horticultura brasileira

Research

CAMPOS, AMD; LUZ, JMQ; SANTANA, DG; MARQUEZ, GR. 2019. Influences of plant density and fruit thinning on watermelon hybrid production cultivated in different seasons. *Horticultura Brasileira* 37: 409-414. DOI - http://dx.doi.org/10.1590/S0102-053620190408

Influences of plant density and fruit thinning on watermelon hybrid production cultivated in different seasons

Antônio Marcos D Campos [1]; José Magno Q Luz [2]; Denise G Santana [2]; Guilherme R Marquez [2]

[1]Basf Vegetable Seeds, Uberlândia-MG, Brasil; antonio.campos@vegetableseeds.basf.com; [2]UFU, Uberlândia-MG, Brasil; jmagno@ufu.br; denise.santana@ufu.br; grepeza@gmail.com

ABSTRACT

Brazilian watermelon productivity is not efficient when compared to the largest producer countries, due to abiotic and biotic factors. Some of the difficulties are because of a small number of studies on this crop in Brazil. The aim of this study was to evaluate the effects of plant density and fruit thinning on two commercial watermelon hybrids (Talisman and Youlie), using trials which were carried out in two different seasons (April - July and August - November). The experiment was conducted in Uberlândia-MG and consisted of two managements of fruit position (A-basal and B-distal) and four plant densities (3,000, 4,000, 5,000 and 6,000 plants/ha). In season 1, the distal management was the most productive in relation to all cultivation densities. The distal management shows higher productivity in both hybrids, with greater increase in mass, productivity and ^{0}Brix content in hybrid Talisman, however with lower density, firmness and internal cavity compared to hybrid Youlie. Weather conditions determined the influence of fruit management on watermelon crop. Cultivation during the hottest period and with a better water supply (season 2), basal management (A) showed a performance similar to the distal management. At this time, hybrid Talisman surpassed hybrid Youlie concerning productivity, average mass, fruit density, firmness and internal cavity. In both seasons, higher densities are related to higher productivities. Hybrid Talisman showed higher productivity in cultivation from April to July (season 1) under distal fruit management.

Keywords: *Citrullus lanatus*, spacing, fruit position, hybrids.

RESUMO

Densidade de plantas e desbaste de frutos na produção de híbridos de melancia, em diferentes épocas

A produção brasileira de melancia é menos eficiente se comparada aos principais países produtores devido a fatores bióticos e abióticos. Parte das dificuldades vem da escassez de estudos sobre a cultura no Brasil. Em razão disso, objetivou-se avaliar os efeitos da densidade de plantas e do desbaste de frutos em dois híbridos comerciais de melancia (Talisman e Youlie), a partir de ensaios realizados em duas épocas (abril - julho e agosto - novembro). Além das duas cultivares comerciais utilizadas, o experimento, conduzido em Uberlândia-MG, consistiu de dois manejos de posição de frutos (A-basal e B-distal) e de quatro densidades de plantas (3.000, 4.000, 5.000 e 6.000 plantas/ha). Na época 1 o manejo distal é o mais produtivo em todas as densidades de cultivo. O manejo distal revela maior produtividade em ambos híbridos, com maior incremento de massa, produtividade e teor de ^{0}Brix no híbrido Talisman, porém menor densidade, firmeza e cavidade interna que o híbrido Youlie. As condições climáticas determinam a influência do manejo de frutos no cultivo de melancia. O cultivo em época mais quente e com melhor aporte hídrico (época 2), o manejo basal (A) apresenta desempenho semelhante ao manejo distal. Nesta época, o híbrido Talisman supera Youlie em produtividade, massa media, densidade de frutos, firmeza e cavidade interna. Nas duas épocas, maiores densidades relacionam-se a maiores produtividades. O híbrido Talisman apresenta maior produtividade em cultivo entre abril e julho (época 1) sob manejo distal de frutos.

Palavras-chave: *Citrullus lanatus*, espaçamento, posição de frutos, híbridos.

Received on May 13, 2019; accepted on September 24, 2019

Watermelon (*Citrullus lanatus*) is an excellent source of vitamins, minerals and antioxidants like lycopene, carotenoid responsible for the red color and related to protection against chronic health problems like cancer insurgence and cardiovascular disorders (Naz *et al*., 2014; Suwanaruang *et al*., 2016; Ali *et al*., 2017).

Although Brazil is the world's fourth largest watermelon producer, the biggest challenge is the low average productivity (22,5 t ha^{-1}) (Guo *et al*., 2013), which ranks the Country the 38th worldwide producer (Campagnol *et al*., 2012; Fao, 2010; Agrianual, 2014). In order to achieve better performance, adjust agricultural management to meet market demands concerning quantity and quality is essential.

To reach watermelon maximum potential, solar radiation and photoassimilate production for fruit formation must be efficient (Parry *et al*., 2010). Thus, managing the amount of fruits is crucial, being extra fruit thinning a potential strategy, due to larger quantities of photoassimilates produced for few fruits, allowing fruits reach size, shape and mass desired by consumers (Lins *et al*., 2013).

Variations in cultivation spacing also promote alterations in plant development. An increase in density, despite providing increased production, the fruit produced will be smaller, since fruit mass is inversely proportional to the increase in density (Goreta *et al*., 2005). Careful management of the area stand provides fruits at a size required by the market. However, we emphasize the importance of further studies on optimal density (Milanez, 2010).

Watermelon quality is determined by several factors: size, appearance, maturity degree, sugar content, texture, pulp firmness, water content as well as internal defect (Kyriacou *et al.*, 2016; Lv *et al.,* 2015; Soteriou *et al.*, 2014). Influences of plant density on any qualitative traits had been already studied for other cucurbits such as melon (*Cucumis melo*) (Kultur *et al.*, 2001). Information on the magnitude of this trait in watermelon is still incipient, though.

Studies on optimal density and thinning management can help out increasing watermelon production (Dong *et al.*, 2012), since effects of plant population on productivity are not completely known. These days, recommendations which can be found in literature for thinning management and population density are based on old cultivars or on empirical observations conducted by producers and technicians. Identifying the best managements will lead to an increase in production efficiency, with productive gains for farmers and the development of producer regions.

Given the above, this study aims to evaluate the effects of plant density and fruit thinning on two commercial diploid watermelon hybrids, *Crimson sweet*, using a trial carried out in two different seasons (April - July and August - November).

MATERIAL AND METHODS

This study was carried out in two different seasons: between April and July (autumn-winter) and between August and November (winter-spring) in the same year, on the experimental farm of Bayer Vegetable Seeds, located in Uberlândia (18°54'41''S, 48°15'21''W, altitude 887 m), Southeast region of Brazil, in 2013. Direct sowing was performed in both seasons, first cycle on April 10 and, second cycle, on August 10. The soil was classified as Red-Yellow Latosol (Embrapa, 2006), showing nearly flattened topography (season 1: 10%; season 2: 15%)

A randomized complete block design with five replicates, arranged in split plot scheme, 4 x 2 x 2, was used. In the plots, we distributed four spacings between plants (1.33 m), (1 m), (80 cm) and (67 cm) and 2.5 m spacing between lines, which resulted in densities of 3,000, 4,000, 5,000 and 6,000 plants/ha. In the subplots, we evaluated two fruit thinning managements [Management at position A (Basal, up to 8^0 node) and Management at position B (Distal, between 12^0 and 16^0 node); and two commercial hybrids with fruits type *Crimson sweet* (Talisman and Youlie). Each split plot consisted of three 8-meter cultivation lines, considering useful split plot only the three plants of the central line. Thus, we tried to reduce the interference between managements. Twelve plants per plot were evaluated, each plant conducted with only one fruit, similar management to the one carried out by almost all producers. Final value of each split plot consisted of the average of fruits of the three plants.

Soil was harrowed and we built seedbeds measuring 50-m long x 40-cm wide x 15-cm high. Moreover, level curves were built, aiming to reduce damages caused by rain water, protecting the experiment and soil, mainly, in the second season, when higher rainfall was noticed. After building the seedbeds, planting fertilizations were performed and sprinklers were installed; then, mulching was applied.

Planting fertilization was manually performed, using 7.5; 45 and 22.5 grams of potassium/pit, respectively, using the formulation (4-14-8) and Yoorin K (14% P_2O_5; 16% Ca; 4% Mg; 8% Si). Top dressing fertilization consisted of 150 g of formulation 20-00-20, 70 g potassium sulphate and 12.5 grams of super simple/plant, respectively, splitted in three parts: 20, 40 and 60 days after sowing. Nutrients were provided according to the recommendation for the crop, based on the absorption curves built by Bayer in partnership with government agencies and based on soil analyses performed before the experiment installation. These analyses showed the following characteristics of the soil: pH= 5.4; MO= 2 dag kg^{-1}; T= 5.1 cmolc dm^{-1}; V= 39% (season 1) and pH= 6.9; MO=1.9 dag kg^{-1}; T= 6.3 cmolc dm^{-1}; V= 74.6% (season 2).

Plants were irrigated through conventional sprinkler system; spacing between emitters was 20 cm, using an average flow rate of 4 L h^{-1}. Irrigation project was sectorized: each plot had a water depth compatible with the population density. Each plant was irrigated using 35 liters water. Two weekly irrigations were performed, aiming to deduct, from the water depth, the necessary water to be applied.

The local average temperature was 21.5°C, in the first season (April-July), average maximum temperature 27°C, average minimum temperature 15°C and rainfall 283 mm. In the second season (August-November), the average temperature was 23.2°C, average maximum and minimum temperatures were 29.4 and 16.9°C, respectively, and rainfall 298 mm.

Harvest was manual, 45 days after flowering, collecting 12 fruits per plot (three per split plot), evaluating the following traits: average mass and fruit density, total soluble solids (^{0}Brix), firmness and pulp color, presence of internal cavity and productivity. The values of average fruit mass (kg/fruit) were obtained using average values of the split plot. Productivity (t ha^{-1}) was estimated using values of the mass from each split plot multiplied by number of plants/ha that each plot represented.

Weight and fruit volume ratio was used to estimate fruit density (kg L^{-1}); the fruit volume was estimated using the water displacement caused by the fruit, measured in a millimeter bucket. ^{0}Brix (%) was estimated in a central portion of the fruit pulp with a refractometer. Firmness (lb) was evaluated using a penetrometer (pound reading), performing four readings in fruit: the first, 1 cm from the center of the fruit (avoiding the most fibrous and hard part of the endocarp) and other three readings, in radial regions, avoiding the measurement in placental part. The value considered for each fruit was the average of the four evaluations. For color and presence of internal cavity, we used a note scale from 1 to 9, considering note 9 related to the greatest commercial interest. The used scale was developed by the company itself, as a result of years of trials and evaluations, considering the following: note 1= white pulp; note 2= white pulp, pink color in placental parts; note 3= 50% white and 50% pink pulp; note 4= uniformly light pinkish pulp; note 5= uniformly pinkish pulp; note 6= light red pulp; note 7= red pulp; note 8= dark red pulp and; note 9= intense dark red pulp.

The evaluated traits were submitted to ANOVA F test and polynomial regression was used to study plant density. Statistical analyses were performed using computer statistical software SISVAR 5.3 (Ferreira, 2008). We highlight that the experiments were carried out individually and then joint analysis of data was performed, comparing the averages in each kind of management (management A= basal and management B= distal) using Tukey test (α=0.05).

RESULTS AND DISCUSSION

Season 1 (April - July)

No significant interaction among fruit managements, plant density and cultivars was noticed, for any evaluated parameter, from April to July (autumn-winter). We noticed double interaction between spacing and fruit management for fruit productivity (Figure 1), with linear adjustment for both managements (basal and distal), considering distal management superior to basal management for all spacings.

An increase in density promoted a substantial increase in productivity (Figure 1). Managing the double population comparing to the initial (6,000 plants/ha) provided an increase in productivity of 75.2% in basal management and 94.5% in distal management. Watermelon cultivation in a density of 3,000 plants/ha using the distal management showed productivity 12.5% superior comparing to basal management. For cultivation, at a denstity of 6,000 plants/ha fruit productivity in distal management was 24.7% superior comparing to basal management.

Adlan & Abu-Sarra (2018) stated that watermelon yield per area unit tends to increase with plant density up to a certain level and afterwards it tends to decrease due to competition between plants; the authors found an optimum spacing of 70 cm. Cecílio Filho *et al.* (2015) highlighted that higher planting density for watermelon cultivation, allows to maximize land use without compromising productivity.

Resende *et al.* (1998) evaluated spacings from 40 to 80 cm between cucurbit plants and observed that the optimum spacing for watermelon crop ranged from 60 to 80 cm, corresponding to productivity of 42.5 t ha^{-1} and 45.3 t ha^{-1}, respectively. This result was also found in this study, with exception for spacing 67 cm which resulted in a productivity of 57.5 t ha^{-1} (Figure 1). This variation can be attributed to optimum technical management conditions adopted and genetic potential of the selected hybrids, which provide higher production and more uniform fruits (Amaral *et al.*, 2016).

Interaction between management of fruits and hybrids was significant for average fruit mass, fruit density, firmness, internal cavity and fruit productivity (Table 1). Distal management was superior to basal management for the two hybrids related to average fruit mass. Hybrids did not show any differences in management A cultivation. In management B, hybrid Talisman showed an average mass 26.9% superior in comparison to Youlie.

No difference between managements for density and firmness of fruits in hybrid Youlie and internal cavity in hybrid Talisman was noticed. Cultivation of hybrid Talisman in management A resulted in density and firmness 6 and 21.1% superior to management B,

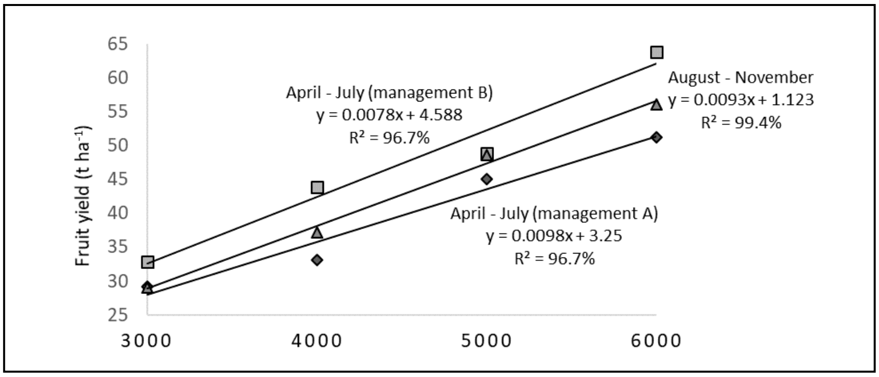

Figure 1. Production performance of watermelon hybrids, under two fruit thinning types, management A (basal): Fruit setting up to the 8th node and management B (distal): Fruit setting between the 12nd and 16th nodes, according to plant density in season 1 (April-July) and in season 2 (August-November). Uberlândia, UFU, 2013.

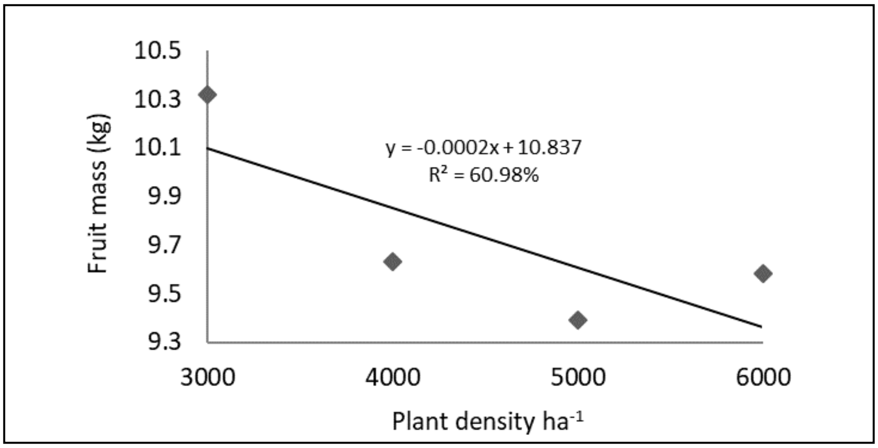

Figure 2. Average fruit mass of watermelon according to plant density in season 1 (April-July). Uberlândia, UFU, 2013.

respectively (Table 1).

No difference between hybrids for density, firmness, internal cavity and productivity of fruits under basal management was achieved. In distal management, Youlie stood out in relation to Talisman in 5, 16.3 and 16.4% for density, firmness and fruit internal cavity, respectively. Hybrid Talisman cultivation in management B resulted in a productivity 27.7% superior when compared to management A. Hybrid Youlie cultivation in management B resulted in internal cavity and productivity 16.4 and 10.8 superior to management A, respectively. The authors also observed that under management B (distal), productivity of hybrid Talisman was superior to hybrid Youlie in approximately 24.9% (Table 1).

Although no interaction between hybrid and management for ^{0}Brix and pulp color was verified, the variables revealed an isolated effect of such factors (Table 2). Management B (distal) favored ^{0}Brix and pulp color, being 4 and 5% superior to management A, respectively. Hybrid Youlie showed ^{0}Brix 3.9% superior to hybrid Talisman.

The results confirmed that the management adopted by the producers, conducting the plants with fruits on the nodes farther from the stem (management B) is feasible, since this management provided fruits with higher mass and productivity for both hybrids, making this management the most profitable for farmers.

The results found in this study corroborate the results obtained by Ding & Syazwani (2012) studying watermelon fruit management (1 = 8^o - 11^o node, 2 = 13^o - 16^o node and 3 = 18^o - 21^o node), concluded that more distal managements show fruits with higher mass, better quality attributes, higher ^{0}Brix and more intense red color.

In indeterminate-growth-habit vegetable species, such as watermelon, sprouts, flowers and fruits developed progressively in the same plant due to continuous flowering and fruiting. Thus, the fruits of one plant compete strongly among each other for available assimilates, which affects fruit size, as well. According to Njoroge & Reighard (2007), photoassimilate limitation can lead to smaller fruits.

Thus, setting and development of the fruit in a more advanced stage of the plant (distal management) may have provided greater stability for water absorption and nutrient uptake, larger photosynthetic area by thinning basal fruits, contributing to photoassimilate accumulation in distal fruits.

Maximum average fruit mass (10.32 kg) was related to density of 3,000 plants/ha (Figure 2). Superior densities resulted in linear reduction of fruit mass, which was also reported in studies carried out by Bastos *et al.* (2008), evaluating the effect of spacings from 0.3 to 1.2 m, between plants, on watermelon crop.

This result was expected due to a higher competition for light, water and nutrients at higher densities. The results found in this study suggested that fruits formed on basal nodes are smaller, in mass, in comparison to fruits formed in distal nodes. Moreover, an increase in density may reduce interception of solar radiation by the leaves of the lower portion of the plant, which results in a decrease in their photosynthetic efficiency, it means, the amount of photoassimilates directed to the fruits (Campagnol *et al.*, 2016).

Season 2 (August - November):

No significant interaction among fruit managements, density of plants and cultivars, fruit management and plant density, managements of fruits and cultivars and density of plants and cultivars for any evaluated parameter from August to November (winter-spring) was noticed. Thus, we evaluated isolate effects of these factors.

Fruit average mass, fruit density, ^{0}Brix, firmness, internal cavity of fruits did not differ between fruit managements (distal and basal). Basal management showed fruits presenting color 8.6% superior to distal management (Table 3).

Hybrid Talisman stood out for productivity, average mass, fruit density, firmness and internal cavity, being 13; 14.6; 6.1; 12.8 and 11.6% superior to Youlie, respectively (Table 3). ^{0}Brix was 3.8% superior in hybrid Youlie, though.

Hybrid Talisman showed largest internal cavity and greater firmness. We highlight that larger internal cavity is related to a less resistance to transport and handling (Dalastra *et al.*, 2016). Pulp firmness is essential for postharvest shelf life (Silva *et al.*, 2017).

The lack of significant responses between managements in season 2 is due to favorable weather conditions for watermelon development. Higher temperature during this period favored photoassimilate accumulation, as well as water availability potentiated liquid

Table 1. Performance of hybrids Talisman and Youlie related to average fruit weight, fruit density, pulp firmness, internal cavity and productivity according to management A (basal) and B (distal) in season 1 (April-July). Uberlândia, UFU, 2013.

Hybrids	Mass (kg)		Fruit density		Firmness (lb)		Internal cavity (note)		Productivity (t/ha)	
	Management		Management		Management		Management		Management	
	A	B	A	B	A	B	A	B	A	B
Talisman	9.3aB	11.8aA	0.83aA	0.78bB	2.30aA	1.90bB	6.1aA	5.5bA	41.2aB	52.6aA
Youlie	8.5aB	9.4bA	0.80aA	0.82aA	1.97aA	2.21aA	5.5aB	6.4aA	38.0aB	42.1bA
DMS	0.78	0.78	0.034	0.034	0.32	0.32	0.69	0.69	3.5	3.5
CVS (%)	9.48		6.7		29.22		20.39		10.17	

Averages followed by lowercase letters in column and uppercase letters in line do not differ significantly (Tukey test, 5%); Management A (basal: fruit setting up to the 8th node); management B (distal: fruit setting between the 12th and 16th node).

photosynthesis. Due to the fact that in high temperatures, plants sweat more, pull more water from the ground, consequently larger amounts of nutrients enter the plants and actively take part in metabolism. Thus, greater chances of fruit development are possible, allowing them to be better formed, even in the first positions of the plant (management A-basal)

Given the above, management A (basal) during season 2 showed an increased effect, making it similar to management B (distal), considered by producers to be the best thinning management.

Higher temperatures are also related to the increased pollination rate, which resulted in higher fruit setting (Noh *et al*., 2012), which may have favored the basal management.

Plant density presented an isolated effect, with linear increase in productivity, with an increase in density (Figure 1). In the evaluated maximum density (6,000 plants/ha) productivity was 92.9% superior to the half plant density (3,000 plants/ha).

Joint analysis between seasons for each hybrid

No interaction among season, fruit management and plant density in joint analysis was verified, both for hybrid Talisman and for Youlie.

For hybrid Youlie, significant interaction between fruit management and season for ^{0}Brix and fruit firmness was noticed. ^{0}Brix was superior in season 1, for both managements. In season 2, no difference between managements occurred and in season 1, distal management was superior to the basal. For fruit firmness, we observed fruits 13.7% firmer in cultivation in season 2. The other variables did not differ among each other.

For hybrid Talisman, significant interaction between fruit management and season for average mass and productivity of fruits and ^{0}Brix was verified. Season 1 provided mass accumulation 13.85 superior to season 2 in distal management of fruits, being this management the one which favored mass accumulation in season 1, compared to basal management. Fruit productivity did not differ between seasons in basal management. For distal management, season 1 produced 9% more fruits than season 2. In both seasons, distal management stood out, showing productivity superior to basal management. Season 1 showed higher ^{0}Brix values than season 2 for both managements. However, the managements themselves did not differ between each other, in both seasons. We highlight that alter planting season determines alteration in development environment for plants, which affect significantly productivity and fruit quality (Mota *et al*., 2009). However, the response varies according to the cultivar, considering that some are more plastic and can adapt better to alterations with close productivities, as observed for hybrid Youlie.

In Talisman, higher productivity is related to cultivation from April to July under fruit distal management. Oliveira *et al*. (2015) found better performance in watermelon cultivation in August planting, being productivity superior to the one found for the best performance obtained in this study (64.92 t ha^{-1}).

In season 1, distal management showed to be the most productive in all cultivation densities. Distal

Table 2. ^{0}Brix and pulp color values according to management A (basal) and B (distal) and hybrids Talisman and Youlie performance in season 1 (April-July). Uberlândia, UFU, 2013.

Management	^{0}Brix (%)	Color (note)
A	10.03 b	5.39 b
B	10.44 a	5.67 a
DMS	0.37	0.28
CV (%)	6.31	15.22
Hybrids		
Talisman	10.04 b	5.51 a
Youlie	10.43 a	5.53 a
DMS	0.37	0.09
CV (%)	6.31	15.22

Averages followed by lowercase letters in column do not differ significantly (Tukey test, 5%); Management A (basal: fruit setting up to the 8th node); management B (distal: fruit setting between the 12th and 16th node).

Table 3. Values of fruit average weight, fruit density, ^{0}Brix, pulp firmness, pulp color, internal cavity and productivity according to managements A (basal) and B (distal) and hybrids Talisman and Youlie performance in season 2 (August-November). Uberlândia, UFU, 2013.

Management	Productivity (t/ha)	Weight (kg)	Fruit density	^{0}Brix (%)	Firmness (lb)	Color (note)	Internal cavity (note)
Basal (A)	42.6 a	9.49 a	0.84 a	8.90 a	2.33 a	5.80 a	7.30 a
Distal (B)	42.8 a	9.55 a	0.84 a	8.91 a	2.33 a	5.34 b	7.52 a
Hybrids							
Talisman	45.39 a	10.2 a	0.87 a	8.74 b	2.47 a	5.64 a	7.81 a
Youlie	40.12 b	8.9 b	0.82 b	9.07 a	2.19 b	5.49 a	7.0 b
DMS	2.63	0.58	0.03	0.26	0.15	0.40	0.38
CVS (%)	15.82	17.04	5.93	6.13	19.62	13.84	10.22

Averages of each management followed by lowercase letters in column do not differ significantly (Tukey test, 5%).

management shows higher productivity in both hybrids, with an increase in mass, productivity and ^{0}Brix content in hybrid Talisman, lower density, firmness and internal cavity than hybrid Youlie, though.

Weather conditions determined the influence of fruit management on watermelon crop. Cultivation during hotter weather and better water supply (season 2), basal management (A) showed performance similar to distal management. In this season, hybrid Talisman surpassed Youlie in relation to productivity, average mass, fruit density, firmness and internal cavity. In the two seasons, higher densities are related to higher productivities.

Hybrid Talisman showed higher productivity during cultivation between April and July (season 1) under distal fruit management.

ACKNOWLEDGEMENTS

The authors thank Bayer Vegetable Seeds and FAPEMIG (Foundation for Research Support of Minas Gerais) to support this study.

REFERENCES

ADLAN, AM; ABU-SARRA, AF. 2018. Effects of plant density on yield and quality of watermelon (*Citrullus lanatus* thunb) under Gezira conditions, Sudan. *Net Journal of Agricultural Science* 6: 1-5.

AGRIANUAL – Anuário da Agricultura Brasileira. 2014. *Cultura da melancia*. Available at http://www.agrianual.com.br. Accessed July 15, 2014.

ALI, MM; HASHIM, N; BEJO, SK; SHAMSUDIN, R. 2017. Rapid and nondestructive techniques for internal and external quality evaluation of watermelons: A review. *Scientia Horticulturae* 225: 689-699.

AMARAL, U; SANTOS, VM; OLIVEIRA, AD; CARVALHO, SL; SILVA, IB. 2016. Influência da cobertura morta em mini melancia Sugar baby no início da frutificação. *Revista Verde de Agroecologia e Desenvolvimento Sustentável* 11: 164-170.

BASTOS, FGC; AZEVEDO, BM; REGO, JL; VIANA, TVA; DAVILA, JHT. 2008. *Efeitos de espaçamentos entre plantas na cultura da melancia na Chapada do Apodi, Ceará*. Available at http://www.redalyc.org/pdf/1953/195317754008.pdf. Accessed January 3, 2016.

CAMPAGNOL, R, MELLO, SC, BARBOSA, JC. 2012. Vertical growth of mini watermelon according to the training height and plant density. *Horticultura Brasileira* 30: 726-732.

CAMPAGNOL, R; MATSUZAKI, RT; MELLO, SC. 2016. Condução vertical e densidade de plantas de minimelancia em ambiente protegido. *Horticultura Brasileira* 34: 137-143

CECÍLIO FILHO, LAB; FELTRIM, AL; CORTEZ, JWM; GONSALVES, MV; PAVANI, LC; BARBOSA, JC. 2015. Nitrogen and potassium application by fertigation at different watermelon planting densities. *Journal of Soil Science and Plant Nutrition* 15: 928-937.

DALASTRA, GM; ECHER, MM; KLOSOWSKI, ES; HACHMANN, TL. 2016. Produção e qualidade de três tipos de melão, variando o número de frutos por planta. *Revista Ceres* 63: 523-531.

DING, P; SYAZWANI, S. 2012. Postharvest quality of red-fleshed watermelon affected by fruit position in vine. *Journal of Ornamental and Horticulture Plants* 2: 213-224.

DONG, H; LI, W; ENEJIA, E; ZHANG, D. 2012. Nitrogen rate and plant density effects on yield and late season leaf senescence of cotton raised on a saline field. *Field Crops Research* 126: 137-144.

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. 2006. *Sistema Brasileiro de Classificação de solos, 2ª edição*. Brasília: Embrapa. 306p.

FAO – Food Agriculture Organization. 2010. *Countries by commodities – Top Production*. Available at http://www.faostat.fao.org/site/339/default.aspx. Accessed July 20, 2014.

FERREIRA, DF. 2008. SISVAR: Um programa para análises e ensino de estatística. *Revista Symposiu*m 6: 36-41.

GORETA, S; PERICA, S; DUMICIC, LB; ZANIC, K. 2005. Growth and yield of watermelon on polyethylene mulch with different spacing and nitrogen rates. *Hortscience* 40: 366-369.

GUO, S; ZHANG, J; SUN, H; SALSE, J; LUCAS, WJ; ZHANG, H; ZHENG, YL; REN, Y; WANG, Z; MIN, J; GUO, X; MURAT, F; HAM, B; ZHANG, Z; GAO, S; HUAN, MG; XU, Y; ZHONG, S; BOMBARELY, A; MUELLER, LA; ZHAO, H; HE, H; ZHANG, Y; ZHANG, Z; The draft genome of watermelon (*Citrullus lanatus*) and resequencing of 20 diverse accessions. *Nature Genetics* 45: 51-58.

KULTUR, F; HARRISON, HC; STAUB, JE. 2001. Spacing and genotype affect fruit sugar concentration, yield, and fruit size of muskmelon. *Hortscience* 36: 274-278.

KYRIACOU, MC; SOTERIOU, GA; ROUPHAEL, Y; SIOMOS, AS; GERASOPOULOS, D. 2016. Configuration of watermelon fruit quality in response to rootstock-mediated harvest maturity and postharvest storage. *Journal of the Science of Food and Agriculture*, 96: 2400-2409.

LINS, HA; QUEIROGA, RCF; PEREIRA, AM; SILVA, GD; ALBUQUERQUE, JRT. 2013. Produtividade e qualidade de frutos de melancia em função de alterações na relação fonte-dreno. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, 8: 143-149.

LV, P; LI, N; LIU, H; GU, HH; ZHAO, WE. 2015. Changes in carotenoid profiles and in the expression pattern of the genes in carotenoid metabolisms during fruit development and ripening in four watermelon cultivars. *Food Chemistry*, 174: 52-59.

MILANEZ, G. 2010. Adensamento de plantio da melancia. *Nippo no campo*. Available at http://www.nippo.com.br/campo/artigos/artigo448.php. Accessed December 25, 2015.

MOTA, CS; AMARANTE, CVT; SANTOS, HP; ALBUQUERQUE, JA. 2009. Disponibilidade hídrica, radiação solar e fotossíntese em videiras 'Cabernet Suavignon' sob cultivo protegido. *Revista Brasileira de Fruticultura* 31: 432-439.

NJOROGE, S.M.C. and REIGHARD, G. L. 2007. Thinning time during stage I and fruit spacing influences fruit size of "Contender" peach. Sci. Hort. 115: 352-359.

NAZ, A, BUTT, MS; SULTAN, MT; QAYYUM, MN; NIAZ, RS. 2014. Watermelon lycopene and allied health claims. *Experimental and Clinical Sciences International online journal for advances in science* 13: 650-660.

NOH, J; SHEIKH, S; CHON, HG; SEONG, MH; LIM, JH; LEE, SG; JUNG, GT; KIM, JM; JU, HJE; HUH, YC. 2012. Screening different methods of tetraploid induction in watermelon [Citrullus lanatus (thunb.) Manst. And Nakai]. *Horticulture, Environment and Biotechnology* 53: 521-529.

OLIVEIRA, JB; GRANGEIRO, LC; SOBRINHO, JE; MOURA, MSB; CARVALHO, CA. 2015. Rendimento e qualidade de frutos de melancia em diferentes épocas de plantio. *Revista Caatinga* 28: 19-25.

PARRY, MAJ; REYNOLDS, M; SALLUCCII, ME; RAINES, C; ANDRALOJC, PJ; ZHU, XG; PRICE, GD; CONDON, AG; FURBANK, RT. 2010. Raising yield potential of wheat. II Increasing photosynthetic capacity and efficiency. *Journal of Experimental Botany* 62: 453-467.

RESENDE, GM; COSTA, ND. 1998. Produtividade da melancia em diferentes espaçamentos de plantio. *Horticultura Brasileira*. 36: 9-15.

ROBERTS, W; DUTHIE, J; EDELSON, J; SHREFLER, J; TAYLOR, M. 1998. Relationship between watermelon foliage and fruit. Porceedings of the 17th Annual Horticulture Industries Show, January 9-10. p229-234.

SILVA, ES; CARMO, ILGS; MONTEIRO NETO, JLL; MEDEIROS, RD; MENEZES, PHS; RODRIGUEZ, CA. 2017. Características agronômicas de cultivares de melancia nas condições do cerrado de Roraima, Brasil. *Scientia Agropecuaria* 8: 193-201.

SOTERIOU, GA; KYRIACOU, MC; SIOMOS, AS; GERASOPOULOS, D. 2014. Evolution of watermelon fruit physicochemical and phytochemical composition during ripening as affected by grafting. *Food Chemistry* 165: 282-289.

SUWANARUANG, T. 2016. Analyzing lycopene content in fruits. *Agriculture and Agricultural Science Procedia* 11: 46-48.