Original Research Article

Agronomic characteristics correlation of sunflower genotypes grown in the second crop in the Cerrado

ABSTRACT

The present work aimed to evaluate the agronomic characteristics correlation of sunflower genotypes grown in seven years in the State of Mato Grosso, Brazil, as an aid for the indirect selection of genotypes. The data were obtained from experiments conducted in the period from 2009 to 2017, in the count of Campo Verde, Mato Grosso, Brazil, using different sunflower genotypes. Pearson correlation analysis was performed among the agronomic characteristics: initial flowering (IF), physiological maturation (PM), plant height (PH), weight of a thousand achenes (WTA), achenes yield (AY), oil content (OC) and oil yield (OY). Strong positive correlation (r = 0.75*) was observed between IF and AY and moderately strong positive correlation (r = 0.67*) between PM e AY. There was a negative correlation (r = -0.51*) to the characteristics WTA and OC, and plant height with the achenes yield (r = -0.32*) and oil (r = -0.34*). Late-genotypes show a positive correlation with achenes yield and oil yield. Smaller plants favor productive parameters. Further studies and anticipation of second crop sowing season are suggested due to local edaphoclimatic conditions.

Keywords: achenes; Central-West; Cerrado; Helianthus annuus L.; oil content.

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1. INTRODUCTION

The area of sunflower cultivation in Brazil has been expanded mainly by the versatility of using the crop, as edible oil, for biodiesel production, ornamentation, animal feeding, among others [1].

In addition to the varied utilities, the sunflower presents desirable agronomic characteristics, such as short cycle, high quality and quantity of oil, adaptation to different edaphoclimatic conditions, well defined cultural treatments, and is a good alternative for crop rotation/succession [2, 3].

Thus, the crop represents an important income option for Brazilian producers, because in addition to allowing grain production in the off-season, it reduces idleness and optimizes the use of industries, land, machinery and labor [4, 2].
Due to the diversity of use, the desirable cultivation characteristics and the increasing demand of the industrial and commercial sector, there are prospects for an increase in the cultivated area of the sunflower, especially in the Brazilian Cerrado. In this region, it is common to perform a second crop in February/March, in which sunflower cultivation can be used in different production systems [5].

In this scenario stands out Mato Grosso, Brazil's largest sunflower producer, which reached 98.8 thousand tons in the 2017/2018 crop [6]. In order to maximize production in the state, the importance of the use of adapted genotypes is one of the main factors for the success of

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the establishment of the crop, in order to facilitate cultural practices, reducing the risk of losses and providing greater profitability to the producer [5, 7].

In this sense, the agronomic characteristics desirable for the selection of genotypes for a region must meet market demand, especially in relation to the production of achenes, oil content and quality [8]. It is known that the production characteristics of sunflower can be related to each other [5, 9]. The generation of this information is relevant because it allows identifying how plant development characteristics such as height, cycle and weight of achenes can influence final production components.

Comment [U3]: Multiple paragraphs should be reframed into 3 to 4 paragraphs.

The present work aimed to evaluate the agronomic characteristics correlation of sunflower genotypes grown in seven years in the State of Mato Grosso, Brazil, as an aid for the indirect selection of genotypes.

2. MATERIAL AND METHODS

The data used were obtained from experiments conducted through the Official Evaluation Network of Sunflower Genotypes, under the coordination of the Brazilian Agricultural Research Corporation (Embrapa) Soybean and collaborators. These results were published in the Reports of the Evaluation of Sunflower Genotypes [10, 11, 12, 13, 14, 15, 16].

The experiments of 2009, 2010 and 2011 were conducted at Santa Luzia Farm, in the municipality of Campo Verde, Mato Grosso, Brazil. In the years 2013, 2014 and 2016, the tests were carried out in the experimental area of the Federal Institute of Mato Grosso (Instituto Federal de Mato Grosso – IFMT), São Vicente Campus, located in the municipality of Campo Verde, Mato Grosso. And in 2017, in the experimental area of the Reference Center of Campo Verde, also belonging to the IFMT, São Vicente Campus. The experiments of 2012 and 2015 were not considered in the joint analysis because the coefficient of variation was higher than 20%.

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The experimental design was a randomized complete block design with four replications. The sowing was done manually, placing three seeds per hole, and the thinning of the plants occurs between 7 and 10 days after emergence (DAE). In all experiments, the plots consisted of 4 lines of 6 m in length, the spaces used being 0.9 m between rows and 0.25 m between plants, from 2009 to 2014, and 0.7 m between rows and 0.3 m between plants in 2016 and 2017. In addition, the plot area was composed of 9.0 m² in the tests from 2009 to 2013, and by 7.2 m², 6.3 m² and 5.0 m² in 2014, 2016 and 2017, respectively.

In the 2009 trial 18 genotypes were evaluated (Table 1). Seeds were sown on 09 March and were used for fertilizing the 30-80-80 kg ha^{-1} NPK and 2.0 kg ha^{-1} of boron. 30 kg ha^{-1} of N (urea) was applied and the harvest was done between June 24 and July 9. In 2010, 17 genotypes were evaluated. In this experiment the sowing was done on March 10, applying 30 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5, 80 kg ha^{-1} of K_2O, 2.0 kg ha^{-1} of boron and, in coverage, 30 kg ha^{-1} of N. The harvest occurred from July 14 to 21. In 2011, 10 genotypes were evaluated, and sowing was performed on March 4. 30-80-80 kg ha^{-1} of NPK and 2.0 kg ha^{-1} of boron were used for fertilization in the row and 30 kg ha^{-1} of N for cover fertilization. The harvest was carried out between June 17 and 29.

In 2013, 16 genotypes were evaluated (Table 2). Sowing was done on March 15 and fertilization using 60-80-80 kg ha^{-1} of NPK (04-14-08) and 2.0 kg ha^{-1} of boron. In the cover, 30 kg ha^{-1} of N (urea) and 40 kg ha^{-1} of K (potassium chloride) were applied. The harvest took place from June 15 to July 5. In the year 2014, 16 genotypes were evaluated, of which 5 were excluded due to lack of data for the present study. Sowing was carried out on March

08, with sowing fertilization performed with 500 kg ha^{-1} of NPK (04-14-08) and 2.0 kg ha^{-1} of boron. At 30 DAE, 60 kg ha^{-1} of N and 2.0 kg ha^{-1} of boron were applied and the harvest was performed on June 22. In 2016, six genotypes were evaluated whose sowing occurred on February 26. For fertilization of sowing, 571 kg ha^{-1} of NPK (04-14-08) and 2.0 kg ha^{-1} of boron were applied using 82 kg ha^{-1} of potassium chloride. The harvest was carried out from 02 to 16 June. In 2017, five genotypes were evaluated. Seeds were sown on March 16 with fertilization using 30 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5, 40 kg ha^{-1} of KCl and 2.0 kg ha^{-1} of boron. For cover, 30 kg ha^{-1} of N and 40 kg ha^{-1} of K_2O were used. The harvest was carried out from June 23 to July 10.

In all experiments, at the time of flowering, the plant height (PH) was measured, from the insertion of the stem to the crown region (at soil level). To avoid damage by bird attack, in chapters R7 the chapters were covered with non-woven fabric bags. In the trials of 2014, 2016 and 2017 the initial flowering time (IF) was recorded in days, and in the years 2013 and 2014, the physiological maturation (PM) was also checked in days.

Harvesting and threshing were performed manually with subsequent cleaning of the grain mass to remove the impurities. Then, the weight of a thousand achenes (WTA) was determined, except for the 2014 test, and the achenes yield (AY). Samples containing approximately 200 g were sent for analysis of the oil content (OC) of the achenes. Thus, the oil yield (OY) was calculated by multiplying the yield of achenes by the oil content.

The data were analyzed using statistical software SAS Studio, for analysis of Pearson's correlation among the agronomic characteristics of the sunflower, considering the level of significance of 5%. The results were interpreted according to Shikamura [17] that proposes values of r = 0.10 to 0.19 for very weak correlation; r = 0.20 to 0.39 for weak correlation; r = 0.40 to 0.69 indicating moderate correlation; r = 0.70 to 0.89 for strong correlation; and r = 0.90 to 1.00 determining very strong correlation.

Table 1. Agronomic characteristics of sunflower genotypes grown in the years 2009, 2010 and 2011 in the state of Mato Grosso, Brazil

Genotype	IF (days)	PM (days)	PH (cm)	WTA (g)	AY (kg ha^{-1})	OC (%)	OY (kg ha^{-1})
			YEAR 2009				
AGROBEL 960	-	-	113	59	2619	47	1233
BRS G06	-	-	108	64	1772	43	762
BRS G26	-	-	123	56	2133	44	950
EXP 1450 HO	-	-	159	62	3055	46	1420
EXP 1452 CL	-	-	124	46	2662	46	1239
HELIO 358	-	-	114	63	2270	47	1069
HLE 15	-	-	126	58	2158	44	969
HLS 07	-	-	115	63	2302	42	983
HLT5004	-	-	145	50	2937	50	1470
M 734	-	-	138	70	2854	38	1089
NEON	-	-	149	80	4267	39	1680
NTO 3.0	-	-	151	61	3318	48	1601
PARAÍSO 20	-	-	157	52	3045	48	1469
PARAÍSO33	-	-	128	50	2581	46	1200
SRM822	-	-	127	51	2752	49	1365
TRITONMAX	-	-	140	60	3101	46	1446
V20041	-	-	147	59	2970	44	1313

ZENIT	-	-	120	46	1989	44	883
YEAR 2010							
ALBISOL 2	-	-	160	63	3150	44.2	1394
ALBISOL 20 CL	-	-	153	55	2532	46.5	1177
AROMO 10	-	-	145	67	2584	45.9	1188
BRS G24	-	-	139	77	2822	42	1186
BRS G27	-	-	155	73	3281	41.7	1370
EMBRAPA 122	-	-	132	72	2130	45.6	972
EXP 1456 DM	-	-	160	70	3133	44.2	1387
HLA 211 CL	-	-	142	65	3024	42.3	1279
HLA 860 HO	-	-	166	67	3025	42.3	1278
HLA 887	-	-	159	58	3619	48.3	1745
M 734	-	-	147	71	2580	38.4	988
M 735	-	-	159	71	2986	39.6	1184
MULTISSOL	-	-	166	72	2973	39.1	1164
NTO 2.0	-	-	159	61	3059	43.7	1338
PARAISO 22	-	-	149	60	2976	45.7	1360
V 50070	-	-	154	65	3474	42.1	1461
V 70003	-	-	168	72	3465	45.5	1575
YEAR 2011							
BRS G29	-	-	112	59	2411	41.2	994
CF 101	-	-	141	55	2787	44.9	1249
GNZ CIRO	-	-	159	60	2620	42.6	1112
HELIO 358	-	-	123	54	2328	44.9	1048
HLA 11-26	-	-	176	64	2303	46.7	1088
HLA 44-49	-	-	141	58	2391	41.3	984
M 734	-	-	148	70	3311	38.8	1292
QC 6730	-	-	158	58	2634	42.5	1117
SULFOSOL	-	-	162	55	1625	42.8	697
V 70004	-	-	164	59	2259	42.3	955

IF: initial flowering, PM: physiological maturation, PH: plant height, WTA: weight of a thousand achenes, AY: achenes yield, OC: oil content, OY: oil yield.

Table 2. Agronomic characteristics of sunflower genotypes grown in the years of 2013, 2014, 2016 and 2017, in the state of Mato Grosso, Brazil

Genotype	IF (days)	PM (days)	PH (cm)	WTA (g)	AY (kg ha^{-1})	OC (%)	OY (kg ha^{-1})
YEAR 2013							
BRS G34	-	104	156	75	2352	41.5	978
BRS G35	-	115	171	62	1362	45.5	617
BRS G36	-	111	189	70	2266	42.6	962
BRS G37	-	104	163	80	2462	42.4	1045
BRS G38	-	95	156	75	1849	45.6	842

BRS G39	-	111	163	70	2583	41.6	1070
BRS G40	-	99	152	72	2170	42.8	953
BRS G41	-	105	166	67	1231	48.1	583
EMBRAPA 122	-	96	165	70	1650	45.2	746
HELIO 358	-	104	150	45	2046	47.7	881
HLE 20	-	95	148	66	1997	44.6	888
HLE 22	-	99	153	60	2465	46.0	1134
HLE 23	-	99	180	65	2437	46.9	1143
MG 431	-	105	184	55	1347	47.7	643
M734	-	115	181	67	2355	37.1	875
V 90631	-	105	188	52	1560	46.5	750
YEAR 2014							
AGUARÁ 04	31	80	192	-	1150	44.6	512
AGUARÁ 06	32	79	200	-	1438	40.5	609
GNZ NEON	44	80	215	-	1561	38.2	591
HELIO 251	34	80	212	-	981	41.6	430
HLA 2012	35	80	194	-	1141	45.8	592
M734	41	72	200	-	1325	39.4	516
MG 360	33	79	191	-	1215	48.7	575
MG 305	36	79	213	-	1214	46.3	561
PARAÍSO 20	35	79	202	-	1110	45.3	505
SYN 045	42	80	194	-	1455	40.8	595
SYN 3950 HO	37	80	205	-	969	45.8	444
YEAR 2016							
BRS G35	53	-	177	63	2347	44.5	1042
BRS G47	50	-	193	52	2821	45.3	1282
BRS G48	53	-	207	49	2833	43.9	1353
MULTISSOL	47	-	194	66	2893	39.4	1134
M734	55	-	200	70	2668	39.8	1061
SYN 045	59	-	211	68	3316	45.7	1513
YEAR 2017							
BRS G40	55	-	143	80	1721	43.5	750
BRS G49	55	-	143	80	1673	42.0	750
BRS G50	54	-	118	78	1619	41.7	677
BRS G51	59	-	164	81	2311	43.0	993
SYN 045	59	-	158	81	1936	43.1	836

IF: initial flowering, PM: physiological maturation, PH: plant height, WTA: weight of a thousand achenes, AY: achenes yield, OC: oil content, OY: oil yield.

3. RESULTS AND DISCUSSION

Significant correlations were observed among the characteristics: initial flowering and plant height; initial flowering and achenes yield; initial flowering and oil yield; physiological maturation and plant height; physiological maturation and achenes yield; physiological maturation and oil yield; plant height and achenes yield; plant height and oil yield; weight of a thousand achenes and oil content; achenes yield and oil yield (Table 3).

Table 3. Correlation coefficient (r) among agronomic characteristics of sunflower genotypes grown in Mato Grosso

	IF	PM	PH	WTA	AY	OC
PM	-0.28	-	-	-	-	-

PH	-0.52*	-0.67*	-	-	-	-
WTA	0.57	-0.12	0.11	-	-	-
AY	0.75*	0.67*	-0.32*	-0.01	-	-
OC	-0.19	0.08	-0.09	-0.51*	-0.09	-
OY	-0.73*	0.67*	-0.34*	-0.13	0.97*	0.13

*IF: initial flowering, PM: physiological maturation, PH: plant height, WTA: weight of a thousand achenes, AY: achenes yield, OC: oil content, OY: oil yield; * significant to 5%.*

According to Massignam and Angelocci [18] the initial flowering on the sunflower is more related to the genotype, than to the environmental conditions. According to a study by Amorim et al. [19], it was found that the flowering contributed considerably with the genetic divergences among several sunflower genotypes.

One of the objectives of the genetical enhancement has been the selection of earlier sunflower genotypes, as it facilitates the adaptation of the sowing season within the production system, since much of the crop in Brazil is carried out in the second crop. In addition, precocity in flowering, by favoring the anticipation of the harvest, avoids losses from intense rainfall, bird attack or end-of-cycle pests [5, 20].

In spite of these advantages, it is emphasized that the anticipation of flowering and physiological maturation performed in early genotypes should allow final yield similar to those of the medium or late cycle, so that there is no economic loss to the producer. However, the results of the work involving the influence of the anticipation of flowering on the final yield of the crop are contradictory. In a study with sunflower genotypes in Pakistan, Tahir et al. [21] found a positive correlation for the characteristics. On the other hand, Kaya et al. [22, 23] found negative correlation.

In the conditions of the present study, strong correlations (r = 0.75*) between IF and AY and moderate positive (r = 0.67*) were observed between PM and AY (Table 3), which allows us to infer that genotypes with cycle later yielded higher yields of achenes when compared to plants whose cycle was earlier. This is possibly related to the fact that later-cycle genotypes present a longer time to produce achenes, tending to higher yields [8].

Moreover, according to Santos et al. [24] can anticipate the flowering of the sunflower due to irregularity in rainfall distribution, a common situation in the second harvest crop in the Brazilian Cerrado. Thus, under unfavorable conditions in the phases of flowering and maturation of the sunflower, such as water deficit and high temperatures, there is damage to the accumulation of dry mass by the plants, which causes a negative impact on crop productivity [25]. This may have contributed to the positive correlations observed between IF and AY, and PM and AY, in the present study (Table 3).

On the other hand, there was a strong negative correlation (r = -0.73*) between IF and OY (Table 3). Although it was not significant, it was also found a negative correlation between IF and OC (r = -0.19), a relevant result considering that the oil yield is obtained from the multiplication of the achenes yield by the oil content. Similarly, Arshad et al. [26] studying 20 sunflower hybrids found negative correlation (r = -0.66) for IF and OC.

However, physiological maturation correlated positively (r = 0.67*) with oil yield (Table 3). Considering that the efforts of sunflower breeding programs have been in the development of earlier genotypes with higher production of achenes and oil [8, 27], it is assumed, with the results obtained in the present study, that the sowing period adopted and the edaphoclimatic conditions of the region were unfavorable for the expression of the productive potential of the earlier materials.

In addition to the reduction of the cycle, among the current objectives of the sunflower breeding programs in Brazil is the smaller size of the plant, aiming at better adaptation to the climatic conditions at the time of cultivation used and optimization of the harvest practice [8, 27].

In this sense, the negative correlations (Table 3) between PH and IF (r = -0.54*) and PH and PM (r = -0.67*) indicate that there can have been growth restriction of longer cycle plants , especially in the stem elongation period, due to unfavorable edaphoclimatic conditions [28], recurrent in the second harvest in the region of study. Thus, the plants whose initial flowering and physiological maturation were later presented a smaller size at flowering and at the time of maturation.

However, the negative correlations observed between plant height and the yield parameters of achenes (r = -0.32*) and oil (r = -0.34*) for the crop (Table 3) allow to infer that the reduction in the size of the later cycle plants did not affect the final production. Larger plants have a higher proportion of leaves, and therefore, they perform carbon fixation more efficiently, which can result in greater accumulation of dry mass in the plant [21]. This greater accumulation of dry mass, because it generates an intense contribution of nutrients to the aerial part in favor of the growth of the plant, can reduce the allocation of nutrients to the achenes, resulting in less developed achenes, being able to reflect in a lower yield.

For the WTA and OC characteristics (Table 3), a moderate negative correlation was observed (r = -0.51*), a result similar to those obtained by Mijic et al. [29] and Hladni et al. [30]. According to Leite et al. [8], the achenes located at the periphery of the chapter are heavier in relation to the central ones, and have a larger volume and shell surface in relation to the seed, reason why heavier achenes can have a lower oil content.

Although no significant correlation was found between WTA and AY in this study (Table 3), many studies found a positive relationship between these characteristics [9, 19, 22, 29, 31, 32]. In sunflower plants, the achenes can be malformed in the center of the chapter, among other factors, by the ripening pattern from the periphery to the center. Thus, depending on the nutritional conditions at this stage, losses in water absorption and photo-assimilates can occur, generating a large amount of achenes achy and floral remains, which can result in lower yield. The influence of the WTA on yield for the crop can also be related to the genetic characteristics and the time of filling of the achenes.

Very strong positive correlation (r = 0.97*) was observed for AY and OY (Table 3). Corroborating with the results obtained, Dalchiavon et al. [5], Pivetta et al. [9] and Mijic et al. [29] found a positive correlation between the characteristics. However, Dalchiavon et al. [5] elucidated that for this correlation, the increase in oil yield of the genotypes should not be attributed to the higher oil content, since the correlations of OC with AY and OY were not significant (Table 3). Thus, genotypes that generated higher oil yield were not necessarily the ones with the highest oil content. This same explanation fits the correlation between PH and OY (r = -0.34).

With the results obtained, it is necessary to carry out more studies in the evaluated region, since the reduction in the plant cycle is a trend in the Brazilian sunflower breeding programs. Therefore, it is important to verify if the use of early genotypes in the sowing period used in the region, considering the edaphoclimatic conditions, can imply significant losses, especially in the achenes yield, which constitutes one of the main parameters of interest for the crop.

4. CONCLUSION

Comment [U6]: Conclusion should be improved and specific recommendations should be added

In the conditions of the present work, the later cycle genotypes present positive correlation with the production parameters of achenes yield and oil yield.

For plant height, negative correlations were observed with the characteristics: initial flowering, physiological maturation, achenes yield and oil yield.

It is necessary to carry out further studies, especially with early genotypes, suggesting the anticipation of the sowing season of the second harvest considering the local edaphoclimatic conditions.

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COMPETING INTERESTS

We declare that no competing interests exist.

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Comment [U7]: References should follow journal guidelines

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