

# Impacts of meteorological attributes on agronomic characteristics of sunflower cultivated in the Cerrado

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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 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 Helió 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.

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*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.

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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

26 flowering, filling of achenes and harvesting has been one of the major aspects that can  
27 determine the success of the production [3, 4].

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

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

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

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## 50 2. MATERIAL AND METHODS

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

55 The research was carried out using two sunflower genotypes (M 734 and Helio 358), in three  
56 years (2009, 2011, 2012) with four replications. The experimental design was randomized  
57 complete block (RCBD) in which the plots were constituted by four rows of 6.00 m, spaced of  
58 0.90 x 0.25 m, considering as a useful area, the two central lines, eliminating 0.5 m from the  
59 margins.

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

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

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

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

80 The calculation of climatological water balance was performed according to the method  
 81 proposed by the authors cited in the reference [12], with precipitation and temperature data  
 82 grouped in in periods of ten days. The precipitation values were collected at the experiment  
 83 installation site and the temperature (minimum, maximum and mean compensated) obtained  
 84 from the Poxoréo Conventional Surface Weather Observation Station, located in Poxoréo-  
 85 MT, near the experiment site, based on the National Institute of Meteorology (INMET)  
 86 database. The maximum yield was estimated using the Agroecological Zone Method (FAO)  
 87 described by the authors cited in the reference [13], adopting a leaf area index for the crop of  
 88 15, according to the author cited in the reference [14].

89 After obtaining the agronomic characteristics of the sunflower (Table 1) and the  
 90 meteorological attributes (Table 2), Pearson correlation analysis was performed. The  
 91 interpretation was made according to the author cited in the reference [15]:  $r = 0.10$  to  $0.19$   
 92 (very weak);  $r = 0.20$  to  $0.39$  (weak);  $r = 0.40$  to  $0.69$  (moderate);  $r = 0.70$  to  $0.89$  (strong);  $r =$   
 93  $0.90$  to  $1$  (very strong), considering the significance level of 5%.

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 96 **Table 1. Averages of plant height (PH), capitulum diameter (CD), mass of a**  
 97 **thousand achenes (MTA), oil content (OC), oil yield (OY) and achenes yield**  
 98 **(AY) of sunflower genotypes grown in Mato Grosso, Brazil, in 2009, 2011 and**  
 99 **2012**

Year	Genotype	PH (cm)	CD (cm)	MTA (g)	OC (%)	OY (kg ha <sup>-1</sup> )	AY (kg ha <sup>-1</sup> )
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

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 102 **Table 2. Real estimated yield (REY), maximum temperature (T<sub>MAX</sub>), average**  
 103 **temperature (T<sub>MED</sub>), minimum temperature (T<sub>MIN</sub>), water deficit (DEF), crop**  
 104 **evapotranspiration (ETC) and real evapotranspiration (ETR) of sunflower**  
 105 **genotypes grown in Mato Grosso, Brazil, in 2009, 2011 and 2012**

Year	REY (kg ha <sup>-1</sup> )	T <sub>MAX</sub> (°C)	T <sub>MED</sub> (°C)	T <sub>MIN</sub> (°C)	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

106 *Temperature data: Poxoréo Conventional Surface Weather Observation Station (2009, 2011*  
 107 *and 2012).*  
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110 **3. RESULTS AND DISCUSSION**

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112 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),  
 113 corroborating with results obtained by the authors cited in the reference [16], who verified  
 114 that the increase in soil water level provides an increase in height of the sunflower plant.  
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117 **Table 3. Correlation coefficient (r) between meteorological attributes and**  
 118 **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*

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$T_{MAX}$ : maximum temperature ( $^{\circ}C$ ),  $T_{MED}$ : average temperature ( $^{\circ}C$ ),  $T_{MIN}$ : minimum  
 120 temperature ( $^{\circ}C$ ), DEF: water deficit (mm), ETC: crop evapotranspiration ( $mm\ day^{-1}$ ), ETR:  
 121 real evapotranspiration ( $mm\ day^{-1}$ ), PH: plant height (cm), CD: capitulum diameter (cm),  
 122 MTA: mass of a thousand achenes (g), OC: oil content (%), OY: oil yield ( $kg\ ha^{-1}$ ), MRY:  
 123 measured real yield ( $kg\ ha^{-1}$ ), REY: real estimated yield ( $kg\ ha^{-1}$ ).

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\*significant at 5% probability.

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127 **Table 4. Correlation coefficient (r) between meteorological attributes and**  
 128 **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*

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$T_{MAX}$ : maximum temperature ( $^{\circ}C$ ),  $T_{MED}$ : average temperature ( $^{\circ}C$ ),  $T_{MIN}$ : minimum  
 130 temperature ( $^{\circ}C$ ), DEF: water deficit (mm), ETC: crop evapotranspiration ( $mm\ day^{-1}$ ), ETR:  
 131 real evapotranspiration ( $mm\ day^{-1}$ ), PH: plant height (cm), CD: capitulum diameter (cm),  
 132 MTA: mass of a thousand achenes (g), OC: oil content (%), OY: oil yield ( $kg\ ha^{-1}$ ), MRY:  
 133 measured real yield ( $kg\ ha^{-1}$ ), REY: real estimated yield ( $kg\ ha^{-1}$ ).

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\*significant at 5% probability.

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

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For the M734 genotype, there was a very strong positive correlation of the capitulum  
 143 diameter with the real evapotranspiration ( $r = 0.95^*$ ) and very strong negative correlation ( $r =$   
 144  $-0.97^*$ ) with the water deficit (Table 3), agreeing with results obtained by the authors cited in

145 the reference [8] who verified greater capitulum diameter with the increase of water  
146 availability.

147 Water deficit in sunflower may cause floral abortion and reduction of the capitulum diameter  
148 resulting in decrease of achenes production [3]. The influence of water deficit on the  
149 capitulum diameter was observed in Helio 358 (Table 4), a result that reinforces that  
150 tolerance to low water availability depends not only on the species, but also to the cultivar  
151 [19].

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

159 For mass of a thousand achenes, there was a very strong negative correlation with the  
160 maximum ( $r = -0.98^*$ ) and minimum ( $r = -0.96^*$ ) temperatures, and with evapotranspiration ( $r$   
161  $= -0.98^*$ ) in the Helio 358 (Table 4). In sunflower, the increase in temperature decreases the  
162 accumulation of intercepted radiation, which may cause losses in mass of achenes [9].

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

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

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

179 For oil yield, there was a very strong negative correlation between real evapotranspiration in  
180 the genotypes M734 and Helio 358 ( $r = -0.97^*$ ), and with the water deficit in Helio 358 ( $r = -$   
181  $0.98^*$ ) (Tables 3 and 4). The measured yield of achenes showed no correlation with the  
182 meteorological attributes, but for estimated yield there was a very strong positive correlation  
183 with real evapotranspiration ( $r = 0.99^*$ ) and very strong negative correlation ( $r = -0.99^*$ ) with  
184 water deficit in both genotypes.

185 In cultivation, the productivity and the quality are strongly influenced by genotype,  
186 environment and their interaction [25]. The water deficit may prolong the total sunflower  
187 growth period [26], increasing the risk of losses in the final yield of the crop. The lack of  
188 water in the vegetal tissues implies less leaf expansion, as a mechanism to minimize the  
189 loss by evapotranspiration. When water stress occurs in later stages of plant development,

190 the reduction of leaf expansion in the anthesis period causes a lower yield of achenes, in  
191 addition to hindering the absorption of important nutrients to the plant, such as boron [20].

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

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#### 199 4. CONCLUSION

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

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

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

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