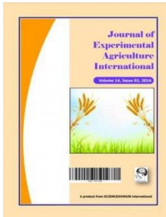

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Performance of Sunflower Hybrids Cultivated in Different Sowing Seasons in Mato Grosso, Brazil

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to evaluate the agronomic performance of five sunflower hybrids during two sowing seasons in Campo Novo do Parecis, the main sunflower producing municipality of Mato Grosso, Brazil. The trials were sown in March 2016 (second summer crop) and October 2017 (main summer crop) in a completely randomised block design with five hybrids (ACA 869, ACA 889, 13P30, 15P29, SYN 045) and five replicates. The hybrids showed higher achene yield in the second summer crop due to their lower incidence of Alternaria leaf spot. This increase was reflected in the largest number of achenes per head and mass of a thousand achenes. The hybrids SYN 045, 15P29, ACA 869 and ACA 889 showed satisfactory achene yield in the second summer crop. The SYN 045 hybrid presented higher values for shoot dry mass and shoot green mass in the two sowing seasons and therefore greater potential for silage. The cultivation of sunflower hybrids in the main summer crop in Campo Novo do Parecis (MT) may show low achene yield when satisfactory control of the Alternaria leaf spot is not established.

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Keywords: Achece yield; Helianthus annuus; second summer crop.

1. INTRODUCTION

From the sunflower achenes (*Helianthus annuus*) is extracted high-quality oil used mainly in the food industry [1,2]. This species presents important agronomic characteristics, such as greater resistance to drought, cold and heat than most species normally grown in Brazil [3,4,5]. In addition, its yield is little influenced by latitude, altitude and photoperiod [6]. These characteristics allow the sunflower to have good adaptation to regions with different soil and climatic conditions.

In the 2016/2017 harvest, the state of Mato Grosso produced 50.71% of the Brazilian sunflower production, being Campo Novo do Parecis (MT) the main producing municipality [7]. On this State it is a common agricultural practice the summer double cropping, meaning that the main crop is planted from October to early November, allowing its harvesting by February. Then a second crop follows in February/March, taking advantage of adequate temperature and rainfall conditions. Sunflower is one of the crops suitable as the second summer crop [8].

As few crops, main soybean, are sown in the main summer crop in Campo Novo do Parecis, the sunflower can also be an alternative for crop rotation to reduce the occurrence of pests and diseases. But considering that Brazil has little global representation in the production of sunflower seeds and its cultivation is practically restricted to the second summer crop in a few states, especially in Mato Grosso [9,10], little information is available about the performance of genotypes in the main crop.

The purpose of this work was to evaluate the agronomic performance of sunflower hybrids during two sowing seasons in Campo Novo do Parecis, the main sunflower producing municipality of Brazil.

2. MATERIALS AND METHODS

The experiments were carried out in the experimental field at the Federal Institute of Education, Science and Technology in Mato Grosso, in Campo Novo do Parecis, in two sowing seasons: the second summer crop (SV2), in the 2015/2016 cropping season, and in the main summer crop (SV1), in the 2016/2017 cropping season.

The experimental area has the following geographical coordinates: 13° 40' 37.96" S latitude, 57° 47' 30.45" longitude and 564 m altitude. The soil, according to the Brazilian Soil Classification System [11], is typically dystrophic Red-Yellow Latosol (Typic Tropudox). Its initial fertility characterization, for the 0-0.20 m layer, presents the following values: pH ($CaCl_2$) = 4.97; MO = 27.02 g dm^{-3}; K^+ = 0.05 $cmol_c$ dm^{-3}; Ca^{+2} = 2.17 $cmol_c$ dm^{-3}, Mg^{+2} = 0.85 $cmol_c$ dm^{-3}; H^+ = 4.61; H + Al = 4.61 $cmol_c$ dm^{-3}; P = 7.47 mg dm^{-3}; Cu = 1.03 mg dm^{-3}; Zn = 4.19 mg dm^{-3}; Fe = 189.53 mg dm^{-3}; Mn = 15.76 mg dm^{-3} and V = 39.98%.

The local climate, according to the Köppen classification, is type Aw, with well-defined seasons (dry and rainy), the dry season taking place from May to September and the rainy season from October to April [12]. Medium, maximum and minimum temperature averages occurring during the SV2 and SV1 tests were 23,4; 31,2 e 18,4°C (SV2) and 24,0; 30,5 and 20,3°C (SV1), respectively. Accumulated rainfall was 435,8 mm for SV2 and 899,6 mm for SV1 (Figs. 1A, B).

The trials were sown in March 2016 (SV2) and October 2017 (SV1) in a completely randomised block design with five replicates. The experimental plot consisted of four 6.0 m lines, with 0.45 m between them, with a population of 45,000 plants ha^{-1}. The two external lines of each plot were discarded, as well as 0.5 m from each end of the two central lines, which represented a useful area of 4.5 m^2. The cultivars evaluated were ACA 869, ACA 889, 13P30, 15P29 and SYN 045.

The preparation of the area was carried out with subsoiling + harrowing, followed by the sowing of millet (*Pennisetum americanum*) 30 days before sunflower sowing; the millet was desiccated with acid equivalent (1.5 L ha^{-1}) of glyphosate ammonium salt 792.5 g kg^{-1} + Clorimurom-ethyl 250 g kg^{-1} (70 g ha^{-1}). The sunflower sowing occurred on March 12 (SV2) and October 15, 2016 (SV1), using planting and fertilizing equipment, at the depth of 0.04 m. The treatment of the seeds was carried out at the IFMT Seed laboratory, using fipronil 250 g L^{-1} (Pyrazole) insecticide and Pyraclostrobin 25 g L^{-1} (Estrubirulinas) + methyl thiophanate 225 g L^{-1} (Benzimidazois) fungicides, 200 mL p.c. /100 kg of seeds.

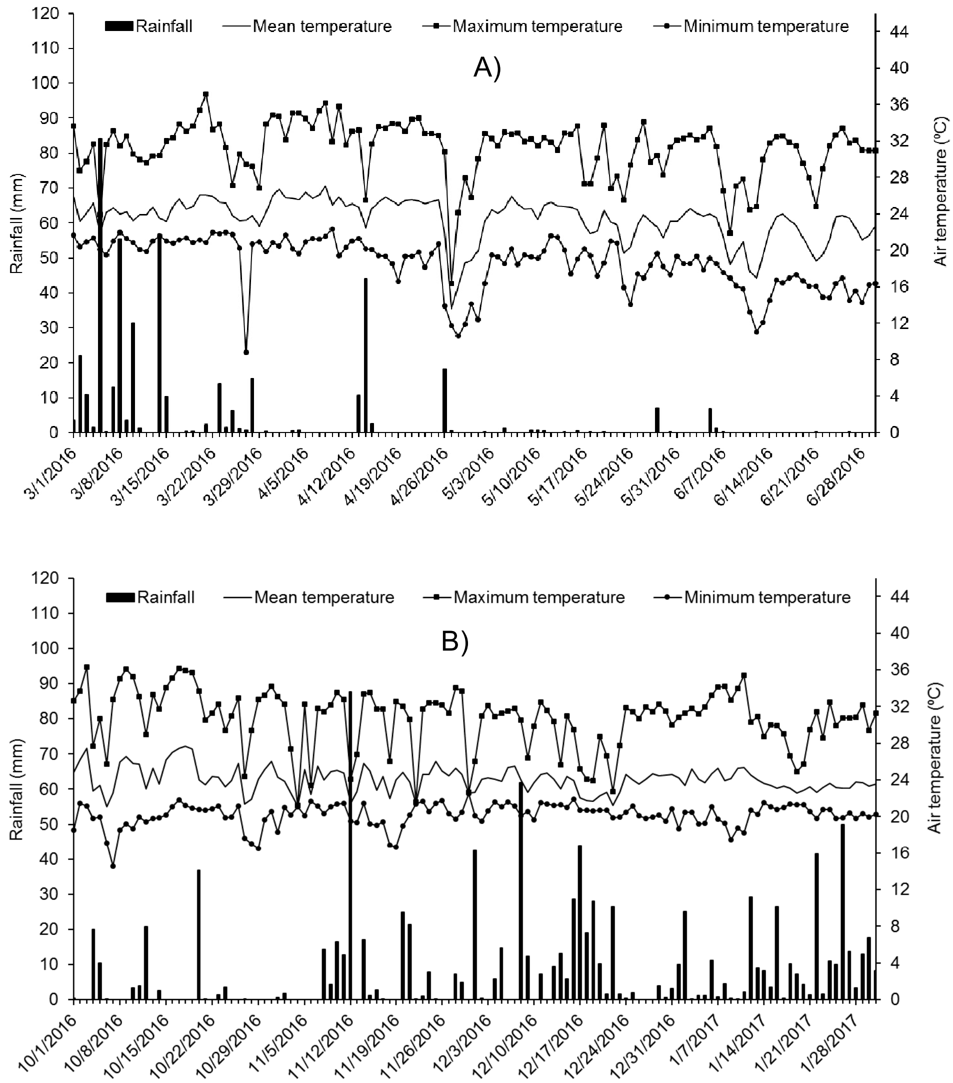

Fig. 1. Rainfall and temperature averages observed in the experimental area from March to June 2016 (SV2; A) and from October 2016 to January 2017 (SV1; B) (Campo Novo do Parecis, MT, Brazil)

The basic fertilisation, at the depth of 0.10 m, was carried out according to the recommendation made by Leite et al. [13], by chemical analysis of the soil, seeking to meet the needs of the crop (per ha): 10 kg of N, 70 kg of P_2O_5; 60 kg of K_2O and 2 kg of B. For top dressing of the soil, 60 kg ha^{-1} of N (Urea) + 1 kg ha^{-1} of Boron (Borosol) were used 30 days after the emergence (DAE).

Weed control was carried out manually, with the aid of hoes, at 15 and at 45 DAE. Pest and disease controls were carried out by constant monitoring, by the applications of insecticides and fungicides whenever necessary. For the control of insect pests, applications of Tiametoxan + lambda Cyhalothrin (14.1% + 10.6% a.i.), were made, dose of 250 mL ha^{-1}, with applications at 21, 37, 50 DAE (SV2) and at 18, 30, 45, 60, 80 DAE (SV1). The applications of azoxystrobin fungicide (estrobilurin 200 g L^{-1} a.i.) + difenoconazol (triazol 125 g L^{-1} a.i.) dose of 0.3 L ha^{-1} and difenoconazole (triazole 250 g L^{-1} a.i.) dose of 0.35 L ha^{-1} were carried out at 30 and 50 DAE (SV2) and at 30, 47, 60, 70, 83 DAE (SV1), always with the alternation of the

products, seeking the control of Alternaria leaf spot.
The agronomic characteristics evaluated in the ACA 869, ACA 889, 13P30, 15P29, SYN 045, and in R5.5 (full bloom) hybrids, in five plants per plot were: plant height (m), measured with the aid of a measuring tape, from the level of the soil to the highest part of the plant, stem diameter (mm), measured with a digital caliper (Digimess, São Paulo, Brazil), 5 cm from ground level, shoot green mass (kg ha^{-1}) and shoot dry mass (kg ha^{-1}), after weighing (Mettler Toledo, Barueri, Brazil) and drying the plants in a greenhouse (Marconi, Piracicaba, Brazil) at 105°C. Five heads were evaluated in R9: head size (cm), measuring the extremities with the aid of a measuring tape; harvest index, dividing the achene mass by the head mass; number of achenes per head, with the aid of a grain counter (model NV-C/01, Sanick, Chapecó, Brazil) and the mass of one thousand achenes (g). The achene yield (kg ha^{-1}) was carried out based on the collection of plants from the useful area of the plot. The harvest of the head was carried out manually in the two 5.0 m central lines, when the crop reached phenological maturation stage (R9), on June 29th, 2016 (SV2) and on January 28th, 2017 (SV1). After the harvest, manual tracking was carried out, as well as weighing and correction of the humidity of the achenes to 11% (humid base-bu), according to Dalchiavon et al. [14].

The data, when meeting the assumptions of homogeneity and constant variance of the residues, were subjected to analysis of variance and with the occurrence of significant F, Tukey's test was applied to the hybrids and the sowing seasons, always at 5% probability (P = .05), using the SISVAR statistical software [15].

3. RESULTS AND DISCUSSION

Differences between genotypes and between sowing seasons (first summer harvest – SV1 and second summer harvest – SV2) and the interaction of genotypes x environments for the evaluated items were usually significant according to the F test (P < .01), indicating that the difference between genotypes should be analysed at each sowing season and the difference between sowing seasons should be evaluated for each genotype (Table 1).

The smallest plant height of hybrids was observed in SV2 and the largest stem diameters in SV1 (Table 2). The 15P29 hybrid presented lower size and larger stem diameter in the two sowing seasons. Sunflower plants with these traits are desirable since they lower the risk of lodging [16]. In addition, the low height makes handling and mechanised harvesting easier.

The hybrids presented larger head size in SV1, and the highest values were obtained with ACA 889 (17.0 cm), SYN 045 (15.7 cm) and 13P29 (15.5 cm) in the two sowing seasons (Tables 3 and 4). According to Amorim et al. [17], the head is responsible for the higher proportion of accumulation of shoot dry mass among the morphological characteristics of the plant, influencing the harvest index of each genotype. However, although the hybrids presented larger head in SV1, they usually had similar shoot dry mass in SV2 (Table 2). Only SYN 045 had larger shoot dry mass in SV1, having been the best hybrid in performance for this trait, producing 9,198 kg ha^{-1}. This value was lower than the one obtained by Mello et al. [18], which, when testing sunflower genotypes at different sowing times for silage production, reported maximum shoot dry mass productivity of 11,410 kg ha^{-1} for hybrid M 734 at the December sowing, in Santa Maria (RS).

Due to the expressive productivity of shoot dry mass and shoot green mass, the Sunflower is seen as having great potential for silage. Similarly to shoot dry mass, the hybrids presented similar shoot green mass in the two sowing seasons, except for SYN 045 (Table 2). This hybrid presented larger shoot dry mass and shoot green mass in the two sowing seasons, and thus, greater potential for silage. According to Mello et al. [18], the sunflower has the potential of producing a similar amount of shoot green mass per area than maize and sorghum, since, in its experiment, the green mass produced reached 46,760 kg ha^{-1}, with approximately 57,000 plants ha^{-1} in Santa Maria (RS). In Campo Novo do Parecis, for example, the SYN 045 hybrid produced green mass of 59,465 kg ha^{-1} in the first summer harvest.

Harvest index reflects the plant's efficiency in producing grains using less energy in the production of shoot dry mass. There was a significant effect of sowing season, but not of genotypes, at 5% probability (Table 1). This index was greater in SV2 than in SV1 for all hybrids (Table 3). The values of the hybrids in SV2 corroborate those obtained by several authors [11,19] in an essay conducted in Campo

Novo do Parecis, in the second summer harvest (0.66 and 0.67, respectively).

Since shoot dry mass tended to be similar in the two sowing seasons, the greater harvest index value in SV2 was obtained due to the mass of grains (Table 3). In SV2 the hybrids had a more significant number of achenes per head and mass of one thousand achenes, which resulted in larger grain mass. In addition, the larger plant height, stem diameter and head size values in SV1 did not result in higher values for shoot dry mass and shoot green mass (Tables 2 and 3). The two sowing seasons had similar shoot dry mass and shoot green mass, for although SV1 presented higher values for plant height, stem diameter and head size, SV2 had a greater number of achenes per head and mass of one thousand achenes. The ACA 869 and ACA 889 hybrids presented the largest number of achenes per head averages (Above 1,000 achenes) and mass of one thousand achenes (above 40 g) in the two sowing seasons.

The number of heaviest achenes in smaller head size at SV2 compared to SV1. This may be due to the lower incidence of Alternaria leaf spot in SV2, resulting in a higher harvest index, higher number of achenes per head and a greater mass of one thousand achenes (Tables 2 to 4).

Table 1. Variance analysis for the agronomic traits of sunflower genotypes sown in two different sowing seasons – second summer harvest in the 2015/2016 cropping season (SV2) and first summer harvest in the 2016/2017 cropping season (SV1) (Campo Novo do Parecis, MT)

FV	Genotype (G)	Season (S)	G * E	Block/ Season	CV[b] (%)	Average
	F[a]					
Plant height (m)	6.3**	97.4**	4.0**	1.7	6.3	1.66
Stem diameter (mm)	3.6*	74.8**	3.1*	1.7	10.2	24.2
Head size (cm)	8.2**	59.0**	0.8	2.7**	7.3	15.6
Shoot dry mass (kg ha^{-1})	3.4*	9.4**	6.1**	0.4	23.8	5591
Shoot green mass (kg ha^{-1})	3.1*	21.4**	6.0**	0.5	22.9	36019
Harvest index	1.9	163.4**	1.5	1.4	12.7	0.52
Number of achenes per head	5.0**	44.5**	1.3	2.9*	14.5	1012
Mass of one thousand achene (g)	5.1**	29.1**	1.7	3.8**	11.4	40.1
Achene yield (kg ha^{-1})	4.4**	349.7**	2.2	4.1**	15.9	1352.1

*[a] * and ** significance at 5 and 1%, respectively; [b] CV = Coefficient of variation*

Table 2. Average values for plant height, stem diameter, shoot dry mass and shoot green mass of sunflower genotypes sown in two sowing seasons – second summer harvest in the 2015/2016 cropping season (SV2) and the first summer harvest in the 2016/2017 cropping season (SV1) (Campo Novo do Parecis, MT)

Genotypes	Plant height (m)		Stem diameter (mm)	
	SV2	SV1	SV2	SV1
ACA 869	1.49 Bbc	1.98 Aa	19.2 Bb	29.2 Aa
ACA 889	1.50 Bb	1.83 Ab	23.3 Ba	29.1 Aa
13P30	1.53 Bab	1.65 Ac	20.5 Bab	25.6 Abc
15P29	1.42 Bc	1.68 Ac	21.6 Bab	28.4 Aab
SYN 045	1.60 Ba	1.88 Ab	21.3 Bab	23.8 Ac
	Shoot dry mass (kg ha^{-1})		Shoot green mass (kg ha^{-1})	
ACA 869	5,566 Aa	5,978 Ab	30,379 Aa	37,309 Ab
ACA 889	4,563 Aa	4,772 Ab	30,128 Aa	32,900 Ab
13P30	5,558 Aa	5,150 Ab	30,132 Aa	36,828 Ab
15P29	4,986 Aa	5,755 Ab	36,317 Aa	40,619 Ab
SYN 045	4,385 Ba	9,198 Aa	26,114 Ba	59,465 Aa

Different letters, uppercase in lines and lowercase in columns, differ from each other according to Tukey's test; P < .05 probability

Table 3. Average values for head size, harvest index, number of achenes per head, mass of one thousand achenes and achene yield of sunflower genotypes sown in two sowing seasons – second summer harvest in the 2015/2016 cropping season (SV2) and first summer harvest in the 2016/2017 cropping season (SV1) (Campo Novo do Parecis, MT)

Sowing seasons	Head size (cm)	Harvest index	Number of achenes per head	Mass of one thousand achenes (g)	Achene yield (kg ha^{-1})
SV1	16.8 a	0.40 b	873 b	36.6 b	785.2 b
SV2	14.3 b	0.64 a	1150 a	43.5 a	1,919.0 a

Different letters in columns differ according to Tukey's test; P < .01 probability

Table 4. Average values for head size, number of achenes per head, mass of one thousand achenes and achene yield of sunflower genotypes sown in two sowing seasons – second summer harvest in the 2015/2016 cropping season (SV2) and first summer harvest in the 2016/2017 cropping season (SV1) (Campo Novo do Parecis, MT)

Genotypes	Head size (cm)	Number of achenes per head	Mass of one thousand achenes (g)	Achene yield (kg ha^{-1})
ACA 869	14.1 c	1001 abc	41.7 ab	1,375.6 ab
13P30	15.4 bc	938 bc	37.0 b	1,108.1 b
13P29	15.5 abc	1086 ab	36.2 b	1,444.3 a
SYN 045	15.7 ab	891 c	43.6 a	1,464.5 a
ACA 889	17.0 a	1142 a	41.8 ab	1,367.8 ab

Different letters in columns differ according to Tukey's test; P < .05 probability

The SYN 045 (1,464.5 kg ha^{-1}), 15P29 (1,444.3 kg ha^{-1}), ACA 869 (1,375.6 kg ha^{-1}) and ACA 889 (1,367.8 kg ha^{-1}) hybrids presented the highest achene yield in SV1 and SV2. The same shoot dry mass and shoot green mass of the hybrids did not reflect the differences found in achene yield (Tables 2 and 4). All hybrids presented higher achene yield in SV2, compared to those obtained in SV1 (Table 3). The cumulative precipitation in SV2 (435.8 mm) was slightly below the sunflower demand for water (500 to 700 mm) [20]. On the other hand, there was a water surplus of 199.6 mm in SV1 (Figures 1A, B), which is common in this sowing season. The high cumulative precipitation in SV1 associated with high temperatures favoured the severe occurrence of Alternaria leaf spot (*Alternaria* spp.) from full bloom (R5.5), causing early partial defoliation (especially of lower leaves) and the reduction in the photosynthetically active leaf area [21,22]. The occurrence of the disease in SV1 caused also the reduction of the values of a number of achenes per head and mass of one thousand achenes and, consequently, achene yield.

The higher achene yield in the second summer crop resulted from it higher number of achenes per head and mass of one thousand achenes, as already reported by Kaya et al. [9]. Although the highest head size and plant height and similar shoot green mass and shoot dry mass was verified in SV1, the occurrence of Alternaria leaf spot reduced the grain mass, influencing harvest index, number of achenes per head, mass of one thousand achenes and achene yield, even though chemical control of the disease was carried out (Tables 2 and 3). The average of achene yield observed in SV2 (1,919 kg ha^{-1}) was higher than the national average of the crops, which in the 2016/2017 harvest was 1,653 kg ha^{-1} [7]. On the other hand, the achene yield in SV1 was much lower (785 kg ha^{-1}), indicating that the sunflower sowing in main summer crop of Campo Novo do Parecis, the main producing region of the country, may not be feasible in years with favourable climatic conditions for the appearance of Alternaria leaf spot, depending on the management of the disease.

4. CONCLUSIONS

The cultivation of sunflower hybrids in the main summer crop in Campo Novo do Parecis (MT) may result in low achene yield when suitable management of Alternaria leaf spot is not carried out.

The hybrids SYN 045, 15P29, ACA 869 and ACA 889 show satisfactory achene yield in the second summer crop in Campo Novo do Parecis (MT), when there is a lower incidence of Alternaria leaf spot.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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