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Agro-Morphological Evaluation of Sixteen Spinach Accessions (*Spinacia oleracea* L) Grown in Burkina Faso

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A B S T R A C T

In order to lay the scientific foundations for the valorisation of the *Spinacia oleracea* L species, a prospecting collection of accessions was carried out in the previous studies. The survey enabled to build up a collection of sixteen (16) accessions and to record farmers' practices for managing the species. The general objective of this study is to contribute to a better understanding of the features of spinach produced in Burkina Faso. Specifically, it has been about assessing the morphological variability of the accessions collected. The agro-morphological evaluation of these accessions, carried out with five (05) qualitative and eight(08) quantitative variables, revealed a high degree of variability. It also revealed a structuring of the accessions into four (04) groups and the fourth group has a high-performance accessions with yields (1640 g) which is interesting for a programme of valorisation and improvement of the spinach in Burkina Faso.

Introduction

The spinach (*Spinacia oleracea* L) is an annual and biennial leaf vegetable from the family of the Chenopodiaceae (Meng *et al.,* 2016). It is grown and consumed all over the world because of its richness in diverse nutritive elements and composition beneficial for the health (Shi *et al.,* 2016). In Burkina Faso, the leaf vegetables are an essential part of the food diet of many households and contribute to have food security (Millogo-Rasolodimby, 2001). They also provide incomes and are topics of many studies. The studies on the leaf vegetables have mostly been carried out on the genetic diversity and agronomic performances of the amaranth (Amaranthus L.) (Ouédraogo *et al.,* 2021); on the agro morphological characterization of the cleome (*Cleome gynandra* L.) (Kiébré *et al.,* 2016) and on the ogro morphological evaluation of the jute mallow (*Corchorus olitorius* L.) (Kiebre *et al.,* 2018). As to the spinach, any study on its agro morphological has not yet

been studied in Burkina Faso. The spinach is a plant preciously rich in proteins; fibers, vitamins A, B1, B2, C, E and minerals such as iron, potassium, phosphorus, magnesium, sodium, iodine, zinc and folic acid (Gupta and Wagle, 1988). Spinach leaves contain up to 60 – 80 mg of vitamin C, carotin (Holland *et al.,* 2010). Thus, the spinach is one of the best providers of calcium among the leaf vegetables (Gupta and Wagle, 1988; Chitwood *et al.,* 2016). Beside their nutritive importance, leaf vegetables constitute economic and social advantages not to be neglected because they are relatively cheaper and they can be easily and rapidly cooked (Gupta and Wagle, 1988).

Considering the nutritive and socio-economic importance of the spinach, it is urgent that a programme of managing the genetic resources of the plant be undertaken so as to know the characteristics of the spinach grown in Burkina Faso. It is in this context that this study entitled ''Agro-morphological Evaluation of sixteen spinach accessions grown in Burkina Faso'' is carried out. The general objective of this study is to contribute to a better understanding on the diversity of the spinach grown in Burkina Faso and the specific objective is to assess the morphological and agronomic variability of the collected accessions.

Materials and Methods

Study Area

The experimental study has been carried out by the Environmental, Agricultural Training and Research Center of Kamboinsé (CREAF-K). The center is located in the province of Kadiogo at 12 Km of the Northern part of the town of Ouagadougou on the road of Ouaga-Kongoussi. The geographic coordinates are the following: 12.49°of North Latitude, 1,43° of West Longitude and about 296 meters of Altitude.

Plant Material

The plant material consists of the seeds of sixteen (16) accessions of spinach composed of grain seeds, cutting seeds with red stems, green stem and seeds of young plants (spinach from Bobo). The accessions have been collected at Kamboinsé (spinach from Bobo), in a vegetable garden located in the quarter of Tanghin in the compound of the hospital Schiphra, in the gardens near the industrial area of Ouagadougou in the quarter of Kossodo and in the gardens out of Ouagadougou in Saaba, Loumbila, Kaya and Manga.

Experimental device

The experimental device used, was a completely randomized Fischer block with four (04) repetitions. The repetitions were 1 meter distant. Two consecutive lines of each accessions were 0.5 meters distant. Each accession was represented by a line of 10 plants distant from one another by 20 cm.

Conducting the test

The test took place in the rainy season from the 14th of July to the 30th of September at the INERA / Kamboinsin. The sowing took place on the 14th of July. Before the sowing, organic fertilizer has been put in the furrow with the dosage of 5T/Ha. The seed holes were separated from 0.2 meters and the Five (05) seeds were sown or a cutting or a young plant was transplanted per seed holes. On each line, we counted ten(10) seed holes. Upon the plants' rising, a separation, of two plants per hole 14 days after, cuttings, and transplantation were carried out. Weed cutting was carried out 18 days after sowing and 21 days after, sowing was carried out using mineral fertilizers NPK14-23-14 with a dosage of 35 g per line. The plans have been watered when they needed it and a month after sowing, the qualitative and quantitative parameters except the weight of the fresh leaves (45JAS) have been determined on the produced plants.

Data Collection

Qualitative Parameters

Qualitative data collection displayed all over the development of the plant. The data are: the colour of stem (CT), the colour of petiole (CP), Leaf blade colour (CLm), leaf shape (FF) and the type of inflorescence (INF).

Quantitative Parameters

Eight (08) quantitative features have been considered. There are: length of the leaf blade (LLm), the width of the leaf blade (LgLm), the length of the petiole (LP), the height of the main stem (http), the diameter of the main stem (DTP), the length of the knot (LEN), the number of

leaves per main stem (NFTP) and the weight of the fresh leaves (PFF).

The first seven parameters have been measured one month after sowing whereas the fresh weight has been measured 45 days after sowing.

Data Analysis

The collected data have been seized, treated and analysed with Excel table that also served for the graphs representations. The variance analysis and the comparison of the average have been done at the boundary of 5 per cent following Tukey ‘s test with the software Minitab 18 to emphasize the parameters that distinguish the studied accessions. The analysis of the main composition of the parameters and the accessions, the ascending hierarchical classification have been performed with the software R version 4.1.0

Results and Discussion

Qualitative Parameters of plants within the collection of accessions

Colours of the stem, petiole and the leaf blade

Basing on the colour of the stem, petiole and the leaf blade, two morphtypes were obtained: the green spinach and the red spinach. The majority of accessions 92.30 per cent produced plants with stem, petiole or green leaf blade. Only 7.70 per cent of plants showed red stems, petiole and leaf blades. (p□0,001) (Tableau I).

Shape of Leaves

Four morphotypes were obtained for this feature: morphotypes with round leaves, morphotypes with ovale leaves, morphotypes with sharp leaves and morphotypes with spatula leaves shape.

Types of Inflorescences

Basing on the types of influorescence, two types have been observed. They are an influorescence of ear at the end of the green spinach stem (Figure 2A) and red spinach stem (Figure2B) and an influorescence dispersed with flowers growing individually at the corners of the leaves and at the end of the Bobo spinach stem. (Figure 2C).

Quantitative Parameters of Plants

The descriptive analysis of the studied material enabled to determine for each measured quantitative parameter, minimal and maximal values, means and the standard deviation (Tableau 5). For the features: leaf blade length (LLm), width of leaf blade (LgLm) and petiole length (LP), they respectively represent each other a means of 8.53±1.68 cm, 6.45±1.34 cm and 1.97±0.69 cm. The length of the petiole (LP) presents the most important variability (CV = 34.91%). The feature of the heigth of the main stem (HTTP) varies from 2.2cm to 20cm with a means of 12.32±3.81cm and a variability of 30.92%. The length between the knots (LEN) presents a means of de 2.13±0.84 cm and a means of 10.63±3.06 cm for the number of leaves per main stem. (Table II).

Multivaried Analyses of quantitative parameters

Principle Components Analyses (ACP)

The results of the ACP revealed that the first two axes (Dim1 et Dim2) explain 90.19% of complete variability (Figure 3). The parameters length of the meaf blade, width of leaf blade, number of leaf per main stem, petiole length contribute the most to the formation of the axis 1(Dim1) that explains 65.11% of complete variability (Figure 3). The parameters fresh weigth of leaves, heigth of main stem and the diameter of the main stem contribute to teh formation of the axis 2 (Dim2) that explain 65.11% of complete variability. Moreover, these parameters distinguish well the accessions permit te see clearly the different groups.

Hierarchical Ascending Classification

The analysis of the dendogram (Figure 4) reveals four groups or classes. A group (C1) constituted of 2 accessions, another group(C2) includes 3 accessions, a group (C3) including 6 accesssions and the group (C4) composed of 4 accessions.

The ascending hierarchical classification graph reveals that the class 1 is composed of individuals such as Acc 10 and Acc7, all characterized by weak values for the variables of length of leaf blade (LLm), width of leaf blade (LgLm), number of leaves (NFTP), petiole length (LP) and length between knots(LEN). Class 2 is composed of accessions Acc 15, Acc 8 et Acc 9 characterized by weak values for variables DTP, HTTP

and PF (from the most extreme to the least extreme). Class 3 is composed of individuals like Acc 4: This group is characterized by variables which values do not differ significantly from the means. Class 4 is composed of individuals as Acc16 and Acc 5 characterized by high values for the variable PF.

The analysis of the qualitative parameters showed a variability of accessions. In fact, the majority of the accessions (92.30%) presented green petioles and stems opposed to 7.70% of red petioles and stems. So, The green colour of the collected accessions is predominant.

This can be explained by the fact that, for the large number of leaf vegetables, consumers like the more green leaves. Stems et petioles colours give a general aspect of the plant (Ramazani, 2009; Mazollier, 2011) distinguished by two colours of spinach on the basis of the stem colour.

The difference of colour among accessions could witness a genetic variability which can exist among the collection and perceptible since the early stage of young plants. These observations related to the colour have been a criterion of diversity among the collection of *Cleome gynandra from Burkina Faso* obtained by Kiebre 6 in 2016. The latter showed that 38.32 % of these accessions were green whereas 4.37 % of the accessions are dark purple. The green colour of gardening plants could interest the producers, which would make them choose the green plants.

Four morphotypes have been noticed concerning the shape of leaves: the round shape, the oval shape, the sharp shape and the spatula shape. These results are similar to those described in the catalog of young growth and spinach (2021), and this difference of shape among accessions could witness a genetic variability within the collection or could be explained by the nature of the cultivation place.

These observations related to the shape of the leaves have been a criterion of diversity within the collection *Corchorus olitorius* L. (Kiébré, 2018). As to the types of fluorescence, the plants which flowers grow individually at the corners of the leaves could be female flowers and those which flowers present in form of corn ear could be considered as male flowers (Prakash *et al.,* 2017; Zbigniew *et al.,* 2019). Besides, the analysis reveals that only the accessions 7 and 10 have produced plants with a single morphotype of leaves and inflorescence proving that these accessions are homogeneous. The variability of the leaves shape of the other accessions showed that they are heterogeneous.

The hierarchical ascending classification (HAC) obtained with all the accessions studied enabled us to group them into four groups: a group of accessions with low values for the variables leaf blade length (LLm), leaf blade width (LgLm), number of leaves (NFTP), length between nodes (LEN) and frizzled leaf weight (PFF) (group 1); a group with low values for the variables stem diameter (DTP), height of main stem (HTTP) and fresh leaf weight (PFF) (group 2), a group with values not significantly different from the mean (group 3); a group characterized by high values for the variable fresh leaf weight (PFF) (group 4). These results show that group 4 is the group of high-performing accessions, since it is the group that produces a high yield in fresh leaf weight, which is the goal pursued by the growers. The accessions in group 4 are therefore potential sources of fresh leaf weight.

The shape variability of the other accessions show that these leaves are heterogeneous. The variance of the analysis reveals significant differences between accessions for the variables length of the leaf, the width of the leaf blade, the height of the main stem, the diameter of the main stem, the distance between the knots, the fresh weight of the leaves.

There is similarly a significant difference between the accessions in terms of the variables such as length of the petiole, and number of leaves per leaves per main stem. These results show that these parameters are determinant in the genetic variability of the spinach. The Hierarchical ascending classification resulted from the set of the studied accessions enabled to classify them into four groups: a group of accessions weak values for the variables length of the leaf blade (LLm), number of leaves, length between (LgLm), and the fresh weight of leaves(PFF) (group1) ; a group of accessions with weak values for the variables stem diameter (DTP), height of the main stem (HTTP) and the fresh weight of the leaves (PFF) (group2); a group where the values do not differ significantly the average (group3); a group characterized by high values for the variables of fresh weight of leaves (PFF) (group4). These results show that the group 4 has high performance accessions because it is the one which produces the higher yield regarding the fresh weight of leaves, followed by the producers. Group 4 accessions, therefore, constitute potential sources for improvement programmes of plants.

Table.1 Rate of colour repartition of stems, petioles and leaf blade from the collection of accessions

Parameters	Stem colour		Petiole colour		Leaf blade colour	
	Green	Red	Green	Red	Green	Green-Red
Rate (%)	92,30*a*	7,70*b*	92,30 *a*	7,70 *b*	92,30*a*	7,70 *b*
Probability P	**0,001**		**0,001**		**0,001**	

Table.2 Quantitative parameters of accessions within the collection

Variable	Means	ET	CV	Minimum	Maximum
LLm (cm)	8.53	1.68	19.79	4.84	11.75
LgLm (cm)	6.45	1.34	20.77	2.93	8.13
LP (cm)	1.97	0.69	34.91	0.61	4.27
HTTP (cm)	12.32	3..81	30.92	2.2	20
DTP (cm)	0.92	0.22	24.45	0.37	1.52
LEN (cm)	2.13	0.84	39.33	0.2	4.2
NFTP	10.63	3.06	28.77	4	16.75
PFF (g)	637.1	409.2	64.24	49	1640

Legend: ET: *standard deviation* ***; CV:*** *variance coefficient* ***; LLm****: length of leaf blade ;* ***LgLm****: width of leaf blade ;* ***LP****: length of petiole ;* ***HTTP****:* Height *of the main stem ;* ***DTP:*** *diameter of the main stem ;* ***LEN****:* Length *between knots ;* ***NFTP****: number of leaf per main stem ;* ***PFF:*** *fresh weight of leaves .*

Figure.1 Différent morphotypes of spinach leaves

A: Round leaf **B:** ovale leaf **C:**sharp leag **D:** spatula leaf

Figure.2 Types of inflorescence the collected spinach

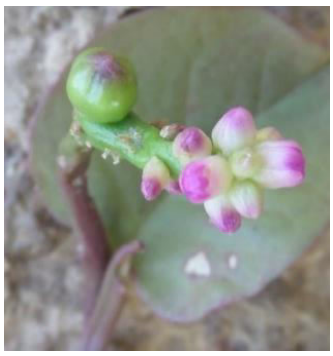
A: Inflorescence of green spinach	B:Inflorescence of red spinach	**C:** Inflorescence of Bobo spinach
		

Figure.3 Analysis of variables main des components

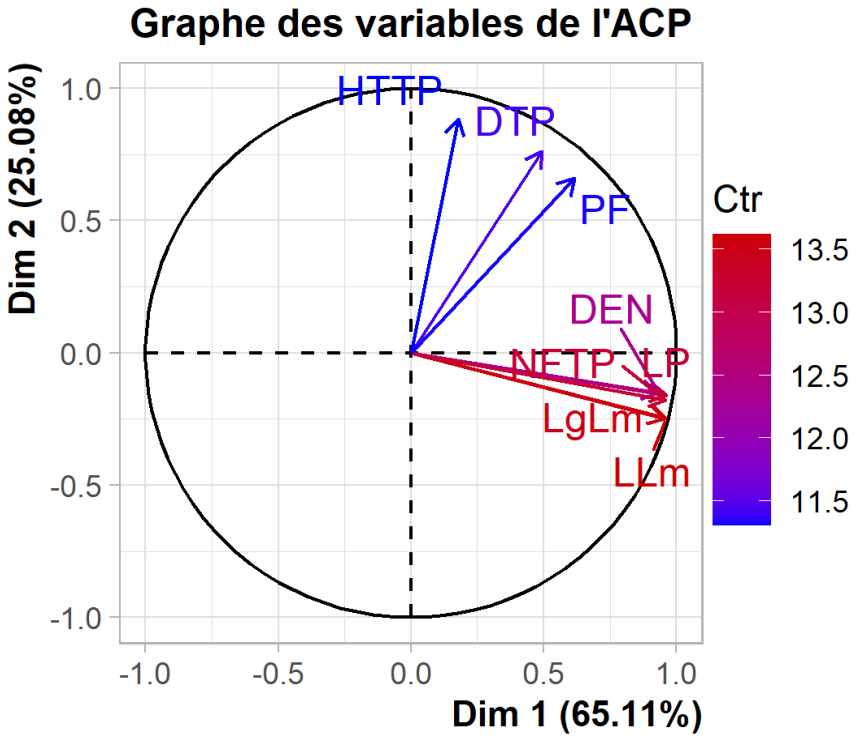
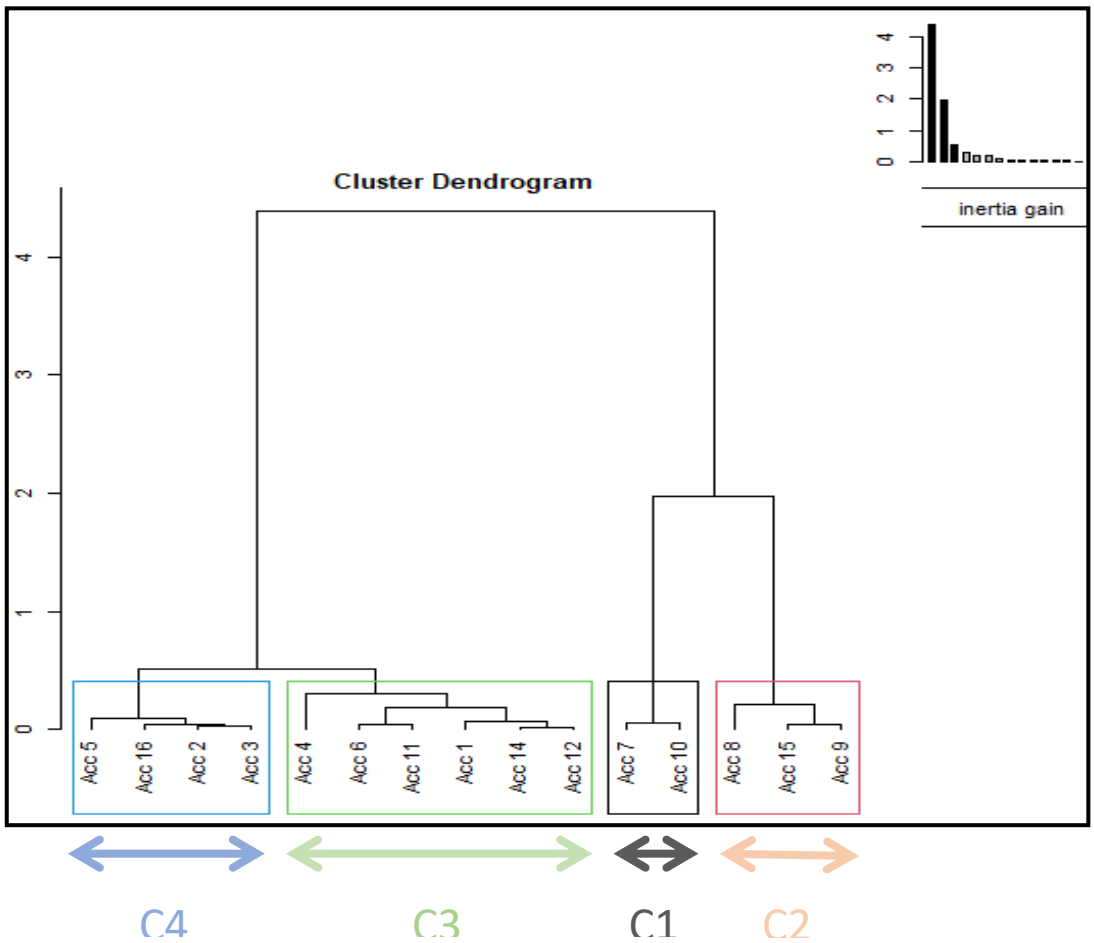


Figure.4 Ascending hierarchical classification of spinach accessions



At the end of this study, it results that used the accessions *Spinacia oleracea* presented an important genetic variability. On the basis of the colour of stems and seedings, two groups (green and red) were revealed. However, during the development of plants, we obtained four groups. Quantitatively, we observed the variabilities relying on the studied parameters and the hierarchical ascending classification also resulted in four groups. The accessions of group 3 constitute a significant genetic basis for building up an improvement and valorisation programme of plants in Burkina Faso because it represents leaves with high dimensions (LP, LLm et LgLm), and an important production of leaves.

Author Contributions

Tiama Djakaridia: Investigation, formal analysis, writing—original draft. Ouedraogo R. Fanta: Validation, methodology, writing—reviewing. Ouedraogo Nogowaya Rosine:—Formal analysis, writing—review and editing. Ouedraogo W. Caleb: Investigation, writing—reviewing. Some Koussao: Resources, investigation writing—reviewing. Sawadogo Nerbéwendé: Validation, formal analysis, writing—reviewing. Zongo Jean-Didier: Conceptualization, methodology, data curation, supervision, writing—reviewing the final version of the manuscript.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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