RESEARCH ARTICLE

Agromorphological variability of *Solenostemon rotundifolius* [(Poir.) J. K. Morton] accessions from Burkina Faso and Ghana

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Solenostemon rotundifolius is an herbaceous plant from Labiatae family which produces edible tubers. It is one of the minor crops with high nutritional and socio-economic potential. Previous research works on its genetic resources made it possible to identify around sixty traits that can serve as descriptors for the plant. Agromorphological characterization of partial collections of *S. rotundifolius* revealed low variability for the main traits related to tuber size and yield. As a vegetatively propagated and minor crop, evaluation of the depth of the variability of *S. rotundifolius* requires larger collections from different agroecological conditions. A collection of 174 accessions of *S. rotundifolius* from nine (9) provinces of Burkina Faso and nine (9) districts of Ghana was characterized in a Randomized Complete Blocks Design with three replications. Twelve quantitative traits related to the cycle, the canopy, and leaf size and yield were measured. Analysis of Variance (ANOVA) revealed significant differences within the collection (at level P=0.05 or 0.01) in all the traits. Based on hierarchical ascendant classification, six different agromorphological groups were identified. Analysis of variance revealed significant differences among the accessions based on the mean rainfall of their area of origin. This study provided useful data for a better understanding of the agromorphological variability of *S. rotundifolius*. Such variability could help build up a breeding program or for further research on the genetic diversity of *S. rotundifolius*.

Key Words: *Lamiaceae; Tuber; Minor crop; Agromorphological variability*

INTRODUCTION

Solenostemon rotundifolius [(Poir.) J. K. Morton] or frafra potato is one of the most widespread Lamiaceae. It is one of the promising neglected species well known for its potentialities. It is cultivated for its edible tubers in many tropical regions in Africa and Asia [1-3].

The tubers of *S. rotundifolius* contain antioxidant substances, mainly flavonoids, saponins and anthraquinones which play a role in human disease prevention [4-6]. A survey carried out in Ouagadougou (Burkina Faso) revealed that 16 to 32 Kg of tubers are sold per day/trader and the prices varied from 1.2 to 3 USD/kg [7]. *S. rotundifolius* is also known to be one of the most adapted tuber crops of West Africa. It is suited for cultivation in marginal areas in dry savannah regions with poor soils fertility [8]. The potential yield reported in West Africa ranged from 7 to 15 t/ha [9]. In the current context of disruption of the rainfall regime and soil degradation, the valorization of *S. rotundifolius* is an alternative to ensure food security in areas with critical pedoclimatic conditions.

The small size of tubers (diameter less than 1.6 mm) and their rapid deterioration were identified as the main constraints for its valorization. Building up a breeding program could help develop varieties that meet farmers' and consumers' expectations. Such a program is based on agromorphological variability within *S. rotundifolius* genetic resources. Some research activities on the agromorphological variability of *S. rotundifolius* were carried out based on local collections [10,11]. Around sixty traits were suggested as descriptors for the characterization of *S. rotundifolius* germplasm. These research works revealed low variability in traits related to yield and tuber size. As a vegetatively propagated and minor crop, evaluation of the depth of the variability of *S. rotundifolius* requires larger collections including different agroecological conditions. This study aims at describing the agromorphological variability of *S. rotundifolius* from Ghana and Burkina Faso.

MATERIALS AND METHODS

Plant material

Plant material used for the study consisted of 174 accessions from Burkina Faso (58) and Ghana (116). The accessions from Burkina Faso were collected in 9 provinces covering three agro-climatic zones of the country (Figure 1). The accessions were registered in the gene bank of the University Joseph KI-ZERBO. The accessions from Ghana were collected in 9 districts in the northern part of the country and registered in the CSIR-Savanna Agricultural Research Institute (CSIR-SARI) gene bank (Figure 2). The collection areas covered the main cultivation zones of *S. rotundifolius* in both countries.

Study area and experimental design

The agromorphological characterization was carried out at the research station of the Institute of Rural Development of Nazi BONI University. The station is located at Gampela (1°21'W and 12°24' N). A total rainfall of 865.6 mm was registered during the the period of the experiment (July 2020 to December 2020).

Before planting, the experimental plot was tilled after applying 15 t/ha of organic manure. The experimental design was a randomized complete block with three replications. Each block consisted of 174 lines. Pregerminated tubers were planted on ridges, 4.5 m long (25 cm high and 25 cm wide) with a spacing of 0.5 m between the ridges and 0.5 m between the holes.

Quantitative traits

Twelve (12) traits were used for describing the agromorphological variability of *S. rotundifolius* (Table 1). Five of them were measured on leaves and stems during the vegetative development stage (40 days after planting). These were: Plant Heiht (PHe), Canopy Circumference (CCi), Central Stem Length (CSL), Leaf Width (LWi), and Leaf Length (LLe).

After spike initiation (40 to 100 days after planting), two traits related to the life cycle were measured. These were: Days to Spike Initiation (DSI), and Days to Last Maturity (DLM). These traits were evaluated from the planting date as the reference (day 0 after planting).

At maturity (100 to 160 days after planting), five traits were measured. These were total number of Tubers Per Plant (TNT), Tubers Weight per Plant (TWP), Tuber Weight (TWe=TWP/TNT), Tuber Length (TLe) and Tuber Diameter (TDi). The length and the diameter were measured on ten

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randomly selected tubers, then the mean value was estimated per plant. The tubers weight was measured using an electronic balance of 1000 g maximum with a precision of 0.1 g.

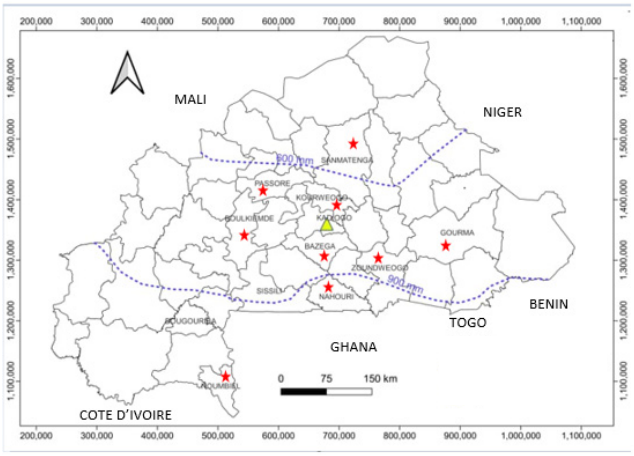

Figure 1) *Collection areas of* S. rotundifolius *accessions from Burkina Faso;* **Note:** *(* * *) Isohyets 600 and 900 mm, (★) Sampling zones, (▲) Experiment site*

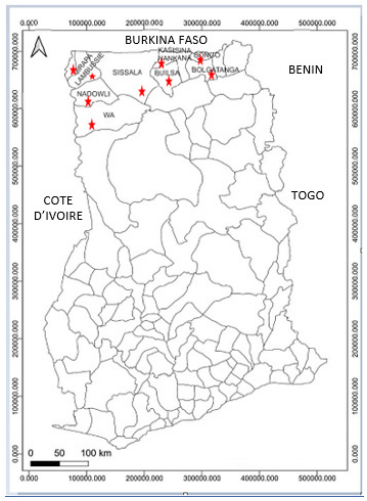

Figure 2) *Collection areas of* S. rotundifolius *accessions from Ghana;* **Note:** *(★) Sampling zones*

TABLE 1

Traits used to describe agromorphological variability of accessions of *S. rotundifolius*

Traits	Meaning	Abbreviations	Units
Traits related to the canopy	Plant height	PHe	cm
	Central stem length	CSL	cm
	Canopy circunference	CCi	cm
	Leaf width	LWi	cm
	Leaf length	LLe	cm
Traits related to the cycle	Days to spike initiation	DSI	days after planting
	Days to last maturity	DLM	days after planting
Traits related to tubers size and weight	Total number of tubers	TNT	number/plant
	Tubers weight per plant	TWP	g
	Tuber weight	TWe	g
	Tuber length	TLe	mm
	Tuber diameter	TDi	mm

Statistical analysis

Mean values, minimum, maximum, standard deviation and coefficient of variation of the traits were calculated for the whole collection. Analysis of Variance (ANOVA) was carried out using GENSTAT 10.1 and the differences between the mean values were verified using the Student-Newman-Keuls test at the significant level P=0.05. An analysis of variance was also carried out to compare the accessions according to the country (Burkina Faso and Ghana) and climatic zones of origin. The Pearson correlation coefficients between the traits were calculated at the significant levels P=0.05 and P=0.01. A set of not strongly correlated traits covering vegetative development, cycle, and yield were used for the analysis of the structuration of the variability based on Hierarchical Ascendant Classification (HAC) with the middle link as aggregation criterion. The differentiation of the groups from the HAC was evaluated using a Discriminant Factor Analysis (DFA). This analysis was carried out using XLSTAT 7.5.2.

RESULTS AND DISCUSSION

Variability in quantitative traits of *S. rotundifolius*

The accessions significantly differed (at level P=0.01) in the traits related to canopy and leaf size (Table 2). Plant Height (PHe) varied from 9 to 47 cm and the Canopy Circumference (CCi) from 35 and 220 cm. The mean values of Plant Height (PHe) and Canopy Circumference (CCi) were respectively 17.74 cm and 104.75 cm with high coefficients of variation (CV>21%). Central Stem Length measured 17.39 cm (CSL) but varied from 7 to 45 cm. Leaf Length (LLe) was 4.35 cm and Leaf Width (LWi) was 2.77 cm with low coefficients of variation (14.65% and 17.10% respectively).

Significant differences (at level P=0.01) were observed between the accessions in traits related to the cycle. The earliest accessions initiated spike (DSI) at 44 days after planting but the latest spike initiation occurred 90 days after planting. The accessions also differed significantly in number of days to maturity. The cycle to maturity (DLM) varied from 110 days for the early maturing accessions to 141 days for the late maturing accessions.

The traits related to the tubers were the most variable. The less productive accessions produced only 4 tubers (TNT) for a total weight (TWP) of 3.6 g. However, the total number and weight of tubers per plant for the most productive accession were respectively 172 and 409.9 g. The highest coefficients of variation were observed for these two traits (68.25 for TNT and 88.57 for TWP).

The mean potential in tubers production of the accessions was 32 tubers and 57.56 g per plant. The mean value of the Tuber Weight (TWe) was 1.73 g but a large variation was observed in this trait (0.35 to 8.32 g). A large variation was also observed for tuber size. Tuber Length (TLe) varied from 14.90 mm to 110.70 mm and the Tuber Diameter (TDi) from 7.00 mm to 45.75 mm. The average tuber size was 32.93 mm long and 13.59 mm large.

Variability of the accessions of *S. rotundifolius* based on the country of origin

Significant differences (at levels P=0.05 or 0.01) were observed between the accessions based on the country of origin for six (6) traits. These were the Plant Height (PHe), Canopy Circumference (CCi), Days to Last Maturity (DLM), Number of Tubers per Plant (TNT), Tubers Weight Per Plant (TWP), and Tuber Length (TLe) (Table 3).

The accessions from Ghana developed a large canopy (PHe=19.85 cm and CCi=106.97 cm). These accessions were also late maturing and more productive compared to those from Burkina Faso. The number of days to maturity (DLM) was 132 and the number and weight of tubers per plant (TNT and TWP) were respectively 39 and 60.92 g. The Tubers Length (TLe) was 33.52 mm. The mean Plant Height (PHe) and Canopy Circumference (CCi) of the accessions from Burkina Faso were 17.51 cm and 99.83 cm, respectively. These accessions were early maturing (DLM=125 days) and with low productivity (TNT=28, TWP=50.10 g) and small-size tubers (TLe=28.63 mm) compared to those from Ghana.

No significant difference was observed between the accessions based on the country of origin for Central Stem Length (CSL), Leaf Width and Leaf Length (LWi and LLe), Days to Spike Initiation (DSI), Tuber Weight (TWe), and Tuber Diameter (TDi).

Variability of the accessions of *S. rotundifolius* based on the rainfall of the zone of origin

The comparative analysis of the accessions based on the climatic zones of origin revealed a significant difference for the Plant Height (PHe), Canopy Circumference (CCi), Days to Last Maturity (DLM), Total Number of Tubers (TNT), Tubers Weight Per Plant (TWP), Tuber Weight (TWe), Tuber Length (TLe) and Tuber Diameter (TDi) (Table 4). Differences between accessions were not significant for Central Stem Length (CSL), Leaf Width (LWi), Leaf Length (LLe) and Days to Spike Initiation (DSI).

TABLE 2

Variability of *S. rotundifolius* accessions for quantitative traits

Traits	Min.	Max.	Mean	Standard deviation	CV (%)	R^2 (%)	F	p-value	Meaning of F
PHe (cm)	9	47	17.74	3.88	21.86	49.85	1.84	<0.0001	**
CCi (cm)	35	220	104.75	30.67	29.28	56.83	2.44	<0.0001	**
CSL (cm)	7	45	17.39	4.29	24.68	55.41	2.31	<0.0001	**
LLe(cm)	2.4	6.5	4.35	0.64	14.65	49.71	1.83	<0.0001	**
LWi (cm)	1.2	4.6	2.77	0.47	17.1	50.74	1.91	<0.0001	**
DSI (days)	44	90	67.63	7.15	10.57	61.95	3.02	<0.0001	**
DLM (days)	110	141	131.92	5.48	4.15	68.6	4.05	<0.0001	**
TNT (number)	4	172	32.27	22.03	68.25	53.54	2.14	<0.0001	**
TWP (g)	3.6	409.9	57.56	50.98	88.57	52.56	2.06	<0.0001	**
TWe (g)	0.35	8.32	1.73	0.81	46.91	54.01	2.18	<0.0001	**
TLe (mm)	14.9	110.7	32.93	7.69	23.35	58.63	2.63	<0.0001	**
TDi (mm)	7	45.75	13.59	2.82	20.73	52.93	2.09	<0.0001	**

Note: CV (%):coefficient of variation; F: Fisher's coefficient from the analysis of variance; R^2 (%): coefficient of determination, **: significant at the threshold of 0.01; Phe: plant height, CCi: canopy circumference, CSL: central stem length, LWi: leaf width, LLe: leaf length, DSI: days to spike initiation, DLM: days to last maturity, TNT: total number of tubers, TWP: tubers weight per plant, TWe: tuber weight, TLe: tuber length, TDi: tuber diameter, cm: centimetre, g: gram, mm: millimeter.

TABLE 3

Variability of accessions of *S. rotundifolius* based on the country of origin

Traits	F	p-value	Meaning of F	Country of origin	
				Burkina Faso	Ghana
PHe (cm)	0.79	0.037	*	17.51(b)	19.85(a)
CCi (cm)	5.82	0.02	*	99.83(b)	106.97(a)
CSL (cm)	1.47	0.23	NS	17.05	17.55
LLe (cm)	0.06	0.8	NS	4.34	4.35
LWi (cm)	0.07	0.79	NS	2.78	2.77
DSI (days)	1.26	0.26	NS	68	67
DLM (days)	4.47	0.03	*	125(b)	132(a)
TNT (number)	7.36	0.01	**	28(b)	39(a)
TWP (g)	4.82	0.03	*	50.10(b)	60.92(a)
TWe (g)	0.09	0.76	NS	1.91	2.04
TLe (mm)	6.5	0.01	**	28.63(b)	33.52(a)
TDi(mm)	0.02	0.88	NS	17.56	19.6

Note: CV (%): coefficient of variation, F: Fisher's coefficient from the analysis of variance, **: significant at the threshold of 0.01, *: significant at the threshold of 0.05, a and b: classes of values resulting from the comparison by the Newman and Keuls test such that a>b, PHe: Plant height, CCi: canopy circumference, CSL: central stem length, LWi: leaf width, LLe: leaf length, DSI: days to spike initiation, DLM: days to last maturity, TNT: total number of tubers, TWP: tubers weight per plant, TWe: tuber weight, TLe: tuber length, TDi: tuber diameter, cm : centimetre, g: gram, mm: millimetre.

TABLE 4
Variability of the accessions of *S. rotundifolius* based on the climatic zone of origin

Trait	F	Pr > F	Burkina Faso		Ghana		
			Sahelian (<600 mm)	Sudano-Sahelian (600-900 mm)	Sudanese (>900 mm)	Sudan savanah (900-1000 mm)	Guinea savanah (1100-1200 mm)
PHe (cm)	2.14	0.032	14.97c	16.79b	18.34a	18.64a	19.68a
CCi (cm)	2.7	0.032	79.52c	97.13b	102.85a	103.00a	107.10a
CSL (cm)	2.43	0.063	17.13	17.33	17.4	17.52	17.64
LLe (cm)	6.4	0.052	4.06	4.11	4.5	4.3	4.55
LWi (cm)	3.66	0.061	2.4	2.62	2.84	2.86	2.89
DSI (days)	2.23	0.057	71.7	66.66	69.02	68.14	65.88
DLM(days)	1.91	0.01	112c	121b	131a	132a	132a
TNT (number)	2.65	0.034	20c	25b	36a	36a	37a
TWP (g)	3.67	0.0067	41.62c	56.67b	85.01a	86.12a	87.98 a
TWe (g)	5.31	0.0004	1.10c	1.34b	1.85a	1.90 a	1.90 a
TLe (mm)	2.91	0.022	28.03c	30.40b	32.51a	33.27a	34.66a
TDi(mm)	1.76	0.013	12.28c	15.89b	21.54 a	22.31a	23.93 a

Note: CV (%): coefficient of variation, F: Fisher's coefficient from the analysis of variance, a, b and c: classes of values resulting from the comparison by the Newman and Keuls test such that a>b>c, PHe: Plant height, CCi: canopy circumference, CSL: central stem length, LWi: leaf width, LLe: leaf length, DSI: days to spike initiation, DLM: days to last maturity, TNT: total number of tubers, TWP: tubers weight per plant, TWe: tuber weight, TLe: tuber length, TDi: tuber diameter, cm: centimetre, g: gram, mm : millimeter.

The small-size plants were those collected in the sahelian zone (<600 mm) (PHe=14.97 cm and CCi=79.52 cm). The Plant Height (PHe) and Canopy Circumference (CCi) of the accessions from Sudano-Sahelian zone (600 to 900 mm) were 16.79 cm and 97.13 cm, respectively. The accessions from the sudanian zone of Burkina Faso, sudan-savanah from Ghana and guinea-savanah from Ghana (>900 mm) developed large canopy. The Plant Height (PHe) and the Canopy Circumference (CCi) of the accessions collected in these zones varied from 18.34 cm to 19.68 cm and from 102.85 cm to 107.10 cm, respectively.

The accessions from the sahelian zone (<600 mm) were early maturing and less productive than those from the other zones. The maturity of the tubers of these accessions occurred 122 days after planting (DLM). They produced 20 tubers (TNT) corresponding to 41.62 g (TWP). The small-size tubers were recorded in this climatic zone (TLe=28.03 mm and TDi=12.28 mm). The tuber weight (TWe) was 1.10 g. The cycle and the productivity of the accessions of the sudano-sahelian zone (600 to 900 mm) were intermediate between the sahelian zone and the other climatic zones (>900 mm). The maturity (DLM) of the accessions of this climatic zone occurred 121 days after planting, the Total Number of Tubers (TNT) and Tubers Weight (TWP) per plant were 25 and 56.67 g, respectively. The Tuber Weight (TWe), the Tuber Length (TLe) and Tuber Width (TWi) were respectively 1.34 g, 30.40 mm, and 15.89 mm. The accessions from the sudanian zone of Burkina Faso, sudan-savanah and guinea-savanah of Ghana (>900 mm) were late maturing with higher productivity than the accessions of the other climatic zones. The cycle from planting to maturity (DLM) was 131 or 132 days, the Number of Tubers (TNT) and the weight of the Tubers Per Plant (TWP) varied from 36 to 37 and from 85.01 g to 87.98 g. The tuber weight ranged from 1.85 g to 1.90 g. The Tuber Length (TLe) varied from 32.51 mm to 34.66 mm and the diameter (TDi) from 21.54 mm to 23.93 mm.

Correlations between the traits of *S. rotundifolius*.

There were significant correlations (at levels P=0.05 or 0.01) among many of the evaluated traits (Table 5). Positive correlation coefficients between the traits related to the canopy and leaf size varied from 0.58 (PHe and CCi) to 0.77 (LLe and LWi). For the traits related to productivity, significant correlations were found between the Number and Weight of Tubers Per Plant (TNT and TWP) with r=0.85; between Tuber Weight (TWe) and Tuber Length (TLe) with r=0.44 and also between Tuber Weight (TWe) and Tuber Diameter (TDi) with r=0.58. The Number and Weight of Tubers (TNT and TWP) were correlated to Tuber Diameter (TDi) with r=0.24 and r=0.44, respectively.

Structuration of the agronomical variability of *S. rotundifolius*

The Hierarchical Ascendant Classification (HAC) was performed on the basis of the number of Days to Last Maturity (DLM), Plant Height (PHe), Canopy Circumference (CCi), Total Number of Tubers (TNT) and Tubers Weight Per Plant (TWP). The dendrogram from the HAC with a truncation at 10,000 dissimilarities revealed a distribution of the 174 accessions into six groups (Figure 3).

The six groups included variable numbers of accessions from both countries (Burkina Faso and Ghana) (Table 6). The first group (Group I) consisted of nine (09) accessions including six (06) accessions from Ghana and three (3) from Burkina Faso. The second group (Group II) contained 12 accessions including eight (8) accessions from Ghana and four (4) accessions from Burkina Faso. The third group (Group III) is made up of 32 accessions, including 25 accessions from Ghana and seven (7) from Burkina Faso. Groups IV and VI were the most numerous with 43 accessions (31 from Ghana and 12 from Burkina Faso) and 49 accessions (31 from Ghana and 18 from Burkina Faso). Group V consisted of 29 accessions including 15 from Ghana and 14 from Burkina Faso.

TABLE 5

Pearson correlation coefficients between morphometric traits of *S. rotundifolius*

Variables	DSI	DLM	PHe	CSL	CCi	LLe	LWi	TNT	TWP	TWe	TLe	TDi
DSI	1											
DLM	0.33**	1										
PHe	0.07	0.11	1									
CSL	0.04	0.18*	0.67**	1								
CCi	0.18*	0.04	0.58**	0.69**	1							
LLe	-0.06	-0.02	0.27**	0.20**	0.27**	1						
LWi	-0.08	-0.17*	0.18*	0.13	0.2^{5**}	0.77**	1					
TNT	0.16*	0.18*	0.25**	0.31**	0.52**	0.05	0.14	1				
TWP	0.22**	0.17*	0.38**	0.35**	0.61**	0.17*	0.22*	0.85**	1			
TWe	0.24**	0.08	0.29**	0.17*	0.36**	0.18*	0.18*	0.17*	0.58**	1		
TLe	0.14	0.06	0.33**	0.22**	0.34**	0.20**	0.20**	0.31**	0.48**	0.44**	1	
TDi	0.29**	0.12	0.26**	0.18*	0.33**	0.08	0.1	0.24**	0.44**	0.56**	0.51**	1

Note: *: significant at the 0.05 level, **: significant at the 0.01 level, DSI: days to spike initiation, DLM: days to last maturity, PHe: Plant height, CCi: canopy circumference, CSL: central stem length, LWi: leaf width, LLe: leaf length, TNT: total number of tubers, TWP: tubers weight per plant, TWe: tuber weight, TLe: tuber length, TDi: tuber diameter.

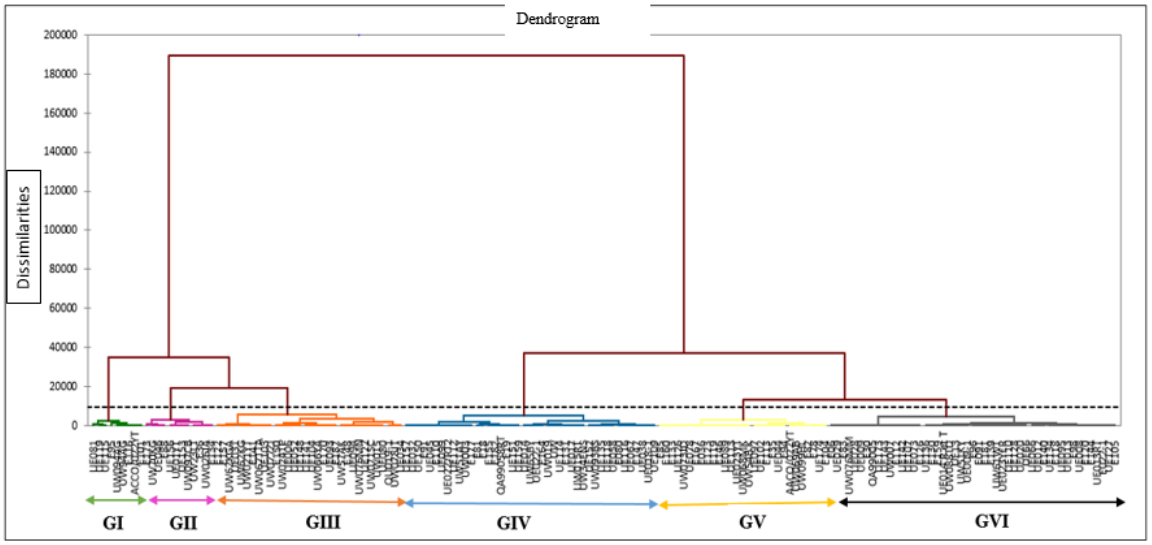

Figure 3) *Dendrogram from the hierarchical ascendant classification of the 174 accessions of* S. rotundifolius

TABLE 6

Origin and number of accessions of agromorphological groups of *S. rotundifolius*

Groups		I	II	III	IV	V	VI	Total
Number of accessions		9	12	32	43	29	49	174
Origins	Burkina Faso	3	4	7	12	14	18	58
	Ghana	6	8	25	31	15	31	116

Characteristics of agromorphological groups of *S. rotundifolius*

The groups generated by the HAC were analyzed using Discriminant Factorial Analysis (DFA) which considered the number of Days to Last Maturity (DLM), Plant Height (PHe), Canopy Circumference (CCi), Total Number of Tubers (TNT), and Tubers Weight Per Plant (TWP) (Figure 4). The DFA's ½ plan, accounting for 98.67% of the total inertia, associated Plant Height (PHe), Tubers Weight Per Plant (TWP), and Total Number of Tubers (TNT) to axis F1 (representing 89.26% of total inertia). The same plan combined Canopy Circumference (CCi) and the number of Days to Last Maturity (DLM) to axis F2 (representing 9.41% of total inertia).

The position of the agromorphological groups in DFA's ½ plan showed that the first group (GI) is positively correlated to axis F1 while group VI was negatively correlated to this axis. Groups II and IV were positively correlated to the axis F2 and groups III and V were negatively correlated to this axis (Figure 5).

The analysis of variance revealed significant differences between the groups. The first group (GI) was characterized by large foliage development (PHe=20.61 cm and CCi=160.91 cm), a long cycle (DLM=132 days) with good productivity (TNT=62 and TWP=148, 21 g).

The second group (GII) was characterized by large foliage development (PHe=19.62 cm and CCi=150.78 cm), and a long cycle (DLM=130 days). The Number of Tubers Per Plant (NTP) of the accessions of this group was 46 and Tubers Weight (TWP) was 90.88 g. The third group (GIII) was characterized by medium leaf development (PHe=18.89 cm; CCi=115.37 cm), medium cycle (DLM=127 days) with average productivity (TNT=42 and TWP=85.42 g). The fourth group (GIV) was characterized by medium leaf development (PHe=17.91 cm; CCi=113.47 cm), medium cycles (DLM=122 days) and medium productivity (TNT=39; and TWP=83.46 g). The fifth group (GV) opposite to the first one (GI), was characterized by the small size of the canopy (PHe=16.50 cm; CCi=99.57 cm), early maturing (DLM=121 days) a medium productivity (TNT=26 and TWP=39.81 g). The sixth group (GVI) was characterized by the small size of the canopy (PHe=15.84 cm; CCi=98 .63 cm), early maturity (DLM=118 days) and low productivity (TNT=24; TWP=37.36 g) (Table 7).

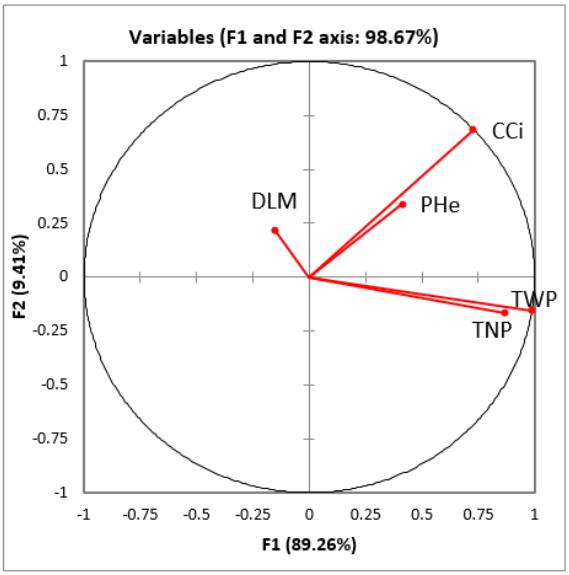

Figure 4) *Association of the quantitative traits of* S. rotundifolius *to DFA's axis;* **Note:** *PHe: Plant Height, CCi: Canopy Circumference, DLM: Days to Last Maturity, TNT: Total Number of Tubers Per Plant, TWP: Tubers Weight Per Plant*

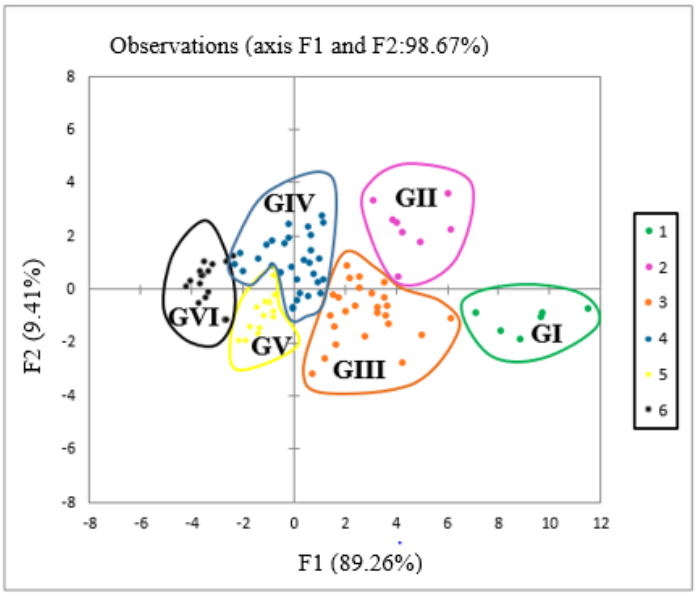

Figure 5) *Position of agromorphological groups of* S. rotundifolius *in ½ plan of the DFA;* **Note:** *GI, GII, GIII, GIV, GV and GVI: different groups from the HAC*

TABLE 7
Variability of agromorphological groups

Groups	PHe (cm)	CCi (cm)	DLM (days)	TNT (number)	TWP (g)
I	20.61a	160.91a	132a	62a	148.21a
II	19.62b	150.78b	130b	46b	90.88b
III	18.89c	115.37c	127c	42c	85.42c
IV	17.91d	113.47d	122d	39d	83.46d
V	16.50d	99.57e	121d	26e	39.81e
VI	15.84e	98.63f	118e	24f	37.36f
dfr	5	5	5	5	5
F	9.97	28.59	43.04	11.61	14.28
p-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: a, b,c,d ,e and f: classes of values resulting from the comparison by the Newman and Keuls test such that a>b>c> d>e>f, dfr : degree of freedom, F: F of Fischer resulting from analysis of variance, PHe: plant height, CCi: canopy circumference, DLM: days to last maturity, TNT: total number of tubers, TWP: tubers weight per plant.

The conservation and sustainable utilization of plant genetic resources are crucial to ensure food security [12]. The management of plant germplasm requires the evaluation of the magnitude of genetic variability [13]. In this study, an agromorphological variability of 174 accessions from Burkina Faso and Ghana was described using 12 quantitative traits related to plant canopy size, plant cycle and yield. Significant differences were observed for all the traits. These traits were already used for the agromorphological characterization of *S. rotundifolius* in previous research works [10,11,14,15]. They can be included as descriptors for *S. rotundifolius*.

Significant differences (at level P=0.01) and a large amplitude were observed in all the traits. The variability for traits related to canopy and leaf size was higher than the findings of previous research works on *S. rotundifolius*. The plant height (9-47 cm), the canopy circumference (35-220 cm) and the leaf length (2.40-6.40 cm) and width (1.20-4.6 cm) covered the values mentioned previously, 14.5-30.38 cm, 33.89-100.43 cm, 3.8-6.1 cm and 2.3-5.1 cm [11,14,15]. The present study included accessions from different climatic zones in two countries (Burkina Faso and Ghana) and could have contributed to capturing more variability within the species.

Despite the large amplitude of variation of traits related to the plant cycle, the results of current study for spike initiation (44-90 days) and maturity (110-140 days) did not cover the whole variation of *S. rotundifolius* mentioned in previous works. Spike initiation occurred 61 to 90 days and the maturity 113 to 164 days after planting [14]. According to Guillaumet et al., [16] and Abhraham et al., [5], *S. rotundifolius* is a photosensitive plant. The cycle and the yield varied according to the planting periods. This could explain the early transplanting in rural areas as mentioned by Nanema [17] and Sugri et al., [3].

The small tuber size was identified to be one of the main constraints for *S. rotundifolius* promotion [7]. The nonmarketable tubers rate could be as high as 90% per harvest [14]. In this study, the accessions produced 3.6 to 409.9 g of tubers per plant. Tuber length and diameter varied from 14.90 to 110.7 mm and 7 to 45.75 mm, respectively. Despite the presence of some accessions with low productivity and small-size tubers in the collection, significant number of accessions with high yield and big tubers could be selected. The total weight of tubers per plant is therefore less than the potential yield mentioned by Opoku-Agyeman et al., [10] and Asha et al., [15]; 480 g and 465.3 g respectively. The potential yield of the accessions could be improved through adequate conditions of cultivation including early planting, improved soil fertility and good agronomic practices.

The collection included accessions from two countries and various climatic zones (<600 mm to 1200 mm). The climatic zone of origin was revealed to be more discriminant than the country of origin. The accessions from the sahelian were early maturing and less productive when the zones with more than 900 mm rainfall were late maturing, with high potential and large canopy. *S. rotundifolius* is cultivated in pluvial conditions [3,17]. Without any irrigation facilities, farmers should select and cultivate landraces that fit with their farming conditions. This practice should have contributed to landraces distribution in different climatic zones. In the context of climate changes, significant variations in rainfall could lead to the disappearance of *S. rotundifolius* from some areas. The collaboration between scientists from Burkina Faso and Ghana that made it possible for the exchange of germ plasm should be commended. This effort offers the scientists opportunity to select appropriate accessions that will match the changing rainfall patterns as a result of climate change and variability in the various agroecological zones in their respected countries.

High correlations (>0.6) were observed between main stem length and foliage height and between leaf length and leaf width and between main stem length and tubers weight per plant and total number of tubers. These correlations were also observed by Nanema et al., [14]. In the breeding process, these correlations should be helpful for plant selection. According to the breeding objective, the evaluated traits with positive correlation could be highly relevant for selection.

Six groups were identified within the collection. These groups differed in canopy size, cycle, yield, and tuber size. Nanema [18] mentioned the size of the foliage, productivity, and cycle as the main traits for cluster analysis. The number of groups is higher than in previous work on *S. rotundifolius* [15,17].

CONCLUSION

This study highlighted the existence of great variability within *S. rotundifolius* accessions from Burkina Faso and Ghana. Such a level of variability confirmed the importance of a large collection in the agromorphological characterization of vegetatively propagated species. The results could help build up relevant descriptors for *S. rotundifolius* and for breeding purposes. The higher groups atained in the current study emphasis the importance of large number of accessions in such a study to bring out very minute differences among the accession. The six groups therefore offered more opportunities for selection within the collection.

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