https://doi.org/10.47456/bjpe.v10i2.44380 ARTIGO ORIGINAL | OPEN ACCESS

NÚCLEO DE PESQUISA EM GESTÃO DE SISTEMAS DE PRODUÇÃO - NP GSP
Brazilian Journal of Production Engineering
BJPE - Revista Brasileira de Engenharia de Produção
Disponível em: https://periodicos.ufes.br/bjpe
ISSN: 2447-5580
Campus São Mateus
UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO
Pró-Reitoria de Pesquisa e Pós-Graduação
Universidade Federal do Espírito Santo

AGRONOMIC AND BROMATOLOGICAL CHARACTERISTICS OF GENOTYPES OF *CARTHAMUS TINCTORIUS* L. POTENTIAL FOR THE CERRADO REGION

CARACTERÍSTICAS AGRONÔMICAS E BROMATOLÓGICAS DE GENÓTIPOS DE CARTHAMUS TINCTORIUS L. POTENCIAIS PARA A REGIÃO DO CERRADO

CARACTERÍSTICAS AGRONÓMICAS Y BROMATOLÓGICAS DE LOS GENOTIPOS DE CARTHAMUS TINCTORIUS L. POTENCIAL PARA LA REGIÓN DEL CERRADO

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ARTIGO INFO.

Recebido: 24.04.2024
Aprovado: 28.05.2024
Disponibilizado: 08.06.2024

KEYWORDS: *Safflower; Plant Breeding; Ether Extract; Crude Protein.*

PALAVRAS-CHAVE: Cártamo; Melhoramento Vegetal; Extrato Etéreo; Proteína Bruta.

PALABRAS CLAVE: *Cártamo; Fitomejoramiento; Extracto Etéreo; Proteína cruda.*

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) can be an alternative crop in the off-season in Cerrado regions because it has high productivity with low demand for water during its cycle, in addition to being a fully mechanized crop. It is currently cultivated mainly for the production of edible oil, cooking oil and for pharmaceutical applications. In view of this, the present work aims to evaluate the agronomic performance and the bromatological and morphological characteristics of 19 safflower genotypes in the semiarid north of Minas Gerais. The work was carried out at the Institute of Agricultural Sciences of the Federal University of Minas Gerais (ICA/UFMG). The design used was completely randomized with 19 treatments (where each genotype was considered as a treatment) with 16 replications. Morphological characteristics, crude protein and ether extract contents were evaluated. The data obtained were submitted to analysis of variance and the averages were grouped by the Skott-knott test and multivariate analysis (P<0.05). The evaluated genotypes showed protein contents varying between 18.65% and 26.69%. The ether extract contents of the grains of the evaluated genotypes ranged from 18.54% (genotype 63) to 24.98% (genotype 119). Genotypes 73, 77 and 63 have superiority in their morphological and bromatological characteristics, thus allowing further research to be carried out in order to obtain genetic material with great potential for the Brazilian semi-arid region.

RESUMO

O cártamo (Carthamus tinctorius L.) pode ser uma cultura alternativa na época de safrinha nas regiões de cerrado por apresentar alta produtividade com baixa demanda por água durante seu ciclo, além de ser uma cultura totalmente mecanizável. Atualmente é cultivado principalmente para produção de óleo comestível, óleo de cozinha e para aplicações farmacêuticas. Diante disso, o presente trabalho tem como objetivo avaliar o desempenho agronômico e as características bromatológicas e morfológicas de 19 genótipos de cártamo no semiárido norte mineiro. O trabalho foi realizado no Instituto de Ciências Agrárias da Universidade Federal de Minas Gerais (ICA/UFMG). O delineamento utilizado, foi inteiramente casualizado com 19 tratamentos (onde cada genótipo foi considerado como um tratamento) com 16 repetições. Avaliou-se características morfológicas, teores de proteína bruta e extrato etéreo. Os dados obtidos foram submetidos à análise de variância e as médias foram agrupadas pelo teste de skott-knott e analise multivariada (P<0,05). Os genótipos avaliados apresentaram teores de proteína, variando entre 18,65% e 26,69%. Os teores de extrato etéreo dos grãos dos genótipos avaliados variaram de 18,54 % (genótipo 63) a 24,98 % (genótipo 119). Os genótipos 73, 77 e 63, possuem uma superioridade em suas características morfológicas e bromatológicas, podendo assim ser feito novas pesquisas, afim de obter um material genético com grande potencial para o semiárido brasileiro.

RESUMEN

El cártamo (Carthamus tinctorius L.) puede ser un cultivo alternativo fuera de temporada en regiones del cerrado porque tiene alta productividad con baja demanda de agua durante su ciclo, además de ser un cultivo totalmente mecanizado. Actualmente se cultiva principalmente para la producción de aceite comestible, aceite de cocina y para aplicaciones farmacéuticas. Ante esto, el presente trabajo tiene como objetivo evaluar el desempeño agronómico y las características bromatológicas y morfológicas de 19 genotipos de cártamo en el norte semiárido de Minas Gerais. El trabajo fue realizado en el Instituto de Ciencias Agrícolas de la Universidad Federal de Minas Gerais (ICA/UFMG). El diseño utilizado fue completamente al azar con 19 tratamientos (donde se consideró cada genotipo como tratamiento) con 16 repeticiones. Se evaluaron características morfológicas, contenido de proteína cruda y extracto etéreo. Los datos obtenidos fueron sometidos a análisis de varianza y los promedios fueron agrupados mediante la prueba de Skott-knott y análisis multivariado (P<0,05). Los genotipos evaluados presentaron contenidos proteicos que variaron entre 18,65% y 26,69%. Los contenidos de extracto etéreo de los granos de los genotipos evaluados oscilaron entre 18,54% (genotipo 63) y 24,98% (genotipo 119). Los genotipos 73, 77 y 63 presentan superioridad en sus características morfológicas y bromatológicas, permitiendo así realizar más investigaciones con el fin de obtener material genético con gran potencial para la región semiárida brasileña.

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an annual cycle crop in the Asteraceae family. The cultivation of this herbaceous oilseed has expanded in Asian, European and American continents, due to its ability to overcome environmental adversities, as well as the recognition of its numerous uses (Sehgal et al., 2009). Among the uses, the high percentage of oil in its composition (35% - 45%), food, ornamental and medicinal use stands out (Oliveira, 2021).

Although safflower is cultivated extensively in many countries as an oilseed crop, there are cultivars with characteristics associated with oil production that are little known in Brazil. However, the country imported about 16340 kilograms net of safflower oil in the year 2022, indicating that there is a domestic demand (*Ministério da Indústria Comércio Exterior e Serviços* [Brasil], 2024).

The agronomic characteristics of safflower make it suitable to different regions of the world, due to its characteristics of resistance to water stress, versatile to different types of soils and climates, especially the semi-arid (Alves et al., 2018). These characteristics make it interesting for genetic improvement, selection and crossbreeding of promising genotypes for transition regions from Cerrado to semi-arid.

The careful selection of genotypes, considering not only the germination process and the initial establishment of the plants, but also the productive quality of the oils and protein contents, is essential for the species (Kayaçetin, 2022). This process not only ensures the vigorous development of crops in the early stages, but also makes it possible to produce higher percentages of oils or crude protein contents.

Climate change has resulted in water scarcity in many regions, along with unpredictable precipitation patterns. In the northern region of Minas Gerais state, known for its semi-arid climate, climate change has led to prolonged drought in different municipalities (Melo & Sousa, 2021).

This drought in the region has resulted in supply problems, affecting rural communities and harming both human and animal consumption. Additionally, it reduces the standard of living of the affected population and brings losses to local agriculture and livestock (Ribeiro et al., 2024).

In this scenario, diversifying agricultural production with alternative species such as safflower can offer additional resistance to adverse climatic conditions, helping to ensure food security and the livelihoods of affected communities.

However, edaphoclimatic conditions such as precipitation and average temperature can influence the concentrations of safflower seed components (Chaves et al., 2020). In this context, the objective was to test the agronomic performance, bromatological and morphological characteristics of 19 safflower genotypes in the *Cerrado* biome.

2. METHODOLOGY

2.1 EXPERIMENTAL FIELD

The experiment was carried out at the Center for Research in Agrarian Sciences (CPCA) belonging to the Institute of Agrarian Sciences of the Federal University of Minas Gerais (*Universidade Federal de Minas Gerais* - ICA/UFMG), in the municipality of Montes Claros, state of Minas Gerais (latitude 16º40'59.7'' S, longitude .43º50'21.9'' W, altitude 680 m). According to the climate classification, Köppen (Alvares et al., 2013) is an area with a tropical dry climate, with annual rainfall between 1000 - 1300 mm, with a dry winter and an average temperature of 23.1ºC.

2.2 EXPERIMENTAL DESIGN

The experimental design was completely randomized with 19 treatments (each genotype was considered as one treatment) and 16 replicates (each replicate was composed of a pot, containing 6 seeds). The genotype used were: Gen04, Gen07, Gen08, Gen09, Gen30, Gen32, Gen50, Gen54, Gen63, Gen65, Gen73, Gen77, Gen88, Gen119, Gen122, Gen133, Gen135, Gen139 and Gen211. Static analyses were performed using the Scott-Knott test (ExpDes.pt package). For a better determination of the variables analyzed, the graphical distribution by multivariate analysis becomes an alternative in the selection of promising genotypes. A dendrogram was constructed based on the Numerical Taxonomy System of similarity coefficients. The statistical analysis software used was RStudio®, version 3.5.3.

2.3 CONDUCTING THE EXPERIMENT

Six safflower seeds were sown per pot, provided by the Mato Grosso Cotton Institute, IMA-MT. In each pot, 14 L of substrate composed of an oxisol and tanned cattle manure were used, in a 3:1 ratio, in addition, for each 50 liters of substrate, 60 g of Simple Super Phosphate and 20g of the formulated N-P-K (5-20-5) were added. Due to the lack of information on fertilization for this crop, the recommendation for *Helianthus annuus* (sunflower) was used, as both belong to Asteraceae.

After emergence and establishment of the crop, thinning was carried out, with three seedlings per pot. Irrigation was performed manually every two days. The harvest was carried out manually, the seeds were separated by genotypes in Craft paper bags and stored in BOD at a temperature of 8°C and 13% humidity.

2.3.1 MORPHOLOGICAL ASSESSMENTS

The seedling emergence (EP) rate was evaluated directly in the pots at 10, 20 and 30 days after planting. At 30, 45, 60 and 120 days, plant height (AP) was measured in centimeters with the aid of a graduated ruler, taking the soil surface to the top of the panicle as a base. Evaluations took place until growth stabilized. The number of flowers head (CAP) was counted before harvesting.

2.3.2 BROMATOLOGICAL EVALUATIONS

CRUDE PROTEIN (PB)

Crude protein analysis was performed at the Bromatology Laboratory of ICA/UFMG. The method adopted for crude protein quantification was the one proposed by Kjeldahl in Denmark in 1883, with its three distinct stages (digestion, distillation and titration).

Digestion is based on heating the sample with sulfuric acid until the organic compounds are oxidized, the N of the protein (organic) is reduced and transformed into ammonium sulfate (inorganic) which is a stable substance (Pomeranz & Meloan, 1978), but not easily quantifiable. Potassium sulfate was added in order to raise the boiling point of sulfuric acid allowing the decomposition of organic matter, and a metal catalyst that increases the oxidation power of the medium. Subsequently, concentrated sodium hydroxide was added and the solution was heated to release ammonia into boric acid solution, forming ammonium borate which constitutes the quantifiable form of N. The ammonium borate formed was titrated with a standardized solution of hydrochloric acid (HCl) (Souza et al., 2016).

Thus, with the help of the formulas below, it was possible to determine the total nitrogen and crude protein content.

$$\%\ total\ nitrogen = \frac{\mathrm{V} \times \mathrm{M} \times \mathrm{f} \times 0{,}014 \times 100}{\mathrm{p}}$$

$$\%\ crude\ protein = \%\ \text{total nitrogen} \times 6{,}25$$

Where:

V = Milliliters of 0.1mol/L hydrochloric acid solution spent on titration after blank correction;

M = Theoretical molarity of the 0.1mol/L hydrochloric acid solution;

f = Correction factor of hydrochloric acid solution 0.1mol/L;

p = Mass of the sample in grams.

Ether Extract (EE)

The oil extraction was carried out at the Bromatology Laboratory of ICA/UFMG, with the ethyl ether solvent in a Soxhlet extractor, according to the AOCS methodology for soybean, due to the lack of information for the safflower culture (American Oil Chemists' Society [AOCS], 1997).

The samples were weighed and identified on filter paper, folded so that the sample was not lost, and placed inside a cartridge. The cartridge was introduced into the Soxhlet extractor in such a way that it was completely submerged in 100 ml of ethyl ether during extraction. After 4 hours of extraction, followed by cooling, the solution was taken to the oven at 80°C and then transferred to the desiccator with silica gel until it was cooled to room temperature and, finally, weighed. The percentage of oil was calculated by multiplying the mass of the oil by 100 and dividing by the initial weight of the sample (grains).

3.RESULTS AND DISCUSSION

Genotypes Gen07, Gen09 and Gen139 did not germinate under experimental conditions, while Gen04 required more than 10 days for at least one seedling to emerge. Only genotypes Gen63, Gen65, Gen73, Gen77, Gen88, Gen133 emerged more than 50% at 20 days after sowing (Table 2). Not enough seeds were obtained for ethereal extract and crude protein analyzes for the genotypes Gen04, Gen07, Gen08, Gen09, Gen30, Gen88 and Gen 139.

Table 2. Seedling Emergence (EP), Plant Height (AP), Number of Flowers Head (CAP), Ether Extract (EE) and Crude Protein (PB) assessments of *Carthamus tinctorius.* Means followed by different lowercase letters in the column differ statistically by the Scott-Knott test at 0.05% significance

Genotypes	EP	AP (cm)						CAP	EE(%)	PB(%)
	10	20	30	30	45	60	120			
Gen04	0,00 d	0,12 e	0,12 e	0,10 c	0,16 f	0,77 i	1,46 f	4,18 h	N/A	N/A
Gen07	0,00 d	0,00 e	0,00 e	0,00 c	0,00 f	0,00 i	0,00 f	0,00 i	N/A	N/A
Gen08	0,18 d	1,93 c	2,31 c	2,82 b	7,20 e	16,31 h	34,99 e	6,81 f	N/A	N/A
Gen09	0,00 d	0,00 e	0,00 e	0,00 c	0,00 f	0,00 i	0,00 i	0,00 i	N/A	N/A
Gen30	0,31 c	1,06 d	1,12 b	2,80 b	7,07 e	19,95 g	45,08 c	5,81 g	N/A	N/A
Gen32	0,43 c	1,75 c	2,43 c	13,53 a	15,40 d	22,18 f	69,63 b	12,37 d	20,01 e	23,64 b
Gen50	0,62 c	1,50 c	2,62 c	13,11 a	18,26 b	40,38 b	69,80 b	10,18 e	17,13 g	23,04 b
Gen54	0,06 d	1,68 c	2,50 c	12,18 a	15,51 d	33,61 d	71,65 a	13,00 c	22,98 c	22,20 c
Gen63	0,43 c	3,50 a	4,31 a	12,93 a	17,09 c	43,32 a	71,10 b	11,62 d	18,54 f	26,69 a
Gen65	0,62 d	3,43 a	4,43 a	13,03 a	19,45 b	40,33 b	69,71 b	14,18 c	23,82 b	25,97 a
Gen73	0,50 c	3,62 a	4,50 a	14,07 a	19,50 b	36,51 c	72,54 a	11,81 d	21,35 d	26,22 a
Gen77	0,56 c	3,50 a	4,43 a	13,43 a	23,41 a	38,66 b	74,20 a	10,62 e	19,48 e	26,66 a
Gen88	0,43 c	3,43 a	4,37 a	12,81 a	20,71 b	38,83 b	74,69 a	16,18 b	N/A	N/A
Gen119	1,56 a	2,50 b	3,50 b	13,26 a	19,45 b	38,78 b	72,94 a	19,81 a	24,98 a	20,81 d
Gen122	1,81 a	2,18 b	3,75 b	12,57 a	24,31 a	39,56 b	69,10 b	16,00 b	17,28 g	19,17 e
Gen133	1,06 b	2,68 b	3,62 b	13,43 a	24,28 a	43,35 a	68,36 b	11,43 d	17,31 g	18,94 e
Gen135	0,06 d	2,31 b	3,50 b	13,38 a	17,77 c	26,93 e	40,93 d	7,81 f	21,79 d	22,71 c
Gen139	0,00 d	0,00 e	0,00 e	0,00 c	0,00 f	0,00 i	0,00 f	0,00 i	N/A	N/A
Gen211	0,75 c	2,37 a	3,50 b	12,61 a	16,93 c	25,45 e	34,37 e	9,62 e	19,48 e	18,65 e

Source: The authors (2024).

Menegaes et al. (2017) in an experiment with safflower with different substrates, in Santa Maria, Rio Grande do Sul, obtained a mean emergence time between 9.65 and 10.21 days. This difference can be linked to the climatic difference of the regions, since in the region of this study the average annual temperature is on average 6°C higher than in the southern region of Brazil. However, Montiel *et al.* (2017) evaluated the germination of safflower seeds at different temperatures, and according to the author, higher temperatures accelerate the biochemical reactions of seeds, causing them to germinate faster compared to seeds at 15°C, a condition under which their metabolic processes are slower and there is a consequent reduction in the germination speed index.

The mean plant height of the evaluated genotypes differed significantly ($P \leq 0.05$) at 45 and 60 days after planting. The genotypes Gen63, Gen122 and Gen133 had better averages at 45 days (23.41, 24.31 and 24.28 cm, respectively). While the genotypes Gen54, Gen73, Gen77, Gen88 and Gen119 stood out at 120 days after planting. The data obtained in this study were lower than those presented by Silva (2013) evaluating 19 safflower accessions in Botucatu, São Paulo state, who observed a variation from 65.31 cm to 131.07 cm in the accessions evaluated. These values are similar to those observed by Gerhardt (2014), who evaluated 16 safflower accessions in Botucatu, São Paulo state, and found plant heights ranging from 60 to 97 cm at 150 days after planting. Possibly, the evaluations at the end of cultivation provided a greater development of the plants, presenting this variation between the values observed in this study and contained in the literature.

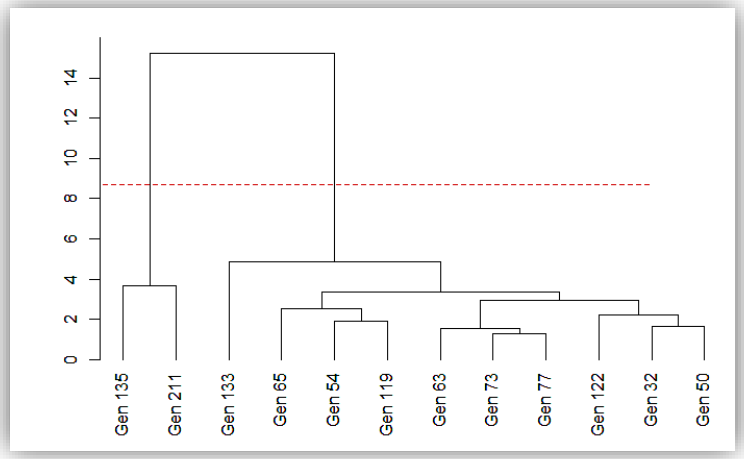
For the CAP variable, there was a statistical difference (P≤ 0.05) between the genotypes, ranging from 4.18 (Gen04) to 19.81 (Gen133). These values are higher than those observed by Gerhardt (2014), with a number of flower heads between 4 and 9. On the other hand, Zanotto (2015) obtained mean values close to those observed between 8.2 and 15.6 flowers head, evaluating 12 different genotypes.

For some genotypes regarding the ether extract contents, due to the low amount of seeds produced, it was not possible to evaluate their ether extract content. The ether extract contents ranged from 18.54 % (Gen63) to 24.98 % (Gen119). The lipid content (ether extract) was lower than the values observed in the literature. Abud et al. (2010) found lipid levels in safflower seeds to be around 40%, the main reserve compound of the seed, classifying it as oilseed.

Regarding the crude protein content of the grains of the genotypes evaluated, due to the amount of seeds produced by some genotypes, it was not possible to evaluate the crude protein content of these genotypes. The genotypes evaluated showed a low protein content, ranging from 18.65% to 26.69%. Such values are below those observed by Rech (2012) evaluating the performance of safflower at different sowing times in Dourados, Mato Grosso do Sul state, with averages close to 40% of crude protein. However, Maziero (2019) evaluated different safflower cultivars in Cascavel, Paraná state, and observed protein contents ranging from 7.7 to 16.6%. The concentration of oil and protein is inherited as a quantitative trait, influenced by the environment (Wilcox & Guodong, 1997). The protein content in the grains varies around 20%, while the seed cake has 35% to 45% protein and can be used in ruminant and monogastric feed, as it does not have anti-nutritive factors (Ebrahimian & Soleymani, 2013).

Twelve genotypes of carts with all the variables obtained were grouped into two main groups (Figure 1). Using the cut-off point by the Mojena method (1977), we obtained this separation at K=1.25 (8.69714). These groupings were 1st (Gen135 and Gen211) and 2nd (Gen133, Gen65, Gen54, Gen119, Gen63, Gen73, Gen77, Gen122, Gen32, Gen50).

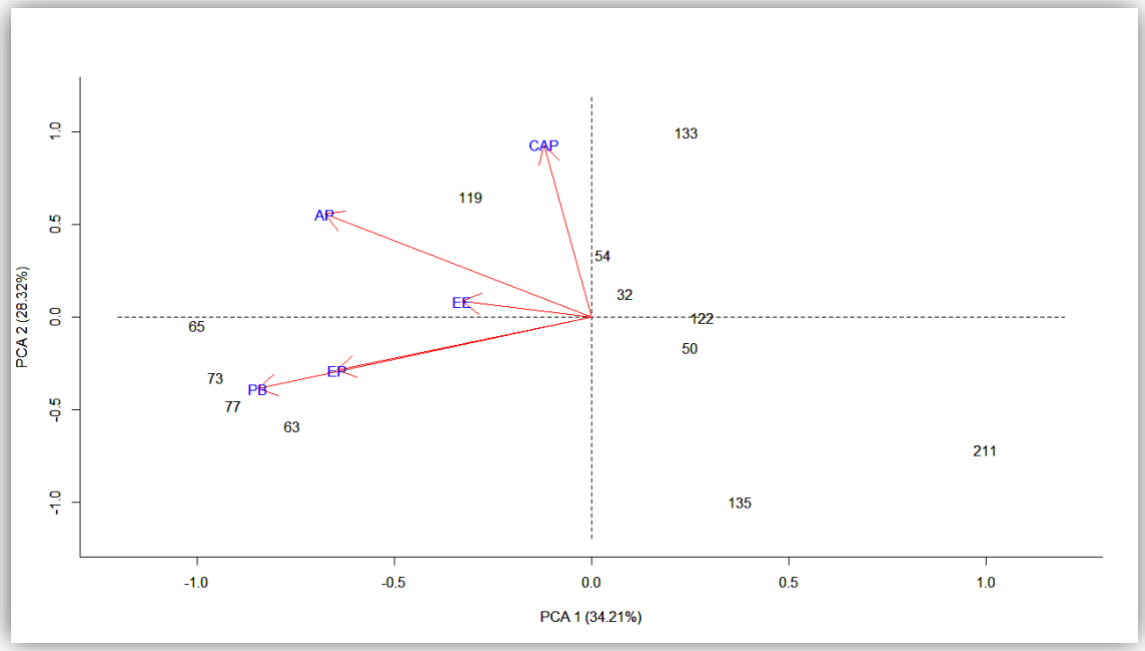
Figure 1. Dendrogram of genetic dissimilarity of the 12 genotypes of *Carthamus tinctorius*



Source: The authors (2024).

When examining the principal components (Figure 2), we observed that 62.53% of the variability in the data can be explained by the first two components. Principal component 1 (PCA1) reveals that this component explains 34.21% of the total variance of the data and principal component 2 (PCA2) explains 28.32% of the variation.

Figure 2. Multivariate analysis containing Seedling Emergence (EP), Plant Height (AP), Number of Flowers Head (CAP), Ether Extract (EE), Crude Protein (PB) correlating the 12 genotypes of *Carthamus tinctorius*



Source: The authors (2024).

The analysis of the graphic dispersion allows us to visualize a considerable variability regarding the morphological and bromatological parameters of the safflower. For the genotypes Gen63, Gen65, Gen73 and Gen77 there is a low estimate for the two main components. However, we observed that the genotypes Gen73 and Gen77 exhibit high estimation for the crude protein variable, differing from the other points in the quadrant where they are located. In addition, for both Gen73 and Gen77 genotypes, seedling emergence is also highly estimated, although with a lower influence on crude protein.

On the other hand, the genotype Gen119 was the only one that presented high estimates for principal component 2, presenting higher estimates for the variable's flowers head, plant height and etheric stratum.

As for the genotypes Gen32, Gen50, Gen54, and Gen122, it is observed that they are more closely grouped in space, indicating the existence of similar characteristics among these genotypes. On the other hand, for the genotypes Gen135 and Gen211, they were the ones that presented high estimates for the main component 1. Nevertheless, genotype Gen133 was the only one with a high estimate for both principal components and does not share similar characteristics with any other genotype.

By multivariate analysis, genotypes Gen73, Gen77 and Gen119 showed advantageous characteristics for selection criteria when correlated with crude protein and ether stratum. This is due to the fact that the first two exhibit the highest values of crude protein, while the third demonstrates the highest values for ether extract. Therefore, the choice of the best genotype will depend on the purpose, since crude protein assumes special importance in cattle feed. On the other hand, Ethereal Extract plays a key role in the production of safflower oil.

4.FINAL CONSIDERATIONS

The genotypes of *Carthamus tinctorius* L. Gen73, Gen77 and Gen63 when compared to the others, have a superiority in their morphological and bromatological characteristics.

The genotypes evaluated are promising for use in the *Cerrado*, especially in the transition region to semi-arid.

Further studies focusing on the planting time and crosses of these genotypes are recommended.

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