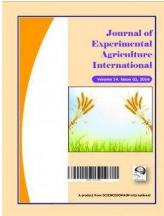

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Agronomic Characteristics Correlation of Sunflower Genotypes Grown in the Second Crop in the Cerrado

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DAF, ABBF and JGA designed and wrote the protocol. Authors OHSR, DAF, ABBF, WN and VATM conducted the experiment and wrote the first draft of the manuscript. Authors DSP, LSC and JGA managed the analyses of the study. Authors OHSR, DAF, ACDA, YRVBS and WMP discussed the results and improved the writing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The present work aimed to evaluate the correlation of the agronomic characteristics of sunflower genotypes grown for 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 municipality of Campo Verde, Mato Grosso state, Brazil, using different sunflower genotypes. Pearson correlation analysis was performed between the following agronomic characteristics: Initial flowering (IF), physiological maturation (PM), plant height (PH), thousand

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achene weight (TAW), achene yield (AY), oil content (OC) and oil yield (OY). A strong positive correlation (r = 0.75*) was observed between IF and AY, and a moderately strong positive correlation (r = 0.67*) between PM and AY. There was a negative correlation (r = -0.51*) between TAW and OC, as well as between plant height and achene yield (r = -0.32*) and oil yield (r = -0.34*). Late-cycle genotypes showed a positive correlation with achene yield and oil yield. Smaller plants favor productive parameters. Further studies and the anticipation of the crop sowing season in the second crop are suggested due to the local edaphoclimatic conditions.

Keywords: Achenes yield; genotype selection; Helianthus annuus L.; plant breeding; oil content.

1. INTRODUCTION

The sunflower-cultivated area in Brazil has been expanding mainly due to the versatility of the crop, which is employed in the production of edible oils and biodiesel, ornamentation and animal feeding, among others [1]. Furthermore, the sunflower presents desirable agronomic characteristics, such as a short plant cycle, high quality and quantity of oil, adaptation to different edaphoclimatic conditions, well defined cultural treatments, besides being a satisfactory alternative for crop rotation/succession [2,3].

Due to the diversity of its use, the desirable cultivation characteristics and the increasing demand of the industrial and commercial sectors, there are prospects for an increase in the sunflower cultivated area, especially in the Brazilian Savannah region (Cerrado). In this region, it is common to conduct a second crop in February/March, in which sunflower cultivation can be employed in different production systems [4,5].

In this perspective, the Mato Grosso state stands out as the largest Brazilian producer state of sunflower, reaching 98.8 thousand tons in the 2017/2018 season [6]. In order to maximize production within the state, the importance of the use of adapted genotypes is one of the main factors for the success of crop establishment, by facilitating cultural practices, reducing the risk of losses and providing higher profitability to the producer [5,7].

In this regard, the desirable agronomic characteristics for the selection of genotypes for a region must meet market demands, especially with regard to achene production and oil content and quality [8]. It is known that the characteristics of sunflower production can be correlated to each other [5,9]. The generation of this information is relevant because it allows identifying how plant development characteristics, such as height, plant cycle, and achene weight can influence the final production of components. The present work aimed to evaluate the agronomic characteristics correlation of sunflower genotypes grown in seven years in the Mato Grosso state, Brazil, as an aid for the indirect selection of genotypes.

2. MATERIALS AND METHODS

The data used in this work were obtained from experiments conducted by the Official Evaluation Network of Sunflower Genotypes, under the coordination of the Brazilian Agricultural Research Corporation (Embrapa Soja) 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 the Santa Luzia Farm, in the municipality of Campo Verde, Mato Grosso state, Brazil. In the years 2013, 2014 and 2016, the tests were performed in the experimental area of the Federal Institute of Mato Grosso (IFMT), São Vicente Campus, located in the municipality of Campo Verde, Mato Grosso. In 2017, the assays were performed 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 since their coefficient of variation was higher than 20%.

The experimental design was in randomized blocks, with four replications. The sowing was manually performed, placing three seeds per hole, and the thinning of the plants occurred between 7 and 10 days after emergence (DAE). In all experiments, the plots consisted of 4 lines of 6 m in length, with a 0.9 m between-row and 0.25 m within-row spacing. In addition, the plot area was composed of 9.0 m² in the tests from 2009 to 2013, and of 7.2 m², 6.3 m² and 5.0 m² in 2014, 2016 and 2017, respectively.

In the 2009 assay, 18 genotypes were evaluated (Table 1). Seeds were sown on March 9, using for fertilization a proportion of 30-80-80 kg ha^{-1}

NPK and 2.0 kg ha^{-1} of boron, along with 30 kg ha^{-1} of N (urea). The harvest was performed between June 24 and July 9. In 2010, 17 genotypes were evaluated. In this experiment, the sowing was performed 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, as topdressing, 30 kg ha^{-1} of N. The harvest occurred from July 14 to July 21. In 2011, 10 genotypes were evaluated, and the sowing was performed on March 4. The proportion of 30-80-80 kg ha^{-1} NPK and 2.0 kg ha^{-1} of boron were used for fertilization in the row and, along with 30 kg ha^{-1} of N as topdressing. The harvest was performed between June 17 and June 29.

In 2013, 16 genotypes were evaluated (Table 2). Sowing was performed on March 15 with the fertilization using a proportion of 60-80-80 kg ha^{-1} NPK (04-14-08) and 2.0 kg ha^{-1} of boron, along with 30 kg ha^{-1} of N (urea) and 40 kg ha^{-1} of K (potassium chloride) as topdressing. 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 the lack of data for the present study. Sowing was performed on March 8, with the fertilization employing 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 at sowing, 571 kg ha^{-1} of NPK (04-14-08) and 2.0 kg ha^{-1} of boron were applied, also using 82 kg ha^{-1} of potassium chloride. The harvest was performed from June 2 to June 16. In 2017, five genotypes were evaluated. Sowing took place 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 topdressing, 30 kg ha^{-1} of N and 40 kg ha^{-1} of K_2O were used. The harvest was performed from June 23 to July 10.

In all experiments, at the flowering time, the plant height (PH) was measured based on the insertion of the stem in the crown region (at soil level). In order to avoid damages by bird attack, the R7 stage capitula were covered with non-woven fabric bags. In the assays performed in 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 registered in this standard.

Harvesting and threshing were manually performed with subsequent cleaning of the grain mass in order to remove impurities. The thousand achene weight (TAW) was subsequently determined except for the 2014 test, along with and the achene yield (AY). Samples containing approximately 200 g were sent for analysis of the oil content (OC) of the achenes. The oil yield (OY) was then calculated by multiplying the achene yield by the oil content.

Pearson's correlation analysis was performed using the data from the PH, TAW, AY, OC and OY of the 18 genotypes evaluated in 2009; PH, TAW, AY, OC and OY of the 17 genotypes evaluated in 2010; PH, TAW, AY, OC and OY of the 10 genotypes evaluated in 2011 (Table 1); PM, PH, TAW, AY, OC and OY of the 16 genotypes evaluated in 2013; and IF, PM, PH, TAW, AY, OC and OY out of 11 of the 16 genotypes evaluated in 2014. The SYN 3950HO, BRS G42, BRS 323, CF 101, ADV 5504 and HELIO 250 genotypes were excluded from the analysis since they did not present AY, OC and OY data. The IF, PH, TAW, AY, OC, and OY of the 6 genotypes evaluated in 2016, as well as the IF, PH, TAW, AY, OC, and OY of the 5 genotypes evaluated in 2017 were also employed in the correlation analysis (Table 2).

The data were analyzed using the SAS Studio statistical software for Pearson's correlation analysis between the sunflower agronomic characteristics, considering a 5% significance level. The results were interpreted according to Shikamura [17], who proposes the following interpretation of values: 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 for moderate correlation; r = 0.70 to 0.89 for strong correlation; and r = 0.90 to 1.00 determining a very strong correlation.

3. RESULTS AND DISCUSSION

A significant correlation was observed between the following characteristics: initial flowering and plant height; initial flowering and achene yield; initial flowering and oil yield; physiological maturation and plant height; physiological maturation and achene yield; physiological maturation and oil yield; plant height and achene yield; plant height and oil yield; thousand achene weight and oil content; achene yield and oil yield (Table 3).

The initial flowering on the sunflower is more related to the genotype, than to the environmental conditions [18], and it was found that the flowering contributed considerably with the genetic divergences among several sunflower genotypes [19]. One of the objectives

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 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].

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

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%*

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 was found a positive correlation for the characteristics [21]. On the other hand, in other studies it was reported negative correlation [22,23].

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, the flowering of the sunflower can be anticipated due to irregularity in rainfall distribution [24], 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, in a study involving 20 sunflower hybrids was found negative correlation (r = -0.66) for IF and OC [26].

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 in other studies [29,30]. In sunflower, 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 [8].

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, in studies with sunflower was found a positive correlation between the characteristics [5,9,29]. However, 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 [5]. 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

Under the conditions of the present study, the genotypes presenting later initial flowering and physiological maturity are related to higher achenes yields. Genotypes that have lower weight of thousand achenes are related to higher oil content.

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

Authors have declared that no competing interests exist.

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