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AGRONOMIC CHARACTERIZATION OF SUNFLOWER CULTIVARS FOR ANIMAL FEEDING IN TROPICAL CONDITIONS

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Abstract

This study was developed to examine morpho-agronomic traits of 18 sunflower cultivars and identify superior cultivars in terms of grain yield, forage quality, or both, for animal feeding. Twenty-two morpho-agronomic traits related to plant development and architecture; earliness of maturity; grain yield (achenes); dry matter yield; and dry matter content were evaluated. Cultivars Hélio 253, Hélio 358, Embrapa 122, BRS 321, and Hélio 360 showed inflorescence at the final stage. Aguará 4 showed the lowest flowering rate, characterizing it as late-maturing. For grain yield, cultivars Charrua, Olisun 3, BRS 321, Paraíso 103CL, Paraíso 65, Aguará 6, and CF 101 are recommended, as they showed the highest achene yields (average: 1,541.67 to 2,148.81 kg.ha^{-1}, respectively). Cultivars Charrua, Hélio 251, Olisun 3, Hélio 360, Paraíso 55, and Paraíso 103CL exhibited higher dry matter yields (9,550.93 to 11,789.91 kg ha^{-1}) and were thus indicated for forage production. Cultivars Charrua, Olisun 3, BRS 321, Paraíso 103CL, Paraíso 65, Aguará 6, and CF 101 are recommended for grain yield, for the diet of monogastric animals; Charrua, Hélio 251, Olisun 3, Hélio 360, Paraíso 55, and Paraíso 103CL for forage yield, for ruminant feeding; and Charrua, Olisun 3, and Paraíso 103CL for both purposes.

Keywords: Animal Feeding. *Helianthus annuus* L. Plant Production.

1. Introduction

The sunflower (*Helianthus annuus* L.) crop is notable for producing grains intended for oil extraction (Jayme et al. 2007). Additionally, the plant, grains and remains of the crop and the generated by-products can be used in animal feeding (Nobre et al. 2011). There are several possible uses for this forage, e.g. grain production and oil extraction (Lamm et al. 2010; Akbari et al. 2011; Alberio et al. 2016), bran production (Mohammadabadi et al. 2010; Maheri-Sis et al. 2011), oil production for animal feeding (Spugnoli et al. 2012; Prado et al. 2016), and forage production for animal feeding (Silva et al. 2014).

When compared to other annual crops in major agricultural regions of Brazil, sunflower stands out with its tolerance to low temperatures in the initial growth phase and resistance to drought (Nobre et al.

2011). These characteristics render it a viable alternative in sectors such as biodiesel (Del Gatto et al. 2015), agricultural industries and forage production (Martins et al. 2014; Mustafa et al. 2015); and an option to produce high-quality animal feed in the critical period of the year (Fernandes et al. 2016). Regardless of its destination, sunflower must be grown adequately to maximize its yields. In this regard, the evaluation of morphological traits, grain yield, and dry matter yield per hectare in this forage can provide great contributions to agricultural and livestock systems, since efficient plants may be indicated for their specific uses, in addition to dual-purpose cultivars.

To achieve high grain yields, sunflower crops should exhibit the following characteristics: high oil content, early maturity, small size, resistance to biotic and abiotic factors, and high seed-yield potential (Oliveira et al. 2005). Del Gatto et al. (2015) evaluated the potential of different sunflower cultivars for oil production in Northern, Central, and Southern Italy and observed grain yields ranging from 1 to 4 $t.ha^{-1}$.

As for the genotypic characteristics for forage yield in ruminant feeding, it is important to consider that production is little influenced by latitudes and altitudes or by the photoperiod, which facilitates planting in different soil-climatic conditions (Castro et al. 1996). Therefore, research is necessary to assess the performance of forage cultivars in regions with low water availability and select phenotypes adapted to those environments. In other words, one must consider that crops display changes in behavior depending on the region and time of sowing, due to phenotypic variations (genotype × environment interaction). In this way, continuous evaluations of cultivars are warranted since soil and climatic conditions affect the production potential of crops (Porto et al. 2007; Porto et al. 2009).

In view of the above-described scenario, this study proposes to evaluate and identify morphological and agronomic traits of 18 sunflower cultivars with potential for grain and forage yield for animal feeding.

2. Material and Methods

Location and experimental design

The study was conducted at the Experimental Farm of the Federal University of Bahia, located in São Gonçalo dos Campos - BA, Brazil (12°25'58 "S latitude, 38°58'1" W longitude, 245 m asl). Sunflower seeds were sown in July of 2013 and 2014. Eighteen sunflower cultivars from different breeding programs were evaluated (Table 1). A randomized-block experimental design was adopted, with 18 cultivars in four blocks. Each plot consisted of four 6.0-m rows with 0.70 × 0.30 m spacing, totaling 16.8 m^2, where we evaluated six plants marked with a colored ribbon since germination within the plot, observing the borders.

Table 1. Sunflower cultivars evaluated and respective countries of origin.

Cultivar	Type	Country
Aguará 04	Single hybrid	Argentina
Aguará 06	Single hybrid	Argentina
BRS 321	Single hybrid	Brazil
BRS 323	Single hybrid	Brazil
BRS 324	Variety	Brazil
CF 101	Single hybrid	Argentina
Charrua	Triple hybrid	Argentina
Embrapa 122	Variety	Brazil
Hélio 250	Single hybrid	Argentina
Hélio 251	Single hybrid	Argentina
Hélio 253	Single hybrid	Argentina
Hélio 358	Single hybrid	Brazil
Hélio 360	Triple hybrid	Argentina
Olisun 3	Triple hybrid	Argentina
Paraíso 103cl	Single hybrid	Argentina
Paraíso 55	Single hybrid	Argentina
Paraíso 65	Single hybrid	Argentina
Zenit	Single hybrid	Argentina

Maximum and minimum temperature (°C) and precipitation (mm/month) data in the experimental area were collected with a digital thermometer and a pluviometry, respectively (Figure 1).

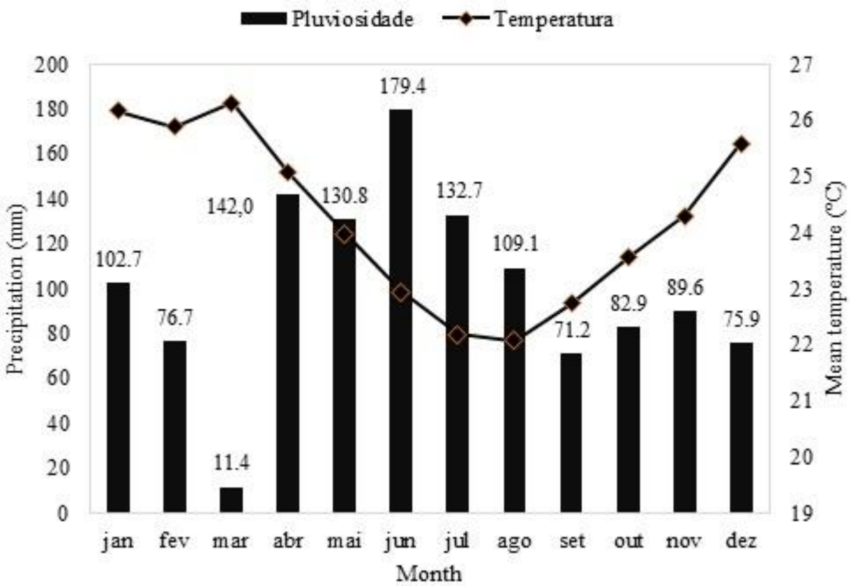

Figure 1. Mean monthly values for maximum and minimum temperatures (ºC) and total monthly precipitation (mm) of 2013 and 2014 in São Gonçalo dos Campos - BA, Brazil.

Soil preparation and management

The soil from the experimental area was classified as a Red-Yellow Argisol, according to the Brazilian Soil Classification System (Santos et al. 2006). The soil was prepared using a tractor, with one plowing and two grass-leveling disking operations. Soil chemical analysis revealed the following characteristics: pH in water - 5.6; P - 6.6 mg dm^{-3}; K - 0.11 cmol dm^{-3}; Ca - 1.4 cmol dm^{-3}; Mg - 1.3 cmol dm^{-3}; Al - 0.1 cmol dm^{-3}; H+Al - 1.6 cmol dm^{-3}; CEC - 3.1 cmol dm^{-3}; base saturation - 58%; and organic matter - 1.6 g dm^{-3}.

Fertilization at planting was performed according to soil analysis and following the indication of the 5th Approach of the Soil Fertility Committee of Minas Gerais State, Brazil (Ribeiro et al. 1999) for the sunflower crop, with 23 kg ha^{-1} N, 110 kg ha^{-1} P_2O_5, and 30 kg ha^{-1} K_2O. Topdressing was performed 30 days after sowing, using 30 kg ha^{-1} N, 30 kg ha^{-1} K_2O, and 2 kg ha^{-1} B. Another application was made with 2 kg.ha^{-1} B, at 15 days before flowering.

Data collection and measurements

Fifteen days after seeding (DAS), the plants were thinned to maintain a population of 47,619 plants per hectare and to evaluate the germination of cultivars (GER); both methodologies are described in Table 2. At 30 DAS, we started the evaluations of plant height (PH30), stem diameter (SD30), and number of leaves (NL30), which were measured in the six plants marked previously. At 60 DAS, we evaluated PH60, SD60, and flowering stage (FS60). At 90 DAS, we measured PH90, SD90, number of green leaves (NGL90), number of dry leaves (NDL90), head height (HH90), head diameter (HD90), stem curvature (SC90), head shape (HS90), total plant stand (TS90), head weight (HW), head weight without achenes (HWWA), number of achenes (NAC), 1000-achene weight, (TAW), achene yield per hectare (AY), and dry matter yield per hectare (DMY). Visual assessments of flowering stage (FS) were performed following Schneiter and Miller (1981). Head shape and SC90 were determined according to Knowles (1978).

Table 2. Plant morpho-agronomic and architecture traits and methodologies employed for the analyses.

Trait	Methodology
Germination	Percentage of germinated achenes at 7 DAS
PH (in cm)	Measured from soil to plant apex
SD (in cm)	Measured 5 cm above the soil
NL and NDL	Counted at the plants
SI	Visual assessment in the physiological-maturation stage, on a scale of 1 to 7 (Knowles 1978), as follows: 1- curved, 2- vertical, 3- semi-inverted straight stem, 4- semi-inverted with stem curved, 5- vertical with stem straight, 6- inverted with stem curved, and 7- reflexive
HH	Measurement of distance from soil to insertion of head (neck)
FS	According to Schneiter and Miller (1981): 1- R1, 2- R2, 3- R3, 4- R4, 5- R5, 6- R6, 7- R7, and 8- R8
TAW (in g)	Obtained by weighing one thousand achenes from the heads harvested per plot
NAC	Number of achenes per head
HS90	Visual assessment of the head according to Knowles (1978), in summary: 1-flat, 2- concave, 3- convex, 4- flat but periphery of head rolled up, 5- irregular, 6- trumpet-shaped
TS90	Percentage of plants at end of cycle
HW	Full head weight with achenes
HWWA	Head weight without achenes
YD	Average achene yield in the experiment, extrapolated to one hectare
DMY	Average dry matter yield in the plots, extrapolated to one hectare

PH – plant height; SD: stem diameter; NGL – number of leaves; NDL – number of dry leaves; SI – stem inclination; HH – head height; FS – flowering stage; TAW – 1000-achene weight; NAC – number of achenes; HS90 – head shape; TS90 – total stand; HW – head weight; HWWA – head weight without achenes; YD – yield; DMY – dry matter yield.

Statistical analysis

Data were subjected to analysis of variance by the F test ($P < 0.05$) and cluster analysis by the Scott and Knott (1974) test. Genetic correlations (Pearson's correlation coefficient, r) were obtained as described by Steel and Torrie (1980). Based on the genetic distance matrix, the genotypes were grouped by Tocher's method using GENES software (Cruz and Regazzi 1997) and the relative contribution of Singh's characters (Singh 1981). To build the dendrogram, we used production traits (GER, HD90, PH90, TS90, HH90, NGL90, HW, NAC, TAW, AY, and DMY) and the mean-clustering method (UPGMA), in R software.

3. Results

No differences were observed between the treatments for the variables of SD30, HD90, or TS90. However, NL30, PH30, SD60, PH60, FS60, SD90, PH90, HH90, HS90, SC90, NGL90, NDL90, HW, HWWA, NAC, TAW, AY, and DMY were affected by the treatments (Tables 3 and 4).

Cultivars BRS 321, Hélio 358, Embrapa 122, Paraíso 103CL, BRS 323, Paraíso 55, Paraíso 65, Aguará 04, CF 101, and Olisun 3 had a higher NL30 (Table 3). The PH30 variable was higher in cultivars Embrapa 122 and BRS 321 in the first evaluation (30 DAS), averaging 50.92 and 50.17 cm, respectively, which characterizes them as superior to the other cultivars (Table 3). For SD60, cultivars Charrua, Hélio 253, Embrapa 122, Paraíso 103 CL, and Aguará 6 showed the highest values (Table 4). As for PH60, the highest means were found in cultivars Charrua, Paraíso 103 CL, Aguará 4, Paraíso 55, Paraíso 65, Hélio 251, BRS 324, Aguará 6, and Zenit (Table 3). Cultivars Hélio 253, Embrapa 122, Hélio 358, BRS 321, and Hélio 360 had higher mean values for FS60; of this group, Aguará 4 was the latest-flowering cultivar (Table 3).

Table 3. Mean values for plant morpho-agronomic and architecture traits of 18 sunflower cultivars evaluated in São Gonçalo dos Campos, BA, Brazil.

Cultivar	NL30	PH30 (cm)	SD60 (cm)	PH60 (cm)	FS60	SD90 (cm)	PH90 (cm)	HH90 (cm)	HS90	SC90	NGL 90	NDL 90
Aguará 04	10.13^{a}	40.00^{b}	1.60^{b}	167.50^{a}	1.50^{d}	1.60^{b}	137.25^{a}	133.42^{a}	2.25^{b}	2.25^{b}	14.29^{b}	8.17^{b}
Aguará 06	9.79^{b}	30.58^{b}	1.84^{a}	156.87^{a}	3.25^{c}	1.84^{a}	126.92^{b}	122.71^{b}	2.50^{b}	3.00^{b}	14.21^{b}	8.58^{b}
BRS 321	11.58^{a}	50.17^{a}	1.58^{b}	146.68^{b}	6.75^{a}	1.58^{b}	116.59^{b}	107.96^{c}	3.00^{a}	3.25^{a}	21.63^{a}	1.13^{c}
BRS 323	10.38^{a}	39.50^{b}	1.40^{b}	144.46^{b}	6.00^{b}	1.70^{a}	114.92^{b}	99.13^{c}	2.75^{a}	4.00^{a}	22.21^{a}	3.08^{c}
BRS 324	9.25^{b}	35.13^{b}	1.49^{b}	156.92^{a}	6.00^{b}	1.49^{b}	126.34^{b}	120.13^{b}	2.75^{a}	2.50^{b}	15.46^{b}	5.96^{b}
CF 101	10.04^{a}	35.54^{b}	1.61^{b}	135.75^{b}	3.50^{c}	1.47^{b}	118.17^{b}	115.84^{b}	2.25^{b}	3.50^{a}	18.42^{a}	3.84^{c}
Charrua	9.09^{b}	30.84^{b}	2.11^{a}	173.50^{a}	3.50^{c}	2.11^{a}	144.12^{a}	137.33^{a}	2.25^{b}	2.50^{b}	11.96^{b}	12.67^{a}
Embrapa 122	10.71^{a}	50.92^{a}	1.92^{a}	144.75^{b}	7.00^{a}	1.47^{b}	124.50^{b}	114.96^{b}	2.00^{b}	3.00^{b}	16.00^{b}	1.46^{c}
Hélio 250	9.33^{b}	28.67^{b}	1.45^{b}	130.96^{b}	3.75^{c}	1.42^{b}	106.00^{b}	97.00^{c}	3.00^{a}	4.00^{a}	16.33^{b}	6.58^{b}
Hélio 251	8.88^{b}	33.96^{b}	1.44^{b}	158.83^{a}	3.75^{c}	1.65^{b}	134.09^{a}	129.86^{a}	3.00^{a}	3.00^{b}	14.00^{b}	6.93^{b}
Hélio 253	8.08^{b}	30.63^{b}	2.03^{a}	140.34^{b}	7.25^{a}	1.56^{b}	120.69^{b}	118.02^{b}	3.00^{a}	2.75^{b}	13.74^{b}	6.22^{b}
Hélio 358	11.13^{a}	39.11^{b}	1.68^{b}	147.08^{b}	7.00^{a}	1.82^{a}	118.59^{b}	112.71^{b}	3.00^{a}	3.00^{b}	13.88^{b}	6.50^{b}
Hélio 360	9.63^{b}	34.38^{b}	1.46^{b}	147.13^{b}	6.75^{a}	1.62^{b}	117.88^{b}	108.96^{c}	3.25^{a}	3.50^{a}	13.21^{b}	6.67^{b}
Olisun	10.04^{a}	33.08^{b}	1.29^{b}	176.06^{a}	3.75^{c}	1.72^{a}	146.64^{a}	146.00^{a}	2.33^{b}	2.00^{b}	13.89^{b}	11.06^{a}
Paraíso 103	10.54^{a}	33.92^{b}	1.92^{a}	170.04^{a}	5.50^{b}	1.92^{a}	139.23^{a}	135.46^{a}	2.50^{b}	2.75^{b}	12.46^{b}	8.21^{b}
Paraíso 55	10.37^{a}	36.29$_{b}$	1.46^{b}	162.63^{a}	6.00^{b}	1.46^{b}	131.87^{a}	127.29^{a}	2.75^{a}	2.75^{b}	16.21^{b}	8.12^{b}
Paraíso 65	10.29^{a}	33.46^{b}	1.69^{b}	161.92^{a}	6.00^{b}	1.74^{a}	134.29^{a}	130.79^{a}	2.25^{b}	2.75^{b}	14.08^{b}	8.54^{b}
Zenit	9.46^{b}	31.71^{b}	1.38^{b}	155.54^{a}	3.75^{c}	1.60^{b}	126.96^{b}	120.59^{b}	2.50^{b}	2.75^{b}	20.33^{a}	4.42^{c}

NL30 – number of leaves at 30 days; PH30 – plant height at 30 days; SD60 – stem diameter at 60 days; PH60 – plant height at 60 days; FS60 – flowering stage at 60 days; SD90 – stem diameter at 90 days; PH90 – plant height at 90 days; HH90 – head height at end of the cycle, at 90 days; HS90 – head shape at 90 days; SC90 – stem curvature at 90 days; NGL90 – number of green leaves at 90 days; NDL90 – number of dry leaves at 90 days. Means followed by common letters in the row do not differ by the Scott-Knott test at the 5% probability level.

In the evaluation of SD90, cultivars Charrua, Paraíso 103 CL, Aguará 6, Hélio 358, Paraíso 65, Olisun 3, and BRS 323 showed the highest mean values (Table 3). The group of cultivars Charrua, Paraíso 103 CL, Aguará 6, Hélio 358, Paraíso 65, Olisun 3, and BRS 323 had an average diameter of 1.84 cm, whereas the second group, with the remaining cultivars, averaged 1.53 cm. As regards PH90, cultivars Olisun, Charrua, Paraíso 103CL, Aguará 4, Paraíso 65, Hélio 251, and Paraíso 55 displayed higher mean values. Cultivars Olisun, Charrua, Paraíso 103CL, Aguará 4, Paraíso 65, Hélio 251, and Paraíso 55 showed higher means in the evaluation of HH90 (Table 3).

For NGL90, cultivars BRS 323, BRS 321, Zenit, and CF 101 exhibited higher means than the other cultivars, averaging 15.68, obtained after flowering. Cultivars Charrua and Olisun 3 showed a higher mean NDL90 than the others, while BRS 321, BRS 323, CF 101, Embrapa 122, and Zenit exhibited lower values for this parameter (Table 3).

For HW, which was obtained by weighing the whole heads, cultivars Charrua and Olisun 3 showed the highest means (728.75 g and 588.50 g, respectively; Table 4). For HWWA, however, the highest means were found in cultivar Charrua (375.25 g; Table 4). As for NAC, cultivars Charrua, Olisun, BRS 321, Paraíso 103 CL, Paraíso 65, Aguará 6, and CF 101 obtained the highest mean values (Table 4). Cultivars BRS 321, BRS 323, Aguará 6, Paraíso CL 103, and EMBRAPA 122 showwed the highest mean values for TAW (Table 4). For AY, cultivars Charrua, Olisun 3, BRS 321, Paraíso 103 CL, Paraíso 65, Aguará 6, and CF 101 stood out with their average yield being above 1500 kg achenes ha^{-1} (Table 4). For DMY, Charrua, Hélio 251, Olisun 3, Hélio 360, Paraíso 55, and Paraíso CL 103 were superior, with mean values greater than 9,550 kg ha^{-1} (Table 4).

Table 4. Mean values for production traits of 18 sunflower cultivars evaluated in São Gonçalo dos Campos, BA, Brazil.

Cultivar	HW (g)	HWWA (g)	NAC	TAW (g)	GW (kg.ha^{-1})	DMY/ha (kg)
Aguará 04	272.00^{b}	105.75^{c}	153.25^{b}	33.84^{b}	1216.27^{b}	6710.25^{b}
Aguará 06	393.25^{b}	131.33^{c}	198.00^{a}	45.64^{a}	1571.43^{a}	7437.18^{b}
BRS 321	416.25^{b}	141.75^{c}	218.00^{a}	54.01^{a}	1730.16^{a}	8450.82^{b}
BRS 323	359.25^{b}	118.25^{c}	173.00^{b}	49.26^{a}	1373.01^{b}	8679.61^{b}
BRS 324	331.00^{b}	152.50^{c}	132.50^{b}	40.17^{b}	1051.59^{b}	7517.34^{b}
CF 101	307.25^{b}	72.25^{c}	194.25^{a}	36.88^{b}	1541.67^{a}	7244.52^{b}
Charrua	728.75^{a}	375.25^{a}	270.75^{a}	29.16^{b}	2148.81^{a}	11789.91^{a}
Embrapa 122	257.00^{b}	73.75^{c}	160.75^{b}	43.96^{a}	1275.79^{b}	8174.67^{b}
Hélio 250	284.50^{b}	122.25^{c}	139.00^{b}	36.62^{b}	1103.17^{b}	7001.38^{b}
Hélio 251	381.25^{b}	174.00^{c}	178.25^{b}	36.28^{b}	1414.68^{b}	10400.54^{a}
Hélio 253	359.25^{b}	187.50^{c}	126.75^{b}	37.70^{b}	1005.95^{b}	8642.77^{b}
Hélio 358	385.50^{b}	166.50^{c}	143.00^{b}	35.39^{b}	1134.92^{b}	8591.59^{b}
Hélio 360	424.50^{b}	165.25^{c}	182.50^{b}	33.55^{b}	1448.42^{b}	10186.46^{a}
Olisun 3	588.50^{a}	240.25^{b}	239.50^{a}	28.69^{b}	1900.79^{a}	10398.90^{a}
Paraíso 103cl	491.25^{b}	230.50^{b}	200.33^{a}	44.02^{a}	1589.95^{a}	9550.93^{a}
Paraíso 55	343.50^{b}	148.25^{c}	153.50^{b}	30.55^{b}	1218.25^{b}	10148.48^{a}
Paraíso 65	449.50^{b}	250.00^{b}	199.33^{a}	32.72^{b}	1582.01^{a}	7085.63^{b}
Zenit	377.75^{b}	159.75^{c}	156.50^{b}	31.53^{b}	1242.07^{b}	7944.78^{b}

HW – head weight; HWWA – head weight without achenes; NAC – number of achenes, TAW – 1000-achene weight; AY – achene yield; and DM.ha−1 – dry matter yield per hectare. Means followed by common letters do not differ by the Scott-Knott test at the 5% probability level.

According to the phenotypic correlation matrix for the evaluated variables (Table 5), NAC showed a strong correlation (r = 1) with achene yield. High correlations were also observed between PH60 and PH90 (r = 0.95), PH60 and HH90 (r = 0.90), and PH60 and HD90 (r = 0.71). Plant height at 90 DAS showed a high correlation (r = 0.97) with HH90. Head diameter at 90 DAS exhibited high correlation coefficients with SD90 and PH90: 0.78 and 0.70, respectively.

A table describing the relative percentage contribution of the traits for divergence was developed based on the mean values of morphological data for agronomic and animal production obtained from the studied cultivars (Table 6). According to the analysis to estimate the relative contribution of each trait for the expression of genetic diversity, AY (49.55%) and NAC (49.49%) were the traits that most contributed to total divergence among the 18 sunflower cultivars analyzed (Table 6).

Mean values of morphological data pertaining to agronomic and animal production (GER, HD90, PH90, TS90, HH90, NGL90, HW, NAC, TAW, AY, and DMY) from the studied cultivars were used to obtain the Mahalanobis distance, as show in the dendrogram (Figure 2). Four distinct groups were formed, with subdivisions. The first and largest group comprised the following cultivars: Hélio 253, Hélio 358, BRS 324, Aguará 6, Hélio 360, Hélio 251, Paraíso 55, Zenit, CF 101, Paraíso 65, Paraíso 103 CL, Aguará 4, and Embrapa 122. The second group was formed by cultivars BRS 321 and BRS 323. The third group comprised Charrua and Olisun 3, and the fourth and last group contained only cultivar Hélio 250.

Table 5. Phenotypic correlations among 22 agronomic traits evaluated in 18 sunflower cultivars.

	GER	NL30	PH30	SD30	PH60	SD60	FS60	HD90	HS90	SC90	PH90	TS90	HH90	SD90	NDL90	NGL90	HW	HWWA	NAC	TAW	AY	DMY
GER	1																					
NL30	−0.18	1																				
PH30	0.01	0.49*	1																			
SD30	−0.01	0.13	0.53*	1																		
PH60	0.59*	−0.01	−0.01	−0.07	1																	
SD60	0.42*	−0.03	−0.05	0.00	0.55*	1																
FS60	0.11	0.12	0.27*	0.02	0.08	0.21	1															
HD90	0.48*	0.16	0.07	0.04	0.71*	0.55*	0.23*	1														
HS90	0.32*	−0.03	−0.10	−0.09	0.26*	0.18	0.37*	0.39*	1													
SC90	0.34*	0.03	0.14	0.23*	0.05	0.10	0.24*	0.26*	0.29*	1												
PH90	0.55*	0.01	0.03	−0.04	0.95*	0.55*	0.08	0.70*	0.17	0.05	1											
TS90	0.75*	−0.13	0.01	−0.07	0.64*	0.30*	0.17	0.47*	0.26*	0.29*	0.63*	1										
HH90	0.52*	−0.01	−0.02	−0.03	0.90*	0.55*	0.01	0.63*	0.12	−0.04	0.97*	0.58*	1									
SD90	0.42*	0.05	−0.03	0.11	0.67*	0.64*	0.12	0.78*	0.23	0.20	0.66*	0.37*	0.60*	1								
NDL90	0.31*	0.28*	0.38*	0.09	0.20	−0.01	0.20	0.27*	0.18	0.35*	0.22	0.27*	0.18	0.06	1							
NGL90	0.16	−0.14	−0.42*	−0.14	0.52*	0.36*	−0.25*	0.39*	0.08	−0.10	0.54*	0.19	0.55*	0.55*	−0.36*	1						
HW	−0.27	0.12	−0.09	0.06	−0.07	0.01	−0.17	0.05	−0.22	−0.12	−0.04	−0.14	−0.04	0.21	−0.29*	0.42*	1					
HWWA	−0.08	0.03	−0.21	−0.13	0.15	0.19	−0.11	0.17	−0.08	−0.12	0.17	0.03	0.17	0.34*	−0.29*	0.57*	0.90*	1				
NAC	−0.16	0.16	0.14	0.22	−0.03	−0.01	−0.25*	0.10	−0.23	0.00	−0.01	−0.16	−0.03	0.23	−0.15	0.26*	0.63*	0.44*	1			
TAW	−0.06	0.09	0.38*	0.28*	−0.05	0.04	0.27*	0.17	0.09	0.18	−0.08	−0.15	−0.15	0.06	0.22	−0.38*	−0.14	−0.26*	0.05	1		
AY	−0.16	0.16	0.14	0.22	−0.03	−0.01	−0.25*	0.10	−0.23	0.00	−0.01	−0.16	−0.03	0.23	−0.15	0.26*	0.63*	0.44*	1*	0.05	1	
DMY	0.00	−0.02	−0.04	0.08	0.31*	0.02	0.12	0.01	0.14	−0.06	0.32*	0.18	0.20	0.26*	−0.28*	0.30*	0.32*	0.34*	0.16	−0.24*	0.16	1

*Significant at 5%. GER – germination percentage of plants; NL30 – number of leaves at 30 days; PH30 – plant height at 30 days; SD30 – stem diameter at 30 days; PH60 – plant height at 60 days; SD60 – stem diameter at 60 days; FS60 – flowering stage at 60 days; HD90 – had diameter at 90 days; HS90 – head curvature at 90 days; SC90 – stem curvature at 90 days; PH90 – plant height at 90 days; TS90 – total plant stand at 90 days; HH90 – head height at end of the cycle, at 90 days; SD90 – stem diameter at 90 days; NDL90 – number of dry leaves at 90 days; NGL90 – number of green leaves at 90 days; HW – head weight with achenes; HWWA – head weight without achenes; NAC – number of achenes; TAW – 1000-achene weight; AY – achene yield kg.ha^{-1}; and DMY – dry matter yield kg.ha^{-1}.

Table 6. Relative percentage contribution of the traits for divergence (D^2) 18 sunflower genotypes based on the criterion of Singh (1981).

Variable	S,j [1]	S,j (%) [2]	S.j acum. (%) [3]
AY	153259.5	49.55	49.55
NAC	153096.8	49.49	99.04
HH90	915.9	0.29	99.33
TAW	633.1	0.21	99.54
NGL90	395.3	0.13	99.67
DMY	340.9	0.11	99.78
PH90	210.7	0.07	99.85
HW	184.8	0.06	99.91
HD90	161.5	0.05	99.96
GER	52.6	0.02	99.98
TS90	52.6	0.02	100.00

AY – achene yield, $kg.ha^{-1}$; NAC – number of achenes; HH90 – head height at end of the cycle, at 90 days; TAW – 1000-achene weight; NGL90 – number of green leaves at 90 days; DMY – dry matter yield, $kg.ha^{-1}$; PH90 – plant height at 90 days; HW – head weight with achenes; HD90 – head diameter at 90 days; GER – germination percentage of plants; TS90 – total plant stand at 90 days. [1]S.j: contribution for genetic divergence; [2]S.j%: relative contribution; [3]S.j acum. %: cumulative contribution.

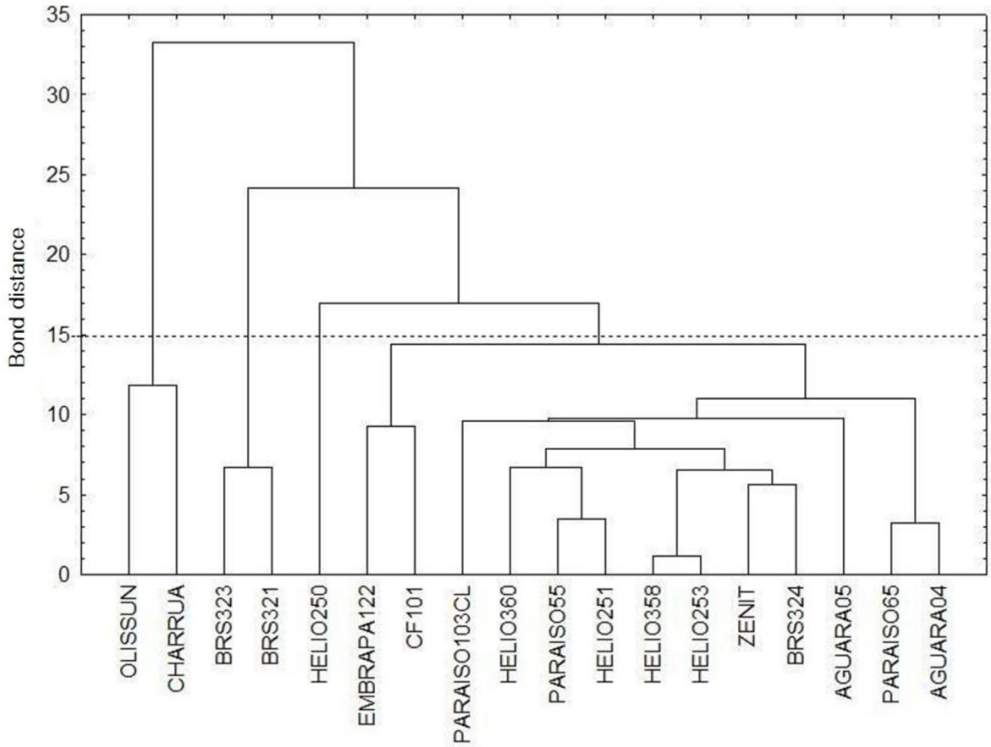

Figure 2. Dendrogram obtained from 11 agronomic traits (GER, HD90, PH90, TS90, HH90, NGL90, HW, NAC, TAW, AY, and DMY) evaluated in 18 sunflower cultivars based on Mahalanobis distance (D^2).

4. Discussion

Although no differences were observed among the cultivars for GER, SD30, HD90, and TS90, the variables of NL30, PH30, PH60, SD60, IDF60, HS90, SC90, PH90, HH90, SD90, NDL90, NGL90, HW, HWWA, NAC, TAW, AY, and DMY were influenced by the treatments, indicating the existence of genetic variability in the morphological traits. Cultivars BRS 321, Hélio 358, Embrapa 122, Paraíso 103CL, BRS 323, Paraíso 55, Paraíso 65, Aguará 04, CF 101, and Olisun 3 showed higher NL30, with values ranging from 10.04 to 11.58 (Table 3), similarly to the results reported by Braz and Rosseto (2009).

Cultivars Embrapa 122 and BRS 321 stood out in the measurements of PH30 in the first evaluation (30 DAS), with mean values of 50.92 and 50.17 cm, respectively, which are close to those described by Gomes et al. (2010). As stated by Pivetta et al. (2012), plant height is an important trait in mechanized agriculture, and it should be uniform so that mechanized harvest can be performed properly and crop losses minimized.

According to Biscaro et al. (2008), stem diameter is an important morphological trait that plays a part in resistance to lodging. In the present experiment, cultivars Charrua, Hélio 253, Embrapa 122, Paraíso 103

CL, and Aguará 6 showed the highest mean values for SD60, which are close to those obtained by Gomes et al. (2010), who evaluated stem diameter at 75 DAS.

In the evaluation of PH60, cultivars Charrua, Paraíso 103 CL, Aguará 4, Paraíso 55, Paraíso 65, Hélio 251, BRS 324, Aguará 6, and Zenit exhibited higher mean values than the other evaluated cultivars, averaging 154.27 cm, which is higher than the 48 to 131 cm found by Gomes et al. (2010) at 40 and 75 DAS, respectively. The flowering stage at 60 DAS (FS60) was measured to demonstrate the earliness of the cultivars, in which Hélio 253, Embrapa 122, Hélio 358, BRS 321, and Hélio 360 stood out. In this respect, cultivar Augará 4 was the latest to flower. Afférri et al. (2008) observed that Aguará 3 and 4 are late-flowering cultivars.

The group of cultivars Charrua, Paraíso 103 CL, Aguará 6, Hélio 358, Paraíso 65, Olisun 3, and BRS 323 exhibited an average diameter of 1.84 cm, whereas the second group, which contained the remaining cultivars, averaged 1.53 cm for this variable. The average diameters of all studied cultivars were 1.65, which is lower than the values described by Gomes et al. (2010) at 75 and 95 DAS, respectively. The mean of the present study was also lower than these reported by Biscaro et al. (2008). Castro and Farias (2005) stated that stem development is the factor that most influences dry matter accumulation in the sunflower crop, which makes it a trait of high relevance for silage production for animal feeding. This assertion is corroborated by the data presented in Table 5, which shows a positive correlation for these two traits at 90 DAS.

Plant height, together with stem diameter and the type of root system, is directly related to the lodging process in sunflower plants (Carvalho et al. 2005). In this context, in the evaluation of PH90, cultivars Olisun, Charrua, Paraíso 103CL, Aguará 4, Paraíso 65, Hélio 251, and Paraíso 55 showed higher mean values, agreeing with the values found by Gomes et al. (2010).

Cultivars Olisun, Charrua, Paraíso 103CL, Aguará 4, Paraíso 65, Hélio 251, and Paraíso 55, showed the highest mean value for HH90: 121.01 cm. It should be noted that this result was obtained during the off-season, when lower rainfall and insolation are predicted, as observed by Amorim et al. (2008).

The sunflower head must not be too high, so lodging and losses can be reduced. This facilitates the harvest, especially when it is performed mechanically (Carvalho et al. 2005).

Knowles (1978) developed a scale to evaluate the different head shapes, with scores ranging from 1 to 6. The scores found in this study ranged from 2 to 3. According to Oliveira et al. (2005), class-1 and -4 heads are the most desirable for agronomic traits when aiming at improved pollination and harvest and reduced water in the receptacle. This last characteristic is related to the plant dry matter content (Oliveira et al. 2005). As mentioned by Oliveira et al. (2005), SC90 should show scores between 3 and 4, which reduces bird attacks. We also stress the importance of HS90 in reducing bird attacks, consequently minimizing losses. Hanzel (1992) stated that around 5 to 10% of productivity is lost due to bird attacks. Even though some of the studied cultivars did not present the desired head shapes, their stem curvature might have minimized these losses.

Cultivars BRS 323, BRS 321, Zenit, and CF 101 showed higher means for NGL90, averaging 15.68, obtained after flowering. Aquino et al. (2013) obtained a higher average; however, this measurement was performed during flowering. Furthermore, the number of green leaves is directly related to the greater plant yield (Sabbi et al. 2010), as can be confirmed in Table 5, based on the positive correlation between NGL90 and AY.

As declared by Lobo and Grassi Filho (2007), HD is a production-related component of great importance in the comparison of sunflower cultivars, given its positive association with AY. According to Amorim et al. (2008), to ensure high yields, genotypes with larger heads should be selected, because of the positive correlation between this variable and yield. The average HD obtained in this study was 13.57, which is lower than the average described by Mello et al. (2006).

Cultivars Charrua, Olisun, BRS 321, Paraíso 103 CL, Paraíso 65, Aguará 6, and CF 101 displayed the highest means for NAC90, which were, however, lower than those found by Pivetta et al. (2012). Aquino et al. (2013) found an average 1000-achene weight of 73g but using irrigation.

Cultivars Charrua, Olisun 3, BRS 321, Paraíso 103CL, Paraíso 65, Aguará 6, and CF 101 showed average achene yields greater than 1,500 kg.ha^{-1}. The average achene yield found in the current experiment was 1,419.38 kg.ha^{-1}, which is lower than these observed by Gomes et al. (2010) and Gomes et al. (2012).

The average yield obtained in the present experiment (1,419.38 kg.ha^{-1}) almost equaled the Brazilian national average of 1,500 kg.ha^{-1} in 2016 (AGRIANUAL 2016) and is close to the 1,468.75 kg.ha^{-1} obtained by Pivetta et al. (2012). According to Dallagnol et al. (2005), the explanation for the low yields in Brazil is the little use of technologies in production since sunflower is viewed as a secondary crop.

As for dry matter yield—an important measurement to increase animal production—, the highest values were found in cultivars Charrua, Hélio 251, Olisun 3, Hélio 360, Paraíso 55, and Paraíso 103 CL, whose means were greater than 9,550 kg.ha^{-1}. Gomes et al. (2012) obtained a DM yield of 10,992 kg.ha^{-1}, and Mello et al. (2006), 11,000 kg.ha^{-1}.

Based on the phenotypic correlation matrix for the analyzed variables (Table 5), in highly correlated traits, the choice of one trait directly modifies the other. Besides, AY and NAC were the parameters that most contributed to total divergence among the 18 sunflower cultivars evaluated in the analysis for the estimate of relative contribution of each trait (Table 6). These data corroborate the main result for correlation presented in Table 5 (AY and NAC with r = 1). In the study of Rigon et al. (2012), NAC contributed with 50% to divergence among cultivars, which is close to the value found in the present experiment. Additionally, the other agronomic traits of interest for yield had a low-magnitude S.j.

The present results confirm the high morphological variability between the different sunflower cultivars assessed. There were no equal phenotypes, which reinforces the diversity derived from the parents. Moreover, the morphological dissimilarity dendrogram (Figure 2) revealed that the most morphologically similar cultivars were Hélio 253 and Hélio 358, while the most dissimilar were BRS 321 and Charrua. Smith et al. (2009) conducted a study with sunflower hybrids used in the United States and based on the parental lines, they divided 15 hybrids into two groups, demonstrating lower variability.

5. Conclusions

Cultivars Hélio 253, Hélio 358, Embrapa 122, BRS 321, and Hélio 360 were characterized as early-flowering and Aguará 4 as late-flowering. Charrua, Olisun 3, BRS 321, Paraíso 103CL, Paraíso 65, Aguará 6, and CF 101 are recommended for grain yield, which is an important peculiarity for the rearing and feeding of monogastric animals; and Charrua, Hélio 251, Olisun 3, Hélio 360, Paraíso 55, and Paraíso 103CL for forage yield, with a possible indication for ruminants. It is noteworthy that cultivars Charrua, Olisun 3, and Paraíso 103CL showed potential for both grain and forage yield (dual-purpose) in the soil-climatic conditions of the studied region.

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