SELECTION OF PHENOTYPIC INTERESTS FOR THE CULTIVATION OF THE PLANT *Cleome gynandra* L. IN THE VEGETABLE GARDENS IN BURKINA FASO

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ABSTRACT

Present study was aimed to understand the scientific basis of the farmer's nomenclature of the local varieties of *Cleome gynandra* L. and to identify the characters of interests that can be used for the varietal improvement of the species. A survey was carried out in five cities of Burkina Faso with 56 producers of *C. gynandra* with the help of semi-structured interviews to identify the preferential characters. Furthermore thirty accessions were collected and evaluated in July 2014 at Gampela according to randomized complete block design with seventeen variables. The study revealed that in the denomination of local varieties, the farmers use agromorphological characters such as the color of the stem, leaves and the vegetative cycle of the plant. It was also revealed that the selection of plant in the vegetable gardens is preferred for the green color of the stem, leaves, long vegetative cycle, height of the plant, dimensions of the leaves and the number of primary branches. These were the selective interests for the farmers identified during the survey. The study also revealed that the process of selection is more advanced in Ouagadougou, where the demand is very high and where the consumers are more as compared to the other localities where the choice of the plant has just began for consumption. The results of this study have permitted to undertake the varietal improvement of the species according to the needs of the producers whose majority have a particular preference for the green ecotypes with long cycle.

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1 Introduction

Cleome gynandra L. is an annual plant of the family Capparaceae (Short, 2011). It is commonly known as spider flower, spider plant, cats' whiskers or African cabbage. Plant originated in tropical Africa and South-East Asia (Chweya & Mnzava, 1997) it used as leafy vegetable in these areas (DAFF, 2010). Leaves of the plant are rich in vitamin A and C, β -carotene, iron, calcium, magnesium, protein, phosphorus (Chweya & Mnzava, 1997; Soro et al., 2012; Agbo et al., 2014) and it plays an important role in the overcoming nutritional deficiencies. This vegetable stimulates the restoration of blood after delivery by increasing the number of red blood cells and the corpuscular hemoglobin concentration. In fact, it stimulates the synthesis of iron biomarkers such as transferrin and ferritin (Bosire, 2014). In Burkina Faso, *C. gynandra* also used as a food of famine, floods and dryness (Millogo- Rasolodimby, 2001) becomes more popular leafy vegetable because of its national interest.

Traditionally it harvested directly from the nature and used as a dietary supplement, nowadays, this vegetable is in domestication in vegetable gardens. Domestication is the process which involved genetic transformation of naturally existing form into the human required form. Thus, *C. gynandra* gradually undergoes in the selection for vegetable gardens according to the preferential criteria of producers and consumers. The knowledge of these criteria is very important for varietal improvement that must take into account the needs and preferences of the producers and the consumers. Thus present study has been conducted on the general framework of the varietal improvement of *C. gynandra* aims (i) to understand the scientific basic nomenclatures of local varieties adopted by farmers, (ii) to identify the characters morphological interest of this plant, which can be used in plant breeding and to estimate their heritability and (iii) and to study the agromorphological diversity.

2 Material and Methods

2.1 Genetic material

Thirty (30) accessions of *C. gynandra* were randomly collected from the vegetable gardens, of five different localities of Burkina Faso i.e. Ouagadougou, the capital (1° 31'05"W 12° 21'58"N), Bobo Dioulasso (4° 17' 00"W, 11° 11'00"N), Houende (3° 31' 0W, 11° 30' 0N), Boromo (2° 55'53"W, 11° 44' 55"N) and Toma (4°25'W, 12° 38'N). During the collection, surveys were conducted from 56 producers through semi-structured questionnaire based interviews to know the preferential characters. The questionnaire designed to extract the information like number of locally cultivated varieties, names of local varieties cultivated by farmers, the morphological characters of interest for producers and consumers, the seeds obtainment modes, the plant cultivation period, the aim of the cultivation (consummation or selling), the accessions first cultivation date, etc.

2.2 Study site

The agromorphological evaluation was conducted at the research station of Gampela, agronomic research center of the Institute of Rural Development (IDR). The neighborhood is located in North-Sudan zone (1° 21' W and 12° 24' N), with an annual rainfall ranging from 600 to 900 mm (Thiombiano & Kampmann, 2010). The maximal annual temperature varies between 35 to 40°C and minimal temperature varies between 18 to 19°C.

2.3 Experimental design

The study was conducted in randomized complete block design (RCBD). Each block was separated by one meter distance. In each block every accession was represented by a row of 5 meters on which 11 hills were sown. The spaces between the rows and the plants were 0.5 m. Because of the low rate of the seeds germination, ten seed per hill were sown. A thinning to one plant per hill was then done 10 days after sowing. Before starting trial, the land was plowed, amended with organic matter and leveled. An application of NPK (15-15-15) was carried out at the rate of 200 kg / ha.

2.4 Characters measured and variables analyzed

Seventeen (17) variables including six (6) qualitative and eleven (11) quantitative traits were analyzed. Except the number of days to 50% flowering and the number of days to plants emergence measured on the entire row, the other quantitative variables were measured on 4 plants by row 45 days after sowing. These studied traits are the plant height (measured from the ground to the last leaf of the main stem); stem diameter; number of primary branches; the length of leaflet (measured from the top from the pulvinus of the central leaflet); the width of leaflet (measured at the middle portion of the central leaflet); the length of petiole (measured to the sheath from the pulvinus) and the biomass of leaves. The fruit length and the fruit width were also measured on the three first fruits of four plants per row. The stem color, leaf color, flower pieces color, the plant pubescence, the plant type (erect, semi-erect), the fruit shape and the flowers abundance were also observed throughout the plant cycle.

2.5 Statistical analysis

Analysis of variance (ANOVA) was performed using the GenStat v4.10.3 software (VSN International, 2011) on the quantitative variables to determine those that discriminate the accessions. It also aimed to know, after separation of the means by Newman-Keuls test of separation of means at 5%, if there are significant differences between the accessions of the 5 cities on the one hand, and between the different modes of seeds obtainment by the producers on other hand. For each of discriminating characters, the broad sense heritability (H^2) was calculated using the genotypic variances (VG) and phenotypic

variances (VP): $H^2 (\%) = (VG/VP) * 100$ (Johnson et al., 1955). The software XLSTAT 2013.2.03 has served to multivariate analysis. A principal component analysis was performed and the coordinates of individuals from this analysis were used to accessions regrouping by hierarchical cluster analysis. The clusters obtained from this analysis were characterized by factorial discriminating analysis.

3 Results

3.1 Botanical characterization of available varieties

Result of the study revealed that the gardeners of Ouagadougou produced *C. gynandra* in any season of the year they produced it mainly for the selling. Thus, in a year this plant undergoes several cultivation cycles. Contrary, in the other localities, it produced only in rainy season for family consummation. Therefore suffers less cultivation cycles per year compared to accessions of Ouagadougou.

Producers use three modes to obtain seeds (Table 1). The seeds have undergone several cultivation cycles, whose the first cultivation date is over 5 years. These are obtained by selection from population. The seeds obtained by purchase/donation for the first cultivation date is unknown. The seeds having undergone only 1-2 cultivation cycles for the first cultivation date is one year. These have recently taken from the natural ecotypes. In the capital, Ouagadougou, producers primarily use seeds from selection and purchase/donation respectively 53 and 40% of producers, while in the other localities, it's recently cultivated seeds that are encountered in gardens (40 to 75% of the producers).

For the nomenclature of the local varieties of *C. gynandra*, producers mainly used stem color and plant cycle. With reference to the stem color, two morphotypes were reported in the studied localities. Among these two, first morphotype is with green stem called in moore "*keneb Pelga*" which means "*white C. gynandra*" and the second morphotype with violet stem called "*keneb miougou*" in moore which means "*red C.*

gynandra" However, 3.33% of the Ouagadougou producers distinguish two types of green morphotypes viz local and improved (or introduced) type. Here, improved or introduced type of *C. gynandra* is called in moore "*Tampouy kenebdo*" or "*Baskuy kenebdo*" with reference to the district where the seeds were purchased from the store. Improved or introduced type also called "*Nasaa n kenebdo*" which means "*European C. gynandra*" indicating that it would be an improved variety or introduced variety. This improved variety was characterized by long plant height, high plant pubescence and a long cycle.

The majority of gardeners (83.33%) prefer the green variety with a long cycle for the consumer's needs (organoleptic quality, great biomass) while only 16.67% of producers who are indifferent to stem color. With reference to the plant cycle, Ouagadougou's producers distinguish two local varieties: a variety called "*keneb raaga*" which means "*Male C. gynandra*" due to its early flowering, abundant production of flowers and a small plant height while the second variety was known by moore "*keneb gnan-ga*" which means "*female C. gynandra*" due to its late flowering, long plant height and few flowers. Although, in moore, "*keneb raaga*" (*male C. gynandra*) is most often used to refer *C. viscosa*, some gardeners (53.33%) use it to refer to varieties of *Cleome gynandra* L. with short cycle. All Ouagadougou's producers prefer the variety with a long vegetative cycle while those of the other cities do not have preferences.

3.2 Agromorphological evaluation

3.2.1 Phenotypic variability using qualitative characters

Agromorphological evaluations have been suggested two types of morphotypes on the basis of stem and leaf color (Figure 1). A morphotype with green stem and cleared green leaves (Figure 1a) mostly met in accessions from Ouagadougou vegetable gardens (68.75%) and morphotype with very violet stem (Figure 1b) or slightly violet stem (Figure 1c) having dark-green leaves, mostly met in accessions from the other localities (50-75%).

Table 1 Distribution of surveyed farmers for cultivation period and the seeds obtainment modes by city.

Cities	Seasons of Production (%)		Mode of Seed Collection (%)		
	Both Rainy and dry season	Only in Rainy Season	Selection	Purchase / donation	Recently collected from natural ecotypes
Ouagadougou	60	40	53	40	6.66
Bobo	50	50	25	25	50
Houndé	0	100	13	12	75
Toma	0	100	12	13	75
Boromo	33.33	66.67	30	30	40

a: Green morphotype

b: Violet morphotype

c: Slightly violet morphotype

Figure 1 Variation of the stem color of *C. gynandra*.Table 2 Analysis of the variation in qualitative characters of the collection of *C. gynandra* according to the collection sites (%).

Variables	Modality	Cities				
		Ouaga	Bobo	Hounde	Toma	Boromo
Stem color	green:	68.75	25	0	50	25
	violet:	25	50	75	50	75
	variable:	6.25	25	25	0	0
Leaf color	cleared-green:	68.75	25	0	50	25
	dark-green:	25	50	75	50	75
	variable:	6.25	25	25	0	0
Plant type	erect	62.5	0	0	66.67	66.67
	semi-erect	31.25	75	75	33.33	33.33
	variable	6.25	25	25	0	0
Flowers abundance	few abundant:	81.25	0	0	33.33	33.33
	very abundant:	12.5	100	100	66.67	66.67
	variable:	6.25	0	0	0	0
Fruits Shape	big and rough:	75	12	13	15	33.33
	thin and smooth:	48	75	75	75	66.67
	variable:	6.25	13	12	10	0
Plant pubescence	great:	25	25	33.33	0	25
	weak:	68.75	75	66.67	100	50
	variable	6.25	0	0	0	25

Ouaga: Ouagadougou, Bobo: Bobo Dioulasso

The table 2 and 3 shows variation in the qualitative characters in the collection of *C. gynandra* respectively according to the collection sites and the seeds obtainment modes. Results of these tables revealed that the accessions with green stems, cleared-green leaves, few flowers, big rough fruit (Figure 2a) and erect type are mostly encountered in those from Ouagadougou, obtained by selection. On the contrary, accessions with violet stem, dark-green leaves, many flowers, thin and smooth fruits (Figure 2b), semi erect type are mostly encountered in those from the other localities, recently collected from natural populations. For the entire collection, the majority of accessions of all the cities show the plant present with variation in pubescence (Figure 3a&b). Except

floral pieces, all the characters studied were polymorphic and reported variability inside accessions for each of the variables analyzed.

3.2.2 Phenotypic variability using quantitative characters

Analysis of variance (Table 4) revealed highly significant differences at 1% between the accessions for all the characters studied except the number of flowers pieces. All the coefficients of variation are low (<30%) except for the leaves biomass which was reported higher than 30%. At 45 days after sowing, the plants have in an average height and biomass 61.60 cm and 71.96 g respectively.

a: Big and rough fruits

b: Thin and smooth fruits

Figure 2 variation of fruits shape of *C. gynandra* L.

a: Weak pubescence

b: Great pubescence

Figure 3 variation of pubescence of *C. gynandra* L.Table 3 Variation in some qualitative characters in the collection of *C. gynandra* according to the seeds obtainment modes.

Variables	Selection	Purchase/ donation	Recently taken from the natural ecotypes
Green stem, cleared-green leaves	55.6	50	18.18
Violet stem, dark-green leaves	44.4	50	81.82
Big and rough fruits	60	77.78	18.18
Thin and smooth fruits	40	22.22	81.82
Few abundant flowers	60	77.78	18.18
Very abundant flowers	40	22.22	81.82

The emergence of the plants varies from 4 to 7 days after sowing and heritability is higher for all the reported characters (>80%). According to Johnson et al. (1955), the heritability (H^2) is higher when its value is greater than 50%. Also, there are highly significant differences at 1% between the seeds obtainment modes for all the characters studied (Table 5). The accessions from the selection have higher performances of vegetative growth parameters than the others. The weakest performances were noted in accessions collected in the natural population. In addition, the geographical origins effects, highly significant at 1% (Table 6) were observed for all the characters. Those collected from Ouagadougou have higher performance than those collected in the other localities.

3.2.3 Principal component analysis

The first three components (Table 7) show 85.39% of the total variability. It revealed that the plant height, plant diameter, primary branches number, leaf dimensions, fruit length and the

leaves biomass are associated with the first factor (F1) which explains 59.13% of the variability. The number of days of emergence and the fruit width are associated with the second factor (F2) which explains 18.03% of the diversity observed. The cycle of the plant is associated with the third factor (F3) and explains 8.23% of the variability.

3.2.4 Agromorphological diversity structuring

Agglomerative hierarchical clustering (Figure 4) based on the factor scores of the tree factors (F1, F2 and F3) revealed that the accessions form three distinctive clusters with 83.02% dissimilarity between clusters and 16.98% dissimilarity within cluster. Cluster 1 has the best agronomic performances. It mainly contains the accessions from Ouagadougou, obtained by selection. Cluster 2, formed by the accessions from diverse geographical origins including some from Ouagadougou, it contains mostly the accessions obtained by purchase / donation.

Table 4 Performances of accessions studied, ANOVA results and broad sense heritability of eleven characters.

Variables	Min.	Max.	Means	CV%	F	H^2 (%)
Plant height (cm)	36.67	87.40	61.60±12,47	20.24	10.32**	97.19
Stem diameter (cm)	1.10	2.02	1.56±0,41	25.92	4.11**	80.65
Primary branches number	3.08	7.00	4.87±1,34	27.51	6.14**	84.36
Petiole length (cm)	4.71	11.16	8.67±2,17	25.00	5.65**	84.40
Leaflet length (cm)	4.56	9.49	7.06±1,33	18.82	9.59**	90.12
Leaflet width (cm)	1.97	3.83	3.02±0,51	16.80	8.13**	89.81
Fruit width (cm)	0.33	0.77	0.58±0,11	19.27	10.56**	91.11
Fruit length (cm)	7.88	13.74	11.00±1,72	15.60	7.47**	86.95
50%flowering	21.33	24.00	23.32±0,68	2.93	14.15**	93.07
Leaves biomass (g)	17.00	130.73	71.96±46,91	65.18	4.69**	81.30
DPE	4.00	7.00	5.00±0,57	11.54	19.96**	95.26

DPE: number of days to plants emergence, Min.: Minimum, Max.: Maximum, CV% = coefficient of variation, F: F of Fisher **: significant at 1% , H^2 : Heritability, ±: standard error

Table 5 Reproductive and vegetative growth parameters of accessions of *Cleome gynandra* L. according to the seeds obtainment modes.

Variables	Seeds obtainment modes by the producers		
	Selection	Purchase/ donation	Recently taken from the natural ecotypes
Plant height (cm)	70.62 A	59.32 B	53.64 C
Stem diameter (cm)	1.74 A	1.48 B	1.43 B
Primary branches number	5.49 A	5.00 B	4.10 C
Petiole length (cm)	9.74 A	8.24 B	7.87 B
Leaflet length (cm)	7.81 A	6.99 B	6.30 C
Leaflet width (cm)	3.29 A	2.98 B	2.76 C
Fruit width (cm)	0.62 A	0.52 B	0.58 A
Fruit length (cm)	11.40 A	10.85 AB	10.69 B
50%flowering	23.63 A	23.11 B	23.17 B
Leaves biomass (g)	94.68 A	67.97 B	50.47 C
DPE	4.61 B	5.25 A	5.16 A

Means followed by the same letter in the column are not significantly different at 1%. DPE: number of days to plant emergence.

Table 6 Reproductive and vegetative growth parameters of accessions of *C. gynandra* according to the collection sites.

Variables	Geographical origin of the accessions				
	Ouaga	Bobo	Boromo	Hounde	Toma
Plant height (cm)	66.72 ^a	54.46 ^b	58.17 ^b	37.93 ^c	57.77 ^b
Stem diameter (cm)	1.66 ^a	1.34 ^c	1.44 ^{bc}	1.16 ^c	1.61 ^{ab}
Primary branches number	5.38 ^a	3.98 ^{bc}	4.67 ^b	3.2 ^c	4.37 ^b
Petiole length (cm)	9.07 ^a	7.51 ^b	9.31 ^a	4.90 ^c	8.95 ^a
Leaflet length (cm)	7.59 ^a	5.83 ^c	6.92 ^b	4.69 ^d	6.97 ^b
Leaflet width (cm)	3.21 ^a	2.60 ^c	2.93 ^b	2.07 ^d	3.04 ^{ab}
Fruit width (cm)	0.56 ^b	0.51 ^c	0.65 ^a	0.50 ^c	0.69 ^a
Fruit length (cm)	11.18 ^a	10.43 ^{ab}	11.23 ^a	9.38 ^b	11.17 ^a
50% flowering	23.43 ^a	23.25 ^a	23.44 ^a	21.87 ^b	23.33 ^a
Leaves biomass (g)	87.01 ^a	55.14 ^b	57.70 ^b	17.36 ^b	54.78 ^b
DPE	5.07 ^b	5.50 ^a	4.22 ^d	5.00 ^{bc}	4.58 ^{cd}

Means followed by the same letter in the column are not significantly different at 1%. DPE: number of days to plant emergence, Ouaga: Ouagadougou, Bobo: Bobo Dioulasso.

Table 7 Squared Cosines of 11 Characters on tree Factors and total variability explained of 11.

Variables	Principal components		
	F1	F2	F3
Plant height (cm)	0.882	0.015	0.021
Stem diameter (cm)	0.839	0.004	0.008
Primary branches number	0.519	0.282	0.045
Petiole length (cm)	0.896	0.001	0.010
Leaflet length (cm)	0.934	0.002	0.012
Leaflet width (cm)	0.882	0.004	0.005
Fruit width (cm)	0.376	0.274	0.018
Fruit length (cm)	0.266	0.589	0.058
50% flowering	0.633	0.223	0.068
Leaves biomass (g)	0.080	0.229	0.599
DPE	0.197	0.361	0.063
Eigenvalue	6.505	1.983	0.905
Variability (%)	59.132	18.029	8.229
Cumulative (%)	59.132	77.161	85.391

Values in bold correspond for each character to the factor for which the squared cosine is the largest and show the association of characters with the principal component, DPE: number of days to plant emergence

Cluster 3 on the contrary, contains mostly the accessions from the other cities and recently introduced in cultivation. This cluster has the weakest agronomic performances.

4 Discussions

4.1 Agromorphological variability and farmer's nomenclatures of local varieties

The study revealed a diversity of local names of *C. gynandra* derived primarily from morphological characteristics.

These results are in accordance with Jiro et al. (2011) those have studied on okra and revealed that farmers name their ecotypes using agromorphological and phenotypic characteristics such as stem and fruits color, fruit shape, vegetative cycle (long or short) and those of N'da et al. (2013) studied on maize has permitted to know that farmers identify varieties on the basis of their grain colors. Thus, green morphotype with great plant height, long cycle, few flowers and high leaves biomass observed corresponds to the one called by producers "*keneb Pelga*" (white *C. gynandra*) or "*Tampouy kenebdo*" (*C. gynandra* L. of Tampouy) or "*Baskuy kenebdo*" (*C. gynandra* of Baskuy).

Figure 4 Dendrogram of Dissimilarity among 30 accessions of *Cleome gynandra* L. using Ward's Minimum Variance Method of Cluster Analysis.

Violet morphotype corresponds to the name "*keneb miougou*" (Red *C. gynandra*). The designation "*keneb raaga*" (Male *C. gynandra*) by some producers would correspond to the small violet morphotype with a small plant height, feeble leaves biomass, abundant flowers and short cycle.

4.2 Producers preferential characters

In gardens, the selection of producers is oriented to the characters such as great plant height, green stem, cleared-green leaf, long cycle, high leaves biomass, high primary branches number and small flowers number. These characters match to those identified by the survey as preferential characters of most producers. The selection leads to the suppression of some wild characters and favors those desired. This selection pressure would explain the phenotypic differences and the significant differences of reproductive and growth vegetative parameters observed between the accessions from the three seeds obtainment modes on one hand and between the accessions from Ouagadougou and those from the other cities on the other hand.

The domestication that automatically provokes a gradual evolution of populations by spreading them from the wild plants which they derive from (Bouharmont, 1995) also explains the differences between the accessions of different seeds obtainment modes. Indeed, the accessions from selection benefited a longer time of domestication than those recently collected from the wild ecotypes which have undergone few

cultivation cycles. According to Bouharmont (1995), domesticated plants are characterized by hypertrophy of harvested organs (stems, leaves, fruits, etc.), their high yield, their uniformity, their taste or their color. The best performances of the accessions from Ouagadougou compared to those from the other localities could be explained by the fact that the domestication and the selection are more advanced in Ouagadougou than in those other cities where the cultivation of the plant for the selling comes first. Similar results (K'Opondo, 2011; Masuka et al., 2012) have revealed that the differences observed between agronomic characters of Kenyan morphotypes and those of Zimbabwe could be due to a greater selection in Kenya where the domestication is more advanced compared to Zimbabwe where it is still only confined to only research centers. Contrary to the observations of some producers, great pubescence of plants could not be related to green morphotype.

4.3 Diversity organization

The accessions were grouped according to their geographical origin and the degree of selection pressure practiced by the producers. The accessions of the capital, Ouagadougou, mostly from selection, were met almost in the same cluster (cluster 1). The cluster contains accessions of better agronomic performances. The demand of *C. gynandra* is higher in urban centers than in rural zones as also noted by Bosire (2014) in Kenya. Thus, the producers of Ouagadougou the capital city, to respond to this important consumers demand, produce *C.*

gynandra several times per year (several cultivation cycles in a year) on one hand, and practice a selection oriented to the consumers preferential characteristics on the other hand. The cluster 2, made up of diverse geographical origin accessions, contains accessions obtained by purchase / donation. This cluster is more heterogeneous than the others. Indeed, the seeds obtainment mode per purchase/donation favors genetic material exchanges between different localities. This explains the fact that some accessions grown in Ouagadougou gardens, but initially originated from elsewhere (Kongoussi for example), are regrouped with the accessions of other localities. Cluster 3, made up of diverse geographical origins accessions, contains those of feeble agronomic performances; recently introduced in cultivation and including always several wild characters. This is the cluster of accessions which have undergone lower selection pressure.

5 Conclusions

The study revealed the relationship between farmer's nomenclatures of local varieties and the agromorphological characteristics of accessions of *Cleome gynandra* L. in Burkina Faso. The selection for cultivation of the plant based on the phenotypic interests of the farmers which can further be used for varietal improvement such as the green color of the stem, the cleared-green color of leaves, the low production of flowers, the late cycle of the plant, the long height of plant, the large dimensions of leaves, the high leaves biomass and the high primary branches number.

All these characters, highly heritable, discriminate the accessions studied. The study also revealed that the degree of selection varies according to the city of collection and could be primarily responsible for the structuring of the agromorphological diversity. Gardeners whose produce *Cleome gynandra* L. for marketing exercise a stronger selection pressure than those whose produce it for family consumption.

Conflict of interest

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