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Effect of a novel hydrogel amendment and seedling plugs volume on the quality of ornamental/miniature tomato

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Abstract: The market for ornamental/miniature plants values aesthetic morphological characteristics, which give harmony to the potted plant. These traits depend on the growing media capacity to maintain quality and plant longevity. The use of hydrogels has increased recently in order to achieve visually attractive and long-lasting plants. Thus, this study aimed to evaluate the effects of a novel hydrogel (H) amendment and seedling plugs volume (SPV) on the quality of ornamental/miniature tomato. Seedlings of tomato cv. BRS Finestra were produced in 200 and 162 plugs plastic trays - with 18 cm³ trapezium-shaped plugs and 50 cm³ conically shaped plugs, respectively. 18 cm³ plugs and H amendment presented several significant responses for plant characters - height, soluble solids, number of leaves, stem diameter, shoot dry matter and fruits weight per plant; making evident the advantages of using a growing medium of smaller volume and this copolymer amendement. Although consistent results were obtained, a combination of both these factors in terms of an optimal aesthetic value and considering all the morphological traits could not be accomplished. Therefore it's necessary to study other elements such as plant nutrition and the use of plant growth regulators to complement them, aiming to promote better quality.

1. Introduction

Miniature tomatoes can be grown singly in small pots, or more plants in larger hanging pots. They are also ideal for window boxes or garden borders because their plant canopy diameter is little (Scott and Harbaugh, 1995). These plants combine ornamental aspects of a well-proportioned, diminutive, tomato plant with tasting fruits that can be eaten. Small plant sizes are ideal for commercial growing, shipping, and retail selling (Scott and Harbaugh, 1995).

The commercial success of the cultivation of miniature/ornamental potted plants such as tomatoes and peppers depends on consumer appeal conferred by the plant beauty, quality, vigor, color, shape, and size of leaves and fruits. In addition to that, the cultivars must present canopy harmony and be able to develop in relatively small pots (Costa *et al.*, 2015).

Non-miniature tomato cultivars tend to overgrow small containers, and their plant size is restricted by the container size (Scott and Harbaugh, 1995), producing commercially unviable plants, requiring the use of plant growth regulators (PGR) to achieve attractive compact potted grown plants (Moraes *et al.*, 2005). Another important feature of ornamental plants is the maintenance of interior quality and longevity, a never-ending effort by producers (Wang, 1992).

Growing medium ability to prevent drying out is desirable, especially in peat-based substrates. Some growers report a benefit when plants are watered with a wetting agent prior to shipment, thus making it easier for retail clerks and consumers to thoroughly rewet the medium. Interest has increased recently among growers and mass market buyers in using water-absorbing gels (Nell, 1991). However, studies investigating the effects of hydrogel (H) application on ornamental plants are scarce and limited (Ljubojević *et al.*, 2017). Particularly to ornamental/miniature vegetables, this scenario can be considered negligible.

In regard to this matter, a promising nanocomposite hydrogel developed by an innovative technique using calcium montmorillonite showed great swelling degree, higher than 2000 times in water. The formulated H with high calcium montmorillonite content (approximately 50.0% wt) as well as featuring high loading capacity and individual and simultaneous release, denotes an interesting material for agricultural applications (Bortolin *et al.*, 2016). Thus, the present study has the objective of evaluating the effects of a novel hydrogel amendment and seedling plugs volume (SPV) on the quality of ornamental/miniature tomato.

2. Materials and Methods

Plant material and growth conditions

An experiment was conducted from July 18 (sowing) to October 25 (harvest), 2017 at Embrapa Vegetables - 996 m altitude, 15° 56' S, and 48° 08' W - Brasília-DF, Brazil, in a glass-glazed greenhouse. A photoselective shading net (Aluminet® IC 50 - Ginegar Polysack®) was installed 2 m above the benches. The greenhouse presented an air temperature of 15°C minimum and 44°C maximum, average DLI (daily light integral) of ≈ 11 $mol.m^{-2}.d^{-1}$ considering a 12h period of sunlight and 81% maximum and 11% minimum of humidity. Measures were taking after seedlings transplantation 15 minutes apart by sensors connected to a Datalogger (Watchdog 1000 Series Micro Station - Spectrum Technologies®).

Seedlings were produced in plastic trays with 200 and 162 plugs (JKS® - 18 cm^3 trapezium shaped plugs and 50 cm^3 conically shaped plugs, respectively) using a peat moss based substrate (Carolina Soil®) (Fig. 1 A). *Solanum lycopersicum* L. cv. BRS Finestra was selected, being the first Brazilian ornamental/miniature tomato cultivar released by Embrapa as a product for a very specific and demanding market (Giordano *et al.*, 2001).

They were transplanted at 36 DAS (days after sowing) to 1 dm^3 pots (Nutriplan® NP14) filled with a pine bark-based substrate (Rohbacher®) with the following characteristics: EC - 0.4; pH - 6.0; Water holding capacity - 50%; Humidity - 60%; Density - 185 kg m^3. Filling were complemented with 5 g of Bokashi compost per pot (Korin® - Garden Bokashi).

Nutrients were supplied weekly during the experiment, with a solution developed for ornamental peppers containing 14.4, 1.95, 12.92, 2.5, 1.0, 2.44 mmol/L of N, P, K, Ca, Mg, S and 30, 5, 50, 40, 2 and

Fig. 1 - (A) Seedling plugs volume and visual comparison - 50 cm^3 (left) and 18 cm^3 (right); (B) plants from 50 cm^3 plugs with hydrogel amendment (left) and without (right); (C) plants from 18 cm^3 plugs with hydrogel amendment (left) and without (right).

0.1 mol/L of B, Cu, Fe, Mn, Zn and Mo, respectively, according to Costa *et al.* (2015).

Watering from seeding to the transplantation was performed twice daily with enough water to start the run off at the bottom of the trays. All other cultural practices were performed using technical recommendations for controlled environment miniature tomato cultivation (Schwarz *et al.*, 2014).

Plant morphological characteristics and fruit quality analysis

All plant morphological characteristics were analyzed when a commercial stage was reached, meaning that when 50% of the plant population of each treatment had at least 30% of fully ripe fruits or visually marketable fruits with the maximum size and shape typical of growth for miniature/ornamental tomato. These agronomic characteristics are based on the morphological descriptors suggested by IPGRI (1995) and were validated by Costa *et al.* (2015) for ornamental peppers:

(P) - Precocity - expressed by the number of days between transplantation and commercial stage;

Dry matter content of shoot (SDM) - parts were dried in oven at 70°C until constant weight and values were obtained by equation:

SDM% = {dry weight (g)/fresh weight (g) x 100};

(PH) Plant height (cm) - measured using a ruler, from the stem bottom until the last fully expanded leaf;

(SD) Stem diameter (mm) - measured above the cotyledon leaves using a digital caliper;

(CR) Plant canopy ratio - obtained from between the longitudinal (LD) and transverse diameters (TD), where the closer the value to 1, more circular is the canopy.

(NL) Number of leaves - expressed by counting the number of leaves per plant;

Number of fruits per plant (NFP);

Number of fully ripe (NR);

(FW) Fruit weight per plant (g) - expressed by the sum of different fruits ripening stages per plant;

(FD) Ripe fruits diameter (cm) - obtained from the longitudinal diameter of 4 fruits from each treatment.

The following fruit quality basic parameters were analyzed by AOAC (2010) and McGuire (1992) methodologies, utilizing 4 fruits from each treatment:

(SS) Soluble solids (°brix);

(AC) Acidity;

SS/AC ratio;

Color (C) - evaluated by means of ripe fruits with the measurement of the colorimetric parameters L*, a*, b* C* and angle Hue (h°) in fruits. The L * coordinate expresses the degree of clarity of the measured color (L = 100 = white; L = 0 = black), C* the intensity of the color and h ° the saturation of the color.

Statistical design and analysis

The trial was conducted in a 2x2 factorial design in a complete randomized scheme, with six replications. The presence (amendment) and absence of H represented the first factor. SPV- 18 cm³ plugs and 50 cm³ plugs - represented the second factor. Each replication was composed of 10 plants. The rate of H per substrate consisted of 2.0% (on volume/volume basis) and followed previous studies recommendations (Bortolin *et al.*, 2016). Data were subjected to an analysis of variance (ANOVA). All computations were performed with ASSISTAT® software (Silva and Azevedo, 2016). Preliminary analysis indicated that PH, and NPP presented a skew and overdispersed distribution, and it was required a transformation to normalize data. Thus, their means were evaluated after square root transformation. Normality of residuals was tested using Shapiro-Wilk test (alpha 5%) and the distribution presented as normal subsequently.

3. Results

Plants grown utilizing 50 cm³ plugs required a shorter period of time to reach the ideal commercial stage - precocity (P). When 18 cm³ plugs were used, this stage was reached at the same time, independently of H amendment (Table 1). This differentiates the 50 cm³ plugs in 5 days (earlier) when compared to 18 cm³ plugs. A difference of 9 or 14 days when 50 cm³ plugs were amended or not with H, respectively, was also observed when comparing to 18 cm³ plugs. 50 cm³ plugs use resulted in plants with a very long stem (Fig. 1 B).

Table 1 - Ornamental/miniature tomato precocity (P) stage reached according to hydrogel amendment and seedlings plugs volume

Plug volume	P (days after transplantation)	
	With hydrogel	Without hydrogel
18 cm³	57	57
50 cm³	43	48

P= when 50% of the plant population had at least 30% of fully ripe fruits or visually marketable fruits with the maximum size and shape typical of growth for miniature/ornamental tomato.

PH values were significant for both factors and their interaction (Tables 2 and 3), with 18 cm³ plugs and H combination reaching 19.63 cm. The general mean height value achieved in this trial (17.1 cm) is typical of the cv. BRS Finestra and is within the values quantified by Scott and Harbaugh (1995) evaluating different miniature tomatoes, ranging from 9 cm with cv. Micro-Tom to 25 cm with cv. Micro-Gold.

Characters of aesthetic significance, such as plant architecture, number, position, and color of fruits, leaves shape and density are some of the reasons that ornamental species of the *Solanaceae* family are admired, being strictly related to plant longevity and to facilitate cultural handlings (Neitzke *et al.*, 2016). One of these traits, NL, is consistent with the cultivar and growing conditions, presenting a significant response for all the studied factors. The interaction of 18 cm³ plugs and H enhanced the NL to 51.6 (Table 2) which can be perceived by the observation of leaves density in Fig. 2 D, but this response was not converted into a greater NFP.

CR represents the aspect of the aerial parts of the plant, where the closer the value to 1, more circular it is the canopy. Therefore, when 50 cm³ plugs were used, a more circular shape was attained (LD/TD = 1.16) (Table 2). This format has a greater visual appeal, which is often decisive in the choice of the consumer to become more attractive and makes it easier to handle (Costa *et al.*, 2015), although with plants being long-stemmed, a visual aspect uncommon for miniature tomatoes was observed, resembling a palm tree shape (Fig. 1 B).

Table 2 - Interaction between hydrogel and seedling plugs volume for plant ornamental/miniature tomato characters

Plug volume	50 cm³	18 cm³
Plant height (cm)		
With hydrogel	16.49 aB	19.63 aA
Without hydrogel	16.30 aA	16.02 bA
Soluble solids (°Brix)		
With hydrogel	4.65 aB	5.35 aA
Without hydrogel	4.50 aB	5.20 aA
Number of leaves (per plant)		
With hydrogel	37.41 aB	51.60 aA
Without hydrogel	37.45 aB	43.88 bA
Canopy ratio		
With hydrogel	1.16 aB	1.32 aA
Without hydrogel	1.23 aA	1.26 aA

Means followed by the same lowercase letters in the columns and capital letters in the lines do not differ by Tukey test at 5% probability.

Table 3 - Hydrogel amendment and seedlings plug volume effect on ornamental/miniature tomato plant characters

Plant characters	Hydrogel		Plug volume	
	With	Without	50 cm³	18 cm³
Stem diameter (mm)	5.53 a	5.31 b	5.29 b	5.55 a
Shoot dry matter (%)	19.49 a	18.37 b	18.31 b	19.55 a
Fruit weight per plant (g)	68.39 a	67.17 b	77.39 a	58.17 b
Number of fully ripe fruits			3.08 a	2.43 b
Number of fruits per plant			9.90 a	6.01 b

Means followed by the same lowercase letters in the columns and capital letters in the lines do not differ by Tukey test at 5% probability.

Fig. 2 - Ornamental/miniature tomato plants visual aspect when precocity stage was reached. (A) from 50 cm³ plugs with hydrogel amendment; (B) from 50 cm³ plugs without hydrogel amendment; (C) from 18 cm³ plugs without hydrogel amendment; (D) from 18 cm³ plugs with hydrogel amendment.

SDM and SD values were significant for both treatments (Table 3). Costa *et al.* (2015) evaluated the quality of ornamental pepper using two substrates and genotypes, founding distinct SDM content responses, with values ranging from 20.58% to 26.54%, corroborating with the best results here found. SD results presented in this study (5.53 mm with H amendment and 5.55 mm from 18 cm³ plugs)

(Table 3) are inferior but consistent with the ones found in the work of Backes *et al.* (2007) with ornamental pepper. They obtained an SD of 6.42 mm as the best result using controlled release fertilizer mixed to a commercial substrate. Even though SD values in this study were significant to H and SPV, only a slight increase was observed amongst treatments.

NFP, NR, and FW values were superior with the use of 50 cm³ plugs (Table 3). With a compact canopy and well-distributed leaves, the photosynthetic process that depends on the interception of light energy most likely was converted into chemical energy in an efficient way, resulting in this positive response.

SS and AC values were significant for SPV and also for the interaction of 18 cm³ plugs with H. The values of 5.35 and 0.61 achieved for SS and AC, respectively, are comparable to 5.37 and 0.65 from cv. Micro-Gold bred by Scott and Harbaugh (1995), ensuring that cv. BRS Finestra produces mild tasting fruits that can be appreciated/consumed.

NI (general mean value of 1.52), FD (general mean value of 3.1 cm), SS/SC ratio (general mean value of 8.38) and C (general mean value of L* 40.67; C* 51.05 and h° 48.51) were not significant (NS) to both treatments. For C values, although being NS, ripe fruits exhibited an intense red coloration (Fig. 1B). This color is favored by consumers, a point which is believed to possess the highest carotenoids content such as β-carotene and lycopene (Kader *et al.*, 1977).

4. Discussion and Conclusions

Plants grown with 50 cm³ plugs, in the presence or absence of H amendment, demanded a shorter period of time to reach the ideal commercial stage - precocity (P). Precocity is a very important attribute, as it would allow the grower to commercialize plants earlier and to reutilize the spaces emptied in the greenhouse benches. But for its recommendation, the fact that PH in this plug volume resulted in an undesired visual aspect displaying a very long stem, needs to be taking in to account.

The 50 cm³ plugs were significant for NFP, NR, NG, and FW characters as well. An efficient interception of light with plants produced using this plugs made most likely converted chemical energy into fruits, being a response of a compact canopy with well-distributed leaves. 18 cm³ plugs were significant for SD, SDM and FW, making evident the advantages of using a smaller volume of substrate, which can be fully employed for the growing of ornamental/miniature tomatoes in 1 dm³ pots.

The use of H resulted in higher SD, SDM and FW values, considered fundamental in the aspect of the plant canopy and its longevity. H and SPV interaction responded differently to the analyzed plant characteristics, with 18 cm³ plugs and H amendment together showing significant responses only for PH and NL.

In conclusion, although several consistent results for plant characters were obtained when 18 cm³ plugs and H were used solely, a combination of both in terms of an optimal aesthetic value and considering all the morphological traits could not be accomplished. Therefore it's necessary to study other elements such as plant nutrition and the use of PGR to complement them, aiming to promote better quality.

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