively would cause embryo abortion and lead to synthesis of seedless fruits. The viable seeds are much and more rigid than the aborted ones. In genus *Opuntia*, parthenocarpic fruits of normal size containing empty seeds were obtained when emasculated flowers were repeatedly treated with gibberellic acid [11].

Thus, frequent applications of gibberellic acid, NAA or boron during blossoming period of prickly pear has the potential to cause embryo abortion or produce soft seeds as a desired fruit trait.

Thus, the objectives of this study were to investigate the possibility of reducing the rigidity of "Shamiya" prickly pear seeds by frequent applications of GA, NAA or boron during the critical duration of blossoming while improving fruit characteristics at harvest. The outcome of this study would also encourage more growers to explant the cultivation of prickly pear under arid conditions.

MATERIALS AND METHODS

This work had been carried out during two successive seasons 2015 and 2016 on "Shamiya" prickly pear cactus (*Opuntia ficus- indica* L.) growing in a private orchard at Badr Center region, Behira governorate, Egypt. Plants were uniform in growth, grown in a sandy soil, spaced at 2 × 2 m, under drip irrigation system and received the common horticulture practice. Twenty four plants (each one represented a replicate) were selected for this investigation. After full bloom on 28 April for the two seasons, flowers of each three cactus plants were sprayed three times four days intervals, with one of the following treatments: - Water (control), NAA at 50 ppm, GA_3 at 100 ppm, calcium borate at 500 ppm and their combinations which included NAA plus GA_3, calcium borate plus GA_3, calcium borate plus NAA and finally calcium borate plus GA_3 and NAA at the above- mentioned concentrations. Tween- 20 (as a surfactant agent with 0.05 % v/ v) was added to all these solutions. Fifteen fruits, at maturity stage (greenish- yellow), from each sprayed plant per each treatment (45 fruits/ treatment and 15 fruits/ replicate) were collected and these fruits were free from apparent infection, uniform in shape and color as possible. Maturity stage was on 20 and 18 of July for the two successive seasons, respectively. The collected fruits were exposed to some physical and chemical assays as shown:

Physical Characteristics: Prickly pear fruits were weighed before and after being peeled to determine fruit pulp and rag weights (gm). In addition, pulp firmness was checked using pressure tester and the values of firmness were expressed as Newton unit. Weight of fifty dried seeds (dried in the air until the stability of weight twice consecutive) was also determined.

Chemical Characteristics: The percentage of electrolyte leakage at both fruit stem end and seeds were calculated according to the method of Gary [12]. Moreover, seed viability was determined using 2, 3, 5 trichloro phenyl tetrazolium chloride (2, 3, 5 TTC), then using alcohol to extract the red formazan pigment from seeds, measured at 485 nm according to Saupe [13] and Verna and Majee [14] then the values of seed viability were expressed as optical density (O.D). In addition, the percentages of total sugars were extracted and measured using the method of Egan *et al.* [15]. Furthermore, the percentage of total soluble solids (TSS) were checked using a pocket refractometer. Acidity content was determined according to the method described by Spayed and Morris [16] and

expressed as gm citric acid (the dominant acid in prickly pear fruit) per 100 ml fruit juice which prepared by using fruit juicer. The ratio between total soluble solids to acidity was also calculated. Vitamin C content was measured and expressed as mg ascorbic acid per 100 ml juice according to the method of Egan *et al.* [15]. Finally, the content of pigments which presented of carotene in both peel and pulp plus chlorophylls a and b, were extracted, measured and calculated as mg/ 100 gm according to the method of Wintermans and Mots [17].

Experimental Design and Statistical Analysis: All the data was laid out and analyzed as randomized completely blocks design (RCBD) using SAS program [18]. This analysis was performed by the determination of the means and the comparison among these means was done by letters which were determined according to the least significant difference (LSD) at 0.05 level [19].

RESULTS AND DISCUSSION

The Effect of Treatments on Physical Characteristics at Harvest: The effect of frequent applications of NAA, GA_3 alone or in combination with Ca borate on some physical characteristics of prickly pears at harvest during the two successive seasons 2015 and 2016 was reported in Table 1. The data revealed that fruit weight was significantly increased by all used treatments in both seasons when compared with the control. However, the magnitude of such increase varied among the treatments since the greatest increase in fruit weight was obtained with either the multiple applications of GA_3 alone or in combination with NAA in a consistent manner in both seasons. The incorporation of calcium borate to GA_3 plus NAA was also positive in terms of obtaining an enhancement of fruit weight but was still relatively lower than the outcome of applying GA_3 plus NAA. Meanwhile, the application of NAA was also able to increase fruit weight more than the control but was still less than those values obtained with GA_3 alone.

The response of pulp weight to various applied treatments during 2015 and 2016 seasons indicated that all used treatments were able to significantly increase pulp weight as compared with the control. Moreover, the superior influence on pulp weight was found with the application of either GA_3 alone followed by its combination with NAA. The individual application of calcium borate was also effective on increasing pulp weight relative to the control. In addition, the formulation containing calcium borate plus GA_3 and NAA resulted in greater pulp weight than that found when calcium borate was combined with each of GA_3 or NAA individually.

The non- edible part of the prickly pear fruit was reported as the rag weight in Table 1. The effect of various used treatments on rag weight revealed that the great rag weight was obtained with the combination of NAA plus GA_3. However, the individual application of NAA resulted in a significant reduction of such rag weight relative to NAA plus GA_3. Moreover, the application of calcium borate alone resulted in more rag weight than that found with its combination with NAA in both seasons.

The influence of various used treatments on pulp firmness in the two seasons was reported in table 1. It was evident that pulp firmness was significantly enhanced by all applied treatments in a consistent manner in both seasons relative to the control. However, the greatest enhancement of such firmness was found with the formulation that included calcium borate plus GA_3 and NAA in both seasons. Moreover, the incorporation of calcium borate with either GA_3 or NAA was also effective on increasing pulp firmness relative to the control. Furthermore, the application of each of GA_3, NAA or calcium borate were effective on retarding the loss of pulp firmness relative to the control in both seasons. The response of pulp firmness to the individual treatment of calcium borate was even superior to that found with GA_3 or NAA, only in the second season.

The Effect of Treatments on Seed Characteristics: The data shown in Table 2 reported the effect of various used treatments on seed characteristics of "Shamiya" prickly pear at harvest. The data indicated that frequent applications of all used treatments resulted in a significant reduction of seed weight when compared with the control in a consistent manner with varying degrees of efficacy. In other words, GA_3 alone or in combination with NAA were equally effective and resulted in lower seed weight in both seasons than that obtained with the application of NAA alone. Meanwhile, calcium borate led to the formation of the lowest seed weight among other used treatments. Meanwhile, the formulation of calcium borate plus both GA_3 and NAA was still able to reduce seed weight relative to the control in both seasons. Moreover, the combination of calcium borate plus either GA_3 or NAA gave similar values of seed weight to each other except calcium borate plus NAA in the first season that was even greater in such weight than calcium borate plus GA_3.

Table 1: Effect of preharvest treatments with calcium borate, some growth regulators and their combinations on some physical characteristics of "Shamiya" prickly pear fruits during 2015 and 2016.

	Characteristics							
	Fruit weight (gm)		Pulp weight (gm)		Rag weight (gm)		Pulp firmness (Newton)	
Treatments	2015	2016	2015	2016	2015	2016	2015	2016
Control	50.42 d	52.08 e	26.04 f	27.08 g	24.38 e	25.00 d	12.45 d	13.34 d
NAA	65.10 c	80.73 c	36.46 de	44.28 e	28.64 de	36.45 b	15.56 c	16.10 c
GA_3	93.75 a	100.26 a	52.69 a	62.50 a	41.05 ab	37.76 b	15.56 c	16.68 c
Calcium borate	75.53 b	82.81 c	39.06 d	44.28 e	36.47 bc	38.52 b	16.01 c	18.42 b
NAA plus GA_3	93.75 a	96.35 a	47.91 b	52.09 b	45.84 a	44.26 a	15.74 c	18.11 b
Calcium borate plus GA_3	75.53 b	80.73 c	42.98 c	46.88 d	32.55 cd	33.85 bc	17.29 b	18.51 b
Calcium borate plus NAA	63.54 c	65.63 d	34.90 e	36.46 f	28.64 de	29.17 cd	15.88 c	18.34 b
Calcium borate plus GA_3 and NAA	78.13 b	87.50 b	45.84 b	49.48 c	32.29 cd	38.02 b	21.35 a	22.73 a

Means having the same letter (s) within the column are not significantly different when compared according to the least significant difference (LSD at 0.05 level).

With regard to the response of electrolyte leakage of the seeds at harvest as influenced by preharvest applications of various treatments, the data in Table 2 indicated that the highest leakage was found with the application of calcium borate in both seasons. Meanwhile, its combination with either GA_3 or NAA achieved greater electrolyte leakage than that of the control but lower than that found with the individual application of each one of them. Meanwhile, the combination of both NAA plus GA_3 resulted in more electrolyte leakage of the seeds than that found in the control consistently.

In terms to seed viability in harvested fruits as a consequence of frequent applications of used treatments before harvest, the data in Table 2 (as shown by the density of the formed formazan red pigment, as indicator to the reduction of the 2, 3, 5- triphenyl tetrazolium chloride) clearly indicated that the highest seed viability was found in the control fruits. Meanwhile, all other used treatments resulted in a significant reduction of seed viability when compared with the control. Moreover, the application of calcium borate was more effective in reducing seed viability relative to other treatments in a consistent manner in both seasons followed by the combination of GA_3 plus NAA and the frequent application of GA_3 alone. However, the inclusion of calcium borate in a formulation with either GA_3 or NAA or both did not result in the same magnitude of seed viability reduction in both seasons. The reduction in the optical density is an indicator or a reflection of the embryo viability inside the prickly pear seeds. The darker the color, the greater the respiratory activity in the seed. Light pink color indicates to a seed with reduced viability when compared with a seed that stains dark red.

The Effect of Treatments on Chemical Characteristics at Harvest: The data in Table 3 showed the response of some chemical characteristics of prickly pear fruits to preharvest applications of calcium borate, NAA, GA_3 or their combinations. The results revealed that leakage of electrolyte from the stem end of the fruit was the greatest in the control fruits in both seasons while the least significant leakage was obtained with the combination of calcium borate plus GA_3 or its formulation with GA_3 and NAA. Healthy tissue must be able to control the loss of electrolytes, especially at the spot of its separation from the mother stem. It was also found that the leakage of electrolytes from the fruit- stem end with the application of calcium borate was significantly less than that of the control and even smaller than the resulting leakage due to the applications of GA_3 alone or its combination with NAA in the two seasons.

Total sugars values were also affected in response to preharvest treatments as reported in Table 3. The data revealed that the control fruits had more total sugars when compared with other used treatments in both seasons. However, the combination of both calcium borate and NAA resulted in total sugars values close to that of the control, then NAA alone which also resulted in similar total sugars value to that obtained by calcium borate or its combination with GA_3. Moreover, the application of GA_3 alone or its combination with NAA resulted in a significant reduction in total sugars at harvest relative to the control or to the individual application of NAA in both seasons.

With regard to the effect of various preharvest treatments on the percentage of total soluble solids (TSS) at harvest, it was clear that the control fruits had more TSS than other applications (Table 3). Meanwhile, all used treatments were equally effective in their influence on TSS. Their slight variations in TSS in both seasons were not significant.

Table 2: Effect of preharvest treatments with calcium borate, some growth regulators and their combinations on some seed characteristics of "Shamiya" prickly pear during 2015 and 2016.

	Characteristics					
	Weight of 50 dried seeds (gm)		Electrolyte leakage of seeds (%)		Seed viability (Optical density)	
Treatments	2015	2016	2015	2016	2015	2016
Control	1.84 a	1.90 a	3.00 f	3.33 h	0.48 a	0.53 a
NAA	1.00 c	1.05 c	7.57 c	8.46 d	0.22 d	0.23 d
GA_3	0.63 d	0.77 d	8.06 c	11.33 c	0.17 e	0.19 e
Calcium borate	0.47 e	0.53 e	11.25 a	17.11 a	0.11 f	0.13 f
NAA plus GA_3	0.60 d	0.73 d	8.75 b	13.33 b	0.14 e	0.17 e
Calcium borate plus GA_3	1.04 c	1.07 c	6.25 d	7.14 e	0.24 d	0.25 d
Calcium borate plus NAA	1.09 b	1.07 c	3.73 e	4.89 f	0.29 c	0.30 c
Calcium borate plus GA_3 and NAA	1.11 b	1.15 b	3.39 ef	4.38 g	0.32 b	0.37 b

Means having the same letter (s) within the column are not significantly different when compared according to the least significant difference (LSD at 0.05 level)

Table 3: Effect of preharvest treatments with calcium borate, some growth regulators and their combinations on some chemical characteristics of "Shamiya" prickly pear fruits during 2015 and 2016

	Characteristics											
	Electrolyte leakage of stem end (%)		Total sugars (%)		TSS (%)		Acidity content (gm / 100 ml juice)		TSS: Acidity ratio		Ascorbic acid ontent (mg / 100 ml juice)	
Treatments	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Control	17.11 a	17.50 a	16.98 a	18.21 a	13.80 a	14.20 a	0.61 c	0.64 d	22.62 a	22.20 a	17.55 a	18.00 a
NAA	11.25 b	13.33 b	11.55 c	11.75 d	12.60 b	13.07 b	0.70 b	0.77 c	17.92 c	16.99 c	15.97 c	16.20 cd
GA_3	8.33 c	8.75 c	10.00 d	10.03 e	12.20 b	12.80 b	0.93 a	1.00 a	13.13 d	12.80 e	14.62 d	15.07 e
Calcium borate	4.14 e	4.38 e	11.75 c	12.39 d	12.60 b	13.00 b	0.70 b	0.75 c	18.00 c	17.28 c	16.65 bc	16.65 bcd
NAA plus GA_3	8.06 c	8.46 c	10.00 d	10.29 e	12.40 b	12.80 b	0.71 b	0.90 b	17.40 c	14.17 d	10.75 e	15.75 de
Calcium borate plus GA_3	3.33 f	3.59 f	11.64 c	12.39 d	12.60 b	13.00 b	0.70 b	0.73 c	18.01 c	17.78 c	16.42 bc	16.42 bcd
Calcium borate plus NAA	6.25 d	6.57 d	14.13 b	15.40 b	13.00ab	13.20 b	0.64 c	0.66 d	20.31 b	20.11 b	17.10ab	17.32 ab
Calcium borate plus GA_3 and NAA	3.00 f	3.73 f	12.03 c	13.17 c	12.60 b	13.13 b	0.64 c	0.64 d	19.59 b	20.52 b	16.87ab	17.10 abc

Means having the same letter (s) within the column are not significantly different when compared according to the least significant difference (LSD at 0.05 level)

Juice acidity of fruits at harvest significantly varied among used treatments since the highest acidity was found in GA_3 – treated fruits in both seasons while its combination with NAA was also higher in juice acidity relative to the control. Moreover, such acidity was similar when calcium borate results were compared with that found with NAA. In addition, the formulations of calcium borate with NAA alone or in the presence of GA_3 had similar juice acidity in both seasons (Table 3).

The trend of results regarding the TSS to acidity ratios in prickly pear juice revealed that the applied treatments resulted in a significant reduction in TSS to acidity relative to the control. However, formulation of calcium borate plus both GA_3 and NAA markedly differed in their TSS to acidity from the control. Meanwhile, calcium borate alone or its combination with GA_3 had similar TSS to acidity ratios in the two seasons while the combination of calcium borate plus NAA was equally effective on that ratio when compared with the formulation that included GA_3 additionally.

With respect to the effect of various applied treatments on vitamin C content in the fruit juice, the data in Table 3 also showed that the application of calcium borate plus NAA alone or plus both NAA and GA_3 led to significantly greater values than that found with the combination of NAA plus GA_3 in the absence of calcium borate. Furthermore, the control fruits had similar vitamin C content to that found with the applications of calcium borate plus NAA or plus both NAA and GA_3. Eventhough, calcium borate resulted in lower vitamin C content than the control but led to the formation of vitamin C similar to that obtained with the combination of NAA plus GA_3 in the second season, only.

The Effect of Treatments on Chlorophylls and Carotene Contents: With regard to the influence of various applied treatments on chlorophyll a content in the peel of "Shamiya" prickly pears at harvest, the data indicated that chlorophyll a in the control was the greatest among all treatments (Table 4). Meanwhile, the least chlorophyll a content was found with the application of calcium borate plus NAA followed by the formulation that contained the same compounds in addition to GA_3 in both seasons. The individual application of either NAA or GA_3 showed that NAA was more effective than GA_3 in reducing chlorophyll a content in the peel in the two seasons.

Table 4: Effect of preharvest treatments with calcium borate, some growth regulators and their combinations on carotene, chlorophyll a and chlorophyll b contents of "Shamiya" prickly pear fruits during 2015 and 2016

	Characteristics							
	Carotene content of peel (mg / 100 gm)		Chlorophyll a content of peel (mg / 100 gm)		Chlorophyll b content of peel (mg / 100gm)		Carotene content of pulp (mg / 100 gm)	
Treatments	2015	2016	2015	2016	2015	2016	2015	2016
Control	0.42 h	1.06 h	1.07 a	2.91 a	1.16 a	3.94 a	4.60 a	5.20 a
NAA	1.60 e	1.65 e	0.57 d	0.59 d	0.43 d	0.48 d	2.90 d	2.90 e
GA_3	1.39 f	1.53 f	0.65 c	0.70 c	0.55 c	0.60 c	1.20 f	1.80 g
Calcium borate	1.99 c	2.01 c	0.42 f	0.46 f	0.39 e	0.41 e	3.30 c	3.30 d
NAA plus GA_3	1.20 g	1.27 g	0.85 b	0.87 b	0.86 b	0.89 b	2.00 e	2.40 f
Calcium borate plus GA_3	1.71 d	1.74 d	0.51 e	0.53 e	0.42 d	0.42 e	3.00 d	3.20 d
Calcium borate plus NAA	2.34 a	2.80 a	0.33 g	0.35 h	0.07 g	0.26 g	3.90 b	4.60 b
Calcium borate plus GA_3 and NAA	2.07 b	2.08 b	0.35 g	0.37 g	0.29 f	0.29 f	3.40 c	3.70 c

Means having the same letter within the column are not significantly different when compared according to the least significant difference (LSD at 0.05 level)

The frequent applications of GA_3 alone or when combined with NAA resulted in increasing chlorophyll a in the peel at harvest as compared with all other treatments, except the control.

Moreover, chlorophyll b in the peel of “Shamiya” prickly pear was also affected by preharvest applications of all treatments in both seasons. Again, the greatest content of chlorophyll b was found in the control peels while the least content was found with the application of calcium borate plus NAA. Each of calcium borate alone or with NAA resulted in a significant reduction in chlorophyll b relative to the control. However, GA_3- treated fruits had a reduction in chlorophyll b as compared with the control but its combination with NAA was slightly effective on that reduction but still had less chlorophyll b than that of the control peels.

The response of carotene content in the peel of “Shamiya” prickly pear was also reported in Table 4. It was evident that the greatest increase of carotenes was found with the application of calcium borate plus NAA in the two seasons as compared with the control and all other applied treatments. Meanwhile, the least carotene content was reported in the control peels. Treatments containing calcium borate had an enhanced formation of carotenes in the peel of prickly pears at harvest while GA_3 alone resulted in less carotenes but in combination with other treatment was significantly effective on increasing carotene content in the prickly pear peels.

Finally, in terms of the response of carotene content in the pulp, the assessment of its content showed that the control pulp had more carotenes than other used treatments followed by the application of calcium borate plus NAA. However, the single use of GA_3 caused a significant reduction of carotenes in the pulp relative to the control or other used treatments. Similarly, the application of NAA plus GA_3 could not increase carotenes in the pulp in a similar marked manner. Furthermore, the incorporation of calcium borate to both NAA and GA_3 induced higher content of carotenes in the pulp when compared with the single use of each component in that formulation.

The present study provided more evidences about the possibility of improving fruit quality of “Shamiya” prickly pear by frequent applications of NAA, GA3, calcium borate andtheir combinations. Three applications starting at full bloom and right after embryo formation due to fertilization of the ovule in the ovary were made. The large increase in fruit weight and pulp weight could be ascribed to the action of GA_3 and the auxin NAA that were reported to enhance cell enlargement by GA_3 and cell elongation by NAA [20]. Gibberellins were also reported to enhance sink strength, especially in the seeded fruit that represent a strong sink in the plant. The increase in GA_3 and NAA was able to retard the loss of flesh firmness that was further increased, when calcium was included in the formulation that contained calcium borate plus both GA_3 and NAA. Calcium role in increasing cell wall strength and maintaining the plasma membrane integrity has been reported by many studies [12].

The changes in seed characteristics, in response to the frequent applications of GA_3, NAA and calcium borate at this critical stage of blooming then during embryos formation are logic since the increase in boron in the tissue could cause an embryo abortion according to Arteca [20] while gibberellins enhance the breakdown of endosperm starch to sugars [21]. The above changes might lead to the reduction in seed weight that occurred

with many treatments relative to the control, especially with GA_3 alone or in combination with NAA in both seasons, in addition to calcium borate alone or in combination with GA_3 in a consistent manner in the two seasons. The above results were further supported by the reduction of the red pigment formazan that was formed due to the oxidation of the 2, 3, 5- triphenyltetrazolium chloride. The greatest absorbance value by the control seeds reflected more tissue viability while the least values of optical density (absorbance) were found with the application of calcium borate as well as the highest values of electrolyte leakage of seeds (Table 2).

Meanwhile, the leakage of electrolytes from the stem end was significantly lower than the control with the tissues that were treated with calcium or its combination with GA_3, NAA or both. These findings might be supported by role of calcium in binding to the polar head groups of phospholipids in the plasma membrane of tissues which reflected on reduced tissue leakage of electrolytes [12]. The fruit- stem end deterioration represents a major cause of loss at harvest or during marketing of prickly pears.

Since the application of various treatments was early in the season, it did delay the biosynthesis of carotenes but even enhanced chlorophylls breakdown in the peel, when compared with the control in a consistent manner.

In conclusion, this study provided evidences about the possibility of reducing seed rigidity while increasing fruit and pulp weight of prickly pears by frequent application of NAA plus GA_3 especially with the incorporation of calcium borate. Moreover, the feasibility to improve the edible part of the fruit while reducing the severity of seed toughness was achieved.

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