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Analysis of The Agromorphological Variability of Ten (10) Okra Cultivars (*Abelmoschus esculentus* L. Moench) in Niger

ADAMOU IBRAHIM Maman Laouali[1*], MOUMOUNI SEYNI Charifatou[1], ALIO MOUSSA Abdourazak[1], RAFIOU OUSMANE Abdoulaye[1], MAHAMANE Adamou[1], IDI SAIDOU Sani[2] and BAKASSO Yacoubou[1]

[1]*Department of Biology, Faculty of Science and Technology, Abdou Moumouni University, Niamey, Niger*
[2]*Faculty of Science and Technology, University of Diffa, Niger*

**Corresponding author*

A B S T R A C T

Okra (*Abelmoschus esculentus*) is a fruit vegetable belonging to the Malvaceae family. In Niger, the genetic diversity of okra can be a major advantage in meeting the varied preferences of consumers and the demands of national and international markets. The objective of this study is to contribute to a better understanding of the phenotypic characteristics of ten okra cultivars in Niger. The experiment was conducted at the botanical garden of the Faculty of Science and Technology at Abdou Moumouni University in Niamey using a randomized complete blocks design with three replications. Observations focused on eight quantitative traits and two qualitative traits. The results of the analyses showed significant variability among cultivars for all traits studied, except for fresh and dry weight and the effect of cultivar on the number of pods. Ascending classification allowed the cultivars to be divided into three groups. The first group (Group I), consisting of the okra long, okra short, and Tillabéry cultivars, is characterized by an early growth cycle with short stem height and diameter and average petiole length. These cultivars have high yields (high number of pods, high fresh and dry weights); the second group (Group II) is characterized by a late growth cycle with tall stems, large diameter, and average petiole length. The Gueskerou, Lada, Diffa, Sakoira, and Balleyara cultivars belong to this group and are characterized by low yield. The third group, Group III, includes the Harey Garey and Gazelle cultivars, is characterized by an early growth cycle with short stem height and small diameter. These cultivars have an average yield. This same classification made it possible to categorize the cultivars into three groups based on qualitative traits: Group I consists solely of the Tillabéry cultivar; Group II includes the Harey Garey, okra long, okra short, and Gazelle cultivars; and Group III comprises the Gueskerou, Lada, Diffa, Sakoira, and Balleyara cultivars. Five cultivars were identified for a breeding program: Harey Garey, Okra long, Okra short, Gazelle, and Tillabéry. This study provides essential information for ongoing efforts to improve productivity and study the genetic diversity of okra in Niger.

Keywords

Variability, Phenotype, Cultivar, Okra, Niger.

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Introduction

Okra (*Abelmoschus esculentus* L. Moench), which was previously classified under the genus Hibiscus, is now classified in the genus *Abelmoschus* of the Malvaceae family (Hamon and Charrier, 1997). Several species are recognized, of which only two (02) are cultivated in West Africa for their fruits (Hamon and Charrier, 1997). Okra is cultivated in tropical, subtropical, and temperate regions due to its high market value, rich nutrient content, and importance in the diet (Hamon, 1988). Okra is an exceptional and unique plant because all its parts are utilized for food, medicine, handicrafts, and even industrial purposes (Abdou *et al.,* 2022). Okra is rich in protein, carbohydrates, vitamins A and C, iron, phosphorus, potassium, and magnesium (Nzikou *et al.,* 2006). Thus, a daily intake of 100g of fresh okra would provide approximately 20% of the recommended daily intake of calcium, 15% of iron, and 50% of vitamin C (Dantas *et al.,* 2021). According to FAOSTAT (2024), global okra production as a fruit vegetable in 2020 was 10,445,458 tons, with 3,344,344 tons coming from Africa, including 132,138.74 tons from Niger, which is the 7th largest producer in Africa. In West Africa, okra ranks second in terms of vegetable production after tomatoes (Hamon and Charrier, 1997). Despite this, the country's primary agricultural concern has long been food security (Abdou *et al.,* 2022). How can the production of food crops, in particular cash crops, be increased? This situation is partly caused by climate change, such as recurrent droughts, rainfall deficits, and irregular rainfall patterns, as well as rapidly growing population pressure leading to environmental degradation (Boubacar, 2006). In Niger, okra is one of the most important vegetable crops (Abdou *et al.,* 2022). Okra is produced in all regions of the country, with the highest production in Zinder, Tahoua, Dosso, Tillabéry, and Niamey regions (Abdou *et al.,* 2022). In Niger, it ranks among the top vegetable crops alongside tomatoes and onions (Ryckewaert, 2009). Farmers rely on this crop as a key tool in the fight against poverty in rural, urban, and peri-urban areas (Fondio *et al.,* 2011). However, despite its socioeconomic importance, okra cultivation faces challenges such as climate change, diseases, pests, and the degradation of natural resources particularly soil as well as limitations in variety selection that prevent high-performing varieties from being made available to farmers (Pizongo, 2014). In this context, assessing the phenotypic variability of okra cultivars in Niger is therefore necessary, as it provides a better understanding of the agromorphological traits of cultivars of this species. The main objective of this study is to contribute to a better understanding of the agromorphological characteristics of okra cultivars in Niger.

Materials and Methods

Experimental site

The study was conducted at the botanical garden of the Faculty of Science and Technology (FAST) at Abdou Moumouni University in Niamey, Niger. It covers an area of 5.19 ha. The experimental site is located between 13°30'09.4'' north latitude and 02°05'56.3'' east longitude (Figure 1). It is characterized by a southern Sahelian climate (Saadou, 1990). The soil at the site is sandy loam (Garba *et al.,* 2020).

Plant Material

The plant material (Table 1) consists of ten (10) okra cultivars from various locations in Niger.

Methods

Experimental design

The experiment was conducted during the 2024 rainy season within the botanical garden of the Faculty of Science and Technology at Abdou Moumouni University in Niamey, Niger. The trial was conducted using a randomized complete blocks design with three replicates. Then, the third block split into two parts of five rows each, distributed across the first two blocks. Cultivar was the only factor studied, with 10 treatments corresponding to the different cultivars. The total area of the trial was 93m² (6m × 15.5m). Each block consists of ten (10) rows of five (5) plots each, for a total of fifty (50) plots per block. Of the five plots in each row, the three central plots are the focus of our study, for a total of 90 plots across all blocks. In each block, a cultivar is represented by a 2m row on which five (05) plots are arranged at 0.5m intervals. The area of an entire block is 18m^2, and the distance between rows is 1m (Figure 2).

Cultural process

Field preparation focused primarily on plowing with a plow to remove weeds; afterward, stakes were set to mark the boundaries of the blocks and the perimeter of the experimental field. The seeding rows were marked with a row marker, and seed holes were placed at the intersections of the rows. Before planting, base fertilizer was applied to each plot. Seeding took place on July 20, 2024, with five seeds per hole. In each plot, a cultivar is represented by a 2m row on which five (05) holes are spaced every 0.5m. Manure was applied 21 days after sowing to each block, and mineral fertilizer was applied using the "three-finger" technique at the 40th days after sowing standard to all planting holes to compensate for the low soil fertility.

An initial thinning to three plants per planting hole was carried out 3 weeks after sowing. The second thinning, to one plant per hole, took place two weeks after the first thinning. Maintenance operations began on August 04, 2024, with an initial weeding and hoeing session, followed by two more on August 25 and September 10, 2024, to control weeds and aerate the soil. A treatment with 20% EC chlorpyrifos (250 ml of insecticide per 10 liters of water) was applied on September 14 and 28 in the experimental field to control borers and sucking pests on the okra. The first harvest began on September 14, 2024, followed by two more on September 21 and October 10, 2024.

Collected data

Three central pockets in each row of the block were the subject of various measurements. The parameters studied were both qualitative and quantitative. Qualitative characteristics were assessed through visual observation, and quantitative characteristics were obtained through measurements. Table 2 presents the quantitative and qualitative observed parameters.

Data Analysis

Microsoft Excel was used to construct graphics describing qualitative parameters. After analyzing the dispersion of productivity-related variables, the fish-family model was selected to evaluate the productivity dynamics of the ten (10) okra cultivars, specifically the zero-inflation poisson model. Principal component analysis was used to describe the relationships among the quantitative variables. Discriminant factorial analysis was used to characterize cultivars based on quantitative traits. Ascending hierarchical clustering was used to classify cultivars or individuals into homogenous groups. All statistical analyses were performed using R software, version 4.2.1 (R Core Team, 2025).

Results and Discussion

Analysis of Relationships among the Traits

Figure 3 shows the projection of the variables into plane defined by 2 first axes, based on their representativeness within the plane. Thus, the projection of these various traits onto the plane defined by the first two PCA axes which account for 62.85% of the total variability shows that the number of pods, fresh weight, and dry weight are positively correlated with Axis 1 (38.63%), while the number of days to germination and the number of days to flowering are negatively correlated with the same axis. These variables are well represented and contribute significantly to the formation of this axis. Furthermore, petiole length, main stem height, and stem diameter are positively correlated on axis 2 (24.22%). Stem diameter, stem height, and petiole length are positively correlated with one another; the number of days to germination and the number of days to flowering are also positively correlated with one another; and finally, the number of pods, fresh weight, and dry weight are positively correlated with one another. This figure shows that cultivars with a high number of pods and high fresh and dry weights have a short number of days to germination and flowering (Figure 3).

Principal component analysis table 3 allows us to assess the correlation between the axes and the various variables. Table 3 illustrates this correlation between the axes and the various variables. Dimension 1 (Dim.1) is positively correlated with the traits, number of pods ($r = 0.916$), fresh weight ($r = 0.958$), and dry weight ($r = 0.946$). It is also negatively correlated with the number of flowering days ($r = -0.539$). Dimension 2 (Dim.2) is positively correlated with petiole length ($r = 0.570$), stem diameter ($r = 0.862$), and main stem height ($r = 0.844$).

Dimension 3 (Dim.3) is positively correlated with the number of days to flowering ($r = 0.540$) and the number of days to germination ($r = 0.769$). It means that number of pods, fresh weight, dry weight are positively correlated with one another and negatively correlated with number of days of flowering. The height of the main stem, petiole length and shaft diameter are positively correlated with one another. The number of germination days and number of days of flowering are positively correlated.

Analysis of Phenotypic Variability in Ten (10) Okra Cultivars

Variability among Cultivars Based on Quantitative Traits

Hierarchical ascending classification, performed using the means of quantitative traits based on Euclidean distance, produced a truncated dendrogram with a cut-off (Figure 4). This classification allowed the ten (10) okra cultivars to be grouped into three clusters. The total number of cultivars in Groups I, II, and III is 3, 5, and 2, respectively. The first two groups (GI and GII) each consist of morphologically similar cultivars. Cultivars C9, C6, and C5 represent the first group; cultivars such as C8, C10, C4, C3, and C2 are in the second group; and cultivars C1 and C7 represent the third group. The projection of the different groups into the factorial plane formed by the first two dimensions of the PCA shows that they are well-structured into three groups (Figure 4).

Figure (5) shows the projection of the quantitative traits into the plane formed by the two axes (Dim 1 and Dim 2). Cultivars C10, C8, C4, C2, and C3 have a very high number of days to flowering; they also have a high main stem height and diameter. Furthermore, these cultivars have average germination and petiole length, and finally, they have a low number of pods, fresh weight, and dry weight. Cultivars C1 and C7 have very early germination and a very high petiole length; they also have a low number of days to flowering, along with low main height and stem diameter and their number of pods, fresh weight, and dry weight are average. Cultivars C9, C5, and C6 have very high pod numbers, fresh weight, and dry weight, with average germination and petiole length; they also have a low number of days to flowering and very low main height and stem diameter (Figure 5).

Evaluation of the Effects of Cultivars and Time on Okra Pod Productivity

An analysis of Figure (6) shows that the coefficient of variation is greater than 1, and that the variance and mean are different, which allows us to use the Poisson model with zero inflation to analyze the effect of the cultivar and time factors on the number of pods.

Analysis of Table 4 at the 5% probability threshold shows a significant difference among the cultivars in terms of the number of pods (C2, P-value = 0.049, and C3, P-value = 0.048). No significant differences were observed regarding values above the threshold.

Analysis of Table 5 at a 5% probability threshold shows that no difference was observed between the considered collection periods with respect to the number of pods (P-value = 0.494; P-value = 0.241).

Analysis of Genetic Variability among Cultivars Based on Qualitative Traits

Analysis of Figure (7A) shows variability in the color of okra fruits. This variability is subdivided into three categories (light green, dark green, and green), with frequencies of 37%, 29%, and 34%, respectively. Analysis of Figure (7B) shows variability in the shape of okra leaf. This variability is subdivided into three categories (lobed-shape, divided-shape and heart-shape), with frequencies of 53%, 30%, and 17%, respectively.

The ascending hierarchical classification allowed us to classify the ten okra cultivars into three groups. The individuals within each group share identical morphological characteristics. The arrangement of the different groups on the PCA factor plot indicates that the groups are distinct (Figure 8).

By examining the relationships between several pairs of variables in this study, we were able to establish correlations among them. Positive and highly significant correlations link the number of pods to fresh weight and dry weight pods. This explains why, as the number of pods increases, so do both fresh weight and dry weight. In this case, fruit yield can be increased by improving these traits. The variable "number of days to flowering" shows highly significant negative correlations with all the variables. This indicates that an earlier growth cycle has a greater impact on achieving a high number of pods. This explains why the earlier a cultivar's growth cycle, the higher the yield. The analysis of the variability among all okra cultivars used in this study identified three (03) significantly different groups based on the considered parameters. Analysis of their performance allowed them to be classified as follows: the first group (GI), consisting of the okra long, okra short, and Tillabéry cultivars (C5, C6, and C9), is characterized by an early growth cycle with short stem height and diameter and average petiole length.

Table.1 The ten (10) studied cultivars with their origin.

Cultivars	Name	Origin
Cultivar 1 (C1)	Okra Harey garey	Tillabéry
Cultivar 2 (C2)	Okra from Gueskerou	Diffa (Gueskerou)
Cultivar 3 (C3)	Okra from Lada	Diffa (Lada)
Cultivar 4 (C4)	Okra from Diffa	Diffa (Diffa)
Cultivar 5 (C5)	Okra long	-
Cultivar 6 (C6)	Okra short	-
Cultivar 7 (C7)	Okra Gazelle	-
Cultivar 8 (C8)	Okra from Sakoira	Sakoira
Cultivar 9 (C9)	Okra from Tillabéry	Tillabéry
Cultivar 10 (C10)	Okra from Balleyara	Balleyara

Table.2 Observed parameters.

Characters	Characters
Date of germination	Weight of fresh fruit (g)
Flowering Date	Dry fruit weight (g)
Stem/plant diameter (cm)	Fruit size
Plant height (cm)	Fruit coloring
Petiole length (cm)	Fruit diameter
Number of pods per plant	Leaf shape

Table.3 Correlation of the various traits on the first five components.

Parameters	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Number of germination days	-0.289	-0.282	**0.769**	0.340	-0.355
Number of days of flowering	**-0.539**	0.112	**0.540**	-0.309	**0.556**
Height of the main stem	0.158	**0.844**	0.081	-0.282	-0.205
Petiole length	0.097	**0.570**	-0.053	**0.750**	0.306
Shaft diameter	0.172	**0.862**	0.196	-0.077	-0.148
Number of pods	**0.916**	-0.232	0.078	-0.007	0.116
Fresh Weight	**0.958**	-0.079	0.223	-0.029	0.035
Dry Weight	**0.946**	-0.074	0.197	-0.052	0.090

Table.4 Effect of cultivars on the number of pods.

Cultivars	Coefficients	Standard Erreur	Z-Statistic	Pr(>|z|)
Constant	-1.216	0.353	-3.440	0.000 ***
Cultivar 10	-1.386	0.790	-1.754	0.079
Cultivar 2	-2.079	1.060	-1.961	0.049 *
Cultivar 3	-2.079	1.060	-1.961	0.048 *
Cultivar 4	-0.470	0.570	-0.824	0.409
Cultivar 5	0.318	0.464	0.685	0.493
Cultivar 6	0.405	0.456	0.888	0.374
Cultivar 7	0.117	0.485	0.242	0.808
Cultivar 8	-1.386	0.790	-1.754	0.079
Cultivar 9	0.223	0.474	0.470	0.638

Table.5 Effect of time on the number of pods.

Time	Coefficients	Standard Erreur	Z-Statistic	Pr(>|z|)
Constante	-1.555	0.229	-6.780	0.000 ***
Time 2	-0.236	0.345	-0.684	0.494
Time 3	0.351	0.299	1.173	0.241

Figure.1 Map of the study area (Garba *et al.,* 2020).

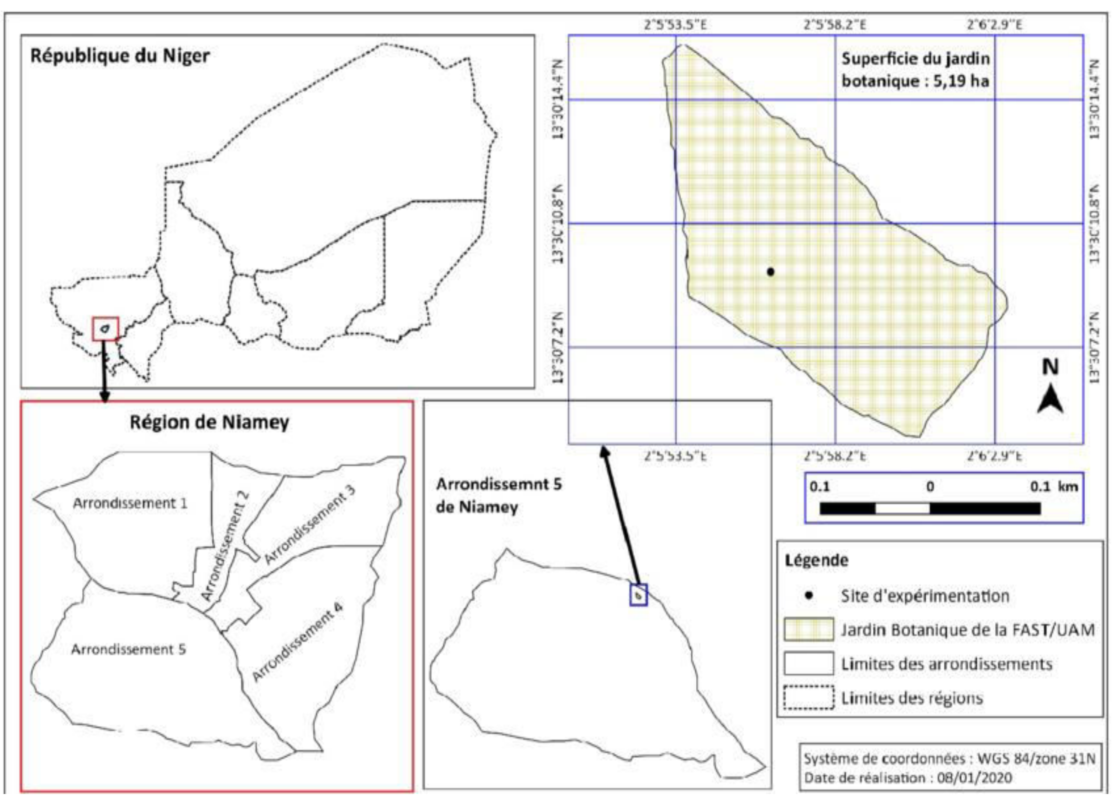


Figure.2 Experimental design.

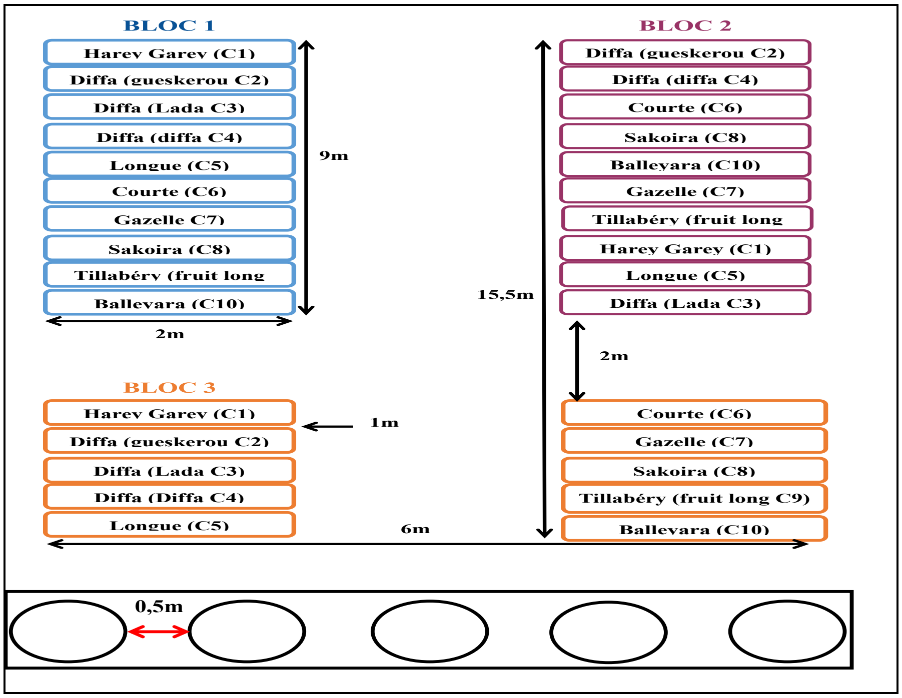
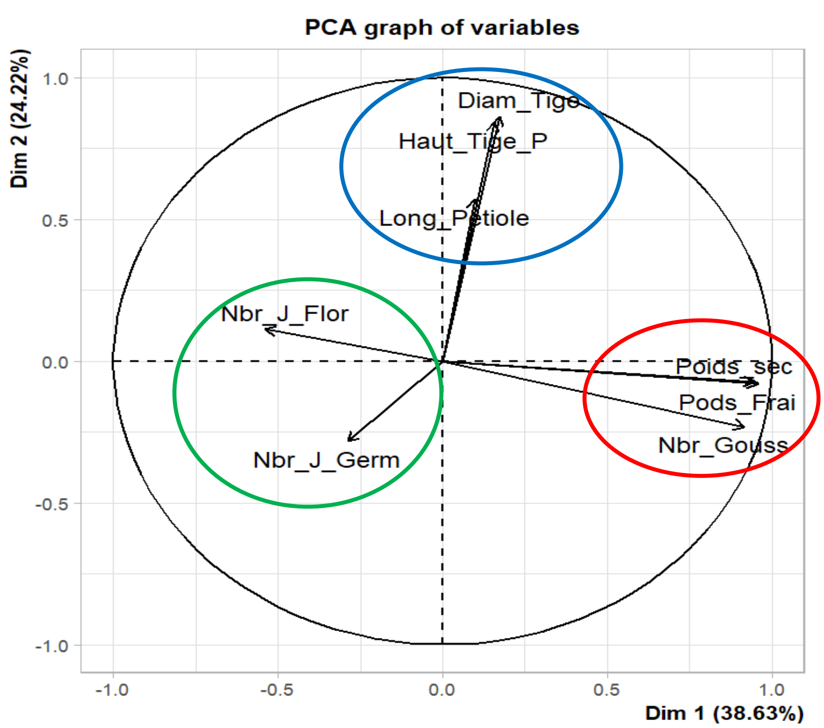


Figure.3 Projection of the characteristics into the plane defined by dimensions 1 and 2 of the PCA.



Legend: Nbr_J_Germ = Number of germination days; Nbr_J_Flor = Number of days of flowering; Haut_Tige_P = Height of the main stem; Long_Petiole = Petiole length; Diam_Tige = Shaft diameter; Nbr_Gouss = Number of pods; Pods_Frai = Fresh Weight and Poids_Sec = Dry Weight.

Figure.4 Dendrogram generated by CHA for ten okra cultivars and a plot of the groups in the space defined by the two PCA axes.

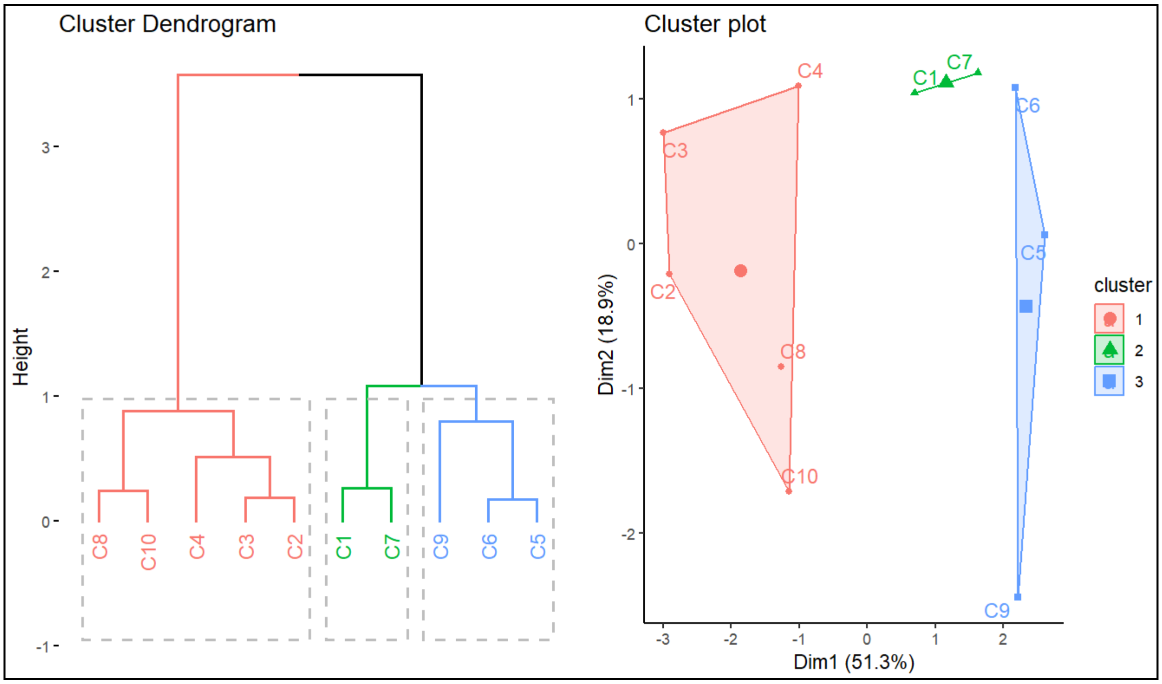
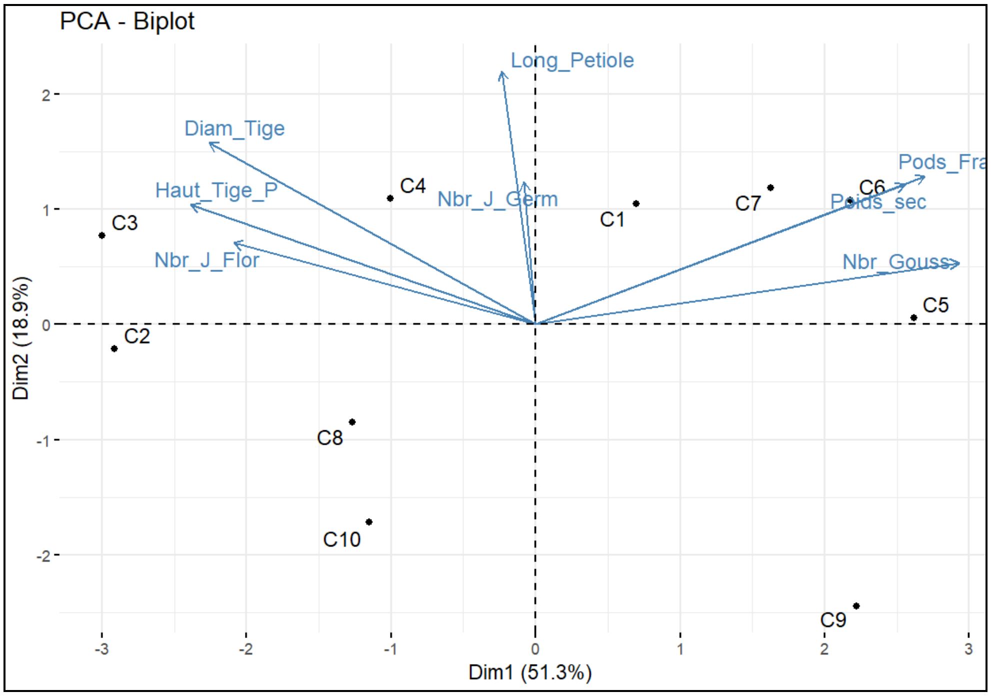


Figure.5 Differentiation of cultivars based on quantitative traits.



Legend: Nbr_J_Germ = Number of germination days; Nbr_J_Flor = Number of days of flowering; Haut_Tige_P = Height of the main stem; Long_Petiole = Petiole length; Diam_Tige = Shaft diameter; Nbr_Gouss = Number of pods; Pods_Frai = Fresh Weight and Poids_Sec = Dry Weight.

Figure.6 Analysis of the dispersion of the number of pods parameter.

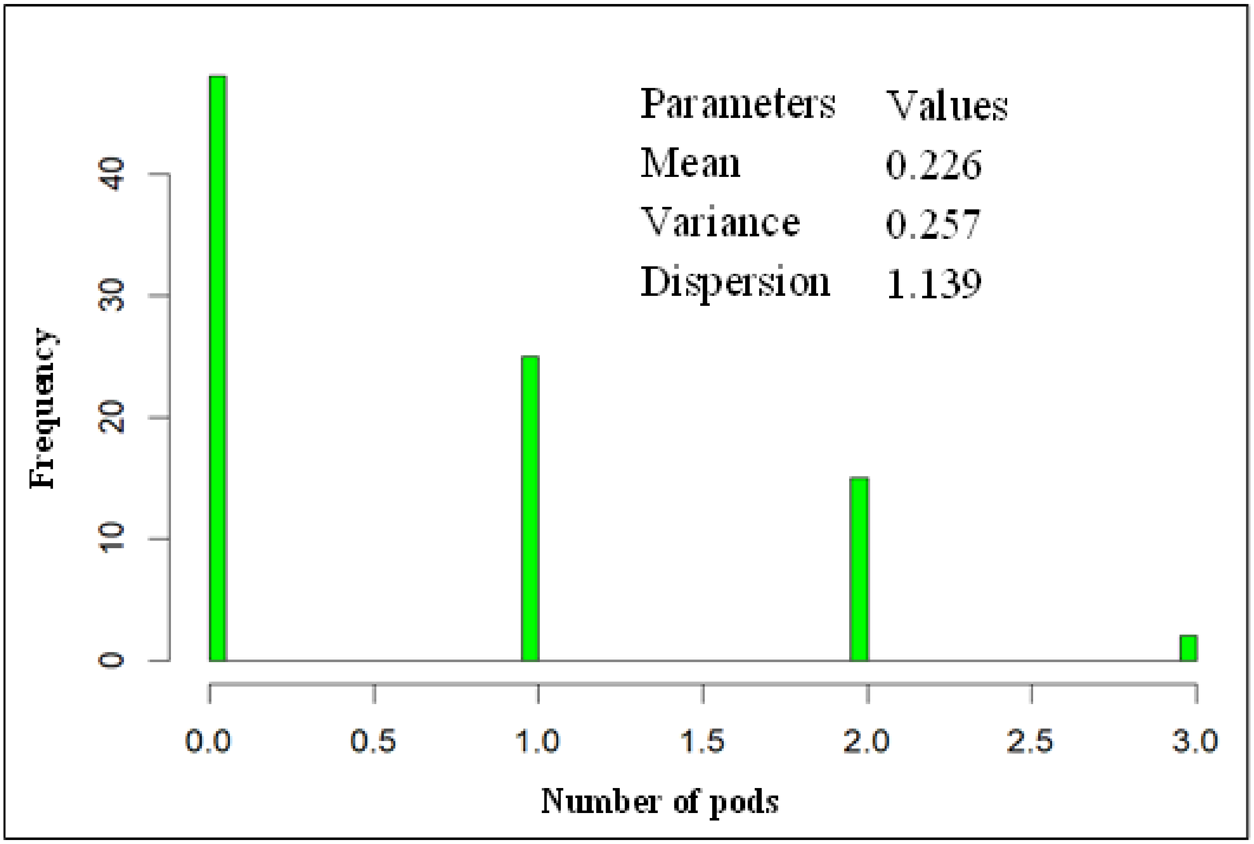


Figure.7 A = Distribution of cultivars by fruit color and B = Classification of cultivars based on *shape of* leaf.

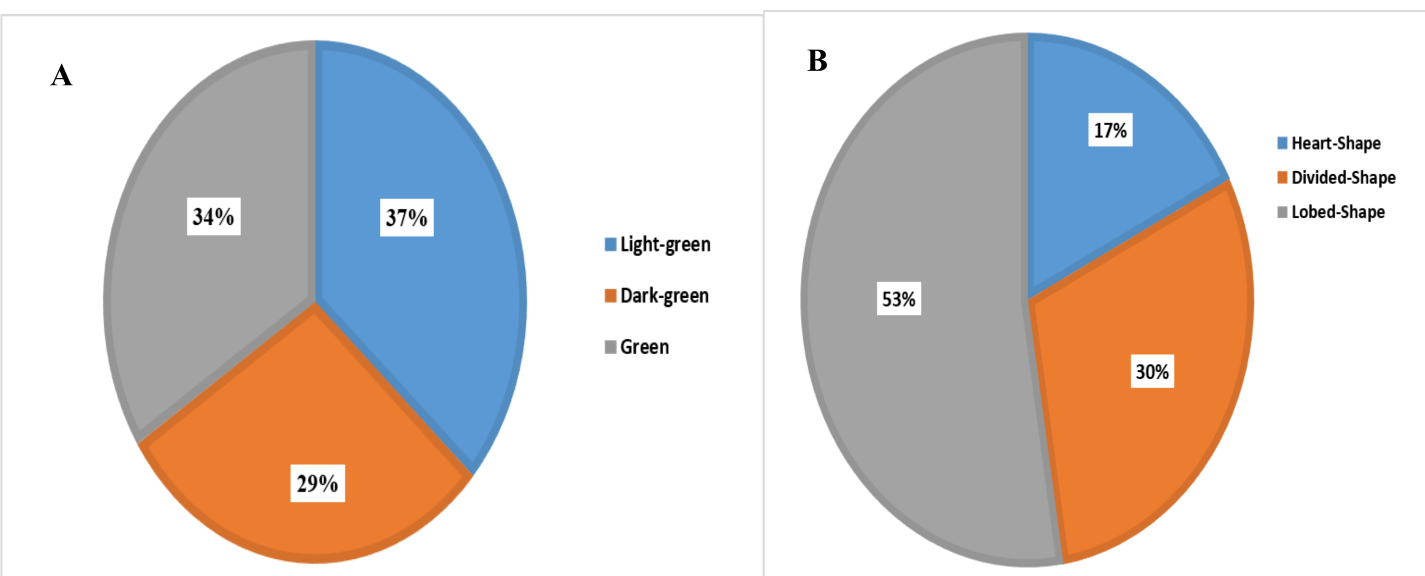
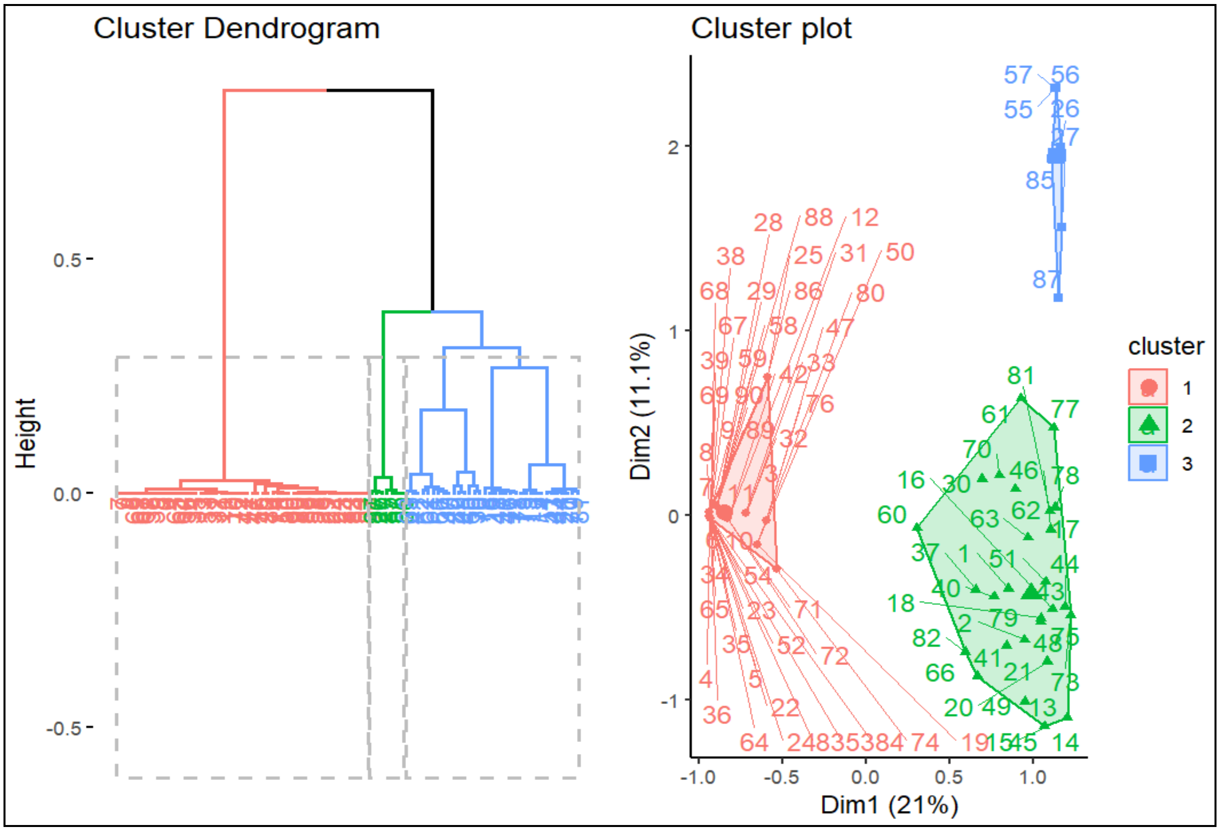


Figure.8 Classification of cultivars into groups based on qualitative traits.



These cultivars have high yields (high number of pods, high fresh and dry weights of pods). The second group (GII) is characterized by a late growth cycle with a tall stem, large diameter, and average petiole length. The cultivars from Gueskerou, Lada, Diffa, Sakoira, and Balleyara (C2, C3, C4, C8, and C10) belong to this group and are characterized by low yield. The third group (GIII) includes the cultivars Harey Garey and Gazelle (C1 and C7) and is characterized by an early growth cycle with a short stem height and small diameter. These cultivars have average productivity in terms of the number of pods. This classification of cultivars into three groups is like that observed by Ouédraogo (2016) in the comparative agromorphological characterization of five okra varieties at the University of Ouagadougou. The effect of cultivars on okra yield revealed a significant difference for the Gueskerou and Lada cultivars (C2 and C3) and no significant difference for the Diffa, long, short, Gazelle, Sakoira, Tillabéry, and Balleyara cultivars (C4, C5, C6, C7, C8, C9, and C10). Similarly, the effect of harvest time on okra productivity showed no significant difference among the harvest periods. Analysis of variance revealed considerable variation in leaf shape, size, fruit diameter, and color. According to Koechlin *et al.,* (1992), fruit color is a highly variable trait that is independent of the coloration of vegetative organs. Furthermore, the classification of cultivars based on agromorphological traits showed that the cultivars are grouped into three morphologically distinct groups.

This study shows that okra is characterized by significant phenotypic variability. The results of the analysis of agromorphological parameters, based on considered traits (qualitative and quantitative), revealed the existence of diversity among the studied okra cultivars. The quantitative results of the study indicated that, apart from fresh weight, dry weight, and the number of pods, all other traits showed significant differences among the cultivars. Analysis of the variability allowed the ten (10) okra cultivars to be classified into three groups, with three cultivars belonging to Group 1: okra long, okra short, and Tillabéry (C5, C6, and C9); five cultivars in the second group (GII): Gueskerou, Lada, Diffa, Sakoira, and Balleyara (C2, C3, C4, C8, and C10); and the third group (GIII) with two cultivars: Harey-garey and Gazelle (C1 and C7). The cultivars in Group 1 and those in Group 3 are early-maturing and showed higher yields in terms of the number of pods, proving to be promising. About qualitative traits, the okra cultivars were grouped into three groups that differed morphologically from one another. The results of the evaluation of pod yield over time revealed no significant differences among the ten okra cultivars.

Author Contributions

Adamou Ibrahim Maman Laouali and Moumouni Seyni Charifatou: Investigation, formal analysis, writing the original draft. Alio Moussa Abdourazak, Rafiou Ousmane Abdoulaye, Mahamane Adamou, Idi Saidou Sani: review the manuscript et Bakasso Yacoubou: review and validation 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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