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Plant Physiology/ Original Article

Yield and photosynthetic attributes of sunflower cultivars grown under supplemental irrigation in the Semiarid Region of the Brazilian Northeast

Abstract – The objective of this work was to identify the sunflower cultivar with the highest-yield potential for cultivation in the Semiarid Region of the Brazilian Northeast, under field conditions, with supplementary irrigation. Plant photosynthetic performance and yield were determined in field trials. The experiments were carried out in a randomized complete block design with 12 cultivars planted at 0.70 x 0.30 m, in Poço Redondo, Sergipe state. Net photosynthetic rates above 27 $\mu mol \cdot m^{-2} \cdot s^{-1}$, average 2,364.68 $kg \cdot ha^{-1}$ achene, and 961.96 $kg \cdot ha^{-1}$ oil yield were determined. This performance was achieved because of high-stomatal conductance (in sunflower 'Aguara 4', 'BRS 322', and 'CF101'), or low-water loss through transpiration (in 'M 734', 'BRS 321', 'BRS 324', 'BRS 387', and 'HELIO 251'), or high-intrinsic photosynthetic efficiency (in HELIO 251 and 'BRS 387'). Most cultivars provided grain amounts and oil contents similar to those of cultivars grown in the largest Brazilian producing areas. 'Aguara 4', 'CF 101', and 'BRS 322' (high achene and oil yield), and 'M 734' (high-achene yield) are the cultivars that provide the highest yield in the Brazilian Semiarid Region, when grown under supplementary irrigation conditions. 'HELIO 251' and 'BRS 387' (high-intrinsic photosynthetic efficiency) are the less susceptible cultivars to severe water deficit.

Index terms: *Helianthus annuus*, grain, oil, stomatal conductance.

Rendimento e atributos fotossintéticos de cultivares de girassol cultivadas com irrigação suplementar na Região do Semiárido do Nordeste Brasileiro

Resumo – O objetivo deste trabalho foi identificar a cultivar de girassol com maior potencial produtivo para cultivo no Semiárido Nordestino, em condições de campo, com irrigação suplementar. Determinaram-se o desempenho fotossintético e o rendimento em ensaios de campo. Os experimentos foram realizados em delineamento de blocos ao acaso, com 12 cultivares plantadas em espaçamento 0,70 x 0,30 m, em Poço Redondo, no estado de Sergipe. Foram determinadas taxas fotossintéticas acima de 27 $\mu mol\ m^{-2} \cdot s^{-1}$, rendimento médio de grãos de 2.364,68 $kg \cdot ha^{-1}$ e de óleo de 961,96 $kg \cdot ha^{-1}$. Este desempenho foi possível em razão da alta condutância estomática (em 'Aguara 4', 'BRS 322', 'CF 101'), ou pela baixa perda de água por transpiração (em 'M 734', 'BRS 321', 'BRS 324', 'BRS 387', 'HELIO 251'), ou pela alta eficiência fotossintética no uso de água (em 'HELIO 251', 'BRS 387'). A maioria das

Luciana Marques de Carvalho[1 ✉], Hélio Wilson L. de Carvalho[1] and Claudio Guilherme P. de Carvalho[2]

[1]Embrapa Tabuleiros Costeiros, Avenida Beira mar, n.º 3.250, CEP 49025-480 Aracaju, SE, Brazil. E–mail: luciana.carvalho@embrapa.br, helio.carvalho@embrapa.br

[2]Embrapa Soja, Caixa Postal 231, CEP 86001-970 Londrina, PR, Brazil. E–mail: portela.carvalho@embrapa.br

✉ Corresponding author

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cultivares forneceu grãos e óleo em quantidades similares àquelas das maiores áreas produtoras brasileiras As cultivares com maior rendimento no Semiárido brasileiro, cultivadas com irrigação suplementar são ‘Aguara 4’, ‘CF 101’ e ‘BRS 322’ (alto rendimento de aquênios e óleo) e ‘M 734’ (alto rendimento de aquênios). As cultivares de menor susceptibilidade ao estresse hídrico severo são ‘HELIO 251’ e ‘BRS 387’ (maior eficiência fotossintética no uso da água).

Termos para indexação: *Helianthus annuus,* grãos, condutância estomática, óleo.

Introduction

Sunflower (*Helianthus annuus* L.) stands out among oilseeds as it contributes for about 12% of the world’s edible oil production (Saba et al., 2016). The world demand for sunflower oil has been increasing on average by 1.8% per year, whereas the internal demand in Brazil increases on average at 13% per year (Rosa et al., 2009). However, Brazilian sunflower production is still small, and there is a need of imports to meet the country´s demand (Brasil, 2018).

The largest Brazilian producing areas are in the Southern and Central regions, where the annual rainfall supports the water requirements of the sunflower cultivation (Dalchiavon et al., 2016). However, in a number of countries worldwide, such as Turkey and Italy, sunflower is also grown in semiarid areas due to its drought escape behavior worldwide (Onemli & Gucer, 2010; Garofalo & Rinaldi, 2015; Kaya et al., 2015). The Brazilian Semiarid Region is the world’s most densely populated dry land region with more than 53 million inhabitants. Inside this region lies the so called ‘drought polygon’, an area of about 940,000 km² where risk of drought is above 60% (Krol & Bronstert, 2007; Marengo & Bernasconi, 2015). However, part of these areas might be irrigated. Both irrigated and rainfed farming are practiced in the potentially irrigated lands (Krol & Bronstert, 2007). Therefore, the advance of sunflower production areas, in the Brazilian semiarid zones, may be one of the alternatives for increasing the Brazilian production and income for farmers.

Some authors categorized the sunflower as a low to medium drought sensitive crop due to its well-developed root system, the capacity to avoid transient wilting, and ability to withstand short periods of severe soil-water deficit (Saba et al., 2016; Hussain et al., 2018). However, long periods of deficit at any growth period cause leaf drying and diminish the plant photosynthetic performance with a subsequent reduction of seed yield (Ghaffari et al., 2012; Pekcan et al., 2015). Several management strategies are used to minimize water stress and to reduce the yield gap between the actual and the maximum yield in sunflower grown in water-limited areas, including drought-tolerant genotypes (Onemli & Gucer, 2010; Pekcan et al., 2015) and supplemental irrigation (Anastasi et al., 2010; Kaya et al., 2015; Birck et al., 2017). In addition, sowing in the rainy season ensures available water at the initial growth stages, which may result in good vegetative growth, although the subsequent low-moisture availability at flowering and grain filling stages may significantly reduce the yield due to high-transpiration demands (Aboudrare et al., 2006).

The choice of productive cultivars in semiarid environments constitutes an important low-cost input (Birck et al., 2017). Many studies worldwide have involved the evaluation of morphological and physiological characteristics of sunflower because of the economic importance of its oilseed. Furthermore, according to Rauf & Sadaquat (2008), plant breeders focused mainly on the lower-leaf canopy and reduced transpiration over the past decades, which are not necessarily associated with high yield in sunflower plants. Thus, they would have evolved cultivars with poor yield under stress condition. In addition, most of these studies have been conducted in greenhouses or growth chambers and include a few cultivars (Hussain et al., 2018). In Brazil, the evaluation and selection of hybrids and varieties (open-pollinated population) of sunflower from several companies have been mainly performed in areas where water is not limiting (Dalchiavon et al., 2016). However, few studies were done in the Brazilian Semiarid Region (Carvalho et al., 2018; Souza et al., 2019).

The objective of this work was to identify the sunflower cultivar with the highest-yield potential, for cultivation in the Semiarid Region in Northeast Brazil, under field conditions with supplementary irrigation.

Materials and Methods

Four field experiments with sunflower cultivars (*Helianthus annuus* L.) were performed during the rainy-season cultivation (June-November) of 2012, 2013, 2014, and 2015. They were carried out in Poço

Redondo (9°47’ S, 37°1’ W, at 188 m altitude), in the state of Sergipe (SE), Brazil, in an area with Chromic Luvisol (IBGE, 2011; Moura et al., 2017; Santos et al., 2018), a typical soil of the Brazilian Northeastern’s Semiarid. According to Köppen-Geiger the climate classification is classified as Bsh (extremely hot and semiarid). The scarce and irregular rainfalls are often concentrated between May and August, when crops are grown. Air temperatures above 29°C were observed in 47 (in 2012), 58 (in 2013), 66 (in 2014), and 56 (in 2015) days, including some days during the field trials (Table 1). Weather records during the of experimental period were collected by an agrometeorological station [TRMM.5503 (9007655)] installed in Canindé de São Francisco (9.75°S 38°W, 147 m altitude), in Sergipe state, which is located 15 km from the experimental site (Agritempo…, 2017).

Although the experimental site is in the semiarid environment, it is located inside the irrigated perimeter of the São Francisco River. Thus, the farmers usually irrigate their crops, during part of the day, to mitigate drought effects and avoid great losses of the productivity. Similarly to them, and because of the scarcity and irregularity of the rain distribution associated to the local high-air temperatures, supplemental water was provided to plants, for 40 min every day in the morning, by micro sprinklers (7 L m^{-2} per day).

Each trial was carried out in a randomized complete block design, with twelve treatments (cultivars) and four replicates. Each four-row plot was 6.0 m long, spaced at 0.70 m apart, with 0.30 m between holes, in a total of 20 plants per row, and 80 plants per plot. Additionally, border rows on each side of the plot, as well as border plants on each end of the plot, were installed using plants of the same cultivar as the one being tested. The evaluated sunflower cultivars, adapted to the Brazilian central and south regions (Dalchiavon et al., 2016), are

Table 1. Weather data during the growth period of sunflower (2012–2015), in the municipality of Poço Redondo, in the state of Sergipe, Brazil[(1)].

Year	Month	Rainfall		Air temperature		
		Total volume	No-rain days	Maximum		Median (°C)
		(mm)	(n°)	(°C)	(n° of days)	
2012	June	0	30	32	8	25.38
	July	0	31	30	2	23.4
	August	6.96	30	31	2	23.4
	September	5.76	29	34	4	25.15
	October	5.61	30	35	1	26.5
2013	June	0	30	32	4	25.7
	July	56.1	27	30	2	24.03
	August	0	31	32	1	24.5
	September	0	30	35	2	26.15
	October	7.17	30	37	1	26.82
2014	June	0	30	33	1	25.3
	July	7.35	30	32	2	24.56
	August	7.62	29	32	1	23.82
	September	0	30	36	1	25.68
	October	9.42	30	34	6	26.32
2015	June	16.26	29	32	4	24.88
	July	44.7	28	30	5	24.23
	August	15.42	30	33	1	24.03
	September	0	30	34	10	26.28
	October	0	31	37	1	27.50

[(1)]Data obtained from the weather station TRMM/Agricola, installed at 9.88S, 37.6W (Agritempo…, 2017).

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the following ones: ‘M 734’ (Dow AgroSciences, São Paulo, SP, Brazil); ‘Aguara 4’, ‘Aguara 6’, and ‘Olisun 3’ (Atlântica Sementes, Curitiba, PR, Brazil); ‘CF 101’ (Advanta, Campinas, SP, Brazil); ‘HELIO 251’ (Heliagro do Brasil, Araguari, MG, Brazil); ‘BRS 321’, ‘BRS 322’, ‘BRS 323’, ‘BRS 387’, (Embrapa, Brasília, DF, Brazil). Except for ‘BRS 324’ and ‘Embrapa122’ (open-pollinated populations), all others are simple hybrids. Seed were obtained from the national sunflower genebank of Embrapa (Brasília, DF, Brazil). In all trials, the fertilization was performed by taking into account the chemical analysis of the soil. Sowing occurred in June, during the rainy season, for all trials. After planting and emerging, plants were thinned, and only one was left in each hole. The soil between cultivation rows was maintained free of weeds using post-emergence herbicides. All recommended cultural practices were followed to allow of the suitable plant development (Oliveira & Rosa, 2013).

In September 2014 (90 days after sowing), at the beginning of flowering (R4-R5 stage), leaf gas exchange rates and associated attributes were measured on two fully expanded leaves (3, 4, acropetally numbered) of three plants per plot, which were chosen at random in each plot. The measurements were taken from plants between 9:00-10:00 h. Similarly to Tabatabaei et al. (2012), rates of net photosynthetic (Pn), stomatal conductance to water vapor (gs), transpiration (E), and the estimate of intrinsic water-use photosynthetic efficiency (Pn/gs) were performed in the field. Measurements were taken on intact, individually attached leaves by using a portable infrared CO_2 analyzer (LCpro+, ADC, Hoddesdon, UK), with 1800 $\mu mol\ m^{-2} s^{-1}$ photosynthetic active radiation supplied by a light unit mounted on the top of leaf chamber, and 365 ppm ambient CO_2.

In all trials (2012-2015) the achenes (grains) were harvested at maturity and their weights were recorded. From these data, the achene yield was calculated ($kg \cdot ha^{-1}$), and the achene’s oil percentage and the oil yield ($kg \cdot ha^{-1}$) were determined. The oil percentage content was determined using petroleum ether as solvent, and the oil yield was calculated from the oil percentage and the achene yield (Grunvald et al., 2014).

The recorded data were subjected to the analysis of variance, and the cultivars were grouped using the Scott-Knott’s test when significant effects were detected by the F-test, at 5% probability. Previously, root square transformations were used for all data that did not follow the normal distribution. In addition, data of achene and oil yield from the average of the years (2012-2015) were statistically analyzed for simple correlation with grain and oil yields from 2014.

Results and Discussion

Sunflower cultivars differed from each other for achene and oil yield, and oil content (Table 2). Yield means by the sunflower cultivars in the present work were higher than those reported for plants grew in Campo Novo do Parecis, in Mato Grosso state, the largest Brazilian producer of sunflower (Birck et al., 2017). They were also similar to those found in cultivars planted in the Brazilian southern and central states (Dalchiavon et al., 2016). The desirable oil content in achenes –from 37.48 to 43.41% – was observed in the present work, in most of the studied sunflower cultivars, taking into account the reference of 40% for oil content in the achenes quoted by Dalchiavon et al. (2016). Carvalho et al. (2018) also verified the high yield and quality of the oil of sunflower plants, in the conditions of Northeast Brazil, including the state of Sergipe. Our results confirm the production feasibility of sunflower in Brazilian Northeast, particularly in Poço Redondo, SE, in the semiarid region of Sergipe, at least where supplementary watering (rainfall + supplementary irrigation) is available. It is also important to highlight that a significant correlation was found for yield in the period 2012-2015, and that recorded in 2014 for achene (0.82) and oil averages (0.81), which indicates the similarity among the field trials performed in all years.

Total rainfall recorded in Poço Redondo, across the years 2012 to 2015, was low during every experimental period, and ranged from 12.72 to 76.38 mm (Table 1). This fact proved the need for supplemental irrigation on crops. According to Marengo et al. (2017), the drought intensified in 2012 in the Semiarid Region of Northeast Brazil extended onto 2015, and is considered as the most severe drought of the last decades. Except for sunflower ‘BRS 321’, all the other cultivars showed lower-achene yields in 2012, and there was no significant difference between them. The climatic data (Table 1) and the achene yield (Table 2) suggest that water deficit may have occurred across the years 2012-2015. According to Lamaoui et al. (2018), water stress takes place when humidity in the soil and in the atmosphere is low, and the ambient-air temperature is high. These conditions would be the result of an imbalance between the evapotranspiration flux and water intake from the soil. Based on these data, we can infer that a more severe water deficit possibly occurred in 2012 and 2015, and a milder one in 2014.

Sunflower ‘M 734’ provided the greatest yield of achene in 2014, followed by ‘Aguara 4’, ‘CF 101’, ‘HELIO 251’, ‘BRS 322’ (Table 2). In average, for four consecutive years (2012-2015), the largest yield of achene was obtained by ‘M 734’ and ‘Aguara 4’, followed by ‘CF 101’, ‘HELIO 251’, ‘BRS 322’, ‘Aguara 6’, and ‘Olisun 3’. The highest-oil percentage was recorded in ‘BRS 321’, ‘BRS 324’, ‘CF 101’, and ‘Aguara 4’, in contrast to the lowest-oil percentage found for ‘M 734’ and ‘BRS 387’ (Table 2). Therefore, sunflower ‘Aguara 4’ and ‘CF 101’ outstood for their biggest achene and oil yield. Except for ‘M 734’ and ‘BRS 387’, the evaluated cultivars were capable of producing achenes with the desirable oil content, in Poço Redondo, SE, in the Brazilian semiarid zone.

Most of the sunflower cultivars achieved the greatest yield in 2014, when few rains fell down in July, at the flowering stage, and in August, at the filling-grain stage, in contrast to no rain in July 2012, and much rain in July 2013 and 2015 (Table 1). In addition, days with higher-air temperatures were more frequent in 2015 than in 2014. In addition, the lowest means for achene yield were found in 2012 and 2015. Chimenti & Hall (2001) suggest that a high-rainfall volume at the flowering period impairs the fertilization of the flowers and compromises the achene production due to the impact of the rains on flowers. They also state that air temperatures above 30°C significantly increase the number of unfilled (flats) grains.

In the present study, the averages of stomatal conductance rate varied from 0.060 to 0.240 mol H_2O m^{-2} s^{-1}. Some cultivars showed a greater stomatal closure (‘BRS 321’, ‘BRS 324’, ‘BRS 387’, and ‘HELIO 251’), which allows of the decrease of water loss by transpiration. However, other cultivars displayed a high-stomatal conductance rate (‘Aguara 4’, followed by ‘BRS 322’ and ‘CF 101’). Garofalo & Rinaldi (2015) found a lower rate of stomatal conductance for sunflower plants grew in a greenhouse under controlled water deficit. According to them, the stomatal closure favors the reduction of water loss through the leaves due to the transpiration. In addition, they suggest that the stomatal closure would be the main adaptation mechanism to water stress for sunflower plants that had not yet reached the stage of full flowering.

Table 2. Means of oil (OY) and achene yield (AY), and oil percentage (OPA) of sunflower cultivars (*Helianthus annuus*), and means of achene yield per year, in the municipality of Poço Redondo, in the state of Sergipe, in the Semiarid Region of Brazilian Northeast, from 2012 to 2015[(1)].

Cultivar	Oil yield (kg ha^{-1})	Achene yield per year (kg·ha^{-1})				Mean	Oil percentage (%)
	2012-2015	2012	2013	2014	2015	2012-2015	2012-2015
M 734	1,023.54b	2,093aC	2,699bB	3,795aA	2,352aC	2,734.63a	37.48c
Aguara 4	1,131.30a	2,204aB	3,205aA	3,077bA	2,405aB	2,722.81a	41.41a
CF 101	1,143.40a	2,019aC	2,990aB	3,243bA	2,124bC	2,593.81b	43.41a
HELIO 251	1,004.44b	1,768aD	2,875aB	3,317bA	2,183bC	2,535.63b	39.58b
Aguara 6	1,020.22b	2,002aC	2,948aA	2,713cA	2,356aB	2,504.75b	40.65b
Olisun 3	999.75b	2,049aB	2,818aA	2,868cA	2,130bB	2,466.10b	40.06b
BRS 322	966.96b	1,984aC	2,588bB	3,125bA	2,021cB	2,429.19b	39.91b
BRS 323	871.07c	2,002aB	2,428bA	2,382dA	1,934cB	2,186.13c	39.78b
Embrapa122	843.17c	1,940aB	1,880cB	2,561cA	1,950cB	2,082.63c	40.36b
BRS 387	797.86c	1,930aB	1,888cB	2,410dA	1,984cB	2,052.75c	38.73c
BRS 324	872.92c	1,861aB	1,833cB	2,735cA	1,748dB	2,044.19c	42.23a
BRS 321	868.93c	1,944aA	2,125cA	2,218dA	1,810dB	2,023.63c	42.90a
Average	961.96	1,983 C	2,523 B	2,870 A	2,083 C	2,364.68	40.54

[(1)]Means followed by equal letters, lowercase in the columns and uppercase in the rows only for achene yield, do not differ by Scott-Knot’s test, at 5% probability.

Similarly to the stomatal conductance rate (gs), the intrinsic photosynthetic efficiency (Pn/gs) showed a wide variation among cultivars: from119.80 to 479.01 (Table 3). The lower intrinsic photosynthetic efficiency in water use indicates a higher susceptibility to water deficit, whether supplemental irrigation is available or not (Casadebaig et al., 2011). In contrast to these cultivars, the high-achene yield found in 'HELIO 251' (although lower than in 'Aguara 4') may be explained by its lowest rates of stomatal aperture and transpiration, associated with its high intrinsic photosynthetic efficiency. The high efficiency of 'HELIO 251' suggests that it has a greater potential for water deficit tolerance, as well as potential to produce more achene in drier years. A similar performance was found in the cultivar 'BRS 387'. Despite their lower achene yield, 'BRS 321' and 'BRS 387' stood out for their higher stability across the years 2012-2015, which also suggests their great suitability to local conditions.

In contrast to gs and Pn/gs, the net photosynthetic rate of the studied sunflower cultivars displayed a narrow range of variation, which was between 27.13 and 31.72 mmol of CO_2 m^{-2}-s^{-1} (Table 3). Considering only the field studies performed in the semiarid conditions, these values were similar to those reported by Liu & Shi (2010) and Silva et al. (2013) for plants grew under controlled irrigation. Furthermore, they were also similar to those reported for plants grew in nonirrigated semiarid areas (Tabatabaei et al., 2012; Garofalo & Rinaldi, 2015; Hussain et al., 2018). Thus, despite the relatively high-air temperatures and number of no-rain days (Table 1), the sunflower cultivars maintained high photosynthetic rates. From this result, we can infer that possibly a possible mild-water deficit only occurred, and it was not able to prevent that these high-net photosynthetic rate were converted into a great achene and oil yield. Lamaoui et al. (2018) suggest that the stomatal closure would have a more inhibitory effect on transpiration of water than on CO_2 diffusion into leaf tissues, and then on the net photosynthetic rates.

Silva et al. (2013) verified no significant differences between rates from plants irrigated and from those subjected to natural water stress. In contrast, Cechin et al. (2010), Zlatev & Lidon (2012), and Ucak (2018) reported decreases of photosynthetic rates for sunflower grew in pots under controlled water deficit. Silva et al. (2013) suggest that the lack of decrease in photosynthetic rates of plants grew in the field is due to the changes of the water status in these plants which

Table 3. Means of net photosynthetic (Pn), transpiration (E), stomatal conductance rates (gs), and intrinsic water-use photosynthetic efficiency (Pn/ gs), for sunflower cultivars grew in Poço Redondo, SE, in the Semiarid Region of Brazilian Northeast[(1)].

Cultivar	Pn ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	E ($mmol \cdot m^{-2} \cdot s^{-1}$)	gs ($mol \cdot m^{-2} \cdot s^{-1}$)	Pn/gs
M 734	30.61a	1.957c	0.127c	254.47c
Embrapa122	31.72a	1.750c	0.116c	285.62c
BRS 321	27.13b	1.167d	0.076d	368.96b
BRS 322	31.09a	2.670a	0.210b	151.47d
BRS 323	31.30a	1.760c	0.120c	274.02c
BRS 324	27.84b	1.100d	0.070d	398.64b
BRS 387	27.16b	1.117d	0.060d	452.66a
HELIO 251	28.39b	1.050d	0.060d	479.01a
Aguara 4	28,68b	2.867a	0.240a	119.80d
Aguara 6	31.04a	1.607c	0.100c	310.99c
Olisun 3	30.88a	1.733c	0.110c	284.96c
CF 101	30.78a	2.360b	0.186b	167.35d
Average	29.54*	1.718**	0.1195**	301.13**
CV (%)	6.12	12.03	15.03	15.05

[(1)]Means followed by equal letters do not differ by Scott-knot's test at 5% probability. * and **Significant by the F- test, at 5% and 1% probability, respectively.

would be slow and gradual. According to them, this would favor the establishment of the acclimatization mechanism, which includes the morphological and physiological adjustments that provide an escape to the water stress, including an increased root system, reduced the stomatal number and conductance, decreased leaf area, increased leaf thickness, and leaf rolling, or folding to lessen evapotranspiration (Lamaoui et al., 2018).

Silva et al. (2013) warn, however, that instantaneous (transient) measurements of gas exchange might not reflect the authentic physiological behavior of the field-grown plants in face of the stress conditions throughout the day and, therefore, need to be evaluated with some caution. Taiz & Zeiger (2012) reported that there is an imbalance between the water absorbed by the root system and that transpired by the leaves through the day, regardless of the condition of the water supply, due to the oscillation of the evaporative demand of the atmosphere along the day. Even considering the limitation of the instantaneous photosynthetic measurements, it is important to highlight that among the five most productive cultivars in the present study, 'M 734', 'BRS 322', and 'CF 101' displayed the greatest Pn (Table 3). In addition, the highest Pn were supported by high gs and, consequently, a great water loss by transpiration and low Pn/gs. In addition, 'Aguara 4', achieved a high achene and oil yields, despite its great water loss through stomata by transpiration and, consequently, its lower Pn. Therefore, we suppose that if 'Aguara 4' was grown under more severe water stress, this cultivar would provide fewer grains than the cultivars with a greater stomatal closure.

Conclusions

1. The sunflower cultivars providing the highest yield in the Brazilian Northeast Semiarid Region, with supplementary irrigation, are 'Aguara 4', 'CF 101', 'BRS 322' (high-achene and oil yields), and 'M 734' (high-achene yield); and the less susceptible cultivars to severe water deficit are 'HELIO 251' and 'BRS 387' (which show a higher intrinsic photosynthetic efficiency).

2. There is a narrow variation among the sunflower cultivars for the net photosynthetic rate in the semiarid conditions under supplementary irrigation.

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