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Weed interference in melon crop under semi-arid conditions

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ABSTRACT. The management of weeds in melon is hindered by the slow initial growth of the crop, favouring weed infestation and reducing production. During the years 2016 and 2017, weed interference periods were evaluated in two melon hybrids, yellow and frog skin, to determine the time of weed control in the crop. Four-parameter logistic regression was used to determine the critical weed control period (CPWC). The weed species with the highest occurrences in 2016 were *Merremia aegyptia*, *Senna obtusifolia*, and *Urochloa plantaginea*. In 2017, there was a predominance of *M. aegyptia*, indicating the possibility of successive cultivation, favouring the predominance of species with growth habits similar to melons. The increase in the period of living with weeds reduced the productivity and quality of melon fruits. Coexistence with weeds throughout the cycle reduced productivity by about 50%. The CPWC was 15 to 58 and 10 to 45 for frog skin and 12 to 52 and 4 to 50 days for yellow melon in 2016 and 2017, respectively, considering a productivity loss of 5%. These results underscore the importance of adopting strategies that allow melons to grow free from the presence of weeds, especially before they are fully established in the growing area.

Keywords: *Cucumis melo* L.; competition; frog skin; yellow; productivity.

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Introduction

The cultivation of melon in Brazil has been concentrated in the semi-arid region of the Northeast of the country, responsible for more than 98% of the fruit production that is destined for the domestic market and exports to several countries, such as the United States, Chile, Argentina, Uruguay, and Russia, in addition to European Union countries (IBGE, 2017).

The cultivation system in this region is characterised by the intensive use of machines for the preparation of the soil, the use of agro textile blanket (TNT), in the form of a tunnel over the culture in the first weeks of cultivation for the control of pests and mulching over the soil, along with transplanting seedlings from hybrid seeds and localised irrigation (Aguiar Neto, Grangeiro, Mendes, Costa, & Cunha, 2014). The last three contribute to the cultural and physical control of weeds, but they are not enough to eliminate negative interference from the weed community.

The control of weeds in melon has been carried out through weeding and the use of chemical control, however; the use of the latter is restricted due to the low number of herbicides registered for the crop (Lins et al., 2018). Besides, the blanket over the plants is used during the first 30 days to avoid pest infestations, which also makes it difficult to carry out weeding before the first month (Teófilo et al., 2012). This fact can be harmful since the slow initial growth of the seedling can favour the infestation of weeds causing a reduction in fruit productivity and quality due to competition with the crop (Santos et al., 2015). In addition, when handled incorrectly, weeds can cause losses of up to 100% in commercial productivity due to loss of fruit quality (Bairambekov, Sokolova, Gar'yanova, Dubrovin, & Sokolov, 2016).

Morphophysiological aspects of the hybrids, such as height, leaf area, number of leaves and length of stems influence the determination of the spacing and population of the different genotypes of the cultivated species and, consequently, may influence the period of weed control (Holmes & Sprague, 2013). The environmental and cultivation characteristics also affect the performance of the melon hybrids, which can change the time when weed control begins, as well as the duration, an important factor in the production costs of the crop. In this way, knowledge of information related to the weed interference period can assist in planning for management practices aimed at reducing the interference of the weed community (Lins et al., 2019).

The efficiency of weed management strategies in reducing interference depends on knowledge of the control periods and the factors that influence the interaction. In this research, the effects of the coexistence of the weed community on the productivity and quality of the fruits of the yellow and frog skin melons were evaluated as a way of determining the critical period of weed control.

Material and methods

Location and characterisation of the experimental area

Field studies were conducted at the Rafael Fernandes Experimental Farm (5°03'37" S, 37°23'50" W and 81 m elevation), located in Mossoró, Rio Grande do Norte State, Brazil, from October to December of the years 2016 and 2017.

The climate of the region, according to the Köppen classification, is of the BSh type, hot and dry, with an average annual rainfall of 673.9 mm (Alvares et al., 2013). The average data of air temperature, the relative humidity of the air during the conduction of the experiments of each year of cultivation are presented in Figure 1. There was no occurrence of rain during the conduction of the experiment over the two years.

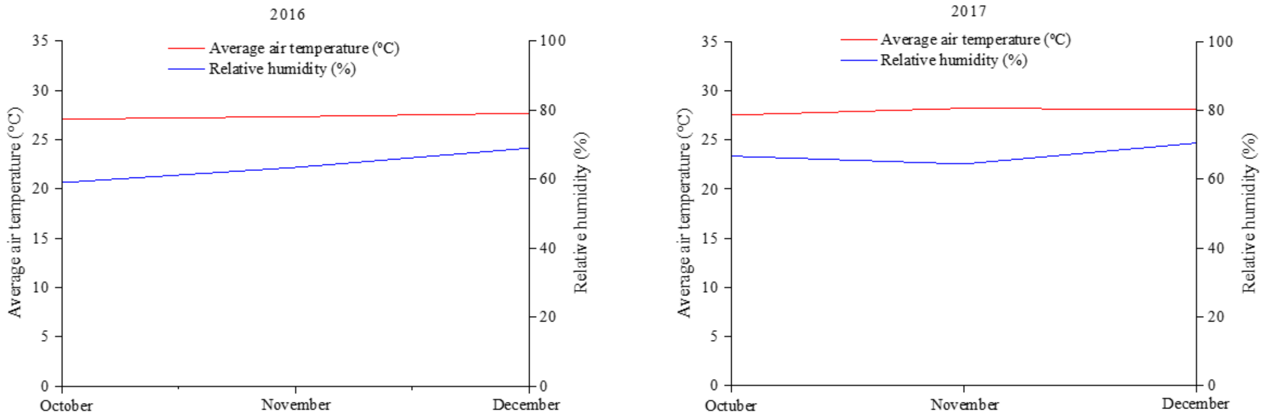

Figure 1. Average values of temperature and relative humidity in the two years of cultivation of the melon. Source: INMET Automatic Meteorological Station and rain gauge installed on the experimental farm (UFERSA, 2016–2017).

The soil in the experimental area is classified as typical Red Dystrophic Argisol (Santos et al., 2018) and presented 13% clay, 84% sand and 3% silt.

Experimental design and treatments

The experimental design used was randomised blocks (DBC), with three replications. The treatments were arranged in a split-plot scheme, with the parcels consisting of two melon hybrids: 'Goldex' (yellow) and 'Grand Prix' (frog skin). The subplots were of the weed coexistence periods with the crop. There were two types of treatments: (i) the plots were left in contact with the weeds for 0, 10, 20, 30, 40, and 75 days after transplanting (DAT) to assess the start of the critical weed control period and (ii) the plots were kept free from the weed community for 0, 10, 20, 30, 40, and 75 DAT to determine the end of the critical period. Control plots kept free of weeds were weeded manually as the weed community appeared.

Installation and conduction of experiments

The soil preparation consisted of ploughing and harrowing, followed by raising the beds using a rotary hoe. Fertilisation was carried out according to the needs of the crop, based on soil analysis (Table 1) following recommendations proposed by Cavalcanti (2008). Fertilisation before planting was carried out with 180 kg ha^{-1} of P_2O_5 (simple superphosphate), 3 kg ha^{-1} of zinc (zinc sulphate), and 1.1 kg ha^{-1} of boron (boric acid). In addition, covering fertilisation with 165 kg ha^{-1} of nitrogen (urea) and 30 kg ha^{-1} of K_2O (potassium chloride) was carried out, proceeding to the application via fertigation, with the aid of a bypass tank. This fertilisation was used for both years of cultivation.

Table 1. Chemical characterisation of the soil in the melon cultivation area. Mossoró, Rio Grande do Norte State, Brazil, 2020.

Year	pH	OM	K	P	Na	Ca	Mg	Al^{3+}	$H+Al^{3+}$	CEC
	H_2O	g kg^{-1}	-----mg dm^{-3}-----			------------ $cmol_c$ dm^{-3} ------------				
2017	6.6	2.6	33.8	25.5	6.9	0.5	0.7	0.0	0.0	1.3
2018	6.9	2.3	39.1	14.1	7.3	1.1	0.4	0.0	0.17	1.8

pH = hydrogen ionic potential; OM = organic matter; K = potassium; P = phosphorus; Na = sodium; Ca = calcium; Mg = magnesium; Al = aluminium; H+Al = potential acidity; CEC = cation exchange capacity.

The drip irrigation system was located, with emitters showing a flow rate of 1.7 L h^{-1}, spaced 0.3 m apart, proceeding to irrigation daily according to the estimated ETc of the culture (ETc = ETo × Kc). The Kc values corresponding to the stages of development were estimated by reference evapotranspiration using the equation of Penmam Motheith (Allen, Pereira, Raes, & Smith, 1998).

After the irrigation was set up, mulching (polyethylene film) was placed on the beds, double-sided black and white, leaving the white face up and the black face down. The holes for planting seedlings in the mulching were from the factory, spaced 0.4 m apart and 5 cm in diameter.

The melon seedlings were produced in polypropylene trays with 200 cells of 20 cm^3, using a commercial substrate. Seedlings were transplanted 12 days after sowing, when they were approximately 5 cm tall and had the first true leaf and spaced 0.4 m between plants and 2 m between rows (beds). Each experimental plot consisted of three beds, measuring 2.8 m long, 1 m wide, and 10 cm high each. The line of the central bed was considered a useful area, totalling five plants in the useful area of each experimental plot. Pesticides were applied according to the appearance of pests and diseases while maintaining the plants' health.

Evaluated characteristics

At the end of each coexistence period, weeds present in the useful area of each plot were collected. This collection occurred in the mulching holes (19.63 cm^2) of the five melon plants in the useful area. All weeds that germinated in the area of the mulching hole were collected. After collection, the weeds were counted, identified, packed in paper bags and dried in a forced-air circulation oven for 72 hours at 65°C, to determine the dry matter. The dry matter of the weed community was extrapolated to g m^{-2} of dry matter, and the data were later transformed into relative dry matter (%).

In both years, the melon harvest was carried out at 75 DAT, when the content of soluble solids in the fruits produced in the plots maintained by weeding was close to 10° Brix. For that, the fruits of the plants of the useful area were harvested to determine commercial productivity. Fruits weighing more than 0.9 kg and without apparent defects were considered marketable (Filgueira, 2000).

The qualitative characteristics of the fruits were evaluated based on a sampling of two fruits per plot. The average fruit mass was obtained from weighing on a digital scale with 0.1 g precision. The content of soluble solids was determined using a digital refractometer, obtaining the values in ° Brix. The dimensions of the fruits were made by measuring the longitudinal, transverse diameter and thickness of the pulp, with the aid of a graduated ruler. The firmness of the pulp was determined utilising two readings in the peripheral region of the pulp of each fruit, using a penetrometer with an 8 mm diameter plunger, with the results being presented in Newtons (N).

Statistical analysis

The data were subjected to Bartlett and Shapiro-Wilk tests to verify the homogeneity of variance and normality of the residues, respectively. The weed dry matter was evaluated and compared descriptively between treatments. The relative yield was calculated and submitted to regression analysis (Knezevic, Streibig, & Ritz, 2007). A log-logistic model was used, where *y* represents the relative productivity, x is the days after transplanting and *A*, *B*, and *EC*50 are parameters of the equation:

$$y = A + (B - A)/(1 + \left(\frac{X}{EC50}\right)^{-C}$$

Losses of 5 and 10% were established to determine the critical period of weed control (CPWC) of the hybrids. The post-harvest data were subjected to analysis of variance by the Scott-Knott test ($p \leq 0.05$). The regression analysis and the creation of the graphics were performed using the SigmaPlot® software version 12.0.

Results

Dry weed matter

The main species of plants that occurred in this study were *E. indica*, *P. oleracea*, *D. horizontalis*, *S. obtusifolia*, *I. triloba*, *M. aegyptia*, *T. portulacastrum*, *Blainvillea* sp., *U. plantaginea*, *A. tenella*, and *M. pudica* for the areas with both hybrids of melon, in the years 2016 and 2017 (Figure 2).

In 2016, in the area planted with yellow Melon, at 10 DAT, the species with the highest accumulation of dry matter were *S. obtusifolia* (41.4 g m^{-2}) and *T. portulacastrum* (27.3 g m^{-2}). At 20 DAT, the species were *P. oleracea* (32.5 g m^{-2}), *S. obtusifolia* (40.6 g m^{-2}) and *M. aegyptia* (41.1 g m^{-2}). *Senna obtusifolia* maintained the dry matter accumulation until 40 DAT, significantly reducing it by 75 DAT. On the other hand, *M. aegyptia* (68.7 g m^{-2}) and *U. plantaginea* (28.9 g m^{-2}) increased their dry matter accumulation at 75 DAT (Figure 2A). For the frog skin melon, at 20 DAT, *M. aegyptia* was the species that had the highest accumulation of dry matter (82.2 g m^{-2}), reducing it to 47.5 g m^{-2} and 28.65 g m^{-2} at 30 and 40 DAT, followed by an increase to 46.6 g m^{-2} at 75 DAT. The species *I. triloba* presented a dry matter accumulation of 26.4 g m^{-2} at 30 DAT. At 40 DAT, *U. plantaginea* and *T. portulacastrum* presented dry matter of 23.6 and 28.1 g m^{-2}, respectively. At 70 DAT, the species with the highest dry matter values were *M. aegyptia* (46.6 g m^{-2}) and *D. horizontalis* (25.7 g m^{-2}) (Figure 2B).

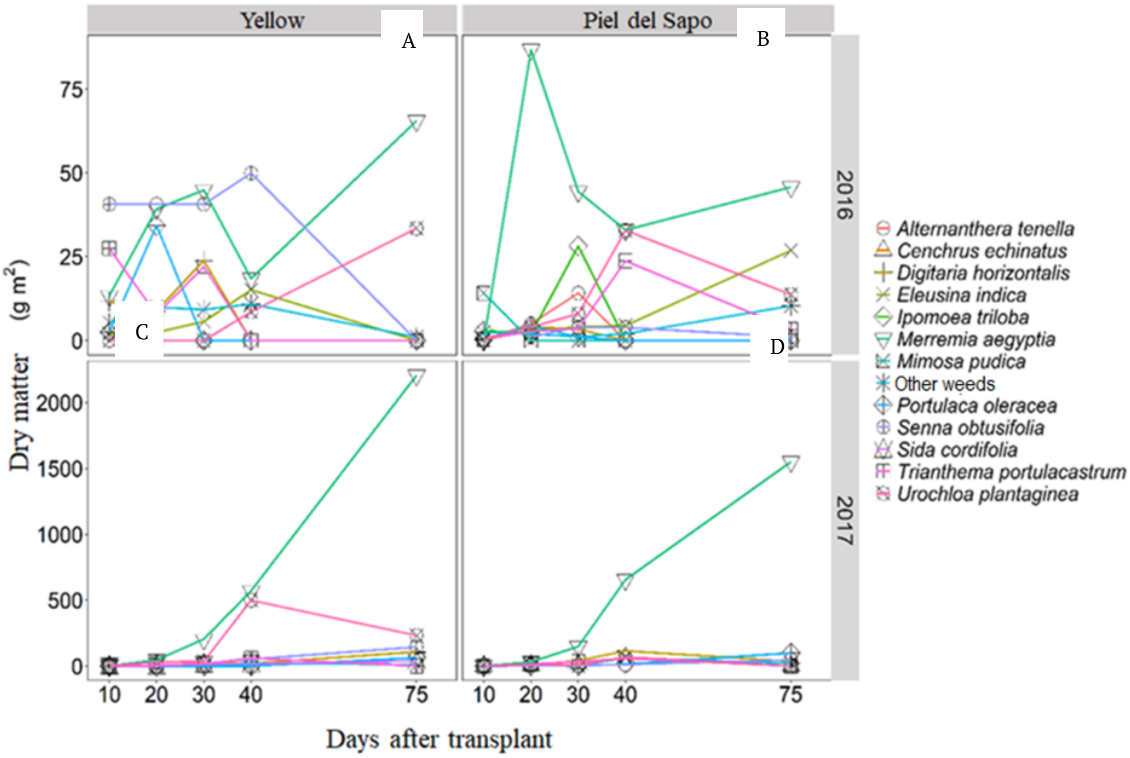

Figure 2. Weed relative dry matter in the area evaluated at 10, 20, 30, 40, and 75 DAT in the melon. A: yellow in 2016; B: frog skin in 2016; C: yellow in 2017; D: frog skin in 2017. UFERSA, Mossoró, Rio Grande do Norte State, Brazil.

In 2017, in the area of yellow melon, during all periods of evaluation, *M. aegyptia* was the species that most accumulated dry matter. At 40 DAT, *U. plantaginea* also showed high dry matter (496.4 g m^{-2}). The other species had less dry matter in all periods of evaluation (< 10 g m^{-2}) (Figure 2C). In the area with yellow melon, *M. aegyptia* was the species with the highest dry matter, reaching 1,486.5 g m^{-2} at 75 DAT. The dry matter accumulated by the other species was less than (< 10 g m^{-2}) in all periods of evaluation (Figure 2D).

Effects of the duration of the coexistence period on the qualitative characteristics of melon fruits

The quality characteristics of frog skin melon fruits were impaired by weed interference. As weed coexistence time increased with the crop, there was a reduction in the pulp firmness (PF), soluble solids (SS), longitudinal diameter (LD), transverse diameter (TD), and in the pulp thickness (PT) (Figure 3). The SS and PF content were affected by living with weeds from 40 and 30 DAT, respectively, in both years. The reduction in LD occurred from 10 DAT and TD decreased from 40 DAT in 2016 and 2017, respectively. The PT reduced up to 10 DAT in competition, remaining constant for the other seasons in the year 2016. In 2017, there was a reduction in PT from the 30 DAT of the crop in competition with the weeds (Figure 3).

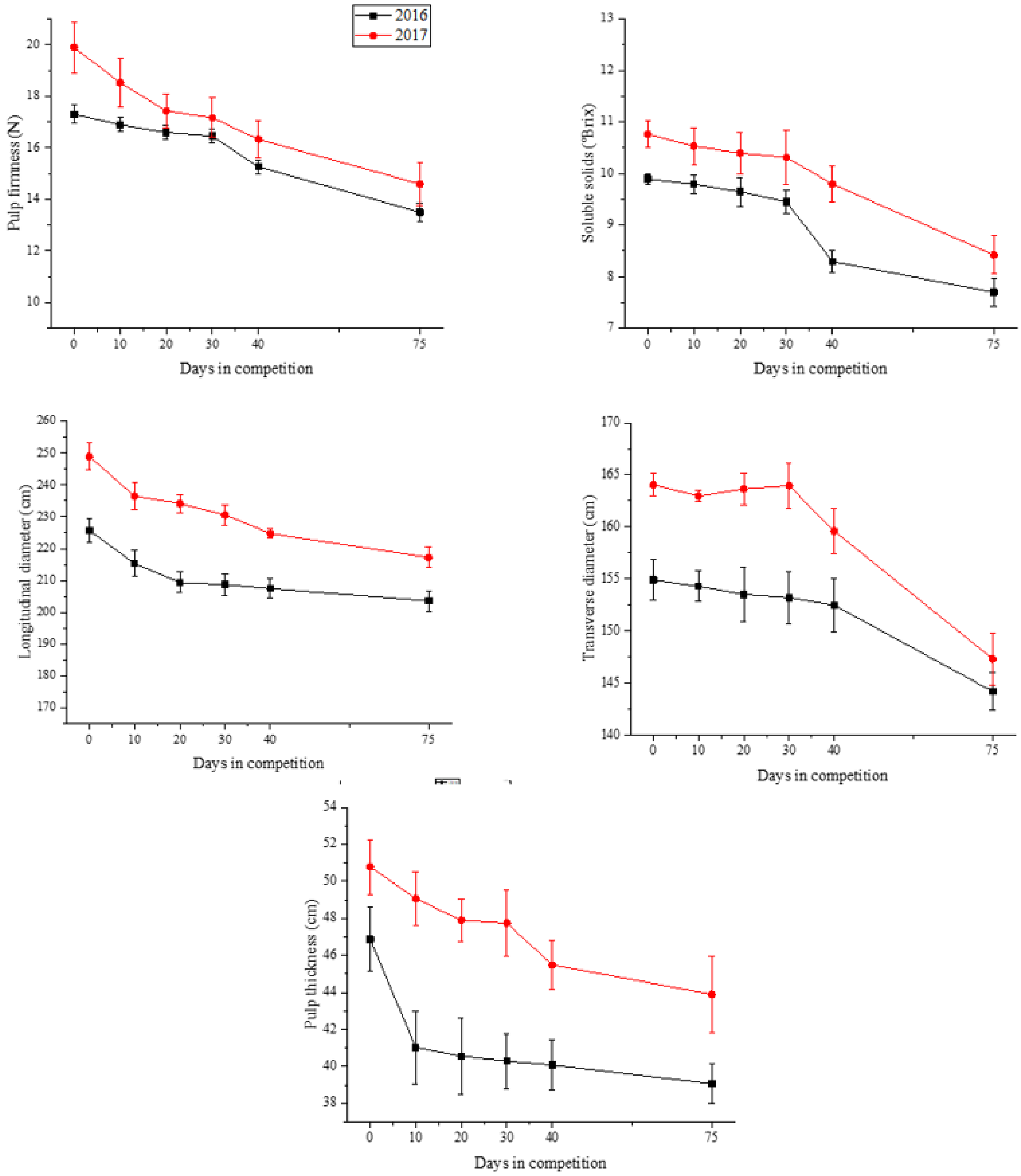

Figure 3. Pulp firmness (PF), soluble solids (SS), longitudinal diameter (LD), transverse diameter (TD), and pulp thickness (PT) of frog skin melon fruits harvested at different times of competition with weedy plants (0, 10, 20, 30, 40, and 75 days) in 2016 and 2017. Bars represent the standard deviation of the means (n = 3).

The average levels of soluble solids observed at 40 DAT in coexistence with weeds, was 8.7° Brix in 2016 and 9.6° Brix in 2017 (Figure 3). The lowest desirable value to the SS content in the export market is 10° Brix. Although there was a reduction in this attribute, the values are within the standards required by the standards for melons of the United Nations Economic Commission for Europe (UNECE, 2018).

The qualitative characteristics of the yellow melon were also affected by living with weeds (Figure 4). Living for at least 40 DAT reduced the SS content by more than 20% in the two years of cultivation. The PF was reduced after 30 DAT and the DT of the fruit from 40 DAT. The LD and the PT were not significantly reduced by the time of coexistence of the culture with the weeds.

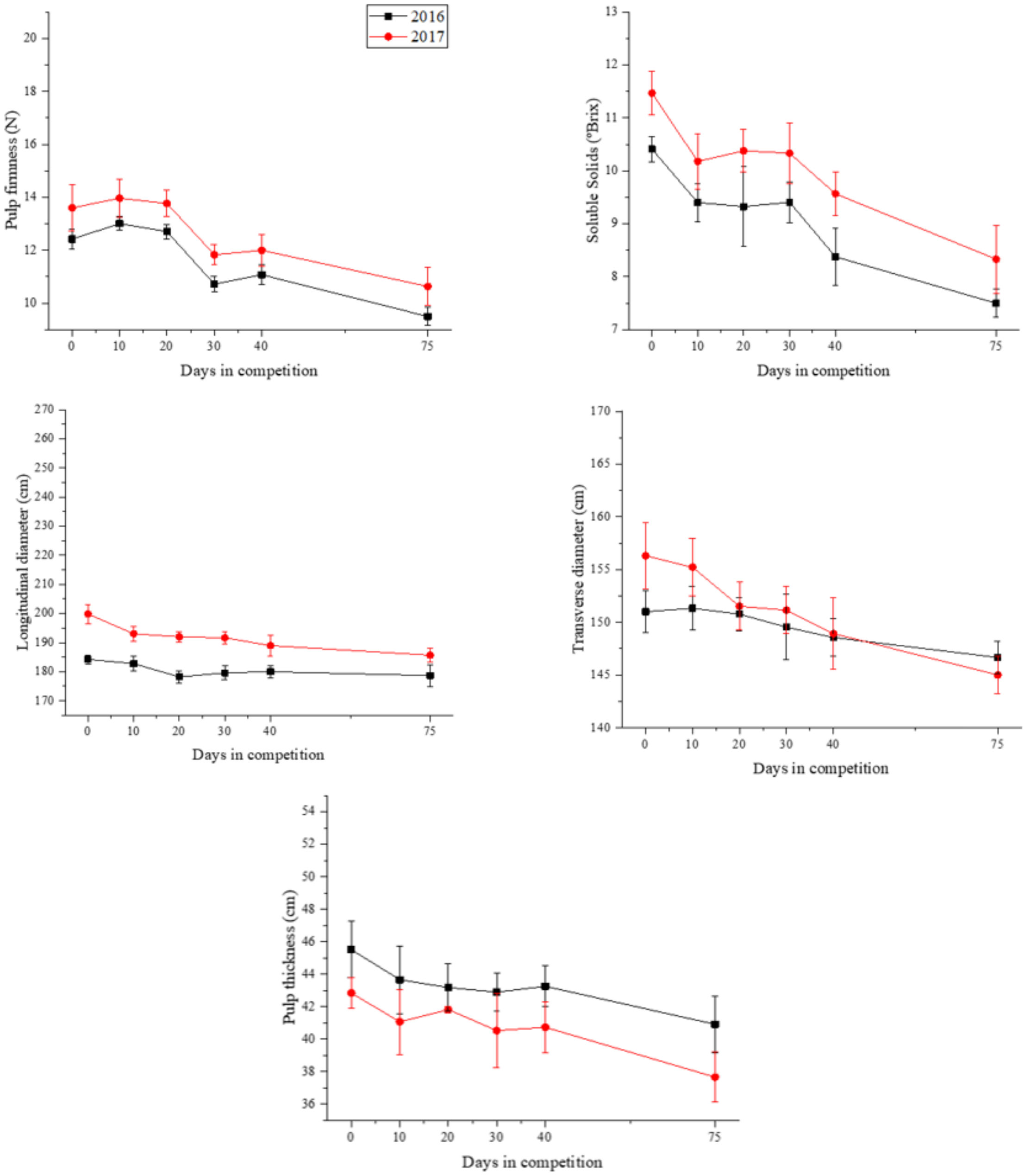

Figure 4. Pulp firmness (PF), soluble solids (SS), longitudinal diameter (LD), transverse diameter (TD), and pulp thickness (PT) of yellow melon fruits harvested at different times of competition with weeds (0, 10, 20, 30, 40, and 75 days) in 2016 and 2017. Bars represent the standard deviation of the means (n = 3).

Critical period of weed control (CPWC)

The data referring to the relative productivity of the melon in the two hybrids were independently analysed to determine the beginning and end of the CPWC each year (Figure 5, Table 2). The production of the two melon hybrids, in the two years, was reduced by living with weeds. The yields of weed-free plots ranged from 59.06 to 45.38 t ha^{-1} in the yellow melon and 62.97 to 50.86 t ha^{-1} in the frog skin melon, compared to the yields obtained of 28, 41 to 34.51 t ha^{-1} for yellow melon and of 26.12 to 32.67 t ha^{-1} for frog skin melon in plots with the presence of weeds throughout the cycle in the years 2016 and 2017, respectively. This reduction was equivalent to the loss of 58 and 52% for frog skin melon and 52 and 48% for yellow melon in the years 2016 and 2017, respectively.

The duration of CPWC varied between years and hybrids (Table 3). Considering the loss level of 5%, the CPWC duration of the frog skin hybrid was 43 and 40 days, while for the yellow hybrid it was 40 and 46 days for the years 2016 and 2017, respectively. Considering an average cycle of 75 days between transplanting the seedling and harvesting the fruit, the control period is equivalent to approximately 55% of the crop cycle.

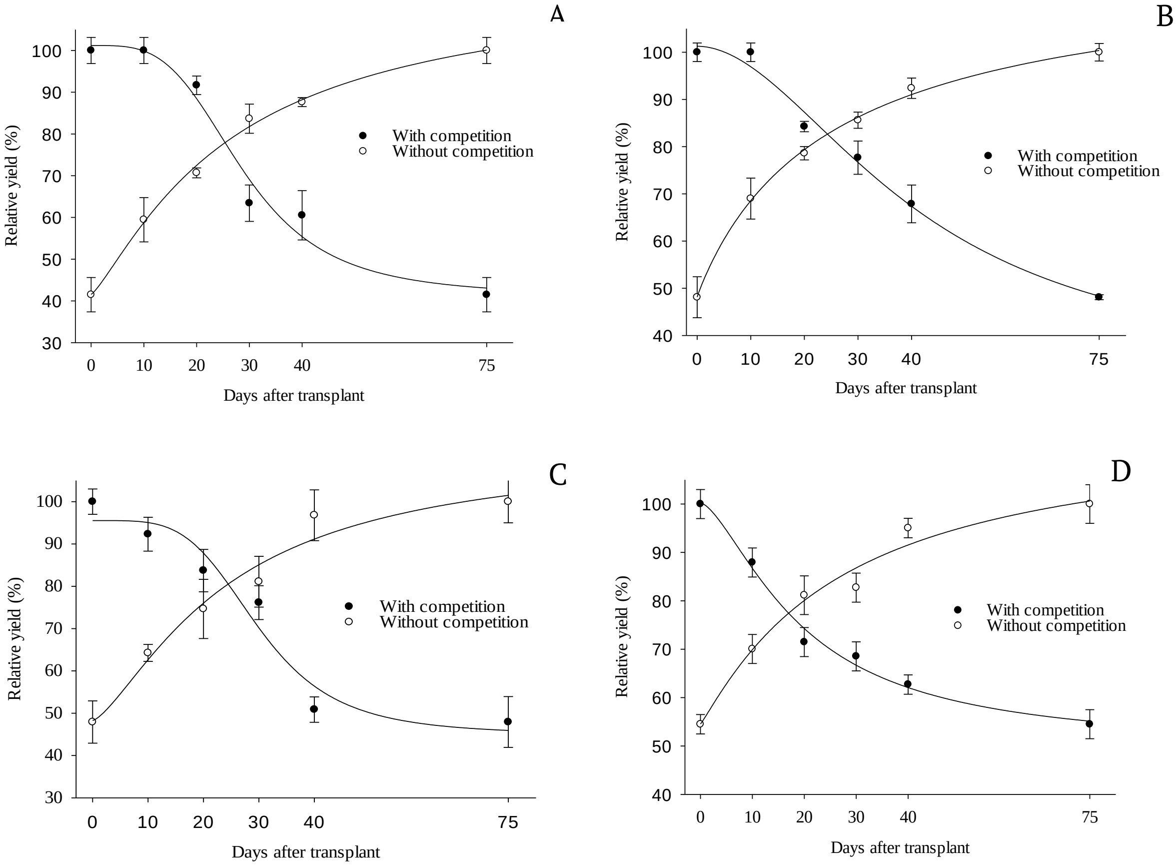

Figure 5. Relative productivity of frog skin (A and C) and yellow (B and D) melons in 2016 (A and B) and 2017 (C and D), depending on the days after transplanting in coexistence or not with weeds. UFERSA, Mossoró, Rio Grande do Norte State, Brazil.

Table 2. Estimated regression parameters between years (2016 and 2017) and the two melons (frog skin and yellow) for the log-logistic model of four parameters characterising the influence of the weed interference duration on the relative productivity.

			Regression parameters				
Year	Hybrid	Curve	*A*	*B*	EC_{50}	*C*	R^2
2016	frog skin	Without competition	41.57	116.52	26.44	1.23	0.99
		In competition	41.46	101.96	28.51	-3.54	0.98
2017	frog skin	Without competition	48.14	134.04	38.92	1.14	0.98
		In competition	41.29	98.90	30.82	-3.61	0.97
2016	yellow	Without competition	48.15	119.93	25.59	0.96	0.99
		In competition	31.62	101.27	41.12	-1.9190	0.99
2017	yellow	Without competition	54.51	160.06	81.59	0.8310	0.99
		In competition	43.60	100.22	22.94	-1.38	0.99

A = slope of the line to the inflection point; C = lower limit; B = upper limit; EC50 = 50% point of the response between the upper and lower limit; R^2 = coefficient of determination.

Table 3. Period Prior to Interference (PPI), Critical period of weed control (CPWC) and Total Period of Interference Prevention (TPIP) for two melon hybrids (frog skin and yellow) in two years of cultivation (2016 and 2017). UFERSA, Mossoró, Rio Grande do Norte State, Brazil.

			Interference periods		
Year	Reduced productivity (%)	Hybrid	PPI	CPWC	TPIP
2016	5	frog skin	15	43	58
		yellow	12	40	52
	10	frog skin	18	27	45
		yellow	16	22	38
2017	5	frog skin	10	40	50
		yellow	4	46	50
	10	frog skin	16	22	38
		yellow	8	30	38

The beginning of the control varied between the 15th and 10th day for the frog skin hybrid and the 12th and 4th day for the yellow hybrid in the years 2016 and 2017, respectively, considering a loss of productivity of 5% (Table 3).

Discussion

Dry weed matter

Most of the weed species observed in the study area are common in the semiarid region of Brazil (Lins et al., 2019; Mesquita et al., 2017; Marques et al., 2011). The use of mulching as a control method was not sufficient to suppress weeds, and species with a growth habit similar to the culture of melon prevailed, which were possibly favoured by the cultivation system and because they presented the same requirements for growth factors.

The cultivation of melon in the same area for two consecutive years may have favoured the establishment of *M. aegyptia* since the species accumulated more dry matter in the second year and was more efficient to occupy the area. *M. aegyptia* excels in more hostile environments, even with the presence of mulching and localised irrigation (Bianco, Carvalho, Panosso, & Bianco, 2009). The climbing habit of *M. aegyptia* is even more harmful to the culture of the melon, since it shadows part of the leaf area of the culture, preventing its full development. This reduction in the availability of light throughout the cycle can lead to a reduction in photosynthesis, a fact that even contributed to the decline of other weeds in cultivation (Pereira, 2003).

Despite the presence of weeds with C4 metabolism present greater photosynthetic and productive capacity than C3 plants under conditions of full illumination and high temperature, they were suppressed by the adaptation of *M. aegyptia* (Bellasio & Griffiths, 2014; Tsutsumi, Tohya, Nakashima, & Ueno, 2017).

Effects of the duration of the coexistence period on the qualitative characteristics of melon fruits

The factor that may have contributed to the decrease in the qualitative characteristics of the frog skin melon was the aggressiveness of some weeds present in the area, in the case of *M. aegyptia*, competing for environmental factors with the crop, mainly at the end of the cycle in both years, demonstrating a greater competitive capacity to culture (Tursun et al., 2016).

The reduction in the content of soluble solids for yellow melon caused by the longer period of living with weeds is due to the negative effects of competition for nutrients and mainly for light, due to the presence of larger weeds compared to melon plants, reducing the crop canopy, the photosynthetic rate, providing a decrease in the production of photoassimilates (Ghanizadeh, Lorzadeh, & Aryannia, 2014). The harvest season directly interferes with the final quality of the product and is related to several factors, mainly crop management, showing that the qualitative characteristics of the melon culture are affected by weed management practices and different hybrids (Biabani, Golesorkhy, Sabouri, Moghadam, & Esmaeili, 2015).

Critical period of weed control

The reduction in productivity observed in Figure 5 for the yellow melon and frog skin hybrids in the years 2016 and 2017 for the treatments that remained in coexistence with the weeds was smaller than that observed by other authors, who found that weed interference reduced commercial productivity in yellow melon by up to 100% in conventional planting (Teófilo et al., 2012). This lower loss of productivity can be explained by the predominance in the studied area of species with the C3 photosynthetic route (less competitive) than species with the C4 photosynthetic route (more competitive).

In Table 3, the results indicate that weed control must begin between the first and second week of cultivation, when the melon is covered with a blanket to prevent the attack of pests, such as the *B. tabaci* and the *L. sativae* (Azevedo & Bleicher, 2003; Mesquita, Azevedo, Sobrinho, & Guimarães, 2007). The control of weeds at this time is hampered by the use of the blanket, making it more costly, since the procedures for removing and re-covering with the blanket delay the operation and, consequently, increase production costs (Johnson & Mullinix, 2002).

The use of mulching promotes soil cover and favours the emergence of weeds only at the place where the seedling is planted. However, this fact combined with the slow initial growth of the melon crop (Medeiros, Duarte, Fernandes, Dias, & Gheyi, 2008; Gurgel, Gheyi, & Oliveira, 2010) also contributes to inefficient control of weeds in the region close to the plant, due to the exposure of the crop to light incidence, allowing the growth of weeds that will compete with the crop for growth factors.

The results at the end of the TPIP indicate that control strategies must be adopted even after the blanket is removed. Mechanical control is impaired by the risk of withdrawal from the melon plant due to the proximity between the crop and the weeds. The use of herbicides in post-emergence may also not be effective, since the umbrella effect provided by the melon can reduce the absorption of the herbicide by the weed and, consequently, compromise the efficiency of control (Freitas et al. 2007).

To obtain a yield with up to 5% losses in yellow melon and frog skin in the two years of cultivation, weed control started between the first and the second week and end between the seventh and the eighth week after transplantation.

Conclusion

The predominant weed species in melon cultivation was *Merremia aegyptia*. The presence of weeds reduces the yield of the frog skin melon hybrid by up to 58% and the yield of the yellow melon by 52%. The quality of the frog skin and yellow melon hybrids is reduced with the increase in the time spent with weeds. Weeds must be controlled from 10 DAT for frog skin melon and 4 DAT for yellow melon. The weed control period should be maintained up to 43 DAT for the frog skin melon and 46 DAT for the yellow melon to avoid more than 5% loss of yield of these hybrids.

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