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Diversity Assessment of Sunflower (*Helianthus annuus* L.) varieties in Cameroon through Agromorphological and Biochemical Traits

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ABSTRACT
Objectives: The sunflower (*Helianthus annuus L.*) is an important worldwide oilseed crops, with new available genetic resources preserved by growers. It is rich in lipids and protein that could be suitable for direct consumption. The purpose of this research is to assess and characterize sunflower varieties maintained by growers in Cameroon.
Methodology and Results: Nine varieties collected from producers in Cameroon were evaluate using thirteen agro-morphological and four biochemical parameters. Analysis showed significant differences ($P < 0.05$) among the cultivars evaluated across all traits measured. The principal component analysis showed that the first two axis explained 70.44% highlighting information relating to biochemical parameters. The diameter of the flower head correlated positively with the collar diameter ($r = 0.75$). Protein content correlated positively and significantly with number of achenes per flower ($r = 0.64$) and oil content is correlated with leaf surface ($r = 0.60$). Seeds of DsZM variety were richer in lipids and DsZG and MbBM, richer in protein.
Conclusions and application of findings: This study shows a remarkable genetic diversity of the studied sunflower varieties as an indication of a broad genetic base potential that could be performed for sunflower breeding programs in Cameroon. These findings show that growth parameters have an impact on plant yield while good vege/tative development of the plant promotes good development of the reproductive system. Sunflower seeds rich in lipids could be appropriated for the production of vegetable oils while those were rich in protein, could be suitable for direct consumption.
Key words: *Helianthus annuus*, morphological characters, nutritional values, varieties, yield.

INTRODUCTION

The Sunflower (*Helianthus annuus L.*, Fig. 1) is the fourth (9%) worldwide most consumed oilseed plant after oil palm (33%), soya (26.4%) and rapeseed (15%) (Duriez, 2019); with about a global production of around 47 million tonnes in 2023 of vegetable oil (USDA, 2023). Its positive properties such as the high content of unsaturated fatty oleic and linoleic acids, the lack of linolenic and trans fatty acids, the vitamin E, as well as the strongest resistance to oxidation and the very highest smoke point make it a premium quality oil (Koshani & Zarif, 2023) Zhenyuan *et al.,* 2024). This sunflower oil is recommended for people following a diet because of its high contents of omega 6 (linoleic acid) and Vitamin E (powerful antioxidant) contents and which contribute to the prevention of hyper-cholesterolemia and hypertriglyceridemia (Huth *et al.,* 2015). Livestock equally consume sunflower meals for protein needs (Allinne *et al.,* 2023). These numerous positive properties are associated with sunflower species genetically well-known, performed or even modified for reaching the highest production rate in industrial exploitations.

Fig. 1: Visual depiction of Sunflower (*Helianthus annuus* L.)

Numerous varieties with unknown genetic characteristics continue to be cultivated by growers on a small scale solely for family consumption and therapeutic purposes. The occurrence of this plant in Cameroon results in the existence of varieties as different from each other, differentiated by growers based on their organoleptic characteristics and the various uses in the ancestral pharmacopoeia. In Cameroon for instance, studies were carried out in the far North Region, in collaboration with the Institute of Agricultural Research for Development (IRAD) reporting a production of grains which yield ~1.62 t/ha (Wey *et al.,* 2008). The plant growth is considered satisfactory in sunny areas and on light, well-drained sandy loam soils (Yerima *et al.,* 2014). Despite the economic advantages and the resilience of the sunflower to colonize various types of soil, very little work has been devoted to identifying the performance of sunflower varieties grown by farmers in Cameroon. The increasingly growing trend of sunflower production in Cameroon, statistical data and those related to the performance of its cultivars remain unknown (Shah *et al.,* 2013; Asongwe *et al.,* 2014). In parallel, the country has enormous potential for expansion of cultivation in respect to its different agro pastoral zones and the increasing demands for vegetable oils for human consumption (Yerima *et al.,* 2014). Knowledge of the genetic parameters of a species is essential for its characterization and for guiding the processes involved in genetic improvement programs. Such knowledge is also critical for promoting sustainable development and ensuring food security, in line with the United Nations Sustainable Development Goals (SDGs) (Esquinas-Alcázar, 2005). Consequently, the search for new genotypes that combine superior agronomic performance with enhanced nutritional value remains a continuous objective, aimed at developing germplasm suitable for breeding programs. Genetic diversity within germplasm plays a crucial role in the selection of parental lines for the development of high-yielding varieties. Moreover, information on variability is vital for establishing effective selection criteria to improve seed yield and related traits (Singh, 2019). In this context, the present study seeks to assess the genetic diversity potential of several sunflower varieties cultivated in the West and Centre Regions of Cameroon.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted in Melong 2 village (792 m above sea level; 5°93'19.950''N, 9°57'19.906''E), located in Baré-Bakem (Moungo Division, Littoral Region), between August and December 2023. The site experiences a climate with an average temperature of approximately 22.5°C (ranging from 18°C to 31°C) and an annual rainfall of around 1364.4 mm. The soil is clay-loamy, acidic in nature (pH = 5.2) (Table 1).

Table 1. Soil physicochemical analysis

Parameters	Unity	Value
Sand	%	27
Clay	%	42,5
Silt	%	30,5
PH		5,2
Organic carbon	%	3,33
Total nitrogen	%	0,21
carbon/nitrogen ratio		15,99
CEC	me/100g	18
Assimilable phosphorus	mg/Kg	44.78
Saturation	%	55
Calcium	meq/100g	5
Magnesium	meq/100g	4.40
Potassium	meq/100g	0,35
Sodium	meq/100g	0,11

Legend: ppm=part per million;

Plant material: The plant material tested consists of nine varieties (DsNM, DsZM, DsNd, DsZG, YdeZM, MbZG, BhZM, YdeZP and MnBM) which were collected from the producers at West (Dschang, Mbouda, Bangang, Baham) and Centre (Yaounde) Regions of Cameroon (Figure 2;Table 2).

Figure 2. Sunflower achenes collected in field producers.

Table 2: Origins and characteristics of achenes presented in figure 2.

Code	Origin	Characteristics of achenes (shell colour and nature)
DsNM	Dschang	Black and Rigid
DsZM	Dschang	Zebra and Rigid
DsNd	Dschang	Black and Soft
DsZG	Dschang	Zebra and Rigid
YdeZM	Yaounde	Zebra and Rigid
MbZG	Mbouda	Zebra and Rigid
BhZM	Baham	Zebra and Rigid
YdeZP	Yaounde	Zebra and Rigid
MbBM	Mbouda	White and Rigid

Methods

Culture and experimental conditions : The achenes were selected based on their physical quality and health, and were treated with Nordox powder, a copper-based fungicide. Sowing was done at a depth of 3 cm in polystyrene bags filled with a potting mix consisting of 1 part chicken droppings and 4 parts black soil. An area of 300 m² was ploughed, and ridges were constructed and amended with laying hen droppings at a rate of 3 kg per ridge. Twenty plants from each cultivar were transplanted into a single row within each block, 20 days after sowing (DAS). The plants were spaced 50 cm apart within rows and between rows. After transplantation, the plants were treated with an organic insect repellent made from fresh *Tithonia diversifolia* leaves fermented for seven days in tap water (Ngando *et al.*, 2022).

Manual weeding was performed twice during the growing period: once at one month and again at two months after transplantation. The trial was initiated in September and harvested in December 2023. For the measurements, ten plants per row were selected. The observations focused on thirteen agro-morphological descriptors and four biochemical parameters, recorded at both flowering and post-harvest stages (Table 3). A completely randomized block design with three replications was used for the agro-morphological evaluation of the nine cultivars.

Table 3. Agro-morphological and biochemical descriptors of Sunflower cultivars

Type of descriptors	Descriptors	Abbreviations	Units
Agronomic	Collar diameter	DC	(cm)
	Plant height	HP	(m)
	Number of leaves	NTF	---
	Leaf area	SF	(cm^2)
	Diameter of the flower head	Dca	(cm)
	Number of achenes per flower head	NbrG	----
	Weight of a thousand grains	PMG	(g)
	Achene yield	Rgrs	(t/ha)
	Length of the achene	LG	(mm)
	Width of the achene	Lg	(mm)
	Thickness of the achene	EG	(mm)
	Shell weight	Pco	(g)
	Seed weight	PA	(g)
Biochemical	Moisture content	Thu	(%)
	Ash content	TC	(%)
	Oil content	Thuile	(%)
	Protein content	Tpro	(%)

Analytical methods: An analysis of variance (ANOVA) was conducted to identify the parameters that distinguish between cultivars, using a 5% probability threshold. Descriptive statistics were applied to compare the quantitative morphological traits of the studied varieties. Pearson correlations were used to examine the relationships between the various parameters. Principal component analysis (PCA) and Agglomerative Hierarchical Clustering (AHC) were performed to organize the data, assess the degree of similarity, and explore the relationships between the cultivars. All statistical analyses were carried out using EXCEL version 2013 and R software version 4.3.3.

RESULTS

Agronomic and biochemical diversities: Tables 4 and 5 display growth and yielded performances of agronomic and biochemical sunflower cultivars. The collar diameter (DC) ranges from 1.69 ± 0.33 to 2.65 ± 0.49 cm (~2.24 cm); the plant height (HP) from 1.73 ± 0.29 to 2.36 ± 0.15 cm (~2.05 cm); and the leaf area (SF) from 3.04 ± 0.78 to 6.41 ± 2.28 cm^2 (~4.78 cm^2) for p-value > 0.05. The number of leaves (NTF) varies between 32.3 ± 7.1 and 42.6 ± 4.85 (~36.94); the diameter of the flower head (Dca) from 9.01 ± 0 and 19.33 ± 0.5 cm (~13.10 cm); the weight of a thousand achenes (PMG) between 43.3 ± 0 and 100 ± 10 g (~56.7 g); the number of achenes per flower head (NbrG) between 377.4 ± 97 and 1298.33 ± 1.50 (~679.3); achene yield (Rgrs, t/ha) between 0.82 ± 0.03 and 5.19 ± 0.52 (~1.91 t/ha); the length of the achene (LG) between 10.57 ± 0.77 and 13.42 ± 0.08 cm (~12.67 cm);

the width of the achene (Lg) between 4.77 ± 0.25 and 7.04 ± 0.06 cm (~5.67 cm); and the thickness of the achene (EG) between 2.84 ± 0.03 and 4.13 ± 0.12 cm (~3.30 cm) for all p-values <0.001. The weight of the shell is between 40 - 65% of the weight of the total achene. The weight of the seed is inversely proportional to the weight of the shell and ranges between 35 - 65% of the weight of the achene.

Table 4: Growth performances of sunflower cultivars

Cultivars	**DC**	**HP**	**SF**	**NtF**
DsNM	2.65 ± 0.49 **ab**	2.32 ± 0.24**a**	5.84 ± 3.15**a**	42.6 ± 4.85**a**
DsZM	2.25 ± 0.60**abc**	1.75 ± 0.56**b**	6.41 ± 2.28**cd**	32.53 ± 5.27**cd**
DsNd	2.39 ± 0.59**abc**	1.73 ± 0.29**b**	5.06 ± 2.68**cd**	32.6 ± 2.35**cd**
DsZG	2.32 ± 0.18**abc**	2.1 ± 0.04 **ab**	5.64 ± 0.12**bcd**	34.7 ± 0.3**bcd**
YdeZM	2.24 ± 0.02**abc**	2 ± 0 **ab**	3.56 ± 0.06**ab**	41 ± 1**ab**
MbZG	1.69 ± 0.33**c**	1.93 ± 0.32 **ab**	3.04 ± 0.78**d**	32.3 ± 7.1**d**
BhZM	1.86 ± 0.34**bc**	2.1 ± 0.2 **ab**	4.07 ± 0.01**abcd**	36.2 ± 0.4**abcd**
YdeZP	2.33 ± 0.84 **abc**	2.05 ± 0.02**ab**	4.78 ± 1.16**abc**	39.27 ± 2.9**abc**
MbBM	2.8 ± 0.10 **abc**	2.36 ± 0.15**a**	6.39 ± 0.19**ab**	41.44 ± 0.5**ab**
Mean	2.24	2.05	4.78	3.02
Standard deviation	0.32	0.30	1.79	4.17
F value	1.58	2.03	1.61	4.01
Pr (>F)	0.19	0.10	0.18	0.0068

Values with the same letter in a row are not significantly different from each other (P < 0.05).

Biochemical analyses reveal the protein and fat/lipid contents in seeds, which vary between 13.34-16.35% and 31.85-49.5%; while the moisture content and the ash content range from 2 to 5.73% and between 12.6% and 19.7%, respectively (Figure 3).

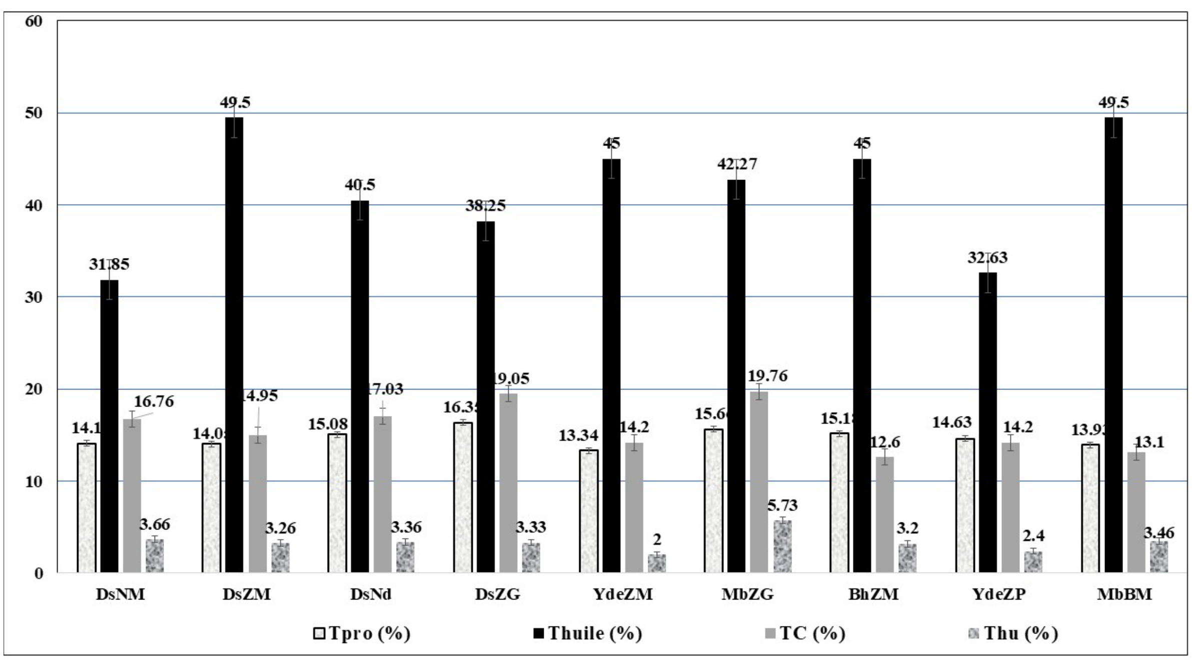

Figure 3. Biochemical variables of sunflower seed.

Performances and correlations

Agronomic and biochemical performances : The MbZM cultivar cumulates most of all the best performances observed in studied cultivars for DC, HP, Dca, PMG, Rgrs, NbrG, laG and EG parameters. DsZM, DsNM and DsZG each have a single best performance for SF, NtF and LG, respectively. DsZG shows the best performance of protein content for ~16.35%. DsZM and MbBM oil contents culminated at ~49.5% each while MbZG displayed 19.76% of ash content. The dimensions of the achenes show that the length, width and thickness of the achenes are 12.67 cm, 5.67 cm and 3.30 cm, respectively. The weight of a thousand achenes (PMG) is between 43.33 ± 0 g and 110 ± 10g. Achene yield (Rgrs) showed significant differences between cultivars with values ranging from 0.82 t/ha to 5.19 t/ha and an average of 1.91 t/ha (Tables 4 and 5).

Table 5. Agronomic Performances of cultivars

Cultivars	Dca (cm)	PMG(g)	NbrG	Rgrs(t/ha)	LG	Lg	EG	Pco	PA
DsNM	13.23 ± 0.73**bc**	65.77 ± 3.27**bc**	942.33 ± 410.76**ab**	2.44 ± 0.94**b**	12.72 ± 0.62**bc**	6.43 ± 0.28**ab**	3.44 ± 0.24**b**	23.01 ± 2.12**b**	42.74 ± 2.12**cd**
DsZM	14.4 ± 1.74**ab**	54.97 ± 9.76**cd**	881.56 ± 313.88**abc**	2.006 ± 0.95**bc**	12.8 ± 1.42**bc**	5.65 ± 1.49**abc**	3.73 ± 0.52**bc**	28.03 ± 4.78**cde**	26.93 ± 4.78**bc**
DsNd	13.4 ± 5.09**bc**	51.37 ± 7.27**d**	662.78 ± 133.36**bc**	1.38 ± 0.44**cd**	11.05 ± 1.67**d**	6.01 ± 1.33**abc**	3.38 ± 0.05cd	30.82 ± 2.91**ef**	20.55 ± 2.91**b**
DsZG	12.72 ± 2.61**bc**	71.03 ± 6.75**b**	601.4 ± 32**bcd**	1.71 ± 0.25**bcd**	16.58 ± 0.47**a**	5.71 ± 0.03**ab**	3.21 ± 0.02**bcd**	28.41 ± 4.05**b**	42.62 ± 4.05**bc**
YdeZM	9.4 ± 0.2**cd**	47.63 ± 1.87**d**	714 ± 14**abc**	1.36 ± 0.06**cd**	11.98 ± 0.01**cd**	5.29 ± 0.01**bc**	3.38 ± 0.13**cd**	19.05 ± 1.12**def**	28.58 ± 1.12**d**
MbZG	9.01 ± 0**d**	56.67 ± 13.35**cd**	377.4 ± 97**d**	0.82 ± 0.03**d**	12.62 ± 1.18**b**	4.81 ± 0.54**c**	2.89 ± 0.32**d**	27.20 ± 6.94**c**	29.46 ± 6.94**bc**
BhZM	12.93 ± 1.25**bc**	43.3 ± 0**d**	574.17 ± 105.16**cd**	0.99 ± 0.18**cd**	11.01 ± 0.08**d**	5.34 ± 0.14**bc**	2.97 ± 0.04**cd**	23.81 ± 0**f**	19.48 ± 0**cd**
YdeZP	13.77 ± 0.2**bc**	44.4 ± 0.52**d**	717.33 ± 246.56**bc**	1.27 ± 0.42**cd**	10.57 ± 0.77**d**	4.77 ± 0.25**c**	2.84 ± 0.03**cd**	22.20 ± 0.26d**ef**	22.2 ± 0.26**cd**
MbBM	19.33 ± 0.5**a**	100 ± 10**a**	1298.33 ± 1.50**a**	5.19 ± 0.52**a**	13.42 ± 0.08**bc**	7.04 ± 0.06**a**	4.13 ± 0.12**a**	42 ± 5.8**a**	58 ± 4.2**a**
Mean	13.10	56.7	679.3	1.91	12.67	5.67	3.30	27.17	32.28
Standard deviation	3.02	17.59	263.82	1.32	1.86	0.73	0.44	6.65	12.89
F value	3.75	17.6	5.11	18.79	12.48	3.298	9.67	33.16	10.70
Pr (>F	0.0093**	4.909e-07***	0.0019**	3.22e-07***	6.36e-06***	0.016*	3.82e-05***	3.11e-09***	1.89e-05***

Values with the same letter in a row are not significantly different from one another ($P < 0.05$).

Agronomic and biochemical correlations: Table 6 displays relationships between agromorphological and biochemical parameters. The diameter of the flower head correlated positively with the collar diameter (r = 0.75), the leaf surface (r = 0.78), the number of achenes per flower head (r = 0.89), the achene yield (r = 0.83) and the weight of thousand achenes (r = 0.67). However, cultivars whose flower heads have a large diameter carry numerous achenes but with considerable thickness, hence the strong correlation (r = 0.70). Plant height correlated strongly and positively with thousand achene weight (PMG) (r = 0.65), NTF (r = 0.79) and achene yield (r = 0.64). Protein content (Tpro) correlated with NTF (r = 0.62), NbrG (r = 0.64), EG (r = 0.55) and Pco (r = 0.70). However, the oil content (Toil) is positively and significantly correlated with SF (r = 0.60), LG (r = 0.60) and EG (r = 0.54). Table 7 highlights the eigenvalues and percentages of variation of each axis of the PCA. The first two axes represent 70.44% of the total variation with 51.42% for axis 1 and 19.01% for axis 2, respectively. The first axis showed positive correlations with the parameters Tpro, TC and Thu. However, the second axis showed positive correlations with the parameters DC, HP, NTF, Dca and NbrG. Axis 2 can therefore be described as the axis of vegetative development and achene yield while axis 1 provides information relating to biochemical parameters (Figure 4a). The AHC groups the 9 sunflower cultivars into three classes or groups (Figure 4b). Group 1 is made up of 2 cultivars (DsNM and MbBM) having the highest performances for vegetative growth parameters (DC, HP, SF, NtF) and dimensions (LG, Lg et EG) of the achenes. Group 2 consists of 2 cultivars (DsZG and MbZG) with the longest achenes and high protein content. Group 3 is composed of DsZM, DsNd, YdeZM, BhZM and YdeZP with small plants with small seed sizes but a diameter medium flower head and a high oil content.

Table 6. Correlation matrix of agronomic and biochemical parameters

	DC	**HP**	**SF**	**NTF**	**Dca**	**PMG**	**NbrG**	**Rgrs**	**LG**	**Lg**	**EG**	**Pco**	**PA**	**Tpro**	**Thuile**	**TC**	**Thu**
DC	1																
HP	0.52	1															
SF	0.77	0.25	1														
NTF	0.68	0.79	0.15	1													
Dca	0.75	0.44	0.81	0.27	1												
PMG	0.67	0.65	0.59	0.31	0.68	1											
NbrG	0.89	0.55	0.76	0.59	0.84	0.70	1										
Rgrs	0.82	0.64	0.68	0.49	0.84	0.90	0.92	1									
LG	0.21	0.27	0.38	-0.08	0.10	0.60	0.10	0.30	1								
Lg	0.82	0.51	0.73	0.27	0.69	0.72	0.87	0.86	0.32	1							
EG	0.74	0.27	0.71	0.27	0.69	0.72	0.87	0.86	0.28	0.84	1				2		
Pco	0.49	0.24	0.54	-0.10	0.75	0.82	0.56	0.77	0.32	0.68	0.67	1					
PA	0.68	0.75	0.54	0.48	0.54	0.95	0.68	0.85	0.66	0.74	0.66	0.62	1				
Tpro	-0.46	-0.17	-0.18	-0.62	-0.23	-0.062	-0.64	-0.40	0.39	-0.30	-0.54	0.07	-0.13	1			
Thuile	-0.10	-0.18	0.05	-0.26	0.22	0.25	0.23	0.32	0.06	0.18	0.53	0.46	0.10	-0.25	1		
TC	-0.26	-0.25	-0.14	-0.48	-0.47	0.02	-0.51	-0.33	0.52	-0.16	-0.30	-0.02	0.07	0.65	-0.35	1	
Thu	-0.38	-0.04	-0.20	-0.46	-0.19	0.22	-0.30	-0.05	0.20	-0.04	-0.14	0.30	0.15	0.49	0.062	0.62	1

Table 7. Eigenvalues and percentage of variation of two axes of the PCA

Axes	Real value	% of variation	%cumulative variation
Axe 1	8.74	51.42	51.42%
Axe 2	3.24	19.01	70.44%

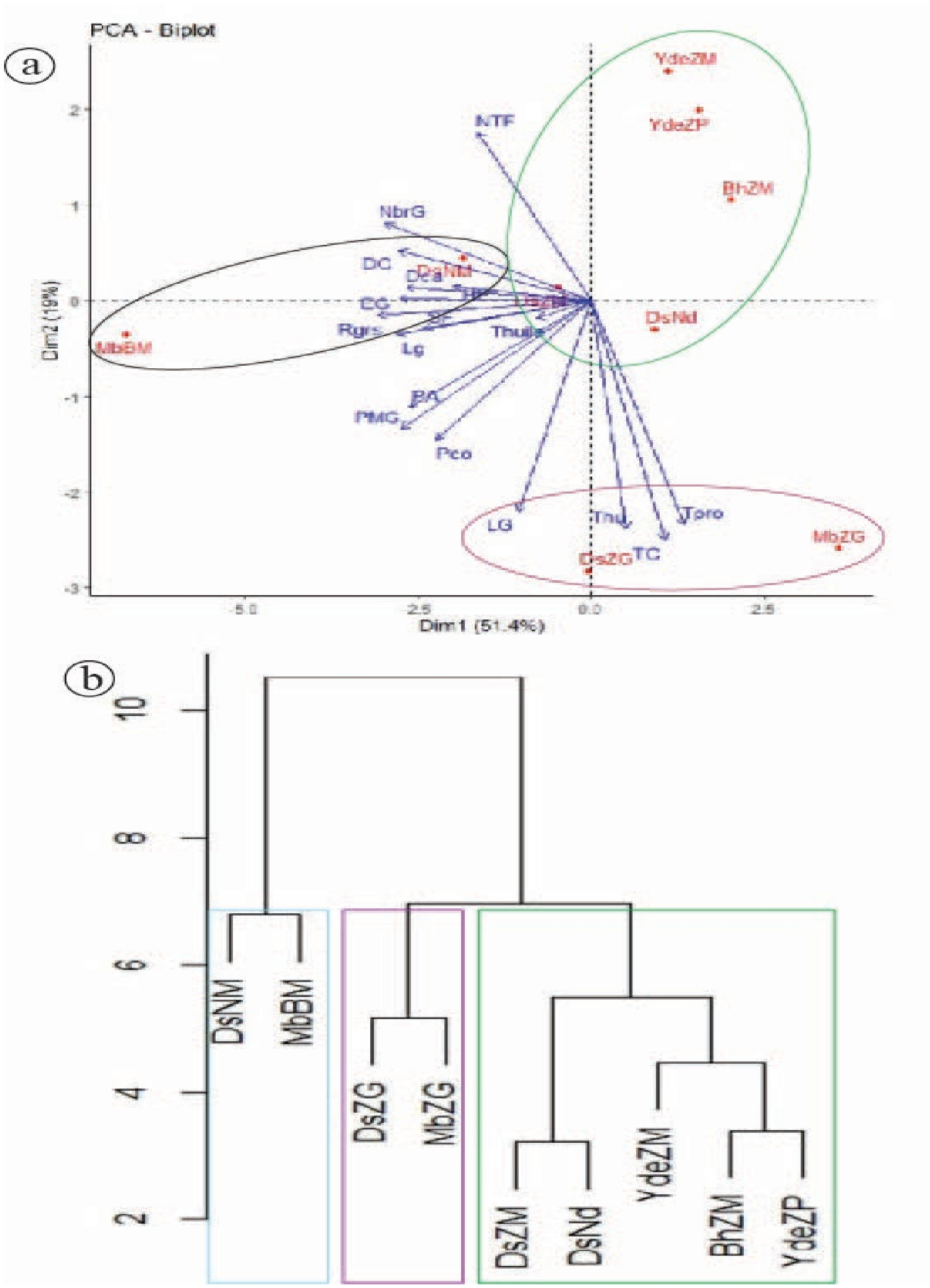

Figure 4. Grouping of cultivars based on agronomic and biochemical traits. a) PCA biplot; b) Dendrogram.

DISCUSSION

To identify many crops, knowledge of the morphological, agronomic, biochemical and molecular diversity of germplasm collections is fundamental importance for plant genetic resources. This is an earliest efficient step for the development of breeding programs since it provides a reliable classification system and facilitates the identification of accessions with potential utility for specific traits (De la Vega *et al.,* 2007; Prada, 2009). The studied agromorphological and biochemical parameters have been routinely included in many diversity surveys of sunflowers (Ahmadpour *et al.,* 2013; Saremirad & Mostafavi, 2020; Sasikala *et al.,* 2020). There are indicators of genetic diversity which can be considered as the key success for crop improvement strategy (Terzić *et al.,* 2020). They are highlighted by additive valuable main effects and multiplicative interaction in several bi-plots, such as ANOVA, PCA, HAC and Pearson correlations in order to assess the level of resemblance of cultivars, their existing relationships and genetic diversity.

Genetic diversity: The studied nine sunflower varieties were characterised by using thirteen quantitative agromorphologic traits (Tables 3, 4 and 5). Except MbZG and BhZM, all other traits have a DC higher than 2 and which culminates at ~2.8 in MbBM. HP which is lower to 2 in MbZG, DSND and, higher than 2 in others, reached a maximum value in MbBM. All SF values are greater than 3 and culminate in MbBM (~6.39) and DsZM (~6.41), respectively. NtF were greater than 32.53 and reached good to best performances culminating in MbBM (41.44 ± 0.5) and DsZM (~42.6 ± 4.85). All these trait values are quite similar, greater or to those reported in literature (Yerima *et al.,* 2014; Punitha *et al.,* 2010; Mohd *et al.,* 2014, Zhenyuan *et al.,* 2024). These highlight the MbBM, DsNM and YdeZM cultivars as are the best sunflower candidates for growth performance criterion. These quantitative variables indicate their different distinctive origins as well as they revealed a high variability of genetic heterogeneities. For fourth studied biochemical variables and excluding YdeZM, all cultivars have Tpro <16% reaching the best performance in DsZG (Tpro ~16.35%) which remains is lower than 28% to 37% and 18.46 to 22.57% reported in Duriez (2019) and Zhenyuan et al. (2024), respectively. Thuile (31.85% to 49.5%) is quite similar to available results such as 43.1 - 45.1% of Wey et al. (2008notably 39.80 - 52.24% and 47.6 - 52.13% in endogenous and improved varieties (Ramdé, 2014), respectively. The relatively low moisture content in studied samples (2 - 5.73%), is quite comparable to 3.91% - 5.04% and 3.56% - 4.97% for endogenous and improved cultivars from Burkina Faso (Ramdé, 2014) as well as edible sunflower achenes (4.40~5.08%) generally higher than those (2.72~5.08%) reported by Zhenyuan et al. (2024) suggesting a good protection against seeds deterioration as well as a high oil potential, the pleasant aroma and suitability of edible sunflower after roasting (Zhenyuan *et al.,* 2024). Ashes content (12.6% - 19.7%) are higher to Ramdé (2014) reported local varieties (3.35% - 6.34%). These biochemical findings equally suggest different distinctive origins and the highest genetic diversity of studied varieties.

Correlation between agronomic and biochemical parameters: The correlations between the morphological and biochemical parameters shown significant and positive correlations between the yield of achenes and other studied components such as HP, DC, DCa, PMG and NbrG which are consistent with the results of Kaya et al. (2009), Mudassar *et al.* (2013) and Yerima et al. (2014). Dca correlated positively with SF and NTF reported by Abrar et al. (2010). The highest correlation coefficient between HP and Rgrs pinpoints the plant height's important role in improving achene yield and other yield components (Kaya *et al.,* 2009). Large surface leaf areas could equally increase the total production of biomass and increase the fixation of carbon ultimately distributed in the reproductive organs linking leaf surface and diameter of the flower head and the weight of thousands of achenes. Arshad *et al.* (2018) found a direct effect of plant height on sunflower yield. Amin *et al.* (2016) reported a positive and significant correlation between plant height and stem diameter, head diameter, 100-achene weight, and achene yield per plant. Mudassar et al. (2013) noted a positive and significant relationship between stem diameter and head diameter in sunflower. Additionally, oil content and achene yield were positively and significantly correlated, consistent with the findings of Shankar *et al.* (2006) and Farratullah *et al.* (2006), while they showed a negative correlation with protein content, as reported by Zhenyuan et al. (2024).

Genetic promoting potential: MbZM appears to be the top-performing variety, exhibiting the best results for parameters such as DC, HP, Dca, PMG, Rgrs, NbrG, laG, and EG. On the other hand, DsZM, DsNM, and DsZG each show the highest performance for SF, NtF, and LG, respectively. DsZG, DsND, and MbZG stand out for their superior protein content (>15%), while DsZM and MbBM have the highest oil content (>49.5%). These findings suggest that vegetative development positively impacts achene sunflower yields, highlighting strong variability in the cultivars and their diverse origins. In addition, the percentage of variance explained by the first two principal component axes is high (70.44%), indicating a strong genotypic and phenotypic differentiation among the cultivars (Do *et al.*, 2020). This contrasts with the relatively low percentages reported by other authors for different species (Djè *et al.,* 2007; Do *et al.*, 2020). These results further demonstrate that growth parameters significantly influence plant yield, and that robust vegetative development fosters effective reproductive system growth. This correlation underscores the importance of both factors in sunflower genetic diversity studies and breeding programs (Carvalho *et al.*, 2017). The cluster analysis identified three main groups, with varieties within each group sharing similar sets of agronomic and biochemical traits. These clusters, based on a combination of vegetative and production-related traits, provide valuable insights for sunflower genetic diversity and can aid in breeding program development.

CONCLUSION

The characterization of 9 sunflower varieties was carried out using thirteen morphological and agronomic markers and four biochemical markers in order to evaluate their origin and genetic diversity. It appears at the end that:

- agro-morphological and biochemical markers are complementary for better characterizing and studying the genetic diversity of sunflowers in Cameroon.
- the morphological and biochemical characterizations allowed the identification of an important agro-morphological variability and genetic diversity among the varieties for improving the sunflower breeding programs.
- DsZM, MbBM and DsZG seeds are best candidates for oil production and proteinic direct consumption.

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