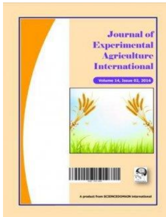

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Impacts of Meteorological Attributes on Agronomic Characteristics of Sunflower Cultivated in the Cerrado

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ABBF, JHCJ, JGA, ECC and CGPC designed and wrote the protocol. Authors DAF, KCS, ACDA and MF conducted the experiment and wrote the first draft of the manuscript. Authors DSP, JGA and CGPC managed the analyses of the study. Authors DAF, DSP, ABBF, JHCJ and ECC discussed the results and improved the writing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The sunflower has adaptation for cultivation in Brazilian conditions and the main product is the oil extracted from the seeds. This study aimed to verify the impacts of meteorological attributes on agronomic characteristics of sunflower genotypes cultivated as a second crop, in Mato Grosso, Brazil. The experimental design was randomized complete block design (RCBD), cultivating the two sunflower genotypes, M734 and Hélio, in three years (2009, 2011, 2012) with four replications. The agronomic characteristics evaluated were: plant height, capitulum diameter, weight of a

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thousand achenes, yield of achenes, oil content and oil yield. Then, water deficit and the maximum crop yield are estimated for correlation analysis between meteorological attributes and agronomic characteristics. In both genotypes studied there was a very strong correlation between plant height with evapotranspiration (r=0.99*) and very strong negative correlation (r=-0.99*) with water deficit. For mass of a thousand achenes, there was a very strong negative correlation with the maximum (r=-0.98*) and minimum (r=-0.96*) temperatures, and with evapotranspiration (r=-0.98*) in the Helio 358. In addition, effect of the water deficit on the oil yield (r=-0.98*) was verified for the same genotype. Very strong negative correlation was found between maximum temperature and oil content (r=-0.96*) in genotype M734. In sunflower cultivation in Mato Grosso, Brazil, water deficit reduces plant height, capitulum diameter and oil yield. The oil content of the achenes reduces when the maximum temperature increases, during the cultivation. For those reasons, the use of sunflower genotypes with shorter cycles and the earlier sowing could benefit the crop developing, by suiting the management, to avoid unfavorable climatic conditions that can cause reduction in production parameters.

Keywords: Climatic factors; correlation; Helianthus annuus L.; oil yield of achenes.

1. INTRODUCTION

Sunflower is an efficient oilseed plant in nutrient cycling, drought tolerant and adapts to different soil and climate conditions. Due to these characteristics, the diversity of use and the growing demand of the commercial sector for sunflower products, an increase in cultivated area is expected, especially in the central of Brazil [1,2]. In this region it is common to seed a second crop in February or March, once the conditions are favorable to a second crop.

Due to the low photoperiod sensitivity of the sunflower plant, the cultivation period in Brazil can be carried out all year round. However, despite being a rustic plant, the sunflower has low efficiency of water use and the occurrence of high air temperatures in the periods of flowering, filling of achenes and harvesting has been one of the major aspects that can determine the success of the production [3,4].

In this context, there is the importance of solar radiation in the stage of filling achenes, the availability of water throughout the crop cycle, as well as the air temperature in the duration of development stages and total cycle of the culture [5,6]. In Mato Grosso it is common that after the harvest of the crop, a second crop is grown, whose sowing occurs between the months of January and February, to take advantage of the rains before the dry period. The temperature during sunflower development in the region is quite different between these two sowing periods, and the second crop is featured by higher temperatures and also higher risk of water deficit, which implies in the occurrence of anthesis at different times [7]. In a study with sunflower, it was observed that the diameter of chapters, the mass of achenes and the oil content of the achenes are affected by the availability of water [8].

Environmental conditions may also alter the oil content and fatty acid profile of sunflower achenes [7,9]. In addition, the genotype x environment interaction, which may differ in the plant performance according to the cultivation region and between different cultivars [10,11].

Due to these factors, the meteorological conditions that occur in the period of second crop in the sunflower cultivation in the Cerrado can cause substantial differences in the morphological characteristics, the yield and the oil content of achenes. Through the determination of the main meteorological attributes that affect the productive characteristics of the sunflower cultivated in the region, it becomes possible to plan management strategies that reduce the losses caused by environmental conditions. Thus, it was aimed to verify the impacts of meteorological attributes on agronomic characteristics of two sunflower genotypes cultivated as a second crop, in the State of Mato Grosso, Brazil.

2. MATERIALS AND METHODS

The experiments were carried out at Santa Luzia Farm, in Campo Verde, Mato Grosso, Brazil (latitude 15°45’12” S and longitude 55°22’44” W). The soil of the experimental area is classified as Red-Yellow Latosol, where soybeans preceded the sunflower.

The research was carried out using two sunflower genotypes (M 734 and Helio 358), in three years (2009, 2011, 2012) with four replications. The experimental design was randomized complete block (RCBD) in which the plots were constituted by four rows of 6.00 m, spaced of 0.90 x 0.25 m, considering as a useful area, the two central lines, eliminating 0.5 m from the margins.

In the three years, the sowing was carried out at the beginning of March by manually placing three seeds per hill. Seven to ten days after the emergence the thinning was done leaving in each hole the most vigorous plant. The fertilizer used was 30-80-80 kg ha^{-1} of NPK and 2.0 kg ha^{-1} of boron on the sowing hill and 30 kg ha^{-1} of N top-dressing, at 30 days after sowing.

The crop area was kept free from weed interference and the necessary phytosanitary treatments were carried out. At the beginning of flowering, the capitulum diameter and plant height measurements of ten random plants of the area of each plot were made, and then the mean values for these characteristics were calculated. The capitulum diameter was obtained by measuring from one edge to another in the center of the capitulum and the plant height from the insertion of the capitulum on the stem to ground level. When the plants were in stage R7 (first phase of development of achenes), the capitulums were covered with bags to avoid damages by birds.

After harvesting, manual threshing of the capitulum was performed and the impurities were separated. Then, the mass of one thousand achenes was determined by weighing eight replicates of 100 achenes, on an analytical balance. The yield of achenes was obtained by weighing all the achenes harvested from the useful area of each plot, with subsequent moisture correction to 11%.

From each plot a sample of approximately 200 g of achenes was separated to determine the oil content. After this, the oil yield was calculated by multiplying the oil content by the achenes yield.

The calculation of climatological water balance was performed according to the method proposed by the authors cited in the reference [12], with precipitation and temperature data grouped in in periods of ten days. The precipitation values were collected at the experiment installation site and the temperature (minimum, maximum and mean compensated) obtained from the Poxoréo Conventional Surface Weather Observation Station, located in Poxoréo-MT, near the experiment site, based on the National Institute of Meteorology (INMET) database. The maximum yield was estimated using the Agroecological Zone Method (FAO) described by the authors cited in the reference [13], adopting a leaf area index for the crop of 15, according to the author cited in the reference [14].

After obtaining the agronomic characteristics of the sunflower (Table 1) and the meteorological attributes (Table 2), Pearson correlation analysis was performed. The interpretation was made according to the author cited in the reference [15]: r = 0.10 to 0.19 (very weak); r = 0.20 to 0.39 (weak); r = 0.40 to 0.69 (moderate); r = 0.70 to 0.89 (strong); r = 0.90 to 1 (very strong), considering the significance level of 5%.

3. RESULTS AND DISCUSSION

For plant height, there was a very strong positive correlation with real evapotranspiration (r = 0.99*) and very strong negative correlation (r = -0.99*) with water deficit (Tables 3 and 4), corroborating with results obtained by the authors cited in the reference [16], who verified that the increase in soil water level provides an increase in height of the sunflower plant.

Table 1. Averages of plant height (PH), capitulum diameter (CD), mass of a thousand achenes (MTA), oil content (OC), oil yield (OY) and achenes yield (AY) of sunflower genotypes grown in Mato Grosso, Brazil, in 2009, 2011 and 2012

Year	Genotype	PH (cm)	CD (cm)	MTA (g)	OC (%)	OY (kg ha^{-1})	AY (kg ha^{-1})
2009	M734	138	17	70	38.0	1089	2854
	Helio 358	114	17	63	47.0	1069	2270
2011	M734	148	17	70	38.8	1292	3311
	Helio 358	123	18	54	44.9	1048	2328
2012	M734	178	19	70	39.1	814	2082
	Helio 358	147	18	52	44.0	827	1878

Table 2. Real estimated yield (REY), maximum temperature (T_{MAX}), average temperature (T_{MED}), minimum temperature (T_{MIN}), water deficit (DEF), crop evapotranspiration (ETC) and real evapotranspiration (ETR) of sunflower genotypes grown in Mato Grosso, Brazil, in 2009, 2011 and 2012

Year	REY (kg ha^{-1})	T_{MAX} (ºC)	T_{MED} (ºC)	T_{MIN} (ºC)	DEF (mm)	ETC (mm)	ETR (mm)
2009	1473	31.59	23.38	18.07	204.52	378.53	174.00
2011	1910	32.03	24.05	18.41	159.44	389.29	229.86
2012	2753	31.98	23.94	18.58	18.12	369.17	351.05

Temperature data: Poxoréo Conventional Surface Weather Observation Station (2009, 2011 and 2012)

Table 3. Correlation coefficient (r) between meteorological attributes and agronomic characteristics of the genotype M734 cultivated in Mato Grosso, Brazil

	PH	CD	MTA	OC	OY	MRY	REY
T_{MAX}	0.61	0.40	-0.80	-0.96*	0.01	-0.04	0.68
T_{MED}	0.57	0.36	-0.77	-0.91	0.06	0.01	0.65
T_{MIN}	0.89	0.76	-0.98	-0.97	-0.41	-0.46	0.93
DEF	-0.99*	-0.97*	0.95	-0.85	-0.78	-0.81	-0.99*
ETC	-0.69	-0.84	0.46	-0.22	0.99	0.98	-0.61
ETR	0.99*	0.95*	-0.97	0.89	-0.97*	-0.77	0.99*

T_{MAX}: maximum temperature (ºC), T_{MED}: average temperature (ºC), T_{MIN}: minimum temperature (ºC), DEF: water deficit (mm), ETC: crop evapotranspiration (mm day^{-1}), ETR: real evapotranspiration (mm day^{-1}), PH: plant height (cm), CD: capitulum diameter (cm), MTA: mass of a thousand achenes (g), OC: oil content (%), OY: oil yield (kg ha^{-1}), MRY: measured real yield (kg ha^{-1}), REY: real estimated yield (kg ha^{-1}).
**significant at 5% probability*

Table 4. Correlation coefficient (r) between meteorological attributes and agronomic characteristics of the genotype Helio 358 cultivated in Mato Grosso, Brazil

	PH	CD	MTA	OC	OY	MRY	REY
T_{MAX}	0.63	0.99*	-0.98*	-0.92	-0.47	-0.29	0.68
T_{MED}	0.59	0.98*	-0.94	-0.90	-0.43	-0.24	0.65
T_{MIN}	0.90	0.94	-0.96*	-0.99	-0.80	-0.67	0.93
DEF	-0.99*	-0.68	0.80	0.86	-0.98*	-0.93	-0.99*
ETC	-0.67	0.04	0.13	0.25	0.80	0.90	-0.61
ETR	0.99*	0.74	-0.98*	-0.90	-0.97*	-0.90	0.99*

T_{MAX}: maximum temperature (ºC), T_{MED}: average temperature (ºC), T_{MIN}: minimum temperature (ºC), DEF: water deficit (mm), ETC: crop evapotranspiration (mm day^{-1}), ETR: real evapotranspiration (mm day^{-1}), PH: plant height (cm), CD: capitulum diameter (cm), MTA: mass of a thousand achenes (g), OC: oil content (%), OY: oil yield (kg ha^{-1}), MRY: measured real yield (kg ha^{-1}), REY: real estimated yield (kg ha^{-1}).
**significant at 5% probability*

Plant height reflects the nutritional conditions in the stem elongation period, and the response of the cultivars can show the efficiency of the plant to the edaphoclimatic conditions of cultivation [17], including water availability. In low water conditions, the decrease in height of sunflower plants possibly occur due to the increase of abscisic acid level that slows plant growth, the stomatal closure as a mechanism to reduce water loss, as well as by changes in hormonal activity [18].

For the M734 genotype, there was a very strong positive correlation of the capitulum diameter with the real evapotranspiration (r = 0.95*) and very strong negative correlation (r = -0.97*) with the water deficit (Table 3), agreeing with results obtained by the authors cited in the reference [8] who verified greater capitulum diameter with the increase of water availability.

Water deficit in sunflower may cause floral abortion and reduction of the capitulum diameter resulting in decrease of achenes production [3]. The influence of water deficit on the capitulum diameter was not observed in Helio 358 (Table 4), a result that reinforces that tolerance to low water availability depends not only on the species, but also to the cultivar [19].

In the Helio 358, there was a very strong positive correlation of the capitulum diameter with the maximum (r = 0.99*) and mean (r = 0.98*) temperature (Table 4). For sunflower, low temperatures generate an increase in the plant cycle, causing losses in productivity, especially when it occurs at the beginning of flowering [20], which is related to the size of the capitulum to be formed. The capitulum diameter depends on the environmental conditions, management and genotype. This characteristic is relevant because capitulums with larger diameters provide higher yields of achenes [21].

For mass of a thousand achenes, there was a very strong negative correlation with the maximum (r = -0.98*) and minimum (r = -0.96*) temperatures, and with evapotranspiration (r = -0.98*) in the Helio 358 (Table 4). In sunflower, the increase in temperature decreases the accumulation of intercepted radiation, which may cause losses in mass of achenes [9].

Similarly, reductions in the production of dry mass of achenes and oil content occur due to the lower availability of water at the beginning of flowering or in the filling of achenes, which reflects the climatic conditions in the second crop in the region [22,23]. The translocation of assimilates in the plant is very related to evapotranspiration, and the need for water increases with the development of the plant. In sunflower, this demand generally ranges from 0.5 to 10 mm per day depending on the phenological stage [20].

There was a very strong negative correlation of the maximum temperature with the oil content (r = -0.96*) in the M734 (Table 3). Generally, raising the maximum temperature causes damage to the production of oil in the plant. The authors cited in the reference [24] studying the influence of air temperature on the oil content of sunflower seeds found that there was a decrease in the total content at higher temperature.

In addition to the loss of oil content, the temperature affects the fatty acid composition of sunflower oil [7]. According to the authors cited in the reference [20], a mild temperature during the synthesis of oil benefits the concentration of linoleic acid, while the occurrence of temperature above 35ºC between flowering and physiological maturation causes the irreversible increase of the content of oleic acid.

For oil yield, there was a very strong negative correlation between real evapotranspiration in the genotypes M734 and Helio 358 (r = -0.97*), and with the water deficit in Helio 358 (r = -0.98*) (Tables 3 and 4). The measured yield of achenes showed no correlation with the meteorological attributes, but for estimated yield there was a very strong positive correlation with real evapotranspiration (r = 0.99*) and very strong negative correlation (r = -0.99*) with water deficit in both genotypes.

In cultivation, the productivity and the quality are strongly influenced by genotype, environment and their interaction [25]. The water deficit may prolong the total sunflower growth period [26], increasing the risk of losses in the final yield of the crop. The lack of water in the vegetal tissues implies less leaf expansion, as a mechanism to minimize the loss by evapotranspiration. When water stress occurs in later stages of plant development, the reduction of leaf expansion in the anthesis period causes a lower yield of achenes, in addition to hindering the absorption of important nutrients to the plant, such as boron [20].

In sunflower, the authors cited in the references [27,28] found higher yields of achenes due to the increase of water availability through irrigation. In the culture, the most sensitive development phases to water deficiency are from the beginning of capitulum formation to the beginning of flowering and the formation and filling of achenes. About 500 mm of water, well distributed throughout the cycle, resulted to yields close to the maximum potential for the crop [8,29].

4. CONCLUSION

The water deficit decreases plant height, capitulum diameter and yield of oil in sunflower cultivated as a second crop in Mato Grosso, Brazil.

Increases in maximum temperature during sunflower cultivation reduce the oil content of achenes in the region studied.

The impacts of meteorological attributes on some agronomic characteristics of sunflower depend on the genotype.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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