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Original Research Article

Agronomic Performance of Sunflower Hybrids in Brazilian Savannah Region

ABSTRACT

The establishment of sunflower crop in the Brazilian savannah region depends, among other factors, on the use of cultivars with adequate characteristics and adaptation to the growing regions. The objective of this work was to evaluate the agronomic performance of sunflower cultivars sown in the summer double cropping in Campo Novo do Parecis (Mato Grosso), the main sunflower producing region in the Brazilian savannah, In the years 2014 and 2015. The experimental design was a randomized complete block with eight treatments (AGUARÁ 04, AGUARÁ 06, CF 101, GNZ NEON, HELIO 251, MG 305, SYN 045 and SYN 3950HO) and four replications. Seeding and fertilization were carried out on March 7, 2014 and March 3, 2015. Plant height, capitulum diameter, harvest index, mass of one thousand achenes, achene productivity, oil content and oil yield were assessed. Data were submitted to analysis of variance and the Scott-Knott test at 5% probability ($P < .05$). The hybrids AGUARÁ 04, SYN 3950HO, SYN 045, CF 101 and MG 305 stand out for grain and oil yields. Of these, AGUARÁ 04 and CF 101 presented the lowest plant heights and the highest harvest rates. The hybrid SYN 3950HO associated high oil quality with high grain and oil yields.

Keywords: grain yield; Helianthus annuus L; oil yield; varietal competition.

1. INTRODUCTION

From the sunflower (*Helianthus annuus* L.) achenes can be extracted high quality oil for human consumption and high protein meal for the production of animal feed [1,2,3], besides the plant serve as ornamentation [4]. Sunflower oil may be rich in linoleic (traditional sunflower) or oleic (high oleic sunflower) fatty acids that favor the reduction of the LDL-cholesterol (bad cholesterol) fraction and, consequently, the risk of cardiovascular disease [5]. In addition, oil with high oleic acid content is less susceptible to oxidative changes during refining, storage and frying.

In the 2015/2016 harvest, the sunflower was the third oilseed in achene production (40.57 million tons) and the fourth in oil production (15.5 million tons) in the world [6]. Despite the relevance, the Brazilian cultivation area is still reduced. In this harvest, it was 51.4 thousand ha, 80% of which was established in the savannah region, mainly in Campo Novo do Parecis (Mato Grosso) with an area of over 20 thousand ha [7].

In Brazilian savannah region, the sunflower is grown in the summer double cropping from February / March due to the occurrence of suitable rainfall (500 to 700 mm) and temperature (20 to 28ºC) conditions for its cultivation [8]. Currently, soybean is usually sown in October and November and harvested between January and March and maize is the most sown crop in the second crop in a total area of approximately 10.0 million hectares [7]. Sunflower cultivation may be an option for crop rotation with maize.

In order to increase the area of sunflower cultivation in the country it is relevant to have information on the agronomic behavior of hybrids in the producing regions in order to increase the producer profitability and to facilitate the cultivation practices [9]. In Brazil, this evaluation is being carried out by the Sunflower Trial Network, coordinated by Embrapa, which counts with the participation of public and private companies [10,11,12,13] In this network, hybrids are assessed for two years under different soil and climatic conditions. Thus, the evaluation of cultivars (best hybrids evaluated in this

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network) under the same growing conditions can facilitate the choice of the best cultivar by the producer.

The objective of this work was to evaluate the agronomic performance of sunflower cultivars sown in the summer double cropping in Campo Novo do Parecis (Mato Grosso), the main sunflower producing region in the Brazilian savannah.

2. MATERIAL AND METHODS

2.1. Field Trials

The trials were carried out in Campo Novo do Parecis (Mato Grosso), in a system of summer double cropping in succession to soybean in 2014 and 2015. In the last five years the area was cultivated in the soy/corn succession system. The geographical coordinates of the area are latitude 13º40'37" S, longitude 57º47'30" W and altitude of 564 m. The soil is classified as typical dystrophic Red Latosol (Typic Tropudox) [9].

The soil textural characterization in the 0-0.20 m depth layer is 506, 134 and 360 g kg-1 for clay, silt and sand, respectively. The initial characterization of fertility (0-0.20 m) showed the following values: pH ($CaCl_2$) = 5.7; OM = 26 g dm^{-3}; P (resin) = 5.9 mg dm^{-3}; K, Ca, Mg and H + Al = 1.5; 32; 11 and 40 $mmol_c$ dm^{-3}, respectively; with BS = 54.8%.

The local climate is the type AW according to Köppen, the dry season taking place from May to September and the rainy season from October to April [14], as indicated in the historical series of the years from 2003 to 2010 (Fig. 1). However, the precipitation height was 570 and 820 mm (Figs. 2A,B), values sufficient to satisfy the water demand of the crop, since this requires accumulated precipitation of 500 to 700 mm, regularly distributed throughout its cycle [8]. The mean values for maximum, average and minimum temperatures were 30.3; 23.2 and 18.9 °C (2014) and 30.6; 23.5 and 19.5 °C (2015), respectively.

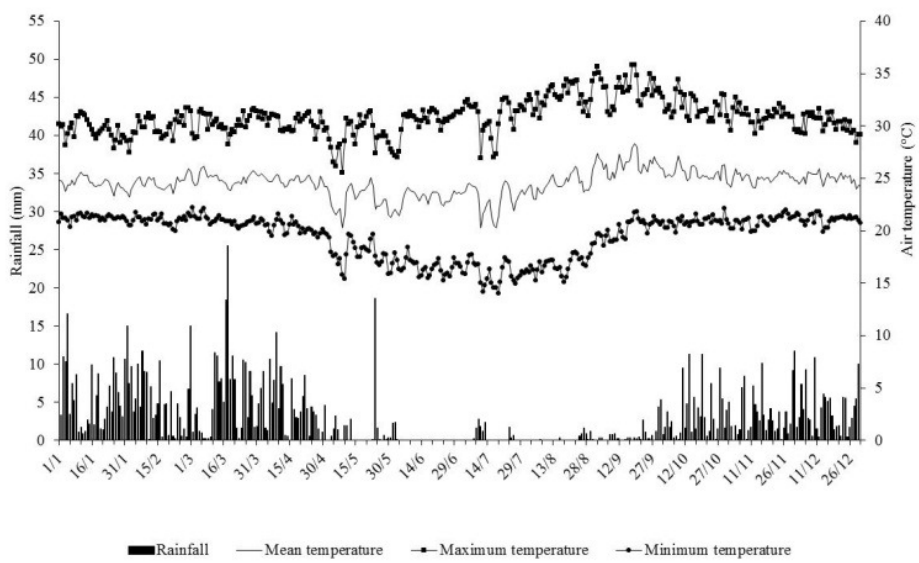

Fig. 1. Rainfall and thermal averages in the experimental area between 2003 and 2010 (Campo Novo do Parecis, Mato Grosso)

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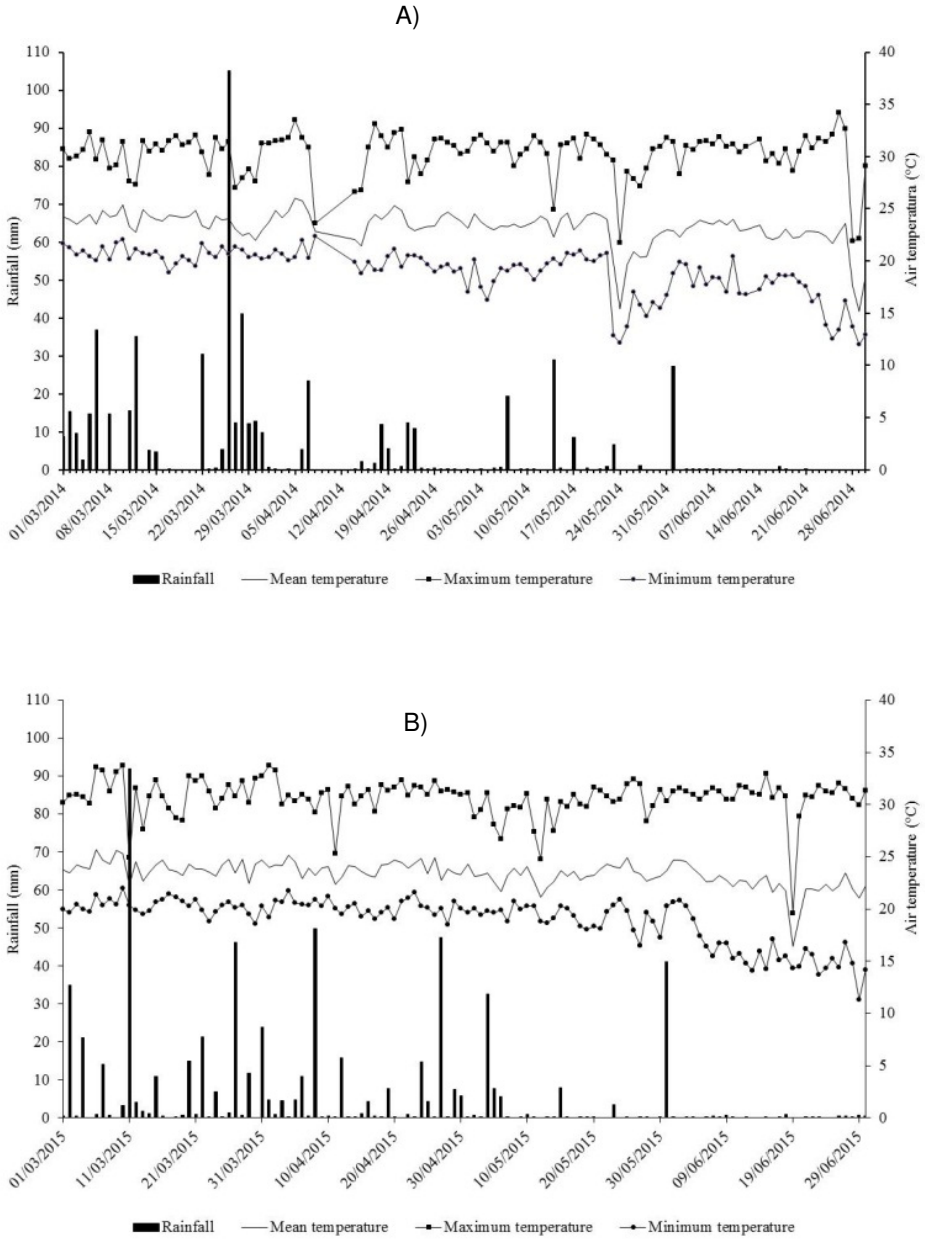

Fig. 2. Rainfall and thermal averages in the experimental area between March and June of 2014 (a) and of March and June of 2015 (b) (Campo Novo do Parecis, Mato Grosso)

Seeding and fertilization were carried out on March 7, 2014 and March 3, 2015. A total of 267 kg ha^{-1} of NPK 10-30-20 + 45 kg ha^{-1} of Potassium Chloride were applied - 26.7 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of K_2O, according to interpretation of soil analysis and crop demand [15]. The desiccation together with the application of 2 kg ha^{-1} of boron (boric acid) were carried out on the same day of sowing. At 32 DAE, nitrogen fertilization was performed at a dose of 50 kg ha^{-1} of N (urea). Other cultural practices were made to allow optimum plant development [15].

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2.2. Agronomic traits

The agronomic traits were evaluated in 10 plants randomly sampled in the useful area: achene yield (AY, kg ha^{-1}) obtained from all plants (R.9) of useful area and corrected for 11% moisture; oil content (OC %) predicted by spectroscopy [16]; oil yield (OY, kg ha^{-1}) calculated by the product between the oil content (%) and achene yield (kg ha^{-1}) / 100; plant height (PH, cm) measured from the soil base to the plant apex, in R5.5; head diameter (HD; cm), measured in R9; harvest index (HI), determined by dividing the achene mass by the head mass and 1000-grain mass (1000GM) obtained by counting and weighing samples with a thousand achenes.

2.3. Experimental design and statistic

The experimental design was a randomized complete block with four replications. Each plot (replicate) consisted of four rows 6.5 m long and spaced from 0.45 m. The two external rows of each plot (borders) were discarded, as were 0.5 m from each end of the two central rows, leaving a useful area of 4.5 m^2.

The treatments were the hybrids (commercial cultivars) AGUARÁ 04, AGUARÁ 06, CF 101, GNZ NEON, HELIO 251, MG 305, SYN 045 and SYN 3950HO. These hybrids are simple and traditional (their oils are rich in linoleic acids), except SYN 3950HO which is high oleic. The analysis of variance and Scott-Knott test ($P < .05$) were carried out by using SISVAR software program [17].

3. RESULTS AND DISCUSSION

3.1. Achene and oil yields

The producer must take into account the achene and oil yields in choosing the best hybrid sunflower. In the 2014 and 2015 harvests, there were significant differences ($P = .01$) between hybrids grown in the Brazilian summer double cropping for oil content and oil yield, but not for achene yield (Table 1). The non-distinction between the hybrids for this trait may be due to them being commercial cultivars with wide adaptability to the edaphoclimatic conditions of Brazilian savannah [10,11,12,13].

The hybrids did not differ in the achenes yield ($P > .05$), even when this difference was above 300 kg ha^{-1} (Table 2). The AGUARÁ 06 yield (1368.3 kg ha^{-1}) was, for example, 22% higher than that of GNZ NEON (1671.3 kg ha^{-1}). The highest achene yield were obtained in 2014 (mean of 2086.6 kg ha^{-1} in 2014 and 1090.6 kg ha^{-1} in 2015), year with the lowest rainfall (Figs. 2A,B), reflecting in higher leaf health due to the lower incidence of *Alternariaster helianthi* and *Sclerotinia sclerotiorum*. These are the main diseases of the culture in the Brazilian savannah region and that drastically reduces the photosynthetically active leaf area [15].

Table 1. Analysis of variance for agronomic traits of sunflower hybrids grown in the summer double cropping (Campo Novo do Parecis, Mato Grosso, 2014 and 2015)

Trait	F	C.V. (%)[a]	GM[b]
Plant height (cm)	48.1**	2.1	170.8
Head diameter (cm)	4.9**	4.2	15.4
Harvest index	8.9**	6.1	0.61
1000-grain mass (g)	16.4**	5.7	44.8
Achene yield (kg ha^{-1})	1.9	9.4	1588.6
Oil content (%)	57.2**	1.8	42.1

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Oil yield (kg ha^{-1})	3.8**	9.7	671.5

*** significant at P < .01 probability; [a] C.V. = coefficient of variation; [b] GM = general mean.*

Table 2. Mean values for achene yield (AY), oil content (OC) and oil yield (OY) of sunflower hybrids grown in the summer double cropping (Campo Novo do Parecis, Mato Grosso, 2014 and 2015)

Hybrid	AY (kg ha^{-1})	OC (%)*	OY (kg ha^{-1})
AGUARÁ 04	1670.5	45.0 a	755.8 a
AGUARÁ 06	1368.3	40.9 c	562.0 b
CF 101	1559.0	44.2 a	694.5 a
GNZ NEON	1671.3	37.6 d	629.5 b
HELIO 251	1624.3	38.4 d	626.8 b
MG 305	1535.5	43.4 b	666.5 a
SYN 045	1652.5	42.6 b	708.3 a
SYN 3950HO	1627.3	44.5 a	728.5 a

* Means followed by the same letter, in the column, do not significantly differ from each other by the Scott-Knott test at P < .01 probability.

The hybrids AGUARÁ 04, SYN 3950HO and CF 101 showed the highest oil contents, with values between 44.2 and 45.0% (Table 2), while GNZ NEON (37.6%) and HELIO 251 (38.4% %) showed the lowest contents. The mean oil content of the hybrids was 42.1%. The desirable oil content set by the industry is above 40%. Some industries provide subsidies to farmers who produce achenes with values higher than this index [10,11,16,12,13], since oil is the main commercial product of the sunflower crop. However, the hybrid with higher achenes yield will not always result in higher oil yield. Therefore, the higher the subsidy, the greater the preference of producers for hybrids with higher oil contents and oil yields.

In this study, as there was no statistical difference between hybrids for achenes yield, those with the highest oil yield were those with the highest oil content, such as AGUARÁ 04 (755.8 kg ha^{-1}), SYN 3950HO (728,5 kg ha^{-1}), SYN 045 (708.3 kg ha^{-1}), CF 101 (694.5 kg ha^{-1}) and MG 305 (666.5 kg ha^{-1}) (Table 2). Of which, the hybrid SYN 3950 is the only high oleic. Grunvald et al. [16] also reported hybrids grown in Brazilian savannah with high achene and oil yields associated with oil quality.

The mean of hybrid oil yields was 671.5 kg ha^{-1} (Table 1), higher than the value highlighted by Silva et al. [19], who worked with two hybrids in Lavras (Minas Gerais) (savannah region) and obtained a mean of 565.4 kg ha^{-1}. On the other hand, Grunvald et al. [10] worked with several hybrids in the Sunflower Trial Network, between 2004 and 2007 in Brazilian savannah region, and obtained mean of oil productivity from 861.0 to 1022.0 kg ha^{-1}, with achenes productivity ranging from 2021.0 to 2245.0 kg ha^{-1} and oil contents ranging from 43.8 to 45.5%. These values show that other regions are favorable to sunflower cultivation, in addition to Campo Novo do Parecis (Mato Grosso).

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3.2. Other agronomic traits

Head size can be considered an indicator of the plant development, as well as the achene yield, even in situations of environmental stress [8]. Heldwein et al. [20] reported that the both head size and 1000-grain mass have direct implication on the achenes yield. In the present study, the hybrids AGUARÁ 06 (16.6 cm), AGUARÁ 04 (16.0 cm), HELIO 251 (15.7 cm) and MG 305 (15.6 cm) showed the highest means for head size (Tables 1 and 2). The overall mean was 15.4 cm. On the other hand, the hybrids SYN 045, MG 305 (48.1 cm), SYN 3950HO (47.4) and GNZ NEON (46.6) showed the highest 1000-grain mass (53.9 g) (Table 3). Thus, the hybrids that stood out for head size showed lower 1000-grain mass, so that there was no significant difference (P > .05) between hybrids for achene yield (Table 1).

In addition to grain and oil yields, plant height (PH) is relevant for sunflower crop. The overall mean of the hybrids for plant height was 170.8 cm (Table 1). Those of smaller height were CF 101 (147.7 cm), HELIO 251 (162.1 cm), MG 305 (165.4 cm) and AGUARÁ 04 (166.8 cm) (Table 3). Nobre et al. [21] reported an average of 170.0 cm for CF 101 in the North of Minas Gerais (savannah region), which shows an environmental effect for this characteristic. In addition to facilitating cultural practices, lower-sized reduces the lodge and stem breakage under unfavorable climatic conditions and minimizes losses in mechanized harvesting [22,8].

Table 3. Mean values for plant height (PH), head diameter (HD), harvest index (HI) and 1000-grain mass (1000GM) of sunflower hybrids grown in the summer double cropping (Campo Novo do Parecis, Mato Grosso, 2014 and 2015)

Hybrid	PH* (cm)	HD (cm)	HI	1000 GM (g)
AGUARÁ 04	166.8 b	16.0 a	0.69 a	40.7 c
AGUARÁ 06	179.7 a	16.6 a	0.59 b	38.3 c
CF 101	147.7 c	14.9 b	0.65 a	42.0 c
GNZ NEON	181.5 a	14.8 b	0.50 c	46.6 b
HELIO 251	162.1 b	15.7 a	0.60 b	41.1 c
MG 305	165.4 b	15.6 a	0.63 a	48.1 b
SYN 045	184.4 a	14.4 b	0.64 a	53.9 a
SYN 3950HO	178.7 a	15.2 b	0.61 b	47.4 b

*Means followed by the same letter, in the column, do not significantly differ from each other by the Scott-Knott test at P < .01 probability.

The values of the hybrid harvest indexes are also shown in Table 3. The higher the value, the greater the commercial mass of the head, increasing the interest of the industry, since this requires the achenes for the industrial processing [9]. Hybrids AGUARÁ 04, CF 101, SYN 045 and MG 305 showed the highest harvest indexes, ranging from 0.63 to 0.69, while GNZ NEON showed the lowest index (0.5), indicating that most of the energy translocated to heads of this hybrid is used to form the floral receptacle that has no commercial value, and not to form the achenes. This result corroborated Dalchiavon et al. [9] which evaluated the agronomic performance of SYN 045 in the Campo Novo do Parecis (Mato Grosso) and reported a harvest index of 0.66.

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4. CONCLUSION

For the summer double cropping of Brazilian savannah region, the hybrids AGUARÁ 04 and CF 101 associate high achene and oil yields with lower-sized and good harvest index and the hybrid SYN 3950HO associates high achene and oil yields with quality of oil.

REFERENCES

1. Balbinot Jr AA, Backes RL, Souza AM de. Performance of sunflower cultivars at three sowing times in the northern plateau of Catarinense. Sci Agrar. 2009;10(2):127-133.
2. Brighenti AM. Control of volunteer soybean plants in sunflower crop. Pesqui Agropecu Trop.2015;45(3):274-281. Portuguese.
3. Azerbaijan MMLC, Farias ME de, CF Pine de, Teixeira SB, Ávila GE, Deuner C, Borella J, Deuner S. Antioxidant Defense in Sunflower against Drought. Journal of Experimental Agriculture International. 2018;25(1):1-9.
4. Souza, RN de, Paz VP da S, Gonçalves KS, Soares TM, Azevedo Neto AD, Gheyi HR. Treated Domestic Effluents: An Option for Cultivation of Ornamental Sunflower in a Hydroponic System. Journal of Experimental Agriculture International. 2018;24(6):1-11.
5. Miller JF, Zimmerman DC, Vick BA. Genetic control of high oleic acid content in sunflower oil. Crop Sci.1987;27(5):923-926. http://dx.doi.org/10.2135/cropsci1987.0011183X002700050019x
6. United States - Department of Agriculture - Foreign Agricultural Service. Oilseeds: world markets and trade. Washington. 2017, 36 p.
7. Conab - National Supply Company - Monitoring of harvest: grains. Joint monthly, March 2017. Brasília, National Supply Company. 2017, 172 p. Accessed 25 April 2017. Available in <http://www.conab.gov.br>.
8. Castro C, Farias JRB. Ecophysiology of Sunflower. In: Milk RMVB, Brighenti AM, Castro C, editors. Sunflower in Brazil. Londrina: Brazilian Agricultural Research Corporation - CNPSo, 2005. 163-210.
9. Dalchiavon FC, Montanari R, Andreotti M, Dallacort R, Souza MFP. Relationship between sunflower productivity and soil´s chemical properties by geo-statistical techniques. Afr J Agric Res. 2015;10(35):3525-3532. http://dx.doi.org/10.5897/AJAR2014.9472
10. Grunvald AK, Carvalho CGP de, Oliveira ACB de, Andrade CA de B. Adaptability and stability of sunflower genotypes in Central Brazil. Pesqui. Agropecu. Bras. 2008;43(11):1483-1493. http://dx.doi.org/10.1590/S0100204X2008001100006. Portuguese.
11. Porto WS, Carvalho CGP de, Pinto RJB, Oliveira MF de, OlIveira ACB de. Evaluation of sunflower cultivar for central Brazil. Sci Agric. 2008;65(2):139-144. http://dx.doi.org/10.1590/S010390162008000200005.
12. Carvalho CGP de, Ozawa EKM, Amabile RF, Godinho V de PC, Gonçalves SL, Ribeiro JL, Seifert A. L. Adaptability and stability of sunflower genotypes resistant to imidazolinones in second crop crops. Brazilian Journal of Agricultural Sciences. 2015;10(1):1-7. http://dx.doi.org/10.5039/agraria.v10i1a3804. Portuguese.
13. Dalchiavon FC, Carvalho CGP de, Amabile RF, Godinho VPC, Ramos NP, Anselmo JL. Agronomic characteristics and their correlations in sunflower hybrids adapted to the second harvest. Pesqui. Agropecu. Bras. 2016;51(11):1806-1812. http://dx.doi.org/10.1590/S0100-204X2016001100002. Portuguese.
14. Dallacort R, Martins JA, Inoue MH, Freitas PSL, Coletti AJ. Distribution of rainfall in the municipality of Tangará da Serra, northern region of the state of Mato Grosso, Brazil. Acta Scientiarum Agronomy. 2011;33(2):193-200. Portuguese.
15. Oliveira ACB de, Rosa APSA da. Practical guide to sunflower cultivation. Brasília: Embrapa; 2013:53 p.
16. Grunvald AK, Carvalho CPG de, Leite RS, Mandarino JMG, Andrade CA de B, Scapim CA. Predicting the oil contents in sunflower genotype seeds using near-infrared reflectance (NIR) spectroscopy. Acta Scientiarum. Agronomy,2014a;36(2):233-237. http://dx.doi.org/10.4025/actasciagron.v36i2.17677

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17. Ferreira DF. Sisvar: a computer statistical analysis system. Science and Agrotechnology. 2011;35(6):1039-1042. http://dx.doi.org/10.1590/S1413-70542011000600001
18. Grunvald AK, Carvalho CGP de, Amabile RF, Godinho V de PC, Oliveira ACB de, Ramos NP. Adaptability and stability of conventional and high oleic sunflower genotypes cultivated in Central Brazil. Genomics and Quantitative Genetics. 2014b;8(1):7-15.
19. Silva MDL, Faria MA de, Morais AR de, Andrade GP, Lima EM de C. Growth and productivity of sunflower grown in the off season with different water depths. Brazilian Journal of Agricultural and Environmental Engineering. 2007;11(5):482-488. http://dx.doi.org/10.1590/S1415-43662007000500006. Portuguese.
20. Heldwein AB, Loose LH, Lucas DDP, Hinnah FD, Bortoluzzi MP, Maldaner IC. Production and growth characteristics of sunflower seeded from August to February, in Santa Maria - RS. Brazilian Journal of Agricultural and Environmental Engineering. 2014;18(9):908-913. http://dx.doi.org/10.1590/1807-1929/agriambi.v18n09p908–913. Portuguese.
21. Noble DAC, Resende JCF, Junior DSSB, Costa CA. Agronomic performance of sunflower genotypes in northern Minas Gerais. Magazine Agro@mbiente On-line. 2012;6(2):140-147. http://dx.doi.org/10.18227/1982-8470ragro.v6i2.781. Portuguese.
22. Pivetta LG, Guimarães VF, Fioreze SL, Pivetta LA, Castoldi G. Evaluation of sunflower hybrids and relationship between productive and qualitative parameters. Cienc Agron. 2012;43(3):561-568. Portuguese.