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Article

Influence of Seed and Fruit Characteristics of *Lagenaria siceraria* on Production and Quality of Grafted Watermelon

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Abstract: The use of *Lagenaria siceraria* rootstocks in watermelon production has favored fruit yield and quality under conditions of environmental stress. However, it is necessary to know if the differential characteristics of fruit and seed *L. siceraria* are related to watermelon yield and fruit in grafted plant. The objective was to evaluate two dissimilar groups of Mexican *L. siceraria* as rootstock in Tri-X 33 watermelon variety to relationship the morphological characteristics of rootstock with productive variables and fruit quality. The treatments were Tri-X 313 variety ungrafted and grafted with accessions of group 1 (L46 and L56) and group 2 (L48, L50 and L54). Variables evaluated were fruit and yield and quality parameters. No differences were found between groups of *L. siceraria* in fruit yield and external quality parameters. With the exception of pulp firmness and luminosity, LG1 surpassed group LG2 by 30.7 and 5.0%, respectively. While, when comparing grafted and ungrafted plants, it was found that grafted plants were superior, with increases of 277.8% in number of fruits per m^2, 330.2% in commercial production, 54.6% in rind thickness, 85.2% in external firmness and 36.3% in chroma value of fruit pulp. Meanwhile, pulp percentage and hue were reduced by 13.8% and 15.5%, respectively, in grafted watermelons. Thus, the seed and fruit characteristics are not sufficient criteria to select *L. siceraria* rootstocks for watermelon production.

Keywords: *Lagenaria siceraria*; rootstock; watermelon

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1. Introduction

The Cucurbitaceae family includes 120 genera and 825 species, which inhabit tropical and temperate regions around the world [1]. México is considered its origin center and has a dispersion of 5 genera and 67 species [2]. Currently, 141 species are scattered throughout the Mexican territory [3], both wild and cultivated, among which is bottle gourd (*Lagenaria siceraria*). The importance of this species through several generations has been cultural, where dried fruits are used as containers for water conservation [4] and as musical instruments in religious ceremonies [5]. There is also artisanal use, where fruits are decorated with different colors and figures. Bottle gourd and other cucurbits have been used as kitchen utensils such as tortilla holders, serving or storage containers, cups and ladles, among others [4].

L. siceraria as rootstocks in vegetable production, like other cucurbits, began in the late 1920s in Japan [6]. In the year 1990, the sown surface of watermelon, melon and cucumber with grafted plant was 74.5% in Japan and 86.9% in Korea [7]. The grafting technique was introduced to Europe in the late 20th century and later spread to North

America [8], including México. Facing the need to limit the use of methyl bromide as fumigant, the Mexican Ministry of Environment and Natural Resources (SEMARNAT) and United Nations Industrial Development Organization (UNIDO) implemented projects for the use grafts to prevent the incidence of pathogens in watermelon crops [9]. It is estimated that in 2007, approximately 1000 ha of watermelon and 100 ha of melon were planted with grafted plants in México [10]. Evidence of the use of bottle gourd rootstock in watermelon production in México was reported by López-Elías et al. [11], despite being a commercial rootstock.

Availability of genetic resources of *L. siceraria* in México offers the possibility of selecting rootstock to improve cucurbits production, such as cucumber, melon and watermelon. Under this approach, Grimaldo-Juárez and collaborators [12] carried out seed and fruit morphological studies of *L. siceraria* accessions from northern, central and southern country regions, finding phenotypic variation in dissimilar groups. Recent research on Mexican *L. siceraria* landraces as rootstock in watermelon and cucumber production has shown significant positive effects on fruit production and quality even under adverse conditions [13–15].

Other studies have shown greater development of biomass in grafted plants under saline stress [16], as a product of anatomical changes, antioxidant enzymes activity, and sodium exclusion efficiency in the root [17], as well as ion transport regulation, where sodium uptake is limited and absorption of other cations is promoted [18]. In addition, a high enzymatic activity (nitrate and nitrite reductase) in nitrogen metabolism induced by grafting generates greater plant growth and development [19]. In conditions of low soil temperatures, grafted plants have higher H^+-ATPase activity that creates an electrochemical proton gradient, which favors transport of water and nutrients through the plasma membrane [20]. Another alteration is the ratio of male and female flowers due to variations in hormonal concentration in grafted plant [21]. On the other hand, Proietti et al. [22] reported positive grafting effects on antioxidant content (lycopene, dehydroascorbic acid and vitamin C) in fruit.

The plant changes manifest at morphological, physiological, biochemical and enzymatic levels makes evident the effects induced by rootstock. These effects are attributed to the vigor of the rootstock root system [7]. However, there is no relationship of rootstock root development and watermelon yield [23], which suggests that the genetic variations of rootstock interact with the organs of scion. However, it remains to be elucidated whether the differential characteristics of fruit and seed of *L. siceraria* are related to watermelon yield and quality parameters, in order to generate selection criteria for rootstocks based morphological characteristics. For this reason, the objective was to evaluate two dissimilar groups of Mexican *L. siceraria* as rootstock in Tri-X 313 watermelon variety to determine the relationship of the dissimilar characteristics of rootstock with productive variables and fruit quality.

2. Materials and Methods

2.1. Study Site

The experiment was established at the agricultural experiment station of the Instituto de Ciencias Agrícolas, Universidad Autónoma de Baja California, Mexicali, BC, México (32°24′19″ N, 115°11′48″ W, elevation 14 m) in March 2019. The climate of the region is hot desert with scarce precipitation in winter (BW [h′] hs [x′] [e′]) [24]. Conditions of temperature, humidity, precipitation and solar radiation of the experiment station are presented in Table 1. The soil belongs to aquic haplotorrert smectitic, hyperthermic, haplic vertisol (cacaric and endogleyic). The soil properties were clay-textured, pH 7.4, EC 8.2 dS m^{-1}, SAR 6.88, chlorine 1764 ppm, sodium 758 ppm, bicarbonate 738 ppm, calcium 636 ppm, nitrate 620 ppm, sulfate 454 ppm, magnesium 172 ppm, potassium 78 ppm and diacid phosphate 21.8 ppm.

Table 1. Weekly mean values of minimum temperature (Tmin), maximum temperature (Tmax), minimum relative humidity (RHmin), maximum relative humidity (RHmax), precipitation (P) and solar radiation (Rs) in watermelon growing season after planting (March–June 2019).

Week	Tmin [1] (°C)	Tmax (°C)	RHmin (%)	RHmax (%)	P (cm)	Rs (Cal cm^{-2})
1	10.22	26.38	27.85	93.41	0.00	399.47
2	4.89	19.26	29.65	90.82	1.90	389.90
3	8.70	25.70	22.74	85.10	0.00	421.59
4	9.09	26.84	18.72	91.61	0.00	474.51
5	11.52	28.17	15.92	70.28	0.00	521.36
6	12.09	29.47	16.54	78.66	0.00	525.40
7	10.86	28.56	18.07	83.21	0.10	509.47
8	12.43	33.66	13.84	83.95	0.00	591.53
9	12.35	33.61	13.01	85.33	0.00	575.57
10	14.08	33.45	17.07	83.69	0.00	582.49
11	15.45	32.07	24.41	91.55	0.00	572.40
12	11.30	27.67	19.27	78.05	0.00	579.21
13	12.97	30.11	16.92	83.61	0.00	631.49
14	15.91	33.49	18.46	95.87	0.00	633.17
15	18.22	39.34	11.35	83.43	0.00	626.37
16	17.99	37.90	13.46	89.10	0.10	610.46

[1] Agrometeorological data collected from Nuevo Leon Weather Station, Mexicali, B.C., Mex. (2019).

2.2. Plant Materials, Culture and Experimental Design

Five *Lagenaria siceraria* accessions (L46, L56, L48, L50 and L54) grouped into two dissimilar groups in fruit and seed characteristics (Table 2), previously differentiated based on phylogenetic analysis [12], were used as rootstocks in this study. Variety Tri-X 313 was grafted on accessions of group LG1 (L46 and L56) and group LG2 (L48, L50 and L54). Ungrafted plant was considered as a control. Pua grafting technique was used following the procedure described by Maroto et al. [25]. Once grafted, seedlings were kept for a period of 7 days in a humid chamber with relative humidity above 80% and temperature between 20 °C and 25 °C, after which humidity was gradually reduced.

Table 2. Fruit and seed characters of *Lagenaria siceraria* native materials.

Groups	Accessions	Fruit Length (cm)	Fruit Bottom Circumference (cm)	Seed Length (cm)	Arithmetic Seed Diameter (cm)
1	L46 and L56	17.05 ± 0.37 [1]	30.26 ± 0.56	1.23 ± 0.02	0.73 ± 0.01
2	L48, L50 and L54	27.64 ± 0.42	63.01 ± 0.81	2.13 ± 0.03	1.11 ± 0.01

[1] Mean value and standard error.

Planting in open field was carried out when plants presented four true leaves, at a distance between plants of 0.90 m and rows of 3.75 m. Experimental design was a randomized complete block design with three repetitions per treatment and the experimental unit was a group of 50 plants. Sangria variety was used as a pollinator at a 1:3 ratio (Tri-X 313). Two bee hives (*Apis mellifera*) were place before the start of flowering to favor pollination.

Water and nutrients supply was under a pressurized irrigation system. Water had an EC of 1.1 dS m^{-1} and pH of 8.2. Water amount was estimated by crop evapotranspiration (ETc), as the product of reference evapotranspiration (ETo) and crop coefficient (Kc). ETo values were obtained at experiment station of the Instituto de Ciencias Agrícolas (32°24′39″ N, 115°11′50″ W, and elevation 14 m). Kc was considered according to the initial, vegetative, flowering and fattening fruit stages, with 0.4, 0.8, 1.0 and 0.8, respectively. Fertilization was 129 kg N, 92 kg P_2O_5, 154 kg K_2O, 61.5 kg CaO and 15 kg MgO per ha. Fruit harvest was carried out with stipule and tendrils dry on the same node as the fruit.

2.3. Measurements

2.3.1. Yield Parameters

The number, weight (kg) and commercial production (t ha^{-1}) of all the harvested fruits that met the minimum marketing characteristics described by USA standards for grades of watermelon [26] were recorded. Fruit number was counted per square meter. Weight was obtained using a digital balance and commercial production was calculated from an area of 40 m^2.

2.3.2. Fruits External Characteristics

For quality (external and internal) evaluation, ten mature fruits were randomly selected. External quality traits in terms of shape index, pulp (%), external firmness (N) and rind thickness (cm) were recorded. Fruit shape index was calculated as a ratio of equatorial diameter and polar longitude. The fruits were sliced and carefully separated into pulp and rind, and were weighed. Pulp percentage was determined with respect to total fruit weight. Firmness was determined with a digital force meter (Chatillon Ametek DFE-100, Largo, FL, USA) fitted with a flat tip of 11 mm diameter. External firmness was calculated as the average of maximum resistance force of an equatorial section of the fruit epicarp to three punctures of depth 10 mm at penetration constant speed of 1 mm s^{-1}. Fruit rind thickness was measured at three points on the cross section using an electronic caliper.

2.3.3. Fruit Internal Characteristics

The assessed internal quality attributes evaluated in the pulp were internal firmness (N), color (LCh) and soluble solids content (°Brix). Internal firmness was recorded as the average value of three punctures using the same equipment and penetration speed mentioned above. The probe punctured the cross section around the fruit heart to a depth of 50 mm. Flesh color was measured at two loci in the heart region of each fruit in cross section at 90°, using an 8 mm-aperture portable sphere spectrophotometer (X-Rite SP62, Grand Rapids, MI, USA), illuminant D65 and a 10° observer angle. The CIE LCh color space parameters recorded were luminosity (L*), chroma (C*) and hue angle (h°) [27]. Values of L* defines color lightness from 0 (black) to 100 (white). C* specifies color saturation, with values from 0 (grey) to 100 (pure hue). h° denotes hue expressed in degrees from 0 to 360, where values close to 0° or 90° have a red or yellow hue, respectively. Fruit pulp was liquefied, homogenized and filtered. Soluble solids content was determined in the filtered liquid using a digital refractometer (Reichert AR200, Buffalo, NY, USA).

2.4. Statistical Analysis

Data obtained were subjected to one-way analysis of variance using the GLM (general linear model) method in Statistical Analysis System version 9.0 software. Means were compared using orthogonal contrast test. Orthogonal contrast (C) used for comparison were C1) ungrafted vs. grafted with LG1, C2) ungrafted vs. grafted with LG2, C3) ungrafted vs. grafted (LG1 + LG2) and C4) grafted with LG1 vs. grafted with LG2.

3. Results and Discussion

3.1. Yield Parameters

The comparison between groups of *Lagenaria siceraria* (LG1 and LG2) in watermelon yield parameters showed that they do not differ in fruit number and weight as well as commercial production per ha (Table 3). Significant differences were found in fruit number and commercial production, when comparing individually or generally groups of accessions with respect to ungrafted plants, with an increase of 277% and 330%, respectively. Fruits weight was a characteristic that did not show significant change due to grafting.

Table 3. Average and orthogonal contrast of yield parameters of grafted and ungrafted Tri-X 313 watermelon.

Variables	Treatments				Contrast (*p* Value)			
	Ungrafted	LG1 [1]	LG2	LGg	C1 [2]	C2	C3	C4
Fruit number (# m^{-2})	0.18 ± 0.04	0.69 ± 0.09	0.67 ± 0.06	0.68 ± 0.05	0.0018	0.0016	0.0009	0.8284
Fruit weight (kg)	5.14 ± 0.71	5.98 ± 0.25	6.22 ± 0.38	6.12 ± 0.33	0.1183	0.1409	0.1480	0.5338
commercial production (t ha^{-1})	9.53 ± 2.98	40.79 ± 5.07	41.17 ± 3.30	41.00 ± 2.85	0.0010	0.0006	0.0004	0.9446

[1] LG1 = grafted with *Lagenaria siceraria* group 1, LG2 = grafted with *L. siceraria* group 2, LGg = grafted LG1 + LG2, [2] Orthogonal contrast: C1 = ungrafted vs. LG1, C2 = ungrafted vs. LG2, C3 = ungrafted vs. LGg (grafted), C4 = LG1 vs. LG2.

Favorable effects on grafted watermelon yield have been evident when *L. siceraria* accessions were used as rootstock [28]. Karaca et al. [29] found that the 21 accessions of *L. siceraria* evaluated registered higher production and fruit weight. Yetisir and Sari [30] have reported increases of up to 106% when using bottle gourd rootstock in Crimson Tide watermelon. Yield differences are more noticeable when grafted plants are grown in stressful environments. In saline soils, increases of 278%, 123% and 118% have been obtained in watermelon production varieties Sangria, Summer Flavor 800 and Summer Flavor 840, respectively, when using interspecific hybrid squash rootstocks Strong Tosa [31]. This superiority is consistent with our results, where *L. siceraria* rootstocks reached a production of 3.30 times more than ungrafted plants, grown under saline soils (8.2 dS m^{-1}).

The generalized response of increase in watermelon grafted production, which was independent of rootstock variation, is interpreted as fruit and seed dimensions of rootstocks do not influence the yield components of grafted watermelon. Similarly, Pal et al. [23] reported that differences observed in root growth of rootstocks (root fresh and dry weight and root depth) are not correlated with plant yield. Grafted plants superiority is attributed to mechanisms incorporated by rootstocks, such as ion transport regulation by limiting sodium transport and inducing absorption of other cations [18], higher rate of water and nutrition absorption, as well as greater CO_2 assimilation through the leaves [32]. A higher proportion of female flowers in grafted plants favors crop productivity [33], due to changes in plant hormone concentration [21], such as increased cytokine synthesis [34].

3.2. Fruits External Characteristics

Fruits external characteristics in grafted watermelon did not vary when comparing both groups of *L. siceraria* rootstocks (Table 4). However, when contrasting ungrafted with grafted, there were significant differences in most variables, except for fruit shape index. Graft influence on watermelon fruits increased by 54% in rind thickness and 85% in external firmness, while pulp percentage was reduced by 14%.

Table 4. Average and orthogonal contrast of external quality characteristics of grafted and ungrafted Tri-X 313 watermelon.

Variables	Treatments				Contrast (*p* Value)			
	Ungrafted	LG1 [1]	LG2	LGg	C1 [2]	C2	C3	C4
Shape index	0.87 ± 0.01	0.87 ± 0.01	0.88 ± 0.02	0.88 ± 0.01	0.8003	0.7315	0.9169	0.4441
Pulp percentage	76.26 ± 1.45	65.94 ± 0.90	65.62 ± 1.73	65.76 ± 1.08	0.0005	0.0002	0.0002	0.8479
Rind thickness (cm)	0.97 ± 0.51	1.50 ± 0.06	1.50 ± 0.07	1.50 ± 0.05	0.0019	0.0011	0.0008	0.9567
External firmness (N)	164.79 ± 21.21	294.61 ± 19.83	313.50 ± 13.16	305.24 ± 11.53	0.0007	0.0001	0.0001	0.3938

[1] LG1 = grafted with *Lagenaria siceraria* group 1, LG2 = grafted with *L. siceraria* group 2, LGg = grafted LG1 + LG2, [2] Orthogonal contrast: C1 = ungrafted vs. LG1, C2 = ungrafted vs. LG2, C3 = ungrafted vs. LGg (grafted), C4 = LG1 vs. LG2.

Watermelon shape is generally round or elongated depending on variety trait. Tri-X 313 cultivar has oval-shaped fruits. Various studies confirm that rootstock does not alter fruit shape index when grafting watermelon with species of same family, such as *L. siceraria* [35], interspecific hybrid squash (*Cucurbita maxima* × *Cucurbita moschata*) and *Citrillus lanatus* [36–38], even under saline stress conditions [39]. This is consistent with our results, where fruit remained with a shape index of 0.87 ± 0.01. Pattern response was similar in ungrafted and grafted plants, even when rootstock groups present differential characteristics in fruit and seed. In contrast, Pal et al. [23] reported that oblong shape of Suprit variety is maintained with *Citrullus* accessions as rootstock, while when using *Cucurbita* hybrid and *Lagenaria*, fruits with spherical to flat globe shapes are produced. This indicates that the fruit shape depends on the interaction of rootstock and scion.

Increases in rind thickness is a common response in watermelon grafted plants onto *L. siceraria* and interspecific hybrid squash [38,40,41], while this attribute was not altered in Crispy and Obla F1 varieties grafted onto TZ148 (interspecific hybrid squash) [35,36]. Pal et al. [23] observed that 15 of 17 *Citrullus lanatus* accessions used as rootstock in Suprit variety watermelon did not show differences in rind thickness compared to the ungrafted plant. Karaca et al. [29] evaluated 21 genotypes of *L. siceraria* in Crimson Tide watermelon and found that 90.5% of the accessions had greater rind thickness in fruits, with increases between 1.7 mm to 6.3 mm. These differences were similar to those obtained in this study, where thickness increased by 5 mm when using the two groups of *L. siceraria* accessions, as a result of higher nitrogen concentration in the fruit rind [42]. A greater rind thickness is a favorable effect that ensures less physical damage during postharvest storage [43].

The external firmness is another attribute of watermelon fruits that is improved by graft [43], which favors resistance to physical or mechanical damage during fruit harvest, transport and post-harvest. In watermelon grafted with hybrid squash, an up to 46.5% increase has been observed in this variable [37,44]. In Zaojia 8424 variety grafted onto Jingxnzhen1 (*L. siceraria* Stand.), the external firmness increased by 8.8% [42]. This firmness effect was confirmed by the results obtained in *L. siceraria* groups analyzed in this study. A higher external firmness by *L. siceraria* rootstocks is due to upregulation of genes encoding precursors for cell wall strengthening [45].

The external fruit firmness presented a strong and positive correlation (0.86; $p < 0.001$) with rind thickness. Both variables were also negatively related to pulp content, registering a correlation of −0.78 ($p < 0.001$) with external firmness and −0.77 ($p < 0.001$) with rind thickness, generating 14% decrease in pulp in grafted watermelon. Colla et al. [39] found that pulp percentage can be influenced by a combination of grafting and saline level.

3.3. Fruit Internal Characteristics

Watermelon pulp quality was evaluated using firmness, color and soluble solids content (Table 5), and it was found that graft does not influence pulp firmness and luminosity (L*); however, both attributes differ between groups of *L. siceraria* accessions. Fruits generated with LG1 exceeded in pulp firmness and L* by 30.68% and 5.01%, respectively, compared to LG2. High luminosity values in the first group indicate that pulp was lighter. Color saturation (C*) and hue (°h) varied in ungrafted with respect to grafted fruit, exhibiting a redder (hue = 38.97°) and brighter (ΔC* +9.39) pulp in grafted fruits. Regarding the groups of accessions, there were no differences in both color attributes. Soluble solids concentration was a characteristic that was not modified by graft, and statistically, there were no differences between LG1 and LG2.

Internal quality parameters of watermelon are directly influenced by graft [46]. Investigations carried out by Huitrón-Ramírez et al. [47] and Petropoulos et al. [36] in watermelon plants grafted onto hybrids squash found increases from 10% to 69% in pulp firmness. However, when using *L. siceraria* as rootstock, no significant differences were observed [29]. Studies conducted by Yamasaki et al. [34] and Yetisir et al. [48] also agree on pointing out that *L. siceraria* rootstocks do not modify pulp firmness. On the contrary, Suárez-Hernández et al. [13] reported a reduction between 14.5% and 33.0% in firmness of watermelon cv. 2800 and Sangria when grafted on four accessions of *L. siceraria*. Variations in pulp firmness are considered a result of the interaction variety with genotype of

L. siceraria, as was observed in comparison of LG1 and LG2 groups. Differences in pulp firmness are attributed to variations in cells turgidity [49] and to formation of a greater number and size of parenchymal cells [50].

Table 5. Average and orthogonal contrast of internal fruit quality characteristics of grafted and ungrafted Tri-X 313 watermelon.

Variables	Treatments				Contrast (*p* Value)			
	Ungrafted	LG1 [1]	LG2	LGg	C1 [2]	C2	C3	C4
Pulp firmness (N)	11.26 ± 0.71	15.93 ± 0.97	12.19 ± 1.13	13.82 ± 0.92	0.0568	0.6644	0.2445	0.0428
Luminosity (L*)	49.29 ± 0.48	52.36 ± 0.96	49.86 ± 1.02	50.95 ± 0.79	0.0625	0.6916	0.2627	0.0448
Chroma (C*)	25.88 ± 0.57	34.23 ± 0.93	36.09 ± 0.65	35.27 ± 0.59	0.0001	<0.0001	<0.0001	0.1199
Hue (°h)	46.13 ± 1.08	38.84 ± 0.48	39.07 ± 0.63	38.97 ± 0.42	<0.0001	<0.0001	<0.0001	0.8085
Soluble solid (°Brix)	11.70 ± 0.44	11.83 ± 0.32	12.40 ± 0.30	12.15 ± 0.23	0.7994	0.1601	0.3086	0.1481

[1] LG1 = Grafted with *Lagenaria siceraria* group 1, LG2 = Grafted with *L. siceraria* group 2, LGg = Grafted LG1 + LG2, [2] Orthogonal contrast: C1 = ungrafted vs. LG1, C2 = ungrafted vs. LG2, C3 = ungrafted vs. LGg (grafted), C4 = LG1 vs. LG2.

Variation in watermelon pulp coloration is related to differences in fruit maturity stage [46]. *Cucurbita* hybrid rootstocks favor pulp color and reduce discoloration during storage [51]. It has been observed that pulp luminosity (L*) is similar in ungrafted and grafted plants in *L. siceraria*, with values between 48.37 and 51.36 when using creole genotypes (L43, L46, L48, L50 and L54) as rootstocks [14]. Differences between accessions of *L. siceraria* were also recorded when comparing groups LG1 and LG2 in the present investigation. Genotypes with smaller seed and fruit dimensions have lighter pulp (LG1, L* = 52.33) than the accessions (LG2, L* = 52.33) with larger dimensions.

The pulp color saturation (C*) is an attribute that is affected by *L. siceraria* species, presenting C* values between 28.1 and 35.9 in Crimson Tide variety when grafted with different accessions [29]. This response was also obtained when grafting Tri-x 313 watermelon variety with groups of *L. siceraria* (LG1 and LG2), where C* value increased by 36.28% due to graft effect, which indicates that fruits coming from grafted plants present brighter pulps than those from ungrafted plants.

The pulp hue (°h) is a characteristic that depended on fruit maturity and lycopene content [47]. This tribute is favored by using hybrid squash rootstocks, which generates a redder pulp [50] with higher lycopene content [51]. Pulp hue is also affected by using *L. siceraria* species as rootstock. Karaca et al. [29], when evaluating 21 genotypes of *L. siceraria* in Crimson Tide watermelon, found that 15 accessions registered lower values (35 to 40 °h) than those obtained in ungrafted fruits. This performance was also observed when comparing both groups of *L. siceraria* with respect to ungrafted, where reduction in tonality in grafted fruit was 15.5%. These differences indicate that both *L. siceraria* groups had fruits with redder pulp.

Soluble solids content in watermelon is a quality attribute, classifying fruits of good quality with 8 °Brix and of very good quality with more than 10 °Brix [26]. In this sense, fruits obtained from the plants grafted onto *L. siceraria* genotypes (12.15 °Brix) and ungrafted plants (11.7 °Brix) were classified as having very good quality and were statistically were similar. These results are consistent with those found by Huitrón-Ramírez et al. [47] and Bekhradi et al. [52], who indicated that soluble solids content is not altered by *Cucurbita* and *Lagenaria* rootstock, although in some cases, reductions in soluble solids content are reported with *Cucurbita* rootstock [40]. Contrary to *L. siceraria* accessions, it is reported that it can maintain or increase °Brix content. Candir et al. [53] recorded values of 10.1 °Brix to 12.6 °Brix when grafting Crimson Tide variety on 21 accessions of *L. siceraria*, identifying five statistically greater accessions. Suárez-Hernández et al. [13] confirm differential *L. siceraria* rootstocks responses, reporting that five out of six accessions of *L. siceraria* presented significantly higher content of soluble solids in Sangria variety, while these same rootstocks in the 2800 variety presented similar values compared to ungrafted fruit. This indicates that the response depends on the interaction between rootstock and variety to be grafted.

4. Conclusions

Grafted watermelon fruits variables evaluated in production and quality were not related to dissimilar characters of *L. siceraria* groups. Pulp firmness and luminosity were associated to the fruit and seed characteristics of rootstocks, where both parameters were overexpressed to a smaller dimension of rootstocks fruits and seed. Grafting influence of both *L. siceraria* groups with respect to condition without grafting was to favor the fruit number and commercial production per ha, as well as rind thickness, fruit external firmness and pulp coloration (chroma and hue). Pulp percentage was reduced by the graft effect. Fruit weight, shape index and soluble solids remained unchanged.

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