

RESEARCH ARTICLE

# Plant growth and quality of cucumber grafted with *Lagenaria siceraria* in soil infested with nematodes

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## ABSTRACT

Grafting cucurbitaceous crops is an alternative for protection of plants in production systems with biotic or abiotic stress. The grafting cucumber improves the plant growth and development under adverse conditions, such as drought, high salt concentration and soil-borne pathogens. *Lagenaria siceraria* is a species with potential rootstocks in cucumber. Mexican *L. siceraria* accessions are less susceptible to damage caused by *Meloidogyne incognita*. The aim of this study was to evaluate two Mexican *L. siceraria* accessions (Lag 48 and Lag 53) and Forticuke F1 (Numhems®) as rootstocks on plant growth and fruit quality of cucumber in soil infested with root-knot nematodes. Plant ungrafted was used as control. The results show that rootstocks increased plant height, leaves number and leaf area. Forticuke F1 and Lag 53 had a greater response than ungrafted plant. The grafting increased fruit weight in 25.3%, 15.2% and 14.6% with Forticuke F1, Lag 53 and Lag 48, respectively. Internal firmness of the fruits increased by 56.4% in Forticuke F1, 12.6% in Lag 53 and 2.2% in Lag 48 with respect to ungrafted plants. Length, diameter, external firmness and Brix degrees of fruit were not modified by rootstock effect. The use of *L. siceraria* as rootstock is an alternative to improvement plant growth and fruit quality of cucumber in soil infested with root-knot nematodes.

**Keywords:** *Cucumis sativus*; graft; *Meloidogyne incognita*; root-knot nematodes

## INTRODUCTION

One of the limiting factors in cucumber production system is incidence of nematodes that affect normal plants development (Amin and Mona, 2014). Root-knot nematodes reduce water and nutrients transportation in plants (Navarrete et al., 2018). Among root-knot nematodes of greater agricultural importance are *M. incognita*, *M. javanica*, *M. arenaria*, and *M. hapla*, species distributed individual or combined in different agricultural regions of Mexico, with *M. incognita* being predominant species in warm areas (Del Prado-Vera et al., 2001).

The strategy used by farmers to counteract nematodes presence is application of organophosphates and carbamates pesticides, as well as methyl bromide (Jones et al., 2016). These products are considered highly toxic to humans and environment, reason why its use has been restricted (Gupta et al., 2017). The forgoing has led development of ecological alternatives such as

crop rotation, cover crops, resistant varieties, biological control and grafted plants (Ban et al., 2014; Singh and Phulera, 2015).

Some species tolerant to *M. incognita* are of genus Cucurbita, Citrullus and Cucumis (Punithaveni et al., 2015; Thangamani et al., 2018). The species *Lagenaria siceraria* are classified as susceptible. However, *L. siceraria* used as rootstock in root-knot nematode-susceptible cv. Hesham presents moderate resistance (El-Wanis et al., 2013). Cucumber Lama hybrid grafted onto three rootstocks of *L. siceraria* (Emphasis, PI 534556 and Egyptian local variety) increments plant height, internodes length, leaves number and leaf area (El Eslamboly and Deabes, 2014). While in Cucumber cv. Adrian grafted onto three commercial rootstocks (Emphasis, S-1 and Friend) reduces leaves number, and fruit characters such as weight, diameter, degrees brix and pH are not modify (Ban et al., 2014). However, there are no studies on *L. siceraria* accessions as rootstock in soils infested with root-knot nematodes.

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**Received:** 24 September 2020; **Accepted:** 30 December 2020

Recent studies have shown the benefits of using *L. siceraria* as rootstock in cucumber under other environments. *L. siceraria* as rootstock in hybrid cucumber cv. Kalaam F1 under non-stressful environment promotes higher plant growth and fruit quality, mainly in parameters such as plant height, leaf area, fruit weight and yield (Noor et al., 2019). Under saline conditions, cucumber plants grafted increase fruits number and reduce non-marketable percentage (Huang et al., 2009). Tolerance to salinity is result of morphological and physiological changes in plant (Elsheery et al., 2020).

A morphological study of accessions diversity in different regions of Mexico indicates that fruits vary in size and shape (Grimaldo et al., 2018). Mexican *L. siceraria* accessions used as rootstock have positive effects on fruit quality in watermelon (Suárez et al., 2017a, b). Another study related with Mexican *L. siceraria* accessions, indicates that are less susceptible to root-knot nematodes compared with other regions of the world (Levi et al., 2009). However, there is no evidence of studies related to nematodes tolerance of Mexican *L. siceraria* landraces on plant growth and fruit quality of cucumber. Therefore, our objective of this study was to evaluate the effect of two Mexican *L. siceraria* accessions (Lag 53 and Lag 48) and Forticuke F1 (commercial rootstock) on plant growth and fruit quality of cucumber in soil infested with root-knot nematodes.

## MATERIAL AND METHODS

The experiment was carried out in a low-tech greenhouse covered with polycarbonate roof during spring 2019 at Institute of Agricultural Sciences of Autonomous University of Baja California, Mexico (32° 24' 19" N, 115° 11' 48" W, and at an elevation of 14 m). The climate of the region is very dry with 13.6°C and 31.7°C minimum and maximum annual temperature, respectively. Annual

precipitation is 10 mm. The temperature inside the greenhouse oscillated between 20°C to 40°C from April to June 2019 (Fig. 1), presenting higher temperatures in May and June. Relative humidity during the experiment was 20 to 90% (Fig. 2).

Centenario cucumber variety was used as scion, which was grafted in three rootstocks: the commercial hybrid Forticuke F1 (Numhems®) and two Mexican *L. siceraria* accessions (Lag 48 and Lag 53). Centenario ungrafted was included as control. The cleft grafting technique was used (Maroto et al., 2002). The experimental unit consisted of 15 plants. A randomized block design with three replications was used.

Grafted and ungrafted seedlings were established at 21 days after grafting in polyethylene bags with capacity of 10 L. The bags contained 5 kg of contaminated soil with *M. incognita*. Nematological analysis of a composite sample showed a density of 45 second-stage juveniles per 100 grams of soil. The texture was sandy its chemical properties were showed in Table 1.

The water and nutrients were supplied by drip irrigation. Water contained EC 1.1 dS m<sup>-1</sup> and pH 8.3. The nutrient solution was applied 7 days after planting. The nutrient contents were: 8.0 meq K<sup>+</sup> L<sup>-1</sup>, 8.0 meq Ca<sup>+2</sup> L<sup>-1</sup>, 1.25 meq NH<sub>4</sub><sup>+</sup> L<sup>-1</sup>, 16.0 meq NO<sub>3</sub><sup>-</sup> L<sup>-1</sup>, 2.7 meq SO<sub>4</sub><sup>-2</sup> L<sup>-1</sup> and 1.25 meq H<sub>2</sub>PO<sub>4</sub><sup>-</sup> L<sup>-1</sup> (Cadahia, 2005).

The variables evaluated were of plant growth and fruit quality. The plant growth was quantified two months after it was established considering height (cm), internode distance (cm), leaves number and leaf area (cm<sup>2</sup>). Leaf area was determined using an LI-3100C Area Meter (LI-COR Inc. USA). Fruit quality was evaluated on ten fruits considered at random from each experimental unit in the first harvest. Cucumber was harvested in the morning

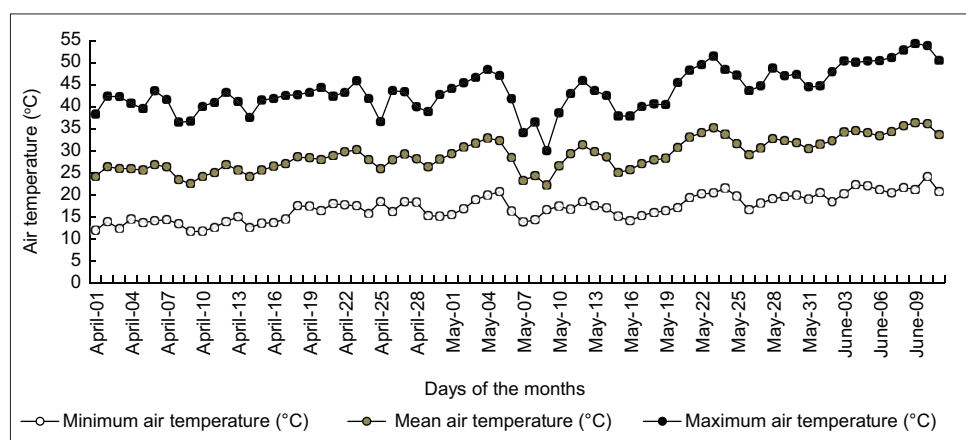


Fig 1. Minimum, mean and maximum daily air temperature during crop development inside the greenhouse in April to June 2019.

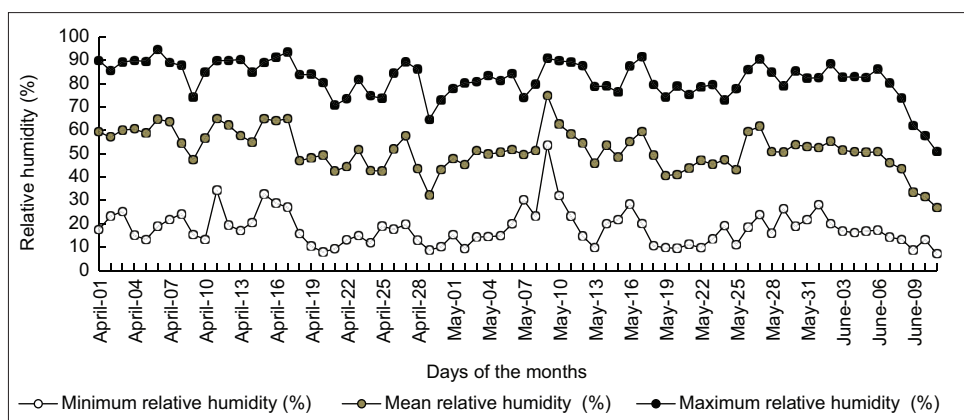


Fig 2. Minimum, mean and maximum daily relative humidity during crop development inside the greenhouse in April to June 2019.

Table 1: Soil fertility analysis and concentrations of specific ions in the extract

Analysis of the soil										
MO	CO	N-NO <sub>3</sub>	P-PO <sub>4</sub>	K int,	Ca int.	Mg int.	Fe	Zn	Mn	Cu
ppm										
10200	8500	14.4	10.9	550	1100	450	4	3	1.9	0.82
Concentrations of specific ions in the extract										
EC	pH	SST	Ca <sup>2+</sup>	Mg <sup>2+</sup>	K <sup>+</sup>	Na <sup>+</sup>	CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SAR
ppm										
2.76	7.2	1766	239	76	30	172	0.00	174	404	2.5

MO: organic matter; CO: organic carbon; K int.: exchangeable potassium; Ca int.: exchangeable calcium; Mg int.: exchangeable magnesium; SST: total soluble salts; SAR: sodium absorption ratio

according to specifications of the National Quality Standard (MMXFF023, 1983). Variables evaluated were weight (g), length (cm), diameter (mm). Firmness was quantified with a Chatillon DFE-100 digital force gauge (AETEK Inc, USA), considering external firmness (N) as average value of three punctures in the whole fruit and internal firmness (N) as average value of three punctures in fruit mesocarp. Content of soluble solids (Brix) was determined with a Digital Reichert AR200 refractometer (Reichert Inc, USA).

All data were subjected to analysis of variance by 5% F test probability. When significant difference was found, the mean test (Tukey at 5% probability) was used.

## RESULTS AND DISCUSSION

### Weather data

Regarding the meteorological data in the months of April, May and June, higher values of air temperatures were recorded as time progressed (Fig. 1). The minimum, mean and maximum air temperature fluctuated in 15°C to 21°C, 27°C to 34°C and 41°C to 50°C, respectively, registering high values in June. The relative humidity decreased as days progressed, minimum varied in 18% to 19%, mean in 47% to 57% and maximum in 78% to 84%, presenting lower values in June (Fig. 2).

### Plant growth

The plant growth and development were favored by grafted condition (Table 2). The height plant, leaves number and leaf area of Centenario variety plant presented higher values ( $P \leq 0.05$ ) in grafted condition compared to ungrafted. The rootstocks Forticuke F1 and *L. siceraria* (Lag 53) presented a significant effect with average height 36.6% and 26.5%, respectively, greater than ungrafted plant. Leaves number development in all grafted plants increased significantly from 46.0% to 49.0%. Leaf area was significantly superior in Forticuke F1 rootstock with 19.0% greater than normal condition, while in materials of *L. siceraria* (Lag 48 and Lag 53) had an increase between 11.6% and 10.2%.

Grafting favors a higher biomass of the plant (Alan et al., 2007) due to a greater root development that supplies more water and nutrients even in adverse conditions (Li et al., 2014; Zhu et al., 2008). Consequently, greater concentration of mineral in stem tissues (Colla et al., 2012). At enzymatic level, increased activity has been evidenced in enzymes nitrate reduction, glutamine synthetase and glutamate synthetase in metabolism without nitrogen stimulated by graft under stress conditions (Yang et al., 2013). The above favours availability of soluble amino acids and proteins resulting in greater growth of plants (Pulgar et al., 2000).

The growth of cucumber plants can be affected by presence of *M. incognita* (Cuadra et al., 2009) due to obstructions in root that reduce the transport of water and nutrients (Devran et al., 2017; Navarrete et al., 2018). However, incorporation of graft in cucumber production has reduced effects of nematodes as with results obtained in this investigation. Similarly, El-Eslamboly and Deabes (2014) observed that when evaluating Lama Cucumber variety grafted with three *L. siceraria* accessions in nematode infested soils, there were increases in plant height, leaf number and leaf area of 63%, 115%, and 26% greater than ungrafted plants, respectively. However, not all *Lagenaria* accessions can present favorable responses in nematode control. Ban et al. (2014) found that cucumber variety Adrian grafted with commercial *L. siceraria* emphasis rootstock showed similar values in stem length when comparing plants without grafting on soil infested with nematodes while the number of leaves was lower.

### Fruit quality

Weight and pulp texture (internal firmness) varied significantly ( $P \leq 0.05$ ) by rootstock used in Centenario variety cucumber, subjected to soil infested with root-knot nematodes (Table 3). Forticuke F1 rootstock promoted greater weight with respect to normal condition in 23.5%, whereas when using *L. siceraria* accessions Lag 48 and Lag 53 the increases were 14.6% and 15.2%, respectively. These results in grafted plants are due to slight increases in fruit dimensions, where a positive correlation of weight was found with parameters of length ( $P < 0.001$ ), diameter ( $P < 0.01$ ) and internal firmness ( $P < 0.05$ ) of fruit (Table 4).

Similar increases in weight were found when evaluating Lama variety grafted with different commercial *L. siceraria* rootstocks on soil infested nematodes, where increases were from 23.6% to 26.3% more than in fruits from ungrafted plants (El-Eslamboly and Deabes, 2014). While, in varieties Sinai and Lama cucumber grafted with *Cucurbita* hybrids there were no significant increases (Amin and Mona, 2014; El-Eslamboly and Deabes, 2014).

Development and greater weight of fruits in grafted plants is attributed to root system of rootstock that tolerates incidence of soil nematodes. *L. siceraria* species used as rootstock in cucumber plant have moderate resistance like other cucurbitaceae species (El-Wanis et al., 2013). Nematode resistance is induced by less amount of root galls, females and egg masses in grafted condition with respect to the non-grafted plant (El-Wanis et al., 2013). This condition makes possible the supply of water and nutrients from root to aerial part of plants expressing greater height, leaves number and leaf area. Another factor associated with development of grafted plants is stimulation of photosynthetic activity, where chlorophyll content in cucumber plants is higher compared to ungrafted condition, being cultivated in soils contaminated with *M. incognita* (Amin and Mona, 2014).

Internal firmness of fruits increased significantly 56.5% in plants grafted with Forticuke F1 rootstock with respect to ungrafted plants, while using creole materials of *L. siceraria* Lag 48 and Lag 53 generated increases of 2.2% and 12.6%, respectively (Table 3). Variation of firmness in cucumber fruits is associated with calcium content that interacts with

**Table 2: Growth parameters of Centenario variety cucumber plant grafted with commercial rootstock and *Lagenaria siceraria* accessions in soils infested with root-knot nematodes**

Variety/rootstock	Height (cm)	Internode distance (cm)	Leaves number	Leaf area (cm <sup>2</sup> )
Centenario (C)	127.01±5.20 <sup>1</sup> b <sup>2</sup>	11.38±0.60	11.12±0.57 b	148.95±7.06 b
C/Lag 48	142.05±2.00 b	12.54±0.29	16.57±1.02 a	166.22±1.99 ab
C/Lag 53	160.69±8.17 a	12.83±0.83	16.23±0.75 a	164.14±5.48 ab
C/Forticuke F1	173.53±2.02 a	13.11±0.29	16.54±1.17 a	177.27±1.33 a
HSD	15.12	2.74	4.52	23.14
CV	3.71	8.12	11.07	5.22

<sup>1</sup>Values as mean ± SE. <sup>2</sup>Values followed by same letters in the column do not differ significantly at  $P < 0.05$  error level, according to Tukey's HSD (honestly significant difference) test

**Table 3: Quality parameters of Centenario variety cucumber fruit grafted with commercial rootstock and *Lagenaria siceraria* accessions in soils infested with root-knot nematodes**

Variety/rootstock	Weight (gr)	Length (cm)	Diameter (mm)	External firmness (N)	Internal firmness (N)	Content of soluble (brin)
Centenario (C)	185.50±03.75 <sup>1</sup> b <sup>2</sup>	19.77±1.25	38.60±3.29	69.97±4.24	36.17±4.28 b	5.10±0.20
C/Lag 48	213.67±21.67ab	21.97±1.27	39.33±3.49	64.85±4.69	36.96±4.47 b	5.90±0.55
C/Lag 53	212.67±13.98 ab	21.13±1.19	41.13±1.94	71.03±3.13	40.74±5.31ab	5.97±0.27
C/Forticuke F1	232.50±02.02 a	21.65±0.03	45.65±0.89	73.64±0.19	56.60±2.56 a	6.05±0.20
HSD	45.52	3.49	10.42	17.36	18.16	1.477
CV	7.98	6.12	9.36	9.19	15.77	9.49

<sup>1</sup>Values as mean ± SE. <sup>2</sup>Values followed by same letters in the column do not differ significantly at  $P < 0.05$  error level, according to Tukey's HSD (honestly significant difference) test

**Table 4: Pearson correlation coefficients among quality parameters of Centenario variety cucumber fruit grafted with commercial rootstock and *Lagenaria siceraria* accessions in soils infested with root-knot nematodes**

	Weight	Length	Diameter	External firmness	Internal firmness
Length	0.823*** <sup>2</sup>				
Diameter	0.802**	0.760**			
External firmness	0.315 <sup>ns</sup>	-0.021 <sup>ns</sup>	0.502 <sup>ns</sup>		
Internal firmness	0.664*	0.413 <sup>ns</sup>	0.731**	0.219 <sup>ns</sup>	
Content of soluble	0.343 <sup>ns1</sup>	0.382 <sup>ns</sup>	0.417 <sup>ns</sup>	-0.340 <sup>ns</sup>	0.521 <sup>ns</sup>

<sup>1</sup>ns; non-significant at  $P \leq 0.05$  error level. <sup>2</sup>\* $P \leq 0.05$ , \*\* $P \leq 0.01$ , \*\*\* $P \leq 0.001$

pectic acid to form calcium pectate to maintain a rigid cell wall structure (Wei and Zhao, 2020). Wherein, the formation of calcium bridges between pectic polymers are responsible for cell adhesion and tissue integrity of cucumber mesocarp tissue (Sajnin et al., 2003). An increase in calcium content is a favorable effect of rootstock that induces greater assimilation, despite incidence of nematodes. Calcium quantifications in foliage of cucumber plants grafted with *L. siceraria* showed an increase of 29.6% and 45.0% in first and second cultivation cycle developed in nematode infested soils (El-Wanis et al., 2013).

## CONCLUSION

Forticuke F1 (Numhems®) and Lag 53 (Mexican *L. siceraria* accession) rootstocks favored the plant height, number of leaves and leaf area and weight and firmness of the fruit in soils infested with *M. incognita*. Lag 53 is a promising source for developing new rootstock cultivars.

## ACKNOWLEDGMENTS

The authors are grateful to the Autonomous University of Baja California for the support granted through the third Internal Call for Special Research Projects.

### Author contributions

A. M. Suárez, O. Grimaldo. Research project planning and design. Prepared the first draft of the manuscript and revised the final version. C. Ceceña, F. Núñez, D. Gonzalez. Analysis and interpretation of the results obtained. All authors performed the literature search, edited the draft and approved the final version.

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