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(RESEARCH ARTICLE)

Agronomic performance and genetic variability of ten (10) accessions of horse gram [*Macrotyloma uniflorum* (Lam.) Verdc.] in Kamboinsé, Burkina Faso

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Abstract

Horse gram [*Macrotyloma uniflorum* (Lam.) Verdc.] is a legume in the Fabaceae family. It has good nutritional quality, numerous therapeutic properties and is adapted to drought and heavy metals. It is an exotic species being introduced into Burkina Faso. This study aims to contribute to a better understanding of horse gram by assessing the agronomic performance of ten (10) accessions. This study was carried out in the field at the experimental station of the "Centre de Recherches Environnementales, Agricoles et de Formation (CREAF) de Kamboinsé" during the 2022 cropping season. Accessions were evaluated in a Fisher block design with three (03) replications. Analysis of variance revealed a high degree of agronomic variability within the accessions studied. Positive and significant correlations were obtained between different variables. Principal Component Analysis (PCA) of the variables identified pod weight, number of seeds per pod, seed weight and seed yield as the parameters that best discriminated between accessions. Accession H46 was the most productive in terms of number of pods (61 pods). Accession H76 achieved a significant seed weight (0.126 kg). However, accession H49, in addition to having an average seed weight (0.114 kg), also presented a good fodder yield (4629.630 kg/ha). Accession H76 (697.972 kg/ha) stood out from the rest with the highest grain yield. This study shows that horse gram can be introduced into future breeding programs to meet the demand for legumes in Burkina Faso, given its agronomic performance.

Keywords: Horse Gram; Accessions; Agronomic Performance; Burkina Faso

1 Introduction

Among plant genetic resources, food legumes occupy an important place after cereals [1]. They are also the second most widely used group of plants in human and animal nutrition [2]. Within this group, there are underutilized legumes, including the species [*Macrotyloma uniflorum* (Lam.) Verdc.] commonly known as horse gram.

Horse gram is mainly grown as a food legume and forage crop in many parts of the world [3]. As a forage crop, it has shown better performance compared with other forage crops such as *Stylosanthes hamata*, *Vigna unguiculata* and *Crotalaria juncea* [4]. It is a legume that tolerates drought [5], heavy metals and salinity [6]. Horse gram's nutritional composition and medicinal properties make it a rich food source [7]. Despite all these properties, its importance has still not been realized and the species has remained unexplored and underutilized in terms of practical extension and breeding and basic research.

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As a legume in its infancy in Burkina Faso, horse gram is considered a minor crop. A number of accessions have been introduced and characterized in recent years by the “Institut de l'Environnement et de Recherche Agricoles (INERA)”. Thus, for their proper introduction and adoption in the cultivation and food system, and for future work, it is essential to study the performance of these accessions. It is in this context that this study entitled "Evaluation des performances agronomiques de dix (10) accessions de horse gram à Kamboinsé, Burkina Faso" (Evaluation of the agronomic performance of ten (10) horse gram accessions in Kamboinsé, Burkina Faso) was carried out. Specifically, the aim is (i) to determine the production cycles of the horse gram accessions (ii) to evaluate the productivity in seeds and haulms of the horse gram accessions and (iii) to identify the accessions of agronomic interest.

2 Material and methods

2.1 Plant material

The plant material used for the study consisted of ten horse gram accessions. Characteristics of these accessions are given in Table 1.

Table 1 List of accessions and characteristics

Number	Accessions	Seed color	Seed texture	Seed shape	Seed eye color
1	H49	Speckled brown-black	Smooth	Rhomboïdale	White
2	H76	Dark brown	Smooth	Rhomboïdale	White
3	H16	Speckled brown-black	Smooth	Rhomboïdale	White
4	H10	Beige	Smooth	Rhomboïdale	White
5	H69	Dark brown	Smooth	Rhomboïdale	White
6	H15	Yellow-orange Speckled	Smooth	Rhomboïdale	White
7	H61	Speckled brown-black	Smooth	Rhomboïdale	White
8	H46	Speckled brown-black	Smooth	Rhomboïdale	White
9	H44	Yellow-orange Speckled	Smooth	Rhomboïdale	White
10	H60	Brown-orange Speckled	Smooth	Rhomboïdale	White

2.2 Study site

The experiment was carried out at the “Centre de Recherche Environnementale, Agricole et de Formation (CREAF)” in Kamboinsé, part of the “Institut de l'Environnement et de Recherches Agricoles (INERA)”. CREAF is located north of the city of Ouagadougou, about 12 km along the Ouagadougou-Kongoussi road. The area's climate is of the Sudano-Sahelian type, alternating between two unevenly distributed seasons [8]. Relative humidity in the center ranges from 60 to 70%, with average rainfall varying from 700 mm to 900 mm per year. During the 2022 cropping season, annual rainfall was 1106.0 mm on 60 rainy days [9]. The soils are leached tropical ferruginous soils underlain by deep, hydromorphic, low-humus sandy materials with inherited pseudogley associated with lithosols. The texture of these soils is predominantly clay at depth and sandy-clay at the surface [10].

2.3 Methods

2.3.1 Experimental design

The trial was planted in a Fisher block design with three (03) replicates. Each replication comprised ten (10) elementary plots, each containing two (02) lines of two meters (02 m). Each elementary plot corresponded to one accession. Accessions were sown with several seeds per plot. Spacing was 0.9 m between rows, 0.4 m between bunches, one meter (01 m) between elementary plots and two meters (02 m) between replications. The surface areas of the elementary plot, one replication and the whole trial were 1.8 m2, 42.5 m2 and 161.5 m2 respectively.

2.3.2 *Crop management*

Soil preparation consisted of ploughing with a tractor, plot demarcation, followed by plot labelling in the three replications. Sowing was manual and carried out in two rows. Maintenance work consisted of weeding, application of NPK fertilizer at a rate of 100 kg/ha and two insecticide treatments, one at flower bud formation and the other at pod formation. Weeding was carried out during the first weeding. The insecticides used were Deltacal 12.5 EC, a broad-spectrum contact insecticide at a dose of 2mL per liter of water, and K-Optima (Lambda-cyhalothrin 15g/L + Acetamiprid 20g/L; EC), a systematic insecticide against pests. Harvesting was based on 95% maturity of the various accessions.

2.3.3 *Data collection*

Data were collected on the two rows of each elementary plot and covered eleven (11) quantitative parameters (Table 2).

Table 2 Quantitative variables

Variables	Descriptions and units of measurement
50% flowering	Number of days from sowing to beginning of flowering of 50% of plants per plot
95% pod maturity	Number of days from sowing to dry maturity of 95% of pods in plot
Number of pods per plant	Obtained by manually counting the number of pods per plant at maturity;
Number of seeds per pod	Average number of seeds per pod based on a sample of 10 pods per plant
Pod length	Distance from receptacle to pod apex on each elementary plot using a graduated ruler
Weight of one hundred (100) seeds in grams	Determined by counting 100 seeds taken at random from each accession per repeat, monitored using an electronic balance.
Pod weight	Weighing of dry pods from each elementary plot using an electronic balance;
Seed weight	Determined by weighing with an electronic balance, expressed in kilograms
Weight of tops	Weighing of dry fodder from each elementary plot using an electronic balance;
Fodder yield	Quantity of product per unit area Determined from the formula: Yield = [(fodder weight x 10000) / unit area] ;
Seed yield	Calculated from the following formula: Yield = [(seed weight x 10000) / elementary area]

2.3.4 *Statistical analysis*

The agronomic data collected were subjected to an analysis of variance (ANOVA) and Newman-Keuls tests at the 5% threshold were performed to identify the variables that discriminate between accessions. Correlations were used to estimate pairwise relationships between variables. A principal component analysis (PCA) was performed to determine the association between the traits studied. All these analyses were performed using XLSTAT 2016 software.

3 Results

3.1 Phenological parameters

The results of the analysis of variance of phenological parameters are shown in Table 3. The average 50% flowering date for the different accessions was 48 JAS. Accessions H49, H60 and H61 were the first to reach the 50% flowering stage as early as 44eme JAS, compared with accession H16 which reached it late at 60eme JAS. Analysis of variance showed a highly significant difference (P=0.000) between accessions in the number of days to 50% flowering.

The number of days for 95% maturity ranged from 91 to 101 days. The average number of days to 95% maturity was 94 days. For this stage, accessions H49 and H61 were the earliest (91 DAY), while accessions H10 and H16 reached their 95% maturity date later at 101 DAY. For this trait, the analysis of variance was also highly significant (P = 0.000) between accessions.

Table 3 Results of analysis of variance for phenological parameters of accessions.

Accessions	50% Flowering	95% Maturity
H49	44[c]	91[b]
H76	47[c]	94[b]
H16	60[a]	101[a]
H10	54[b]	101[a]
H69	46[c]	94[b]
H15	45[c]	95[b]
H61	44[c]	91[b]
H46	47[c]	92[b]
H44	48[bc]	93[b]
H60	44[c]	92[b]
Minimum	44	91
Maximum	60	101
Average	48	94
CV (%)	11	4
Pr > F	0,000***	0,000***

Legend: Means marked with the same letter in the same column are not significantly different at the 5% level; (***) = Very highly significant.

3.2 Yield and its components

Table 4 presents the results of the analysis of variance of yield and its components in grain and haulm. Five (5) variables, namely number of pods per plant, pod length, pod weight, seed weight and seed yield, discriminate between the accessions studied at the 5% significance level.

With an average of 33 pods, the number of pods per plant ranged from 16 to 61. The lowest value was obtained with accession H16, while the highest number of pods per plant was recorded with accession H46.

Pod length ranged from 3.94 to 4.64 cm for the H61 and H16 accessions respectively, with an average of 4.29 cm.

The pod weight parameter recorded an average of 0.119 kg. Accession H60 obtained the lowest value with 0.022 kg and the highest pod weight value was obtained with accession H15 with a value of 0.225 kg.

Seed weight ranged from 0.018 kg for H60 to 0.126 kg for H76, with an average of 0.070 kg. Seed yield ranged from 102.674 kg/ha for accession H60 to 851.852 kg/ha for accession H15. The average seed yield was 439.862 kg/ha.

Table 4 Results of the analysis of variance of yield and its components for the ten horse gram accessions**.**

Accessions	NGP	NGG	LngGs (cm)	PGs (Kg)	P100 Gr (g)	PGr (Kg)	Rdt Gr	PF	RdtF
H49	35ab	6a	4.27ab	0.17abc	3,81a	0.11ab	635.65ab	0,83a	4629,63a
H76	43ab	6a	4.44ab	0.19ab	3,35a	0,13a	697.97ab	0,25a	1388,89a
H16	16b	6a	4,64a	0.05bc	3,69a	0.04cd	272.42bc	0,35a	1851,85a
H10	2b	6a	4.28ab	0.08bc	3,51a	0.06abcd	324.08bc	0,32a	1759,26a
H69	32ab	5a	4.27 ab	0.16abc	3,82a	0.11ab	450.74abc	0,25 a	1388,89a

H15	32ab	6a	4.23ab	0,23a	3,67a	0.05bcd	851,85a	0,18a	1203,70a
H61	35ab	5a	3,94b	0.14abc	3,57a	0.09abc	502.34abc	0,22 a	1203,70a
H46	61a	5a	4.29ab	0.07bc	3,55a	0.05bcd	271.49bc	0,12a	648,15a
H44	26b	5a	4.16ab	0.08bc	3,42a	0.05bcd	289.41bc	0,15a	833,33a
H60	22b	5a	4.37ab	0,02c	3,47a	0,02d	102,67c	0,15a	833,33a
Minimum	16	6	0,02	5,000	3,350	0,02	102,67	0.05	555.56
Maximum	61	5	0,22	6,000	3,823	0,13	851,85	2.00	11111.11
Average	33	5.5	0,12	6,000	3,586	0,07	439,86	0.28	1574.074
CV (%)	0,47	0,06	0,66	0,09	0,08	0,58	0,60	1.20	1.18
Pr > F	0,008**	0,041*	0,001**	0,281 ns	0,582 ns	0,000***	0,000***	0.34 ns	0.35 ns

NGP: Number of pods plants, NGG : Number of seeds per pod, LongGs (cm) : Pod length PGr (kg) : Seed weight, PGs (kg) : Pod weight, PCG (g) : Hundred seed weight, P100Gr (g) : 100 seed weight, RdtG (kg/ha) : Seed yield, PF (kg) : Fodder weight, RdtF (kg/ha) : Fodder yield, (**) = highly significant

3.3 Relationships between the characteristics studied

The results of the Pearson correlation matrix analysis showed the existence of several correlated variables (Table 5). The study revealed a very strong positive correlation between 50% flowering and 95% maturity dates (r = 0.890). A very strong positive correlation was observed between the number of pods per plant and pod length (r = 0.692). Very strong positive correlations were recorded between pod weight and seed weight (r = 0.727) and between seed weight and seed yield (r = 0.636). Hull weight one was positively and very strongly correlated with hull yield (r = 0.998).

Table 5 Results of the correlation matrix between the different varieties

Variables	Flow50	Mat95	NGP	NGG	LongGs	PGs	P100Gr	PGr	RdtGr	PF	RdtF
Flow50	1										
Mat95	0,890**	1									
NGP	-0,416	-0,469	1								
NGG	0,518	0,495	-0,256	1							
LongGs	0,643**	0,528**	-0,239	0,691**	1						
PGs	-0,425	-0,240	0,292	0,133	-0,282	1					
P100Gr	0,012	0,053	-0,135	0,324	0,031	0,287	1				
PGr	-0,314	-0,298	0,349	0,071	-0,220	0,726**	0,212	1			
RdtGr	-0,325	-0,150	0,240	0,272	-0,203	0,974**	0,237	0,636**	1		
PF	0,047	-0,019	-0,121	0,670**	0,126	0,253	0,555	0,464	0,303	1	
RdtF	0,016	-0,032	-0,111	0,671**	0,104	0,293	0,563	0,469	0,344	0,998**	1

Legends: Flow50 (JAS): 50% Flowering, Mat95 (JAS): 95% Maturity, NGP: Number of seed pods, NGG: Number of seeds per pod, LongGs (cm): Pod length PGr (kg): Seed weight, PGs (kg): pod weight, PCG (g): hundred seed weight, P100Gr (g): 100 seed weight, RdtG (kg/ha): seed yield, PF (kg): fodder weight, RdtF (kg/ha): fodder yield, (**) = highly significant

3.4 Principal Component Analysis

Table 6 and Figure 1 show the results of the principal component analysis (PCA) performed with the different parameters. They show the association of traits and variables that form the different axes. In fact, they enabled us to distinguish two axes that explain 67.03% of the total variability within the accessions. The F1 and F2 axes explain 34.99% and 32.04% of variability respectively. The parameters pod weight, seed weight and seed yield are correlated on the F1 axis; while 50% flowering date, 95% maturity, number of seeds per pod and pod length are correlated on the F2 axis.

Table 6 Eigenvalues and percentage of variation expressed for the first two axes based on quantitative characteristics in principal component analysis

	F1	F2
Eigenvalue	3.848	3.524
Variability (%)	34.985	32.040
Cumulative	34.985	67.026
Characters defining axes and their eigenvalues		
50% Flowering	-0.262	0.389
95% Maturity	-0.225	0.366
Number of pods/plants	0.172	-0.268
Number of seeds per pod	0.112	**0.481**
Pod length (cm)	-0.164	0.374
Pod weight (Kg)	**0.433**	-0.057
Weight 100 Seeds (g)	0.237	0.227
Seed weight (Kg)	**0.419**	-0.024
Seed yield	**0.415**	0.002
Weight of tops	0.325	0.332
Fodder yield	0.339	0.324

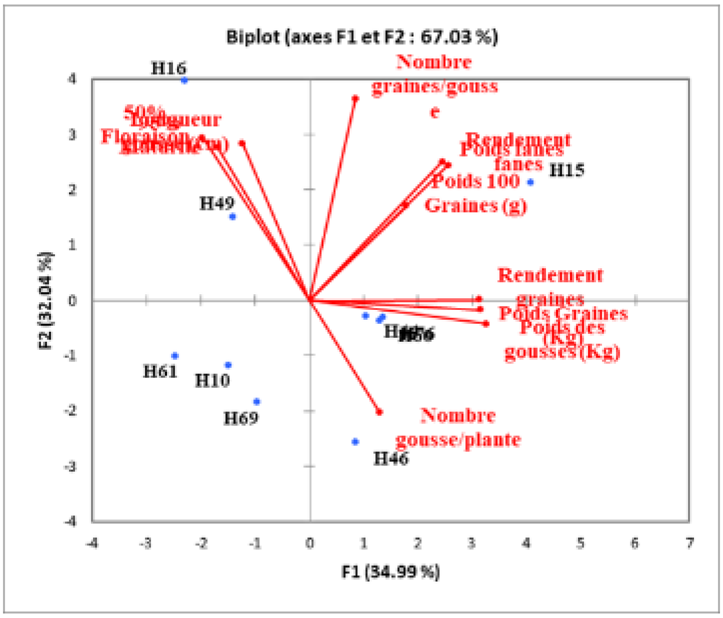

Figure 1 Eigenvalues and percentage variation expressed by the two axes of the principal component analysis.

4 Discussion

The study showed significant genetic variability within the accessions studied across the different parameters investigated. This observed variability offers a good alternative for choosing genotypes according to demand or the type of breeding program for future work on this legume. Such variability had already been reported by [11] and [12] on horse gram accessions in India. The method of seed management and conservation by International Board for Plant

Genetic Resources (IGPBR) growers may be at the root of this variability. In fact, these growers cultivate several morphotypes on the same plots and store them in the same location. [13] have shown that there is 69% conservation within this species, resulting in around 31% transferability.

The highly significant difference observed for the 50% flowering date reflects the fact that the accessions did not flower at the same time, so they would have different cycles. Flowering occurred between the 43rd and 60th day after sowing. Our results differ from those of [14], who in their experimental study in eastern India found horse gram accessions that reached 50% flowering at 35 days after sowing. This difference in 50% flowering could be due to pedoclimatic conditions or the genetic make-up of the genotypes tested [15]. The difference could also be linked to the intrinsic characteristics of the accessions. However, divergence can also be attributed to environmental influences that can exert pressure on the plant material tested.

The highly significant difference obtained for the 95% pod maturity parameter indicates that the accessions also had different cycles. The variation in reaching 95% pod maturity between accessions was between the 91st and 101st JAS. This variation could also be due to the genetic make-up of the genotypes tested and the climate [15]. The results obtained differ from those of [14], who obtained 95% maturity dates between 84 and 93 JAS.

The highly significant difference in seed weight also reflects variability within the accessions studied. The reduction in seed weight could be attributed to the different accumulation of reserves in the seeds, which depends not only on genotype type but also on climatic factors [16]. This result shows that for horse gram accessions, seed weight is a key parameter in genetic variability. Indeed, seed weight would be a determining parameter in selection.

Correlation studies provide information on the magnitude and nature of the association between any two pairs of metric traits [17], making it possible to improve a trait genetically by choosing one or the other pair. As a result, the strong positive correlations obtained between certain agronomic parameters in this study reflect the fact that traits could be improved simultaneously without any offsetting negative effects.

Correlation analysis between the different parameters shows that maturity can be predicted from flowering determination. The 95% maturity date is a function of the 50% flowering date. [14] also noted a strong correlation between 50% flowering and 95% maturity in their study.

The positive and highly strong correlations obtained between the number of seeds per pod and haulm yield show that accessions with a high number of seeds per pod also have a high biomass, which translates into a high haulm yield. This difference is important in agronomy, as it enables the identification of dual-purpose accessions, i.e. high seed and fodder production. It gives the farmer the opportunity to use the same accession to produce seeds and dry haulms in the same environment, instead of using two specific accessions in different environments.

The correlation between pod weight and seed yield shows that accessions with a high pod weight have a consequent seed yield. This shows that selection on the basis of pod weight would result in the selection of accessions with the best seed yields.

Principal Component Analysis (PCA) showed that the agronomic performance of accessions would be structured by yield and yield components. Projection of the accessions in PCA planes 1-2 enabled them to be structured in relation to the main parameters.

In fact, the parameters that were correlated on the F1 and F2 axes are those that best explain the agronomic variability between horse gram accessions. The main discriminating parameters of the study would therefore be pod weight, seed weight, seed yield correlated on the F1 axis (34.99%) and 50% flowering date, 95% maturity, number of seeds per pod, pod length correlated on the F2 axis (32.04%).

5 Conclusion

The study revealed a high degree of variability within the horse gram accessions studied. This made it possible to identify the accessions offering the strongest characteristics of agronomic interest. Accessions H49 and H61 were the earliest to reach 95% maturity (91 JAS). Accession H46 recorded the highest number of pods. Accession H15 obtained the highest seed yield and could therefore be offered to growers. Accessions H49, H16 and H10 are of interest for hay production and could serve as a source of progenitors for the creation of forage varieties for animal production and green manure. In addition to having the best fodder yield, accession H49 also offers an interesting seed yield. It can be recommended not only to breeders but also to growers. Accessions H49 and H15 display the plant's traits of interest, i.e. early maturity cycle, good pod length, and could constitute potential breeding stock. Analysis of variance revealed strong correlations between the various parameters studied. The production cycles and productivity of the ten horse gram accessions enabled us to identify the best accessions for seed yield (H15) and fodder yield (H49, H16 and H10).

Compliance with ethical standards

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Disclosure of Conflict of interest

The authors declare that they do not have any conflict of interest.

Author's contributions

TJN: collected the data, followed the field trial and participated in the analysis and writing of the manuscript. AB: followed the tests, supervised the work and participated in the analysis and correction of the manuscript. BTBJ: participated in the correction of the manuscript. ZC: followed the trial, participated in data collection and manuscript correction.

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