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Production and fruit quality of watermelon hybrids under different plant spacing[1]

Produção e qualidade de frutos de híbridos de melancia em diferentes espaçamentos de plantio

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HIGHLIGHTS:
The fruit quality of the hybrids degenerates from the seventh day after harvest.
The visual and sensory aspects of watermelon are not affected by plant spacing.
Larger watermelon plant spacing improves crop stabilization, physicochemical quality, and fruit yield.

ABSTRACT: Plant spacing management in watermelon alters plant competition for water, light, and nutrients, influencing fruit yield, morphology, and quality. The study aimed to evaluate the spacing management between plants of two watermelon hybrids in terms of morphology and fruit yield and quality. Two watermelon hybrids (NUN 21613 and NUN 21901) and three plant spacings (0.60, 0.80 and 1.0 m with 2,5 m between rows) were studied in a randomized block design arranged in a 2 × 3 factorial scheme with five replications. Fruit firmness, the content of total soluble solids, visual, and sensorial notes at 0, 7 and 14 days after harvest, length of the main branch of the plant, fresh fruit mass, number of fruits per plant and per hectare, and fruit yield were evaluated from August to December 2018. The greater planting spacing provided better vegetative development, higher yield, and increased resistance of the watermelon fruit to deterioration after harvest. The physicochemical and sensory characteristics of the fruits were not affected by the spacing and hybrids of watermelon in this study.

Key words: *Citrullus lanatus*, main branch length, planting density, fruit appearance, sensorial analysis

RESUMO: O manejo do espaçamento entre plantas na melancia altera a competição das plantas por água, luz e nutrientes, pois a população de plantas influencia a produtividade da cultura, a morfologia do fruto e a qualidade. O objetivo deste trabalho foi avaliar o manejo do espaçamento entre plantas de dois híbridos de melancia quanto à morfologia, produtividade e qualidade dos frutos. Híbridos de melancia (NUN 21613 e NUN 21901) e os espaçamentos entre plantas (0,60, 0,80 e 1,0 m) e 2,5 m entre linhas de plantio foram estudados, no delineamento de blocos ao acaso em esquema fatorial 2 × 3, com cinco repetições. Firmeza do fruto, teor de sólidos solúveis totais, notas visuais e sensoriais aos 0, 7 e 14 dias após a colheita, comprimento do ramo principal da planta, massa fresca do fruto, número de frutos por planta e hectare e rendimento foram avaliados de agosto a dezembro de 2018. O maior espaçamento de plantio proporcionou melhor desenvolvimento vegetativo, maior produtividade e maior resistência do fruto da melancia à deterioração após a colheita. As características físico-químicas e sensoriais dos frutos não foram afetadas pelos espaçamentos e híbridos da melancia neste estudo.

Palavras-chave: *Citrullus lanatus*, ramo principal da planta, densidade de plantio, aparência de fruto, análise sensorial

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Introduction

Brazil is the fourth-largest producer of watermelon (*Citrullus lanatus* Schrad) globally, with 90,447 hectares and 2,090.432 tons of fruit, with an average fruit yield of 23 Mg ha^{-1} (Carvalho et al., 2020). The American cultivar Crimson Sweet accounts for approximately 90% of the Brazilian market; however, the cultivation of watermelon hybrids has increased due to their early cycle and uniform production (Amaral et al., 2016), as the regular cycle ranges from 75 to more than 100 days from seedling/ transplanting to harvest (Santos & Nascimento, 2014).

The spacing between plants influences the size of the fruits and yield of the crop since the high planting density produces more fruits per area but reduces the size, weight, and quantity per plant (Ramos et al., 2009; Silva et al., 2021). Campagnol et al. (2016) reported that the ideal watermelon plant population allows a large leaf area, allowing maximum interception of solar radiation and a balanced distribution between the vegetative and reproductive parts of the plant.

The reduction in plant spacing can positively affect crop production, as seen in other crops (Jiang et al., 2013; Fornah et al., 2020). However, it can also alter metabolism, cycle length, plant size, canopy architecture, and plant photosynthesis capacity (Kavut et al., 2014), lower leaf shading, stimulate growth, internode elongation, decrease leaf area, and reduce the number of ramifications (Taiz & Zeiger, 2017).

Expanding and diversifying the genetic base of the watermelon crop to adapt to other regions and managements has become a necessity (Tavares et al., 2018). According to Cruz & Regazzi (2004), the genotype-environment interaction has an important role in the phenotype composition, which justifies the carrying out of studies to assess its magnitude. Also, there is a lack of information on the agronomic performance of the cultivars available on the market. In this context, the study aimed to evaluate the spacing management between plants of two watermelon hybrids in terms of morphology and fruit yield and quality.

Material and Methods

This study was conducted in the experimental area of the company CA Campinas Pesquisa e Comércio de Sementes located in Uberlândia, Brazil, at 18° 43’ 51.6” S, 48° 24’ 06.2” W, and 834 m above sea level, during the period from August (winter-spring) to December (spring-summer) of 2018. The experimental area was previously cultivated with tomatoes.

The soil in the experimental area was classified as Oxisol (Soil Survey Staff, 2014), of medium texture. The soil presents in the 0-0.20 m layer, 350 g kg^{-1} of clay, 625 g kg^{-1} of sand, 25 g kg^{-1} of silt, pH ($CaCl_2$) of 7.0; 71 mg dm^{-3} of P(resin extractor); 0.7 mmol$_c$ dm^{-3} of K, 46 mmol$_c$ dm^{-3} of Ca, 16 mmol$_c$ dm^{-3} of Mg, 15.3 mmol$_c$ dm^{-3} of H + Al, 78 mmol$_c$ dm^{-3} of cation exchange capacity, 62.7 mmol$_c$ dm^{-3} of sum of bases, and 80.7% of base saturation (V).

The climate of the region is classified as Aw-type (humid tropical with a rainy, hot summer, and dry cold winter), according to Beck et al. (2018). The average annual rainfall and air temperatures are 1,479 mm and 22.3 °C, respectively. The accumulated precipitation during the period was 602 mm. The data were collected at the Laboratory of Climatology (Meteorological Station) of the Federal University of Uberlândia, 35 km from the experimental area. The climatic data during the study period are shown in Figure 1.

The experiment was set as a completely randomized block design arranged in a 2 × 3 factorial scheme with five replications. The factors consisted of two watermelon hybrids (NUN 21613 and NUN 21901) and three plant spacings (0.60 × 2.50, 0.80 × 2.50, and 1,0 × 2.50 m, representing 6,666, 5,000, and 4,000 plants ha^{-1}, respectively).

Each plot was composed of three watermelon rows of 12.5 m long, spaced by 2.5 m between rows comprising 93.75 m^2 per plot. The evaluations in each plot considered only central 10 m, leaving 1.25 m at each end. Thus, the useful experimental area in each plot was 25 m^2.

The watermelon hybrids studied were diploid hybrids with seeds (NUN 21613 and NUN 21901), Crimson Sweet type, dark green bark with clear green stripes, and average weight between 8 and 12 kg. The hybrids have a similar cycle that ranges between 95 and 100 days after seedling transplanting, depending on the climatic condition. On August 10, 2018, the watermelon hybrids were sown in plastic bags (400 mL capacity), with two seeds per bag. After ten days, thinning of the seedlings was performed, leaving only one plant per bag.

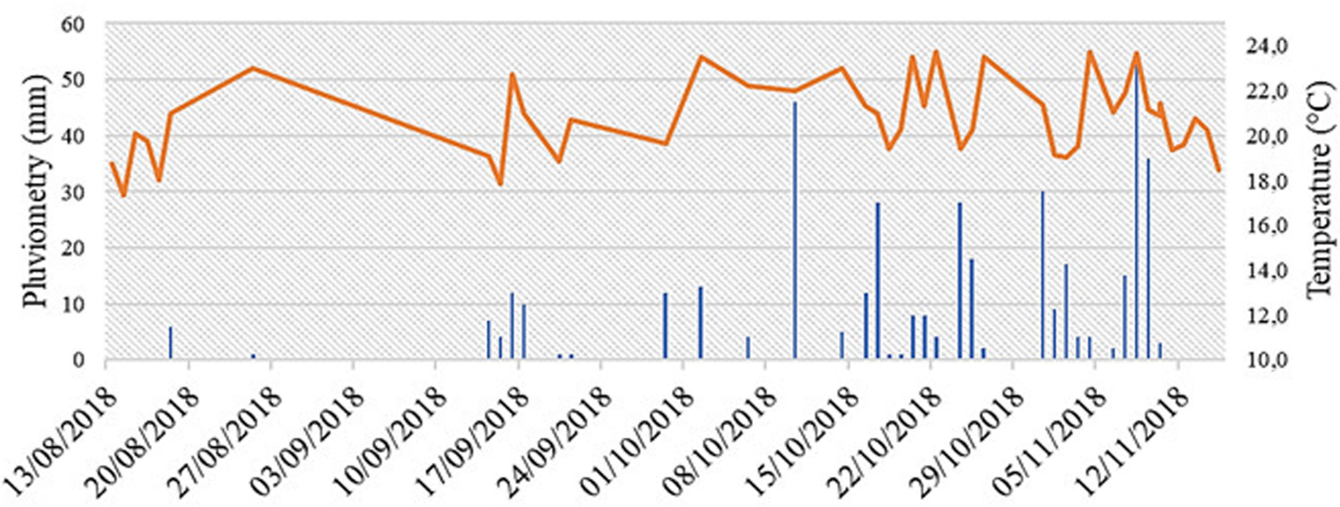

Figure 1. Rainfall and average temperature during the experimental period

The mineral fertilization used at sowing was calculated considering the soil chemical analysis and the recommendations for the expected range of yield (Ribeiro et al., 1999). The fertilizer applied in the sowing furrow for all treatments was 750 kg ha^{-1} of 04-30-10 NPK formulation. During the crop cycle, fertigation (irrigation with soluble fertilizers) was used twice a week, starting the third day after transplanting (DAT). Due to rains in the experimental region, the fertigation was stopped at 65 DAT.

The total amount of fertilizer applied varied according to the plant population, aiming to maintain the same quantity of nutrients per plant within each spacing. For the first 24 days of crop development after transplanting, seven fertigations were performed with a nutrient solution consisting of 7 kg of monoammonium phosphate + 5 kg of magnesium sulfate + 6 kg of potassium nitrate + 0.60 kg of boric acid to every 1,000 plants - the quantity of fertilizer applied to each plot was adjusted according to the population of plants per hectare. The fertigations that occurred from 27 to 62 DAT were 3 kg of monoammonium phosphate + 3 kg of magnesium sulfate + 3 kg of potassium nitrate + 0.6 kg of boric acid applied to every 1,000 plants.

At 65 days after transplanting, the last fertigation consisted of 3.7 kg of potassium nitrate + 8.6 kg of potassium chloride - the quantity applied in each plot was adjusted according to the population of plants per hectare. At the end of the crop cycle, the plots with a spacing of 0.60 × 2.50, 0.80 × 2.50, and 1.0 × 2.50 m received via fertigation, respectively a total of 109.5, 136.9, 180.7 kg ha^{-1} of nitrogen (N); 207.4, 259.3, 342.2 kg ha^{-1} of P_2O_5; 198.6, 248.2, 327.6 kg ha^{-1} of K_2O; 47.5, 59.4, 78.4 kg ha^{-1} of CaO, 24.8, 31.1, 41.0 kg ha^{-1} of MgO, and 7.8, 9.7, 12.8 kg ha^{-1} of boron (B).

The determination of the reference evapotranspiration (ETo) was performed daily by the Hargreaves-Samani equation. The replacement water depth was estimated based on the ETo and the adjusted crop coefficient, with a system equipped with a dripper spaced 0.50 m apart, with the average flow of 4 L h^{-1}, followed the water consumption by the crop during its cycle, on average, a volume of 32 L per plant per day was applied, with water application made twice a week.

The control of invasive plants in the area was carried out with weekly weeding. The control of *Aphis gossypii* (Hemiptera: Aphididae), whitefly *Bemisia tabaci* (Hemiptera: Aleyrodidae), and pickleworm *Diaphania nitidalis* (Lepidoptera: Pyralidae) was carried out with the application of active principle based on Neonicotinoide/Imidacloprid (Commercial product - Actara 250 WG) at a dose of 120 g ha^{-1}, at the spray volume equivalent to 250 L ha^{-1} with a backpack sprayer. There were no problems with disease in the area.

Plant branches were redirected during the crop cycle (combing activity) to avoid their growth on alleys or over other plots. At 25 days after transplanting, two beehives were placed in the experimental area and remained there until 55 DAT to improve flower pollination.

At 62 DAT, the main branch of the plant was assessed. The plants were measured from the stem base until the apical bud. In each plot, five plants were evaluated, and the results were expressed in centimeters. The number of fruits per plant and fruits per hectare was assessed at the harvest. The watermelon harvest was performed when (1) the tendril located on the same node of the fruit dried up, (2) the color of the fruit rind in contact with the soil changes (yellowish), and (3) the resonance of the fruit with the impact made a grave and hollow sound.

The watermelon fruits were counted in 10 m of the central row of each plot. The number of fruits in 25 m^2 (useful experimental area) was converted to the number of fruits per hectare (10,000 m^2) (NFH), and the number of fruits per plant (NFP) was estimated by dividing the respective NFH by the plant population (plants ha^{-1}). The harvested fruits were weighed on an electronic scale obtaining the fruit fresh mass (FFM, kg $fruit^{-1}$). The average fruit weight was multiplied by the NFH to estimate the yield of each treatment per hectare (Mg ha^{-1}). Three fruits of each plot were evaluated for quality - visual note, sensorial note, firmness, and °Brix were assessed at 0, 7, and 14 days after harvest.

The external and internal appearance of the watermelon fruits (visual note - VN) was done following the methodology adopted by Menezes et al. (1998), which uses a subjective scale with notes from 1 to 9, considering the presence, or not, of defects. For internal appearance, the incidence of internal collapse, loose seeds and liquid in the seed cavity were evaluated, being, 1 = rotten fruit; 2 = extremely damaged fruit; 3 = 75% fruit deteriorated; 4 = 50% of the fruit deteriorated; 5 = 50% of the fruit with light damage; 6 = without damage in the fruit rind, pulp firm, seeds connected and, at most, 10% of fruit deterioration; 7 = no damage; 8 = rigid rind, good appearance and firmness, and 9 = rigid rind, excellent appearance and firmness. Fruits, or fruit lots, with notes equal to or lower than 5.0, were considered low quality for consumption.

For fruit firmness, crispiness, and flavor (sensorial note - SN), a slice of the central region of the watermelon fruit was beaten and assessed using the subjective scale with notes from 1 to 9, being, 1 = rotten fruit; 2 = extremely deteriorated fruit flavor; 3 = 75% fruit deteriorated with flavor deteriorated; 4 = 50% of the fruit damaged without taste; 5 = 50% of the fruit with light damage, but with bad taste; 6 = without damage to the fruit, pulp firm and without any deterioration in the taste; 7 = no damage, good taste, and firmness; 8 = great flavor, crispness, and firmness, and 9 = excellent taste, crispness, and firmness. Fruits, or fruit lots, with notes equal to or lower than 5.0, were considered low quality for consumption.

For data homogeneity, the visual and sensory evaluations were performed on the same day by a group of thirty untrained evaluators formed by professors, technicians, and students. The assessment of the fruit firmness was performed using a manual penetrometer with a cylindrical end piece of 12 mm diameter, and the results obtained were expressed in pounds (lb).

For the data collection, a transversal cut of fruit and four readings in the equatorial region of the pulp of the fruit were performed. One of the sampling points was in the center of the watermelon, and the other three points were placed in radial regions equidistant from the center of the fruit avoiding the fruit placenta.

The content of total soluble solids (°Brix) was obtained from the watermelon juice by a diagnostic digital refractometer (Atago® model 4810). The watermelon juice was extracted from a watermelon slice taken from the central region of the pulp of each fruit; three readings of the same sample were performed, and the mean of the three readings was expressed as a percentage.

The results of the factorial "watermelon hybrids × plant spacings" were submitted to the analysis of variance ($p \leq 0.05$) of the sources of variation and their interaction. The means of the factors (watermelon hybrids and plant spacings), or their interactions, were compared by the Tukey test ($p \leq 0.05$) using the Agroestat® statistical software.

Results and Discussion

The development of the main branch of plants at 62 DAT demonstrated significant interaction ($p = 0.0216$) between the hybrids and the plant spacing (Table 1). For all plant spacing studied (0.60, 0.80 and 1.0 m), the main branch length of the NUN 21901 hybrid was less than the lengths observed for the NUN 21613 hybrid, about 45.45, 62.50 and 8.82%, respectively. The watermelon plant spacing of 1.0 m presented the longest main branch for the hybrid NUN 21613, while the longest main branch for the hybrid NUN 21901 was observed in 0.80 and 1.0 m plant spacings.

Increasing the space between plants from 0.60 to 1.0 m reduces plant density from 6,666 to 4,000 plants ha^{-1}, causing a great development of the main branch of the plant, increasing by 15.62 and 54.54% for NUN 21613 and NUN 21901 hybrids, respectively. These results indicate that the hybrid NUN 21901 presented a higher restriction in denser plant spacing than hybrid NUN 21613. The length of the main branch of the NUN 21613 hybrid at 62 DAT ranged between 3.2 and 3.9 m (Table 1), similar to the lengths of the main branch observed by Chaves et al. (2013), which remained between 3 and 5 m range.

Ramos et al. (2009) studied watermelon plant populations of 16,666, 12,500, and 10,000 plants ha^{-1} respectively from plant spacings of 2.0 × 0.30; 2.0 × 0.40 and 2.0 × 0.50 m, respectively, and they did not report differences in the length of the main branch of the plant, up to the time of the opening of the flowers.

Table 1. Main branch length of watermelon plant under different plant spacings at 62 days after transplanting

Watermelon hybrids	Plant spacing (m)		
	0.60 × 2.5	0.80 × 2.5	1.00 × 2.5
NUN 21613	3.2 bA	3.9 aA	3.7 aA
NUN 21901	2.2 bB	2.4 bB	3.4 aB
CV (%)		6.58	

Means followed by the same uppercase letters in rows (comparing the plant spacings) and the same lowercase letter in columns (comparing the watermelon hybrids) do not differ by the Tukey test ($p > 0.05$). CV (%) - Coefficient of variation

Kavut et al. (2014) studied different watermelon plant densities, from 4,762 to 28,571 plants ha^{-1}; the changes in the main branch variable may be related to variations in climatic conditions, soil fertility, and crop management, especially regarding the fertilization routines.

The leaf shading and the suppression of the potential genetic expression in mini-watermelon plant spacing are critical aspects to establish production fields due to the direct effect on photosynthesis. The results observed for the NUN 21901 watermelon hybrid indicated the 1.0 × 2.50 m (4,000 plants ha^{-1}) plant spacing for higher main branch length; however, the plant spacing could be larger than 1.0 × 2.50 m. The closer the plants are placed, the lesser the soil volume available for each plant to explore; consequently, the branches and their leaves capture less luminous radiation, reducing photosynthesis and the ability of plants to accumulate biomass (Campagnol et al., 2016).

The watermelon production parameters assessed presented no significant interaction among hybrids and plant spacing ($p = 0.2056$). The fruit fresh mass (FFM), the number of fruits per plant (NFP) and per hectare (NFH), and yield found for the NUN 21613 hybrid were about 14.65, 29.70, 29.53 and 48.99% higher than the NUN 21901 hybrid (Table 2). These results are a direct consequence of the longer main branch of the plant of NUN 21613, indicating that this hybrid has great genetic potential and is better adapted to the climatic conditions of the region where the study was conducted.

The FFM, NFP, NFH, and yield were superior when the plants were cultivated using the 1.0 × 2.50 m plant spacing, but the number of fruits ha^{-1} was similar ($p > 0.05$) between the 0.80 × 2.50 and 1.0 × 2.50 m plant spacing. The watermelon yield (Mg ha^{-1}) of the largest plant spacing studied (1.0 × 2.50 m) was about 35.23% higher than the yield of the 0.60 × 2.50 and 0.80 × 2.50 m planting spacings.

Ramos et al. (2009) evaluated the effects of planting density on watermelon yield and fruit quality in the plant spacings of 0.30, 0.40 and 0.50 m in six watermelon cultivars. These authors observed FFM ranging from 2.46 to 6.33 kg fruit^{-1}, NFP from 1.8 to 4.4, and yield between 53 and 82.5 Mg ha^{-1}, which were values mostly greater than those obtained in this study for both hybrids, thus, indicating that minor plant spacings increase competition for water, light, and nutrients, producing smaller fruits but increased yield.

Similar results were observed by Resende & Costa (2003), Goreta et al. (2005), and Campagnol et al. (2016) in their studies with plant spacings. Despite the genetic variations or nutritional managements that occurred among these studies,

Table 2. Fruit fresh mass (FFM), number of fruits per plant (NFP), number of fruits per hectare (NFH), and yield of watermelon hybrids under different plant spacings

Factor		FFM (kg fruit^{-1})	NFP	NFH	Yield (Mg ha^{-1})
Watermelon hybrids	NUN 21613	9.23 A	1.31 A	6.43 A	60.00 A
	NUN 21901	8.05 B	1.01 B	4.97 B	40.27 B
Plant spacings	0.60 × 2.50 m	7.83 b	0.77 c	5.10 b	40.37 b
	0.80 × 2.50 m	8.49 b	1.15 b	5.75 ab	49.36 b
	1.0 × 2.50 m	9.61 a	1.56 a	6.25 a	60.67 a
CV (%)	--	9.17	10.56	11.03	15.68

Means followed by the same uppercase letters in rows (comparing watermelon hybrids) and the same lowercase letter in columns (comparing plant spacings) do not differ by the Tukey test ($p > 0.05$). CV (%) - Coefficient of variation all of them indicated that higher plant populations - up to a certain plant density - is a viable strategy to increase fruit yield (Mg ha^{-1}).

Bastos et al. (2008) reported increased watermelon yield as the plant spacing increases, being the widest spacing studied (2.0 × 1.20 m) the best for fruit yield (26.1 Mg ha^{-1}). This fruit production was well below the production observed in the present study for both hybrids, with the highest yield observed in the 1.0 × 1.0 × 2.50 m spacing (60.67 Mg ha^{-1}) (Table 2), which produces about 32,9% more fruits than the spacings of 0.60 × 2.50 and 0.80 × 2.50 m, which presented similar yields. Ramos et al. (2012) observed the highest yields in plant spacings between 0.60 and 0.80 m (42.5 and 45.3 Mg ha^{-1}, respectively). However, Campos (2014) reported the highest yield with 6,000 plants ha^{-1} (2.50 × 0.67 m plant spacing), reaching values above 60 Mg ha^{-1} in March, but did not observe differences between plant spacings in August (winter).

The studies of Ramos et al. (2012) and Cecílio Filho et al. (2015) indicate that denser watermelon plantings maximize land use without compromising yield. The watermelon yield per unit of the area tends to increase with the plant population up to a certain level and then decreases due to the competition among plants. Adams et al. (2019) indicated that the ideal population of plants is with the plant spacing of 0.70 m, being less than the best yield obtained in the present study (1.0 × 2.50 m).

Results observed by Resende & Costa (2003) corroborate with the present study, which obtained lower yields in reduced plant spacings. The authors found a 14 and 58% reduction in the FFM and NFP, respectively, when comparing smaller to wider plant spacings; regarding the yield, the authors observed 45.8, 42.5 and 34.8 Mg ha^{-1} for the plant spacings of 0.40, 0.60 and 0.80 m.

Regarding the quality aspects of the watermelon fruits, no interactions ($p > 0.05$) between factors (watermelon hybrids and plant spacing) were observed for the variables at harvest (day 0) (Table 3) or the fruit visual and sensorial evaluations at any period of assessment. The °Brix, VN, and SN were superior for the NUN 21613 hybrid at harvest (day 0), but the fruit firmness (FF) was about 79.29% inferior for this hybrid compared to the NUN 21901 hybrid.

Bianchi et al. (2018) also observed a distinct response between the mini-watermelon cultivars Rugby and Cuoredolce® at harvest. The mini-watermelon cultivars presented 2.5 and 4.7 lb of firmness (FF), respectively, values within the range found for the watermelon hybrids studied in the present study NUN 21613 and NUN 21901. The reductions in plant population or increase of plant spacing in the present study caused increments to the FF but decrease in the fruit °Brix at harvest (day 0); however, no differences were observed among plant spacings for the VN and SN of the fruits in the first evaluation (day 0).

Araújo Neto et al. (2000) also observed an increase of the watermelon FF of Crimson Sweet cultivar after three days of storage, which remained constant until the end of the experiment (21 DAH). The authors related the increase of firmness to the elasticity of the pulp, which is linked to the reduction of fruit crispness and texture.

Table 3. Fruit firmness (FF), total soluble solids (°Brix), fruit visual (VN), and sensorial notes (SN) of the watermelon hybrids under different plant spacings and periods

Factor		FF (lb)	°Brix	VN	SN
		Days 0 (at harvest)			
Watermelon	NUN 21613	2.80 B	9.86 A	6.11 A	6.63 A
Hybrids	NUN 21901	5.02 A	9.37 B	5.11 B	6.22 B
	0.60 × 2.50 m	3.44 b	10.07 a	5.33^{ns}	6.33^{ns}
Plant spacings	0.80 × 2.50 m	3.92 ab	9.55 ab	5.63	6.54
	1.00 × 2.5 m	4.34 a	9.22 b	5.88	6.40
CV (%)	--	16.82	5.66	12.95	5.35
	--	7 days after harvest			
Watermelon	NUN 21613	3.51^{Int}	9.48 A	6.00 A	5.79 A
Hybrids	NUN 21901	4.95	7.16 B	3.78 B	3.44 B
	0.60 × 2.50 m	3.77^{ns}	7.97^{ns}	4.71^{ns}	4.56^{ns}
Plant spacings	0.80 × 2.50 m	4.30	8.58	5.04	4.79
	1.00 × 2.5 m	4.62	8.40	4.91	4.50
CV (%)	--	13.46	6.81	14.28	14.89
	--	14 days after harvest			
Watermelon	NUN 21613	3.17^{Int}	7.42^{Int}	5.28 A	4.97 A
Hybrids	NUN 21901	3.96	8.57	3.98 B	3.81 B
	0.60× 2.50 m	3.17	8.82	4.17 b	4.00^{ns}
Plant spacings	0.80 × 2.50 m	3.97	7.40	4.54 ab	4.41
	1.00 × 2.5 m	3.54	7.77	5.17 a	4.75
CV (%)	--	13.93	8.34	16.05	15.66

Means in the same moment of evaluation that are followed by the same uppercase letters (comparing watermelon hybrids) or lowercase letters (comparing plant spacings) in the columns do not differ by the Tukey test ($p > 0.05$). CV (%) - Coefficient of variation; ns - Non-significant; Int - Significant interaction between factors ($p > 0.05$)

However, Harker et al. (1997) and Menezes et al. (1998) emphasize that FF is a parameter challenging to measure because of the range of variables that may interfere with the integrity of the pulp of fruits. These variables range from the genetic material and the variability among the fruits in a cultivation area to physiological and biochemical characters, which undergo considerable transformations and dynamics throughout crop development and fruit storage.

The highest watermelon visual and sensorial notes (quality aspects) were observed at harvest (day 0) (Table 3). The NUN 21613 watermelon hybrid presented VN and SN about 19.56 and 6.59% higher than the NUN 21901 hybrid at harvest. The watermelon quality notably decreased their average grades from the harvest to 14 DAH, decreasing about 13.6 and 22.1% for the VN, 25 and 38.7% for the SN, respectively for NUN 21613 and NUN 21901 watermelon hybrids.

No differences were detected among plant spacings for the evaluation of °Brix, visual and sensory aspects at 7 DAH, indicating that plant density has little to no effect on these variables even after a week from the fruit harvest. The differences between the watermelon hybrids continue at this moment of evaluation (7 DAH) for °Brix, visual and sensory aspects, and visual and sensorial aspects at 14 DAH. At this last moment of evaluation (14 DAH), the best VN and SN were observed for the NUN 21901 watermelon hybrid, while no differences were observed among plant spacings for the SN. The watermelon FF presented significant interaction at 7 DAH ($p = 0.0256$) (Tables 3 and 4).

At 14 DAH, the FF ($p = 0.0001$) and the fruit soluble solids (°Brix) ($p < 0.0000$) (Tables 3 and 4) presented significant interaction between the factors. Fruit storage affected the °Brix of each hybrid differently, decreasing about 24.7% for NUN 21613 hybrid and 8.5% for NUN 21901 hybrid on average for

Table 4. Watermelon soluble solids (°Brix) under different plant spacings at 14 days after harvest

Watermelon	Plant spacing (m)		
	0.60 × 2.50	0.80 × 2.50	1.0 × 2.50
NUN 21613	9.11 aA	7.08 bA	6.08 bB
NUN 21901	8.54 abB	7.72 bA	9.46 aA
CV (%)		8.34	

Means followed by the same lowercase letter in the lines (compare plant spacings for the same hybrid) and the uppercase letters in the columns (compare watermelon hybrids for the same plant spacing) do not differ by the Tukey test ($p > 0.05$). CV (%) - Coefficient of variation

all plant spacing after two weeks of the harvest - from 0 to 14 DAH. Reductions in watermelon °Brix with storage period were also reported by Kyriacou et al. (2016), who observed that the general content of sugars decreased after a certain period of the anthesis and the watermelon °Brix response is variable among the genetic materials.

The greatest watermelon firmness at 7 DAH was observed in the NUN 21901 hybrid at 1.0 × 1.0 m plant spacing (Table 5), while the lowest FF was observed for the NUN 21613 hybrid in any planting spacing.

At 14 DAH, the watermelon FF was similar between hybrids for the 0.80 × 2.50 and 1.0 × 2.50 m plant spacings, and the FF was not affected by plant spacing for the NUN 21901 hybrid. However, the 0.60 × 2.50 m plant spacing presented the lowest FF for the NUN 21613 hybrid, being a plant spacing not indicated for the cultivation of this hybrid considering long periods of fruit storage.

The watermelon total soluble solids (°Brix) at 14 DAH (Table 4) were the greatest for the NUN 21613 hybrid in the 0.60 × 2.50 m plant spacing. This result is related to the low FF (Table 5) and the degradation of the fruit pulp, highlighting the disadvantages of such plant spacing for this hybrid. For the NUN 21901 hybrid, the greatest °Brix observed was for the plant spacing of 1.0 × 2.50 m. In this case, since no low FF is associated with the result, it might be a consequence of the low plant population due to the great plant spacing. Fewer plants would cause lower inter-competition and more resources available to produce more photo-assimilates, thus, increasing °Brix.

Bastos et al. (2008) also reported that the plant spacings of 2.0 × 1.20, 2.0 × 0.60, and 2.0 × 0.30 m did not affect the °Brix of the Mickylee PVP cultivar in an equatorial region (Ceará state, Brazil), indicating that watermelon °Brix can change, or not, depending on edaphoclimatic conditions and watermelon cultivars.

Table 5. Watermelon firmness (FF) under different plant spacings at 7 and 14 days after harvest

Watermelon hybrids	Plant spacing (m)		
	0.60 × 2.50	0.80 × 2.50	1.0 × 2.50
		7 days after harvest	
NUN 21613	3.29 aB**	3.83 aB	3.41 aB
NUN 21901	4.26 bA	4.76 bA	5.84 aA
CV (%)		13.46	
		14 days after harvest	
NUN 21613	1.98 bB**	3.91 aA	3.60 aA
NUN 21901	4.35 aA	4.04 aA	3.48 aA
CV (%)		13.93	

** - Significant at 0.05, respectively. Means followed by the same lowercase letter in the lines (comparing plant spacings for the same hybrid in rows), and uppercase letters in the columns (comparing watermelon hybrids for the same plant spacing in the column), do not differ by the Tukey test ($p > 0.05$). CV (%) - Coefficient of variation

The content of total soluble solids (°Brix) is one of the most relevant factors for marketing and acceptance of the watermelon fruit. The °Brix is related to the sweetness of the fruit, which is the result of the levels of glucose, fructose, and sucrose; contents of these sugars are very variable among watermelon cultivars and the maturity stage (Kyriacou et al., 2016). According to Kyriacou et al. (2018), the majority of the watermelon cultivars grown present °Brix ranging between 10 and 13; cultivars with °Brix of 8 and 10 are considered as of good quality, and the cultivars with °Brix greater than 10 as of excellent quality. In the present study, the °Brix of the NUN 21613 and NUN 21901 hybrids at harvest were 9.37 and 9.86, respectively, classified as good quality fruits.

Conclusions

1. The larger planting spacing provides better vegetative development, higher yield, and increased resistance of the watermelon fruit to deterioration after harvest.

2. The physicochemical and sensory characteristics of the fruits were not affected by the spacing and hybrids of watermelon in this study.

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