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Rootstock performance for cherry tomato production under organic, greenhouse production system

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ABSTRACT

Studies have indicated that grafting increases yield and prevents plant diseases. An experiment was installed to evaluate the influence of rootstock on the physicochemical and phytotechnical characteristics of a cherry tomato cultivar (Sweet Grape) under organic, greenhouse production system, from July to December 2014. The experiment consisted of a randomized complete block design, with eight replications. Treatments were composed of four rootstocks (Emperador, Muralha, Enforce, and Enpower) and the ungrafted cultivar Sweet Grape (control). The following variables were analyzed: plant height, yield, firmness, discard, yield/discard ratio, total titratable acidity (TTA), total soluble solids (TSS), ratio, pH, number of clusters, and number of leaves. Data were subject to analysis of variance by the F test, at 5% significance level, and means were compared by the Tukey's test. Plant height was significantly different among treatments. Rootstocks presented no significant differences on yield, number of clusters, and TTA. The rootstocks Emperador, Enforce, and Muralha presented significant difference when compared to the control. For number of leaves, all rootstocks were significant when compared to the control, but not in relation to each other. The rootstocks presented the following yields: Emperador = 66.57 t ha^{-1}; Muralha = 59.79 t ha^{-1}; Enpower = 58.44 t ha^{-1}; Enforce = 57.92 t ha^{-1}; and the control cv. Sweet Grape = 51.28 t ha^{-1}. Results revealed that rootstocks have the potential to improve cherry tomato's yield in an organic cultivation system and do not interfere negatively with the physicochemical quality of the final product.

Keywords: *Solanum lycopersicum*, Sweet Grape, grafting, Emperador, Cerrado.

RESUMO

Desempenho de porta-enxertos para produção de minitomate sob estufa em sistema orgânico de produção

Estudos indicam que a enxertia promove incremento de produtividade e que pode ser usada na prevenção de doenças em plantas. Deste modo, um experimento foi desenvolvido com o objetivo de avaliar a influência do porta-enxerto nas características físico-químicas e fitotécnicas do minitomate, cultivar Sweet Grape, sob cultivo orgânico, em estufa, no período de julho-dezembro de 2014. O experimento foi realizado no delineamento de blocos casualizados, com oito repetições. Os tratamentos foram compostos por quatro porta-enxertos (Emperador, Muralha, Enforce e Enpower) e o pé franco da cultivar Sweet Grape (testemunha). Foram analisados a altura, produtividade, firmeza, descarte, relação produção/descarte, acidez total titulável (ATT), sólidos solúveis totais (SST), *ratio*, pH, número de cachos e de folhas. Os dados foram submetidos à análise de variância, pelo teste F, ao nível de 5% de significância, e quando observado efeito significativo dos tratamentos, procedeu-se o teste de médias, por meio do teste de Tukey. A variável altura apresentou diferença significativa entre os tratamentos. As variáveis produtividade, número de cachos e ATT não exibiram diferenças significativas entre os porta-enxertos e os únicos que apresentaram significância em relação à testemunha foram, respectivamente, o porta-enxerto Emperador, Enforce e Muralha. Para a variável número de folhas, todos os porta-enxertos apresentaram significância em relação à testemunha, mas não foram significantes entre si. As produtividades obtidas para Emperador, Muralha, Enpower, Enforce e pé franco foram 66,57; 59,79; 58,44; 57,92 e 51,28 t ha^{-1}, respectivamente. Portanto, o uso de porta-enxerto tem potencial para melhorar o desempenho da cultura quanto à produtividade no cultivo orgânico, além de não interferir negativamente na qualidade físico-química do produto final.

Palavras-chave: *Solanum lycopersicum,* Sweet Grape, enxertia, Emperador, Cerrado.

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Tomato is one of the most consumed vegetables worldwide, and cherry tomato has increasingly stood out in the market (Azevedo *et al.*, 2010). Consequently, its production has increased each year (IBGE, 2017), which enables the consolidation of the use of techniques to improve yield, mainly under an organic cultivation system.

Grafting stands out among the techniques used to improve yield, not only in tomato crops. This technique has stood out in countries with traditional vegetable cultivation, such as Japan, Spain, and The Netherlands, whose objective was to prevent soil diseases (Pedó, 2012).

Although the main use of grafting is to prevent diseases, studies have proved that rootstocks can significantly increase yield and positively influence fruits' physicochemical characteristics (Pedó, 2012).

Thus, this technique has been applied to studies as a relevant alternative to increase yield and improve fruit's physicochemical quality (Farias *et al.*, 2013). In addition, it can be a promising tool to reduce production costs over time since it is a single-time investment that has already been made at the acquisition and installation of the structure (Vida *et al.*, 1998).

Tomato's physicochemical quality is directly related to the taste, which is influenced by the presence of several chemical compounds (Silva *et al.*, 2003). Therefore, cherry tomatoes need to meet some criteria to be characterized as cultivar Sweet Grape, such as firmness, color, and total soluble solids (Sakata Seed, 2017).

Thus, an experiment was installed in an organic production property to evaluate whether the use of the rootstocks Emperador, Enpower, Muralha, and Enforce significantly increase cherry tomato's yield (cultivar Sweet Grape) under organic, greenhouse production system.

MATERIAL AND METHODS

The experiment was performed in an organic production property (certified by an Inspection and Certification institution) located in Distrito Federal, Brazil (15°58'26''S; 47°29'53''W, altitude 902 m). The climate of the region is characterized by subtropical highland with dry winter and hot summer, according to the Köppen-Geiger classification (Cardoso *et al.*, 2014). The soil is classified as Latosol (Santos *et al.*, 2013).

The experiment was performed in a greenhouse with a 4 m ceiling, and a center with 5.5 m in height, 28 m in width and 45 m in length, with entrance antechamber, transparent polyethylene cover plastic 150 microns, and white 40 mesh anti-aphids screens on the sides.

Before experiment implantation, a soil sample was collected on June 12, 2014, for analysis. The 0-20 cm and 20-40 cm depth layer samples revealed the following results, respectively: ph (H_2O)= 6.4 and 6.2; organic matter 71.4 and 51.8 g kg^{-1}; P_{resin}= 41.5 and 47.8; Na (mg dm^{-3})= 0.57 and 0.28; K= 0.77 and 1.9; Ca= 9 and 7.2; Mg= 1.6 and 1.5; H= 1.90 and 2.00; Al= 0 and 0; CTC (cmol dm^{-3})= 13.37 and 13; and V%= 59 and 71%.

The experiment site and the borders (1,260 m²) were prepared with fertilization at planting on June 26, 2014, which was mixed to the soil, using 21 liters of water, 72 kg of poultry litter, 118.5 kg of compost, 32 kg of wheat bran, 14 kg of gypsum, 500 g of molasses, and 54 kg of thermophosphate.

Fertilization was based on Trani (2014), and the values were converted so that the quantities of each input met the crop's physiological needs. Liming was not performed since the soil was within the culture band.

A rotary hoe was used to prepare the beds. White mulching was used to minimize the stress caused by high temperatures throughout plants' development and to assist in pest control. Seedlings were transplanted on July 18, 2014.

Topdressing was performed on September 18, 2014; October 18, 2014; and November 20, 2014, as follows (on 1,260 m^2): 2.5 L of water, 15.5 kg of poultry litter, 13.5 kg of compost, 6.5 kg of wheat bran, 26.5 kg of gypsum, 200 g of molasses, 1.3 kg of vermiculite, 6 kg of thermophosphate, 24 kg of castor cake, and 9.6 kg of blood meal. The last topdressing contained all the ingredients at the same proportion, except for blood meal, which was modified to 24 kg.

Irrigation was based on daily evapotranspiration (ETP), using data from the property's meteorological station combined with data of the National Institute of Space Research (INPE), correlating them with the crop's tensiometry and evapotranspiration (ETC). The irrigation system consisted of an automated drip and sprinkler, spaced at 20 cm and 12 m x 7 m apart, respectively.

Pest (*Tuta absoluta* and *Aculops lycopersici*) were controlled using nontoxic yellow sticky cards, at the time of bed preparation; by releasing natural enemies (*Trichograma pretiosum*, 360,000 parasitoids ha^{-1}, every two weeks) and applying Dipel (product based on *Bacillus thuringiensis*, at the rate of one gram per liter of water, weekly), both after transplanting; and by applying Kumulus (elemental sulfur product, at a dose of 2 g L^{-1}, weekly), whenever the pest or disease was detected.

The experiment consisted of a randomized block design, with five treatments and eight replications, with an experimental unit of 14 plants, totaling 560 plants. The useful plot corresponded to the ten central plants, discarding the four plants from the border of each plot.

Treatments were: T1= rootstock Emperador RZ F1 (*RijkSwaan*); T2= rootstock Muralha (*Takii*); T3= rootstock Enforce (*Nunhems*); T4= rootstock Enpower (*Nunhems*); and T5= cultivar SC-0163 (Sweet Grape), ungrafted plants (control). Treatments were spaced at 0.30x2.33 m apart (to increase air circulation inside the greenhouse and to facilitate cultural treatments at a higher level than that of the researcher's height), in single rows, totaling 1,260 m² in the center of the greenhouse. The border contained plants grafted with Emperador.

Seedlings were produced by a corporation specialized in grafted plants, located in Goiânia-GO, using the apical grafting technique, and were delivered to the property after acclimatization and emission of the third true leaf.

Seedlings were transplanted on July 18, 2014. Apical pruning was performed on October 25, 2014, at 92 days after transplanting, when plants had reached more than 2.20 m in height. The experiment finished on December 4, 2014.

The conduction system consisted of one two-stemmed plant per hole. One true leaf was removed from the plant for stem conduction. Thus, the lateral shoots from the leaf axilla of the two remaining leaves were conducted in a single vertical staking, resulting in 24,520 stems ha^{-1}. Buds were removed from the axillary shoots throughout the experiment.

The evaluated characteristics were divided into two categories: 1) Phytotechnical characteristics: plant height (PH) (m), yield (Y) (t ha^{-1}), discard (W) (t ha^{-1}); yield/discard ratio (Y/W) (%), number of clusters (NB) (count), and number of leaves (NL) (count); and 2) Physicochemical characteristics: Firmness (FIRM) (Newton), total soluble solids content (TSS), Titratable total acidity (TTA), ratio (TSS/TTA), and pH.

The variables PH, NB, and NL were evaluated at 92 days after transplanting, while the variables Y, W, and Y/W were evaluated until the end of the experiment. Fruits were harvested twice a week, from September 28, 2014 to November 16, 2014, totaling seven weeks of production and 14 harvests.

Cracked, defective, stained, damaged (by diseases and/or pest attacks) fruits were considered as discard and the others were considered as marketable.

On November 16, 2014, 300 g of the fruits of each experimental unit of the plot were randomly obtained. Finally, a compound sample of 300 g of the experimental plot was collected for analyses. Fruits were stored in polystyrene boxes in a refrigerated vehicle and taken to the laboratory.

The pulp was prepared for the physicochemical analyses on the following day, based on the analytical standards of the Instituto Adolfo Lutz (1985) in the Laboratory of Food Analysis, belonging to the Faculty of Agronomy and Veterinary of the University of Brasília (UnB).

The TTA was determined using the potentiometric technique, with 0.1N NaOH solution standardized up to the pH range of 8.2-8.4, adapted by Coimbra (2014). Afterward, a specific formula was used to calculate the amount of citric acid per 100 mL of pulp. The ratio was obtained by the results from the analyses of TSS and TTA. The pH and ºBrix were determined by direct reading in hydrogenation potential and optical refractometer devices, respectively. Firmness of ten fruits of each compound sample of the experimental unit was determined by an analogue penetrometer (8 mm tip), and the results were expressed in Newton (N).

Data were subject to analysis of variance, using the F test, at 5% probability level. Means were compared by the Tukey's test at 5% probability level. Linear correlation analyses (Pearson) among all variables were based on the significance of their coefficients. The correlation intensity for $p \leq 0.05$ was classified as: very strong ($r \pm 0.71$ to ± 0.9), intermediate ($r \pm 0.51$ to ± 0.70); and weak ($r \pm 0.31$ to ± 0.50) (Carvalho *et al.*, 2004). Statistical analyses were performed using the software ASSISTAT (v. 7.7 beta) (Silva & Azevedo, 2002) and SISVAR (v. 4.0) (Ferreira, 2000).

RESULTS AND DISCUSSION

The variables firmness, pH, total soluble solids (TSS), ratio, discard and yield/discard ratio presented no significant difference. Rootstocks did not differ between each other for the variables yield, number of clusters, number of leaves, and total titratable acidity. When compared with the control, the rootstock Emperador presented significance for yield; Emperador, Enpower, and Enforce showed significance for plant height; Enforce exhibited significance for number of clusters; Emperador, Muralha, Enpower, and Enforce indicated significance for number of leaves; and Muralha revealed significance for TTA (Table 1).

Emperador, Muralha, Enpower, Enforce and the ungrafted plant (control) presented yield of 66.57; 59.79; 58.44; 57.92 and 51.28 t ha^{-1}, respectively. However, a significant difference was only observed between the rootstock Emperador and the control (Table 1).

Nevertheless, the yield observed in all graft *versus* rootstock combinations is possibly due to the good compatibility between the vegetative parts of the plant and to the root system vigor of the rootstock.

Similar results were reported by Cantu (2007), who associated the higher yield, in relation to the ungrafted plants, due to the use of rootstocks. Despite being a study with fresh tomatoes, this comparison is effective since both species belong to the same family.

Lopes & Goto (2003) reported that the highest yield gains were also obtained in grafted fresh tomatoes (70.27 t ha^{-1}). Sirtoli *et al.* (2008) observed higher yield in grafted tomato cultivated in a greenhouse. Yield and discard presented a positive, simple linear correlation of weak-intensity, significant at 5% (Table 2). This fact allows inferring that the increase in yield may increase discard since the nutritional and physiological management of the plant must be intensified. This correlation is expected.

Table 1. Mean values of yield, plant height, number of clusters, number of leaves and titratable total acidity of cherry tomato. Distrito Federal, UnB, 2016.

Treatments	Yield (t ha^{-1})	Plant height (m)	N. of clusters (count)	N. of leaves (count)	TTA (%)
Emperador	66.57 a	3.14 a	18.61 ab	63.12 b	0.323 ab
Muralha	59.79 ab	2.37 cd	18.67 ab	62.11 b	0.327 a
Enpower	58.44 ab	2.58 b	18.87 ab	62.88 b	0.301 ab
Enforce	57.92 ab	2.39 c	19.08 a	62.92 b	0.305 ab
SweetGrape (control)	51.28 b	2.30 d	18.40 b	58.41 a	0.291 b
CV (%)	13.01	2.38	2.32	3.57	7.69
DMS	11.15	0.09	0.63	3.22	0.035

Means followed by the same letter in the columns do not statistically differ from each other by the Tukey's test, $p < 0.05$.

Table 2. Linear correlation matrix (Pearson) between the variables of cherry tomato under organic cultivation in a greenhouse. Distrito Federal, UnB, 2016.

	PH	Y	W	Y/W	TSS	TTA	ratio	NL	NB	FIRM	pH
PH	1	0.44**	0.25	0.11	-0.21	0.26	-0.34	0.34	-0.04	-0.01	-0.03
Y		1	0.36*	-0.04	-0.17	0.04	-0.21	0.19	0.18	-0.06	0.00
W			1	0.91**	-0.91	0.24	-0.26	0.29	0.27	-0.22	-0.09
Y/W				1	0.00	0.24	-0.17	0.26	0.21	-0.20	-0.07
TSS					1	0.21	0.74**	0.05	0.23	-0.16	0.20
TTA						1	-0.49**	0.21	0.23	-0.32*	-0.43**
ratio							1	-0.14	0.04	0.07	0.48
NL								1	0.13	-0.10	-0.06
NB									1	-0.52**	-0.09
FIRM										1	0.29
pH											1

PH= plant height; Y= yield; W= discard; Y/W= yield/discard ratio; TSS= total soluble solids; ratio; TTA= titratable total acidity; NL= number of leaves; NB= number of clusters; FIRM= firmness. *,** Significant at 5% and 1% probability.

Total titratable acidity (TTA) ranged between 0.29 and 0.32%. Rootstocks showed no difference between each other. The only treatment that presented significant difference in relation to the control was Muralha (Table 1). Mahakun *et al*. (1979) stated that the genetic factor is the main determinant of the acid content in tomato. Thus, cultivar Sweet Grape may have been influenced only by the rootstock Muralha.

Mattedi *et al*. (2011) stated that fruits with acidity higher than 0.32% are considered of excellent quality. In this study, results obtained for TAA were close to those reported by Loos *et al.* (2009), ranging from 0.31 to 0.44%. Therefore, the fruits are considered of good quality regarding the acidity.

A negative, simple linear correlation, of weak intensity, was observed between TTA and the variables ratio and pH (Table 2). This result was expected since the variable ratio is the relation of TSS/TTA. Thus, the lower the ATT, the greater is the influence on the sensorial characteristics of the fruits, since the acidity tends to decrease as the fruit matures and increases the pH (Candian, 2015). Consequently, the quality may be modified since a fruit with good quality presents a relationship of ratio higher than ten (Rosa *et al*., 2011).

Food good quality was observed in the present research, and the results of the variable ratio for Emperador, Enforce, Enpower, Muralha, and ungrafted plants were 17.18, 19.66, 19.00, 18.41, and 20.19, respectively. These results demonstrate the good quality of the fruits, although treatments presented no significant difference. Finally, TTA and firmness had a negative and weak correlation, with 5% significance (Table 2). Therefore, it can be inferred that the excess nitrogen can decrease fruit firmness (Siueia Junior, 2017) and consequently influence the titratable acidity.

Plant height presented differences between treatments, and only the rootsock Muralha did not significantly differ from the control (Table 1). The values obtained for Emperador, Enforce, Enpower, Muralha, and ungrafted plants were 3.14; 2.39; 2.58; 2.37 and 2.30 meters, respectively.

These results allow assuming that graft and rootstock had a good interaction between each other. Moreover, the genotype might have influenced the greater or lesser nitrogen-absorption capacity. Nitrogen is the most demanded mineral element by plants, constituting several components of the plant cell, such as amino acids, proteins, and nucleic acids. Therefore, nitrogen deficiency rapidly inhibits plant growth (Lincoln & Zeiger, 2013).

Since the organic matter (nitrogen source) at the beginning of the experiment was at a high level, based on the classification of Lopes (1994), Emperador might have been able to more efficiently absorb and/or use the nitrogen in its metabolism, which reflected in the greater plant height between treatments.

Moreover, a positive, simple linear correlation, of weak intensity, significant at 1%, was observed between organic matter and yield (Table 2). Thus, it can be inferred that the greater the plant height, considering the cultural treatments and the nutritional and environmental needs, the greater is the yield per plant. A positive, simple linear correlation of weak intensity, significant at 5%, was observed for the ratio variable (Table 2). This correlation is possibly related to the capacity to absorb nitrogen. N absorption capacity interferes with plant height and yield, which explains the ability to synthesize more carbohydrates and total soluble solids (TSS), with a consequent increase in the ratio (SST/ATT).

For number of leaves, the rootstocks Emperador, Muralha, Enforce, and Enpower presented 63.12; 62.11; 62.92 and 62.88 counts per plant, respectively, with no statistical difference between each other (Table 1). Conversely, all rootstocks had a significant difference when compared with the control, which presented only 58.41 counts.

Reis *et al*. (2013) reported that plants with the greatest number of leaves presented the highest yield. In the present research, only Emperador differed significantly from the control in relation to the number of leaves and yield. The number of leaves presented a positive, simple linear correlation, of weak intensity, but significant at 5% with plant height (Table 2). This result allows inferring that the greater the plant height, the greater is the number of leaves (when the plant nutritional needs are met). This fact improves the photosynthesis performance and can be used to evaluate the yield capacity of the plant when correlated to leaf area index (Gonzalez-Sanpedro *et al.*, 2008).

Number of clusters showed no significant difference between rootstocks; however, Enforce was the only rootstock that differed from the control (Table 1). Reis *et al*. (2013) stated that clusters emission in tomato plants is correlated to leaf area index due to greater absorption of solar radiation. Planting density might also indirectly affect number of clusters due to its relation to luminosity absorbed by the plants. Nonetheless, new experiments that evaluate the correlation between spacing and yield, clusters emission, and leaf area index must be carried out to confirm this hypothesis.

Number of clusters and firmness presented a negative, simple linear correlation, of intermediate intensity, significant at 1% (Table 2). This result allows assuming that the greater the number of clusters, the lower is the fruit firmness, probably due to the greater nutritional demand of the plant. Despite this correlation, treatments did not present a significant difference for firmness; instead, they showed adequate firmness for consumption.

Grafting resulted in a significant yield increase only for the rootstock Emperador when compared with the ungrafted plant of cultivar Sweet Grape (control). The use of rootstock has the potential to improve crops' performance under an organic cultivation system since it does not negatively interfere with the physicochemical quality of the final product, besides increasing yield.

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