Original research article

Yield and Characteristics of Melon Fruits Under Fertilization Management and Soil Cover

ABSTRACT

Aims: To evaluate the 'Canary' and 'Hale's Best Jumbo' melon yield and fruit characteristics as a function of fertilization management and soil cover with mulch.
Study design: The design was a randomized complete block design in a 2x3x2 factorial scheme, with three replications and seven plants per plot.
Place and Duration of Study: The experiment was conducted from June to September 2015, at the Center of Agrarian and Biodiversity Sciences of the Federal University of Cariri, located in the city of Crato, Cariri region, Brazil.
Methodology: The treatments consisted of two varieties of melon ('Canary' and 'Hale's Best Jumbo') under three fertilization managements (mineral fertilization via soil, mineral fertilization via soil + organic fertilization and mineral fertilization via soil + foliar fertilization) with the presence or absence of soil cover with polyethylene mulch. The experiment was conducted on a Yellow Red Latosol using irrigation.
Results: The use of mineral + organic fertilization and mineral + leaf fertilization promoted an increase in fruit mass and yield of approximately 3.93 t ha^{-1} (25.50%) and 4.64 t ha^{-1} (30%), respectively. The two melon varieties presented the best responses when grown on plastic mulch, with a yield increase of 79.66% and 26.16% for 'Canary' and 'Hale's Best Jumbo', respectively. The 'Hale's Best Jumbo' melon presented higher soluble solids content than the 'Canary' melon, with an increase of 11.26% (0.76 ° Brix).
Conclusion: The use, associated or not, of soil cover and additional fertilization (organic or foliar) in the cultivation of melon provides an increase in size, mass and productivity, while soil cover increases the soluble solids content in fruits.

Keywords: Cucumis melo L., 'Canary' melon, 'Hale's Best Jumbo' melon, plant nutrition.

1. INTRODUCTION

The melon (*Cucumis melo* L.) is a plant of Asian origin that belongs to the family Cucurbitaceae. The fruits are widely appreciated and popular around the world [1]. According to data from the Brazilian Agribusiness Foreign Trade Statistics [2], in 2017, 233.6 thousand tons of melons were shipped, totaling more than US $ 162.9 million. Melon shipments increased in almost 4% compared to 2016, when 224.6 thousand tons were exported.

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The 'Canary' melon belongs to the Inodorous group and has Spanish origin. It presents round yellow fruits with thick and whitish inner flesh, having as main characteristics the resistance to transportation conditions and long post-harvest life, which facilitates the commercialization process [3]. However, in recent years the fruits of aromatic types of melon, such as Cantaloupe, have been gaining more attention of producers and consumers, mainly because they have tastier and earlier fruits. The Cantalupensis variety stands out for bearing spherical and reticulated fruits with salmon colored pulp and intense aroma [4]. The fruits of this group, however, present short post-harvest life, which has hampered the expansion of cultivated areas, signaling the need for research to define the best crop management technologies capable of increasing fruit productivity and quality [5].

In modern agriculture, the search for improved yields in agricultural crops has led to expressive gains in production and profit, however, some inadequate agricultural practices such as over fertilization can result in significant economic, social and environmental damages [6]. Thus, the use of alternative sources of fertilization may reduce environmental damage and costs with regular fertilizers [7]. Alternative fertilization practices, such as foliar feeding, improves the availability of nutrients to the plant, especially micronutrients, in periods of greater demand, which favors the production [8,9]. On the other hand, in the last decades, organic fertilization has also been used as an economic and environmental alternative, in the partial or total replacement of chemical fertilizers. Besides releasing nutrients necessary for plant growth, organic fertilizers provide benefits to the soil, such as improvements in structure, aeration and moisture storage capacity, with regulating effect in temperature and cation exchange capacity, which, in turn, potentiates crop productivity [10,11].

A trait in the cultivation of several vegetables has been the use of mulch, which can be of vegetable or synthetic origin. Mulching contributes to the improvement of the production system by reducing temperature fluctuation, loss of water by evaporation and erosion within

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the soil. Furthermore, it lessens the direct contact of the fruits with the soil, reducing damages to the rind and improving fruit appearance and quality [12]. Studies on the effects of soil cover on melon cultivation have been developed [13,14], and a better understanding of its association with fertilizer sources becomes important for sustainable management of the crop.

In view of the above stated, the aim of this work was to evaluate the 'Canary' and 'Hale's Best Jumbo' melon yield and fruit characteristics as a function of fertilization management and soil cover with mulch.

2. MATERIAL AND METHODS

The experiment was conducted from June to September 2015, at the Center of Agrarian and Biodiversity Sciences of the Federal University of Cariri, located in the city of Crato, Cariri region, Brazil, coordinates: 7° 14' 3.4"S, 39° 22' 7.6"W and altitude of 442 m. The climate of the region is characterized as Tropical with dry Summer, type As [15], with precipitation of 700 to 1,000 mm year^{-1} and average annual temperature of 27 ° C.

The area terrain is smoothly undulated and the surface of the soil has a sandy-loam texture. The soil in the area is classified as Yellow Red Latosol [16], and the chemical attributes of the 0-20 cm depth are described as follows: pH in water (potential of hydrogen) = 6; O.M. (organic matter) = 4.3 g Kg^{-1}; P (phosphorus) = 3 mg dm^{-3}; K^+ (potassium) = 1.3 mmol$_c$ dm^{-3}; Na^+ (sodium) = 6.6 mmol$_c$ dm^{-3}; Ca^{2+} (calcium) = 5 mmol$_c$ dm^{-3}; Mg^{2+} (magnesium) = 6 mmol$_c$ dm^{-3}; Al^{3+} (aluminum) = N. D.; $H+Al^{3+}$ (hydrogen + aluminum) =16.5 mmol$_c$ dm^{-3}; SB (sum of bases) = 18.9 mmol$_c$ dm^{-3}; BS (base saturation) = 53%.

The experimental design used was the Randomized Complete Block design in a 2x3x2 factorial scheme, with three replications, totaling 36 plots and seven plants per plot. The treatments consisted of two varieties of melon ('Canary' and 'Hale's Best Jumbo') under

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three fertilization managements (mineral fertilization via soil, mineral fertilization via soil + organic fertilization and mineral fertilization via soil + foliar fertilization) with the presence or absence of soil cover with plastic mulch. Each plot corresponded to a raised garden bed with 0.20 m height, 3.50 m long, 1.80 m wide and area of 6.3 m^2. In each plot seven plants were distributed linearly in the center of the garden bed, spaced apart by 45 cm. The useful part consisted of the five central plants of each plot.

Before sowing, pits with 30 cm in diameter and 25 cm in depth were dug and the fertilizers corresponding to the treatments were incorporated. Three seeds were sown in each planting hole and the thinning was carried out at 15 DAS (days after sowing) in order to maintain only one plant per pit. The irrigation was performed by drip irrigation, with flexible tape and drippers spaced at 30 cm (flow rate 1.6 L h^{-1}). The average irrigation time was 2 hours per day, and the amount of water applied was calculated based on the evapotranspiration records observed and according to the Kc coefficient of the melon, defined by Braga Sobrinho et al. [17].

The raised garden beds were covered with black polyethylene mulch after the preparation of the planting pits and before sowing, maintaining a circular opening measuring 15 cm in diameter.

The mineral fertilization in foundation was carried out in all plants regardless of the treatment, based on the soil chemical analysis results and crop requirements, as follows: 40 Kg ha^{-1} of nitrogen (89 kg ha^{-1} of urea), 120 kg ha^{-1} of P_2O_5 (667 kg ha^{-1} of single superphosphate) and 40 kg ha^{-1} of K_2O (67 kg ha^{-1} of potassium chloride).

For the treatment with organic fertilization, four liters of tanned cattle manure were applied per planting pit during the preparation of the raised garden beds (ten days before sowing). The manure presented the following chemical characteristics: pH in water (potential of

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hydrogen) = 8.25; O.M. (organic matter) = 100.82 g Kg^{-1}; P (phosphorus) = 5.06 mg dm^{-3}; K^+ (potassium) = 0.716 mg dm^{-3}; Na^+ (sodium) = 1.08 $cmol_c$ dm^{-3}; Ca^{2+} (calcium) = 4 $cmol_c$ dm^{-3}; Mg^{2+} (magnesium) = 3.9 $cmol_c$ dm^{-3}; Al^{3+} (aluminum) = 0,0; H+Al^{3+} (hydrogen + aluminum) = 0.49 $cmol_c$ dm^{-3}; CTC (cation exchange capacity) = 10.18 $cmol_c$ dm^{-3}; SB (sum of bases) = 9.69 $cmol_c$ dm^{-3}; BS (base saturation) = 95.10%.

For the treatment with foliar fertilization, the commercial liquid fertilizer Nutrichem Completo® was used at 1% (2L ha^{-1}), and it presents the following composition: N (nitrogen) = 67.5 g L^{-1}, P_2O_5 (phosphorus) = 108 g L^{-1}, K_2O (potassium) = 67.5 g L^{-1}, Mg (magnesium) = 8.1 g L^{-1}, B (boron) = 5.4 g L^{-1}, Cu (copper) = 2.7 g L^{-1}, Mn (manganese) = 6.7 g L^{-1}, Zn (zinc) = 13.5 g L^{-1}, TOC (total organic carbon) = 81 g L^{-1}. The first application of leaf fertilizer was performed at 35 DAS, and repeated twice more, at 10 days intervals.

The weeding, turning of the fruits, pest and disease control were carried out at the experimental area according to the recommendations of Braga Sobrinho et al. [17]. Fruit thinning was performed, leaving two fruits per plant. The 'Canary' melon harvest started at 65 DAS, while the harvest of the 'Hale's Best Jumbo' melon started at 80 DAS. In each variety, five harvests were performed at three day intervals. The fruits were harvested when they presented the formation of the abscission layer of the peduncle [18].

The fruits were weighed on a precision balance, and yield (t ha^{-1}) was estimated based on plant density ha^{-1}. The following variables were measured using a digital caliper: equatorial (cm) and polar diameter of the fruits (cm); thickness of the pulp (cm), corresponding to the average of the thicknesses in the equatorial and polar region after opening of the fruit to the center in the transverse direction; diameter of the internal cavity (cm), measured in the equatorial region. The soluble solids (ºBrix) were determined by direct reading in a portable refractometer (model RT-30ATC) according to the norms of the Adolfo Lutz Institute [19].

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The data were submitted to analysis of variance to evaluate the effects by the 'F' test and the treatments compared by the Tukey test at 5% probability, according to Banzatto and Kronka [20] recommendation, through the statistical program SISVAR, version 5.3 [21].

3. RESULTS

None of the factors studied in the present research influenced the variable equatorial diameter of the fruits. However, there was an effect of all factors on the polar diameter, in addition to significant interaction between variety and soil cover (mulch) for the same variable. The pulp thickness was affected by the soil cover and fertilization, and the internal cavity diameter affected by the variety and soil cover (Table 1).

Table 1. Mean square of the variance analysis for equatorial diameter (ED), polar diameter (PD), pulp thickness (PT) and internal cavity diameter (ICD) of 'Canary' and 'Hale's Best Jumbo' melons as a function of fertilization management and plastic mulch.

Source Variation	ED (cm)	PD (cm)	PT (cm)	ICD (cm)
Variety (V)	1.54^{ns}	151.49**	0.11^{ns}	7.76**
Canary	10.40	16.9 a	2.89	4.43 b
Hale’s Best Jumbo	10.80	12.8 b	3.00	5.36 a
Mulch Cover (MC)	2.82^{ns}	40.68**	2.87**	2.73**
With	10.90	15.9 a	3.23 a	5.17 a
Without	10.30	13.8 b	2.67 b	4.62 b
Fertilization (F)	3.66^{ns}	13.31**	0.84**	0.21^{ns}

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Mineral F.	10.10	13.6 b	2.71 b	4.75
Mineral F. + Organic F.	10.50	15.7 a	3.23 a	5.02
Mineral F. + Leaf F.	11.20	15.1 a	2.90 a	4.93
V x MC	0.37^{ns}	12.80**	0.19^{ns}	0.74^{ns}
V x F	0.73^{ns}	3.78^{ns}	0.05^{ns}	0.03^{ns}
MC x F	2.59^{ns}	0.90^{ns}	0.05^{ns}	0.48^{ns}
V x MC x F	1.54^{ns}	3.89^{ns}	0.00^{ns}	0.19^{ns}
Erro	2.99	1.36	0.07	0.23
CV%	16.30	7.88	9.00	9.86

Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability. ***: significant ($P<0.01$); *: significant ($P≤0.05$); ns: non-significant; CV%: coefficient of variation.*

The polar diameter of the fruits was higher for the treatments with mineral + organic fertilization and mineral + foliar fertilization, promoting increments of 2.39 and 1.79 cm, respectively, when compared to the average value registered for mineral fertilization only (Table 1).

When evaluating the interaction between variety and soil cover for the polar diameter of the fruits (Figure 1), it can be observed that the soil cover promoted a 21.71% increase in the above mentioned variable for 'Canary' melon, while for 'Hales' Best Jumbo' the presence of mulch did not influence this characteristic. When analyzing the variety factor within the soil cover factor, it is noticed that for both covered and uncovered soils the 'Canary' melon obtained the best results for the polar diameter of the fruit compared to the 'Hale's Best

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Jumbo' melon, with increments of 40.15% and 23.58% with and without mulch, respectively (Figure 1).

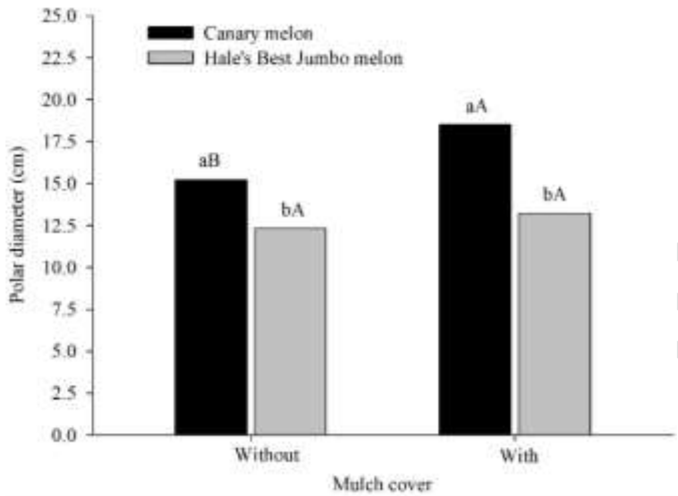

Figure 1. Polar diameter of fruits as a function of variety (Canary and Hale’s Best Jumbo) and plastic mulch (with or without). In the bars, the lowercase letters compare the varieties and the uppercase letters compare the soil cover. Bars with the same letters do not differ by Tukey test at 5% probability.

The pulp thickness of the fruits grown in polyethylene mulched soil presented an average value higher in 0.56 cm than the mean of the uncovered soil. When analyzing the fertilization factor, the lowest average for the pulp thickness was verified for mineral fertilization alone, whereas the addition of organic fertilization increased in 0.52 cm the thickness of the pulp and the addition of foliar fertilization increased in 0.19 cm (Table 1).

The internal cavity diameter of the 'Canary' melon was 17.35% lower than the 'Hale's Best Jumbo' melon, and in the uncovered soil there was a 10.64% reduction in comparison to the plastic mulched fruits (Table 1).

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For the variables fruit mass and yield, significant interactions were verified between variety and soil cover, showing that there was interdependence among these factors. It was also observed an isolated effect of fertilization for the two variables (Table 2).

Table 2. Mean square of the variance analysis for fruit mass (FM), yield (YLD) and soluble solids (SS) of 'Canary' and 'Hale's Best Jumbo' melons as a function of fertilization management and plastic mulch.

Source Variation	FM (kg)	YLD (t ha^{-1})	SS (°Brix)
Variety (V)	0.07^{ns}	39.1263^{ns}	5.17**
Canary	0.83	19.39	6.75 b
Hale's Best Jumbo	0.74	17.31	7.51 a
Mulch Cover (MC)	0.90**	497.6551**	6.89**
With	0.94 a	22.07 a	7.57 a
Without	0.62 b	14.63 b	6.69 b
Fertilization (F)	0.13**	74.8374**	0.44^{ns}
Mineral F.	0.66 b	15.49 b	6.96
Mineral F. + Organic F.	0.83 a	19.42 a	7.09
Mineral F. + Leaf F.	0.86 a	20.13 a	7.34
V x MC	0.19**	106.0350**	2.53^{ns}
V x F	0.01^{ns}	3.0270^{ns}	0.56^{ns}
MC x F	0.01^{ns}	6.9671^{ns}	0.17^{ns}

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V x MC x F	0.02^{ns}	9.0668^{ns}	0.07^{ns}
Erro	0.02	12.7998	0.57
CV%	19.48	19.48	10.6

Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability. ***: significant (P<0.01); *: significant (P≤0.05); ns: non-significant; CV%: coefficient of variation*

The application of mineral plus organic fertilization promoted an augmentation in fruit mass and yield of approximately 25.50%, corresponding to an increase of 3.93 t ha^{-1}, while mineral plus leaf fertilization boosted by approximately 30% the averages for these variables, equivalent to 4.64 t ha^{-1}.

Evaluating the interactions between variety and soil cover for fruit mass and yield (Figure 2), it can be noted that the two melon varieties obtained the best responses when grown on plastic mulch. The 'Canary' and 'Hale's Best Jumbo' melons presented a 79.66% and 26.16% increase in yield, respectively (Figure 2).

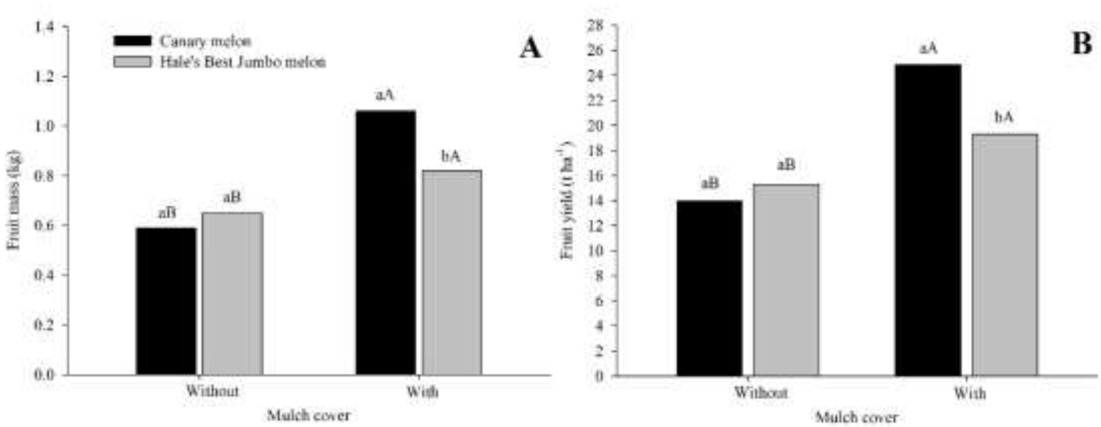

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Figure 2. Fruit mass (A) and yield (B) of melon as a function of variety (Canary and Hale's Best Jumbo) and plastic mulch (with or without). In the bars, the lowercase letters compare the varieties and the uppercase letters compare the soil cover. Bars with the same letters do not differ by Tukey test at 5% probability.

When evaluating the variety factor within the soil cover factor, it is observed that the 'Canary' melon fruit mass and yield were superior to 'Hale's Best Jumbo' when using plastic mulch, with a 28.57% increase in yield; however, without mulching, the melon varieties showed no differences in the responses (Figure 2).

The 'Hale's Best Jumbo' melon presented higher soluble solids content than the 'Canary' melon, corresponding to a 11.26% increase (0.76 ° Brix), whereas for the soil cover factor, fruits grown on plastic mulch presented 0.88 ° Brix more than fruits grown on uncovered soil (Table 2).

4. DISCUSSION

From the results obtained for the equatorial and polar diameters, it was observed that there was a predominance of growth in 'Canary' melons, which is a feature of this oval-shaped fruit variety, different from 'Hale's Best Jumbo' melons, that have round-shaped fruits. However, the fruit diameters registered in the present study for the 'Canary' melon were inferior to those observed by Dalastra et al. [22], whose values ranged from 12.18 to 13.03 cm for the equatorial diameter and 18.53 to 18.96 cm for the longitudinal (polar) diameter. On the other hand, the 'Hale's Best Jumbo' fruits presented higher diameters (9.83 cm of PD and 8.52 cm of ED) than those found by Rizzo and Braz [23].

According to Dalastra et al. [24], the larger the fruit, the bigger its internal cavity. In agreement with this assertion, the fruits grown on plastic mulch exhibited the greatest cavity measurements, but in the isolated analysis between the varieties it is noticeable that

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although 'Canary' melons were bigger in size, the average of its internal cavity measurements was lower than that of 'Hale's Best Jumbo' melons. Fruits with large internal cavity are less resistant to handling and transportation and suffer greater displacement of the placenta, which leads to a shorter post-harvest shelf life [25].

In addition to reduced internal cavity, it is desirable that the fruits have a high pulp thickness, an important feature that makes them more valued in the market [3]. The use of plastic mulch provided better conditions for the fruit pulp development. According to Pinheiro Neto et al. [26], the fact that the mulch keeps soil water from evaporating, thus making it more available to the plants, favors cell division and expansion, which is evidenced by the increased production variables. Braga et al. [27] studied the influence of organic and plastic mulch on the cultivation of melon in Petrolina, Brazil, and did not identify differences in the pulp thickness of mulched and non-mulched fruits. These authors registered 3.87 cm of pulp thickness for fruits grown on polyethylene mulch and 3.35 cm for fruits grown on bare soil, and both results are superior to the ones verified in the present study.

The significant results associated to the application of treatments including organic and foliar plus mineral fertilization are due in part to the higher nutritional supply when compared to the use of mineral fertilization only. Both the tanned cattle manure and the foliar fertilizer have in their composition a greater diversity of nutrients that contribute to the development and fruiting of the melon. According to Mantovani et al. [28], besides favoring the chemical properties of the soil by adding organic matter and nutrients, the manure improves the physical and biological properties of the soil. Values similar to those found in the present study were obtained by Nascimento Neto et al. [1] and Charlo et al. [29] for pulp thickness of ‘Canary’ (3.15 cm) and cantaloupe melon (3.22 cm), respectively.

The application of mineral plus organic fertilization and mineral plus leaf fertilization was beneficial for the variables fruit mass and yield. The mineral + organic fertilization promoted

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a slightly lower result than that verified by the mineral plus leaf fertilization; this difference can be understood taking into account the nutrients availability for the plants in each of the treatments. The bovine manure is conditioned to mineralization to release the nutrients which requires time [30], taking into consideration the short cycle of melon production (80 to 90 days) and the application of the organic source close to the sowing date, possibly there was no full use of the nutritional potential of the organic source by the crop. In melon plants, the leaf constitutes the main source of photoassimilates for the fruits [31], in this sense, the foliar feeding, on the other hand, can give plants a direct boost of nutrients through their leaves, allowing the correction of deficiencies in less time than required by soil fertilization [32].

The interdependence between variety and soil cover for the production variables showed the positive influence of the mulch for the melon crop. Due to inherent features of the studied varieties, there is a tendency for the 'Canary' melon fruits to have higher masses than the 'Hale's Best Jumbo' melons, but from the data in figure 2 it is possible to observe that the absence of mulch limited the production, since the two varieties showed no differences. This fact is due to the several benefits of mulching, such as moisture retention, which facilitates nutrient transportation and absorption through the soil solution, weed growth suppression, that keeps unwanted plants from competing with crops for space, light, water and nutrients, as well as the reduction of soil temperature oscillation [12].

When evaluating the influence of mulching on the cultivation of 'Canary' melon, Dantas et al. [14] verified a 145.62% yield increase when the melons were cultivated on plastic mulch compared to cultivation in uncovered soil. Similarly, Morais et al. [33] registered an increase of 82% in yield for mulched 'Canary' melons, a result that is close to those verified in the present study, evidencing the beneficial influence of plastic mulch on the melon cultivation.

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Under plastic mulch (Figure 2A), the mean fruit mass value verified for 'Canary' melon is similar to that found by Dalastra et al. [24] (1.08 kg), while for the average fruit mass of 'Hale's Best Jumbo', a similar value was verified by Vargas et al. [34] (0.84 kg) in Cantaloupe melon. The fruit mass results obtained for both varieties studied in the present research are close to 1 kg, an ideal weigh for marketing in the international trade [29].

When analyzing the results of soluble solids for both varieties, independent of the other evaluated factors, it is observed that the means obtained are lower than those required by the main buyers in the European market (above 9 ° Brix). The low soluble solids contents verified in the present study are attributed in parts to the application of high water volume during the maturation phase of the fruits. According to Pinheiro Neto et al. [26], gradual reduction of the irrigation when approaching the fruit harvest phase is necessary, since a high water supply causes the dilution of sugars in the plant tissues, leading to a low concentration of soluble solids. During the conduction of the present research, the aforementioned irrigation management was not carried out since the two varieties studied had different production cycles, therefore, different harvest periods, thus the use of a single irrigation system for both of them impeded the reduction of the water volume at the appropriate time for each.

When studying the effect of different irrigation levels on 'Gália' melon, Ferraz et al. [35] observed a reduction in soluble solids content with the increase of irrigation volume. Similarly to what was verified in the present study, Negreiros et al. [13] registered a 19.6% increase in the soluble solids content of melon fruits grown on polyethylene mulch compared to the fruits grown on bare soil. Dalastra et al. [24] recorded higher values of soluble solids content in 'Canary' melon in relation to the 'Cantaloupe' melon, which differs from the results found in this research.

5. CONCLUSION

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The use, associated or not, of soil cover and additional fertilization (organic or foliar) in the cultivation of melon provides an increase in size, mass and productivity, while soil cover increases the soluble solids content in fruits.

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