

# Characterization of Spider Plant (*Cleome gynandra* L.) under Samanko Conditions

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## Abstract

This study aimed to evaluate spider plant (*Cleome gynandra* L.) accessions for agronomic and morphological characteristics. Sixty-four accessions, characterized under Samanko conditions, were assessed using a phenotypic evaluation system. Observations and biometric measurements covered 34 variables, revealing considerable agro-morphological variability among the accessions, particularly in qualitative traits. Significant differences were observed at the 5% threshold between accessions for variables such as plant height, plant diameter, pod width, and 50% flowering date. Several positive correlations were also noted between the traits. The study identified three distinct groups of accessions based on diversity structuring. The first group mainly comprised accessions with a short growth cycle and average yield. The second group was characterized by accessions with superior agronomic performance, featuring a long cycle and high yields. In contrast, class III exhibited lower agronomic performance compared to the other two classes. The variability identified in this study offers potential for use in *Cleome gynandra* L. improvement programs in Mali, with class II accessions distinguished by their dark green, hairy stems and superior agronomic performance being the most promising candidates for improvement.

## Keywords

Mali, Spider Plant, *Cleome gynandra* (L.), Diversity, Agromorphological

## 1. Introduction

The spider plant (*Cleome gynandra* L.) is an annual plant belonging to the *Caparaceae* family [1] [2]. It likely originates from South Asia or Africa, where it is traditionally harvested from the wild or cultivated in kitchen gardens [3]. The

tender leaves, stems, pods, and flowers are consumed as vegetables, either boiled in water or milk, or prepared with other vegetables (e.g., tomatoes) and spices [4]-[6].

*Cleome gynandra* is one of the most important traditional leafy vegetables in Africa [7]. These traditional vegetables play a vital role in food and nutrition security and income diversification, particularly for resource-poor households and those living in areas with challenging environmental conditions, where water is available only during short periods of the crop growth cycle [8].

Despite its significant socio-economic, nutritional, and food security value, the spider plant has long been neglected. The introduction of exotic vegetables into Africa has negatively impacted the cultivation and consumption of indigenous species like spider plants [9]. Over time, it gained a reputation as a “poor man’s food,” causing its cultivation and consumption to decline [10]. This situation has contributed to the reduction of agrobiodiversity globally [11].

To address the genetic diversity loss of neglected species, studies have been conducted across Africa. In West Africa, research on the biochemical composition of spider plants has been undertaken in Côte d’Ivoire [12] [13] and Burkina Faso [14]. In Burkina Faso and Benin, [6] and [15] have shown that the diversity of accessions is influenced by farming practices and climatic zones. Their work classified accessions based on these zones. In Kenya, [16] developed best agronomic practices to improve the profitability of small-scale commercial production of spider plants.

Further studies in Kenya [17] [18] and [19] Zimbabwe revealed the existence of phenotypic diversity within the species. Traits such as stem and pod color, leaf lobule number, pod lining, and pod shape have been used to distinguish between spider plant genotypes [20].

Mali faces urgent nutritional challenges, with an estimated 1.4 million children aged 6 to 59 months projected to suffer from acute malnutrition [21]. Addressing nutritional security is essential for improving human health, and the spider plant offers a nutritious solution. The plant is rich in beta-carotene, vitamin C, and moderate levels of calcium, magnesium, and iron. According to [22], the leaves of *C. gynandra* are used to address malnutrition in several countries.

Despite the high nutritional value of the spider plant, there has been limited research on its crop improvement, particularly regarding phenotypic diversity in Mali. Phenotypic characterization is crucial for identifying accessions with desirable traits for breeding and conservation. Since knowledge of genetic diversity is vital for varietal improvement, there is a need to explore this diversity in Mali. The objective of this study is to evaluate spider plant accessions for their agronomic and morphological characteristics.

## 2. Materials and Methods

### 2.1. Plant Material and Collection Site

The plant material consisted of 64 accessions from the World Vegetable Center Genbank in Arusha (Tanzania).

## 2.2. Study Site and Experimental Design

### Experimental Variables and Collection of Agro-Morphological Data

Observations and biometric measurements were made for 34 variables, including 18 qualitative and 16 quantitative traits. The qualitative variables included: stem color (TigC), leaf color (Fcol), petiole color (CPE), stem hairiness (TiP), shape of the terminal leaflet, plant pubescence (PUB), branching habit (PPL), leaf and stem waxiness/lubricity, upper surface veins, leaf margin shape, and overall plant pubescence. These variables were observed throughout the entire plant development cycle, except for the number of days to 50% flowering (NJF), which was measured across the entire plot. Biometric measurements were conducted on plants per line.

#### Quantitative data were collected for eleven agronomic traits, including:

Plant height (HP)  
 Stem diameter (Dm)  
 Terminal leaflet length (LOF)  
 Terminal leaflet width (LaF)  
 Petiole length (LoP)  
 Leaf area (SuF)  
 Pod length (LoG)  
 Pod width (LaG)  
 Pod area (SuG)  
 1000-seed weight (P1)  
 Leaf yield (RT)

Other measurements included filament length (Lof), gynophore length (LoGy), pedicel length (LoPéd), and days to 50% flowering (50% DF).

#### The qualitative characters observed were:

Growth habit (HC)  
 Branching habit (Pram)  
 Stem color (TigC)  
 Stem hairiness (TigP)  
 Lobed leaf blade (Lmllo)  
 Leaf color (Fcol)  
 Terminal leaflet shape (FormM)  
 Leaf margin shape  
 Leaf pubescence (PuB)  
 Petiole color (PCol)  
 Surface smoothness  
 Upper surface veins (Vei)  
 Immature pod color (CGI)  
 Mature pod color (Cl)  
 Cross-sectional shape of fruit (FL)  
 Pod shape  
 Color of mature seeds (CG)

Data for the 18 coded morphological traits were used to generate a biplot analysis.

### 2.3. Statistical Analyses

Coded data from 18 morphological traits were used to generate a biplot analysis using XLSTAT 2014.5.03 software. An analysis of variance (ANOVA) was performed on the quantitative variables to determine whether significant differences existed between accessions. Mean separation was conducted using the 5% LSD (Least Significant Difference) test to identify these differences.

Variability for each quantitative trait was evaluated through statistical measures, including the mean, standard deviation, and coefficient of variation. The relationships between variables were analyzed using a total correlation matrix. A Principal Component Analysis (PCA) was also carried out using XLSTAT 2014.5.03, and the coordinates of individuals were used to group accessions via Ascending Hierarchical Classification (AHC). These groups were subsequently characterized based on their traits.

## 3. Results

### 3.1. Analysis of the Diversity of Qualitative Characteristics

The results are summarized in **Table 1**. Two growth habits, low and high, were observed in plant stems, with more accessions displaying a low growth habit. Stem color was found to depend on petiole color: accessions with lighter-colored petioles generally had darker stems. Most accessions exhibited medium-dark stem colors, and the majority also had medium levels of pubescence and hairiness. However, there were also accessions with high and low levels of pubescence.

In terms of seed traits, most accessions produced healthy, mature, dark-colored seeds. The only trait that showed no variation among the accessions was the color of the floral parts. Intra-accession variability was noted for all other observed qualitative traits.

**Table 1.** Variation of qualitative characters in the collection of *Cleome gynandra* (L).

Characters	Terms	Percentage (%)
Attitude to growth	Weak	73.8
	Pupil	26.2
Branched habit	Weak	30.8
	Average	35.3
	Pupil	33.8
Stem color	Less Dark	56.9
	Medium dark	40
	Very dark	3.1
Hairiness of the stem	Weak	18.5
	Moyen	41.5
	Pupil	40
Lobed blade	Faible	40
	Average	56.9
	Pupil	3.1

## Continued

Petiole color	Less Dark	67.7
	Medium dark	16.8
	Very dark	15.5
Color of immature pods	Less Dark	93.8
	Medium dark	6.3
Mature pod color	Less Dark	14.1
	Medium dark	18.7
	Very dark	67.2
Pod shape	Weak	98.4
	Moyen	1.6
	Pupil	
Color of mature healthy seeds	Less Dark	12.5
	Medium dark	31.3
	Very dark	56.3
Leaf pubescence/ hairiness on upper side	Weak	9
	Average	66
	Pupil	25

### 3.2. Principal Component Analysis

**Table 2** presents the percentage of variation explained by the first six principal components (PCs) and the vector loadings for each character and PC. These six PCs accounted for 53.42% of the total variation among the 64 accessions studied.

PC1 was predominantly influenced by growth habit, smoothness, fruit cross-sectional shape, and CG2, all of which contributed positively to PC1 (**Table 2**). In contrast, traits such as leaf pubescence and immature pod color had low loadings, with values of 0.0001 and 0.007, respectively. PC2 was largely defined by stem hairiness and leaf color, whereas PC3 was most influenced by stem color, mature pod color, and branching habit.

For PC5, four qualitative traits were significant contributors: leaf pubescence, petiole color, mature pod color, and pod shape. The sixth principal component (PC6) was primarily influenced by lobed leaf blade and leaf margin shape.

**Table 2.** Eigenvalues<sup>a</sup>, eigenvectors<sup>b</sup> and percentage of variation explained by the first six principal components for 64 spider plant accessions.

Qualitative character	Principal component					
	F1	F2	F3	F4	F5	F6
Growth habit	<b>0.580</b>	0.008	0.017	0.000	0.011	0.004
Branching Port	0.020	0.014	<b>0.559</b>	0.002	0.022	0.000
Stem Color	0.085	0.047	<b>0.181</b>	0.105	0.084	0.000
Hairiness of the stem	0.084	<b>0.618</b>	0.013	0.032	0.002	0.011
Lobed leaf blade	0.002	0.000	0.018	0.008	0.001	<b>0.477</b>
Leaf color	0.017	<b>0.659</b>	0.001	0.020	0.000	0.011
Shape of the terminal leaflet	0.007	0.036	0.145	<b>0.185</b>	0.000	0.118
Leaf shape of the margin	0.012	0.009	0.093	0.006	0.012	<b>0.306</b>
Leaf pubescence	0.000	0.080	0.019	0.025	<b>0.328</b>	0.055
Petiole color	0.089	0.094	0.052	0.126	<b>0.157</b>	0.009

## Continued

Smoothness	<b>0.399</b>	0.010	0.067	0.006	0.039	0.011
Veins of the upper surface	0.002	0.088	0.133	<b>0.168</b>	0.006	0.083
Immature pod color	0.007	0.000	0.019	0.004	<b>0.435</b>	0.132
Color of mature pod	0.015	0.004	<b>0.210</b>	0.068	0.004	0.037
cross section of a fruit	0.005	0.001	0.004	<b>0.459</b>	0.000	0.004
Cross-sectional shape of a fruit	<b>0.297</b>	0.001	0.038	0.122	0.017	0.009
Pod shape	0.022	0.010	0.061	0.039	<b>0.383</b>	0.003
Color of healthy mature seeds	<b>0.229</b>	0.037	0.005	0.083	0.130	0.036
<i>Eigenvalue</i>	2.090	1.752	1.696	1.538	1.307	1.233
<i>Cumulative %</i>	11.610	21.345	30.766	39.310	46.570	53.423

<sup>a</sup>Eigenvalues indicate the amount of variance explained by each principal component; <sup>b</sup>Eigenvectors are the weights in a linear transformation when computing principal components; <sup>c</sup>Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

### 3.3. Diversity of Quantitative Characteristics

Average performance of the accessions studied are presented in **Table 3**. Analysis of variance revealed significant differences at the 5% level among the accessions studied for several traits, including plant height, plant diameter, pod width, and the 50% flowering date.

The number of leaflets per leaf ranged from 3 to 7. The flowers displayed 4 green sepals, 4 white petals, and 6 purple stamens. Plant height varied between 8.75 cm and 51.52 cm, while the diameter of the primary stems ranged from 3.5 to 9.5 cm. The coefficients of variation (CV) for all variables were below 40%, with the exception of leaf width.

High coefficients of variation (CV > 30%) were observed for plant height, leaf area, terminal leaflet width, and leaf yield. For other traits, the CV was lower (CV < 30%). All variables showed relatively low coefficients of determination, with values below 50%.

**Table 3.** Average performance of the accessions studied.

Variable	Minimum	Maximum	Mean	CV%	R <sup>2</sup> (%)	P value
TR	60	100	98.17 ± 4.49	4.6	33	0.44
HP	8.75	51.25	26.51 ± 8.56	32.2	43	0.015
Dm	3.5	9.50	5.85 ± 1.06	18.1	42	0.03
LoF	2.72	8.22	6.01 ± 0.99	16.4	33	0.44
LaF	1.3	15.27	2.33 ± 1.07	46	30	0.77
LoP	8.775	21.92	15.67 ± 2.51	16	22	0.99
SuF	4.68	41.62	14.07 ± 5.13	36.4	27	0.88
DR	44	68	60.13 ± 4.28	7.1	32	0.50
LoG	32.5	245.25	62.84 ± 17.38	27.6	33	0.42
LaG	2	6.50	3.78 ± 0.82	22.2	42	0.02
P1	1.53	2.90	2.06 ± 0.26	12.7	25	0.99
RT	143.83	833.46	460.10 ± 141.32	30.6	36	0.25
50%DF	20	28	21.75 ± 1.93	8.9	45	0.007
Lof	1.6	2.85	2.11 ± 0.24	11.3	44	0.011
LoGy	16.25	85.75	47.35 ± 13.98	29.5	40	0.072

Continued

LoPéd	1.45	2.57	1.99 ± 0.19	9.9	26	0.919
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PH: plant height; Dm: stem diameter; LOF: terminal leaflet length; LaF: terminal leaflet width; LoP: petiole length (cm); SuF: leaf area (cm<sup>2</sup>); LoG:-pod length (mm). LaG: pod width (mm); P1: 1000 grain weight (g) and RT: leaf yield (kg); 50%DF: days to 50% flowering; Lof: Filament length (cm); LoGy: Gynophore length (mm); LoPéd: Pedicel length (mm); P value : significance level test.

### 3.4. Correlation Coefficients among Growth and Vegetative Traits in Spider Plant

The analysis reveals several significant or highly significant correlations between various traits (Table 4). After testing the conformity of the correlation coefficients, it was found that plant height and plant diameter (Dm) are positively correlated (0.43), as is the petiole length (LoP). Both plant height and diameter are also positively correlated with leaf yield.

Regarding the days to 50% maturity (50% DF), there is a strongly negative and significant correlation with plant height (−0.488) and plant diameter (−0.211). This indicates that taller plants with larger diameters tend to have shorter times to 50% maturity.

Additionally, significant correlations were found between leaf yield and variables such as recovery rate, terminal leaflet length, and petiole length. Plant height (HP) also shows significant correlations with leaf area and 1000 seed weight.

**Table 4.** Correlation matrix (Pearson).

Variables	TR	HP	Dm	LoF	LaF	LoP	SuF	DR	LoG	LaG	P1	RT	50% DF	Neant	LoGy	LoPéd
TR	1															
HP	0.118	1														
Dm	0.067	<b>0.432</b>	1													
LoF	0.018	0.136	<b>0.251</b>	1												
LaF	−0.068	0.014	0.122	0.047	1											
LoP	0.022	<b>0.149</b>	0.140	<b>0.598*</b>	−0.062	1										
SuF	−0.099	0.089	<b>0.234</b>	<b>0.640*</b>	<b>0.751</b>	<b>0.284</b>	1									
DR	−0.063	−0.087	−0.068	0.086	0.068	<b>0.179</b>	0.108	1								
LoG	−0.014	−0.108	−0.029	0.015	−0.132	0.098	−0.101	−0.113	1							
LaG	0.113	0.062	<b>0.164</b>	−0.046	<b>−0.203</b>	−0.005	<b>−0.190</b>	<b>−0.361</b>	<b>0.306*</b>	1						
P1	−0.001	0.061	0.083	0.014	−0.084	0.089	−0.062	−0.140	−0.024	<b>0.156*</b>	1					
RT	<b>0.256</b>	<b>0.182</b>	<b>0.319</b>	<b>0.293</b>	−0.097	<b>0.271</b>	0.042	−0.070	<b>0.150</b>	0.074	0.055	1				
50%DF	<b>−0.237</b>	<b>−0.488*</b>	<b>−0.211</b>	−0.120	−0.028	−0.109	−0.083	0.080	−0.002	−0.067	−0.076	−0.121	1			
Lof	0.051	<b>−0.168</b>	0.045	−0.007	0.109	−0.094	0.101	0.007	−0.063	0.033	−0.018	<b>−0.157</b>	0.042	1		
LoGy	0.003	<b>−0.267</b>	−0.138	0.119	−0.035	<b>0.183*</b>	0.066	<b>0.437</b>	−0.109	<b>−0.358</b>	0.045	0.125	<b>0.232</b>	<b>0.150</b>	1	
LoPéd	0.116	0.050	−0.054	0.038	−0.121	<b>0.210</b>	−0.114	0.056	<b>0.167</b>	0.006	−0.078	<b>0.214</b>	<b>−0.170</b>	−0.058	−0.040	1

\*Correlation is significant at the  $P > 0.05$  level (1-tailed); HP: plant height; Dm: stem diameter; LOF: terminal leaflet length; LaF: terminal leaflet width; LoP: petiole length; SuF: leaf area; LoG: pod length. LaG: pod width; SuG: pod area; P1: 1000 grain weight and RT: leaf yield, Lof: Filament length; LoGy: Gynophore length; LoPéd :Pedicel length. days to 50% flowering.

### 3.5. Agro-Morphological Diversity

The detailed numerical results of the PCA, including the cosine squares of the characters and their contribution to the total variability, are recorded in **Table 5**. The first six factorial axes explain nearly 65.67% of the total variability among the different active variables. Of the 16 variables used in the analysis, 4 are associated with Factor 1 (F1), while the remaining 12 are associated with Factor 2 (F2). These variables will be utilized for hierarchical ascending classification.

The principal component analysis (**Table 5**) identified 16 factors with eigenvalues ranging from 0.03 to 2.642. The first factor (F1) has an eigenvalue of 2.642, explaining 16.066% of the total variability. Factor 2 (F2) has an eigenvalue of 2.384, contributing 15.34% to the variability. Factors 3, 4, 5, and 6 each have eigenvalues greater than 1, while the eigenvalues of the remaining factors are less than 1, indicating they explain minimal observed variability. Together, the first four factors (F1 and F2) account for 51.07% of the total variability.

Axis 1 is positively associated with plant size ( $r = 0.26$ ), stem diameter ( $r = 0.33$ ), leaf length ( $r = 0.586$ ), petiole length, and leaf surface area ( $r = 0.463$ ). This axis groups accessions with a long semi-flowering cycle on its negative side. Axis 2, representing 14.90% of the total variability, is explained by the length of the gynophore, pod width, and the date of the first harvest. It contrasts individuals with long pedicels on the negative side against those characterized by short pedicels, which tend to have higher leaf yields.

Axis 3 accounts for 11.17% of the total variance and primarily associates leaf width with leaf surface area and average height. Axes 1 and 3 explain most of the traits related to biomass production. Finally, Axis 4 (8.5%) is defined by pod length, pod width, and the 50% flowering date, which all express seed characteristics. This axis distinguishes two groups of accessions: the first group in the positive area displays long pods with a high 1000-grain weight, while the second group in the negative area consists of accessions with smaller pods and a longer time to 50% flowering.

**Table 5.** Eigenvalues<sup>a</sup>, eigenvectors<sup>b</sup> and percentage of variation explained by the first Four principal components for 64 spider plant accessions.

Quantitative character	Principal component			
	F1	F2	F3	F4
Plant recovery rate	0.028	0.092	0.023	0.098
Plant height	<b>0.269</b>	0.164	0.058	0.193
Stem diameter	<b>0.332</b>	0.059	0.059	0.000
Terminal leaflet length	<b>0.586</b>	0.040	0.036	0.086
Terminal leaflet width	0.101	0.220	<b>0.353</b>	0.005
Retiole length	<b>0.394</b>	0.006	0.222	0.037
Leaf area	<b>0.463</b>	0.263	0.133	0.062
Date of harvest of the first seeds	0.006	<b>0.317</b>	0.129	0.103
Pod length	0.000	0.109	0.075	<b>0.294</b>
Pod width	0.001	<b>0.409</b>	0.008	0.227
1000 grain weight	0.005	0.042	0.000	0.020

Continued

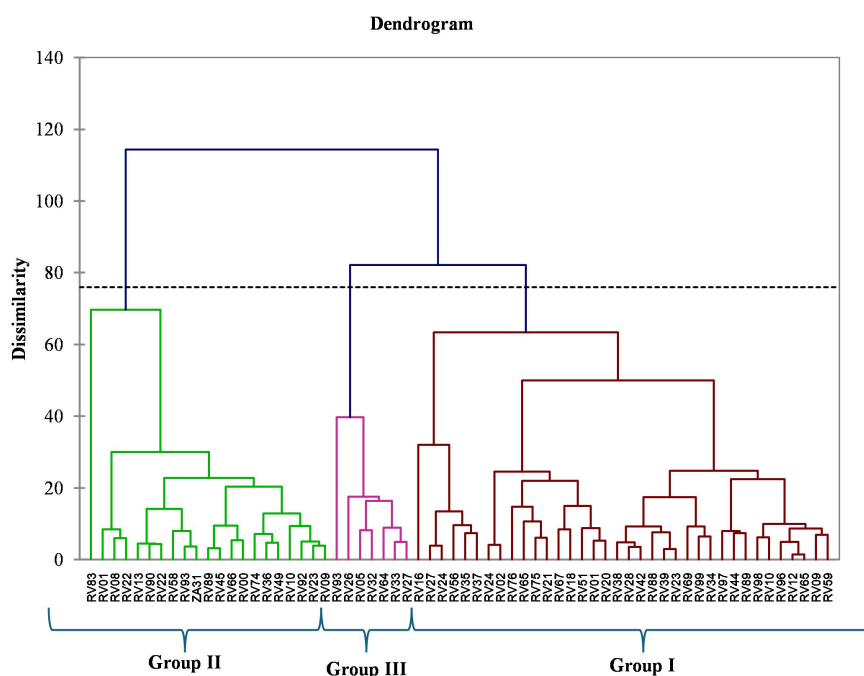
Leaf yield	0.239	0.075	0.166	0.000
Days to 50% flowering	<b>0.193</b>	0.158	0.026	0.179
Filament length	0.005	0.048	0.029	0.026
Gynophore length	0.000	<b>0.332</b>	0.270	0.008
Pedicle length	0.021	0.049	0.20	0.022
<i>Eigenvalue</i>	2.642	2.384	11.17	8.5
<i>Variability (%)</i>	16.510	14.901	11.17	8.5
<i>Cumulative %</i>	16.510	31.411	42.5	51.07

<sup>a</sup>Eigenvalues indicate the amount of variance explained by each principal component; <sup>b</sup>Eigenvectors are the weights in a linear transformation when computing principal components; <sup>c</sup>Values in bold correspond for each variable to the factor for which the squared cosine is the largest.

### 3.6. Ascending Hierarchical Classification (CAH)

The hierarchical ascending classification (**Figure 1**) was performed on the 16 variables identified from the principal component analysis. A truncation level of 75.92% structured the diversity into three distinct groups. A subsequent analysis subdivided each group, revealing an inter-group dissimilarity of 86.51% and an intra-group dissimilarity ranging from 25% to 30%. Analysis of variance indicated significant differences among the groups for all 16 traits.

- **Group 1** consists of 36 accessions.
- **Group 2** is composed of 21 accessions.
- **Group 3** includes 7 accessions.



**Figure 1.** Cluster dendrogram on morphological characteristics in Spider-plant accessions.

### Relationship between Agro-Morphological Characters and Accessions



- 13) Gynophore Length (LoGy)
- 14) Pedicel Length (LoPéd)
- 15) Days to 50% Flowering (50%DF)

#### **Qualitative Variables**

- 1) Growth Habit (HC)
- 2) Branching Port (Pram)
- 3) Stem Color (TigC)
- 4) Hairiness of the Stem (TigP)
- 5) Lobed Leaf Blade (Lmlo)
- 6) Leaf Color (Fcol)
- 7) Shape of the Terminal Leaflet (FormM)
- 8) Leaf Shape of the Margin
- 9) Leaf Pubescence (PuB)
- 10) Petiole Color (PCol)
- 11) Smoothness
- 12) Veins of the Upper Surface (Vei)
- 13) Immature Pod Color (CGI)
- 14) Color of Mature Pod (Cl)
- 15) Cross Section of a Fruit (FL)
- 16) Cross-Sectional Shape of a Fruit (Fl)
- 17) Pod Shape
- 18) Color of Healthy Mature Seeds (CG)

## **4. Discussions**

### **4.1. Agro-Morphological Variability**

The primary objective of this study was to agro-morphologically characterize Spider-plant accessions in Samanko station's conditions. The results revealed substantial variability in morphological characteristics that were measured, counted, and scored during the phenotypic characterization of the four Spider-plant accessions. Notably, variation was observed across all qualitative traits among the sixty-four Spider-plant accessions analyzed.

The genetic variation observed in qualitative characters can be attributed to the additive action of genes, as discussed by [23]-[25]. Additionally, non-additive gene actions and the interaction between genotype and environment also contribute to this variability, as noted by [26]. Such factors help explain the differences observed under the specific conditions in Samanko agro-ecological conditions.

A similar wide range of variation for qualitative traits has been reported by [6] and [15]. The mixed reproduction mode of *Cleome gynandra* L. likely plays a significant role in the observed variability within accessions. Specifically, partial or total allogamy facilitates cross-fertilization, which promotes natural genetic mixing, thereby leading to significant genetic diversity [27]. Previous studies by [19] and [6] indicated that differences in agronomic characters observed between morphotypes in Kenya and Zimbabwe could be attributed to producer selection

practices.

In terms of plant height, measurements ranged from 8 cm to 51 cm. These figures are somewhat higher than those recorded by [6] in Burkina Faso and [19] in Mozambique and Kenya. However, they are comparable to measurements obtained by [28] in South Africa (25 - 60 cm).

Conversely, the average number of days to reach 50% flowering among the accessions studied ( $21.75 \pm 1.93$  days) is slightly higher than the  $20.96 \pm 1.93$  days reported by [29] for accessions from Burkina Faso. This difference could be explained by the presence of similar morphotypes between Burkina Faso and Mali, which likely share comparable environmental conditions. However, the days to flowering recorded in this study are shorter than those reported by [18] for accessions from Kenya (36.5 - 40.3 days). This variation may arise from different morphotypes present in these countries and the broader sample collection area considered in other studies. Specifically, while this study focused solely on samples from Samanko in Mali, the analyses by [19] and [30] included samples from various countries. A broader collection area typically introduces a greater heterogeneity of environmental factors, fostering diversity [31]. Additionally, factors such as water stress can induce flowering even at seedling stages, potentially distorting the count of days to flowering [32].

The observed average amplitudes of variation for plant height, terminal leaflet width, leaf surface area, and leaf yield, coupled with high coefficients of variation ( $CV > 30\%$ ), indicate considerable heterogeneity among the studied accessions [33]. The majority of the variability appears to be primarily explained by the factor “accession,” which demonstrated high coefficients of determination ( $R^2 \geq 30\%$ ) for most of the characters studied. However, approximately 70% of the variability is attributed to other unexamined factors, including climatic conditions, cultivation practices, fertilizer use, and plant density. According to [29], both peasant practices and climatic zones can significantly influence the structuring of diversity in *Cleome gynandra*, with determination coefficients of  $R^2 \leq 19\%$  and  $R^2 \leq 30\%$ , respectively. [34] showed that the application of calcium ammonium nitrate fertilizer significantly influenced all growth and physiological parameters ( $P < 0.05$ ), while [35] found that flower removal had significant effects on growth and leaf yield in Spider-plant.

#### 4.2. Relationships between Characters, Accessions, and Group Characteristics

The Kaiser-Meyer-Olkin (KMO) measure is greater than 0.5, indicating that the correlation matrix is suitable for analysis. Additionally, Bartlett's test is highly significant, suggesting that the correlation matrix is not an identity matrix.

A noteworthy finding from the analysis is the highly significant negative correlation between the number of days to 50% flowering (NJF), plant diameter, plant height (HPL), and leaf yield. This indicates that accessions with a longer flowering cycle tend to be smaller in size and have lower yields. Moreover, a negative

correlation between leaf yield and the date of the first harvest suggests that longer cycling accessions tend to have higher leaf yields and greater weights of 1000 grains. These results align with the findings of [6], which indicate that plants with longer growth cycles have sufficient time for vegetative development and physiological activities, contributing to higher yields and heavier seeds.

The late-flowering accessions identified in Group II could be valuable for selection and breeding efforts aimed at extending the harvest period for Spider-plant. The relatively high coefficients of variation observed indicate significant variability among the accessions concerning the number of days to flowering, suggesting the potential for late flowering, pod formation, and maturation. The late-flowering accessions identified in this study could be particularly beneficial due to their capacity to maintain green leaves for an extended period. This observation is consistent with the findings of [30].

Additionally, the highly significant positive correlation between plant height (HP) and stem diameter (Dm) suggests that taller plants tend to possess adequately developed diameters, contributing to their stability. The positive correlation between stem diameter and yield implies that plants with larger diameters produce thicker stems capable of supporting more branches and greater leaf surface area. These correlations are particularly relevant for producers seeking to cultivate plants that yield substantial biomass, corroborating the results of [6] and [18].

Cluster analysis supported the existence of diversity among the 64 Spider-plant accessions based on the morphological traits studied. The clustering pattern revealed that accessions from Samanko were genetically distant from one another. These findings align with the observations of [36] and [37], who noted that traits with three or four phenotypic classes generally exhibit higher diversity indices than those with fewer classes. Furthermore, significant genetic distance was observed among accessions from Samanko, indicating the potential for genetic diversity in the germplasm available from this region. However, the findings also indicated limited genetic distance among accessions from the same area. According to [30], accessions from the same location typically exhibit limited variation. This close resemblance may suggest that the accessions within each collection region share a similar genetic background. [17] detected close relationships among Spider-plant genotypes following an evaluation of variability in seed proteins, and this close relationship among accessions can be explained by the self-pollinated nature of the crop [38].

## 5. Conclusions

This study highlighted the considerable variability present among *Cleome gynandra* L. accessions from the Worldveg gene bank assessed in the Samanko research station in Mali. Of the 34 characters analyzed, 16 were effective in discriminating the accessions. The strong correlations observed among traits suggest that genetic improvement is feasible based on this variability, particularly given the focus on

accessions assessed in the Samanko region.

Additionally, the research revealed that certain qualitative and quantitative traits were more effective in discriminating among the accessions. The qualitative traits included growth habit, branching port, stem color, hairiness of the stem, lobed leaf blade, leaf color, shape of the terminal leaflet, leaf shape of the margin, leaf pubescence, petiole color, smoothness, veins of the upper surface, immature pod color, color of the mature pod, cross-sectional shape of a fruit, pod shape, and color of healthy mature seeds. The quantitative traits included days to flowering, plant height, stem diameter, terminal leaflet length, terminal leaflet width, petiole length, leaf area, pod length, pod width, pod area, 1000 grain weight, and leaf yield.

The study identified 23 accessions with the best agronomic performance:

RV05, RV08, RV10, RV12, RV22, RV26, RV33, RV58, RV65, RV88, RV93, RV01, RV09, RV18, RV27, RV69, RV74, RV75, RV76, RV89, RV93, and RV96.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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