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Phenotypic characterization of different seed coat color of cowpea cultivars, *Vigna unguiculata* (L). Walp. in West-Central Côte d'Ivoire

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Abstract

Cowpea is a widely consumed legume in sub-Saharan Africa. Several cowpea cultivars based on seed coat color are widely observed. Consumers' choice of cultivar varies from one region to another. However, the lack of improved varieties and the limited availability of information on the productive potential of these cultivars is one of the constraints on the development of cowpea production. Thus, red, white, black and brown seed coat widely consumed were evaluated in the field over two consecutive years, 2022 and 2023 on a plot following a randomized complete block design with four replications. Morphological and agronomic parameters showed that there were two groups of cultivars with interesting agronomic characteristics. The first group composed of the black, brown and red cultivars had a relatively short reproductive time, averaging 66 days. These cultivars are considered early. The number of fruits of these cultivars was also high, with an average of 12 fruits per plant. The second group, consisting exclusively of the white seed coat cultivar produced high biomass and plant length. It had also twice the pod and seed weight of the other cultivars. It would be possible to develop hybrids in the future, seeking, for example, to improve the seed weight of the red cultivar with a short reproductive cycle by crossing with the white seed coat cultivar, with a view to creating an early variety with a high yield.

Keywords: Cowpea; *Vigna unguiculata*; Cultivar; Seed coat color; Agro-morphological evaluation

1. Introduction

Cowpea, *Vigna unguiculata* (L.) Walp. is a widely used legume in most sub-Saharan African countries. In fact, it occupies a prime position because of its source important of cheaper protein and energy for people in developing countries where access to animal protein is difficult [1]. Cowpea is also a multi-purpose plant that plays a role in feeding livestock [2, 3], in soil fertility to its capacity for symbiotic fixation of atmospheric nitrogen [4] and in protecting soils against degradation due to its creeping nature [5].

Despite its food and agronomic importance, cowpea yields remain relatively low. Indeed, Côte d'Ivoire is unable to cover its cowpea needs, with national production accounting for less than 2% of African production [6]. The decline in cowpea production currently observed in Africa is also low compared with the plant's potential, estimated at two tones/ha [7]. In Nigeria and Ethiopia, cowpea yields in farmers' fields are estimated at 0.3 Mg.ha-1 and 0.4 t.ha-1 respectively [8, 9]. The lack of improved varieties and the poor availability of information on the productive potential of different local cultivars are some of the constraints to the development of cowpea production.

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The use of local cultivars varies from one locality to another. The most widely used cultivars are based on the color of the seed coats. Cultivars with red seeds are more popular in Benin [1] and Central Nigeria than those with white seeds, which are highly recommended in the North [10]. Some cowpea consumers prefer larger grains with white coat. In fact, the size and color of the seeds are characteristics that determine the price of the product on the market. Others, on the other hand, have a preference for the brown variety because of its unique, slightly sweet taste [11].

Several studies have evaluated the effect of cowpea seed coat color on nutrient levels [12, 13]. However, very few studies on seed coat color have been addressed from an agromorphological aspect. Agronomic evaluation of these seeds is also necessary to characterize them and assess their production potential. This would enable us to select genotypes that meet farmers' requirements and choices. By considering the above aspects, we initiated the present study to determine the agronomic parameters of different cultivars based on the color of the seed coats. The identification of the most productive cultivars could be used as parents in the breeding program.

2. Material and methods

2.1. Study site

The study was carried out over two growing seasons from March to June, in 2022 and 2023 respectively, in Jean Lorougnon Guédé University in Daloa. The department of Daloa is located in the Upper Sassandra region of Central-Western Côte d'Ivoire, between 6° and 7° north latitude and 7° and 8° west longitude (Figure 1). The region's climate is humid tropical, with two rainy and two dry seasons. Annual rainfall varies between 1,200 and 1,600 mm. Soils are predominantly ferralitic [14]. The region is mostly covered by semi-deciduous forest and grassy and shrubby savannahs.

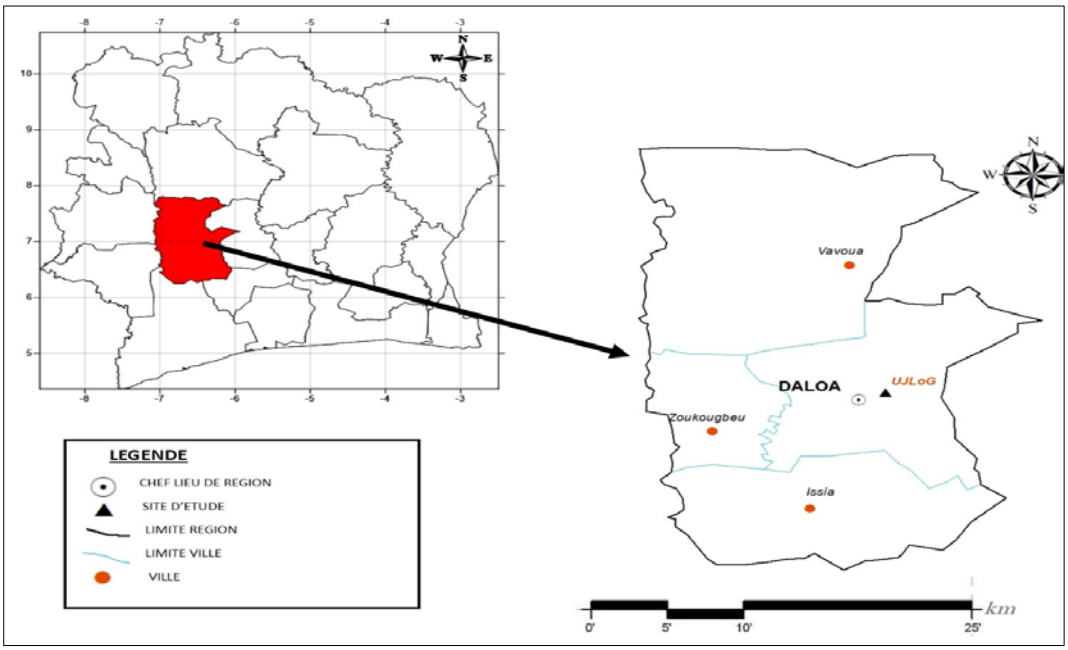

Figure 1 Presentation of the study area [15]

2.2. Plant material

The plant material used consisted of four cowpea cultivars distinguished by seed coat color. These cultivars, originating from the north, west and east of Côte d'Ivoire, were obtained from the seed bank of the Université Jean Lorougnon Guédé collection in Daloa (Côte d'Ivoire). Cultivars with red, white, black and brown seed coats were used in this study (Figure 2).

Figure 2 The different cultivars used in the study

2.3. Experimental design

The trial was carried out on a 225 m^2 (15 m x 15 m) plot in a completely randomized block design with four replications. The 36 m^2 (6m x 6m) blocks were separated from each other by two meters. Ten replications per cultivar were carried out for each block. This gave a total of 40 seeding points per block, or 160 plants per plot. Seeding points as described by Goré *et al*. [16] were spaced 60 cm apart within and between rows. Sowing took place on all plots. Three seeds were sown per plot. One week after sowing, the seed was removed to leave just one plant in each hole. Insect pests were treated with Cypercal 50 EC. Regular weeding is carried out to avoid competition between weeds and cowpea plants.

2.4. Variables measured

Observations were made on each plant. Agro-morphological parameters were measured from emergence to harvest. Ten parameters were measured. The first five concerned the time of the phenological and growth stages of the cultivars, i.e. germination time, date of appearance of the first flowers, pod maturity time, plant length and number of leaves per plant. The other five were agronomic parameters including Number of Pods per Plant, Pod and 100-seed weight, Pod and Seed Number (Table 1).

Table 1 Methods of measuring different parameters

Characters	**Type and period of observation**
Germination Time (GT)	Number of days from sowing to cotyledonary leaf opening
Flowering Time (FT)	Number of days from sowing to first flower opening per plant.
Fruit Maturity Time (FMT)	Number of days from sowing to first mature fruit per plant
Plant Length (PL)	The length of the plant taken by measuring the main stem of each plant with the tape measure. This length corresponds to the distance between the ground and the upper end of the plant (cm)
Pod Length (PoL)	The pod length was measured using a standard 12 inch ruler (cm)
Number of Leaf (NL)	Total number of leaves per plant
Seed Number (SN)	Total number of seeds per pod
Number of Pods per Plant (NPP)	Total number of pods at plant maturity
Pod Weight (PW)	Weight of pods after drying (g)
100 Seed Weight (SW)	Weight of 100 seeds after drying (g)

2.5. Data analysis

The means of morphological and agronomic parameters were compared between cultivars using Analysis of Variance (ANOVA). When a significant difference is revealed between accessions for a given trait, the ANOVA is completed by the Least Significant Difference (LSD) test.

To determine the nature and degree of divergence between the different cultivars, a Principal Component Analysis (PCA) was performed. All these analyses were carried out using STASTISTICA version 7.1 software [17].

3. Results

3.1. Comparison of cultivars according to phenological and growth stages

Seed germination time, flower emergence time, pod maturity time, plant length and number of leaves were the parameters measured for the different phenological and growth stages of the cultivars. The time of the main phenological stages of the cultivars studied were recorded in Table 2. Germination time was identical for all cultivars (*P* = 0.51). However, flower emergence was slower in the white seed coat cultivar (56 days) than in the other cultivars (33 days on average). Pod ripening was also later in the white seed coat cultivar. This cultivar had a relatively long reproduction time compared with cultivars with black, red and brown seed coats. In terms of growth parameters, the length of the main stem and the number of leaves per plant were highest in the white seed coat cultivar, followed by the black, brown and red seed coat cultivars (Table 2).

Table 2 Estimation of phenological and growth parameters of cowpea cultivars

Cultivars	Germination Time	Flowering Time	Fruit Maturity Time	Plant Height	Leaf Number
Black	5.50 ± 0.68^{a}	33.50 ± 4.00^{bc}	68.36 ± 6.89^{b}	76.40 ± 35.46^{b}	71.16 ± 20.01^{b}
Brown	5.6 ±0.67^{a}	32.16 ± 2.81^{c}	65.60 ± 3.67^{c}	54.23 ± 18.69^{c}	55.23 ± 16.56^{c}
Red	5.73 ± 0.69^{a}	35.06 ± 4.23^{b}	64.26 ± 3.05^{c}	54.73 ± 5.02^{c}	64.50 ± 23.56^{bc}
White	5.70 ± 0.70^{a}	56.10 ± 3.70^{a}	82.93 ± 6.70^{a}	103.46 ± 41.27^{a}	108.20 ± 25.00^{a}
F	0.76	276.41	76.99	19.46	34.86
P	0.51	< 0.001	< 0.001	< 0.001	< 0.001

On the same line, values with the same letter are not significantly different according to the Newman-Keuls (SNK) test at the 5% probability threshold.

3.2. Comparison of different cultivars according to agronomic parameters

Among agronomic parameters, only the pod length did not vary between cultivars (Table 3). Pod length was not a criterion for discrimination among cultivars. The number of pods per plant was however higher for the black, brown and red seed coat cultivars than the white seed. Observation of the statistical data showed that the highest pod weight and 100-seed weight were recorded in the white seed coat cultivar. The weight of the pods and seeds of the white seed coat cultivar were twice that of other cultivars. However, the number of seeds inside the pods was lowest for the white seed coat cultivar. Although the seed weight was lowest, the red seed coat cultivar recorded the highest number of seeds in the pods (15,46 ± 1,40).

Table 3 Estimation of agronomic parameters of cowpea cultivars

cultivars	Number of Pods per Plant	Pod Length	Pod Weight	Number of Seeds per Pod	100 seeds Weight
Black	10.66 ± 2.39^{a}	13.84 ± 1.16^{a}	15.50 ± 3.61^{b}	11.37 ± 2.00^{b}	13.53 ± 3.45^{b}
Brown	10.60 ± 1.5^{a}	13.97 ± 2.37^{a}	14.90 ± 2.16^{b}	11.33 ± 2.73^{b}	13.04 ± 1.79^{b}
Red	11.13 ± 2.22^{a}	14.16 ± 1.24^{a}	14.54 ± 3.88^{b}	15.46 ± 1,40^{a}	10.44 ± 2.56^{c}
White	6.80 ± 2.63^{b}	13.85 ± 1.31^{a}	34.92 ± 5.17^{a}	8.76 ± 1.33^{c}	26.03 ± 3.31^{a}
F	1.21	0.25	200.38	60.39	178.24
P	0.004	0.85	< 0.001	< 0.001	< 0.001

On the same line, values with the same letter are not significantly different according to the Newman-Keuls (SNK) test at the 5% probability threshold.

3.3. Distribution of variables and cultivars

In order to determine the relationships between the parameters and the degree of divergence between our cultivars, Principal Component Analysis was carried out. The first two axes of the PCA represent 71.24% (Table 4). These first two axes, forming the 1-2 plane, can therefore be retained for the interpretation of our results, since they bring together the greatest variability. Six of the seven descriptors contributed significantly to the formation of the two axes. Axis 1, which describes 58.10% of the variation, is defined by five variables: flowering time, pod maturity time, number of leaves, fruit weight and seed weight. All these variables are positively correlated with axis 1. Characters strongly correlated with axis 1 are related to yield.

Axis 2 expresses 15.32% variability and defines a single variable, the number of pods per plant. It is characterized by a short reproduction cycle, and hence earliness.

Table 4 Eigenvalue matrix and principal axes revealed by PCA

Main Component	Axis 1	Axis 2
Eigenvalue	4.64	1.05
Total Variance (%)	58.10	13.14
Total cumulative variance (%)	58.10	71.24
Flowering Time	0.892*	-0.088
Fruit Maturity Time	0,.845*	-0.001
Plant Height	0.619	0.116
Leaf Nmber	0.723*	0.087
Number of Pods per Plant	-0.075	0.971*
Weight of 100 seeds	0.944*	-0.070
Fruit Weight	0.942*	-0.089

*Variables contributing most to the formation of the indicated axes

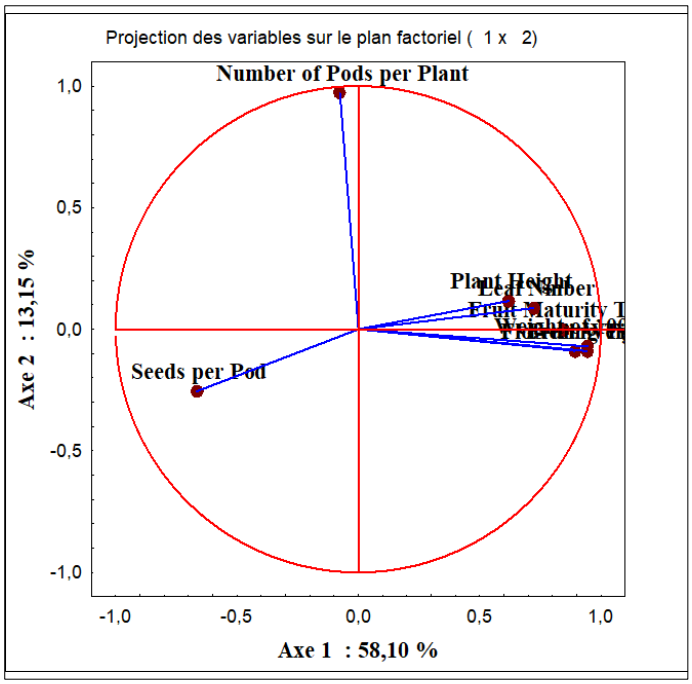

Figure 3 Distribution of variables in the 1-2 plane revealed by PCA

In terms of the distribution of individuals, we can see that the white seed coat cultivar occupied the right-hand side of the plane, while the other cultivars occupied the left-hand side (Figure 4). The distribution of individuals reveals two groups. The first group, on the right of axis 2, was essentially made up of individuals belonging to the white seed coats cultivar. The second group, to the left of axis 2, is made up of individuals belonging to the black, brown and red cultivars.

Individuals belonging to group I are characterized by high growth and yield, but with a late fruit ripening phase. Individuals belonging to group II are characterized by early-ripening plants and a greater number of fruits per plant.

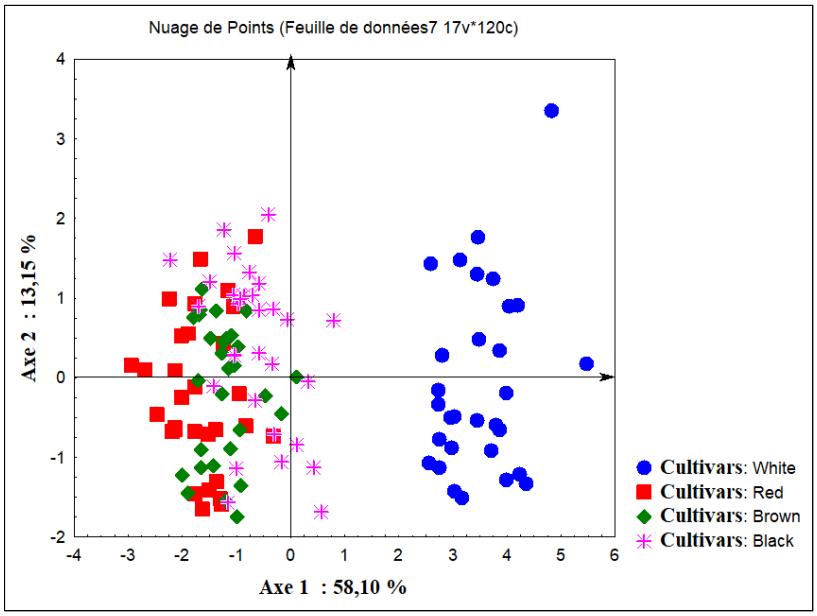

Figure 4 Distribution of the cultivar of *Vigna unguiculata* in plane 1-2

4. Discussion

This work was carried out with the aim of characterizing different seed coats color cultivars of *Vigna unguiculata* (L.) Walp. Despite a consumer's preference or choice for a given cultivar, obtaining a high yield is very important, as this criterion essentially determines the economic profitability of the production activity. Thus, the rational use of different cowpea cultivars requires a good knowledge of quantitative characteristics, notably phenological stages, morphological aspects and agronomic data.

In terms of phenological parameters, flowering time and production of mature pods were longer for the white seed coats cultivar. The difference in flowering and pod ripening times between the black, brown and red seed coats cultivars and the white cultivar was around one month and two weeks respectively. However, germination time was identical for all cultivars. In fact, it gives no indication of the length of the reproductive cycle. Flowering and pod maturity time, on the other hand, are indicators of plant cycle length [18]. Short-cycle cultivars ranged from 64 to 68 days for the three black, brown and red cultivars, compared with 53 days for the early varieties identified in Ghana and Mali [19]. These cultivars are recommended in agriculture because this precocity makes it possible to envisage four crops per year. The use of short-cycle varieties is now also becoming essential in the face of climate change, the late onset of rains and falling rainfall.

While cultivars with long reproductive cycles are undesirable in agriculture, the white seed coats cultivar had the merit of having more leaves than other cultivars. This cultivar's above-ground biomass production is very important for livestock feed requirements. As a result, the white seed coats cultivar would be a solution to the major constraint of livestock farming, whose leaves are often used as animal fodder [3]. Grain and biomass production were the first two criteria on which growers based their choice or adoption of a variety [20]. However, in a region like ours where livestock farming is not traditionally the main activity, grain-related criteria take priority over those linked to biomass.

Grain production was higher for the white seed coats cultivar than for the other cultivars. Its 100-seed weight (26.03 g) was twice that of black (13.53 g), brown (13.04 g) and red (10.44 g). In fact, the large number of leaves on the white tegument cultivar was essential for the photosynthetic activity required for fruiting. The positive correlation between

number of leaves and fruit weight was also reported by [21]. However, the number of pods and the number of seeds in these pods were higher in cultivars with black, brown and red seed coats. Our results contradict other studies, notably in okra [22], bell pepper [23]) and melon [24] which show a strong positive correlation between fruit weight and number of seeds.

Principal Component Analysis was used to establish the relationship between the different cultivars. This analysis enabled the populations to be structured into two groups, confirming the results of the Analysis of Variance, which suggested that the white seed coats cultivar and the other cultivars (black, brown and red tegument) are made up of individuals with phenological, morphological and agronomic differences.

5. Conclusion

Phenotypic characterization of the different cowpea cultivars has highlighted the phenological stages, growth and production performance of each genotype. The study revealed that growth parameters, notably number of leaves and plant length, were higher in the white seed coats cultivar. This cultivar also recorded higher pod and seed weights than the other cultivars. The latter (black, brown and red tegument cultivars) had a shorter reproductive cycle with a higher number of fruits. Latter studies will contribute to setting up a cowpea breeding program. This program will enable us to obtain early cowpea varieties with high yields.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have not declared any conflict of interests.

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