Agro-morphological characterization of beans of the *Phaseolus* genus and identification of their cultivated species in Benin (West Africa)

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Abstract

The local cultivars of the *Phaseolus* genus present within the local communities constitute a considerable source of genes and consequently of genetic diversity which would lead to success of the varietal creation of beans. Nevertheless, these resources suffer from a significant genetic erosion because of the climatic requirement but also of the difficulties related to their cultivation methods. The objective of this study is to identify the phenotypical distinctive features of the species of the *Phaseolus* genus cultivated in Benin for a permanent management. To achieve this goal, an agro-morphological characterization was carried out on two years (2019-2020) from March to August of each, at Ahossougbéta (Abomey-Calavi) following a completely randomized blocks design with three replications. Data were collected on twenty-three measured characters on 88 accessions. Data were subjected to the descriptive analysis, the analysis of variance and the multivariate analyses. Results showed a great variability among the accessions for the studied cultivars. Three major groups were identified and were characterized by the AFD. The studied cultivars were characterized more by the shape of the first leaves, the color of the flowers, the color of the integuments, the width of the pods, times of flowering and appearance of the pods and the width and the length of the pods. These results are significantly important for the classification of beans species of the *Phaseolus* genus. In addition, morphological and molecular genetic characterizations are necessary within each specie in order to define strategies for the improvement and the conservation of their genetic resources in Benin.

Keywords: *Phaseolus* spp; Hierarchical Ascendant Classification (CAH); Discriminant Factorial Analysis (AFD); Abomey-Calavi; Benin

1. Introduction

Food and nutritional security are major priority in the whole world and mainly in the developing countries. Nowadays, food and nutritional demand is mainly assured by resources of vegetable origin because they are easily accessible to the populations [1]. The beans of the *Phaseolus* genus are vegetable resources which appear in good place among food legumes in the world. The *Phaseolus* genus gathers approximately about sixty species belonging all to the family of
Fabaceae [2]. They are annual plants, herbaceous long-lived, seldom woody, with stems short or generally hails and lengthened, climbing and voluble on the right, i.e. rolled up of left on the right, while going upon a tutor [3,4,5]. Belonging to under tribe of Phaseoleae, the tribe of Phaseolineae and the order of Fabales, the beans of the Phaseolus genus have their center of origin in Central and the Southern America. This genus contains species whose morphological characteristics are very similar but with some differences observed on the morphological features among species [4, 6]. Species of great importance, the potential benefits of Phaseolus beans are numerous and for a long time illustrated by results of the studies on animal models [7], the shift and the rotation of crops [8, 9] but also of the studies of intervention from man [10]. Indeed, several studies showed that the consumption of beans is recommended to the people suffering from obesity and having disorders of the nervous system, rheumatisms, of gastro-enteritis or in poultice [10, 11, 12]. They also constitute a significant source of starch (starchy food) with weak index glycaemic [13], cheap sources of proteins [14], and micronutrients such as Iron, Magnesium, Calcium and Zinc, but also of fibres for more than 300 million people in the Tropics [13, 14]. The small African farmers cultivate each year in family agriculture more than four million hectares of beans with approximately 85% of the production used for home consumption [15] constituting a source of food for more than 100 million Africans [16]. Because beans offer a profile in amino acids opposed to that of cereals i.e., that they contain the essential amino acids (32% of the full amino acids) with a strong proportion out of lysine but whose sulphur amino acids (methionine and cysteine) constitute the limiting factors but found in sufficient quantity at cereals, the roots and tubers, etc. [18, 19, 20]; several authors agree that the simultaneous consumption of these food products constitutes a complement to correct the deficit in essential amino acids not only for the vegetarians but more particularly in the most stripped households which have difficult access to animal protein because of its high cost for this social class [5, 21, 22, 23, 24]. Also, in the crops production, the beans just like any other legume plants, nodosities which they carry on their roots or sometimes on their stems containing symbiotic bacteria rhizobia, are regarded as excellent converters of atmospheric mineral easily assimilable ammonia nitrogen by the plants [9, 25]. Therefore, the beans hold a place of choice in agriculture, contributing largely to nutritional and food security and thus with the well-being of many civilizations in the world [26]. These numerous nutritional advantages that the beans offer, attracted for a decade, the attention of the Congolese authorities who selected these speculations among the strategic cultures within the framework of the National Program of Food Safety to solve the problems of malnutrition in RDC [27]. In Benin, the management of these cultures of great importance is still a business of the local populations because the majority of the institutions of search and agricultural services for advisory service of Benin focused mainly their research on the cereal, roots and tubers and cash crops, with little attention on legumes [28, 29] whereas these crops could serve as alternative for mitigating climatic change effects and edaphic constraints in agriculture. Therefore, It become urgent to use the morphological features for the clarification of the various species and local varieties cultivated in Benin with an aim to popularize them in our natural ecosystems and evaluate their molecular genetic diversity for finally projecting relevant programmes of improvement on these cultures. The objective of this study is to evaluate the genetic diversity among the Phaseolus genus. Specifically, this study aimed to identify the distinctive phenotypical features of the species of the Phaseolus genus cultivated in Benin.

2. Material and methods

2.1. Vegetable material

The evaluation of Agro morphological diversity related to a collection of 99 accessions of beans exploited by the populations of Benin of which 88 arrived in the long term. The origin of these accessions, their local names as their codes are consigned in the table 1.

2.2. Description of the site

The study was conducted on an experimental site at Ahossougbeňa (district of Togha) in the Commune of Abomey-Calavi, Department of Atlantic (Figure 1). This zone is located between 7° 30' - 9° 45' N and 0°02'04 - 0°02'11 of the subequatorial zone. The study location is characterized by a sandy and ferrallitic soils. The climate is bimodal with two rainy seasons from March to July and from September to November and two dry seasons from August to September and December to February. The Annual pluviometry varies between 800 to 1200 mm in the West and 1000 to 1400 mm in the East. The relative humidity varied between 69% and 97% and the annual temperature oscillates between 25 and 29°C [30, 31].
### Table 1 Origins and local names of varieties

| N°  | Codes   | Local names                  | Origins          | N°  | Codes   | Local names                  | Origins          |
|-----|---------|------------------------------|------------------|-----|---------|------------------------------|------------------|
| 1   | KpDCn1  | Eglin-jin (noir)             | Djakotomey/Kpayahoué | 45  | SSCn1   | Djiyikun wiwi               | Savalou/Sohèdji |
| 2   | ATDn3   | Koudrokou                    | Toviklin/Adjido   | 46  | SSCn3   | Kpahunkpakalik daninho       | Savalou/Sohèdji |
|     |         |                              |                   |     |         | (danindji)                  |                  |
| 3   | KpDCn6  | Kpahunkundjo wansanwansan    | Djakotomey/Kpayahoué | 47  | SSCn2   | Djiyikun vovo               | Savalou/Sohèdji |
| 4   | HDDCn4  | Kpahunkundjo wansanwansan    | Djakotomey/Houégamey | 48  | SSCn4   | Kpahunto bodého             | Savalou/Sohèdji |
|     |         |                              |                   |     |         | (bodedji)                   |                  |
| 5   | SDCn5   | Ayukpahunkun                 | Djakotomey/Sègbèhoué | 49  | AOGn1   | Akpakun wévé                 | Ouèssè/Gbémè    |
| 6   | ATDn5   | Koudrokooudjo                | Toviklin/Dékandji  | 50  | SBZn1   | Akpakun wlanlan             | Bohicon/SoDoHomé |
| 7   | KpDCn2  | Eglin-jin (rouge)            | Djakotomey/Kpayahoué | 51  | GOLn4   | Akpakun wévé                 | Glazoué/Yagbo   |
|     |         |                              |                   |     |         | winninwinnin                |                  |
| 8   | KDCn1   | Eglin-jin (noir)             | Djakotomey/Kokohoué | 52  | AAZn1   | Akpakun wévé                 | Abangnizoun      |
|     |         |                              |                   |     |         | /Ginizita                   |                  |
| 9   | SDCn3   | Koudrokoou wansanwansan      | Djakotomey/Sègbèhoué | 53  | PBZn1   | Akpakun wlanlan vovo        | Bohicon/Djohounta |
| 10  | HDDCn1  | Koudrokuo                    | Djakotomey/Houégamey | 54  | LBZn2   | Akpakun wlanlan vovo        | Bohicon/SoDoHomé |
| 11  | DDCn2   | Gbodokpahunkun               | Djakotomey/Dahouéhoué | 55  | HZZZn3  | Akpakun wévé                 | Zogbodomey/HlagBa-Zakpo |
| 12  | KDCn4   | Koudrokooudjo                | Djakotomey/Kokohoué | 56  | MaGCn1  | Lègbakpakun                 | Glazoué         |
|     |         |                              |                   |     |         |                             |                  |
| 13  | SDCn1   | Kpahunkunjo                  | Djakotomey/Sègbèhoué | 57  | SGcn1   | Kpamlakun kpikpa            | Glazoué/Sowé    |
| 14  | ATDn4   | Kpahunkunjo                  | Toviklin/Dékandji  | 58  | SGcn2   | Kpamlakun foufoun           | Glazoué/Sowé    |
| 15  | KDCn2   | Kpahunkun yi                 | Djakotomey/Kokohoué | 59  | GOLn    | Séssé                       | Glazoué/Lifodji |
| 16  | HDDCn3  | Kpahunkundjo                 | Djakotomey/Damagahoué | 60  | SDCn2   | Gbodo kpahunkunyi          | Sègbèhoué       |
| 17  | KDCn6   | Eglin-jin (noir)             | Djakotomey/Kokohoué | 61  | ZOGn3   | Séssé                       | Glazoué/Zoungoundo |
| 18  | KpDCn4  | Koudrokoou                   | Djakotomey/Kpayahoué | 62  | ZZZn1   | Akpakun wévé                | Zogbodomey      |
| 19  | HDDCn6  | Kpahunkundjo wansanwansan    | Djakotomey/Gohomey | 63  | GACn1   | Akpakunvovo dogoué-         | Glazoué/Assanté |
|     |         |                              |                   |     |         | dogoué                      |                  |
| 20  | ATDn1   | Kpahunkundjo wansanwansan    | Toviklin/Lalo      | 64  | MSCn3   | Akpakun sanwansan           | Savalou/Monkpa  |
21 DDCn1 Koudrokoudjo Djakotomey/ Dahouéhoué 65 HZZZn2 Akpakun wévé Hlagba-Zakpo
22 ATDn2 Koudrokou wansanwansan Toviklin/ Lalo 66 FOGn1 Dansi kpika Glazoué/ Finangnon
23 DDCn3 Kpahunkundjo Djakotomey/ Dahouéhoué 67 AAZn2 Akpakun wévé Agbangnizoun /Adanhondjigon
24 MSCn2 Akpakun vovo Savalou/ Monkpa 68 DBZn1 Akpakun wlanwan Bohicon/Dan
25 LSCn5 Akpakun vovo Savalou/ Lahotan 69 GOLn8 Akpakun wévé cloclo Glazoué/ Lifodji
26 KpDCn3 Koudrokou wansanwansan Djakotomey/ Kpayahoué 70 MSCn5 Dansi suwanro Savalou/ Monkpa
27 MSCn1 Akpakun wévé Savalou/ Monkpa 71 MSCn6 Akpakun wévébamè Savalou/ Monkpa
28 AAZn1 Awadjihèfoun Agbangnizou / Adanhondjigon 72 MSCn8 Kpahun kpalaki balèdji (balèho) Savalou/ Monkpa
29 LAZn1 Akpakun wlanwan Agbangnizoun / Lissazounmè 73 LSCn2 Akpakun wévé cloclo Savalou/ Lahotan
30 LSCn2 Akpakun sammansamandan Savalou/ Lahotan 74 MSCn7 Dassidjì boubidjì or tchêdêdjì Savalou/ Monkpa
31 LSCn1 Akpakun wlanwilinovo Savalou/ Lahotan 75 LSCn3 Dansi Ikparè Savalou/ Lahotan
32 KDCn5 Kpahunkundjo wansanwansan Djakotomey/ Kokohoué 76 HZZZn3 Akpakun wévé Hlagba-Zakpo
33 SBZn2 Akpakun wévé Bohicon/ Sodohomè 77 LSCbn5 Akpakun wévé cloclo Savalou/ Lahotan
34 GOLn3 Akpakun wiwi Glazoué/ Lifodji 78 GACn2 Akpakun wlanwan Glazoué/ Assanté
35 GOLn2 Akpakun vovo Glazoué/ Lifodji 79 GACn3 Djìyikun Glazoué/ Assanté
36 LBZn1 Akpakun wévé Bohicon/ Lissézoun 80 AAZn3 Akpakun wévé (laiteux) Agbangnizoun /Adanhondjigon
37 FOGn2 Dassidjì daninho Glazoué/ Finangnon 81 DBZn2 Akpakun wévé (laiteux) Bohicon/ Dan
38 AOGn2 Kpahunto bodèho Ouëssé/ Gbémè 82 DBZn3 Akpakunvovo Bohicon/ Dan
39 K1DCn5 Kpahunkundjo Djakotomey/ Kinkinhoùé 83 GOLn6 Akpakunvèdjì vêdjè Glazoué/ Lifodji
40 K1DCn3 Eglin-jìn Djakotomey/ Kinkinhoùé 84 GOLn1 Akpakun vovo Glazoué/ Lifodji
41 K1DCn1 Koudrokou Djakotomey/ Kinkinhoùé 85 OBZn Dansi kpika bagarou Banikoara
42 K1DCn4 Gbodo kpahunkun-iy Djakotomey/ Kinkinhoùé 86 AAZtn1 Akpakun wlanwan Agbangnizoun / Adanhondjigon
2.3. Experimental design

The experimental design used was completely randomised with three replications [32]. It consists of 3 randomised complete blocks comprising each one 3 pieces of which each one comprises 33 cultivars. Each elementary piece measures 16.5 m out of 2.4 m. The pieces are laid out randomly. The spacing between the lines is 0.5 m and that between sowings is 0.4 m. Some intervals of 0.75 m and 1 m isolate two pieces respectively from the same block and the blocks.

2.4. Methodology of data collection

On the whole, 23 characters were measured including 12 quantitative characters and 11 qualitative characters (Table 3). Measurements were carried out according to the recommendations registered in the descriptor of International Board for Plant Genetic Resources [33]. These observations were made according to the various stages of development of the seedlings.

2.5. Qualitative characters and codes

The type of germination (TYG) was determined through the appearance of the cotyledons at the ground surface. Shape of first leaves (FPF), Shape of leaflets (FFE), Chlorophyllous color of leaves (CCF), Way of growth (HCR), Color of first leaves (CPP) and Port color of plants were observed according to the variants of these characters registered in the IBPGR descriptor in 1982 during the different stages of vegetative development of the accessions. Concerning the Color of flower (CFL), Color of integument (COT) Color of the hilum (COH) Shape of seeds (FOG); these parameters were registered respectively three days after the flowering and after the harvest of the seeds.

2.6. Quantitative characters and codes

The Duration of germination (TEG) was registered when the cotyledons emerged at the ground surface. Likewise, the Duration of stay of cotyledons (TSC) and appearance of gimlets (TAV) were registered respectively, the days where each accession shed one’s cotyledons or the gimlets appeared on each plant. The quantitative parameters such as the Length of the leaflets (LOF), the Width of leaflets (LAF), the Length of petioles (LOP), the Length of the pods (LOG) and Width of pods (LAG) were measured with the graduated ruler on average of 10 plants. Period of flowering (TAF) and Period of appearance of pods (TAG) were recorded respectively since the appearance of the first flowers (the first pods) on
each plant. Seeds per pod (NGG) was registered on average of 10 pods for each accession selected at random. Regarding 100 seeds weight (P100G), an exactness balance was used.

2.7. Data analysis

The data were analyzed by the descriptive statistics (average, frequency, percentage, etc.) and the results are presented in the form of tables and of figures. An analysis of variance was carried out with so as to ascertain if significant differences exist between the cultivars for the studied characters. Moreover, it was carried out multivariate analyses. Thus the matrix of correlation and the Analysis Factorial Correspondences (FCA) were carried out to study the relations between the characters. For the Analysis Factorial Correspondences, the qualitative data were transformed into classes. The Hierarchical Ascendant Classification (CAH) made it possible to set up groups which were characterized by the Discriminating Factorial Analysis (AFD). Data were analyzed using XLSTAT software.

3. Results and discussion

3.1. Qualitative characters and inter-cultivars variability

From the morphological point of view, the studied accessions have an inter-cultivars variability for the measured qualitative characters. Thus, for the character chlorophyllous color of leaflets (CCF), cultivars presented individuals with green-pale leaflets (45.57%), other cultivars with leaflets medium-green (26.21%) and individuals with dark-green leaflets (28.22%). Regarding the character flowers color (CFL), it was noted more than 54% individuals were mauve flowers. Individuals with white (23%), purple (10.08%) flowers and individuals with white-purple flower (12.90%) were also noted. For the other qualitative characters such as the shape of leaflets (FFE) more than 93% of the cultivars presented triangular leaflets; 3.61% of the cultivars with simple leaflets and 3.21% of the individuals are with sub-globular leaflets. For the way of growth character (HCR), the majority of the cultivars (96.77%) presented an unspecified way of growth. Only 3.23% of the individuals presented a pseudo-given growth. The standard character of germination (type of germination, TYG) presented two variables: Epigean (87.09%) and Hypogean (12.91%). The port of certain plants was pigmented of anthocyanins (colouring violet) and account for 19.92% of the characterized individuals whereas other stems of beans present green colourings (9.35%) or green-pale (70.73%). The greatest number of phenotypical variables was obtained for the integument color (COT) and hilum color (COH) characters. Concerning the COT, studied cultivars presented seeds at one-coloured integument with five variations of which the white (31.11%), the red (18.6%), the pink (10.91%), the milky white (2%) but equally the black color. Others cultivars presented for the same character, some individuals with two-tone seeds of which approximately 20.75% are with mottled white integument of red or black, 3.7% with mottled pink integument of red or of black then finally 1.4% of the individuals characterized are with mottled red seeds of white. For character COH, seven (07) variables were observed. The seeds of the studied cultivars presented hilums at single colouring of which the white (19.8%), the light grey (7.21%) and the milky white (43.4%) but, also of the individuals with hilums unicoloured of which the periphery is surrounded by another color. It is the case for example of seeds with white hilum surrounded by black (9.8%), of grey (8.62%), red (8.07%) or carmine-red (3.1%) noted in this study. In addition, for the color of the first leaves (CPF) and seeds shapes (FOG), the studied cultivars presented respectively green-pale colourings (89.3%), medium-green (6.8%) and purple (3.9%) as of the appearance at the stage of two leaves while the seeds presented three shapes : kidney-shape (33.2%), round (11.6%), and ovals (55.2%) after harvest. (Table 2).

3.2. Repetition effect and descriptive statistics for the quantitative characters

The descriptive statistics applied to the quantitative variables collected are consigned in Table 3. Significant variations were observed between the average, the minima and the maxima, the standard deviation and the coefficient of variation for the measured characters. Indeed, the evaluated cultivars presented an average value of 6.867 days with a minimum of 5 days and a maximum of 9 days for the time of germination. For the stay time of the cotyledons, it was observed an average of 10.891 days with a minimum of 0 day and a maximum of 23 days. As regards to the time appearance of the gillets, the cultivars gave an average value of 25.885 days with a minimum of 0 day and a maximum of 35 days. The length of the leaflets, width of the leaflets and length of the petioles showed an average of 8.757 cm; 5.454 cm and 9.640 cm, respectively with 4.660 cm; 1.500 cm and 4.000 cm of minima and maximum of 18.160 cm; 13.000 cm and 20.000, respectively. For other characters measured at flowering and fructification stages such as the time of appearance of the floral buttons and the pods, the averages observed were respectively 70.820 and 87.906 whose minimal values were 42.000 and 57.000 and maximum were 103.000 and 127.000. During the harvest, four characters were evaluated. They were the length and the width of the pods, the number of seeds per pods and the weight of 100 seeds. The average values obtained for these various characters were 10.881; 1.407; 7.543 and 53.519, respectively.
### Table 2 Variability in the qualitative characters of the cultivars

| Characters                        | Variables          | Frequency  |
|----------------------------------|--------------------|------------|
| Type of germination (TYG)        | Epigean            | 76.07%     |
|                                  | Hypogean           | 23.93%     |
| Type of growth (HCR)             | Unspecified        | 94.67%     |
|                                  | Pseudo-given       | 5.33%      |
| Shape of first leaves (FPF)      | Heart shape        | 72.58%     |
|                                  | Lanceolate         | 20.56%     |
|                                  | Globular           | 6.85%      |
| Chlorophyllous color of leaflets (CCF) | Green-pale      | 45.57%     |
|                                  | Medium-green       | 26.21%     |
|                                  | Dark-green         | 28.22%     |
| Flowers color (CFL)              | Mauve or lilac     | 54.03%     |
|                                  | White              | 22.98%     |
|                                  | Purple             | 10.08%     |
|                                  | White-purple       | 12.90%     |
| Port color of plants (CPP)       | Green-pale         | 70.73%     |
|                                  | Purple             | 19.92%     |
|                                  | Medium/Dark-green  | 9.35%      |
| Shape of leaflets (FFE)          | Trifoliate Triangular | 93.17%   |
|                                  | Trifoliate simple  | 3.61%      |
|                                  | Trifoliate sub-globular | 3.21%  |
| Integument color (COT)           | White              | 31.11%     |
|                                  | Pink               | 10.91%     |
|                                  | Black              | 2.00%      |
|                                  | Red                | 18.60%     |
|                                  | Milky-white        | 11.53%     |
|                                  | White streaked with black | 14.32% |
|                                  | White streaked with red | 6.43%   |
|                                  | Rose streaked with black | 2.30%  |
|                                  | Rose streaked with red | 1.40%   |
|                                  | Red streaked with white | 1.40%  |
| Hilum color (COH)                | White              | 19.80%     |
|                                  | Light grey         | 7.21%      |
|                                  | Milky-white        | 43.40%     |
|                                  | White surrounded by black | 9.80%  |
|                                  | White surrounded by grey | 8.62%  |
White surrounded by red 8.07%
White surrounded by carmine red 3.10%

First leaves color (CPF)
Green-pale 89.30%
Medium-green 6.80%
Purple 3.90%

Shape of seeds (FOG)
Kidney shape 33.20%
Medium-green 11.60%
Rounded 55.20%

### Table 3 Descriptive analysis

| Measured characters | Number of Individuals | Minimum | Maximum | Average | Standard deviation | Coefficient of variation |
|---------------------|-----------------------|---------|---------|---------|--------------------|-------------------------|
| TAF                 | 256                   | 42.000  | 103.000 | 70.820  | 14.930             | 4.743                   |
| TAG                 | 256                   | 57.000  | 127.000 | 87.906  | 17.493             | 5.025                   |
| LOG                 | 256                   | 5.300   | 34.000  | 10.881  | 5.946              | 1.830                   |
| LAG                 | 256                   | 0.600   | 3.900   | 1.407   | 0.540              | 2.606                   |
| NGG                 | 256                   | 2.000   | 22.000  | 7.543   | 6.019              | 1.253                   |
| LOF                 | 256                   | 4.660   | 18.160  | 8.757   | 1.863              | 4.700                   |
| LOP                 | 256                   | 4.000   | 20.000  | 9.640   | 2.878              | 3.350                   |
| LAF                 | 256                   | 1.500   | 20.000  | 5.454   | 1.903              | 2.866                   |
| TEG                 | 256                   | 5.000   | 9.000   | 6.867   | 0.953              | 7.206                   |
| TSC                 | 256                   | 0.000   | 23.000  | 10.891  | 7.178              | 1.517                   |
| TAV                 | 256                   | 0.000   | 35.000  | 25.855  | 3.940              | 6.562                   |
| P100G               | 256                   | 21.000  | 358.800 | 53.519  | 44.466             | 1.204                   |

Legend: TAF = Time of appearance of the floral buttons, TAG = Time of appearance of the pods, LOG = Length of the pods, LAG = width of the pods, NGG = Number of seeds per pod, LOF = Length of the leaflets, LAF = Width of the leaflets, LOP = Length of the petioles, TEG = Time of germination, TSC = stay time of the cotyledons, TAV = Time of appearance of the gimlets and P100G = Weight of 100 seeds.

### 3.3. Relationship between characters

The two axes of the principal components analysis (PCA) explain respectively 57.49% and 18.26%, respectively of variability that makes 75.74% of total variability (Table 4). These first two components are enough to analyze the morphological variability of the cultivars. Axis 1 was associated with the characters length of the leaflets (LOF), width of leaflets (LAF), width of petioles (LOP), width of the pods (LAG) and the 100 seeds weight (P100G) which are opposed to the character time of appearance of gimlets (TAV). Axis 2 was associated with the characters time of germination (TEG), time of flowering (TAF), the length of the pods (LOG) and the time of appearance of the pods (TAG). The stay time of the cotyledons over seedling (TSC), the length (LOG) and width (LAF) of the leaflets were correlated positively with axis 1 whereas the time of germination (TEG), the time of flowering (TFL), the time of appearance of the pods (TAG) and the time of appearance of gimlets (TAV) were negatively correlated with this axis. On axis 2, only the characters time of appearance of the gimlets (TAV) and stay of cotyledons (TSC) were negatively correlated. (Table 4).
Figure 2 Projection of the characters in the axis system defined by the two first Principal Components

Table 4 Clean vectors and correlations between the variables and the factors (Axis)

| Clean value | Axis 1 | Axis 2 | Axis 3 |
|-------------|--------|--------|--------|
| % of the total variability | 6.898 | 2.191 | 0.945 |
| Plurality of the total variability | 57.486 | 18.259 | 7.875 |

| Code characters | Axis 1 | Axis 2 | Axis 3 |
|-----------------|--------|--------|--------|
| TAF | -0.810 | 0.393 | 0.266 |
| TAG | -0.801 | 0.358 | 0.297 |
| LOG | -0.633 | 0.686 | -0.241 |
| LAG | 0.797 | 0.522 | 0.144 |
| NGG | -0.780 | 0.465 | -0.352 |
| LOF | 0.688 | 0.588 | -0.260 |
| LOP | 0.815 | 0.241 | -0.232 |
| LAF | 0.911 | 0.268 | -0.070 |
| TEG | -0.518 | 0.313 | -0.242 |
| TSC | 0.953 | -0.026 | 0.104 |
| TAV | -0.802 | -0.100 | 0.158 |
| P100G | 0.406 | 0.604 | 0.603 |

3.4. Classification of the cultivars into groups

The hierarchical ascendant classification (CAH) applied to the different cultivars according to the method of Ward aggregation based on the Euclidean distance gave a structuring of the cultivars studied into three groups (Figure 2). The table 5 gives the distribution of the cultivars in the various groups.
Table 5 Groups of cultivars

| Groups | Number of accessions | Compositions |
|--------|----------------------|--------------|
| I      | 63                   | LSCbn5, ATDn4, MSCn3, GOLn1, KpDCn1, MSCn6, MSCn2, SSCn4, ZOGn3, LSCn2, AAZtn1, LSCn5, LSCn3, HDDCn3, SDn5, HZZn3, PBN1, LSCbn2, KDCn5, SBZn3, LBZn2, LScn1, SGCn2, DDCn3, HZZn3, HDDCn6, LBZn1, K1DCn3, AAZn3, KDCn2, SBZn2, K1DCn7, KDCn1, SBZn1, MSCn5, GOLn8, LAZn1, KDCn6, FOGn1, MSCn7, MSCn8, DBZn3, KpDCn6, GOLn2, LScn5, SDCn1, AAZn1, SDCn2, K1DCn4, DBZn1, SSCn3, AAZn2, DDCn2, HZZn2, GOLn6, ZZZn1, AOGn1, SGCn1, MSCn1, AOGn2, ATDn1, GACn2, DBZn2 |
| II     | 3                    | OBZn, GOLn3, MaGn1 |
| III    | 22                   | SSCn2, HDDCn4, HDDCn1, GOLn4, K1DCn1, GOLn, ATDn2, GACn3, K1DCn2, KpDCn2, SSCn1, DDCn1, GACn1, ATDn3, KpDCn4, K1DCn5, ADTn5, KpDCn3, SDCn3, KDCn4, HDDCn5, FOGn2 |

Figure 3 Hierarchical Ascendant Classification

3.5. Characterization of the different groups

The Discriminant Factorial Analysis (AFD) made it possible to characterize the three (03) groups resulting from the Hierarchical Ascendant Classification (CAH). Projection in plane 1/2 (75.74% of total inertia) of different cultivars studied and the quantitative characters made it possible to characterize the three groups resulting from the CAH (figure 4).

Group I is characterized by cultivars having the length (LOF) and width (LAF) of the leaflets, the length of petioles (LOP), the weight of 100 seeds (P100G) and the stay time of the cotyledons (TSC) relatively average. Among these above-mentioned characters, the three characters on which the regrouping of the individuals of group I was based more relate to the length of petioles (LOP), the width of the leaflets (LAF) and the stay time of the cotyledons (TSC). Group II is represented by cultivars characterized by the length of the pods (LOG), the number of seeds by pods (NGG), times of germination (TEG), appearance of gimlets (TAV), the floral buttons (TAF) and appearance of pods (TAG) relatively high and very close to the maximum values. The characters which contributed more to the discrimination of the individuals of this group are the residence time of cotyledons (TSC), dimensions of the leaflets to known LOF and LAF, of the petiole (LOP) but also the weight of 100 seeds (P100G). Group III consists of cultivars whose times of germination (TEG), flowering (TAF), and appearance of the pods (TAG) are relatively low, but whose weights of 100 seeds (P100G), dimensions of leaflets (LOF and LAF), petiole (LOP) and the pods in particular the width of pods (LAG) gave highest values in the studied collection.
4. Discussion

The description of morphological variability within a species or inside a genus constitutes a first stage in varietal selection, essential in the knowledge of the genetic resources [34]. Thus, any serious program of genetic improvement exploits necessarily data of morphological variability [35, 36]. These data allow in the majority of the cases, to direct the improvers in the choice of the objectives of their research [37, 38]. It is in this context that an agro-morphological characterization study of 88 accessions of beans of the *Phaseolus* genus exploited by the local communities of Benin proved to be necessary for the clarifications of species and made it possible to appreciate the current status of the diversity of beans of the *Phaseolus* genus on the one hand and to identify the various species of the genus cultivated in Benin on the other hand. The descriptive analysis showed significant differences between the minimal values and the maximum values for the whole of the analyzed morphological characters. This suggested a significant inter-cultivars variability. This strong morphological diversity would result from the farmers’ practices of management of the seeds [29]. Indeed, several authors showed that the farmers’ practices of management of the seeds, in particular the exchanges of varieties between farmers and associations of cultures in the fields (possible gene flows cause) are at the origin of a significant diversity between the populations of crop plants [4, 29, 39, 40].

The study of the qualitative characters such as the type of germination, the shape of the first leaves, the color and the shape of the leaflets, the color of the flowers, the integument and the hilum and seeds shapes confirms this broad variability within the studied collection. Bouchikhi Tani, 2006 [41] had arrived at the same conclusion as for the extreme variability which characterizes beans of the *Phaseolus* genus. According to the author, beyond the cultivation methods, this significant genetic variability inside this genus would be also justified by the mode of reproduction of the plant which is self-pollination, which make to step in the meiosis process.

In addition, some cultivars presented a hypogean germination. This observation confirms the results of Schmit, 1992; of Baudoin et al., 2002 and from Nyabyenda, 2005 [42, 43, 44] which raised that among the five (05) most cultivated species beans, the species *P. coccineus* presents such a germination. Thus the cultivars of group III which presented hypogean germination in this study would belong to this species.

The strong negative correlations observed between times of appearance of the gimlets, the flowers and the pods on the one hand and the negative correlations between the length of the pods and the number of seeds by pods on the other hand showed dynamic relations between these characters. Similarly, strong positive correlations was observed between the dispatcher of the leaflets and the stay time of the cotyledons on the one hand and positive correlations was also observed between the lengths of the petioles, the leaflets and the pods on the other hand. These strong correlations noted between certain studied characters could be explained by the fact that these characters are genetically dependent on one another i.e. they are probably under the influence of same genes or pleiotropic effect [32, 45]. Consequently,
during studies aiming at the genetic improvement of beans, the choice of the one of the characters for pleiotropic purpose would indirectly imply the simultaneous study of all the characters which depend on the same gene(s).

For the majority of the studied cultivars, an interval from 15 to 24 days separates time from appearance of the pods to the time of flowering. Then, the interval between flowering and fructification of beans of the *Phaseolus* genus remains generally constant whatever the species or the variety. Thus, the differences in cycles observed at the various species and/or varieties generally relate to the vegetative cycle and the period of filling of the pods to maturation. The cultivars which presented some low values of the standard deviations between certain characters permitted to observe a regrouping of these individuals around the average values. However this situation doesn’t mask the existence of a variability between the cultivars in particular for the characters weight of 100 seeds (P100G), time of flowering (TAF) and time of appearance of the pods (TAG). This variability is expressed by relatively large coefficients of variation (4.743 for TAF and 5.025 for TAG). In this study, average values relatively larger were noted for the characters time of flowering and appearance of the pods. These results are not in agreement with those of Okii *et al.*, 2014 [32] and could be explained by the fact that during the test, a hydrous stress has affected the cultivars, which could slow down their vegetative growth and consequently increase the duration of their cycle of development. In the *Phaseolus* genus, it was reported that the cycle of development of species is conditioned by several factors among which the distribution of the rain in time, physicochemical parameters of the ground (salinity, texture, etc.) and many other climatic factors [46, 47, 48, 49]. Indeed, according to whether the distribution of the rain be discontinuous, the deceleration of the cycle of development of certain late varieties can undergo variations up to approximately 300 days, which confirms the observations of our study. The Hierarchical Ascendant Classification (CAH) grouped the cultivars in three major groups (GI, GII and GIII). The genotypes were discriminated more by the number of seeds per pod, times of survey of the gimlets, flowering, the formation of the pods, but also by dimensions of the leaves in particular the length and the width. Similar conclusion was made in the previous reports on the botanical classification of the species of *Phaseolus* genus [42, 43]. These authors described the species *Phaseolus vulgaris* as being a dwarf plant or with raised stems, climbing with average, white flowers or more or less dark lilac whose thimbles are lengthened with parchment or without parchment. The seeds of these plants of extremely variable size, are very flattened, without radiant scratches of which the number can vary from 2 to 12 or more according to the variety. Over the 88 studied cultivars, the individuals of group I confirm the observations of these authors. As for the species *Phaseolus lunatus*, Denaiffe, 1902 in its work decorated with 272 figures and others researchers for this plant [50, 51] describe the species as being some high plants, seldom dwarf, with small or big flowers white whose thimbles are short but broad or very broad. Generally flattened seeds or kidney shape, their number per pod varied from 2 to 4, in the shape of half-circle or crescent, with radiant scratches of the hilum towards the circumference. Group II defined by the CAH presents similar characteristics to those of Denaiffe and would be consequently of this species. This survey which presented an outline of the genetic resources of beans of the *Phaseolus* genus on the one hand and the genetic variability observed within the collected accessions on the other hand, constitutes a significant asset for work of selection and classification of the species of the *Phaseolus* genus. That would allow a better exploitation of their genetic resources in culture in the future programmes of selection of *Phaseolus* spp in Benin, because the preliminary condition for any program of varietal selection remains incontestably the knowledge of the existing germplasm.

5. Conclusion

The results of this study which aimed to evaluate genetic diversity and the identification of the species of beans of the *Phaseolus* genus revealed the existence of a significant diversity inside the studied collection. A wide phenotypical variability was observed among the accessions and they were classified into three groups directly representing species of the genus in study. The tests of correlation indicated a significant correlation between certain morphological characters. The taking into account of the one of these characters in the programs of varietal selection would imply a simultaneous study of the characters genes which carry them. It’s the event for example of the characters Length of the pods (LOG) and Number of seeds per pod (NGG). A molecular characterization is necessary within each species to evaluate the genetic diversity of beans and also to clarify synonymies for finally making a rational use of their resources available.

**Compliance with ethical standards**

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest. This article is one of the results of the first author’s research of doctorate thesis.

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