Investigation note

Cultivation techniques of grafted watermelon, effects on yield and fruit quality

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Abstract

In order to investigate the effect of rootstock patterns and cultivation techniques on the yield and quality of watermelon fruit, a study was conducted between October 2014 and February 2015 in the municipality of Santa Elena, Ecuador. The watermelon hybrid Royal Charleston grafted on three patterns (Shintoza, RS-841, Ercole interspecific hybrids of *Cucurbita maxima* x *Cucurbita moschata*), three planting densities (3 000, 3 500, 4 000 plants ha^{-1}), pruning were evaluated (without pruning, three and four main guidelines) and three doses of gibberellic acid (0, 10, 20 mg L^{-1}), applied in the transplant and 20 and 40 days after it, in an orthogonal design L9 (3)^4 arranged in random blocks with three replicas. The variables evaluated were stem diameter, fruits per plant, fruit mass, agricultural yield (t ha^{-1}), total soluble solids, pulp firmness and bark thickness. In addition, the 'regular analysis' was carried out, which includes the preparation of the response table, selection of the optimal combination and the prediction of the maximum response. The Royal Charleston watermelon hybrid grafted onto the RS-841 pumpkin pattern, using the approximation method, with a density of 4 000 plants ha^{-1}, four main guides and the application of 20 mg L^{-1} gibberellic acid respectively, reached the greater amount of fruits per plant and therefore higher yield, result that was confirmed by the regular analysis performed.

Keyword: *Citrullus lanatus*, density, grafting, production, pruning.

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The greatest economic losses in watermelon cultivation, worldwide, are caused by the *Fusarium oxysporum* f.sp. *niveum*, which is considered the main soil pathogen (Petkar and Ji, 2017). Its spores have high survival capacity, limiting the efficiency of crop rotation (Scott, McRoberts and Gordon, 2014). As a sustainable alternative to this problem, for decades in Japan and later in Europe, watermelon is grafted onto rootstocks (*Cucurbita maxima*, interspecific hybrids of *C. maxima* x *C. moschata*, *Lagenaria siceraria*) whose advantages lie in their tolerance to pathogens from soil (Song *et al*. 2016), at low temperatures (Yang *et al*., 2016), salinity, heavy metals and excess water (Colla *et al*., 2014).

Grafted plants are efficient in nutrient absorption and therefore require less fertilizer (Huang *et al*., 2016). These are more vigorous and due to the late appearance of the pistillate flowers (possibly due to changes in hormonal production), the planting density is lower than that of the ungrafted watermelon (Abarca, 2017). In dense spacing the number of fruits per area increases, the weight of the fruit is reduced and phytosanitary control is difficult; on the other hand, with wide spacing, fruits of greater weight are obtained (Souza, 2008).

Pruning can advance flowering or fruiting, allows to maintain an adequate balance between vegetative growth and fruit load, can be used to produce hybrid seed, adequate control of pests and diseases, with pruning a larger population of plants without reduction could be used significant performance and production of uniform fruits (Oga and Umekwe, 2015).

On the other hand, while branch suppression is not a common practice, it may be interesting to increase production. This work is based on the fact that female flowers, in watermelon, appear in the main and secondary branches, being in them where fruiting occurs (Maroto, 2002). It has also been shown that plant hormones, especially gibberellin (GA3), control the development, growth and yield of a wide range of plant species (Kerbauy, 2012).

In correspondence with the background, the objective of this investigation was to determine the effect that the use of various cultivation techniques, such as the rootstock pattern, planting density, has on the yield and quality of the fruit of the grafted watermelon, pruning and application of the plant hormone gibberellin.

The experiment was carried out in the municipality of Santa Elena, Ecuador, between October 2014 and February 2015. The main climatic variables of the area are average temperature 26.6 ºC, relative humidity between 74 and 82% and precipitation around 100-250 mm December-May (National Institute of Meteorology and Hydrology, 2015). The geographical coordinates of the site are south latitude 1º 56’ 9”and west longitude 80º 41’ 20”, at a height of 47 meters above sea level, the topography is flat.

The soil where the research was implemented is classified as Inceptisol, its main characteristics are: frank texture; cation exchange capacity of 52 meq 100 g^{-1} of soil; 1.5% organic matter, 16 mg mL^{-1} phosphorus, potassium reaches 721 mg mL^{-1}, the electrical conductivity (EC) in the saturation paste is 2.16 mS cm^{-1}.

Watermelon is planted in the experimental field since 1984 and is left fallow every year from May to October. Irrigation water was obtained from an artesian well with EC of 1 833 mS cm^{-1} and pH 8.4.

The Royal Charleston watermelon hybrid grafted on three rootstocks (Shintoza, RS-841, Ercole interspecific hybrids of *Cucurbita maxima* x *Cucurbita moschata*) was evaluated, with three planting densities (3 000, 3 500, 4 000 plants ha^{-1}), three variants in the pruning (without pruning, three and four main guides) and three doses of gibberellic acid (0, 10, 20 mg L^{-1}), applied in the transplant and 20 and 40 days after the transplant). An orthogonal L9 design was used (Taguchi, Elsayed and Hsiang, 1989) arranged in randomized blocks with three replicas (Table 1).

Table 1. Matrix of treatments of the experiment.

Treatments	Matrix Taguchi method (Taguchi *et al*., 1989)				Description of the treatments			
	Patterns	Densities	Pruning	AG	Patterns	Densities	Podas	AG (mg L^{-1})
1	1	1	1	1	RS-841	3 000	0	0
2	1	2	2	2	RS-841	3 500	3	10
3	1	3	3	3	RS-841	4 000	4	20
4	2	1	2	3	Shintoza	3 000	3	20
5	2	2	3	1	Shintoza	3 500	4	0
6	2	3	1	2	Shintoza	4 000	0	10
7	3	1	3	2	Ercole	3 000	4	10
8	3	2	1	3	Ercole	3 500	0	20
9	3	3	2	1	Ercole	4 000	3	0

AG= gibberellic acid.

The planting density 4 000 plants ha^{-1} corresponds to what the producer commonly uses. The other densities were determined according to previous criteria found in the literature (Huitrón-Ramírez *et al*., 2009; López-Elias *et al*., 2011). Pruning was done when the plants had six true leaves leaving three and four, because in this way the growth is controlled and the sprouting of secondary branches is advanced (Camacho-Ferre and Fernández-Rodríguez, 2000).

As for gibberellic acid, the doses were selected according to experiences in watermelon (Sinojyga *et al*., 2015). The watermelon was sown on October 5, 2015 and six days later the pumpkin in trays of 128 alveoli. For the germination and initial development in *Sphagnum* Lambert BM 2 brand peat with fine vermiculite, a macro and micronutrient load and pH adjusted (5.4-6.3). This substrate is also composed of dolomite, calcitic limestone and a wetting agent. The grafting was done by approximation (Gómez, 1997) on October 17 and ten days later the plants were transplanted to the final field.

Each experimental unit was composed of three lines with 17 plants (distance between lines 4 m and between plants 0.6 m) and the central line was considered useful for evaluations. The harvest was carried out when the fruits reached their technical maturity, whose predominant reference is the intense yellowing of the part that is in contact with the soil.

The agronomic variables evaluated were: stem diameter, expressed in mm (measured with a Vernier digital caliper model Truper 14 388), number of fruits per plant; average mass of the fruit in kg (weighed on a digital scale 0-30 kg, GHS); agricultural yield (t ha^{-1}).

The quality variables studied were: total soluble solids expressed in Brix degrees (measured with an Ataga refractometer model Master-20α); firmness of the pulp in kg cm^{-2} (measured with a Wagner penetrometer 0-5 kg), Crust thickness (mm).

With the data obtained, the analysis of the variance was performed. The significant effects of the treatments were determined by the Tukey test ($p \leq 0.05$) with the statistical package Infostat professional version for Windows (Infostat, 2008).

The 'regular analysis' (Taguchi *et al*., 1989) was carried out, which includes: elaboration of the response table, selection of the optimal combination, prediction of the maximum response = $\bar{y} + \Sigma (Ai - \bar{y}) + (Bi - \bar{y}) + (Ci - \bar{y}) + (Di - \bar{y})$. Where: $\bar{y}$ is the general average; Ai is the highest value of level i of factor A; Bi is the highest value of level i of factor B; Ci is the highest value of level i of factor C; Di is the highest value of level i of factor D.

In Table 2 it can be observed that there were no significant differences in the variables stem diameter and fruit weight; on the other hand, as the density increased from 3 000 to 4 000, the number of fruits per plant increased, and therefore the agricultural yield, highlighting the RS-841 treatments, with 4 000 plants ha^{-1}, four main guides and 20 mg L^{-1} AG with 71, 6 t ha^{-1} and Shintoza, with 4 000 plants ha^{-1}, without pruning and 10 mg L^{-1} AG with 62.6 t ha^{-1}.

Table 2. Stem diameter, agricultural yield and performance components of the Royal Charleston hybrid grafted onto pumpkin patterns under different densities and other cultural techniques.

Treatments					Stem diameter (mm)	Number of fruits per plant	Average fruit weight (kg)	Yield (t ha^{-1})
	Patterns	Density	Pruning	AG (mg L^{-1})				
1	RS-841	3 000	0	0	11.9	1.8 bc	7.6	41.5 d
2	RS-841	3 500	3	10	11.8	2 ab	8.2	58.2 abc
3	RS-841	4 000	4	20	12.4	2.2 a	7.9	71.6 a
4	Shintoza	3 000	3	20	12.2	1.8 bc	7.5	40.8 d
5	Shintoza	3 500	4	0	12.9	1.9 bc	8.3	55.9 bc
6	Shintoza	4 000	0	10	13.2	2.1 b	7.6	62.6 ab
7	Ercole	3 000	4	10	11.8	1.7 c	7.4	37.6 d
8	Ercole	3 500	0	20	12.7	1.8 bc	7.3	47.7 cd
9	Ercole	4 000	3	0	13	1.9 bc	7.4	56.4 bc
EE					0.46	0.05	0.36	2.8
CV (%)					6.3	4.5	8.1	9.2

Means with different letters in the same column differ according to Tukey ($p < 0.05$); AG= gibberellic acid.

These results are consistent with those achieved in Brazil, where two planting densities were evaluated: 10 000 and 5 000 plants ha^{-1} and found no significant differences in the number of fruits per plant, equatorial diameter of the fruit, fresh weight of the fruit, but in agricultural yield, the same as with the density of 10 000 plants ha^{-1} was 66.7 t ha^{-1} compared to 33.57 t ha^{-1} with the density 5 000 plants ha^{-1} (Saraiva *et al*., 2013).

Also in Mexico, Triploide Crunchy Red Tri-X 313 was evaluated, grafted onto Robusta (*Citrullus lanatus*) and Super Shintosa (*Cucurbita maxima* x *Cucurbita moschata*) with densities of 4 166 and 2 083 plants ha^{-1} and found a greater number of fruits per square meter and therefore higher performance at the highest density (Alvárez-Hernández *et al*., 2015). The difference in yield is mainly due to the time in which the fruit set occurs, if it takes place with a relatively small plant, the higher the number of plants, the greater the yield will also be.

However, if the setting takes place when the plants have reached their full development, the productions are matched because with all the densities you have approximately the same plant mass (Miguel, 1986).

In Table 3 it can be observed that there were no significant differences in any of the fruit quality variables of the watermelon grafted on pumpkin rootstocks and planted at different densities plus other cultural practices studied.

Table 3. Quality of the Royal Charleston watermelon fruit grafted on pumpkin patterns under different densities and other cultural techniques.

Treatments					Total soluble solids (°Brix)	Bark thickness (mm)	Firm pulp (kg cm^{-2})
	Pattern	Density	Pruning	AG (mg L^{-1})			
1	RS-841	3 000	0	0	12.3	11.4	1.4
2	RS-841	3 500	3	10	10.4	11.6	1.4
3	RS-841	4 000	4	20	12.8	11.2	1.4
4	Shintoza	3 000	3	20	10.3	11.4	1.4
5	Shintoza	3 500	4	0	11.9	12.2	1.5
6	Shintoza	4 000	0	10	11.9	11.5	1.4
7	Ercole	3 000	4	10	10.9	12.5	1.5
8	Ercole	3 500	0	20	11	11.4	1.6
9	Ercole	4 000	3	0	10.8	11.9	1.5
EE					1.02	0.73	0.08
CV (%)					15.4	10.7	9.4

AG= gibberellic acid.

The thickness of the bark of the fruits of the grafted plants fluctuated between 11.2 and 12.5 mm, values that are important in terms of resistance to transport and long service life (Edelstein *et al*. 2014). Firmness may be affected by different factors, but grafting is one of the most important, coinciding with several studies that indicate its increase with this technique (Petropoulos *et al*., 2014; Soteriou *et al*., 2014).

Regarding the total soluble solids, in this investigation, very satisfactory results were obtained unlike other reports that indicate that the graft decreases this variable (Tokgöz *et al*., 2015) or that no differences were found between grafted and ungrafted plants (El-Wanis, El-Eslamboly and Azza, 2013).

The partial effects of the factors: patterns, density, pruning and gibberellic acid indicate that the optimal combination of factors and levels for agricultural yield (t ha^{-1}) is: RS- 841 with the density of 4 000 plants ha^{-1}, four guides and 20 mg L^{-1} gibberellic acid (Table 4).

Table 4. Partial effect of the standard factors, density, pruning and gibberellic acid on the agricultural yield of grafted watermelon (t ha^{-1}).

Levels	Factors				
	Patterns (A)	Density (B)	Pruning (C)	Gibberellic acid (D)	Average
1	57.1	40	50.7	51.3	49.8
2	53.1	54	51.8	52.8	52.9
3	47.3	63.6	55.1	53.4	54.8
Mean	52.5	52.5	52.5	52.5	52.5
Optimal combination	A1	B3	C3	D3	
	RS-841	4 000	4 guides	20 ppm	

The prediction equation obtained was:

$$\bar{y}= 52.5 + \Sigma\ (57.1-52.5) + (63.6-52.5) + (55.1-52.5) + (53.4-52.5)$$

$$\bar{y}= 52.5 + \Sigma\ (4.6) + (11.1) + (2.6) + (0.9) = 52.5 + 19.2 = 71.7 \text{ t ha}^{-1}$$

In the increase of 19.2 t ha^{-1}; 24% corresponds to the employer; 57.8 at density; 13.5% at the pruning of four guides and 4.6% at 20 mg L^{-1} concentration of gibberellic acid.

In terms of commercial production, pruning can be neglected since no differences have been found with or without this agrotechnical measure (Camacho-Ferre and Fernandez-Rodríguez, 2000) and the use of the biostimulant, probably due to the adequate nutrition of the plant and the low content of organic matter in the soil.

Conclusions

The treatment in which the hybrid of watermelon Royal Charleston grafted on the pumpkin pattern RS-841 was combined, with a density of 4 000 plants ha^{-1}, pruning of four main guides and the application of 20 mg L^{-1} of gibberellic acid was the of better agricultural yield when reaching 76 t ha^{-1}. The fruit quality parameters studied did not show significant differences due to the cultivation techniques used. The effect caused by pruning and the use of gibberellic acid, as a biostimulant, in commercial plantations is negligible, at least in the conditions studied.

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