Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

Agro-morphological characterization of selected varieties of vegetable cowpea [*Vigna unguiculata* (L.) Walp.] in Burkina Faso

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Received – February 23, 2023; Revision – May 27, 2023; Accepted – June 14, 2023
Available Online – June 30, 2023

DOI: http://dx.doi.org/10.18006/2023.11(3).550.562

KEYWORDS

Vegetable cowpea

Variety

Agro-morphological characterization

Burkina Faso

ABSTRACT

Vegetable Cowpea (*Vigna unguiculata*) is one of the neglected legumes in Burkina Faso, and as a result, its genetic diversity remains poorly known. The main aim of this study was to know its genetic variability through an agro-morphological characterization. Twenty vegetable cowpea varieties were evaluated at the Kamboinsé Environmental, Agricultural and Training Research Center following a three-replication Fischer block design under rainfed conditions. Fifteen quantitative and nine qualitative variables were collected and subjected to various statistical analyses. Analysis of variance was significant for the variables 50% flowering, vegetable cowpea date, number of pods obtained per plant, number of seeds per pod, fresh pod weight, fresh pod yield, pod length, plant height, seed length and chlorophyll content. Strong correlations were also reported between the various variables. The observed diversity is structured in three morphological groups viz., Group 1 consists of individuals with early flowering, high chlorophyll content and the number of pods obtained per plant. Group 2 brings together the varieties of average agronomic performance for pod length, the number of pods per plant, number of days at 95% maturity, fresh pod weight, yield of fresh pods and group 3 of varieties with long pods, early green date, high pod weight and good fresh pod yield. Among the tested varieties, the varieties IT83S-872 (30 pods), IT84S-2246 (27 pods), Baguette (25 pods), IT83S-818 (26 pods), and IT85F-2682 (24 pods) stood out for their high pod production. In addition, the varieties of vegetable cowpea baguette, baguette grimpant, Telma, and IT83S-911 showed the best performance in terms of early

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

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vegetable cowpea date stage, longest pods, highest pod weight and best yield of fresh pods. The high genetic variability level within the tested varieties could be exploited in future green cowpea breeding programmes.

1 Introduction

Cowpea (*Vigna unguiculata*), a seed legume, is commonly grown and used as a source of diet plant protein in developing countries (Ibrahim et al. 2010). About 10% of this cowpea is cultivated for its fresh pods in East Asia and Africa (Boukar et al. 2015). In Burkina Faso, cowpea is an important staple food and much prized by the local populations. Indeed, it occupies the first place in seed legumes grown in the country and fourth in the national food crops after sorghum (1.929.835 tons), maize (1.700.127 tons) and millet (1.189.079 tons) (DSS/DGESS/MAAH 2019). However, this production only concerns dry-seed cowpea, as Common bean production is poorly developed in Burkina Faso. Vegetable cowpea has been cultivated for their long, soft, succulent and immature tender pods with fewer seeds and ripening late over a long period (Pandey et al. 2006). Like the vegetable cowpea (*Phaseolus vulgaris* L.), the vegetable cowpea is also eaten at the fresh immature pod stage. As a result, it is a subsistence food during the lean season and a source of monetary income by selling pods. Thus, it is an excellent alternative vegetable that is more resilient than bean vegetables and other crops (Peksen and Peksen 2012). However, there is little research on this variant of cowpea in Burkina Faso (Udealor 2002; Ano 2006) because generally, the majority of research on cowpeas is more focused on cowpea with dry seeds considering the green cowpea as a "neglected legume" (Ndukwe et al. 2012). Although there are varieties of vegetable cowpea in the germplasm of the Kamboinsé experimental station, Burkina Faso, very little work has been done on improving its adaptation and production conditions in the country. Nevertheless, some studies have already been undertaken on resistance to Cowpea Aphid-Borne Mosaic Virus and evaluating agronomic and forage performance (Nanama et al. 2020; Coulibaly et al. 2020). Thus, research on vegetable cowpea would allow us to know this variety better and to develop interesting and adapted varieties with agronomic and nutritional performances meeting the expectations of producers and consumers. With this in mind, this study was initiated with the general objective of knowing the agro-morphological variability of a collection of vegetable cowpea varieties to select promising varieties for use in a varietal selection program in Burkina Faso. The specific objectives of this study are (i) to establish the level of variability of the varieties studied through the measured or observed traits; (ii) to establish the relationship between the various characters, and (iii) to identify varieties of agronomic and nutritional interest.

2 Materials and methods

2.1 Experimental site

The study was done at the cowpea breeding unit of the Agricultural Research and Formation Center (CREAF), Kamboinsé, Burkina Faso, from July to September 2019. The center is located at 12°28' North latitude, 1°32' West longitude and 296 m altitude on the Ouagadougou-Kongoussi axis. During the study periods (2019-2020 agricultural season), cumulative rainfall was 782.5 mm, spread over 8 months, and August was the wettest month (MétéoInera 2019). Due to their topographical location, Kamboinsé soils are increasingly poor in organic matter and very sensitive to erosion (Zougmore et al. 2004).

2.2 Plant material

Twenty (20) vegetable cowpea varieties obtained from China and Taiwan constituted the plant material used in this study. Some specific characteristics of the selected varieties are mentioned in Table 1.

Table 1 Specific characteristics of interest of the twenty (20) varieties of vegetable cowpea used

N°	Variety	Color Seeds	Texture	N°	Variety	Color Seeds	Texture
1	IT83S-872	Cream	Smooth	11	IT83S-911	Red	Smooth
2	Ex-Iseke	Cream	Smooth	12	Niébé baguette grimpant	Red	Smooth
3	TZA 2344	Cream	Smooth	13	IT85F-2805-5	Cream	Smooth
4	RW-CP-2	Cream	Smooth	14	RW-CP-5	Red	Smooth
5	IT83S-818	White	Wrinkled	15	TUMAINI	Cream	Smooth
6	UG-CP-8	Cream	Smooth	16	LBR7	Red	Smooth
7	UG-CP-6	Cream (spotted black)	Smooth	17	Baguette	Cream	Smooth
8	IT84S-2246	Cream	Smooth	18	IT85F-867-5	Red	Smooth
9	UG-CP-3	Black	Smooth	19	Telma	Red	Smooth
10	IT85F-2682	Cream	Smooth	20	IT86F-2089-5	Red	Smooth

2.3 Methods

2.3.1 Experimental setup

This study was carried out in a randomized complete block design with three (03) replications. Each repetition comprised twenty (20) elementary plots of each corresponding variety. On each elementary plot, a variety was sown on four (04) lines of 3 m, with a spacing of 0.8 m between the lines to the line and 0.4 m between clusters, i.e. 8 clusters per line. This arrangement gives a plant population of 64 plants per elementary plot. The area of the elementary plot was 7.2 m^2 (3 m x 2.4 m), the spacing between elementary plots was 1 m, and the spacing between replicates was two meters. The total area of the trial was 871 m^2 (67 m x 13 m).

2.3.2 Conduct of the study

The soil was prepared through motorized flat ploughing followed by harrowing. Compost (organova: organic matter>30%) at a rate of 2.5 t/ha and NPK fertilizer (14-23-14-6S-1B) at a rate of 100 kg per hectare were applied to the plot before ploughing as a bottom dressing. Manual striping was done according to the spacing to obtain the seed lines. Semi-seeding was done manually on the lines on July 22, 2019, at two seeds per packet.

Maintenance operations consisted of weeding, application of NPK fertilizer (14-23-14-6S-1B), and insecticide applications. Two weeding seasons were made; the first was fourteen (14) days after sowing, during which fertilizer was applied, and the other thirty-five (35) days after sowing. Similarly, two insecticide application seasons were made. The first application was carried out at the time of flower bud formation, while the second was at the time of pod formation. Treatments were done with Deltacal 12.5 EC insecticide (12.5 g Deltametrine Concentrated Emulsion) with the recommendation of two (2) ml per liter of water.

2.3.3 Data collection

The different variables were collected according to the recommendations in the cowpea descriptors (IBPGR 1983; UPOV 2009). Sixteen (16) plants from the central rows were selected to measure quantitative and qualitative variables' observations. The studied quantitative variables are plant height, date of 50% flowering, the number of days corresponding to the ripening of fresh pods, number of pods obtained per plant, the weight of fresh pods in kilograms, date of 95% dry maturity expressed after sowing (DAS), number of seeds per pod, length and width of seeds, the weight of one hundred (100) seeds in grams, seed weight expressed in kilograms, the number of seeds per pod, the fresh pod yield calculated from the formula Yield = [(Fresh pod weight x 62500 plants/ha) ÷ (Number of plants per unit plot x 1000)] and the seed yield calculated from the formula Yield = [(Seed weight x 62500 plants/ha) ÷ (Number of plants per unit plot x 1000)]. The studied qualitative characteristics are Plant type or stem habit (Creeping, Erect, Semi-erect), Leaf texture (Membranous, leathery), Leaf color (Dark green, Light green), Leaf shape (Hastate, Sub-hastate, Globular and Sub-globular), Flower color (White, Purple), Pod position on peduncles (Erect, curved), green pod shape, pod color, seed color (Cream, Black, White, Red) and seed size as described by Ebong (1970).

2.3.4 Statistical analysis of the collected data

An analysis of variance (ANOVA) and Pearson's correlation test were performed to determine the varieties' discriminating characteristics and the relationships between the variables. An estimate of the degrees of association between the different quantitative traits studied was made through a Principal Component Analysis (PCA). Thus, using the STATISTICA software, well-represented and poorly correlated variables were analyzed in hierarchical ascending classification (HAC) to structure the studied varieties. The different groups from the hierarchical ascending classification (CAH) were characterized by discriminant factor analysis (DFA). The ANOVA, PCA, and DFA were performed with XLSTAT 2016 software.

3 Results

3.1 Variation in quality characteristics of vegetable cowpea

The results of the qualitative characteristics analysis showed the existence of significant variability (Table 2). Thus, four modalities, namely erect, semi-erect, climbing, and creeping, were observed in terms of plant habit type (Figure 1). Thirty-five percent (35%) of the varieties studied showed a semi-erect habit corresponding to most of the collection. On the other hand, the upright varieties (30% of the collection) are characterized by an erect main stem from which secondary branches emerge. While 30% of varieties are creeping, and the rest 5% are climbing type.

Flower color is highly variable among the studied varieties and is classified into two broad categories (Figure 2). Among the studied varieties, about 15% of the varieties produced white flowers, while the rest 85% had purple flowers.

Further, in the case of pod positions, two types of pod positions on the peduncle were observed (Figure 3). In most varieties (85%), the pods are curved at 30-60° while the rest (15%) are erect. Regarding pod shape, 90% of the varieties had linear pods, and only 10% had curved pods (Figure 4).

The selected variants were also identified based on the predominance of pod color, and it found that 70% of the pods are dark green color while the rest 30% are light green pods color characteristics (Figure 5).

Table 2 Variation in quality characteristics in the selected cowpea varieties

Parameters	Modalities	Number of variety	%
Wearing of the stem	Erected	6	30
	Semi-dry	7	35
	Climbing	1	5
	Rampant	6	30
Leaf shape	Hasté	1	5
	Subhasted	8	40
	Subglobular	8	40
	Globular	3	15
Leaf texture	Membrane machine	8	40
	Tough	12	60
Color of the flower	White	3	15
	Violet	17	85
Position of the pod on the stalk	Curved	17	85
	Dressed	3	15
Color fresh pods	Light green	10	50
	Dark green	10	50
Fresh pod shape	Linear	2	10
	Curved	18	90
Color of the seeds	Cream (mottled black)	1	5
	Cream	10	50
	Black	1	5
	White	1	5
	Red	7	35
Seed size	Great	1	5
	Average	18	90
	Small	1	5

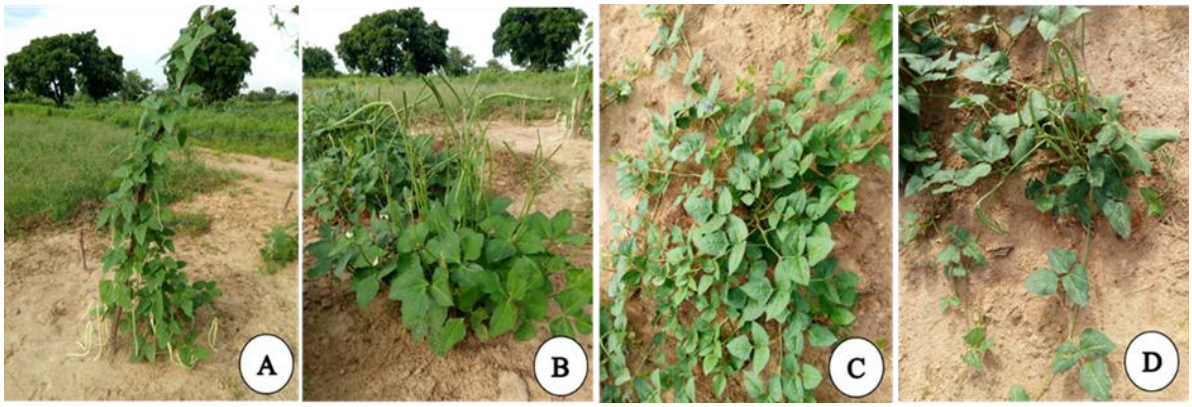

Figure 1 Different types of bearing observed in the varieties studied A: Climbing type, B: Erect type, C: Creeping type, and D: Semi-erect type.

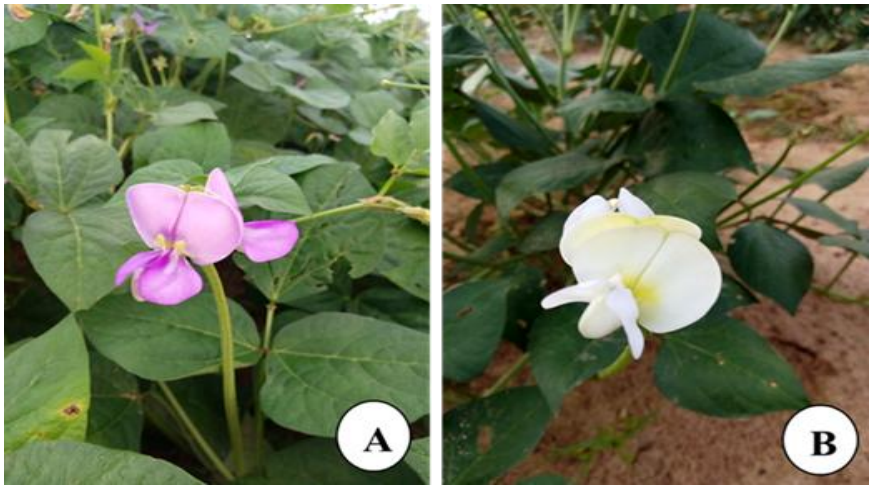

Figure 2 Flower color A: Violet color, B: White color

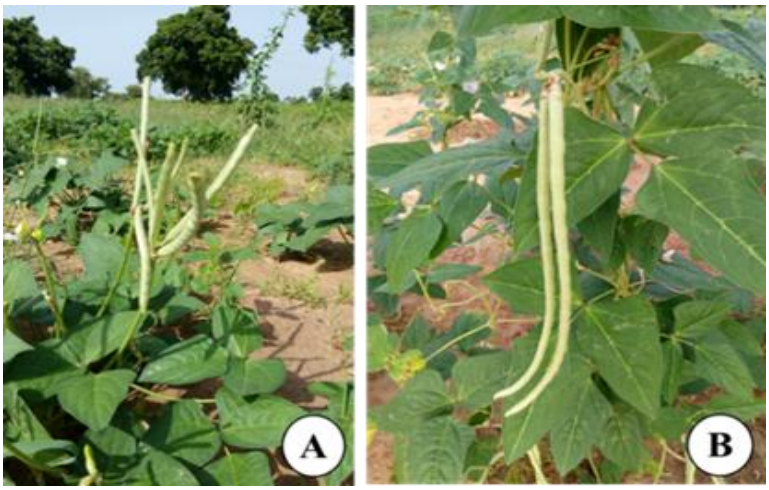

Figure 3 Position of pods on stalk A: upright position. B: curved position

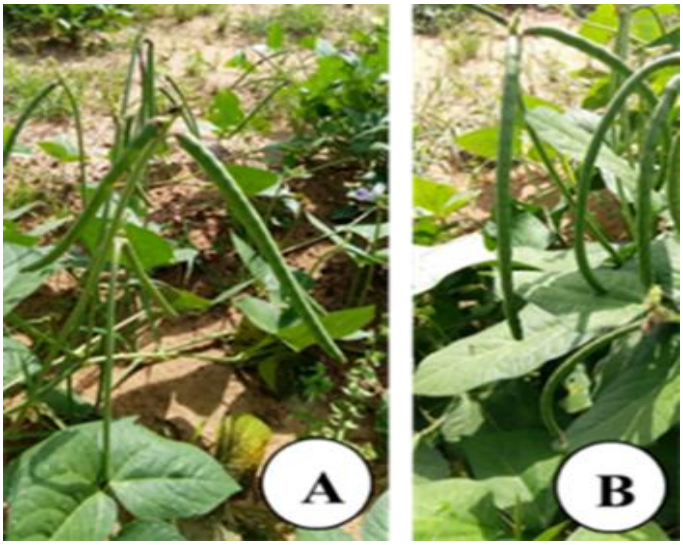

Figure 4 Pod shape. A: linear pods. B: curved pods

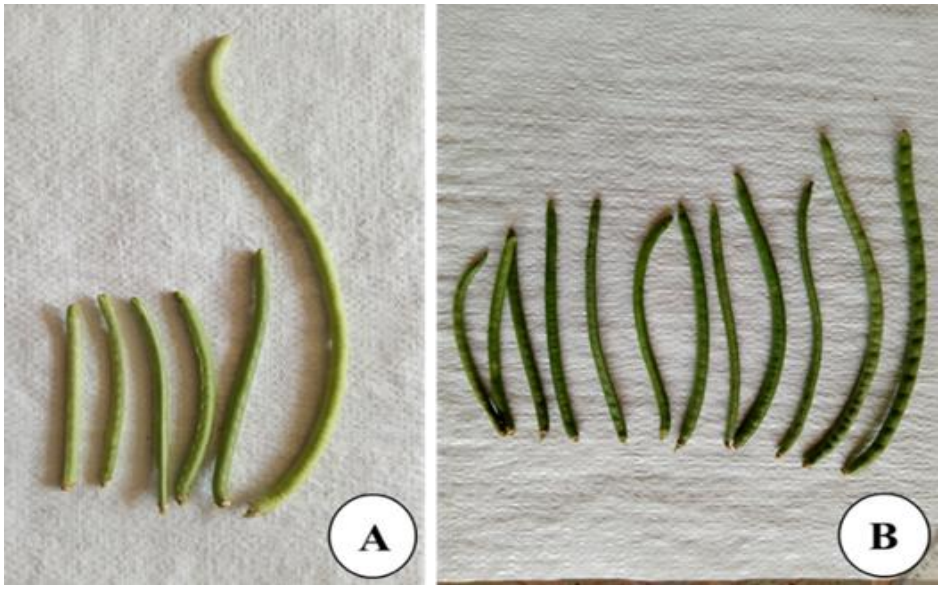

Figure 5 Fresh Pod color A: Light green. B: Dark green

Table 3 Results of analysis of variance of phenological parameters of 20 vegetable cowpea varieties.

Variables	Minimum	Maximum	Average	CV (%)	P-Value (5%)
Plant height (cm)	31.67	265	113.92±34.6	58	0.000**
50% Flowering (DAS)	45	51	47±1.37	5	0.000**
Date vegetable cowpea (DAS)	54	57	55±0.79	2	0.005*
95%Maturity (DAS)	65	73	70±1.96	4	0.006*

*Analysis of variance significant at the 5% level; **Analysis of variance highly significant at the 1% level; CV: Coefficient of variation; P-value - Probability value at 5%; DAS - Day After Sowing

3.2 Variation in quantitative characteristics

3.2.1 Phenological stages

The analysis of variance (Table 3) shows that plant height and date 50% flowering discriminate significantly between varieties at the 1% threshold and the vegetable cowpea date and date 95% maturity significantly from varieties at the 5% threshold. Thus, the height of the plants varied from 31.66 cm (IT86F-2089-5) to 265 cm (baguette grimpant), with an average of 113.917 cm. With an average number of days to 50% flowering of 47 days, the varieties Ex-Iseke; IT85F-2682; IT83S-911 and UG-CP-8 (45 days to 50% flowering) were the first to flower, and varieties UG-CP-6 and TZA 2344 bloomed at 50 JAS. On average, vegetable cowpea varieties reached their vegetable cowpea dates and 95% maturity at 55 JAS and 70 JAS. Thus, the baguette grimpant vegetable cowpea varieties, IT83S-872, IT84S-2246, Telma, IT85F-2805-5, IT83S-911, LBR7, IT85F-867-5, UG-CP-8 reached their vegetable cowpea date as early as the 54th JAS and the TZA 2344 variety at the 57th JAS. Vegetable cowpea varieties IT83S-911 and UG-CP-8 were the earliest (64 and 65 days to maturity) compared with cowpea varieties RW-CP-5, TZA -2344 and baguette grimpant (72 days to maturity). The coefficient of variation was high (CV > 30%) for plant height (58%) but low (CV < 30%) for 50% flowering (CV= 5%), vegetable cowpea date (CV= 2%) and 95% maturity (CV= 4%).

3.2.2 Yields and their components in fresh pods and seeds

The analysis of variance for the parameters of fresh pod yield and its components (Table 4), showed that all the variables discriminate very highly between varieties at the 1% level except for the variable fresh pod yield, which discriminates significantly between varieties at the 5% level.

The average pod length was reported to be 17.07 cm (Figure 6), while the number of pods per plant varied from 9 to 30 pods, with an overall average of 18 pods. Among the tested 20 varieties, the cowpea variety Baguette climber produced the longest pods (28.88 cm), followed by Telma (23.11 cm) and Baguette (21.72 cm). In contrast, the shortest pods (12.51 cm) were recorded in IT83S-818. The highest number of pods (30) was produced by IT83S-872, followed by IT84S-2246 (27), and the lowest number was observed in variety TZA 2344 (9 pods).

Table 4 Results of analysis of variance of pod and seed variables of 20 vegetable cowpea varieties

Variables	Minimum	Maximum	Average	CV (%)	P-Value (5%)
Pod length (cm)	12.51	28.88	17.07±0.78	23	0.000**
Number of pods/plants	9	30	18±3.78	41	0.000**
Weight of fresh pods (kg)	0.01	0.54	0.29±0.11	67	0.000**
Fresh pod yield (t/ha)	0.72	13.16	3.94±2.51	99	0.002*
Number of Seeds/Pod	14	59	29±7.2	43	0.000**
Weight Seeds (kg)	0.08	0.48	0.25±0.21	52	0.008*
Weight 100 Seeds (g)	11.03	19.5	15.1±0.99	16	0.000**
Grain yield (t/ha)	1.67	5.1	3.05±1.12	51	0.056ns

**Analysis of variance highly significant at 1%; *Analysis of variance significant at 5%; ns - Analysis of variance not significant at the 5% level; CV - Coefficient of variation; P-value - Probability value at 5%.

Figure 6 Variability in pod length of vegetable cowpea

For the tested varieties, the average pod yield (t/ha) was 3.94 tons/hectare, with 0.30 kg as the average fresh pod weight. The maximum pod yield was recorded in the baguette variety (13.16 t/ha), followed by Ex-Iseke (8.56 t/ha) and climbing baguette (7.12 t/ha). The variety TZA 2344 produced the lowest yield of fresh pods (0.72 t/ha). While the baguette variety had the highest pod weight (0.54 kg), while the lowest was recorded in the TZA 2344 variety (0.06 kg). Apart from pod length with a 23% coefficient of variation, the other variables had a coefficient of variation greater than 30%. Analysis of variance of seed length, seed width, number of seeds per pod and weight of 100 seeds was highly significant (p = 0.0001) and significant (P = 0.008) for seed weight (Table 4). The average number of seeds per pod ranged from 14 to 59, with 0.25 g as the average seed weight per elementary plot. The high number of seeds per pod was recorded in varieties IT83S-818, with 59 seeds per pod, while the lowest number of seeds was reported for the variety RW-CP-5 (14 seeds per pod). Variety IT83S-872 stood out with the highest seed weight with a value of 0.47 kg, and RW-CP-5 obtained the lowest seed weight of 0.07 kg. Regarding the weight of 100 seeds, the average weight was 15.10g, and it was reported highest (19.5 and 18.067 g) for the varieties UG-CP-6 and RW-CP-5, respectively, while for the varieties UG-CP-8, IT86F-2089-5 lowest 100-seed weights were recorded with 11.03 g and 11.43 g respectively. Coefficients of variation were high for the number of seeds per pod (CV = 43%), seed weight (CV = 52%) and seed yield (CV = 51%).

3.3 Relationships between quantitative Characteristics

The relationships between the studied traits revealed various correlations (Table 5). Strong and positive correlations were obtained between fresh pod yield, pod length (r = 0.37) and fresh pod weight (r = 0.51). Further, a negative correlation was observed between fresh pod yield and the number of days to 50% flowering (r = -0.37). Also, the number of days to 50 % flowering was strongly and positively correlated with the date of vegetable cowpea (r = 0.7)

Table 5 Correlation matrix between the different variables studied

Variables	PL	PH	50%Flo	DNV	95%Mat	NGP	NGG	PGr	PGFr	RoWGr	CCP	Rdt Gr
PL	1											
PH	0.562**	1										
50%Flo	-0.183	-0.049	1									
DNV	-0.322*	-0.159	0.669**	1								
95%Mat	0.079	0.039	0.445**	0.238	1							
NGP	-0.222	-0.346*	-0.459**	-0.289	-0.136	1						
NGG	-0.166	0.091	-0.472**	-0.192	-0.071	0.413**	1					
PGr	-0.126	-0.16	-0.298**	-0.234	0.043	0.243	0.399*	1				
PGFr	0.455**	0.11	-0.488**	-0.421*	-0.106	0.303*	0.152	0.397*	1			
RoWGr	0.366*	0.318*	-0.369*	-0.186	-0.048	0.302*	0.341*	-0.197	0.511**	1		
CCP	0.117	0.362*	-0.091	-0.165	0.056	0.089	0.11	-0.196	0.113	0.358*	1	
Rdt Gr	-0.052	0.246	-0.393*	-0.247	0.051	0.418*	0.734**	0.191	0,055	0.505**	0.268*	1

*significant, **highly significant, PL - Pod length (cm), PH - Plant height (cm), 50 % Flo - 50 % Flowering (JAS), DNV - Green cowpea date (JAS), 95 % Mat - 95 % Maturity (JAS), NGP - number of seedlings pods, NGG - number of seeds per pod, PGr (kg) - seed weight, PGFr (kg) - fresh pod weight, PCG (g) - hundred seed weight, RdtGFr - fresh pod yield(t/ha), RdtGr - grain yield (t/ha)

Table 6 Eigen values and contribution of the characters expressed by the first two (02) axes of the principal component analysis

Main Components	F1	F2
Eigen value	3.785	2.917
Total variance (%)	25.233	19.448
Total cumulative variance (%)	25.233	44.68
Characters defining the axes and their eigenvalues		
LG	-0.145	0.49
HP	-0.113	0.401
LGr	-0.121	0.392
LaGr	-0.118	0.227
50%Flo	0.415	0.061
SPAD	-0.182	0.392
DNV	0.338	-0.103
95%Mat	0.116	0.063
NGP	-0.31	-0.308
NGG	-0.335	-0.247
Weight Gr	-0.188	-0.17
PGFr	-0.341	0.146
RoWGr	-0.326	0.117
Weight 100 Gr	-0.177	0.18
Rdt Gr	-0.328	-0.129

LG - pod length (cm), HP - plant height (cm), LGr - Grain length (mm), LaGr - Grain width (mm), 50% Flo - 50% Flowering (JAS), SPAD - Chlorophyll content, DNV - Vegetable cowpea date (JAS), 95% Mat - 95% Maturity (JAS), NGP - Number of pods plants, NGG - number of seeds per pod, PGr (kg) - seed weight, PGFr (kg) - fresh pod weight, PCG (g) - hundred seed weight, RdtGFr - fresh pod yield(t/ha), RdtGr - seed yield (t/ha), F1 and F2 are axes

and the number of days to 95 % maturity (r = 0.45). However, the number of days to 50% flowering was negatively correlated with fresh pod weight (r = -0.49) and the number of pods per plant (r = -0.46). The strong correlation between vegetable cowpea date and fresh pod weight is negative (r = -0.42). In addition, a positive and strong correlation was obtained between seed yield and the number of seeds per pod (r = 0.73). A strong and positive correlation was observed between the number of seeds per pod and seed weight (r = 0.4).

3.4 Structuring diversity

Principal component analysis (PCA) yields two axes (F1 and F2), explaining 25.23% and 19.44% of the total variability, respectively. The first two components, which absorb 44.68% of the variance, were selected to analyze the agro-morphological variability of the varieties, with an eigenvalue ranging from 2.92 to 3.79 (Table 6). Axis 1 positively associates the number of days to 50% flowering (r = 0.42), vegetable cowpea date (r = 0.34), while it negatively associates the number of pods obtained per plant (r = -0.31), number of seeds per pod (r = -0.34), the weight of fresh pods (r = -0.34), the yield of fresh pods (r = -0.33) and the yield of seeds (r = -0.33). This axis can be defined as the vegetable cowpea cycle and fresh pod yield axis. Axis 2 positively associates pod length (r = 0.49), plant height (r = 0.40) and seed length (r = 0.39). It can be defined as the axis of plant, pod and seed size. F1 and F2 are the two axes of the principal component analysis benchmark.

3.5 Organization of the diversity of vegetable cowpea varieties

The hierarchical ascending classification (HAC) carried out based on the quantitative discriminant variables made it possible to divide the varieties studied into three (3) distinct groups (Figure 7). Among these, Group 1 consisting of three (3) individuals, includes varieties IT84S-2246, IT83S-872 and IT83S-818 while group 2 consisting of five (5) individuals including the varieties TZA 2344, RW-CP-5, Tumaini, UG-CP-5 and RW-CP-2 and the group 3 is made up of twelve (12) individuals and is composed of the varieties Baguette, Ex-Iseke, IT83S-911, Niébé baguette grimpant, IT83S-867-5, IT85F-2682, IT85F-2805-5, IT86F-2089-5, LBR7, Telma, UG-CP-3 and UG-CP-8.

3.6 Characteristics of the groups formed by the HAC

The results of the differentiations factor analysis (Figure 8) were used to characterize the three groups based on traits related to the vegetable cowpea cycle (the date at 50% flowering of plants and vegetable cowpea date), pod yield and its components and plant size. Group 1 includes varieties characterized by early flowering (46 days) and the high number of pods obtained per plant (28 pods). Group 2 includes varieties with average agronomic performance for pod length, number of pods obtained per plant, date at 95% maturity of the pods, fresh pod weight and fresh pod yield. Group 3 includes the best-performing varieties. These varieties are characterized by a high pod length (28.88 cm), an early vegetable cowpea date (55 JAS), a high pod weight (0.54 kg) and a high fresh pod yield (13.16 t/ha).

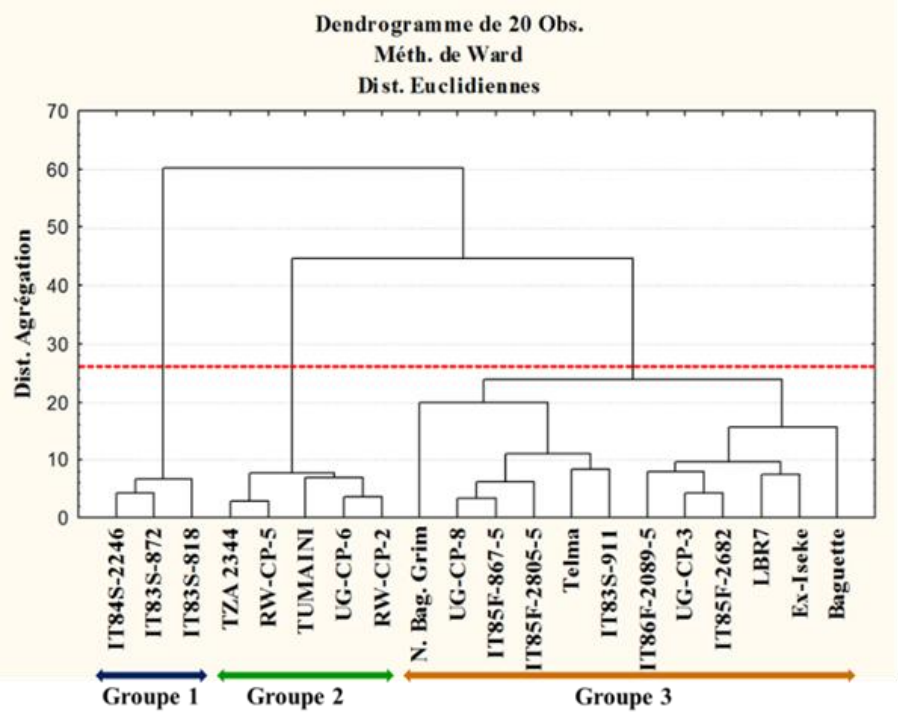

Figure 7 Dendrogram from the hierarchical ascending classification of twenty (20) vegetable cowpea varieties

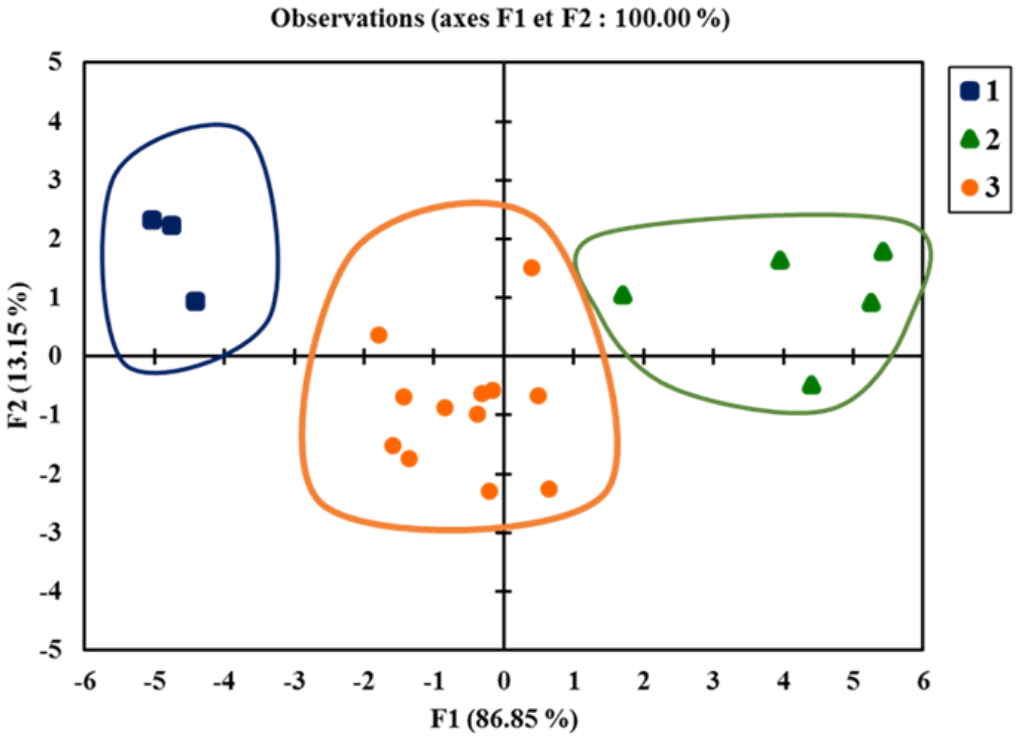

Figure 8 Representation in the ½ plane of the SFM of the variety groups from the HAC

4 Discussion

The results of analyses highlighted a high variability within the studied varieties at the qualitative and quantitative levels. Indeed, the high values of the coefficient of variation for several characters and the number of modalities per qualitative character would indicate a high heterogeneity within the studied material (Boyé et al. 2016). This heterogeneity between varieties is apparent in the principal component analysis with its two components to reflect the diversity within cowpea varieties. The principal component analysis makes it possible to retain the relevant parameters for the realization of a study and thus save time (Abe et al. 2015). This variability resulted in the existence of several discriminating traits and provided opportunities for selection.

The high proportions of the qualitative variables were obtained in the different plant organs' color, shape and type. However, a difference was observed in flower color compared to those observed by Cobbinah et al. (2011), who obtained white-purple flowers in their work in Ghana. This difference is explained by low variability within the material tested for this character. Since the pigmentation of flowers, pods and seed coats in cowpeas is expressed by a single gene, the relationship between flower color and other traits may be useful in selecting important or economic traits (Egbadzor et al. 2014). The type of semi-erect habit within the studied material indicates that these varieties can be retained in a breeding program. Indeed, according to Animasaun et al. (2015), erect plants with the advantage of being less attacked by rodents could also be harvested using mechanical harvesters. Plant habit types are also important in the choice of seeding spacing and the choice of cropping system. Hall et al. (1997) state that climbing and erect plant types are used in monoculture or intercropping production systems. Pod color is an important characteristic in consumer choice (Manju 2006). Indeed, of the observed pod colors, there is a general preference for greener pods in vegetable cowpea (Peksen and Peksen 2012). The dark green color of the pods could therefore have high photosynthetic activity of the plant. Thus, the varieties with green-dark pods may offer the preferred color to the producers and consumers.

Lovely and Radhadevi (2017) observed significant differences in quantitative variables with vegetable cowpea varieties in Kerala, India. The mean flowering cycle (47 JAS) and that of vegetable cowpea date (55 JAS) show that the studied varieties have an early cycle. This early cycle indicates that these varieties could be grown in Burkina Faso, as it is a criterion of choice. Indeed, according to Doumbia et al. (2013), early-flowering varieties are a solution to adapt to the effects of climate change. In addition, according to Vural et al. (2000), the harvest date of vegetable cowpea pods is between 5 and 9 weeks, depending on the environment. Therefore, the average date for harvesting fresh pods would be reached from the seventh (07) week after sowing for semi-early varieties. These flowering cycles and vegetable cowpea stages of the studied varieties differ from those obtained on vegetable cowpea varieties

(Coulibaly et al. 2020). These differences in the number of flowering days and vegetable cowpea dates between varieties would depend on their genotypes. According to Pandey et al. (2006), the difference in the vegetable cowpea cycle is due to the growing environment or the genetic makeup of the varieties. Harvest time is very important to avoid the presence of fiber in fresh pods, which consumers do not appreciate (Peksen 2004). Pandey et al. (2006) indicate that the optimal harvest stage is also important for the vegetable market. Therefore, the pod harvesting period is an important parameter for selecting high-yielding vegetable cowpea cultivars (Kutty et al. 2003). Indeed, this harvest period could be predicted from the dates of flowering or maturity of the pods (Cobbinah et al. 2011), and the strong and positive correlation between flowering and vegetable cowpea date reveals this. Thus, plants that reach their flowering date and vegetable cowpea date very early are precocious. Coulibaly (2018) also mentioned a similar correlation between flowering date, and vegetable cowpea date with varieties grown in Burkina Faso. The mean value of 70 JAS of the 95 % pod maturity date indicates that all the study varieties are early maturing. Early cycle varieties have a maturity between 67 and 70 days, and those with a long cycle have a maturity between 74 and 77 days (N'gbesso et al. 2013). These results are close to those of Coulibaly (2018), who in his work on 12 varieties of vegetable cowpea, observed a maturity between 60 and 70 days. The earliness of vegetable cowpea varieties could help to cope with the constraints of scarce rainfall at the end of the season.

Differences in varietal performance related to fresh pod yield and yield components are thought to be explained by the growing environment or by the genetic makeup of the varieties. These differences are reflected in the structuring into three groups of varieties given by the hierarchical ascending classification. Indeed, according to Pandey et al. (2006), the yield in fresh pods is the determining variable for selecting a particular variety for marketing. Thus, Telma (5.37 t/ha), IT85F-2805-5 (6.03 t/ha), baguette grimpant (7.12 t/ha), Ex-Iseke (8.56 t/ha), and Baguette (13.16 t/ha), were distinguished by their high pod yield. The results of the present study are superior to those of Nwofia (2012), who found fresh pod yield which ranged from 4.5 to 9.57 t/ha in cultivars IT 93k -915, IT86F- 2062-5 and IT81D-1228-14 on vegetable cowpea cultivars in Nigeria. In addition, for Peksen and Peksen (2012), the most important yield components for vegetable cowpea are pod length, pod count per plant, and pod weight. Pandey et al. (2006) identified pod length as one of the key factors in selecting vegetable cowpea varieties. According to Kutty et al. (2003), the number of pods per plant exerts the most important direct effect on fresh pod yield. These effects are reflected in the strong positive correlations between fresh pod yield and pod length, number of pods per plant and fresh pod weight. These correlations corroborate with Peksen (2004), who found that fresh pod yield was correlated with pod length, number of pods obtained per plant and average pod weight. Thus, direct selection is possible for different selected traits. For this purpose, the varieties baguette grimpant, Telma, Baguette, IT83S-911, IT83S-872, IT84S-2246, IT83S-818, IT85F-2682, and LBR7 respond better to the agronomic characteristics expected from vegetable cowpea. Thus, varieties from group 3 of the hierarchical ascending classification with long pods, early vegetable cowpea date, high pod weight and high fresh pod yield in the cross with individuals from group 1 have early flowering, and the high number of pods obtained per plant would allow the creation of early and high yielding varieties. To create vegetable cowpea varieties with high fresh pod yield, it is important to consider pod harvesting time, pod length, number of pods obtained per plant and average pod weight.

The number of seeds per pod, ranging from 14 to 59 seeds, is higher than that obtained by Egbadzor et al. (2014), which varied from 9 to 21 seeds. According to Boyé et al. (2016), the variability observed within varieties concerning the number of seeds per pod reflects their ability to mobilize assimilates to reserve structures. Concerning the weight of 100 seeds, Khan et al. (2010) showed that the variability obtained between varieties depends on genotype and climatic factors. According to Khan et al. (2010) a very significant variation was reported in the 24 cowpea genotypes, and in this, the climatic adaptation factor could also play a role in the increase of seed weight. As a result, vegetable cowpea varieties with the highest number of seeds per pod and weight of 100 seeds could be produced as both seed cowpea and vegetable cowpea. The strong negative correlations between flowering date, the number of pods obtained per plant and fresh pod weight mean that late flowering plants have fewer pods per plant and a lower pod weight, as confirmed in the varieties TZA 2344, RW-CP-2, RW-CP-5, TUMAINI.

Conclusion

The agro-morphological characterization study revealed the existence of significant variability within the studied varieties, which could be exploited and used in a cowpea breeding program for traits of interest. The current study showed that out of all the studied 20 varieties, 12 varieties were identified for their morphological and agronomic performance, which could constitute a base of varieties of interest. The flowering cycle and date of vegetable cowpea, pod length, the number of pods obtained per plant, pod weight and the yield of fresh pods were identified as expected traits of interest for vegetable cowpea in the climatic and economic context of Burkina Faso. Among the tested varieties, IT83S-872 (30), IT84S-2246 (27), Baguette (25), IT83S-818 (26), and IT85F-2682 (24) were thus identified for their high number of pods per plant. The varieties Baguette, baguette grimpant, Telma, and IT83S-911, which reached their vegetable cowpea stage early, have the longest pods and a high fresh pod yield. These varieties

are, therefore, potential parents that meet growers' selection criteria. After genetic improvement and multi-local testing, they could be recommended for the extension. Strong correlations were reported between various quantitative traits, which could facilitate the selection of traits of interest to producers and consumers by reducing the number of parameters to be collected. In addition, this study made it possible to classify the varieties into three groups according to their performance.

Declaration of competing interest

The authors expressed no conflicts of interest in this study.

Acknowledgements

We are grateful to the researchers of the CREAF Plant Genetics and Biotechnology Laboratory for their support with equipment and to the members of the Plant Genetics and Improvement team (UJKZ) for their contribution to the manuscript.

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