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Characterization of Nigerian *Corchorus olitorius* (L.) Accessions using Agro-Morphological Traits

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Abstract
Experiments were carried out in 2018 and 2019 to characterize and assess the genetic diversity in fifty Nigerian accessions of *Corchorus olitorius* at the Teaching and Research Farm of the Department of Crop Science, University of Benin, Benin City in Southern Nigeria. The experiment was set up using the Randomized Complete Block Design, which used three replications. Frequency distribution for qualitative characters showed the accessions had considerable variations for traits such as stem colour, petiole colour, leaf vein colour, leaf type, leaf shape, leaf margin, leaf base shape, and leaf apex shape. Combined Analysis of Variance indicated highly significant genotype differences among the accessions for all quantitative agronomic characters measured except petiole length. Plant height ranged from 62.10cm to 126.49cm, leaf yield varied between 1.4t/ha and 5.7t/ha, while fibre yield ranged from 0.3t/ha to 1t/ha. Principal component analysis showed that most measured characters significantly contributed to the total observed variations among the accessions. This study showed considerable genetic variability exists in agro-morphological characters of these indigenous Nigerian accessions of *C. olitorius*. However, further evaluation across diverse environments will be necessary to gain further information that will be useful in the improvement of any of the economically important characters.
***Keywords**: Corchorus olitorius, accessions, genetic diversity, Cluster analysis*

Introduction

Corchorus olitorius L., commonly called Jute mallow, is an annual herb of the family *Malvaceae* used as a traditional nutraceutical leafy vegetable in Africa. *Corchorus* is mainly known for its fibre product, jute, and its leafy vegetables (Schippers, 2000). The vegetable is also known by several names, including 'Egyptian spinach', and 'bush okra' in South Africa (Van Wyk and Gericke, 2000; Ogunrinde and Fasinmirin, 2011), 'ewedu' in Yoruba, and 'ayoyo' in Hausa (Musa *et al*., 2010). The leaves of *C. olitorius* are a rich source of iron, protein, calcium, thiamine, riboflavin, niacin, folate, and dietary fibre (Palada and Chang, 2003). In Nigeria and most parts of Africa, it is cultivated mainly for the slimy leaves, which are found suitable for the consumption of the staple food crop products such as “amala”, “eba”, “tuwo”, “elubo”, etc. The leaves, roots, and seeds of *C. olitorius* are used as herbal medicine by local people in various parts of the world (Zeghichi*et al*., 2003). Industrially, *C.olitorius*is used extensively in Asia for the production of jute, hence the name 'jute mallow' (Denton, 1993). Jute fibre is a biodegradable, renewable, and environment-friendly cellulose fibre. *C. olitorius is* the second most important natural fibre crop after cotton (Bari *et al*., 2015) and thus of great commercial significance.

Despite the nutritional, therapeutic, and industrial importance of *C. olitorius*, in Nigeria, the plant is largely neglected and underutilized. It has been neglected by scientific research and national agricultural development policies. It is classified as one of the neglected and underutilized leafy vegetables in Africa (Aboagye *et al*., 2007; Dansi *et al*., 2012; Nyadanu and Lowor, 2015). This neglect has greatly affected the cultivation, conservation, and utilization of the genetic resources of *C. olitorius* that are found in abundance in Africa. Cultivated varieties run the risk of genetic erosion, and their cultivation is in serious decline due to low soil fertility, poor yield, pests, and diseases. However, there is also a growing international recognition that Neglected and Underutilized Species (NUS) play a role in providing food and nutrition security and income opportunities among smallholder farmers. These NUS crops, trees, and animals can help in adapting agriculture and food systems to climate change. Many farmers, especially in marginal areas, rely on NUS for their livelihoods. There is therefore a need to promote the utilization and genetic improvement of the *C. olitorius*.

Rapid genetic improvement of crops depends on the availability of sufficient genetic diversity, which could be selected or combined in various forms to produce reasonable improvement (Denton and Nwangburuka, 2011; Wani *et al*., 2011). Information on the genetic diversity within and among closely related crop varieties is essential for crop improvement and to meet the diverse goals like producing cultivars with increased yield, wider adaptability, desirable quality, pest and disease resistance, etc. (Huq *et al*., 2009) and for other goals such as germplasm conservation and cultivar identification (Isuosuo and Akaneme, 2014). The study of the genetic diversity of the many African indigenous leaf vegetables, including *Corchorus olitorius,* will also aid early and adequate exploitation of the desirable nutritional properties of the crops for better nutrition and good health, especially among the rural communities in Africa (Oguntona and Akinyele, 1995). Adequate analysis of germplasm diversity is thus necessary for proper understanding and utilization of genetic variability among accessions and their characters, as it is a tool geared towards harnessing the genetic variability that exists in available germplasm.

Genetic diversity can be assessed by several methods, including morphological data, biochemical data, and DNA-based data (Mohammadi and Prasanna, 2003). DNA-based molecular markers reveal polymorphisms and are extensively used in various fields of plant breeding and germplasm management. These markers can identify many genetic loci simultaneously with excellent coverage of the entire genome. They are phenotypically neutral and can be applied at any developmental stage (Jones *et al.,* 1997).

However, phenotypic characterization of germplasm reveals genetic variability, which is important in a hybridization programme. Compared to other methods, morphological characterization is direct, inexpensive, and easy to use. The presence of genetic variability implies that significant genetic gain through phenotypic selection is possible for the traits assessed (Agre *et al*., 2015). Phenotypic characterization has been extensively used for various crop plant diversity assessments in numerous places in the world (Lacroix *et al*., 2005; K'Opondo, 2011; Julia *et al,* 2016; Ngomuo *et al.,* 2017). Despite environmental effects on the morphology of plant and the subjectivity of measurements, morphological evaluations are considered the strongest determinants of the agronomic value and taxonomic classification of plants and the first step in the assessment of plant diversity (Julia *et al,* 2016; Ngomuo *et al.,* 2017) The objective of this studyis to characterize and assess the genetic diversity in fifty (50) Nigerian accessions of *Corchorus olitorius* using agro-morphological traits.

Materials and Methods

Experimental site

The experiments were carried out in the 2018 and 2019 planting seasons at the Teaching and Research Farm of the Department of Crop Science, University of Benin, Benin City. The location lies on Latitude 8° 10' N and longitude 4° 10' E at an elevation of 152m in the Rainforest zone of Southern Nigeria. The soils are underlain by sands, clayey sands, and discontinuous clay sequences of Benin Formation of the Niger Delta Basin classified as ultisols (Olatunji *et al*., 2014; Umweni *et al*., 2014). Rainfall is of high intensity and bimodal, beginning in March/April and ending in October/November, with a dry little spell in August usually referred to as "August Break". About 2025 mm of precipitation falls annually in Benin City, with an average annual temperature of 26.1 °C (Climate-Data.org, 2016).

Experimental material

Fifty accessions of *Corchorus olitorius* were obtained from the National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, Nigeria. Seedlings of these accessions were raised in a nursery and then transplanted to the main field three weeks after germination. Dormancy in the *C. olitorius seeds* was broken by steeping in hot water for 3 minutes.

Experimental design and cultural practices

The experiment was set up using the Randomized Complete Block Design (RCBD) with three replications. Each experimental unit consisted of a plot measuring 2m x 1m ($2m^2$) in size with an alley of 0.5m between experimental plots. The *C. Olitorius seedlings* were planted in raised beds under rain-fed conditions at a spacing of 50cm between rows and 20cm within rows, giving a plant population of 100,000 plants/ha. Manual weeding was carried out at 4, 8, 12, and 16 weeks after transplanting.

Data collection and analysis

Data were collected on twenty-eight qualitative and quantitative descriptors for *C. olitorius following* the descriptors for Corchorus as outlined by Loumerem and Alercia (2016) and Ngomuo *et al.* (2017). Data collected from the experiments were subjected to analysis of variance (ANOVA) using GenStat for Windows, 12th edition (2009). Principal component analysis was used to decompose the total variation to determine the variables that contribute the most to the total variation. Cluster analysis was used to estimate the phylogenetic distance between the genotypes and to group them according to the extent of closeness or diversity.

Results

Table 1 shows the physico-chemical properties of the soil of the experimental site, while Table 2 shows the meteorological data showing rainfall, relative humidity, maximum and minimum temperatures for Benin City in 2018 and 2019

Distribution frequency of 50 C. olitorius accessions for the qualitative traits.

The distribution frequency of the accessions for the qualitative traits (Table 3) showed that 28% of the accessions evaluated had green stems, 70% had light green stems, while 2% had reddish stems. The leaves of 26% of the accessions were light green, 26% had dark green leaves, 22% had glossy light green leaves, and 26% had glossy dark green leaves. Two percent of the accessions had reddish leaf vein colour, 26% had green leaf vein colour, 36% had light green leaf vein, and 36% had dark green leaf vein. The petiole colour of 38% of the accessions was green, 60% of the accessions had light green petiole colour, while 2% had reddish petiole color. The leaf shape of the accessions was predominantly lanceolate (66%), 14% had elliptical leaves, while 20% had palmate leaves. Twenty percent of the accessions had a hastate leaf base, 8% had a rounded leaf base, while 72% had an oblique-shaped leaf base. The leaf apex shape of the accessions was predominantly acute (90%), while 10% had an obtuse-shaped leaf apex. The leaf margin of the evaluated accessions was basically of two types: serrated leaf margin without leaf lobe, which occurred in 80% of the accessions, and double serrated margin with leaf lobe, which occurred in 20% of the accessions.

Quantitative traits

Combined analysis of variance over both seasons indicated highly significant genotypic differences among the accessions for all quantitative agronomic characters measured except petiole length (Table 4). Year as well as genotype x year interaction also significantly affected many of the traits evaluated. Table 4 shows the mean, minimum, and maximum values recorded for the measured traits over both years. The mean plant height at flowering over the two years was 95.37cm and ranged from 62.10cm to 126.49cm. Nineteen accessions produced plants with mean heights taller than 1m (100cm). On the other hand, nineteen accessions produced plants with mean heights lower than the overall mean plant height, with four accessions producing plants with mean heights that were significantly lower than that of the overall mean. The mean canopy diameter over both years was 4.89cm and ranged from 24.10cm to 59.83cm. Twelve (12) accessions had plant canopy diameters wider than 50cm, while thirteen (13) accessions had mean canopy diameters that were less than 40cm wide. The mean number of branches per plant over the two years was 11.68and varied plant ranging between 8.47 and 16.00. The overall mean number of leaves per plant over both years was 137.2. Among the accessions, mean leaf number per plant ranged from 58.0 to 301.8.

The mean number of days to flowering among the accessions was 101.51 days and ranged from 52.50 days to 142.50 days. Ten accessions took between 50- 70 days to flower, fourteen accessions required between 80-100 days to flower, twelve accessions took between 100-120 days to flower, while fourteen accessions needed about 120-145 days to flower (Table S1). The duration between flowering and pod maturity among the jute accessions ranged from 47.67 days to 105.33 days, with a mean time length of 76.11 days. The number of days from sowing to physiological maturity ranged from 129.50 days to 202.00 days, with a mean of 177.66 days. Twenty-seven accessions needed between 180-200 days to mature, fourteen required between 160-180 days, while nine accessions took less than 160 days to mature.

The mean number of pods per plant produced over both years was 27.55 pods per plant. Among the accessions, the number of pods per plant ranged from as few as 12.97 pods to as many as 84.07 pods. Mean pod length among the accessions varied between 3.050cm to 6.063cm with an overall average of 4.114cm. Over both years, the overall mean number of seeds per pod was 128.62 and ranged from a mean of 68.07 seeds per pod to a mean of 203.17 seeds per pod.

Mean leaf yield of the accessions was 3.050t/ha and varied between 1.408t/ha and 5.653t/ha. Over both years, twenty-three accessions gave leaf yields that were higher than the overall average yield. Five accessions gave mean leaf yields that were below 2t/ha, while five accessions gave leaf yields that were above 4t/ha. Among the genotypes, fibre yield ranged from 0.292t/ha to 0.992t/ha with an overall mean of 0.607t/ha. Twenty-three accessions gave yields that were above the mean fibre yield. In 2018, gave fibre yields above 1t/ha, while in 2019, five accessions gave fibre yields above 1t/ha.

Principal Component Analysis (PCA)

Table 5 shows the eigenvector values for principal components for eighteen agronomic traits of 50 *C. olitorius* accessions. The Principal Component Analysis (PCA) grouped the total variations contributed by all the measured traits into 18 principal components (PCs), accounting for all the genetic variability among the 50 *C. olitorius* accessions. The first seven principal components (PCs) accounted for 79.77% of the total variation. PC1, with an eigenvalue of 2.07, accounted for 23.73% of the variation and had plant height, stem width, number of branches per plant, fresh shoot weight per plant, and fibre yield as the major contributing factors. The major contributors to PC2, which had an eigenvalue of 1.84 and represented 18.91% of the total variation, were number of days to flowering, number of days to maturity, number of pods per plant, pod length, and number of seeds per pod. PC3, with an eigenvalue of 1.42 explaining 11.18% of the total variation, had high loadings for canopy diameter, number of leaves per plant, leaf width, and petiole length. The main contributing traits to PC4 were Number of days to flowering, number of days to maturity, pod length, number of seeds per pod, and seed weight. PC4 had an eigenvalue of 1.23 and accounted for 8.48% of the variations. PC5 had an eigenvalue of 1.07, representing 6.34% of the total variation with stem width, leaf width, number of days to pod maturity, and leaf yield as the major contributing traits. Leaf length and petiole length were the main contributing traits to PC6, which explained 6.11% of the total variability with an eigenvalue of 1.05. PC7, with an eigenvalue of 0.92, captured 4.68% of the total variability and had high loadings for leaf length, petiole length, number of days to pod maturity, number of pods per plant, and leaf yield.

The PCA biplot (figure 1) based on PC1 and PC2, capturing 42.6% of the variation in the data, indicated close correlations among leaf yield, fibre yield, number of leaves per plant, canopy diameter, number of branches per plant, and fresh shoot weight per plant. Plant height and stem width were closely correlated, while the number of pods per plant, pod length, number of seeds per pod as well as number of days to pod maturity were correlated. Strong similarity was also indicated in the relationship between the number of days to flowering and the number of days to maturity.

Cluster Analysis

Hierarchical cluster analysis, following Ward's method using the combination of both quantitative and qualitative traits, divided the fifty jute mallow accessions into five main clusters (Figure 2). Cluster I comprised twelve (12) accessions characterised by shorter plants with wider canopies and a high number of pods per plant. Cluster-II contained eight (8) accessions characterised by taller plants with wider stems, longer petioles, and higher leaf yield and fibre yield. Cluster-III comprised thirteen (13) accessions which produced more branches per plant, a higher number of leaves per plant, and longer leaves. Cluster IV had seven (7) accessions while cluster V contained ten (10) accessions. Cluster-IV was characterised by fewer branches per plant, shorter time to flowering, shorter time to maturity, as well as high leaf yield and high fibre yield. Cluster-V was characterised by shorter plants with narrower canopies and fewer leaves per plant, longer flowering and maturity time, and fewer pods per plant, as well as poorer leaf and fibre yield.

Discussion

Germplasm collections of underutilized traditional vegetables, such as jute mallow, are an important step in crop improvement (Loumerem and Alercia, 2016). Evaluating the diversity in such collections is vital towards breeding for improvement of the crop (Ngomuo *et al*., 2017). The results of this study using both qualitative and quantitative agro-morphological descriptors on 50 *C. olitorius* accessions showed that there was variability among the accessions. Frequency distribution of the accessions for qualitative characters showed considerable variations for traits such as stem colour, petiole colour, leaf vein colour, leaf type, leaf shape, leaf margin, leaf base shape, and leaf apex shape. Similar observations have been reported by Ngomuo *et al*. (2017), Nyanda *et al*. (2017), Adebo *et al*. (2015), and Benor *et al*. (2012).

The result of the combined analysis of variance over both seasons indicated highly significant genotypic differences among the accessions for all quantitative agronomic characters measured except petiole length. These significant genotypic variations in the expression of the various agronomic characters can be attributed to the diverse inherent genetic properties of the jute accessions used in this study and therefore suggest the existence of considerable genetic variations among the accessions for these traits. According to Sumanth *et al*. (2017), the success of any crop improvement program depends on the extent of genetic variations that exist in the available germplasm of that crop. Thus, this result confirms the potential of these accessions as a source of germplasm material for the improvement of the agronomic attributes of *C. olitorius.*

Similar variations across diverse agronomic traits in *C. olitorius* have been reported by Ngomuo *et al*. (2017), Nwangburuka and Denton (2012), Pervin and Haque (2012), and Sawarkar *et al.* (2014). Information about such genotypic differences across diverse traits among individuals or groups of accessions is helpful for management of germplasm collections, determination of the economic potentials of genotypes, as well as their utilization in the improvement of any of the economic characters of the crop (Loumerem and Alercia, 2016). According to Gerrano *et al*. (2014), the existence of significant genetic variability among accessions indicates the potential for exploiting the evaluated germplasm for the improvement of the crop.

The average fibre yield of all 50 *C. olitorius* accessions used in this study over both seasons was 0.607t/ha (Table S1), which was far below the global average of 2t/ha. This wide difference in the average yield may be attributed to the fact that most of the indigenous jute landraces in Nigeria and Africa in general are cultivated and selected by growers mainly for their vegetable leaf yield (Benor *et al*., 2012; Grubben and Denton, 2004; Dansi *et al*., 2012). Also, selection of high fibre-yielding jute varieties with finer and high-quality fibre, informally by growers and officially in crop breeding programs, has received considerable attention over the years in Asian countries such as China, Bangladesh, and India, which are the major producers of jute fibres globally (Nguomo *et al*., 2017; Fondio and Grubben, 2011), while improvement programs on the Jute mallow in Africa are very limited (Nyanda *et al*., 2017; Nwangburuka and Denton, 2012). However, in this study, genotypes with potential for high fibre yield were identified; In 2018, three accessions gave fibre yields above 1t/ha, while in 2019, five accessions gave yields above 1t/ha. These observations, therefore, show that these genotypes can be utilized as germplasm material for the development of high fibre-yielding varieties that are adapted to the agro-climatic conditions of Nigeria. These observations also more or less counter the general assumption that the jute ecotypes found in sub-Saharan Africa cannot be cultivated for fibre production (Fondio and Grubben, 2011; Nwangburuka and Denton, 2012).

Principal component analysis explained the genetic diversity of the evaluated accessions. It measures the contribution of each component to total variance, while each factor loading specifies the amount of contribution of every trait with each principal component associated with that trait (Nachimuthu *et al*., 2014). The first seven principal components (PCs) accounted for 79.97% of the total variation. Each trait was regarded as an important contributor to the variability in a component if its factor loading had a total value ≥0.30, irrespective of the plus or minus sign, as also reported by other researchers (Nsabiyera *et al*. 2012; Nachimuthu *et al*.2014). The result showed that most measured characters significantly contributed to the total observed variations among the accessions. Plant height, stem width, number of branches per plant, fresh shoot weight per plant, and fibre yield were the major contributors in PC1, while number of days to flowering, number of days to maturity, number of pods per plant, pod length, and number of seeds per pod were the major contributors in PC2. PC3 had high loadings for canopy diameter, number of leaves per plant, leaf width, and petiole length. Denton and Nwangburuka (2012) reported that the first two PCs in their study accounted for 80.45% of the total variation. A similar observation was reported by Dube *et al*. (2018). The reason for the relatively lower variations in the first few PCs observed in this present study may be because the *C. olitorius* accessions used in this study contain significant variability for most of the traits assessed.

The PCA biplot based on PC1 and PC2 indicated close correlations among leaf yield, fibre yield, number of leaves per plant, canopy diameter, number of branches per plant, and fresh shoot weight per plant. Plant height and stem width were closely correlated, while the number of pods per plant, pod length, number of seeds per pod, as well as number of days to pod maturity were correlated. Strong similarity was also indicated in the relationship between the number of days to flowering and several days to maturity. This is similar to results reported by Ghosh *et al*. (2013) and Nyadanu *et al*. (2017), and Dube *et al*. (2018).

Hierarchical cluster analysis grouped the accessions into five distinct clusters, suggesting diversity among the accessions of jute mallow in Nigeria. The clustering of accessions from the same origin into different clusters suggests diversity of populations within a geographical origin and similarity of populations beyond geographical limits (Nyadanu *et al*., 2017). This finding agrees with the results of Alemayehu and Becker (2002) and Zada *et al*. (2013) in *Brassica carinata* genotypes. The variability among the accessions from diverse origins could be related primarily to their morphological differences and their uses or selection (Nyadanu *et al*., 2017).

Conclusion

In conclusion, the information obtained from this research work has shown that considerable genetic variability exists in the agro-morphological characters of these Nigerian accessions of *C. olitorius*. However, further evaluation and testing of these genotypes across diverse environments will be necessary to gain further information that will be useful in breeding and improvement of any of the economically important characters.

Competing Interests

Authors have declared that no competing interests exist.

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Authors' Contributions

All the authors collaborated in this work. Richmond E. Edugbo and Godson E. Nwofia designed the study. The field work, data collection, and writing of the initial draft were carried out by Richmond E. Edugbo under the supervision of Godson E. Nwofia and Peter I. Okocha. Chinedu Eze contributed to editing, formatting, and statistical analysis. The final draft was read by all authors.

References

Aboagye, L. M., Obirih-Opareh, N., Amissah, L., & Adu-Dapaah, H. K. (2007). *Analysis of existing national policies and legislation that enable or inhibit the wider use of underutilized plant species for food and agriculture in Ghana*. Global Facilitation Unit for Underutilized Plant Species.

Adebo, H. O., Ahoton, L. E., Quenum, F., & Ezin, V. (2015). Agro-morphological characterization of *Corchorus olitorius* cultivars of Benin. *Annual Research and Review in Biology, 7*(3), 229–240.

Agre, A. P., Dansi, A., Rabbi, I. Y., Battachargee, R., Dansi, M., Melaku, G., Augusto, B., Sanni, A., Akouegninou, A., & Akpagana, K. (2015). Agro-morphological characterization of elite cassava (*Manihot esculenta* Crantz) cultivars collected in Benin. *International Journal of Current Research in Biosciences and Plant Biology, 2*(2), 1–14.

Alemayehu, N., & Becker, H. (2002). Genotypic diversity and patterns of variation in a germplasm material of Ethiopian mustard

(*Brassica carinata* A. Braun). *Genetic Resources and Crop Evolution, 49*, 573–582.

Benor, S., Demissew, S., Hammer, K., & Blattner, F. R. (2012). Genetic diversity and relationships in *Corchorus olitorius* (Malvaceae s.l.) inferred from molecular and morphological data. *Genetic Resources and Crop Evolution, 59*(6), 1125–1146.

Dansi, A., Vodouhè, R., Azokpota, P., Yedomonhan, H., Assogba, P., Adjatin, A., Loko, Y. L., Dossou-Aminon, I., & Akpagana, K. (2012). Diversity of the neglected and underutilized crop species of importance in Benin. *Scientific World Journal, 2012*, 932947. https://doi.org/10.1100/2012/932947

Denton, O. A., & Nwangburuka, C. C. (2011). Heritability, genetic advance, and character association in six yield-related characters of *Solanum anguivi*. *Asian Journal of Agriculture Research, 5*(3), 201–207.

Denton, R. I. (1993). Vegetable jute (*Corchorus*) pulses and vegetables. In J. T. Williams (Ed.), *Underutilized crops* (pp. 167–174). Chapman and Hall.

Dube, S. P., Marais, D., Mavengahama, S., Van Jaarsveld, C. M., & Gerrano, A. S. (2018). Characterisation of agro-morphological traits of *Corchorus* accessions. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*. https://doi.org/10.1080/09064710.2018.1514419

Fondio, L., & Grubben, G. J. H. (2011). *Corchorus olitorius* L. In M. Brink & E. G. Achigan-Dako (Eds.), *Plant Resources of Tropical Africa*. PROTA4U.

Gerrano, A. S., Jansen van Rensburg, W. S., & Adebola, P. O. (2014). Agro-morphological variability of *Amaranthus* genotypes in South Africa. *Acta Horticulturae, 1035*, 183–188.

Ghosh, R. K., Sreewongchai, T., Nakasathien, S., & Phumichai, C. (2013). Phenotypic variation and the relationships among jute (*Corchorus* species) genotypes using morpho-agronomic traits and multivariate analysis. *Australian Journal of Crop Science, 7*(6), 830–842.

Grubben, G. J. H., & Denton, O. A. (2004). *Plant Resources of Tropical Africa 2. Vegetables*. PROTA Foundation.

Huq, S., Islam, S., Sajib, A. A., Ashraf, N., Haque, S., & Khan, H. (2009). Genetic diversity and relationships in jute (*Corchorus* spp.) revealed by SSR markers. *Bangladesh Journal of Botany, 38*(2), 153–161.

Isuosuo, C. C., & Akaneme, F. I. (2014). Genetic variability assessment of accessions of *Corchorus olitorius* L. using sodium dodecyl sulphate polyacrylamide gel electrophoresis. *African Journal of Biotechnology, 13*(20), 2004–2009.

Jones, N., Ougham, H., & Thomas, H. (1997). Markers and mapping: We are all geneticists now. *New Phytologist, 137*(1), 165–177.

Julia, C. C., Waters, D. L. E., Wood, R. H., & Rose, T. J. (2016). Morphological characterisation of Australian ex-situ wild rice accessions and potential for identifying novel sources of tolerance to phosphorus deficiency. *Genetic Resources and Crop Evolution, 63*(2), 327–337.

K'Opondo, F. B. (2011). Morphological characterization of selected spider plant (*Cleome gynandra* L.) types from western Kenya. *Annals of Biological Research, 2*(2), 54–64. http://scholarsresearchlibrary.com/archive.html

Lacroix, C., Jeune, B., & Barabe, D. (2005). Encasement in plant morphology: An integrative approach from genes to organisms. *Canadian Journal of Botany, 83*, 1207–1221.

Loumerem, M., & Alercia, A. (2016). Descriptors for jute (*Corchorus olitorius* L.). *Genetic Resources and Crop Evolution, 63*, 1103–1111.

Mohammadi, S. A., & Prasanna, B. M. (2003). Analysis of genetic diversity in crop plants—Salient statistical tools and considerations. *Crop Science, 43*, 1235–1248.

Nachimuthu, V. V., Robin, S., Sudhakar, D., Raveendran, M., Rajeswari, S., & Manonmani, S. (2014). Evaluation of rice genetic diversity and variability in a population panel by principal component analysis. *Indian Journal of Science and Technology, 7*, 1555–1562.

Ngomuo, M., Stoilova, T., Feyissa, T., & Ndakidemi, P. A. (2017). Characterization of morphological diversity of jute mallow (*Corchorus* spp.). *International Journal of Agronomy, 2017*, 6460498. https://doi.org/10.1155/2017/6460498

Nsabiyera, V., Logose, M., Ochwo-Ssemakula, M., Sseruwagi, P., Gibson, P., & Ojiewo, C. (2012). Morphological characterization of local and exotic hot pepper (*Capsicum annuum* L.) collections in Uganda. *Bioremediation, Biodiversity and Bioavailability, 7*, 22–32.

Nwangburuka, C. C., & Denton, O. A. (2012). Heritability, character association, and genetic advance in six agronomic and yield-related characters in the leaves of *Corchorus olitorius*. *International Journal of Agricultural Research, 7*(7), 367–375.

Nyadanu, D., & Lowor, S. T. (2015). Promoting competitiveness of neglected and underutilized crop species: Comparative analysis of nutritional composition of indigenous and exotic leafy and fruit vegetables in Ghana. *Genetic Resources and Crop Evolution, 62*, 1–4.

Nyadanu, D., Amoah, R. A., Kwarteng, A. O., Akromah, R., Aboagye, L. M., Adu-Dapaah, H., Dansi, A., Lotsu, F., & Tsama, A. (2017). Domestication of jute mallow (*Corchorus olitorius* L.): Ethnobotany, production constraints and phenomics of local cultivars in Ghana. *Genetic Resources and Crop Evolution, 64*(6), 1313–1329.

Ogunrinde, A. T., & Fasinmirin, J. T. (2011). Soil moisture distribution pattern and yield of jute mallow (*Corchorus olitorius*) under three different soil fertility management. In *Proceedings of the Environmental Management Conference*, Federal University of Agriculture, Abeokuta, Nigeria.

Oguntona, E. B., & Akinyele, I. O. (Eds.). (1995). *Nutrient composition of commonly eaten foods in Nigeria: Raw, processed, and prepared*.

Palada, M. C., & Chang, L. C. (2003). Suggested cultural practices for jute mallow. *Asian Vegetable Research & Development Center International Cooperator Guide, 2*(14), 1–4.

Pervin, N., & Haque, G. K. M. N. (2012). Path coefficient analysis for fibre yield related traits in deshi jute (*Corchorus capsularis* L.). *IRJALS, 1*(3), 72–77.

Sawarkar, A., Yumnam, S., Patil, S. G., & Mukherjee, S. (2014). Correlation and path coefficient analysis of yield and its attributing traits in tossa jute (*Corchorus olitorius* L.). *The Bioscan, 9*(2), 883–887.

Schippers, R. R. (2000). *African indigenous vegetables: An overview of the cultivated species*. University of Greenwich.

Sumanth, V., Suresh, B. G., Ram, B. J., & Srujana, G. (2017). Estimation of genetic variability, heritability, and genetic advance for grain yield components in rice (*Oryza sativa* L.). *Journal of Pharmacology and Phytochemistry, 6*(4), 1437–1439.

Van Euwijk, F. A., & Elgersma, A. (1993). Incorporating environmental information in an analysis of GxE interaction for seed yield in perennial ryegrass. *Heredity, 70*, 447–457.

Wani, B. A., Ram, M., Yasin, A., & Singh, E. (2011). Physiological traits in integration with yield and yield components in wheat (*Triticum aestivum* L.), study of their genetic variability and correlation. *Asian Journal of Agricultural Research, 5*(3), 194–200.

Zada, M. U., Zakir, N., Rabbani, M. A., & Shinwari, Z. K. (2013). Assessment of genetic variation in Ethiopian mustard (*Brassica carinata* A. Braun) germplasm using multivariate techniques. *Pakistan Journal of Botany, 45*(S1), 583–593.

Zeghichi, S., Kallithraka, S., & Simopoulos, A. P. (2003). Nutritional composition of molokhia (*Corchorus olitorius*) and stamnagathi (*Cichorium spinosum*). *World Review of Nutrition and Dietetics, 91*, 1–21.

Table 1: Physico-chemical properties of the soil of the experimental site

Parameters	Value
Sand(g/kg)	890
Silt(g/kg)	58
Clay(g/kg)	52
pH	5.1
Organic matter (g/kg)	26.9
Total nitrogen (g/kg)	0.92
Organic carbon (g/kg)	15.6
Available phosphorus (mg/kg)	5.87
Exchangeable potassium(cmol/kg)	0.25
Exchangeable calcium (cmol/kg)	0.65
Exchangeable magnesium (cmol/kg)	0.2
Exchangeable sodium (cmol/kg)	0.12
Aluminium ion (cmol/kg)	0.15
Hydrogen ion (cmol/kg)	0.65

Table 2: Meteorological data showing rainfall, relative humidity, maximum and minimum temperatures for Benin City in 2018 and 2019

	Rainfall (mm)		Relative Humidity (%) 10.00 am		Relative Humidity (%) 4.00 pm		Maximum temp. (°C)		Minimum temp. (°C)	
Months	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**	**2018**	**2019**
January	0.00	0.00	77.9	80.0	74.3	62.0	33.9	33.0	22.0	23.0
February	0.00	0.00	82.2	80.0	78.2	60.0	33.3	35.0	24.2	26.0
March	81.70	90.0	83.9	80.0	80.0	70.0	32.7	33.0	23.1	23.0
April	75.10	107.0	83.2	82.5	77.6	73.6	32.6	33.1	22.4	23.8
May	165.5	56.6	83.5	82.5	74.8	73.6	33.2	33.1	23.3	24.1
June	231.3	381.4	82.8	84.6	73.9	83.1	32.0	31.4	23.2	22
July	260.3	281.0	85.0	87.5	81.0	82.0	30.5	28.5	23.4	23.2
August	230.4	427.0	87.2	92.9	80.7	87.0	30.5	30.2	23.1	23.5
September	269.4	442.9	90.1	88.5	79.9	85.8	30.8	31.3	23.1	23.4
October	177.1	385.9	83.7	73.6	70.5	68.3	32.3	31.9	22.9	23.6
November	28.20	140.8	83.4	84.0	69.5	63.5	32.8	33.2	23.8	23.5
December	0.00	0.00	79.0	78.1	66.0	53.4	33.0	33.0	22.0	21.5
Total	1519	2312.6	1001.9	994.3	906.4	862.3	388.0	386.7	276.5	280.6
Mean	*126.6*	*192.7*	*83.5*	*82.8*	*75.5*	*71.8*	*32.0*	*32.2*	*23.0*	*23.4*

Table 3: Distribution of the phenotypic classes of the 50 *C. olitorius* accessions among qualitative traits

Descriptors	Type	Number of Accessions	Frequency
Stem colour	Green	35	70%
	Light green	14	28%
	Reddish	1	2%
Leaf colour	Light green	13	26%
	Dark green	11	22%
	Glossy light green	13	26%
	Glossy dark green	13	26%
Leaf vein colour	Green	13	26%
	Light green	18	36%
	Dark green	18	36%
	Reddish	1	2%
Leaf petiole colour	Green	19	38%
	Light green	30	60%
	Reddish	1	2%
Leaf shape	Lanceolate	33	66%
	Elliptical	7	14%
	Palmate	10	20%
Leaf base shape	Hastate	10	20%
	Rounded	4	8%
	Oblique	36	72%
Leaf apex shape	Acute	45	90%
	Obtuse	5	10%
Leaf margin	Serrate	40	80%
	Double serrate	10	20%
Leaf lobe	Present	10	20%
	Absent	40	80%

Table 4: Means squares and variance ratios of genotype, year, and genotype x year interaction effects, error mean squares as well as mean, minimum, and maximum values recorded for eighteen agronomic attributes of 50 *C. olitorius accessions* grown in 2018 and 2019

	Genotype		Year		Genotype x year		Error			
Trait	**MS**	**VR**	**MS**	**VR**	**MS**	**VR**	**MS**	**Mean**	**Minimum**	**Maximum**
Plant height (cm)	1192	4.63***	109451.4	424.86***	697.3	2.71***	257.6	95.37	62.10	126.49
Stem width (cm)	0.11364	2.21***	0.16615	3.24^{NS}	0.08633	1.68**	0.05134	1.02	0.71	1.28
Canopy diameter (cm)	384.2	3.07***	1582.9	12.67***	224.7	1.80**	125.0	4.89	24.10	59.83
Number of branches/plants	17.945	2.04***	1897.065	215.65***	16.555	1.88***	8.79	11.68	8.47	16.00
Number of leaves/plant	12078	2.91***	155874	37.50***	5955	1.43*	4156	137.20	58..00	301.80
Leaf length (cm)	8.538	3.17***	890.274	330.39***	7.054	2.62***	2.695	9.99	7.52	12.17
Leaf width (cm)	3.0293	5.78***	386.2405	737.05***	2.7873	5.32***	0.5240	4.62	2.94	6.13
Petiole length (cm)	0.8337	0.92^{NS}	23.6434	26.18***	1.2970	1.44*	0.9032	4.00	3.37	4.85
Number of days to flowering	3677.88	87.31***	5084.08	120.69***	209.57	4.97***	42.13	101.51	52.50	142.50
Number of days to maturity	2248.02	179.52***	509.60	40.669***	92.03	7.35***	12.52	177.66	129.50	202.00
Number of days to pod maturity	886.16	23.21***	2397.01	62.77***	206.25	5.40***	38.19	76.11	47.67	105.33
Number of pods/plant	1151.72	17.91***	1748.70	27.20***	202.22	3.15***	64.30	27.55	12.97	84.07
Pod length (cm)	1.91128	35.06***	1.29363	23.73***	0.02902	0.53^{NS}	0.05451	4.11	3.05	6.06
Number of seeds/pod	3422.6	20.81***	603.2	3.67^{NS}	156.6	0.95^{NS}	164.4	128.62	68.07	203.17
100 seed weight (g)	0.042063	12.50***	0.012160	3.61^{NS}	0.001783	0.53^{NS}	0.003365	0.68	0.47	0.87
Fresh shoot weight/plant (g)	2359.2	4.07***	232287	400.35***	1953.8	3.37***	580.2	88.90	56.60	136.80
Leaf yield (t/ha)	4.72	4.18***	55.384	49.03***	5.021	4.45***	1.130	3.05	1.41	5.65
Fibre yield (t/ha)	0.20718	2.70***	0.04201	0.55^{NS}	0.17287	2.25***	0.07669	0.61	1.29	0.99

MS=Means Square; VR=Variance ratio; NS=Not significant (P>0.05); *=significant at P<0.05; **=significant at P<0.01; ***=significant

Table 5: Eigenvector values for principal components of some quantitative traits of 50 *C. olitorius* accessions

Traits	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC10
PH	**0.39**	-0.14	-0.14	0.03	0.06	0.02	-0.12	-0.13	-0.09	**-0.40**
SG	**0.34**	-0.16	-0.23	-0.06	**0.31**	0.08	0.19	-0.04	-0.12	0.21
CD	0.26	-0.01	**0.43**	-0.23	0.00	0.14	0.07	-0.13	0.08	-0.03
NB	**0.33**	0.07	0.21	-0.11	0.15	-0.14	-0.12	0.02	**-0.63**	0.05
NL	0.29	0.15	**0.32**	-0.17	-0.16	-0.24	0.06	0.11	-0.10	0.07
LL	0.24	-0.02	0.24	-0.02	0.20	**0.56**	**0.40**	-0.01	0.29	-0.05
LW	0.16	-0.23	**-0.39**	0.05	**0.32**	0.04	-0.11	-0.15	0.03	**0.45**
PtL	0.22	-0.05	**-0.30**	0.07	-0.18	**-0.45**	**0.42**	**-0.35**	0.01	-0.28
DF	0.04	**0.48**	0.01	**0.31**	0.18	0.02	-0.01	0.29	0.02	0.17
DPM	-0.05	-0.27	-0.12	-0.15	**-0.58**	0.26	**0.35**	0.07	**-0.31**	0.27
DM	0.03	**0.44**	-0.06	**0.30**	-0.13	0.07	0.25	0.02	-0.16	**0.38**
NP	0.02	**-0.38**	0.27	-0.02	-0.05	-0.17	**-0.32**	-0.09	0.06	**0.40**
PL	-0.06	**-0.35**	0.13	**0.44**	0.24	-0.08	0.23	0.18	-0.04	-0.03
NSP	-0.02	**-0.32**	0.23	**0.38**	-0.02	-0.22	0.19	**0.38**	-0.05	-0.09
100SWt	-0.06	-0.06	0.25	**0.48**	-0.15	0.25	-0.16	**-0.64**	-0.21	-0.07
FSWt	**0.35**	0.05	0.13	0.12	-0.19	-0.28	0.04	-0.04	**0.47**	0.24
LfYld	0.29	-0.04	-0.20	0.19	**-0.41**	0.17	**-0.33**	0.12	0.23	-0.01
FbYld	**0.32**	0.07	-0.13	0.24	-0.08	0.23	-0.23	**0.42**	-0.15	-0.16
Eigen value	2.07	1.84	1.42	1.23	1.07	1.05	0.92	0.87	0.78	0.75
Variability %	23.73	18.91	11.18	8.48	6.34	6.11	4.68	4.21	3.37	3.16
Cumulative %	23.73	42.64	53.82	62.16	68.51	74.69	79.97	83.51	86.87	90.04

Vector values in bold are vectors with loadings of 0.30 and above, and each trait was regarded as an important contributor to the variability in a component if its factor loading had a total value ≥0.30.

EC=Establishment count; PH=Plant height; SG=Stem girth; CD=Canopy diameter; NB=Number of branches/plant; NL=Number of leaves/plant; LL=Leaf length; LW=Leaf width; Pt.L=Petiole length; DF=Number of days to flowering; DPM=Number of days to pod maturity; DM=Number of days to maturity; NP=Number of pods/plant; PL=Pod length; NSP=Number of seeds/pod; 100SWt=100 seed weight; FSWt=Fresh shoot weight; Lf.Yld=Leaf yield; Fb.Yld= Fibre yield; SC=Stem colour; LT=Leaf type; LVC=Leaf vein colour; LPC=Leaf petiole colour; LBS=Leaf base shape; LAS=Leaf apex shape; LS=Leaf shape; LM=Leaf margin

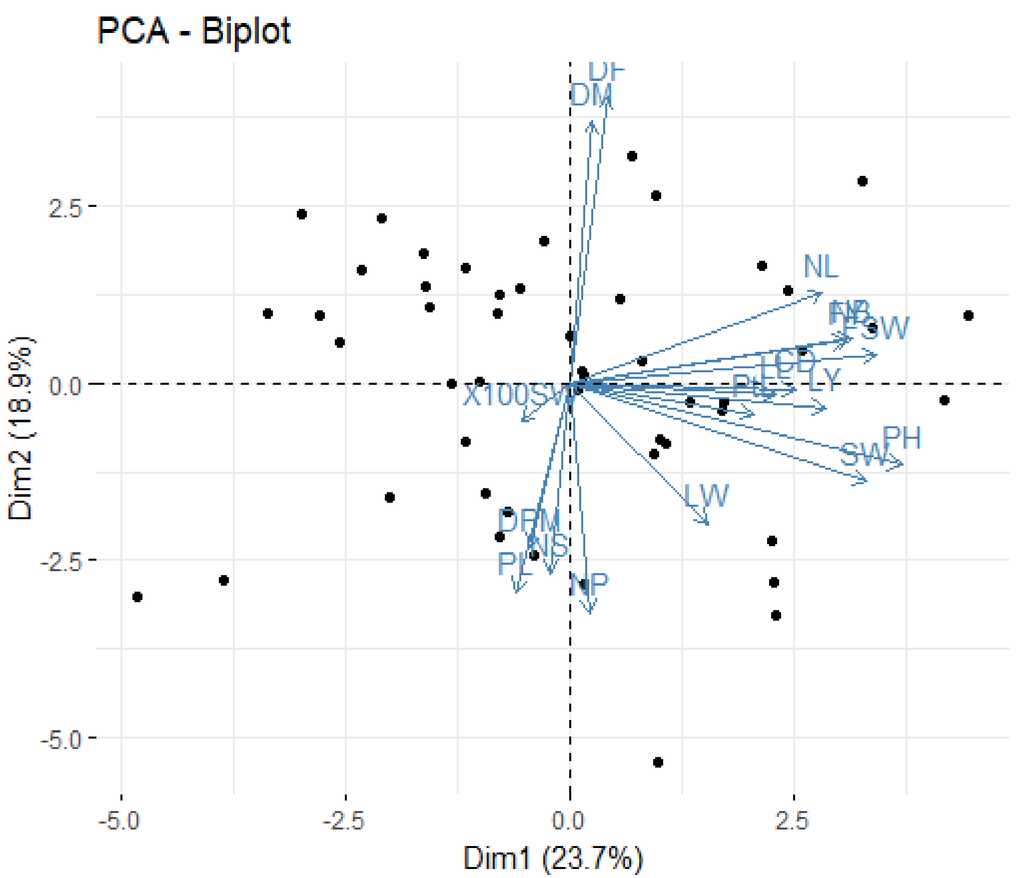

Figure 1: PCA showing correlation among 1 attributes

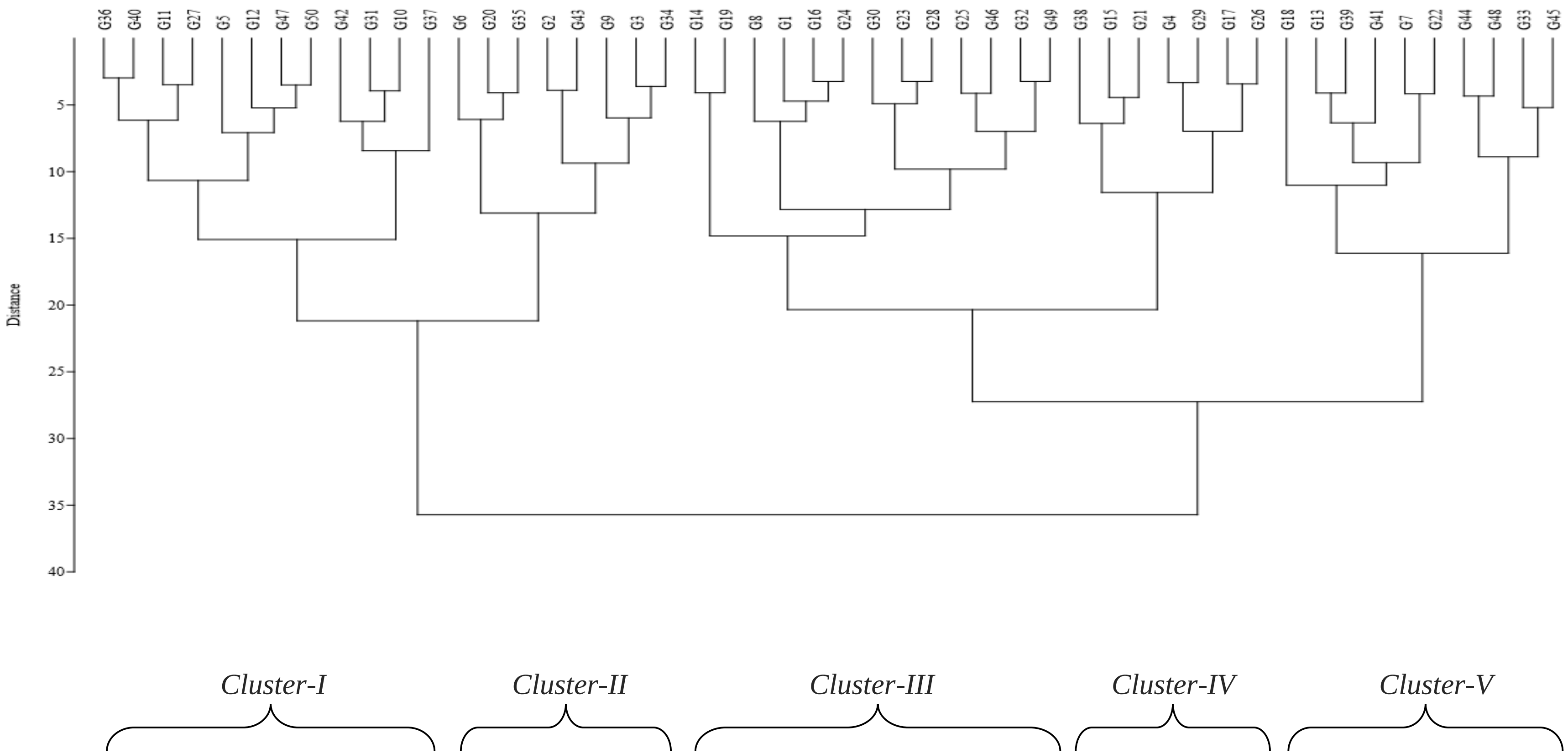

Figure 2: Dendrogram following Ward's method of cluster analysis using both quantitative and qualitative traits