

REGULAR ARTICLE

# Yield potential of different sunflower genetic classes: A multivariate approach

Ziraldo Moreno Santos, Tâmara Rebecca Albuquerque De Oliveira\*, Geraldo Amaral Gravina, Camila Queiroz Sant'Anna, Derivaldo Pureza da Cruz, Gustavo Hugo Ferreira De Oliveira, Avelino dos Santos Rocha, José Geraldo Custodio dos Santos, Rogerio Figueiredo Daher

Instituto Fluminense de Engenharia- IFENG, Universidade Estadual do Norte Fluminense Darcy Ribeiro, Mexico

## ABSTRACT

Breeding programs aim at obtaining superior genotypes. The multivariate analysis allows simultaneously assessing a large number of variables and interesting genotypes. The objective of the present study is to assess the yield potential of different sunflower genetic classes. A randomized block design, with four repetitions, and eight sunflower genotypes was used in the current experiment. Principal component analyses were performed for the variables plant height, lower stem diameter, upper stem diameter, chapter diameter, chapter weigh, achene weight and grouping. The method by UPGMA (Unweighted Pair Group Using an Arithmetic Average) was used to assess the oil content. The upper stem diameter, lower stem diameter and plant height variables showed high positive correlation, as well as chapter diameter, chapter weight and plant height. Variables lower stem diameter and achene weight were not correlated. Genotypes Olisun-3 and Aguará-4 showed potential for the selection of the chapter diameter, chapter weight and achene weight variables; the hybrids Charrua e Olisun-5 was adopted for upper stem diameter, plant height and lower stem diameter character selections. The open-cross varieties presented higher oil content percentage.

**Keywords:** Biplot; Genetic distance; *Helianthus annuus L*; Multivariate analysis

## INTRODUCTION

Sunflower (*Helianthus annuus L.*) is an oilseed crop native to the Americas (Maia Filho et al., 2013). It was widely spread in Brazil back in the nineteenth century, mainly in the south region. However, studies have proved this crop's propensity to grow in other locations in the Brazilian territory (Castro and Farias, 2005). The southeast region presents the highest percentages of explored areas and grain production (CONAB, 2018), and it allows cultivation expansion in different regions and environmental condition alternations.

The cultivation importance given to sunflower lies on its great yield potential and purpose of use. Seed crops can be grown for several purposes, among them, animal feed production, raw material for biodiesel production, medicinal use, vegetable oil extraction and for ornamental ends (Leite et al., 2005; Nobre et al., 2011).

In addition to its great renewable energy capacity, sunflower is an excellent option of crop rotation system

for agricultural production, as well as an alternative to green manure (Pereira et al., 2014).

Studies related with sunflower cultivation try to elucidate growth conditions providing desirable morpho-agronomic characteristics in order to aggregate information and make superior genotypes available to producers.

The use of hybrids stands out in practically all regions, but the enhanced varieties adopted by small and medium producers have shown high yield. However, the lack of resources to invest in better technologies do not allow hybrids to reach their maximum potential. The large production derives from allelic combinations, which are responsible for the superiority of some interesting characteristics.

The correlation between different characteristics in breeding programs attests the likelihood of indirect selection aiming at fastening the genetic gains.

### \*Corresponding author:

Tâmara Rebecca Albuquerque De Oliveira, Instituto Fluminense de Engenharia- IFENG, Universidade Estadual do Norte Fluminense Darcy Ribeiro, Mexico. **E-mail:** tamara\_rebecca@hotmail.com

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The use of multivariate analyses and of other techniques is appropriate to analyze a large number of correlated variables. The principal component analysis enables a possibly better data investigation; it also reduces the data-matrix size through linear combinations and facilitates their interpretation through statistical graphs (Souza, 2005).

The biplot graphic representation is a key element to reveal the relation between variables, between observations, and between variables and observations. Many studies have evidenced that this method completes the data in a practical manner and allows better identifying the genotypes (Leite and Oliveira, 2015).

Examples listed in the studies by Brankovic et al. (2012), Leite and Oliveira (2015) and Oliveira et al. (2018) corroborate the technique adequacy to simultaneously assess different sunflower–crop characteristics.

Given the importance of expanding sunflower crops in Brazil and of content-related research that help making this agriculture more productive and profitable, the objective of the present study was to compare the yield potential of different sunflower genetic classes.

## MATERIAL AND METHODS

The experimental material in the current study consisted of eight sunflower genotypes (Table 1) provided by public and private companies. The assessments were carried out in 2012, throughout two growing seasons (March and November), at PESAGRO-RIO in the Experimental Field of the State Center for Research on Bioenergy and Waste Recover), located in Campos dos Goytacazes County, RJ, Brazil (21°45' South Latitude, and 41°18' Longitude West, altitude 11m from sea-level). The soil in the region is classified as haplumbrept.

The experiment was conducted according to the randomized block design, with four repetitions. Plots were composed of four rows 6.0 m long, spaced 0.90 m from each other, and the pits were set 0.20 m from each other within the rows. The observations covered ten

plants randomly harvested in each plot. Fertilization followed the soil guidelines by Alvarez et al. (1999). Weed and pest controls were applied according to the crop's needs. Complementary sprinkler irrigation was used, whenever required, due water deficit; it was performed at depth 20 mm for crop development.

The analyzed variables were Plant Height (PH) (m), which was measured using a graduated wood ruler from soil level to chapter insertion; Lower Stem Diameter (LSD) (mm), which was measured using a pachymeter placed 5 centimeters from soil level; Upper Stem Diameter (USD), which was (mm) measured using a pachymeter laced 5 centimeters below chapter projection; Chapter Diameter (CD) (cm), which was used to measure the diameter of the inflorescence receptacle using a graduated ruler; Chapter Weight (CW), in grams; Achenes Weight (AW), in grams; and oil content (OC), in percentage.

The evaluation of the diameter of the chapter, weight of achenes and oil content were realized during the physiological maturation period. The other variables were evaluated during the full flowering period.

Data were subjected to analysis of variance through the Biplot method 'genotypes vs variables' to assess the relation between variables, and between variables and genotypes. The Biplot was generated using the standardized values of variable means; the eigenvalues of all Principal Components were calculated; the eigenvectors were used to better differentiating the genotypes. The Biplot 'genotypes vs variables' was generated by plotting the PC1 scores against the PC2 scores of each genotype and variable. The mean oil content in each genetic class was estimated and the values were used in the UPGMA cluster analysis through the Euclidean distance. Such calculation generated a dendrogram that grouped all genetic classes together. The cophenetic correlation coefficient between the cophenetic and the dissimilarity matrices was estimated in order to determine whether the groups presented the observed relations between classes.

The Principal Components analysis, the Biplot graphics and the grouping through the UPGMA method were conducted in R software packages.

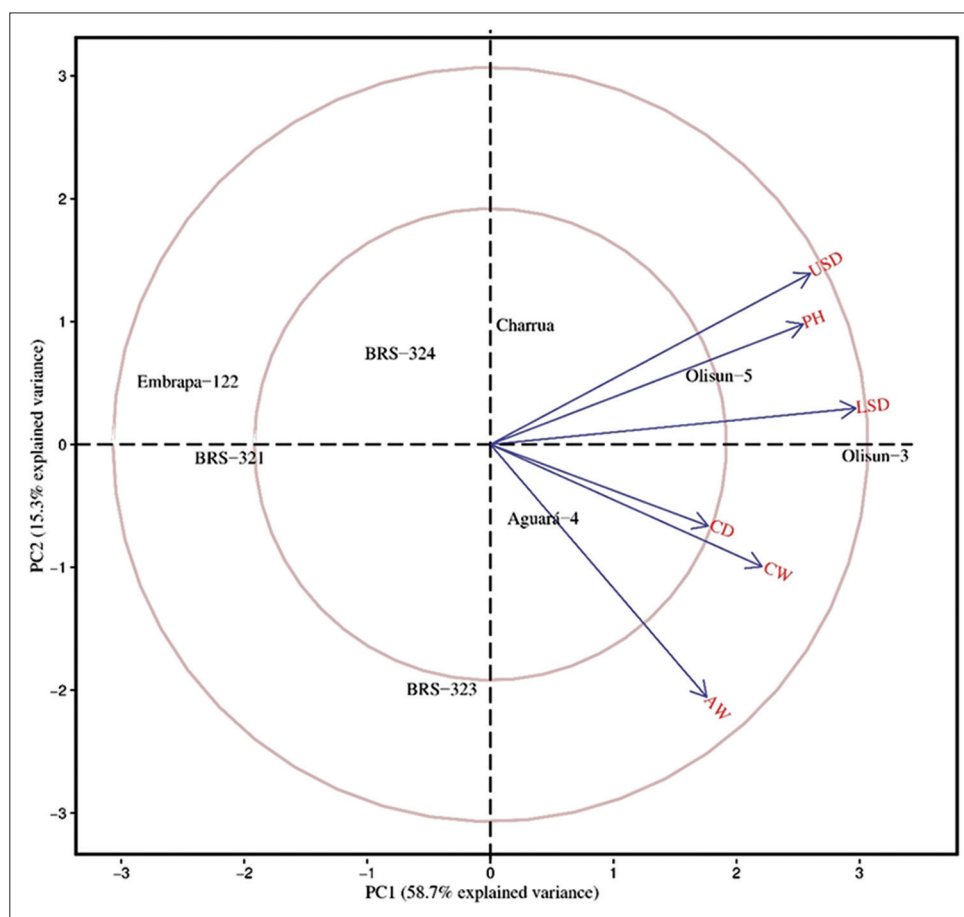
**Table 1: Description of the eight sunflower genotypes assessed in two harvesting seasons in Norte Fluminense, RJ, Brazil**

Genotype	Genetic structure	Cycle	Company
Embrapa-122	Open-pollinated variety	Precocious	Embrapa
BRS-324	Open-pollinated variety	Precocious	Embrapa
Aguará-4	Simply hybrid	Precocious	Atlântica sementes
BRS-321	Simply hybrid	Precocious	Embrapa
BRS-323	Simply hybrid	Precocious	Embrapa
Olisun-3	Triple hybrid	Semi-precocious	Atlântica sementes
Olisun-5	Triple hybrid	Semi-precocious	Atlântica sementes
Charrua	Triple hybrid	Semi-precocious	Atlântica sementes

**Table 2: Summary of the morphoagronomic characters of the eight sunflower genotypes in combination with the analysis of variance**

Sources of variation	DF	Medium square					
		PH (m)	CD (cm)	LSD (mm)	USD (mm)	CW (g)	AW (g)
Block	3	0.05	7.78	0.25	0.14	445500.60	13797.02
Genotype (G)	7	0.22**	5.33	1.15**	0.26**	3790900.36	810932.64
Epoch (E)	1	0.19**	2.38	3.95**	0.42**	30215491.17**	7410056.86**
G x E	7	0.10**	10.86	0.54**	0.30**	1205540.49	130792.63*
Residue	42	0.02	5.93	0.08	0.05	1643907.14	158811.35
C.V. %		9.86	15.87	13.25	16.60	27.69	21.06
Mean		1.32	15.35	2.07	1.31	4624.86	2275.62

\*\* and \*: Related to ( $p < 0.01$ ) and ( $p < 0.05$ ), respectively, through the F test; PH: plant height; CD: chapter diameter; LSD: Lower Stem Diameter; USD: Upper Stem Diameter; CW: chapter weight; AW: achene weight



**Fig 1.** Biplot presenting the variable projection of the eight sunflower cultivars. Mean Plant Height (PH), Chapter Diameter (CD), Lower Stem Diameter (LSD), Upper Stem Diameter (USD), Chapter Weight (CW) and Achene Weight (AW).

## RESULTS AND DISCUSSION

The analysis of variance showed significant plant height, lower stem diameter, and upper stem diameter differences between genotypes, fact that has revealed genetic variability between these cultivars (Table 2).

All variables presented significant differences during the studied timeframe, except for chapter diameter. It proves the importance of analyzing sunflower crops in different growing seasons and of safely selecting the most suitable

period for their cultivation. The significant effect of the genotype x epoch (G x E) interaction on the PH, LSD, USD and AW variables showed how the genotypes have presented different performances in each growing season.

Biplot analysis was carried out to compare the principal component (PCs) values of both the variables and the sunflower genotypes. The first two Principal Components (PC1 and PC2) presented the greatest variability in the tested parameters (74%), which were used in the Biplot analysis (Fig 1). According to Rencher (2002), at least

70% of the total variation must be explained by the first two principal components; therefore, PC1 and PC2 may be used to study this data set. Such result is in compliance with that by Leite and Oliveira (2015) and Mousavi et al. (2016) who found that the first two CPs explain more than 70% of the original variation.

The eigenvalues of the two components were calculated based on results found through the Principal Components technique; they presented values 1.88 and 0.96, respectively. These were high values since the total sum of eigenvalues was approximately 5. In addition, with respect to the association of variables, the vectors denoted the interrelation between all measured characteristics. The lines attached to the variables and the Biplot origin showed the approximate respective standard deviations. The degree of association between the two characteristics was represented by the cosine of the angles formed by the vectors (lines) connected by each variable: acute angle ( $<90^\circ$ ), positively correlated; and obtuse angle ( $>90^\circ$ ), negatively correlated. The vectors forming a right angle ( $= 90^\circ$ ) were uncorrelated and those forming a  $180^\circ$  angle had strong negative correlation.

There was association between different angles and the variables; the USD, PH and LSD variables had high positive correlation and formed acute angles between variables, as well as the CD, CW and AW variables. Positive correlations indicate that the direct selection of one specific characteristic increases the other characteristic. Therefore, if the breeding program is concentrated in plant height, an indirect selection can be performed by using the superior stem diameter or the lower stem diameter variables (Yasin and Singh, 2010). Similarly, the selection of the chapter weight variable may lead to changes in the chapter diameter and achene weight variables (Pivetta et al, 2012; Silva et al, 2011). The USD variable has no correlation with AW; therefore, the upper stem diameter cannot be used in the selection process to increase achene weight.

The Biplot technique can also be used to compare genotypes in the multiple observed traits and to identify responsive genotypes that may be used as potential parents in Sunflower breeding programs. Accordingly, the positive correlations are responsible for the discrimination of genotypes located at the right side of PC1; and for the negative correlation discriminating the genotype at the left side of PC1 (Tobar-Tosse et al., 2015).

The relation between variables in each genotype showed that Olisun-5 and Olisun-3 present the potential for USD, PH and LSD selection. The Charrua genotype also showed the potential for these variables, although a weak one. The Aguará-4 genotype showed higher potential for DG, CW and AW character selections.

Although the open-pollinated varieties lacked breeding potential concerning the studied characteristics, it is known that not every hybrid is superior to varieties; in other words, cultivars should be individually chosen at time, and factors such as genotype quality, yield potential and cultivated environment, among others, should be taken into account.

The discrepancies between genetic classes were clearly attested through the oil content variables. The open-pollinated varieties and the simple hybrids showed percentage higher than the triple hybrids (Table 3). Such result evidences that the existing genetic variability resulted in different behavior, which was mainly caused by environmental conditions that just favor few cultivars.

Hybrids have higher frequency of individuals presenting high heterozygosity, which results in more uniform plants and facilitate management and harvesting. The behavior of phenotypic hybrid plants also depends on the genotype x environment interaction, and the performance of modern hybrids tend to strongly interact with environmental conditions and with the technological standards adopted in each property (Emydio and Teixeira, 2008).

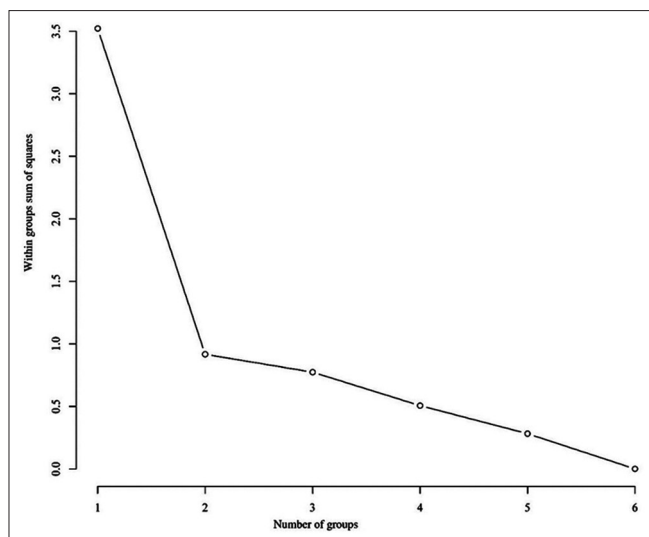
The use of enhanced varieties becomes the best alternative in cases wherein lack of technology impairs the performance and challenges the exploitation of the hybrids' genetic potential. Cultivar superiority is attributed to the breeding process it is subjected to, and to its broad genetic base.

Even if farmers prefer using hybrids when increasing crop technology standards, believing they will give them better economic return, increased yield potential and greater stability, varieties show important allelic combinations that provide rusticity and good adaptation to adverse soil and climate conditions. According to Meneguetti et al. (2002), the good performance of the variety does not justify the lack of efforts to improve soil fertility and infrastructure to increase production.

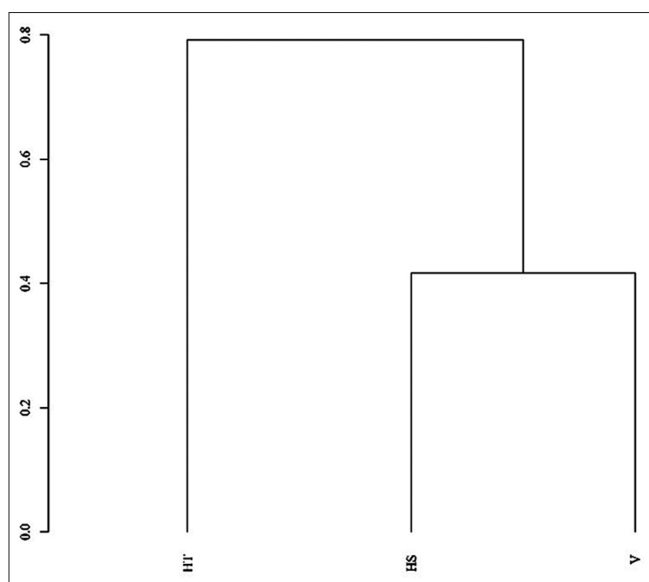
Enhanced seed varieties still have the advantage of being cheaper and of letting producers grow their own seed.

**Table 3: Mean oil content (%) of the eight genotypes assessed in Norte Fluminense, RJ, Brazil**

Genotype	Oil content (%)
BRS-324	39.67
BRS-321	34.72
Embrapa-122	33.84
Olisun-5	28.17
BRS-323	25.47
Aguará-4	25.38
Charrua	21.57
Olisun-3	21.53
Mean oil content (%)	28.79



**Fig 2.** Scree Plot to select the best number of groups based on within groups sum of squares on eight sunflower genotypes.



**Fig 3.** UPGMA grouping of the different sunflower genetic types considering the Standardized Euclidean Distance of the position measures in the oil content (%). SH = Simple Hybrid TH = Triple Hybrid; V: Open-Pollinated Variety.

Unlike hybrids, characteristics last from one generation to another.

These characteristics and the presence of higher seed oil contents - 48% higher than the others (40%) - (Carvalho et al., 2013), explain the BRS-324 variety case, which stands out due to its high oil content (39.67%). Such result evidenced how the use of this variety reduced crop costs and provided high oil content.

The open-pollinated varieties and the BRS-321 simple hybrid - which had no potential to be used in a program aiming at improving the PH, CD, LSD, USD, CW and

AW variables -, generated higher oil content percentage. Therefore, it is possible stating that these cultivars are the most suitable for breeding programs focused on increasing oil content; thus, this variable is negatively correlated with the other ones (Amorim et al, 2008; Dalchiavon et al, 2016; Hassan et al., 2013).

The Scree Plot showed the optimal number of formed groups (Fig 2). The present outcome also confirms the UPGMA grouping, which consisted of two groups in the cut established at 50% dissimilarity. The graphic shows the distance percentages in the Y axis, as well as the genotypes following their genetic structure in the X axis (Fig 3). Group I was composed of triple hybrids (Olisun-3, Olisun-5 and Charrua); and Group II, of double hybrids (Aguará-4, BRS-323 and BRS-321) and open-pollinated varieties (Embrapa-122 and BRS-324).

The clustering analysis results showed that the oil content in open-pollinated varieties is similar to that in simple hybrids. Therefore, these varieties are indicated for use due to their high oil content, lower seed costs and greater plasticity in different environments. Moreover, because they maintain the productive potential when they are applied to subsequent harvests.

## CONCLUSIONS

1. The principal component analysis discriminated the sunflower genotypes, allowing the selection of cultivars with superior agronomic characteristics.
2. The upper stem and lower stem diameter variables showed high positive correlation with plant height.
3. Chapter weight and achene weight were highly influenced by the chapter diameter.
4. The Aguará-4 simple hybrid presented great aptitude for achene weight.
5. Overall, the open-pollinated varieties showed oil content superiority.

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