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Evaluation of Quantitative Traits of Horse Gram Accessions [*Macrotyloma Uniflorum* (Lam.) Verdc] Introduced in Burkina Faso

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Abstract: Major crops will face major challenges in the near future if the climate change trend continues. Thus, diversification away from over-reliance on staple foods will be important as progress towards the goal of nutrition security. Therefore, tolerant underutilized or neglected crop species may be a key to achieving this goal. The gram horse [*Macrotyloma uniflorum* (Lam.) Verdc] of the Fabaceae family, is a minor species. less known. It is a grain legume of excellent nutritional quality, possessing many therapeutic properties. It is resistant to several production constraints which allows it to adapt to the harshest environmental conditions. However, it is being introduced in Burkina Faso. The study was conducted at the Institute of Environment and Agricultural Research (INERA) in Farako-Bâ to assess the nature and extent of variability of 25 accessions introduced and also to identify the best ones for extension or use in other varietal improvement programs. It was conducted according to a Fischer block device with three repetitions in rainfall. The measurements covered fifteen (15) quantitative variables subjected to different statistical analyses. The set of characteristics discriminate between the accessions studied. The results indicated significant differences within accessions for all traits studied, indicating the presence of significant genetic variability. Strong correlations were also observed between variables either positively or negatively. The study of the structuring of accession diversity identified four groups, whose Group I and IV accessions could be used in a hybridization program to develop high-yielding, short-cycle genotypes.

Keywords: Agronomic Evaluation, Burkina Faso, Horse Gram, Quantitative Traits

1. Introduction

In Burkina Faso, the agricultural sector occupies a prominent place in the country's economy. Agriculture is dominated by food crops (sorghum, millet and maize), cash crops (cotton, groundnuts and sesame) and seed legumes such as cowpea and voandzou. These different crops are already the subject of a lot of fundamental and applied research by the various actors in agriculture and research. Indeed, according to Nubé Menso & Voortman Roelf L. [1]. the dependence of a few crops negatively affects ecosystems. dietary diversity and health. Thus, the decrease in the diversity of plant genetic resources contributing to the global food supply has been considered a potential threat to food security [2]. Agricultural diversification is an indispensable tool in achieving food security [3]. However, current agricultural and food systems have limited production diversity, resulting in unbalanced diets and consequently, malnutrition [4]. To maintain food security and address global malnutrition issues, it is imperative to diversify global food sources and cropping systems by explicitly reorienting so-called orphaned or underutilized crops to include agriculture as possible future crops [5]. Neglected species offer immense opportunities to fight poverty, hunger and malnutrition and their incorporation into agricultural systems could lead to nutrient-rich, climate-resilient and sustainable agriculture [6]. They have a high nutritional value and are a good source of micronutrients, protein, energy and fiber. Among these underexploited species is the [*Macrotyloma uniflorum* (Lam) Verdc] commonly known as horse gram or horse grain or kulthi bean. It is a legume native to Southeast Asia where it is widely cultivated, particularly in the dry regions of Australia, Burma, India, Sri Lanka and tropical Africa [7]. It belongs to the Fabaceae family and is a great nutritional richness with a good ability to adapt to harsh environmental conditions [8]. Indeed, the nutritional composition and medicinal properties of horse gram make it a rich and cheap food source [9]. Indeed, one horse gram seed. in addition to vitamins such as thiamine (0.4 mg), riboflavin (0.2 mg) and niacin (1.5 mg) per 100 g of dry matter [10], contains 57.2% carbohydrates; 22% protein; 5.3% dietary fiber; 0.50% lipids; 287 mg calcium; 311 mg phosphorus; 6.77 mg of iron and 321 Kcal [11].

Thus, considering the introduction of new species of legumes is important in the context of increasing the genetic diversity of this family of plants and increasing the supply of legumes in a country. It is in this sense that [*Macrotyloma uniflorum* (L.) Verdc] was introduced to Burkina Faso by the Institute of Environment and Agricultural Research (INERA) as a diversified and drought-tolerant crop. Nevertheless, the efficient exploitation of this crop requires a better knowledge of its adaptation and agro-morphological variability in the ecological context of Burkina Faso. This approach could facilitate the selection of a number of lines adapted to the agro-climatic conditions of the country. It is in this dynamic that the present study is inscribed, which aims to evaluate some introduced accessions of horse gram in Burkina Faso through agronomic traits. Specifically, this involves: (i) establishing the level of variability of the accessions studied; (ii) establish the relationship between the characters; (iii) identify varieties of agronomic and nutritional interest.

2. Materials and Methods

2.1. Experimental Site

The study was carried out at the Environment and Agricultural Research Institute (INERA) at the Farako-Bâ station. The station is located about ten (10) km from Bobo-Dioulasso on the national road No. 7 connecting the city of Bobo Dioulasso to that of Banfora with the geographical coordinates 04°20 west longitude, 11°06 north latitude and 405 m altitude. The soils of the Farako-Bâ station are red soils with low ferralitic. generally deep [12]. These soils have a sandy-silty texture on the surface and clay-sandy texture at depth and are also characterized by relatively low levels of organic matter, exchangeable bases and nitrogen [13]. They have a desaturated absorbent complex and are very sensitive to leaching and erosion. The pH of Farako-Bâ soils is between 5.1 and 5.4 [14]. The climate of the zone is of South Sudanese type characterized by the alternation of two (02) seasons [15]. The vegetation encountered in the station is grassy savannah and wooded rather dense in places [16]. Precipitation is relatively high and varies between 800 and 1100 mm depending on the year.

2.2. Plant Material

Twenty-five (25) accessions of horse grams from the germplasm of the Agricultural Research and Formation Center (CREAF) of Kamboinsé constituted the plant material used in this study. These accessions come from the Nelson Mandela Agricultural Institute of Sciences and Technologies (NM-AIST) in Tanzania.

2.3. Methods

2.3.1. Experimental Device

The experimental device used for the test is a Fisher block with three (03) repetitions. Each elementary plot consists of two (02) lines of 2 m long with a total of 10 pockets. The spacing between the lines and between the pockets was 90 cm and 40 cm respectively. The elementary plots are separated from each other by 1 meter and the repetitions by two (02) meters. The elementary plots are separated by 1 m and the repetitions by 2 m. The total area of the test is 391 m^2 or 8.5 m x 42 m.

2.3.2. Conduct of the Study

The trial was conducted in the field during the rainy season between June and October 2022. Soil preparation consisted first of land clearing. then motorized flat ploughing. followed by harrowing and levelling. After manual shelving, sowing was carried out by hand at the rate of 3-4 seeds per pocket at a depth of 3-5 cm. Two weeks after sowing. weeding and application of NPK fertilizer (15-15-15) at a rate of 100 kg/ha was done. During this weeding operation a start-up to two (02) plants per pocket was carried out. A second weeding was done four weeks after planting to have good aeration of the soil and reduce weed competition. The systemic insecticide K-Optimal (Lambda Cyhalothrin 15 g/L + Acetamiprid 20 g/L) at a dose of 1L per hectare was used to control insect pests. The systemic fungicide Azox (Azoxystrobin 250 g/l) suspension concentrated at a dose of 40 ml/ha, was also used to control fungi in the plot. Insecticide treatments were carried out twice, one against flower insects at the formation of flower buds and the other seven days later against pod-sucking biting insects.

2.3.3. Data Collection

The data collected covered the quantitative characteristics which are: the dates 50% flowering and 95% maturity of the pods, the height of the plants, the chlorophyll content (SPAD), the number of primary branches, the primary leaf length. the terminal leaflet width, the terminal leaflet length, the weight of one hundred (100) seeds in grams, total seed weight, average number of pods per plant, number of seeds per pod, average pod length, pod weight and seed yield.

2.3.4. Data Analysis

In order to determine the discriminating traits, the manifolds and the relationships that would exist between the variables, an analysis of variance (ANOVA) and the Pearson correlation test were performed using GenStat v410.3 software, respectively. Principal component analysis (PCA) and accession coordinates were used for grouping by hierarchical ascending classification (HAC), which was performed by STATISTICA version 10 software. It was also used for the characterization of groups from the discriminant factor analysis (DFA) classification that was carried out using XLSTAT software.

3. Results

3.1. Average Performance of the Accessions Studied

The results of the analysis of variance of the quantitative traits studied are shown in table 1. The analysis of variance reveals highly significant differences for all quantitative traits studied at the 1% threshold. The average plant height of horse gram accessions ranged from 63.22 to 97.75 cm respectively for H44 and H35 accessions with an average of 81.82 cm. At leaflet level, accession H27 has the shortest terminal leaflets of 5.72 cm and H55 the shortest of 7.57 cm and 3.13-6 cm wide with an average of 6.73 cm. The width varied from 3.39 cm (H67) to 5.99 cm (H16). Their average length and width were 6.71 cm and 4.376 cm respectively. As for the length of the primary leaf, it varied from 5.75 cm (H27) to 8.12 cm (H46) with an average of 7.25 cm. The number of primary branches ranged from 5 (H60. H16) to 10 (H8) for an average of 7 branches. For the chlorophyll content of the accessions tested, with an average value of 38.19%, it was between 28.50% and 51.27% respectively for accessions H5 and H54.

Table 1. *Results of the analysis of variance of the quantitative traits studied.*

Variable	Minimum	Average	Maximum	CV (%)	R² (%)	F-Value	P-Value
50%Flo (JAS)	27	33	41	13.19	95.57	44.95	< 0.0001**
95%Mat (JAS)	63	68	76	5.46	87.38	14.42	< 0.0001**
TC	28.50	38.19	51.27	13.74	99.50	416.58	< 0.0001**
HP (cm)	63.22	81.82	97.75	14.82	49.51	2.04	0.017*
LngrFP (cm)	5.75	7.25	8.12	8.45	52.06	2.26	0.007**
LgrFT (cm)	3.39	4.38	5.99	14.50	94.80	37.97	< 0.0001**
LngrFT (cm)	5.72	6.73	7.57	8.82	48.17	1.94	0.025**
NR	5	7	10	17.22	86.71	13.59	< 0.0001**
LG (cm)	4.33	4.76	5.27	7.43	49.35	2.03	0.018**
NGP	53	89	118	18.81	99.50	414.36	< 0.0001**
NGG	5	6	7	8.87	51.69	2.23	0.008**
PG (Kg)	0.20	0.38	0.75	42.35	63.03	3.55	< 0.0001**
PGr (Kg)	0.13	0.22	0.42	35.86	88.37	15.83	< 0.0001**
P100Gr (g)	2.80	3.69	5.37	15.92	74.87	6.21	< 0.0001**
RdtGr (Kg)	719.70	1243.89	2336.54	35.86	88.37	15.83	< 0.0001

*: significant difference at 5%. **, significant difference at 1%, CV: coefficient of variation, R^2 (%): coefficient of determination, 50% Flo: 50% Flowering, 95% Matte: 95% Maturity, TC: Chlorophyll content, HP: Plant height (cm), LgrFT: Terminal leaflet width, LngFT: Terminal leaflet length, LngFP: Primary leaf length, NGP: Number of pods per plant, NGG: number of seeds per pod, NBP: Number of primary branches, LG: Pod length (cm), P100Gr: Weight of one hundred seeds (g), PG: Pod weight (kg), PGr: Seed weight (kg), RdtGr (kg): seed yield.

With an average of about 33 flowering days, the H75 accession was the first to bloom (21 days) while H5 had a late flowering (41 days). Physiological maturity at 95% of the accessions studied averaged 68 days. Thus, accessions H75, H50, H49, H54 reached maturity on the 63rd day compared to accessions H76, H27 which matured between the 74th and 76th days.

Regarding the number of pods per plant ranged from 53 in H27 to 118 in H69. Regarding the number of seeds per pod. accessions H69, H27, H16, H54, H44 and H35 had the highest number with 7 seeds per pod for an average of 6 seeds. The lowest number was obtained in H67 with 5 seeds. The length of the pod is between 4.33 cm and 5.27 cm with an average of 4.77 cm. The longest pods were collected on accessions H46 and H75 and the shortest on accession H35. Pod weights per accessions ranged from 0.198 kg (H74) to 0.746 kg (H55) with an average of 0.384 kg. For the hundred seed weight parameter (P100G). the average was 3.70 g. The H67 and H55 accessions had the highest 100 G weights (4.30 g and 5.37 g) and the H35 and H5 accessions the smallest weights of 2.80 g and 3 g respectively. While accessions H75 and H55 had the highest seed weights (0.393 kg and 0.421 kg). the lowest weights were recorded in accessions H15, H5, H35 and H74 (0.133 kg and 0.134 kg) for an average of 0.224 kg. For the accessions tested, the average seed yield (kg/ha) was 1243.89 kg/ha. The highest seed yields were recorded in accessions H75 and H55 (2185.65 kg/ha and 2336.54 kg/ha). Accession H15 produced the lowest seed yield (719.70 kg/ha).

Coefficients of variation were high (CV > 30%) for pod weight (CV = 42.35%), seed weight (CV = 35.86%) and seed yield (CV = 35.86%). On the other hand, they are low (CV < 30%) for the other characters.

The greater variability revealed within accessions is mainly explained by the "accession" factor. Number of days at 50% flowering (R^2 = 95.57%), number of days at 95% maturity (R^2 = 87.38%), chlorophyll content (R^2 = 99.50%), terminal leaflet width (R^2 = 94.80%). number of primary branches (R^2 = 86.71%), number of pods per plant (R^2 = 99.50%), pod weight (R^2 = 63.03%), seed weight (R^2 = 88.3 7%), weight of 100 seeds (R^2 = 74.87%), seed yield (R^2 = 88.37%) has the highest coefficients of determination ($R^2 \geq$ 60%). The height of the plant (R^2 = 49.51%). Length of the primary leaf (R^2= 52.06%). the length of the terminal leaflet (R^2 = 48.17%), the length of the pods (R^2 = 49.35%), the number of pods per plant (R^2 = 51.69%). have relatively low coefficients of determination ($R^2 \leq$ 50%).

3.2. Relationships Between the Characters Studied

Pearson's bivariate correlation matrix (Table 2) shows many significant correlations at the 5% level. Thus, a strong correlation was observed between the number of days at 50% flowering and the number of days at 95% maturity (r = 0.58). However, it is negative between the number of days at 50% flowering and the yield components and yield. The number of days at 95% maturity is negatively correlated with the number of pods per plant, pod weight, seed weight and seed yield. Strong and positive correlations were also observed between seed yield and the yield components of LG (r = 0.40), NGP (r = 0.36), NGG, PG (r = 0.818), PGr (r = 1), P100Gr (r = 0.439). There is also a positive correlation between the two-to-two performance components. The number of seeds per pod is positively and strongly correlated with plant height (r = 0.48). The number of pods per plant is strongly and positively correlated with the length of the primary leaf (0.54) and also with the length of the terminal leaflet (r = 0.35). Strong and negative correlations were observed between seed yield and the number of days at 50% flowering (r = - 0.50) and the number of days 95% maturity (r = - 0.37). Cycle parameters are negatively correlated with certain yield component parameters (NGP, PG, PGr).

Table 2. Correlation between the quantitative characteristics of the twenty-five (25) accessions of horse gram.

Variables	50%Flo	95%Mat	TC	HP	LngrFP	LgrFT	LngrFT	NBP	LG	NGP	NGG	PG	PGr	P100Gr	RdtGr
50%Flo (JAS)	1														
95%Mat (JAS)	0.58**	1													
TC	-0.19	-0.21	1												
HP (cm)	-0.04	-0.08	-0.14	1											
LngrFP (cm)	-0.28*	-0.40*	-0.02	0.23	1										
LgrFT (cm)	-0.08	-0.11	-0.07	0.16	0.19	1									
LngrFT (cm)	-0.30*	-0.32*	-0.05	0.03	0.56**	0.26*	1								
NBP	0.10	0.18	0.21	-0.01	0.203	-0.04	-0.07	1							
LG (cm)	-0.09	-0.16	0.01	0.23	0.24	0.22	0.01	0.32*	1						
NGP	-0.48*	-0.34*	0.01	0.02	0.54**	0.11	0.35*	0.12	0.192	1					
NGG	0.073	0.11	-0.00	0.48*	0.05	0.20	-0.10	0.20	0.51*	-0.134	1				
PG (Kg)	-0.41*	-0.27*	0.16	-0.01	0.26*	0.16	0.34*	0.12	0.35*	0.27*	0.03	1			
PGr (Kg)	-0.50**	-0.37*	0.23	0.00	0.37*	0.28*	0.39*	0.23*	0.40*	0.36*	0.01	0.82**	1		
P100Gr (g)	-0.32*	-0.22	0.03	0.03	0.42*	0.05	0.41*	0.099	0.23*	0.43*	-0.11	0.42*	0.44*	1	
RdtGr (Kg)	-0.50**	-0.37*	0.23	0.00	0.37*	0.28*	0.39*	0.23*	0.40*	0.36*	0.01	0.82**	1.00**	0.44*	1

*: significant difference at 5%. **, significant difference at 1%, CV: coefficient of variation, R^2 (%): coefficient of determination, 50% Flo: 50% Flowering, 95% Matte: 95% Maturity, TC: Chlorophyll content, HP: Plant height (cm), LgrFT: Terminal leaflet width, LngFT: Terminal leaflet length, LngFP: Primary leaf length, NGP: Number of pods per plant, NGG: number of seeds per pod, NBP: Number of primary branches, LG: Pod length (cm), P100Gr: Weight of one hundred seeds (g), PG: Pod weight (kg), PGr: Seed weight (kg), RdtGr (kg): seed yield.

3.3. Structuring Agro-Morphological Diversity

3.3.1. Agronomical Diversity

Principal component analysis (PCA) shows that the first four (04) axes explain 71.85% of the total variability (Table 3). Thus, axis 1 with 35.57% of the total inertia associates the length of the primary leaf (r = 0.31), the length of the terminal leaflet (r = 0.28), the number of pods per plant (r = 0.29), the pod weight (r = 0.36), the weight of the seeds (r = 0.39), the weight of 100 seeds (r = 0.28) and the seed yield (r = 0.39). Axis 2, which totals 16.63% of the total variance. is positively correlated with pod length (r = 0.45) and number of seeds per pod (r = 0.54). Axis 3, with 10.75% of the total inertia. combines three variables. namely chlorophyll content (r = - 0.48), plant height (r = 0.50) and terminal leaflet width (r = 0.35). Axis 4, which accounts for only 8.89% of total inertia, is positively correlated with the number of days at 50% flowering (r = 0.40), the number of days at 95% maturity (r = 0.42) and the number of primary branches (r = 0.52).

Table 3. Eigenvalues and percentage change expressed by the first four axes from the 15 quantitative characters in principal component analysis.

	F1	F2	F3	F4
Eigen value	5.34	2.50	1.61	1.33
Total variance (%)	35.57	16.63	10.75	8.89
Cumulative variance (%)	35.57	52.20	62.96	71.85
Characters defining the axes and their eigenvalues				
50%Flo (JAS)	-0.28	0.15	-0.02	0.40
95%Mat (JAS)	-0.27	0.17	-0.13	0.42
TC	0.09	0.06	-0.48	-0.23

	F1	F2	F3	F4
HP (cm)	0.01	0.26	0.50	-0.18
LngrFP (cm)	0.31	-0.12	0.27	0.32
LgrFT (cm)	0.15	0.21	0.35	-0.09
LngrFT (cm)	0.28	-0.30	0.19	0.12
NR	0.10	0.32	-0.24	0.52
LG (cm)	0.20	0.45	0.10	0.15
NGP	0.29	-0.15	0.22	0.24
NGG	-0.06	0.54	0.16	-0.16
PG (Kg)	0.36	0.14	-0.23	-0.10
PGr (Kg)	0.39	0.16	-0.19	-0.08
P100Gr (g)	0.28	-0.18	-0.04	0.25
RdtGr (Kg)	0.39	0.16	-0.19	-0.08

50% Flo: 50% Flowering, 95% Matte: 95% Maturity, TC: Chlorophyll content, HP: Plant height (cm), LgrFT: Terminal leaflet width, LngFT: Terminal leaflet length, LngFP: Primary leaf length, NGP: Number of pods per plant, NGG: number of seeds per pod, NBP: Number of primary branches, LG: Pod length (cm), P100Gr: Weight of one hundred seeds (g), PG: Pod weight (kg), PGr: Seed weight (kg), RdtGr (kg): seed yield.

3.3.2. Structuring Accessions

The dendrogram from the hierarchical ascending classification (Figure 1) returned to a truncation at the level of inertia 1000, the twenty-five (25) accessions characterized in four (4) groups. The accessions were classified into different groups based on Euclidean distances using Ward's method. Group 1 consists of two (02) individuals. Group 2 consists of eight (08) individuals. As for group 3, it consists of five (05) individuals and group 4 consists of ten (10) individuals.

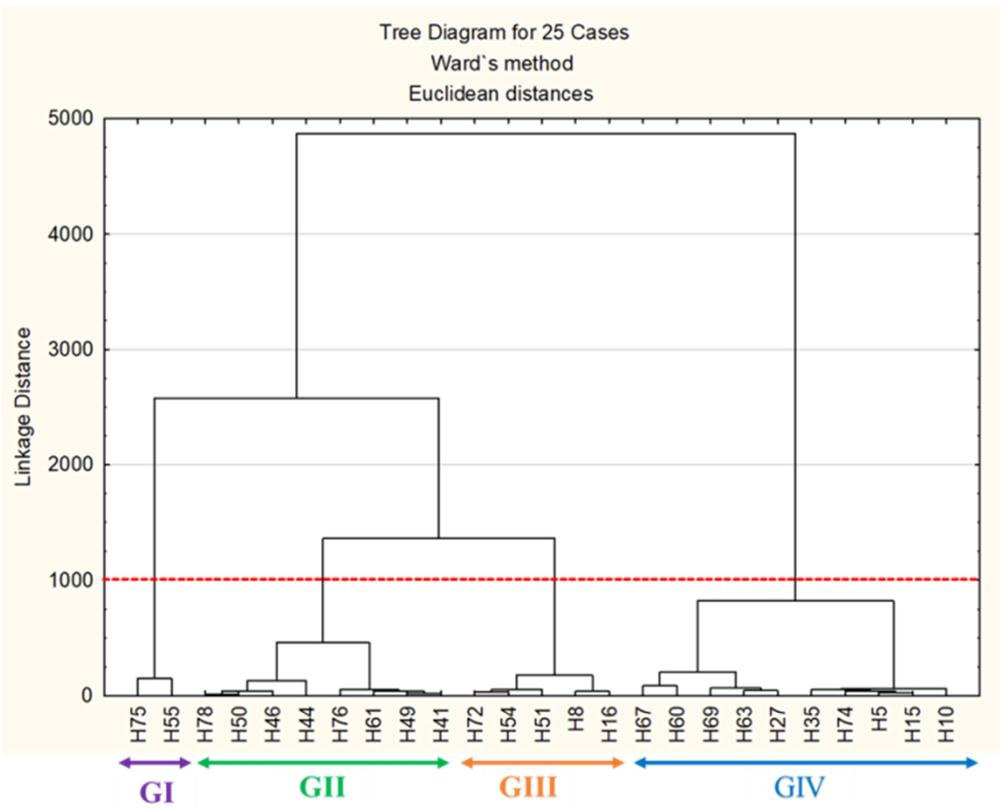

Figure 1. *Dendrogram from the Hierarchical Ascending Classification of the 25 horse gram accessions.*

3.3.3. Group Characteristics

Discriminant factor analysis (DFA) made it possible to characterize the 4 groups obtained on the basis of all the quantitative characteristics studied. Analysis of the values of the Fisher F statistic and the coefficient of determination R^2 indicates that the characters terminal leaflet length. pod weight. seed weight and seed yield are the most discriminating with relatively high values of F and R^2. For the rest. the squares of Mahalanobis distances (Mc Lachlan. 1992) (Table 4) from this analysis show that the groups are significantly different from each other at the 5% threshold. They also reveal that groups I and IV are the most distant (410.30%). These results are confirmed by the Wilks Lambda test (value of 0.008) in discriminant factor analysis which gives values of observed F and critical F respectively of 2.37 and 1.86 with a p-value 0.013 at the threshold of 5% between the 4 groups obtained, showing that they are indeed distinct entities. The relationship of the groups with the axes shows that groups I and IV are opposite and strongly correlated with axis 1 (Figure 2). Groups II and III, on the other hand, are negatively and positively correlated with both axes respectively.

The differentiation between the four phenotype diversity groups was completed by analysis of variance and the Newman-Keuls test. The results in Table 5 showed very highly significant differences (P < 0.001) between groups for the fifteen variables.

The analysis of the statistical values Fisher F and the coefficient of determination R² indicates that the characters 50% flowering, width of the terminal leaflet, pod weight, seed weight, seed yield, are the most discriminating with relatively high values of F and R².

Table 4. *Results of the Mahalanobis Distance Discrimination Test.*

	1	2	3	4
GI	0			
GII	123.22**	0		
GIII	195.27**	16.25**	0	
GIV	410.30**	90.10**	44.81**	0

Table 5. *Average performance of the 4 groups from the CAH.*

Variables	Groupe 1	Groupe 2	Groupe 3	Groupe 4	R² (%)	F
	2	8	5	10		Génotype
50%Flo (JAS)	28.500 b	31.917 ab	32.867 ab	36.067 a	29.97	3.00^{ns}
95%Mat (JAS)	64.167 a	66.917 a	66.467 a	69.767 a	27.13	2.61^{ns}
TC	40.050 a	38.183 a	41.000 a	36.427 a	11.47	0.91^{ns}
HP (cm)	77.967 a	83.096 a	82.758 a	80.731 a	3.27	0.24^{ns}
LngrFP (cm)	7.610 a	7.441 a	7.343 a	6.976 a	27.41	2.64^{ns}
LgrFT (cm)	5.048 a	4.316 a	4.887 a	4.035 a	36.12	3.96**
LngrFT (cm)	7.170 a	6.840 a	6.762 a	6.499 a	23.91	2.20^{ns}
NBP	7.500 a	7.458 a	7.067 a	6.733 a	8.45	0.65^{ns}
LG (cm)	5.067 a	4.854 a	4.805 a	4.630 a	27.74	2.69^{ns}
NGP	94.500 a	100.750 a	86.400 a	80.833 a	26.83	2.57^{ns}
NGG	6.167 a	6.125 a	6.267 a	6.133 a	1.94	0.14^{ns}
PG (Kg)	0.664 a	0.468 b	0.352 c	0.278 c	80.12	28.22**
PGr (Kg)	0.407 a	0.270 b	0.216 c	0.154 d	94.83	128.41**
P100Gr (g)	4.450 a	3.738 a	3.620 a	3.553 a	21.86	1.96^{ns}
RdtGr (Kg)	2261.095 a	1500.567 b	1202.693 c	855.700 d	94.83	128.41**

ns = not significant, **: significant difference at 1%, R^2 (%): coefficient of determination, 50% Flo: 50% Flowering, 95% Matte: 95% Maturity, TC: Chlorophyll content, HP: Plant height (cm), LgrFT: Terminal leaflet width, LngFT: Terminal leaflet length, LngFP: Primary leaf length, NGP: Number of pods per plant, NGG: number of seeds per pod, NBP: Number of primary branches, LG: Pod length (cm), P100Gr: Weight of one hundred seeds (g), PG: Pod weight (kg), PGr: Seed weight (kg), RdtGr (kg): seed yield.

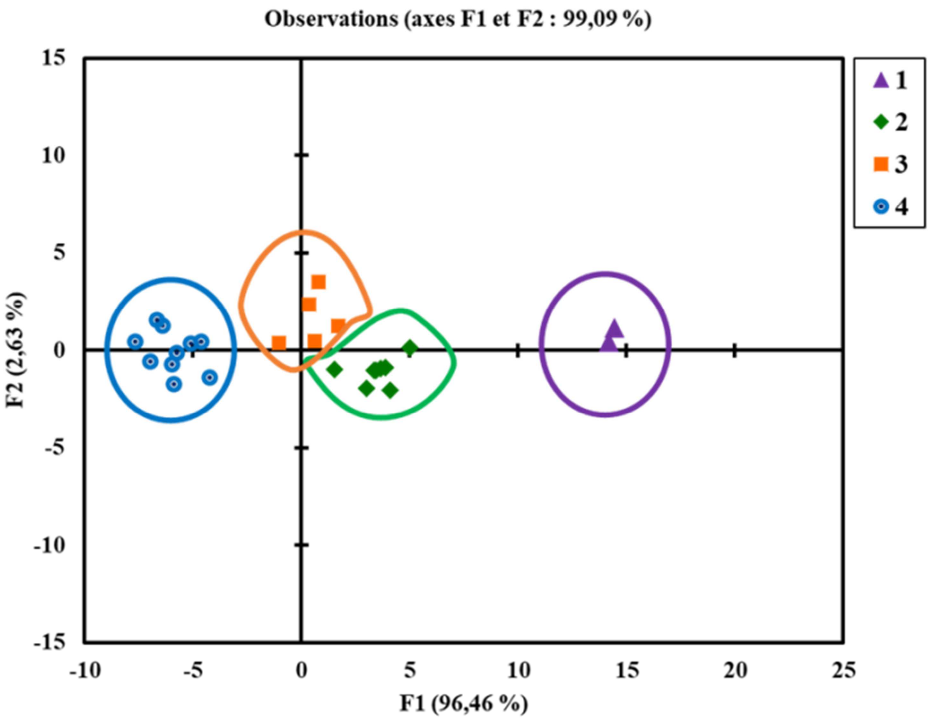

Figure 2. *Projection of the four (04) agro-morphological groups of the 25 horse gram accessions, in the plan formed by the first two axes of AFD.*

4. Discussion

The agro-morphological evaluation of the twenty-five (25) accessions of horse gram revealed a great genetic variability within the accessions studied. This variability, which has resulted in the existence of several discriminating characteristics, offers opportunities for popularization and plant breeding. This inter-accession heterogeneity is expressed by large amplitudes and by the highly significant F-Test, but is also evident in the principal component analysis with its four components strongly correlated with several variables. Information obtained from Principal Component Analysis (PCA) helps breeders identify phenotypic traits that contribute to high genetic variation between genotypes for the selection of potential parents for an improvement program [17]. In a similar study conducted by [18], days at 50% flowering, days at 95% physiological maturity, plant height and grain yield contributed the most to the genetic variability of horse gram. While in this study, in addition to the above traits, the number of pods per plant the length of the pods, the number of seeds per pod, the weight of the seeds and the weight of one hundred seeds, which are the components of yield. also contributed to the variability.

The large differences between the minimum and maximum values, the high coefficients of variation for certain characteristics testify to this heterogeneity [19]. This constitutes a potential basis for the implementation of a program to improve and enhance the value of this legume in Burkina Faso. This observed agronomic variability was reported by Prakash Balaji G. *et al.* [20]; Patil A. V. & Kasturiba B. [21] on horse gram accessions in India. This significant variability within accessions is thought to be related in part to seed management and conservation, as seeds collected from the IGPBR in India could come from a variety of origins. Also, it could be attributed in part to the mode of reproduction of horse gram. Indeed. even if it is a self-pollinating species. Sharma Vikas *et al.* [22] have shown that there is at least 69% conservation within this species therefore about 31% transferability.

The significant difference for cycle parameters such as the number of days at 50% flowering and the number of days at 95% pod maturity would show that the accession cycles are different. Given the total production cycle of the crop, which is generally 4-6 months [23], the production cycle of characterized horse gram accessions is early. This difference may be due to climatic conditions or the genetic makeup of the genotypes tested.

According to Hazra Partha & Basu Debabrata [24] correlation coefficients give an idea of the intensity of associations between different traits. Correlation studies therefore provide information on the nature and magnitude of the association between two pairs of metric characters. It may be possible to bring about a genetic improvement of one trait by choosing the other. Thus, the significant positive correlations among some of the agronomic parameters observed in this study suggest that traits could be improved simultaneously without any compensatory negative effects. Knowledge of the intercorrelation between quantitative traits can help breeders, orient selection on related traits to be improved. Indeed. selection based on yield components, such as the number of pods per plant, the length of the pods, the number of seeds per pod, the weight of the seeds and the weight of one hundred seeds. as well as cycle parameters could make it possible to identify promising genotypes of interest. Therefore, it would be interesting to give importance to traits cited in a breeding program, as there is a significant association with yield and also appears to be promising components contributing to yield [25]. The strong and positive correlation between flowering and maturity suggests that accessions that have an early flowering cycle are those that possess early maturity. This relationship is particularly interesting in plant breeding in that only one of these traits; especially flowering, can be used to predict the day of maturity. The negative correlation between the flowering cycle and yield on the one hand and the maturity cycle on the other could be explained by the fact that early production cycle accessions have a high yield compared to late cycle accessions.

The structuring of the diversity obtained through the hierarchical ascending classification shows that Group IV accessions are the best performing in terms of seed yield, pod length, number of seeds per pod, seed weight, weight of 100 seeds and number of primary branches. Those in group I have earlier flowering and maturity days and tall plants, while those in group II have more seeds per pod.

The minimum distance between groups II and III shows the genetic similarity that exists between these two groups. Thus, a selection of parents from both groups can be avoided, as it represents a narrow genetic basis. Indeed, according to Katiyar Prvan Kumar *et al.* [26], the observed distances reflect the genetic diversity of accessions and their relationships to each other. Further selection of parents for crossbreeding programs should be made from two groups with larger intergroup distances to achieve maximum variability [27]. Therefore, the improvement in accessions in this study is more likely to be achieved if parental combinations involve accessions belonging to Group I and IV. Accessions from both groups could be used in a breeding program to develop high-yielding, short-cycle genotypes. Sunil Narine *et al.* [28] and Viswanath Kannalli P. *et al.* [29] also reported clustering of horse gram genotypes into different groups and remotes for use in improvement.

The great variability observed in this study therefore offers possibilities for selecting genotypes with high yield potential and short cycle corresponding to the needs of producers.

5. Conclusion

In the present study, agronomic characterization revealed the existence of high variability for the traits studied within horse gram accessions. The study showed that of all the 25 accessions studied, twelve (12) accessions were identified for their agronomic performance, which could constitute a base of elite genotypes. These accessions are: H75, H55, H74, H69, H10, H63, H15, H60, H27, H67, H35, H5. Many interesting correlations between characters have been observed. The study also showed that the diversity of accessions is structured according to the cycle and seed yield. Groups I and IV are made up of the best performing accessions in terms of seed yield and short production cycle. A maximum intergroup distance was noted between Group IV and Group I, indicating that the accessions of these groups were relatively more diverse than the accessions of the other groups. This genetic variability obtained is an important asset for horse gram breeding and breeding programs. Finally, a characterization of accessions by molecular markers supplemented by an adaptation test of accessions with a late cycle in the face of increased drought would allow the present diversity study to be better investigated.

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