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Melon cultivation under agrotextile increases production and reduces phytosanitary products

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Abstract

Abiotic and biotic factors influence the productivity and quality of melon fruit; therefore, the protection of plants using agrotextile mesh is a solution that can be agronomically viable, as it reduces the use phytosanitary pesticides and allows for greater productivity and, consequently, quality. The objective this study was to evaluate the influence of coverage time with an agrotextile (0, 21, 26 and 31 days after transplanting (DAT)) in melon hybrids 'Gold Mine', 'Soleares', 'Lual' and 'Natal' on productivity and fruit quality attributes. The plants that were protected with agrotextile mesh for 21 and 26 DAT had higher productivity (53.5 and 52.1 t ha^{-1}). Among the hybrids, all excellent plots produced above 42.4 1 t ha^{-1}. Of the observed hybrid quality parameters, 'Natal' protected for 21 DAT showed a better total phenol content and a higher maturation index, and 'Soleares' protected for 21 DAT showed a higher DPPH antioxidant activity and flavonoid content.

Keywords: agrotextile, *Cucumis melo L.*, fruit quality, productivity, temporarily protected cultivation

Introduction

Melon (*Cucumis melo* L.) is a vegetable from the Cucurbitaceae family that occupies a prominent position in the national agribusiness market, with strategic economic importance for the Northeast region of Brazil. The Northeast is the main melon-producing region, with more than 90% of the planted area (IBGE, 2022). This is due to good edaphoclimatic conditions and high temperatures, low relative humidity and high luminosity during most of the year, which are contributing factors for cucurbit cultivation (Cavalcanti et al., 2015).

The state of Mato Grosso has many challenges and potential for melon cultivation due to its large agricultural frontiers and extensive productive areas. However, its production is small, with only 163 hectares in 2019 and 139 hectares in 2020 (IBGE, 2022), which is insufficient to meet the demand of the local market and necessitates the import of fruit from other states (Rocha et al., 2021). Therefore, there is a need for information on melon cultivation and research that improves the implementation and development of technologies applied to cultivation systems in this and other regions.

Given this scenario, a search for alternatives that improve the productive efficiency of the crop is necessary, aligning with the search for recommended products from crops that have less impact on the environment, with fruit produced with less need for the use pesticides (Vendruscolo et al., 2018). To improve the initial development and increase the use pesticides in melon cultivation, the use cultivation techniques is highly important in the agricultural scenario melon cultivation. One of the alternatives found by producers in the Northeast region is the use of agrotextile mesh combined with plastic mulching (Lambert et al., 2017).

Agrotextile mesh has been used in melon cultivation to reduce pest infestation and, consequently,

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to reduce the incidence of viral diseases in the initial phase (Braga et al., 2017). In the production areas of Rio Grande do Norte and Ceará, the use of white agrotextile mesh in melon cultivation is a consolidated technique (Braga et al., 2010; Bessa et al., 2012; Braga et al., 2012; Santos, 2015; Braga et al., 2017), but the technique has already been tested for other crops, such as watermelon and cabbage, and is effective in reducing pests (Tlili et al., 2011; Ponce et al., 2021).

In view of the use of agrotextile mesh, there is also a relationship with the exposure time the plants, which influences culture development. In melon cultivation, due to the need for pollination, which is necessary in most cucurbits, the mesh coverage time must be observed so that there is no interference with fruit setting. In addition, the agrotextile can influence the physicochemical and biochemical aspects of the fruit due to edaphoclimatic changes caused in the growing environment, such as increased temperatures and reduced light (Seabra Júnior et al., 2019). Thus, the objective was to evaluate the influence of agrotextile use on the productive parameters and fruit quality attributes of yellow melon hybrids.

Material and Methods

General description

The experiment was carried out in the municipality of Nova Mutum, in the mid-northern region of Mato Grosso, located at latitude 13°49'44" south and longitude 56°04'56" west, with an altitude of around 460 m. The climate is classified as Aw (Köppen) tropical, with technical rains in the summer (October to April). The average annual precipitation is 1900 mm and the average temperature is 26°C (Nogueira et al., 2010). The soil in this area is described as Dystrophic Red Yellow Latosol (Embrapa, 2013).

Experimental design

The experimental design was randomized blocks in a 4 × 4 factorial scheme with three replications. The treatments consisted of a combination of four yellow melon cultivars ('Gold Mine', 'Soleares', 'Lual' and 'Natal') and four times in which the plants were protected with an agrotextile (0, 21, 26 and 31 days after transplant – DAT). The experimental plot consisted of 10 plants and considered the six central plants to be the useful area.

Installation, conducting and harvesting

Sowing was carried out in expanded polystyrene trays filled with Vivato ® commercial substrate, which contained 128 seedlings, and organized in a greenhouse for 15 days after transplant- DAT.

Fertilization at planting occurred based on the chemical analysis of the soil, which showed the following: pH (water) 7.4; P = 26 mg dm^{-3} ; K = 42.15 cmg dm^{-3} ; Al = 0.0 cmol dm^{-3} ; Ca = 2 cmol dm^{-3}; Mg = 1 cmol dm^{-3}; H + Al = 1.1 cmol dm^{-3}; B = 0.3 mg dm^{-3}; Zn = 5.8 mg dm^{-3}; SB (Sum of Bases) = 23.1 cmol dm^{-3}; t (effective CTC/CTC at pH 7.0) = 3.1 cmol dm^{-3}; T = 4.2 cmol dm^{-3}; V = 74%; m (Al sat.) = 0% and organic matter – MO (Walkley–Black) = 17.03 g dm^{-3}. The fertilizer at planting was inserted into the furrow using 88.9 kg ha^{-1} of N, 41 kg ha^{-1} of K_2O and 953 kg ha^{-1} of P_2O_5 in the forms of urea, potassium chloride and simple superphosphate, respectively.

Topdressing fertilization was carried out via fertirrigation, with applications every two days using ammonium sulfate and potassium nitrate (Alvarez et al., 1999). The supervision system was drip operated, with emitters spaced 0.3 m apart and self-compensating.

The beds were 1.2 m wide, and the plants were grown in the center of the bed using a spacing of 0.30 m between plants, totaling 27,777.78 plants ha^{-1}. The beds were covered with white plastic mulch.

To assemble the low tunnels, polyvinyl chloride (PVC) pipes of 1/2 inch in diameter and 2 m in length were used to make the arches, which were fixed to the ground by means of iron rods of 0.5 m, which were buried in the ground 0.3 m on the sides of the beds. An arc was used every 3 m. The evaluated environments consisted of an open field and low tunnels covered with a white polyethylene agrotextile mesh with a weight of 15 gm^{-2} and a width of 1.40 m and fixed at the ends with soil f

The control of forecasts and diseases was carried out through monitoring every 3 days, according to the technological guidelines on sampling and recognition of the main issues related to melon. Integrated management of forecasts was performed according to Braga Sobrinho et al. (2003) for more rational and effective control (Figure 3 C–E). Plant control was performed with hoes between the ridges of the plots and manually between the mean weed control.

Analysis of microclimate variables

Temperature and relative humidity readings were recorded using a digital thermo-hygrometer HM-02 installed in the plant canopy of the plants, with daily collections at 1 pm.

Production components

The following productivity results were evaluated: total productivity – PT (t ha^{-1}), commercial productivity – PC (t ha^{-1}), average fruit mass – MMF (kg $fruit^{-1}$), number of total fruits (NFT), number of commercial fruits (NFC) and fruit shape index (IFF), obtained by the relationship between the longitudinal and transverse diameter of the fruit. The fruits were harvested when they completed maturation, which was determined by measuring the soluble solids. Fruit affected by insects, disease, deformation, apical rot, cracking, sunburn or an average mass below 550 g were not measured and were considered non-commercial or refuse.

Chemical and biochemical analyses of fruit

For the analysis of the physical–chemical and biochemical characteristics of the melons, 10 fully ripe commercial fruits were sampled from each plot and processed. From the obtained extracts, the following characteristics were determined: soluble solid (SS) content, with the aid of a refractometer (IAL, 2008); pH and titratable acidity, according to Zenebon et al. (2008); vitamin C content, according to AOAC et al. (1997); flavonoid content, according to Popova et al. (2004); total phenolics, according to Singleton & Rossi (1965); and radical DPPH scavenging, according to Brand-Williams et al. (1995).

Statistical analysis

The data were submitted to analysis of variance, and homogeneity and normality were determined. When significant differences were detected, the data were submitted to the Scott–Knott test ($p<0.05$), using SISVAR 5.3 software. Principal component analysis (PCA) of the data was performed using XLSTAT software, version 2019.

Results and Discussion

Microclimate variables

Covering the plants with agrotextile for up to 31 DAT increased the minimum, average and maximum temperature by 3.3, 1.2, and 5.8°C, respectively (**Figure 1**), with an average temperature of 30.5°C. The increase in temperature from 1 to 4°C with the use of agrotextiles in different crops was also reported by Otto et al. (2000), Pires et al. (2013), Pereira et al. (2017) and Ponce et al. (2021).

In the initial phase of melon cultivation, minimum temperatures reached ± 9°C in the open field environment, but in the same period, the protected environment reached a minimum temperature of 15.1°C. However, this same tendency was presented for the maximum temperatures, where they rose by about 6.2°C, causing the temperatures inside the protected environment to exceed 50°C (Figure 1).

Melon is a tropical plant, and there are reports that plant development is impaired at temperatures below 12°C and above 40°C. Temperatures above 35°C interfere with the photosynthetic rate, and when temperatures reach 40°C, there is an increase in the respiration rate, which interferes with stomatal opening and closing and causes flower and fruit abortion (Amarasinghe et al., 2021). However, Jiménez et al. (2001) showed that the melon plant can withstand temperatures above 40°C without affecting productivity when subjected to agrotextile use in the initial phase due to the porosity of the mesh, where gas exchange occurs between the internal and external environments.

Agrotextile mesh showed a 13% increase in relative humidity, reaching an average of 58% (**Figure 2**). These values favor the development of the plant, as they are closer to the ideal range for melon cultivation, which is 55 to 65% (Hora et al., 2018).

In addition to the increase in humidity and the proportional mesh, it was verified that plants cultivated in an environment protected with an agrotextile present a better visual appearance (**Figure 3** B).

Need to apply phytosanitary products

Agrotextile mesh in melon cultivation prevented the need to apply insecticides and fungicides (**Figure 4**).

Plants grown under agrotextile mesh for 21, 26 and 31 days had a reduction in the need for insecticides by 29, 41 and 47%, respectively, compared to plants grown in the open field. As for fungicide applications, melon plants cultivated under agrotextile mesh for 21 days showed a 44% reduction in the need for application when compared to the open field. Similarly, plants grown under protection for 26 and 31 days reduced the number of applications by 55% compared to the open field. The reduction in the need to apply insecticides and fungicides is probably due to the ability of the mesh to act as a physical barrier.

The use of agrotextile mesh favors photosynthesis, reduces excess sunlight and acts as a physical barrier, helping to reduce the damage caused by various insect pests, because the entry insects inside the tunnel is hampered due to fabric weft. In addition, in rainy seasons, the use mesh reduces injuries caused by water droplets and prevents disease occurrence, thus explaining the reduction in the need for application these phytosanitary products and highlighting the potential of agrotextile mesh as a physical barrier during initial melon development.

The use agrotextiles has been widespread in regions growing melon products to cover the plants during the initial stages, with the intention of mitigating the action of insect pests, especially the whitefly, as it is

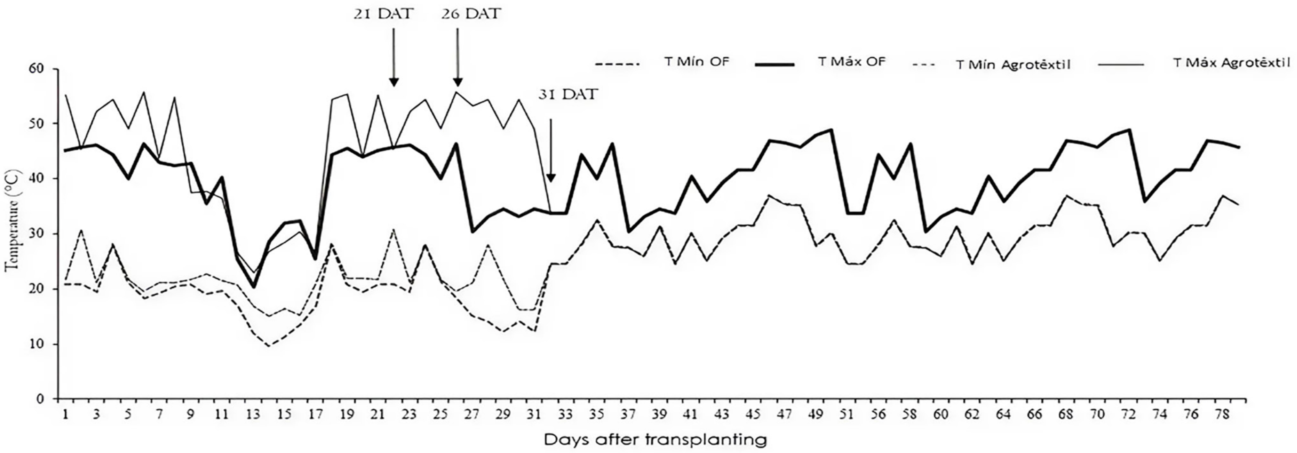

Figure 1 - Minimum and maximum temperatures (°C) recorded in open field (OF) and protected with agrotextile mesh until 21, 26 and 31 days after melon transplanting.

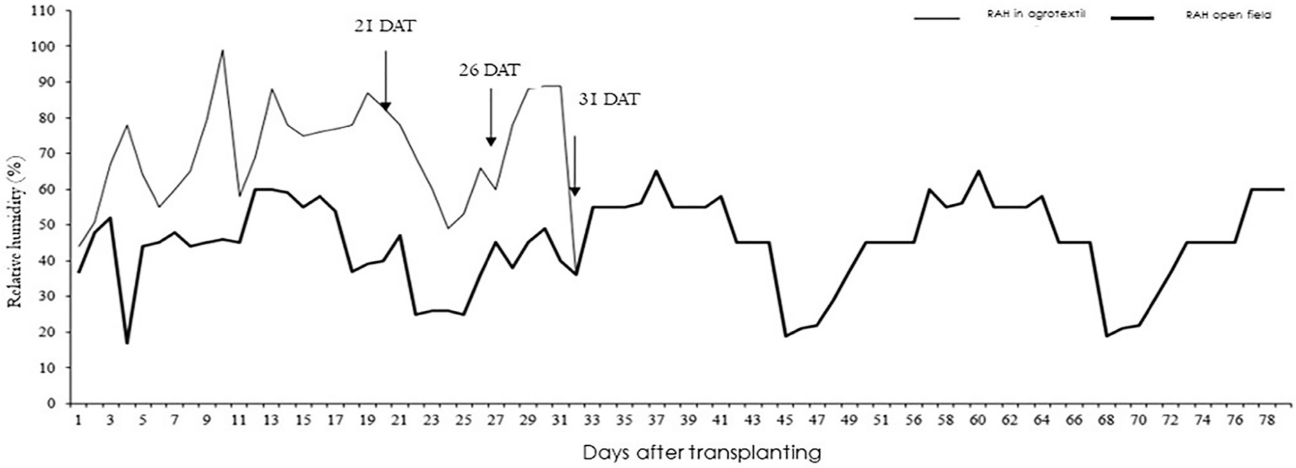

Figure 2 - Relative humidity (RH%) recorded in open field (OF) and protected with agrotextile mesh until 21, 26 and 31 days after melon transplanting.

Figure 3 - Overview of the experiments: (A) Overview of the area with agrotextile and open field (CA); (B) Overview of the first removal time with agrotextile, which presented a better visual appearance compared to the open field (CA) environment; (C) close-up view of plants with agrotextile protection without the presence of whiteflies (*Bemisia tabaci*); (D) close-up view of monitored plants in the open field (OF) with the presence of whiteflies (*Bemisia tabaci*); (E) close-up view of monitored plants in the open field (CA) with the presence of Cucurbit borers (*Diaphania nitidalis* Cramer and *D. hyalinata* Linnaeus).

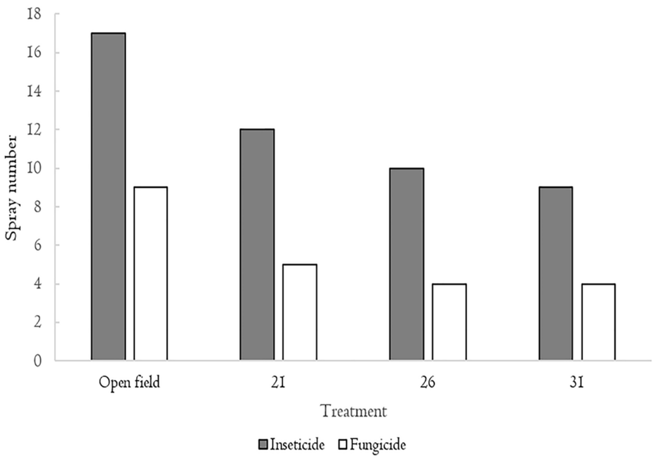

Figure 4. Number of phytosanitary pesticide applications during the melon cycle cultivated at different times of coverage with agrotextile mesh.

a vector of several viruses that affect the crop (Santos, 2015). The use agrotextiles in a low tunnel impairs the action several insect pests in kale, consequently resulting in the need for insecticides applications (Ponce et al., 2021). This response was also observed in grapes, as the use of a high tunnel with vehicular agrotextile reduced the number applications fungicides and insecticides from 8 and 5 applications, respectively, to 3 and 2 applications, respectively (Garcia et al., 2016).

In northeastern Brazil, it is estimated that around 15 applications phytosanitary products are carried out during the melon cycle, with an average one application every 4 days (Paes et al., 2014). In this study, when the agrotextile was used for up to 26 DAT, productivity was 52% higher than the national average, and a 33% reduction in the need to apply insecticides was observed compared to that described by Paes et al. (2014).

Melon cultivated in the studied agroecosystems is quite dependent on pesticide use. Due to the wide use different active ingredients sprayed on the plants and, consequently, on the cultivated land, there is a latent risk of contamination the soil and aquifers in the production regions (Formiga Júnior et al., 2015).

The reduction in pesticide application to melon plants due to the protection the plants with an agrotextile is great benefit, as it reduces the exposure of the plant and fruit to interactions with chemical products. The use agrotextile mesh in the initial phase cultivation will reduce the need for phytosanitary product application, bringing greater security to the consumer and reducing environmental contamination. Therefore, this is a sustainable practice that can be used in the most varied production systems, and because it is a material that can be reused, it is another option for agricultural use.

Influence of the use of agrotextile mesh on the productive, physical–chemical and biochemical parameters of melon hybrids

Melon cultivated with agrotextile mesh during the crop development phase (21 and 26 DAT) showed an increase in total and commercial production and the number of total and commercial fruit (**Table 1**). However, cultivation without protection and protection until 31 days presented a higher fresh fruit mass.

The hybrids showed differences in fruit fresh mass, fruit shape index and soluble solids content. However, the interaction between the agrotextile coverage time and the hybrids influenced all fruit quality parameters (Table 1).

Total and marketable fruit yields were not statistically different from each other (Table 1). Productivity increments above 27% emphasize that the incorporation of cultivation technologies can favor an increase in national productivity, which averaged 25 t ha^{-1} in 2019 (IBGE, 2022).

This result was due to the protection of plants in the initial phase cultivation and alteration of the internal microclimate the protected environment, mainly the increase in relative humidity and its interaction with other factors, such as light intensity and temperature (Figure 2), in addition to protection against insects and disease, which contributes to phytosanitary management (Figures 3 C–E and 4).

The removal of the agrotextile must be carried out between 21 and 26 DAT. After this period, the plant enters the flowering phase, and pollinating agents are necessary for the fruit to be set in the first female and/or hermaphrodite flowers the melon plant (Kill et al., 2015). Thus, protection under local climatic conditions and with the evaluated hybrids should be between 21 and 26 DAT, increasing the NFT and NFC (Table 1).

In this study, high commercial yields were obtained, above 52 t ha^{-1}, for protected cultivation between 21 and 26 DAT, emphasizing that the incorporation of cultivation technologies can favor an increase in national productivity, which presented an average of 25 t ha^{-1} in 2019 (IBGE, 2022).

Our results differ from those values reported by Santos et al. (2014), who obtained commercial productivity between 32.64 and 29.20 t ha^{-1} using protection between 18 and 30 DAT for cantaloupe melon. Similarly, Santos et al. (2015) used protection between 18 and 30 DAT for hybrid melon and obtained commercial productivity between 22.28 and 20.42 t ha^{-1} between 18 and 30 DAT. In both studies, there was no difference between the tested treatments.

Table 1. Total production (PT) and commercial productivity (CP), fruit mass (FM), total number of fruits per plant (TNF), number commercial fruits per plant (NCF), fruit shape index (FSI) and soluble solids content (SS) of yellow melon hybrids as a function the time of agrotextile coverage.

		TP (t ha^{-1})	CP (t ha^{-1})	FM (kg fruto^{-1})	TNF	NCF	FSI	SS (Brix°)
Days after transplanting (DAT)	0	40.75 b	39.4 b	1.11 a	2.78 b	2.67 b	1.20^{ns}	11.30^{ns}
	21	54.87 a	53.5 a	1.07 b	3.53 a	3.40 a	1.23	11.14
	26	53.49 a	52.1 a	1.04 b	3.47 a	3.33 a	1.27	10.90
	31	42.20 b	40.4 b	1.15 a	2.66 b	2.50 b	1.20	10.79
Hibrids	Gold Mine	50.00^{ns}	49.2^{ns}	1.07 b	3.15^{ns}	3.08^{ns}	1.30 a	10.33 b
	Soleares	48.09	47.5	1.16 a	2.97	2.92	1.13 b	11.26 a
	Natal	47.35	46.3	1.05 b	3.15	3.08	1.23 a	11.50 a
	Lual	45.89	42.4	1.09 b	3.16	2.82	1.25 a	11.04 a
				Fvalue				
Time (T)		3.88*	3.99*	4.18*	4.24*	4.57*	0.90^{ns}	1.84^{ns}
Hibrid (H)		0.21^{ns}	0.59^{ns}	3.86*	0.17^{ns}	0.37^{ns}	3.76*	8.77*
(T) x (H)		1.59^{ns}	1.41^{ns}	1.24^{ns}	1.30^{ns}	1.20^{ns}	1.45^{ns}	0.60^{ns}

Means followed by the same lowercase letter in the columns did not statistically differ other using the Scott–Knott test at a 5% probability. ^{ns} Not significant; * significant at 5% probability by the F-test.

In general, the hybrids did not influence the productivity parameters of the melon plant (Table 1), obtaining high total and commercial yields, ranging from 45.9 to 50.0 t ha^{-1} and 42.4 and 49.2 t ha^{-1}, respectively. The Mina de Ouro hybrid obtained a higher commercial fruit yield (98.4%), reaching a high productivity index of 49.2 t ha^{-1}, with a value close (46.9 t ha^{-1}) to that obtained by Pereira et al. (2010) in open field cultivation in Viçosa, MG. However, it was higher than that presented by Freitas et al. (2007), who obtained 28.27 t ha^{-1} with the hybrid 'Gold Mine' in a study carried out in different locations in the Brazilian Northeast. This shows the potential for hybrid production under environmental conditions in the mid-northern region of Mato Grosso.

The results for MMF and the number of fruits were inversely proportional, with the largest fruits produced in unprotected and agrotextile-protected cultivation for 31 DAT, which produced a smaller number total and commercial fruits (Table 1). The greater fruit mass is related to the loss of initial flower probability due to a lack pollination, which was demonstrated by the lower number of fruits per plant and greater mass. This occurs because a greater number fruits requires a greater amount photoassimilates from the plant, thus causing competition between the fruit (Fagan et al., 2006). As the melon plant has limits in its productive capacity, the photoassimilates produced are distributed among the fruits; thus, a greater number fruits results in fruit with lower mass (Duarte & Peil, 2010).

Plants protected with an agrotextile until 31 DAT presented fruits with 1.15 kg fruit^{-1}, similar to plants grown in the open field (1.11 kg fruit^{-1}), deferring to both other treatments. Coverage with agrotextile mesh up to 31 DAT favored fruit mass by 7 and 10%, reaching 1.15 kg fruit^{-1}, when comparing plants grown under agrotextile at 21 and 26 DAT, respectively. The result a higher mass and lower number fruits for the open field is related to the lower number fruits due to environmental factors and planning management. In the open field, not using the mesh allowed the infestation plants by the whitefly (*Bemisia tabaci* (Hemiptera: Aleyrodidae)) and small fruit borer (*Neoleucinodes elegantalis* (Lepidoptera: Pyralidae)), resulting in lower productivity and a lower number of fruits.

However, in relation to the hybrids, 'Soleares' presented the highest MMF (1.16 kg fruit^{-1}; Table 1). This result is a consequence of the genetic factor, where the larger fruit size and mass are related to the number of pericarp cells. However, it is important to point out that the foreign market, for the most part, prefers fruit with an MMF between 1.0 and 1.5 kg fruit^{-1} due to its smaller size and because it can be consumed at once (Franco et al., 2021).

The NFT and NFC of plants grown with protection for 21 and 26 DAT was about 21 and 20% higher compared to plants grown in the open field, reaching averages of 3.53 and 3.47 (NFT) and 3.40 and 3.33 (NFC) per plant, respectively (Table 1). This is due to the protection of the plants from biotic and abiotic factors and the correct management of the mesh, as reflected in the greater number of fruits per plant. Lower results than that study are described by Oliveira et al. (2021), who showed that melon plants grown under protection for 15–24 days did not obtain more than 1.71 (NFT).

As for the IFF, the hybrid 'Soleares' presented more rounded fruits, with a value close to 1 (1.13), while the other fruits had values varying from 1.23 to 1.30 (**Table 2**). However, all hybrids produced oblong fruit with a fruit

Table 2. Hydrogen potential pH, Titratable acidity – TA, maturation index MI), ascorbic acid (AA), flavonoids (FL), total phenols (TP) and antioxidant capacity by DPPH of yellow melon hybrids as a function of time covered with agrotextile mesh.

Variables	Hybrids	Time protection				Fvalue			CV (%)
		0	21	26	31	Híbrido(H)	Tempo (T)	(H) X (T)	
pH	Gold Mine	4.2 cC	4.5 bD	5.0 aC	4.3 cD	623.39*	9585.85*	2546.5*	0.37
	Lual	5.7 cA	5.9 aA	5.8 bA	5.5 dC				
	Natal	5.8 bA	5.8 aB	4.5 cD	5.8 bB				
	Soleares	4.5 dB	4.7 cC	5.4 bB	5.9 aA				
TA[1] (%)	Gold Mine	0.42 aA	0.39 bA	0.38 bB	0.25 cA	272.73*	189.23*	116.56*	4.69
	Lual	0.32 aB	0.28 bC	0.23 cC	0.14 dD				
	Natal	0.19 bC	0.20 bD	0.43 aA	0.20 bB				
	Soleares	0.41 aA	0.37 bB	0.22 cC	0.18 dC				
MI (*Ratio*)	Gold Mine	24.6 bC	26.6 bC	26. 6 bB	40.6 aC	94.97*	89.15*	39.42*	8.26
	Lual	34.6cB	39.7 cB	47.7 bA	79.0 aA				
	Natal	64.8 aA	56.0 bA	26.7 cB	54.9 bB				
	Soleares	28.1 cC	31.7 cC	49.2 bA	60.9 aB				
AA (mg kg^{-1})	Gold Mine	9.2 bA	5.8 cB	5.9 cB	6.3 bB	58.58*	57.03*	151.47*	4.83
	Lual	10.1 aA	6.5 bB	6.6 cB	6.6 bB				
	Natal	9.7 aA	5.9 cB	9.2 bA	9.5 aA				
	Soleares	5.5 cC	12.7 aA	10.6 aB	4.7 cD				
FL (mg QE kg^{-1})	Gold Mine	1.2 aA	1.3 aA	1.2 aA	1.1 aA	8.52*	27*	8.97*	10.13
	Lual	1.2 aA	1.4 aA	1.2 aA	0.6 bC				
	Natal	0.8 aB	0.8 aB	0.9 aB	0.8 aB				
	Soleares	1.2 aA	1.3 aA	1.0 aB	1.3 aA				
TP (mg GAE kg^{-1})	Gold Mine	176.2 aA	165.0 cB	152.2 Dc	187.9 aA	29.89*	60.49*	40.12*	3.60
	Lual	96.8 cB	141.7 bC	178.4 aA	176.2 aB				
	Natal	173.1 bA	191.7 aA	183.9aA	171.3 bB				
	Soleares	174.1 aA	171.1 aB	163.1 bB	177.1 aB				
DPPH~ (mg TE kg^{-1})	Gold Mine	127.2 aA	66.9 cC	79.1 bA	36.1 dC	57.50*	261.42*	156.95*	5.59
	Lual	65.8 aC	30.1 cD	37.8 bC	60.6 aB				
	Natal	37.3 bD	75.4 aB	75.2 aA	38.3 bC				
	Soleares	82.9 bB	96.8 aA	63.9 cB	100.7 aA				

Different lowercase letters in the row and inner letters in the column are significantly different from each other by the Scott–Knott test (p<0.05). Analysis of Variance: *p-value ≤ 0.05, significant at 5% probability; ns, not significant by F test.

shape index between 1.0 and 1.70 (Paiva et al., 2000). This parameter is considered an important attribute when classifying and standardizing fruit, as it defines the type of packaging and the arrangement of the fruit inside (Chitarra & Chitarra, 2005).

To establish a descriptive model regarding the productive aspects of the melon plant, PCA was used to group the hybrids according to the coverage times of the agrotextile mesh, seeking better visualization of the results. The dispersion of varieties according to principal components PC1 and PC2 (Figure 5).

PC1 and PC2 accounted for 89.49% of the data. The variables NFT, NFC, PT and PC presented the highest *scores* in PC1, grouping the hybrids 'Gold Mine', 'Lual', 'Natal' and 'Solearis' in the coverage times 21 and 26 DAT. These hybrids at times 0 and 31 DAT were grouped in PC1, showing the beneficial effects of the coverage time of 21 and 26 DAT on these characteristics. PC1 responded to 71.64% of the total variation data, separating the hybrids and the best coverage times for the agrotextile mesh.

It was found that hybrids had higher total (HT) and commercial (C) productivity and number of total fruits and number of salable fruits when cultivated under agrotextile mesh for 21 and 26 DAT (**Figure 5**). Protection with 21 and 26 DAT protects the plants from biotic and abiotic factors that would result in lower productivity, such as whitefly (*Bemisia tabaci* (Hemiptera: Aleyrodidae)), which was present in the open field and is a vector of several viruses affecting melon (Medeiros et al., 2007). In addition, the use of agrotextile mesh along with plastic mulch reduces water demand and forms a microclimate with a reduction in wind and radiation, directly influencing photosynthesis and favoring productive parameters.

In addition to attributes related to productivity, all hybrids, except 'Soleares', had the best characteristics in terms of IFF. The highest index was analyzed in Mina de Ouro (1.30), indicating that the fruits are oblong (1.1<IFF<1.7), a typical characteristic of the evaluated cultivars. The fruit shape index is an important characteristic both in standardization, packaging and accessibility by the consumer (Chitarra & Chitarra, 2005;

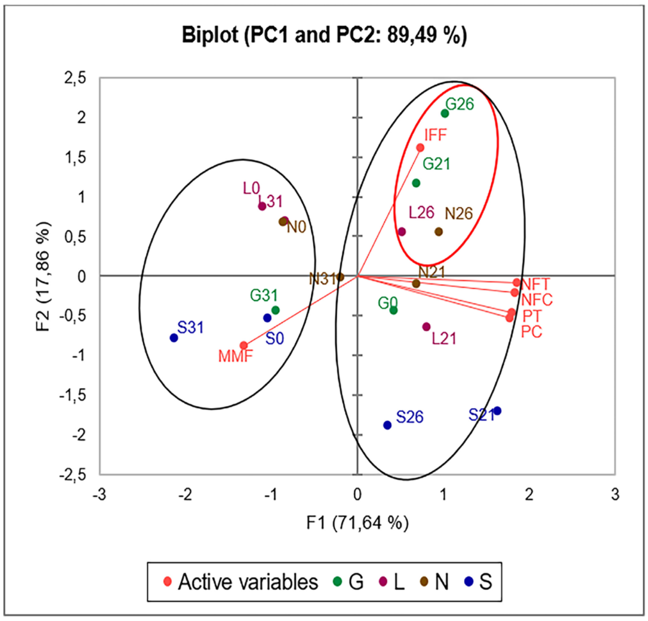

Figure 5 - Two-dimensional projection and scores of production parameters: total yield (PT), marketable yield (PC), fruit fresh mass (MF), number of total fruits (NFT), number of salable fruits (NFC) and fruit formation index (FFI) of yellow melon hybrids as a function of time covered with agrotextile mesh. The treatments are represented by the points in which the letters represent the initials of the hybrids (G – 'Gold Mine'; N – 'Natal'; S – 'Soleares' and L – 'Lual') and the numbers, the coverage times (0 – open field; 21 – 21 DAT; 26 – 26 DAT and 31 – 31 DAT).

Costa, 2017), whereas in relation to the time of cultivation under agrotextile mesh, no interaction on this factor was observed.

Among the treatments applied to the hybrids, for the parameter MF, treatment at 0 and 31 DAT showed the best results (Figure 5). Among the hybrids, 'Soleares' showed the best results. The greater fruit mass for the hybrids in the 0 and 31 DAT treatments is related to the smaller number of fruits per plant and the lower competition for photoassimilates, which resulted in larger fruit. The 31 DAT treatment had a longer protection time, interfering with pollination of the first flowers and causing a reduction in the number of fruits.

Fruit mass is directly related to the number of fruits per plant (Pereira et al., 2017). In addition, it is considered a characteristic of great relevance when selecting melon cultivars and choosing the most adapted cultivars in a given region (Nunes et al., 2011).

'Soleares', 'Natal' and 'Lual' had a higher soluble solids content, ranging from 11.04 to 11.50°Brix, which is considered high sweetness and is higher than the standard required to serve the foreign market (9.0°Brix) (Braga et al., 2017). Even 'Gold Mine', despite having less sweetness, presented a superior result (Table 2).

The variation in soluble solids content between cultivars is related to the results of metabolic, physiological and genetic processes of the plant during development (Beckles, 2012).

As for the pH of the fruit pulp, 'Lual' and 'Natal' obtained pulp pH 35% higher than the other hybrids (Table 2). When cultivated in the open field, the hybrids 'Lual' and 'Natal' had an average pH of 5.7, while 'Gold Mine' and 'Solearis' had a pH of 4.3. The coverage time increased the pH of the fruit of the 'Solearis' hybrid, with a gradual increase with the coverage time, with a pH of 5.95 at 31 DAT. These results indicate that all hybrids cultivated, except 'Gold Mine' at time 0 and 31 DAT, can be considered suitable for the consumer market because they had a pH greater than 4.5, which is the ideal value for marketing the fruit (Munira et al., 2013).

TA is an important indicator of melon fruit quality, as it is one of the main components of flavor in which the balance between fatty acids and sugars supports the sensation of freshness, determining the acceptability of the fruit in the market (Kyriacou et al., 2016). In general, the agrotextile mesh reduced the TA values of the fruits (Table 2). In the hybrids 'Lual' and 'Solearis', the increase in values was 40% when comparing 0 and 31 DAT, whereas in 'Gold Mine', the increase occurred only between days 26 and 31 DAT. In 'Natal', the values increased at 26 DAT. The TA values obtained in the present study ranged from 0.14 to 0.43, being very close to those acceptable for the melon fruit, which ranged from 0.05 to 0.35% (Mendlinger & Pastenak, 1992). Similar results were reported by Santos et al. (2015) in melons with different lengths of coverage with the agrotextile mesh; AT was significantly linear with coverage time, with the control (0 DAT) being 33% superior to the 30 DAT treatment.

The ripeness index (MI) is an important parameter for describing the relationship between soluble solids and titratable fruit acidity, as important indicators of flavor (Santos et al., 2015). In the present study, the length of coverage with the agrotextile mesh influenced our MI values when associated with the hybrids 'Lual', 'Gold Mine' and 'Solearis', with a gradual increase over time up to 31 DAT. However, for the hybrid 'Natal', fruit grown in the open field had a better result (0.65) (Table 2). In a test with melon under agrotextile mesh at different coverage times (0, 21, 24, 26 and 30 DAT), Santos et al. (2015) found results similar to those found in this study, where protection for 30 DAT surpassed the control by 32.39%, from 47.70 at time 0 to 60.76 at 30 DAT. In melon, the fruit is considered suitable for consumption when this ratio is greater than 25:1 and when the acidity is equal to or less than 0.5% (Cruess, 1973).

Considering the ascorbic acid (AA) content, there was a significant interaction between melon hybrids and the coverage time with the agrotextile mesh (Table 2). Comparing the hybrids as a function of coverage time, it was observed that 'Gold Mine', 'Lual' and 'Natal' grown without the agrotextile mesh had a higher AA concentration. 'Gold Mine' and 'Lual' included in the AA contents with the use of agrotextile mesh. However, 'Natal' showed elevation only at 21 DAT, not differing from the treatment without mesh at 26 and 31 DAT. As for the hybrid 'Soleares', the plants kept under cover until 26 DAT had fruit with a higher AA accumulation (12.7). According to Díaz-Pérez (2014), moderate shading (30–47%) can increase yields, probably as a result of improved heat stress compared to plants in the full sun.

Melo et al. (2012) reinforced interest in the cultivation and commercialization of hybrids that have a higher vitamin C content, which has benefits for human health and may be attractive in the commercialization of these fruits.

Flavonoids are important compounds in the plant–environment relationship and are involved in biotic and abiotic stress responses (Carbone et al., 2009), and in humans, they help fight disease (Perez-Vizcaino & Fraga, 2018). The lowest content of this antioxidant was presented in 'Natal', regardless of the coverage time (Table 2). 'Gold Mine', 'Lual' and 'Soleares' showed similar levels of flavonoids. In 'Lual', the coverage time with the agrotextile mesh increased in terms of flavonoid content. In the other hybrids, the use of mesh did not significantly change the content of these compounds in the fruit.

By evaluating the quality, bioactive compounds and antioxidant capacity of commercial hybrids of melon cultivated in CE/RN, Barreto (2011) found that yellow melon fruit had contents ranging from 0.52 to 1.32 mg 100−1 g. These values are in agreement with those found in this work.

Phenolic compounds are secondary metabolites produced by plants that can protect plant cells against free radicals through their antioxidant effects (Bahloul et al., 2009). Therefore, in the open field, 'Lual' presented a lower total phenolic content than the other evaluated hybrids. The use of agrotextile mesh did not cause a significant increase in these compounds in melon fruit (Table 2). The variation in the total phenol content present in the cultivars may be linked to the adaptation of the hybrid since the total phenols are influenced by the environment. In organic and conventional cultivation testing of 10 melon cultivars, there was a variation of 1.7 and 1.6 times the total phenol content between cultivars (Salandanan et al., 2009).

Regarding the DPPH of melons, in the present study, the use of agrotextile mesh impaired the antioxidant activity in 'Gold Mine' grown in the open field, which showed the best results (127.2 mg TE kg−1; Table 2). The other hybrids had varied responses, of which an increase in the antioxidant activity was observed in 'Lual' at 31 DAT compared to 21 and 26 DAT. In 'Natal', an opposite trend was verified, where the antioxidant activity increased between 21 and 26 DAT. In 'Soleares', relatively stable antioxidant activity was observed with the use of mesh. The results of the present study were superior to those of Moreira (2011), who obtained antioxidant capacity values ranging from 0.395 to 0.459 mg TE g−1 in pulp (fresh weight) from minimally processed melon fruit. By evaluating several fruits and vegetables in Belgium, Kevers et al. (2007) observed an antioxidant capacity of 0.56 mg TE g−1 in the pulp (fresh weight) of Charentais melons using the DPPH method.

The high antioxidant capacity attributed to melon is related to the high levels of polyphenols and carotenoids present in melon fruit (Melo et al., 2008; Gómez-García et al., 2020). The greater the antioxidant capacity of a food, the greater the ability to reduce free radicals. The imbalance between radicals and antioxidants in our body can cause oxidative stress and, as a result, the emergence of various diseases (Alkadi, 2020). In this way, the consumption of foods rich in antioxidants can help balance free radicals and antioxidants.

Studies have reported that excess light and high temperatures favor the accumulation of free radicals (Gill & Tuteja, 2010). Thus, a higher antioxidant content has a defense function in plant tissues when a plant is subjected to stress factors (Del Rio et al., 2006; Navrot et al., 2007).

PCA was applied to the physical–chemical and biochemical evaluations of the fruit (**Figure 6**). PC1 and PC2 accounted for 67.6% of the total data variation. PC1 explained 46.46% of the variation in the dataset, in which TA, FL and DPPH antioxidant activity presented the highest scores, grouping the 'Soleares' and 'Gold Mine' hybrids cultivated in the open field, 'Soleares' and 'Gold Mine' cultivated under protection until 21 DAT, and 'Natal' and 'Gold Mine' cultivated under protection until 26 DAT. The MI and pH grouped 'Lual' and 'Natal' grown under protection until 31 DAT and 'Natal' under the open field in PC1.

In PC2, which explained 21.14% of the data variation, total phenolics had the highest score, grouping 'Soleares' and 'Gold Mine' grown under protection up to 31 DAT and 'Natal' under protection up to 21 DAT.

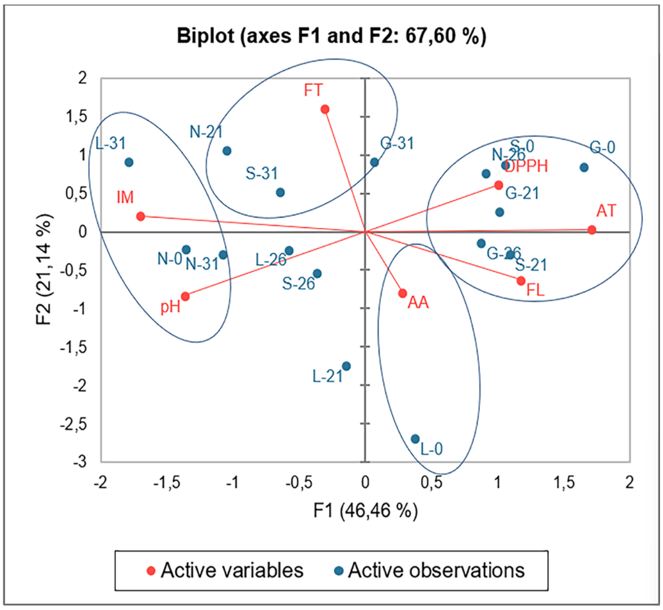

Figure 6 - Two-dimensional projection and scores of the quality parameters soluble solids (SS), titratable acidity (TA), pH, maturation index (MI), total phenols (FT), flavonoids (FL), ascorbic acid (AA) and DPPH of yellow melon hybrids as a function of time covered with agrotextile mesh. The treatments are represented by the points in which the letters represent the initials of the hybrids (G – 'Gold Mine'; N – 'Natal'; S – 'Soleares' and L – 'Lual'), and the numbers represent the coverage times (0 – open field; 21 – 21 DAT; 26 – 26 DAT and 31 – 31 DAT).

Conclusion

Despite increasing the temperature, the use of agrotextile mesh maintained a more suitable relative humidity for cultivation, in addition to hindering insect pest infestation and, consequently, reducing the need to apply phytosanitary products by up to 47% for insecticides and 55% for fungicides with use for 31 DAT when compared to the open field.

The coverage times 21 and 26 DAT showed the best results for the productive intervals to provide protection and assertive management of the mesh and not hindering fruit set, as it depends on pollinating insects.

However, for the hybrids, we found that 'Solares' had larger fruit, but there was no difference in production, while the fruit of the hybrid 'Natal' protected for 21 DAT had a better total phenol content and a higher maturation index. 'Soleares' protected for 21 DAT showed higher DPPH antioxidant activity and flavonoid content.

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