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PRODUCTIVE CHARACTERISTICS OF SUNFLOWER GENOTYPES IRRIGATED WITH DIFFERENT LEVELS OF SALINE WATER

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Abstract

Sunflower is suitable for family farmers from Northeast Brazil who are benefited by the production of grain and oil and is adequate for crop rotation and for honey production. The need for irrigation in this region leads to the realization of this study for evaluating the production components of four sunflower genotypes irrigated with different levels of water salinity. The study was carried out in the municipality of Remigio, Paraíba, Brazil, using a randomized block with split plots experimental design in a 5 x 4 factorial arrangement. Treatments consisted of five electrical conductivity levels of the irrigation water at 25 °C (L1 - 0.14 (reservoir water), L2 - 1.50, L3 - 2.50, L4 - 3.50, and L5 - 4.50 dS m^{-1}), and four sunflower genotypes (C1 - Embrapa 122-V2000, C2 - Olisun 03, C3 - AG 963, and C4 - Multissol) with three replicates. The irrigation water salinity levels tested did not influence the variables studied. Different values of the variables among sunflower genotypes were due to characteristics inherent to each genotype. Sunflower genotype Olisun 03 presented the highest oil content, while the lowest content was observed in Multissol.

Keywords: Achene. Bioenergy crop. Electrical conductivity. *Helianthus annuus* L. Oil content.

1. Introduction

The sunflower (*Helianthus annuus L.)* is an annual oleaginous plant of the Asteraceae family. Its origin is North America and was introduced in Brazil at the end of the nineteenth century. This crop is among the most important oilseed crops in the world, is adapted to different soils, and is little influenced by latitude e altitude variations. The optimum temperature for its development is between 27ºC to 28ºC. The good tolerance of this plant to drought makes it a good alternative for farmers in semiarid regions (Glovatski and Raiher 2013; Bezerra et al. 2014; Gomes et al. 2017; Castro and Leite 2018).

Sunflower is of world importance due to its great economic value for nutrition and energy production and also in the production of products in pharmaceutical, chemical, and cosmetic industries. Its nutritional importance for human consumption is due to the high content (38% to 50%) of high-quality edible oil contained in its seeds, while the cake resulting from the extraction of oil is used in diets for different animal species. In addition, the sunflower is used in silages and in grain mixtures to feed birds. The suitability of sunflowers for small properties is due to their various uses, such as the production of grains and oil, in floriculture, and as an important forage species for honey-producing bees. This crop is also an economical alternative in crop rotation systems in grain-producing regions (Glovatski and Raiher 2013; Bezerra et al. 2014; Gomes et al. 2017; Castro and Leite 2018; Barros et al. 2019).

As an energy crop, the sunflower is a raw material for biodiesel that brings environmental and economic benefits by replacing non-renewable energy sources. It is one of the crops indicated by Brazil's National Program for Production and Use of Biodiesel (PNPB) due to its wide adaptation and high content and quality of its oil (Castro and Leite 2018). The PNPB was created in 2004 by the federal government with economic, social, and environmental objectives and established rules, norms, tax incentives and subsidies for the sustainable production and consumption of biodiesel. Among the objectives are the promotion of sustainability, guaranteeing the supply and quality of biodiesel at competitive prices, the social inclusion of family farming, and the diversification of oilseeds used as raw material to produce biodiesel in the poorest regions of the country. The results obtained were a large increase in the volume of biodiesel produced and a reduction in the cost of diesel oil imports (Alves et al. 2017).

Another government program, the Social Fuel Stamp, was created in 2015 to ensure the PNPB's compliance with the objectives of social inclusion and regional development. It certifies that the biodiesel processing plants use raw material from family farming. The production projects of these companies must provide for a minimum inclusion of family farmers and the purchase of at least 30% of grains from these families in the Northeast and Semi-Arid regions, in addition to providing technical assistance and training for family farmers (Alves et al. 2017).

Despite having the appropriate technology to produce biodiesel and being one of the largest world producers of oilseeds, Brazil still faces problems with raw materials, among which the lack of consensus on which are the most suitable for the production of biodiesel (Glovatski and Raiher 2013). This shows that the tax incentives and subsidies created by the PNPB have failed to diversify the raw material for biodiesel, since soybean oil is still the predominant raw material in Brazil, accounting for about 75% of production (Alves et al. 2017; Castro and Leite 2018). In this context, the sunflower is a promising raw material of vegetal origin, whose cultivation in northeastern Brazil can increase the supply of raw materials and meet the demand of the food sector and the production of biodiesel (Leite et al. 2007).

Among the alternatives to increase biodiesel production are the improvement of cropping techniques to obtain better yields and reduce raw material costs (Sánchez-Faba et al. 2019). For this to occur in semi-arid regions such as the Northeast of Brazil, with low and irregular rainfall and water scarcity, irrigation is necessary. However, soil salinization due to irrigation is more likely to occur in these regions and this is aggravated by the availability of water with high levels of electrical conductivity. If adequate soil, water, and plant management practices are not adopted, there will be economic and environmental damage to agricultural land. The lower growth and yield of several plant species exposed to salinity is due to osmotic effects, which reduce water absorption by plants, and the effects of specific ions, which can cause phytotoxicity and nutritional imbalance (Almeida et al. 2018; Silva Sá et al. 2018).

Another important aspect is the use by farmers of low-quality water resources, such as effluents and saline water. In fact, water sources with a high concentration of salts, mainly sodium, are used in the Brazilian semi-arid region. Agricultural production with saline irrigation water is successfully carried out in various areas of the world, where tolerant species are used and appropriate practices are adopted for the management of crops, soil, and water, with strategies that guarantee the socio-economic and environmental sustainability of agricultural systems (Rhoades et al. 2000; Neves et al. 2009; Neves et al. 2015).

Several well-established strategies allow the use of saline water for irrigation. They reduce the accumulation of salts in the soil, limit negative impacts on the environment and crop development, and save good quality water. Among them are the better water management, mixing water from different sources, using water with different salinities according to the stage of crop development, using saline water only in salt-tolerant growth stages. An alternate application of high and low salinity water can guarantee good development and yield of the crops and the replacement of a significant amount of good quality water with higher electrical conductivity. Rotation of crops with different sensitivity to salinity can be adopted in semiarid environments with water salinity problems. In this case, the sunflower can be used in rotation with traditional crops (Sousa et al. 2008; Neves et al. 2009; Lacerda et al. 2011; Neves et al. 2015).

Therefore, the objective of this work was to evaluate the production components of four sunflower genotypes under different levels of irrigation water salinity.

2. Material and Methods

The trial was carried out from November 2011 to February 2012 at the Sitio Macaquinhos, located 8 km south of the town of Remigio-PB, Brazil (6°53'00'' S, 36°02'00 ''W), and 470 meters above sea level.

According to the Köppen classification, the climate is of the As' type, hot and humid. According to the climatological normal from 1981 to 2010 (INMET 2018) in the months of the experiment, the average temperature varies between 23.1 and 23.5 ° C, with an annual average of 22.5 ° C; the relative humidity of the air varies between 77.5 and 81.5%, with an annual average of 83.3%; the potential evapotranspiration varies between 110.9 and 122.5 mm, with an annual monthly average of 104.2 mm, while the accumulated monthly precipitation varies between 27.5 and 107.4 mm, with an annual average of 1359.7 mm.

According to the Brazilian Soil Classification System (Santos et al. 2018a), the soil of the experimental area is a *Neossolo Regolítico Eutrófico*, and according to Soil Survey Staff (1999) is a Typic Ustipsamments.

The trial was carried out according to a completely randomized block design with three replicates. Five levels of irrigation water electrical conductivity (EC_w) were applied to the plots: L1 - 0.14 dS m^{-1} (water from Macaquinho reservoir); L_2 - 1.50; L_3 - 2.50; L_4 - 3.50; and L_5 - 4.50 dS m^{-1} at 25 ºC). Each plot was divided into four subplots in which four sunflower genotypes were planted: G_1 - Embrapa 122 - V2000; G_2 - Olisun 03; G_3 - AG 963; and G_4 - Multissol. Each experimental unit (subplot) consisted of three rows 4.0 m long spaced one meter apart, and the plants were spaced 0.40 m apart. According to Lorentz et al. (2010), the optimal plot size for sunflower experiments was found to have an area of 2.4 m^2. The two outer rows were left as borders. Evaluations were performed in 10 plants of the central row, from which the fourth and the seventh were used to perform non-destructive measurements during the experiment.

The water from the Macaquinho reservoir, the bovine manure used in the fertilization and the soil collected in five points at depths of 0 - 0.20, 0.20 - 0.40 and 0.40 - 0.60 m were analyzed in the Irrigation and Salinity Laboratory of Federal University of Campina Grande, PB, Campus I, following the methods recommended by Richards (1954) and by Embrapa (2017). The results are presented in Table 1.

Table 1. Chemical characteristics of the soil of the experimental area, of the cattle manure and of the water from Macaquinho Reservoir.

Soil										
Depth	pH	EC	OC	P	K	Mg	Na	Ca	H+Al	Al
cm	-	dS m^{-1}	dag kg^{-1}	mg dm^{-3}		------------	$mmol_c$ kg^{-1}	-----------		
0-20	6.9	0.39	0.7	5.3	1.2	2.3	0.02	0.3	0.8	-
20-40	5.9	0.18	0.1	0.4	0.8	1.4	0.01	0.8	1.7	0.2
40-60	6.2	0.17	0.3	2.1	1.0	2.1	0.01	0.2	2.5	0.1
Cattle manure										
	8.8	3.20	-	5.5	10.2	13.3	2.47	8.8	-	-
Water										
	7.5	0.14	0.5	3.8	3.4	2.6	15.0	0.5	0.6	0.3

EC – soil electrical conductivity; OC – soil organic carbon; H+AL – soil potential acidity.

Ten seeds (achenes) were placed per hill at a depth of 2 cm in moist soil. The first thinning was carried out when 100% germination was observed, five days after sowing, leaving three plants per hill. At 15 days after germination (DAG), another thinning was carried out, leaving one plant per hill.

Fertilization consisted of incorporating 15 kg of cattle manure into the planting furrows 30 days before planting and, when planting, applying 2 kg ha^{-1} of boron and 80 kg ha^{-1} of P_2O_5, in the form of boric acid and simple superphosphate, respectively. In addition, 60 kg ha^{-1} of nitrogen in the form of urea and 80 kg ha^{-1} of K_2O in the form of potassium chloride were applied in four equal portions. The first portion was applied at the time of planting and the other three portions were side dressed at 20, 35, and 50 days after germination.

Irrigation was carried out using a localized system consisting of drip tape with a flow rate of 6.0 L h^{-1} at a service pressure of 0.7 bar. The irrigation schedule adopted was two days. The water depth was calculated based on the reference evapotranspiration (ETo) estimated by the class A tank method, installed at the UFPB Meteorological Station, in Areia, PB, Brazil, located 8 km from the experimental area. The crop coefficients used were 0.3-0.4 during the initial crop stage, 0.7-0.8 in the establishment stage, 1.05-1.2 during the intermediate stage, 0.7- 0.8 during the final stage, and 0.4 during crop maturation (Doorenbos and Kassam 2000).

To obtain the electrical conductivity of the water for each treatment, commercial NaCl without iodine was added to the water of the Macaquinhos reservoir (EC_w = 0.14 dS m^{-1}). The amount of sodium chloride (Q_{NaCl}) used in the preparation of the water was determined taking into account the initial electrical conductivity of the water ($EC_{w\ ini}$) and the electrical conductivity of the water of the treatment in question ($EC_{w\ trat}$), according to Eq. 1 (Richards 1954), modified for the purposes of this experiment.

$$Q_{NaCl}\ (mg\ L^{-1}) = 640 \times (EC_{w\ ini} - EC_{w\ trat}) \qquad \text{Eq. 1}$$

The following variables were evaluated: the number of heads per plot (NH); total achene production (TAP); the total number of achenes per plot (TNA); the number of filled achenes per plot (NFA); internal diameter of the head (ID); the total weight of achenes per plot (TWA); the weight of filled achenes per plot (TWFA); the weight of non-viable achenes per plot (WNVA); the number of achenes per plot (NA); the number of non-viable achenes per plot (NNVA), and weight of 100 achenes (W100A).

The internal diameter of the head is an imaginary line, in the fertilized part of the floral receptacle. Its dimension was the mean of two measurements performed with a ruler in a horizontal line and a vertical line. The readings were always carried out on the day the flower was in the $R_{5.2}$ phase of the scale of Schneiter and Miller (1981).

All achenes of the 4th and 7th plants were weighed to find the number and total weight of the achenes, using an electronic scale with a precision of 0.01 g. We also counted and weighed 100 filled achenes (randomly chosen) and non-viable achenes.

The crop yield was determined once 24 plants were harvested in each plot, considering moisture of 13% at harvest. The moisture content was calculated by the oven method, according to the standards for seed analysis (Brasil 2009). The oil content (OC) was determined according to the method adopted by Embrapa Cotton, Campina Grande, PB, Brazil, using nuclear magnetic resonance spectroscopy (NMRS) (Colnago 1996).

The data were submitted to analysis of variance (ANOVA) with the F-test ($p<0.05$). In the case of significance, regression analysis was carried out as a function of the water electrical conductivity. The Tukey test ($p<0.05$) was used to compare the means between genotypes. The statistical software SISVAR 5.2 was used in the analysis (Ferreira 2014).

3. Results

The level of irrigation water salinity had no significant effect on the variables studied. However, the variables TAP, TNA, NFA, WNVA, and W100A were significantly influenced ($p<0.01$) by the factor genotype. Only OC was significantly influenced ($p <0.05$) by the effect of the interaction between salinity and genotype (Table 2).

The highest total achene production was obtained by the genotype AG 963 (2574 kg ha^{-1}), which did not differ only from Multissol (Table 3). The TAP of AG 963 was 19% higher than Olisun 03 and 42% higher than that of Embrapa 122 - V2000, which had the lowest TAP.

The lowest TAP of Embrapa 122 was due to having the lowest TNA, 11% lower than AG 963, and NFA 19% lower than AG 963, since Embrapa 122 presented the highest W100A, and Olisun 03 had the lowest value. The W100A of Embrapa 122 was higher than AG 963, Multissol, and Olisun 03 by 25, 13, and 44%, respectively.

In turn, the highest TNA was observed in genotype Olisun 03, which value was higher than that of the genotypes Embrapa 122-V2000, AG 963, and Multissol by 51, 29, and 38%, respectively. The genotype Olisun

03 also produced the largest NFA, surpassing the genotypes Embrapa 122, AG 963, and Multissol by 59, 34, and 41%, respectively.

Table 2. Summary of the analysis of variance for the variables number of heads per plot (NH), total achene production (TAP), the total number of achenes (TNA), number of filled achenes (NFA), number of non-viable achenes (NNVA), weight of filled achenes (TWFA), the weight of non-viable achenes (WNVA), the weight of 100 achenes (W100A), the internal diameter of the head (ID) and oil content (OC) of sunflower genotypes irrigated with waters having different electrical conductivities.

	Sources of Variation							
	S	Block	$Error_a$	G	S x G	$Error_b$	CV_a	CV_b
DF	4	2	8	3	12	20	-	-
NH	ns	ns	-	ns	ns	-	7.6	9.6
TAP	ns	ns	-	**	ns	-	16.0	16.8
TNA	ns	ns	-	**	ns	-	12.2	15.4
NFA	ns	ns	-	**	ns	-	18.6	17.2
NNVA	ns	ns	-	ns	ns	-	70.3	67.4
TWFA	ns	ns	-	ns	ns	-	15.3	23.6
WNVA	ns	ns	-	**	ns	-	76.0	82.3
W100A	ns	ns	-	**	ns	-	9.3	11.4
ID	ns	ns	-	ns	ns	-	11.6	12.9
OC	ns	ns	-	ns	*	-	5.6	3.2

S - salinity level; G - genotype; S x G - interaction salinity x genotype; * p< 0.05 and ** p< 0.01.
ns - not significant by the F-test. DF = degrees of freedom; CV = coefficient of variation (%).

Table 3. Comparison of means of total achene production (TAP), the total number of achenes per plot (TNA), number of filled achenes per plot (NFA), weight of non-viable achenes per plot (WNVA), and weight of 100 achenes (W100A) of four sunflower genotypes.

Genotypes	TAP ($kg\ ha^{-1}$)	TNA	NFA	W100A (g)	WNVA (g)
AG 963	2574^{a}	1275^{b}	1178^{b}	8.3^{b}	1.4^{ab}
Embrapa 122	1808^{c}	1090^{b}	993^{b}	10.4^{a}	2.4^{a}
Olisun 03	2159^{cb}	1647^{a}	1578^{a}	7.2^{c}	0.7^{b}
Multissol	2284^{ab}	1194^{b}	1118^{b}	9.2^{b}	1.1^{b}

Means followed by same letter do not differ according to the Tukey test (p <0.05).

The unfolding of the interaction between irrigation water salinity and genotype shows little differences in oil content among salinity levels within each genotype but allows us to identify two groups of genotypes according to their oil contents (Figure 1). In this aspect, the genotype Olisun 03 presented the highest OC, with little difference from AG 963. The lowest OC value was observed in the Multissol genotype, with little difference from Embrapa 122. The average oil contents of Olisun 03 were 22, 17, and 4% higher than genotypes Multissol, Embrapa 122, and AG 963, respectively. The effect of interaction between the factors was due to the behavior of genotypes AG 963 and Multissol, in which oil content presented a quadratic response to irrigation water salinity levels. These genotypes showed a maximum oil content at 3.0 and 2.4 dS m^{-1}, respectively.

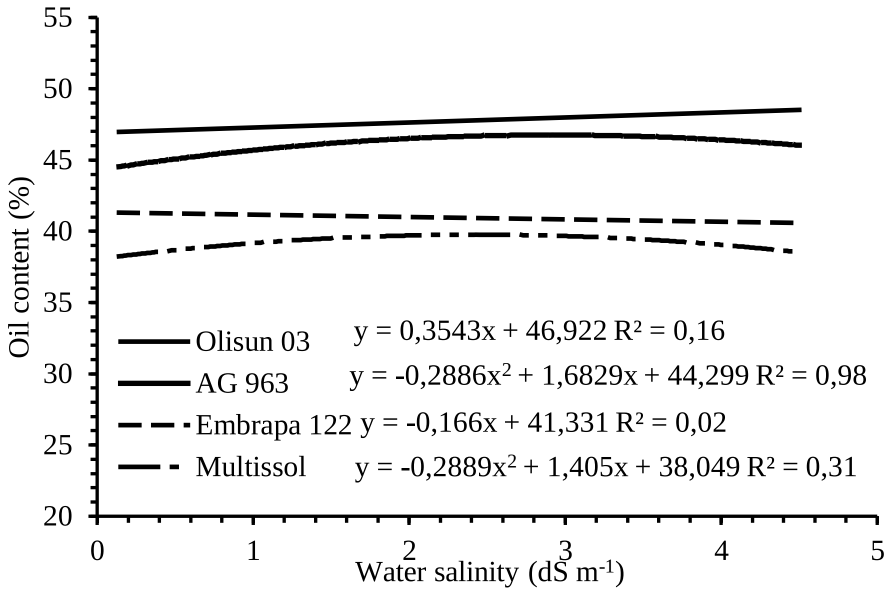

Figure 1. Effect of different electrical conductivities of irrigation water on the oil content of four sunflower genotypes.

4. Discussion

The absence of a significant effect of irrigation water salinity on variables of production of sunflower is in order with the study of Francois (1996), which indicates that sunflower is moderately tolerant to salinity and is suitable for growing in moderate salinity conditions. The author did not observe the effect on grain yield of sunflower with irrigation water salinities up to 4.8 dS $m^{-1,}$ while the seed oil content shows little response to the increase in salinity and was not affected by salinities up to 10.2 dS $m^{-1.}$

Regarding the differences observed between the genotypes, it is important to consider that when using saline water for irrigation the effects of salts on crops depend on the intensity and duration of saline stress and vary according to the species. In addition, genotypes of the same species may respond differently to the effects of salinity, which also manifest themselves differently at different stages of the crop cycle (Neves et al. 2015; Almeida et al. 2018).

The Olisun 03 genotype showed the best results for most of the production variables analyzed, followed by AG 963. These two genotypes are hybrids. Meanwhile, the variety of Embrapa 122 presented the worst results of the variables, with the exception of W100A. According to Grunvald et al. (2008), the varieties of Embrapa 122 and Multissol showed lower grain yield and oil content than hybrids in three years of stability tests of sunflower genotypes in central Brazil.

The TAP of 2574 kg ha^{-1} presented by genotype AG 963 is higher than that obtained by sunflower genotypes Helio 250 and Helio 251 which produced average yields of 2829 and 1051 kg ha^{-1} respectively, in São Paulo (Lemos and Vazquez 2005), 1682 and 1839 kg ha-1, respectively, in Paraná (Leite and Carvalho 2005), and 2000 and 1056 kg ha^{-1}, respectively, in Goiás (Silva et al. 2005).

The hybrid Olisun 03 received a recommendation for intercropping with cassava in Sergipe, both for grains and oil. Between the years 2012 and 2014 this genotype was more productive than the genotype Embrapa 122, both in monoculture and in intercropping, and showed higher oil yield in intercropping (Carvalho et al. 2018b). In Bahia, Olisun 03 was superior to Embrapa 122 in the mass of heads, the yield of achenes, and the number of achenes, while Embrapa 122 stood out for the mass of 100 achenes, as in our work (Sousa 2016).

Regarding the Embrapa 122 genotype, although there was no significant effect of irrigation water salinity on production variables in our study, the increase in irrigation water salinity had a negative linear effect on the production of achenes, the number of achenes, viable achenes and a mass of one hundred achenes of this genotype in pot experiments carried out in the same region (Nobre et al. 2011; Travassos et al. 2011; Centeno et al. 2014).

Meanwhile, the Multissol genotype was part of fourteen of the Embrapa Soja Sunflower Genotype Evaluation Assays in 12 states from north to south of Brazil and the DF from 2017 to 2018 (Carvalho et al. 2018a). The grain yield of this genotype varied between 1720 kg ha^{-1} and 3661 kg ha^{-1}, with an average of 2588 kg ha^{-1}, slightly higher than that obtained in our study. The oil content obtained varied between 32.0 and 39.7%, with an average of 37.5%, very similar to that obtained in our study.

In relation to the effect of water salinity on sunflower oil content, the results presented in Figure 1 indicate different tolerance of sunflower genotypes to saline stress. In our study, the genotype Olisun 03 presented the highest oil content, which was similar to AG 963, whose stress tolerance was indicated by Paixão et al. (2014). These authors considered AG 963 to be tolerant to water stress because it showed the smallest reduction (27%) in the shoot dry mass, among 27 genotypes subjected to water stress in Cruz das Almas, Bahia.

On the other hand, Santos et al. (2018b) obtained higher oil content with the Embrapa 122 genotype, which is an open pollination variety, and therefore considers its use by farmers more advantageous than Olisun 03, which is a triple hybrid. However, Olisun 03 stood out for the higher oil content in our study, in which Embrapa 122 had the lowest levels.

Some mechanisms by which some sunflower genotypes are tolerant to salt stress were presented by Barros et al. (2019). They observed the accumulation of soluble solutes capable of reducing the water potential of plant cells in the sunflower genotypes Catissol 01 and Helio 253 in the presence of a high concentration of NaCl. The preservation of the plasma membranes of these genotypes indicates that they have mechanisms that provide tolerance to the presence of this ion. One of these mechanisms is the high K content in sunflower leaves, which increases the chemo-osmotic potential of the cytoplasm and reduces the transport of Na from the apoplast to the cell cytoplasm. The most important solutes were K and total soluble sugars in Catissol 01, and total soluble proteins in Helio 253.

This highlights the need to choose the more tolerant genotypes, obtained by plant breeding or biotechnology when adopting strategies for use of saline water in irrigation. According to Soares Filho et al. (2016), the use of tolerant plants is one of the main strategies for the agricultural use of salinized areas, besides their reclamation by adequate soil and water management measures.

5. Conclusions

The salinity of the irrigation water did not have significant effects on the sunflower production variables. However, the values of these variables differed between the genotypes, with Olisun 03 and AG 963 standing out. Regarding the oil content, the cultivars showed different behavior as a function of the water salinity, with the highest values obtained by Olisun 03 and the lowest values by Multissol.

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