Australian Journal of Crop Science AJCS

AJCS 12(09):1398-1409 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.09.PNE993

Core collection of two important indigenous vegetables; Gboma eggplant (*Solanum macrocarpon* L.) and Jute mallow (*Corchorus olitorius* L.) in Africa: An important step for exploitation of existing germplasm and development of improved cultivars

Albert Owusu Kwarteng[1, 2, 3], Richard Adu Amoah[3], Daniel Nyadanu[3], Clement Kwarteng Nyam[3], Jonah Zubil Ziyaaba[3], Jennifer Abogoom[3], Aisha Aziz[3], Kenneth Darko Anokye[3], Mary Dufie[3], Mercy Osei Boakye[3], Emmanuella Opoku Danso[3]

[1]School of Biodiversity, Agriculture and Food, Society and the Environment, Université Paris-Saclay, France
[2]AgroParisTech, 16 rue Claude Bernard, Paris, France
[3]Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi Cocoa Research Institute of Ghana, P. O. Box 8, Akim Tafo, Ghana

***Corresponding author: ao.kwarteng@yahoo.com; albert.kwarteng@agroparistech.fr**

Abstract

Gboma eggplant (*Solanum macrocarpon* L.) and jute mallow (*Corchorus olitorius* L.) are important indigenous vegetables of Africa. Even though these two indigenous vegetables are important in terms of nutrition, medicine and resilience of livelihoods, they have been neglected by scientific research and their value chain has not been developed. To ensure effective management and utilization of these important genetic resources in breeding programmes, it is important to collect their core collections. Therefore, eighteen different accessions of gboma eggplant and one hundred and six accessions of jute mallow were evaluated using RCBD with three replications. Results revealed diversity and significant variation among the various agronomic traits of both jute mallow and gboma eggplant. Correlation analyses between morphological traits of both species revealed positive and negative relationships, indicating predictable success for eventual breeding activities. Principal component analyses revealed traits of agronomic importance such as plant height, leaf length and number of leaves per plant as the most important traits for the distinction and separation of *Corchorus olitorius* accessions. The leaf blade length, leaf blade width, fruit colour at ripeness, plant height and fruit length were the most important traits for the distinction and separation of *Corchorus olitorius* accessions. Furthermore, hierarchical cluster analysis grouped the accessions into distinct clusters and accessions from the same geographical origin were classified separately. Nineteen accessions and six accessions were selected to constitute core collections of one hundred and six and eighteen accessions of jute mallow and gboma eggplant, respectively. Examination of the phenotypic traits showed that the genetic variation expressed for each trait in the entire collection has been preserved in the core collection. Core collections of these indigenous vegetables have many potential uses for the development of improved cultivars and should increase the utilization of germplasms of these important indigenous vegetables of Africa.

Keywords: *Corchorus olitorius,* Core collection, Germplasm, Indigenous vegetables, Nutrition and food security, *Solanum macrocarpon.*

Introduction

Indigenous vegetables are locally known plants whose leaves, young shoots and flowers are acceptable for use as vegetables (Mnzava, 1997; FAO, 2006). In Africa, they exist as cultivated, semi-cultivated, wild and weedy plants, with social, ecological and cultural values, playing an enormous role in the day-to-day food and nutritional requirements of people in rural households (Chweya and Eyzaguire, 1999; Gockowski et al., 2003). They are rich in micronutrients such as vitamins and minerals. Some are rich in lysine, an essential amino acid that is lacking in cereal and fibre diets, while others are medicinal (Imungi and Porters, 1983, Maundu et al., 1995, Imungi, 2002, Nyadanu and Lowor, 2014). The green leafy indigenous vegetables contain polyphenols, which have beneficial physiological effects on humans as antioxidants. They are also known to be anti-carcinogenic and anti-arteriosclerotic (Imungi, 2002). Consumption of African leafy vegetables is associated with the treatment of various diseases including therapy for patients with diabetes, high blood pressure and other common ailments (Kimiywe, 2006). They could contribute to improved food security as well as reduce hidden hunger, which is caused by micronutrient deficiency because of overdependence on few staple crops (Nyadanu and Lowor, 2015; Nyadanu et al., 2017; Kwarteng et al., 2017). Studies conducted in the southern parts of Africa have revealed that indigenous vegetables contribute immensely to the resilience of rural livelihoods (Godoy and Bawa, 1993; Arnold and Ruiz, 2001; Shackleton and Shackleton, 2004; Ladio and Lozada, 2004; Scherrer et al., 2005).

Gboma eggplant (*Solanum macrocarpon* L.*)* and jute mallow (*Corchorus olitorius* L.) are important indigenous vegetables of Africa. Gboma (*Solanum macrocarpon* L.) belongs to the family Solanaceae. It is a horticulturally important eggplant species with an African ancestry. It is adapted to the warmer and non-arid regions of Africa, where it serves as a very important fruit or leafy vegetable (Schippers, 2000). Gboma eggplant is a good source of calcium, fibre, protein, iron, magnesium, potassium, phosphorus and sodium (Agoreyo et al., 2012; Nyadanu and Lowor, 2015). The leaf and fruit of Gboma contain protein, which is of a very high quality, and as such, represents an affordable but quality source of nutrition for many families (Adeyeye and Adanlawo, 2011). Gboma is used in traditional medicine for the treatment of various maladies such as asthma, skin infections, rheumatic disease, gastro-oesophageal reflux diseases, to constipation, diabetes as well as weight reduction (Nwodo et al., 2011; Nyadanu et al., 2017).

Jute mallow (*Corchorus olitorius* L.) is annual herb belonging to the Malvaceae family, which is used as a traditional nutraceutical leafy vegetable in Africa (Dansi et al., 2008). It contains significant amounts of carbohydrates, proteins, lipids, vitamins (A, C, E) and mineral nutrients viz. calcium and iron (Steyn et al., 2001; Matshufuji et al., 2001; Adeniyi et al., 2012; Nyadanu and Lowor, 2014; Nyadanu et al., 2017). It also contains high amounts of all essential amino acids (Tulio et al., 2002). Most local folk employ the leaves, roots and seeds of jute mallow in herbal medicine (Zeghichi et al., 2003). Consumption of the leaves of jute mallow has been noted to be demulcent, deobstruent, diuretic, lactagogue, purgative and tonic (Furumoto et al., 2002; Khan et al., 2006). It is also a folk remedy for the treatment of aches and pains, dysentery, enteritis, fever, pectoral pains, ascites, piles, tumours, gonorrhoea, and chronic cystitis (List and Horhammer, 1979; Duke and Wain, 1981, Abu-Hadid et al., 1994; Zeghichi et al., 2003). Intake of Jute mallow provides essential antioxidants needed for good health (Chipurura et al., 2011; Kumawat et al., 2012 and Barku et al., 2013).

Even though these two indigenous vegetables are important in terms of nutrition, medicine and resilience of livelihoods, they have been neglected by scientific research and their value chain has not been developed. Hence, there is the need to conserve and manage their genetic resources. In order to manage conserved germplasm better, there is also the need to understand the genetic diversity that is present in collections (Rao and Hodgkin, 2002). This will help us to rationalize collections as well as develop and adopt better protocols for regeneration of germplasm. Through improved characterization and development of core collections based on genetic diversity information, it will be possible to exploit the available resources in ways that are more valuable.

Furthermore, to ensure effective management and utilization of these important genetic resources in breeding programmes, it is important to collect their core collections. A core collection is a limited set of accessions representing, with a minimum of repetitiveness, the genetic diversity of a crop species and its wild relatives (Frankel, 1984). The establishment of *ex situ* germplasm collection has been the result of a global effort to conserve plant biodiversity (Paredes et al., 2009). Core collections have been proposed as a valuable resource in studying population structure and diversity, discovering new sources of variation and identifying agronomically beneficial and genetically diverse germplasm for use in crop improvement programs (Upadhyaya, 2011)

The objectives of this study were to collect and characterise different accessions of gboma eggplant (*Solanum macrocarpon* L.) and jute mallow (*Corchorus olitorius* L.) morphologically using quantitative and qualitative descriptors. Secondly, to collect core collections of these different accessions for conservation and further breeding programs.

Results

Diversity among the accessions of Jute mallow

The descriptive statistics depicted a considerable level of variability for a number of agro-morphological traits among the different accessions of *Corchorus olitorius* used in this study. Basic statistics (mean ± standard error of means, standard deviation, variance and median) have been tabulated in Table 1. In general, the accessions varied in several traits of economic importance, and dissimilar patterns of variation among the accessions were noticed for various agro-morphological traits. The largest variation was found in number of sub-leaves per plant followed by plant height, number of leaves per plant, dry matter content and number of branches per plant. The observed variances for the said traits were 1396.71, 1256.79, 229.52, 121.86 and 68.142, respectively. Conversely, low variation was observed for stem diameter (0.31), stem habit (0.35), leaf shape (0.66) and leaflet margin (0.92).

The Phenogram generated using 20 morphological descriptors based on Euclidean Distance Coefficient and UPGMA clustering method (Fig. 1) clearly showed hierarchical cluster analysis of 106 accessions of *Corchorus olitorius* evaluated. At a distance scale of 330, the phenogram separated the 106 accessions into three distinct clusters. The clustering revealed diversity and variability among the accessions. The variations in shape and leaf surface features of the accessions are shown in Supplementary figures 1 and 2. Cluster I is made up of thirty accessions. Cluster II comprises of eleven accessions whereas Cluster III was the largest accession consisting of sixty-five accessions (Supplementary Table 1).

Out of the thirty accessions of cluster I, accessions KNUSTC03, KNUSTC09, KNUSTC52, KNUSTC61, KNUSTC70 and KNUSTC94 were selected as the core collection. From the eleven accessions in cluster II, accessions KNUSTC58 and KNUSTC101 were selected as the core collection. Out of the sixty-five accessions found in cluster III, accessions KNUSTC16, KNUSTC22, KNUSTC25, KNUSTC35, KNUSTC37, KNUSTC40, KNUSTC49, KNUSTC68, KNUSTC96, KNUSTC100 and KNUSTC106 were selected as core collection. The accessions selected as the core collection of jute mallow and their different locations are shown in Supplementary Table 1

Table 2 shows correlation among various agronomic traits of 106 accessions of jute mallow. Positive and significant correlation ($p<0.05$) were observed between plant height and number of branches (r=0.380), number of leaves (r=0.526), number of sub-leaves (r=0.587), leaf length (r=0.369), leaf width (r=0.467), stem habit (r=0.295), growth habit (r=0.354) and dry matter (r=0.488). Furthermore, there were significant and positive correlation between number of branches and number of leaves (r=0.287), number of sub-leaves (r=0.558), leaf length (r=0.563), leaf width (r=0.528), stem diameter (r=0.321) and dry matter (r=0.493). Conversely, negative and significant correlation was observed between number of leaves and stem habit (r=-0.249).

Variation among the traits of jute mallow was assessed using principal component analysis. First three principal components accounted for a total of 48 % variability (Table 3). The first principal component had an Eigen-value of 3.875, signifying 27.7% of the entire variation. Traits of agronomic importance such as plant height, leaf length and number of leaves per plant vastly contributed positively to the variation in PC1 whereas traits such as number of plants per pot, growth habit and stem habit contributed negatively to variation in PC1. PC2 had an Eigen-value of 1.927, which represented a proportion variance of 13.8% and PC3 had an Eigen-value of 1.428, which accounted for 10.2% of the total variation. PC2 was positively correlated with traits such as stem diameter, stem habit, leaflet margin and dry matter. Conversely, leaflet surface, number of branches per plant, number of leaves per plant and number of sub-leaves per plant vastly contributed negatively to PC2. The Principal Component Analysis of the jute mallow accessions collected from the various communities revealed diverse grouping patterns for the agronomic traits.

Diversity among the accessions of Gboma eggplant

The descriptive statistics highlighted a considerable level of variability for a number of agro-morphological traits among the different accessions of *Solanum macrocarpon* used in this study (Table 4). In general, the accessions varied in several traits of economic importance, and dissimilar patterns of variation among the accessions were noticed for the agro-morphological traits. The largest variation was found in the tip angle of leaf blade, plant height, leaf blade length and leaf prickles. The variances for the said traits were recorded as 111.24, 76.18, 11.67 and 8.00, respectively. Conversely, no variations were observed for fruit curvature (0.00), fruit cross section (0.00), and fruit apex shape (0.00). In addition, low variation patterns were recorded for traits like fruit length (0.15), corolla colour (0.38) and leaf blade lobing (0.35).

The phenogram generated for the accessions of *Solanum macrocarpon* based on the traits assessed in this study grouped the accessions into 2 clusters at a similarity index of 65% (Fig. 2). Clusters I and II comprised of 9 accessions each. These two clusters were further sub-clustered in order to select the core collection out of them. Figure 3 represents sub-cluster analysis of the 9 accessions of Cluster I. At a similarity index of 73%, the accessions were grouped into three clusters. Sub-cluster I consists of 5 accessions. Out of these 5 accessions, KNUSTG01 was selected as core collection (Supplementary Table 2). Sub-cluster II consists of 2 accessions, of which KNUSTG17 was selected as core collection. Sub-cluster III comprises of 2 accessions, with KNUSTG09 selected as core collection. Figure 4 represents further sub-cluster analysis of 9 accessions of cluster II. At a similarity index of 88%, the accessions were grouped into 4 sub-clusters. Accession KNUSTG04 was selected as core collection for sub-cluster I, with KNUSTG14 being selected as core collection for sub-cluster II. In addition, accessions KNUSTG06 and KNUSTG11 were selected as core collections for sub-clusters III and IV, respectively (Supplementary Table 2).

Figure 4 shows biplot analysis of the eighteen accessions of gboma based on their first and second principal components. Section 1 consists of accessions with high leaf blade tip angle, leaf blade lobing, leaf blade length, leaf blade width and fruit colour at commercial ripeness while section 2 is made up of accessions with high fruit length, plant height and corolla colour. The figure also revealed the traits that are associated with each other. The extent of association is dependent on the angle between the lines joining the two traits. The smaller the angle (acuteness) the more correlated the traits are. A closer look at the figure reveals that fruit length, plant height and corolla colour are associated. Moreover, leaf blade lobing, leaf blade length and leaf blade width are associated.

Table 5 shows correlation analysis between the eighteen accessions of gboma eggplant. Positive and significant correlation ($p<0.05$) were observed between leaf blade length and leaf blade width (r=0.616). In addition, there were significant positive correlation between leaf blade width and fruit colour at commercial ripeness (r=0.534). Conversely, negative and significant correlation were observed between plant height and fruit colour at commercial ripeness (r=-0.469).

Principal component analysis based on the agronomic traits assessed for gboma eggplant yielded informative outcome (Table 6). The cumulative contribution of the first 3 principal components accounted for 63.8% variability. PC1 contributed 25.9% of total variation among various traits. Leaf blade length, leaf blade with and fruit colour at ripeness were among the traits that contributed positively to PC1. In contrast, plant height and fruit length were among the traits which contributed negatively to PC1. Second principal component (PC2) accounted for 21.7% of the total variation, and illustrated primarily by the variation in traits such as plant height, corolla colour, leaf blade length and fruit length. On the contrary, traits such as fruit fruit curvature and fruit colour at ripening were among the traits that were negatively associated with PC2.

Discussion

The main purpose of a core collection is to provide a small representative sample of genetic variation from a large germplasm collection. This will assist germplasm curators in efficient management and more importantly provide breeders with a wide range of diversity for greater utilization in their breeding schemes (Dudnik et al., 2001; Paredes et al., 2010). One of the most crucial aspects to consider in the establishment of a core collection is to ensure the representativeness of genetic diversity within the species (Mario-Paredes et al., 2010). The significant variation among accessions for the various agronomic traits suggests that these traits are under genetic control and should therefore, be liable to genetic improvement. This provides an opportunity to improve desirable morphological traits of *Corchorus olitorius* and *Solanum macrocarpon.* Even though the 106 *Corchorus olitorius* accessions in the present study differed greatly in number of branches per plant, number of leaves per plant, leaf length, leaf width and fresh leaf weight, their overall close morphology allowed them to be grouped in distinct clusters. At a distance scale of 330, the phenogram separated the 106 accessions studied into three distinct clusters by grouping accessions sharing close phenotypic similarities into distinct clusters. Accessions in a cluster are more genetically similar than their counterparts in other cluster groups. The diversity noted in crop performance with respect to the differences in leaf shapes and leaf surfaces in jute mallow, as well as the diversity observed in fruit and corolla colour of gboma eggplant, could be explained by the differences in their genetic composition and farmer selection practices prevailing in areas where they were collected. Adjusting to these conditions for certain desirable characters over a long period of time, directed at fruit morphology across many generations appears to have generated a significant degree of differentiation in local varieties of gboma eggplants and thus given rise to a significant number of local variants with interesting features among the accessions. Naujeer (2009) and Portis et al. (2006) reported similar findings in Mauritius eggplant and Italian pepper landraces.

The grouping of the accessions into specific cultivar groups based on key morphological descriptors will allow a quick and easy discrimination between them. Furthermore, it will enhance the assessment of *Corchorus olitorius'* varietal diversity structure in relation to *in-situ* conservation at specific locations. For instance, very close phenotypic similarities for all the morphological descriptors characterized were observed between clusters I, II, III, IV and V, but clusters VI and VII comprised of larger accessions, and hence they were further sub-clustered to get the mini-core from them. This indicates a high probability of duplication of gene bank collections from these accessions. According to Furini and Wunder (2004), diverse geographical origins of two accessions may not necessarily reflect in genetically diverse plant materials. Frary et al. (2003) explained this observation by stating that, phenotypes for certain traits are controlled by a limited number of genes, with major effects on phenotypic traits and their quantitative trait loci being conserved during domestication and plant evolution. The close similarity and morphological ties between accessions from different agro-ecological zones observed in this study implies that they have conserved their gene functions and thus, linked to the successful expression of their morphological traits over geographical space, isolation and time. The 106 accessions of *Corchorus olitorius* in this study varied greatly in plant height, number of branches per plant, number of leaves per plant, leaf length, leaf width, fresh leaf weight, stem diameter, as indicated by the descriptive parameters analysis to be the most reliable morphological characters that contributed to total variation.

According to Hazra and Basu (2000), correlation coefficients give an idea of the intensity of associations among characters. Thus, correlation studies provide information on the nature and extent of association between any two pairs of metric characters. As such, it could be possible to bring genetic improvement in one character by selection of the other of a pair. Thus, the significant positive correlation among some of the agronomic traits observed in this study suggests that the traits could be improved simultaneously without any compensatory negative effects. For example, the positive and significant correlation ($p<0.05$) observed between plant height and number of leaves of the jute mallow accessions indicates that these two traits could be improved simultaneously. Conversely, negative but significant correlations between some of the traits such as number of leaves and stem habit ($r=-0.249$); leaf length and number of plants ($r=-0.244$); leaf width and number of plants ($r=-0.232$) of jute mallow accessions, as well as between plant height and fruit colour at commercial ripeness ($r=-0.469$) of gboma eggplant accessions suggests that the traits could be improved independently.

The results of the principal components for the agro-morphological characters revealed traits of agronomic importance such as plant height, leaf length, number of leaves per plant number of plants per pot, growth habit and stem habit, stem diameter dry matter, number of branches per plant and number of sub-leaves per plant, as the most important traits for the distinction and separation of *Corchorus olitorius* accessions. However, with respect to *Solanum macrocarpon*, the results of the principal component analysis revealed that leaf blade length, leaf blade width, fruit colour at ripeness, plant height and fruit length were the most important traits for the distinction and separation of gboma accessions. The results therefore indicate significant contributions of these highlighted traits towards diversity. Thus, these traits should be taken into consideration when developing improved cultivars of *Corchorus olitorius and Solanum macrocarpon*, respectively, since they contributed most to the total variation. According to Oyiga et al. (2010), information obtained through principal component analysis may assist plant breeders to identify a limited number of highly differentiated populations for use in hybridization and selection programmes.

Materials and Methods

Plant materials

Eighteen different accessions of gboma eggplant (*Solanum macrocarpon* L.) and one hundred and six different accessions of jute mallow (*Corchorus olitorius* L.) were used in this study. These accessions represent working collections of these crops in the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Ghana. These working collections of the accessions of jute mallow and gboma eggplant were collected from various towns in Ghana listed in Supplementary Tables 3 and 4, respectively. Supplementary Figure 3 shows the map of Ghana indicating the origins of these accessions.

Planting of jute mallow and gboma eggplant

A well-sterilized sandy loam soil was used for the experiment. Planting of the one hundred and six accessions of jute mallow were done in plastic pots with widths and depths of 25 cm and 30 cm, respectively. The pots were filled with the sandy loam soil. All the pots were arranged in a RCBD design with three replications. Seedlings of each accession were thinned to four (4) plants per pot after three months. Relevant agronomic practices such as watering,

Table 1. Descriptive statistics for the Agro-morphological characters of Jute mallow

Trait	Mean±SE Mean	SD	Variance	Median
Plant height	114.55±3.44	35.45	1256.79	120.00
Number of branches per plant	9.38±0.80	8.26	68.142	6.00
Number of leaves per plant	27.66±1.47	15.15	229.52	26.00
Number of sub leaves per plant	51.71±3.63	37.37	1396.71	44.50
Leaf length	9.43±0.25	2.59	6.69	9.40
Leaf width	5.40±0.16	1.66	2.75	5.15
Stem diameter	0.60±0.05	0.55	0.31	0.50
Stem habit	1.64±0.06	0.59	0.35	2.00
Growth habit	2.35±0.09	0.94	0.88	3.00
Leaflet surface	1.92±0.10	1.00	1.00	1.00
Leaflet margin	1.76±0.09	0.96	0.92	1.00
Leaf shape	1.91±0.08	0.81	0.66	2.00
Dry matter	20.76±1.07	11.04	121.86	20.32

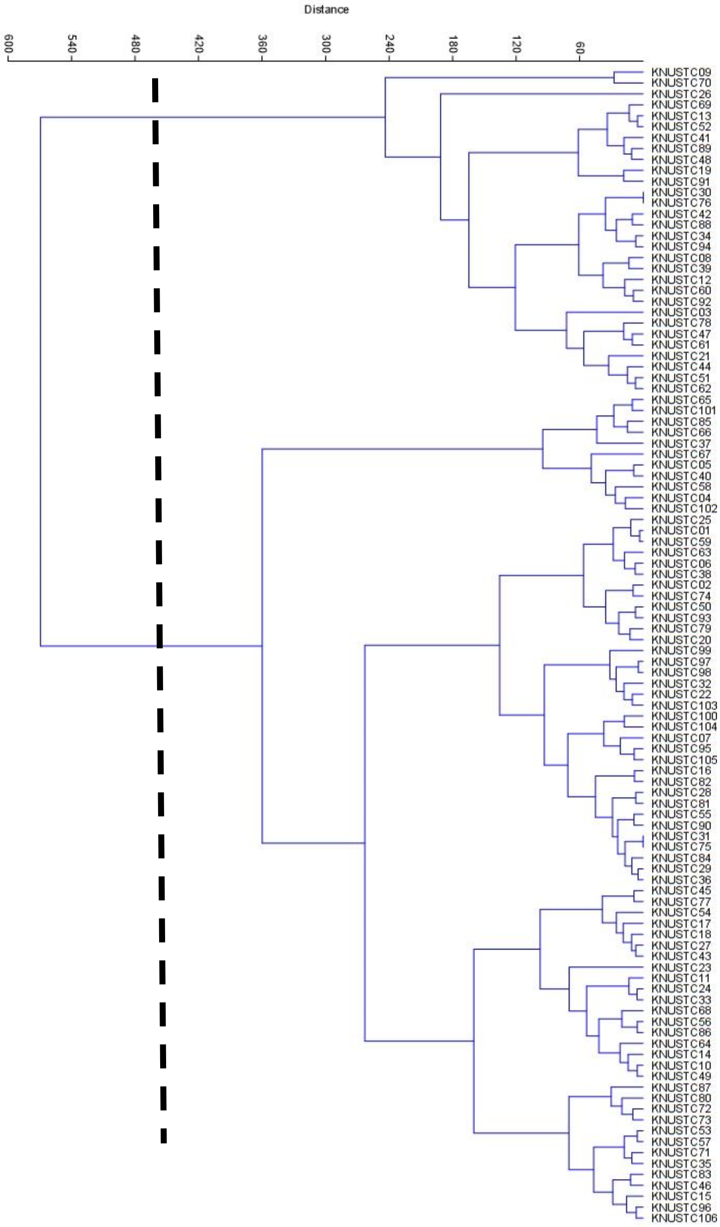

Fig 1. Hierarchical cluster analysis of 106 accessions of Jute mallow.

Table 2. Correlation among various agronomic traits of 105 accession of Jute mallow (*Corchorus olitorius*)

	PH	NB	NL	L	LL	LW	SD	SH	GH	SL	LM	LS	DM
PH													
NB`	0.380*												
NL	0.526*	0.287*											
L	0.587*	0.558*	0.433*										
LL	0.369*	0.563*	0.245*	0.398*									
LW	0.467*	0.528*	0.281*	0.233*	0.739*								
NP	0.136	-0.130	0.331*	-0.128	-0.244*	-0232*							
SD	0.149	0.321*	0.084	0.199*	0.290*	0.252*							
SH	0.295*	-0.089	-0.249*	-0.182	-0.103	-0.165	0.238*						
GH	0.354*	-0.056	-0.052	-0.073	-0.038	0.094	0.037*	-0.011					
SL	0.111	0.075	0.057	0.140	0.002	0.064	0.109	-0.068	0.034				
LM	0.180	-0.103	-0.118	-0.200	0.007	-0.112	0.146	0.355*	0.060	-0.563*			
LS	0.131	0.074	0.178	-0.083	0.207*	0.267*	0.138	0.021	0.043	0.051	-0.047		
DM	0.488*	0.493*	0.154	0.356	0.508*	0.484*	0.303	0.130	-0.062	0.191	0.107	0.180	

KEY: PH = plant height, NB = number of branches, NSL = number of sub-leaves, LL= leaf length, LW = leaf width, SD = stem diameter, SH = stem habit, GH = growth habit, SL = stem leaves NL= number of leaves, LM = leaflet margin, LS = leaf surface, DM = dry matter

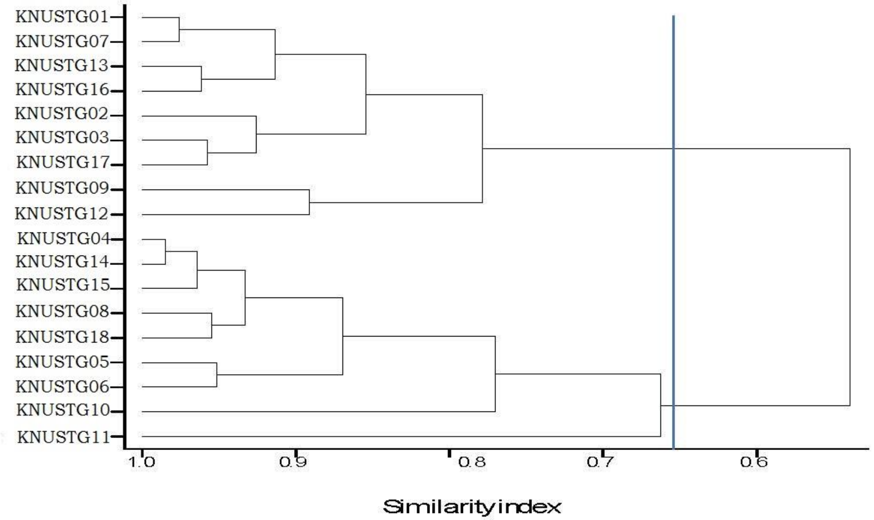

Fig 2. Cluster analysis of the 18 accessions of Gboma eggplant.

Table 3. Principal component analysis for *Corchorus olitorius*

Traits	PC1	PC2	PC3
Plant height	0.400	0.057	0.101
Number of branches per plant	0.299	-0.157	-0.071
Number of leaves per plant	0.300	-0.124	0.193
Number of sub leaves per plant	0.390	-0.108	0.259
Leaf length	0.388	0.184	-0.121
Leaf width	0.392	0.114	-0.205
Number of plants per pot	-0.158	0.162	0.525
Stem diameter	0.182	0.378	-0.037
Stem habit	-0.146	0.415	0.022
Growth habit	-0.064	-0.035	-0.587
Leaflet surface	0.074	-0.436	0.065
Leaflet margin	-0.102	0.537	0.014
Leaf shape	0.135	0.117	-0.402
Dry matter	0.294	0.251	0.190
Eigenvalue	3.875	1.927	1.428
Proportion(%)	27.7	13.8	10.2
Cumulative(%)	27.7	41.4	51.6

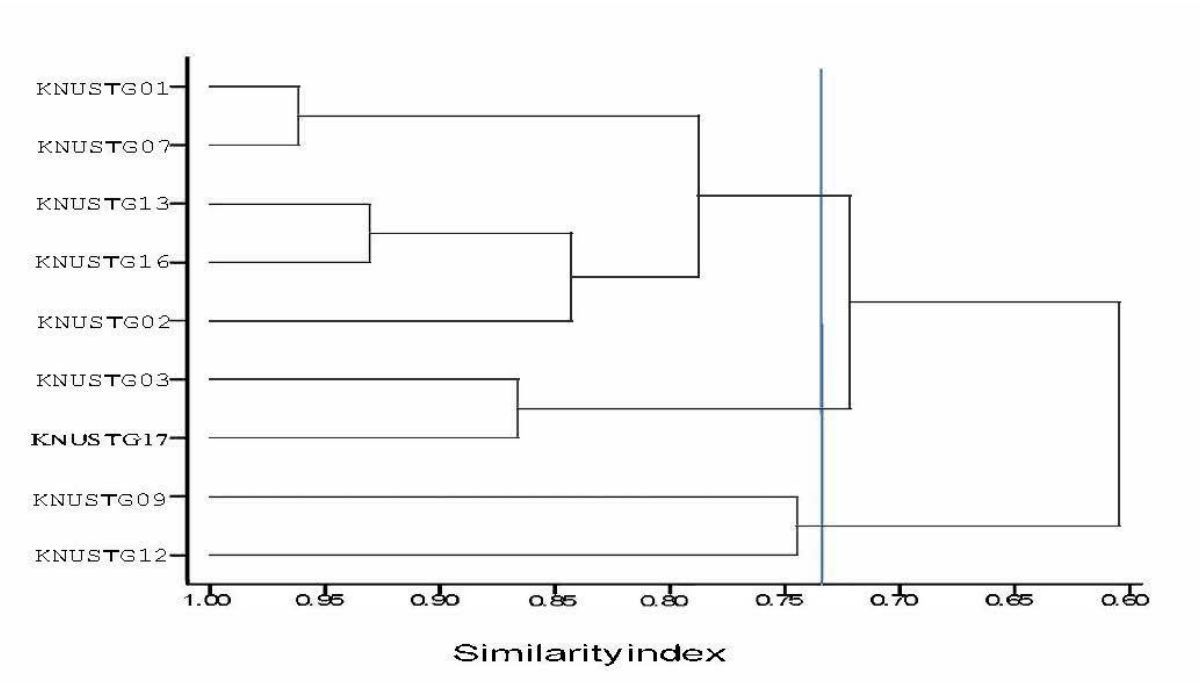

Fig 3. Sub-cluster analysis of cluster I of figure 4

Table 4. Descriptive statistics for the Agro-morphological characters of gboma eggplant

Trait	Mean±SE	SD	Variance	Median
Leaf blade length	20.30±0.81	3.42	11.67	19.30
Leaf blade width	10.24±0.42	1.76	3.11	10.60
Plant height	58.34±2.06	8.73	76.18	56.60
Tip angle of leaf blade	74.22±2.49	10.55	111.24	75.00
Leaf prickles	0.67±0.67	2.83	8.00	0.00
Leaf blade lobing	1.33±0.14	0.59	0.35	1.00
Corolla colour	1.44±0.15	0.62	0.38	1.00
Fruit length	1.17±0.09	0.38	0.15	1.00
Fruit colour at commercial ripeness	2.39±0.28	1.20	1.43	2.50
Fruit curvature	1.00±0.00	0.00	0.00	1.00
Fruit cross section	1.00±0.00	0.00	0.00	1.00
Fruit apex shape	1.00±0.00	0.00	0.00	1.00

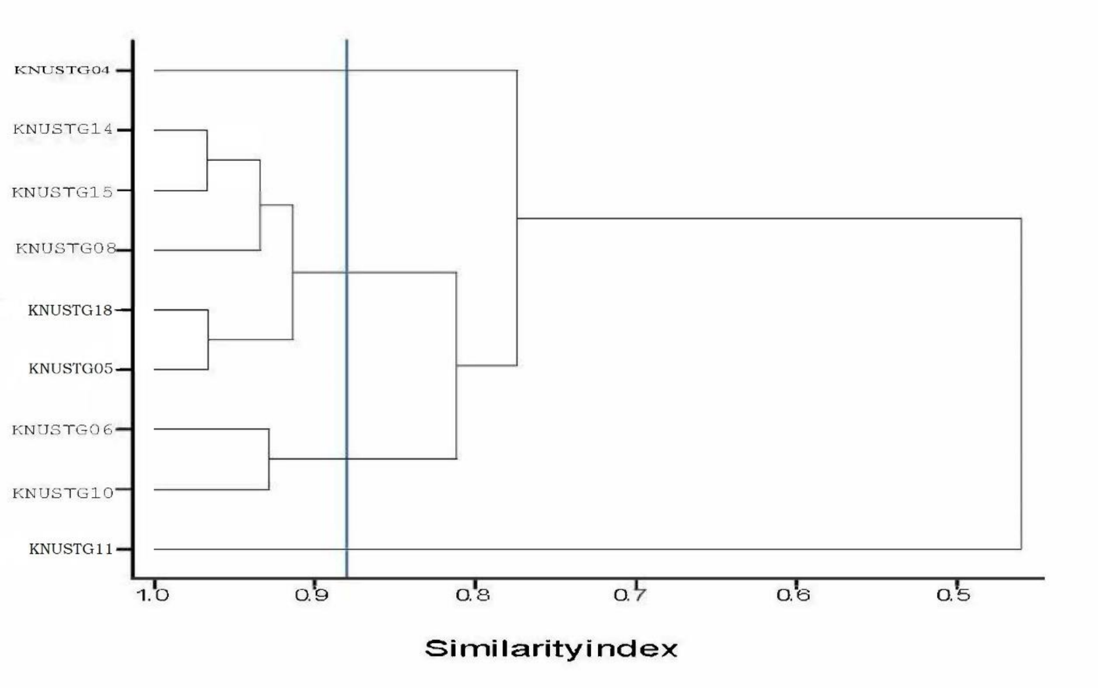

Fig 4. Sub-cluster analysis of cluster II of figure 4

Table 5. Correlation among various agronomic traits of 18 accession of Gboma eggplant

	LBL	LBW	PH	LBTA	LBL	CC	FL	FCCR
LBL	I							
LBW	0.616*	I						
PH	0.123	-0.036	I					
LBTA	-0.172	-0.231	-0.321	I				
LBL	0.400	0.054	0.131	0.016	I			
CC	0.394	0.205	0.179	-0.135	0.054	I		
FL	0.000	-0.167	0.284	-0.090	0.000	0.415	I	
FCCR	0.206	0.534*	-0.469*	0.268	0.221	-0.089	-0.150	I

KEY: LBL = Leaf blade length, LBW = Leaf blade width, PH = Plant height, LBTA = Leaf blade tip angle, LBL= leaf blade lobing, CC = Corolla Colour, FL = Fruit length, FCCR = Fruit Colour at commercial ripeness

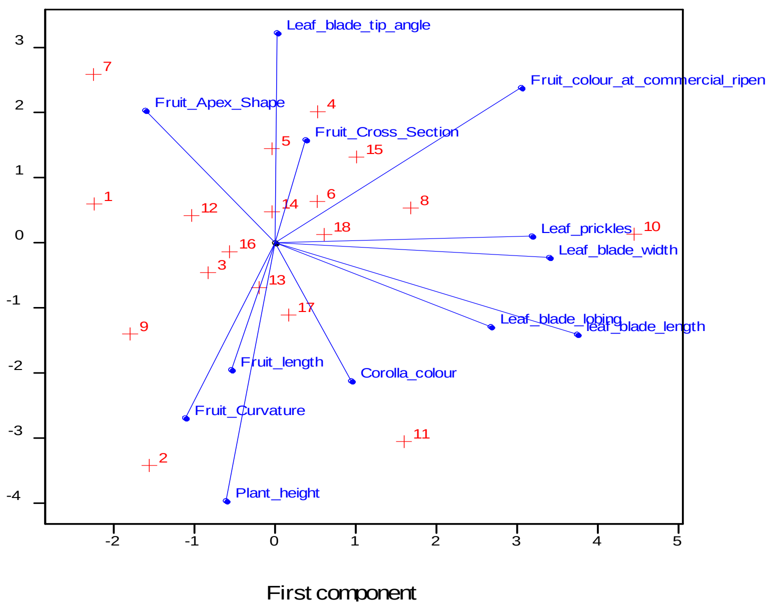

Fig 4. Bi-plot analysis of the 18 Gboma accessions.

Table 6. Principal component analysis for *Solanum macrocarpon*

Trait	PC1	PC2	PC3
leaf blade length	0.428	0.371	0.079
Leaf blade width	0.458	0.044	0.482
Plant height	-0.164	0.464	0.022
Leaf blade tip angle	0.016	-0.326	-0.271
Leaf prickles	0.432	0.105	-0.443
Leaf blade lobing	0.348	0.248	-0.453
Corolla colour	0.019	0.425	0.297
Fruit length	-0.160	0.339	0.108
Fruit colour at ripeness	0.456	-0.266	0.068
Fruit Curvature	0.196	-0.317	0.426
Eigenvalue	2.586	2.166	1.623
Proportion(%)	25.9	21.7	16.2
Cumulative(%)	25.9	47.5	63.8

weeding and fertilizer application were carried out. Eighteen different accessions of gboma eggplant were nursed in three liters plastic pots with well-sterilized sandy-loam soil which were kept under safe conditions. All recommended measures were considered after nursery. After four weeks, seedlings were transplanted into six liters plastic pots of widths and depths of 25 cm and 30 cm, respectively. These pots were filled with a well-sterilized sandy loam soil and arranged using RCBD with three replications in a lath house. Before transplanting, seedlings were watered to soften the soil for easy lifting of the roots in order to prevent damage to the roots. Agronomic practices such as watering, weeding and fertilizer application were carried out.

Data collection; Jute mallow

The morphological characterization was based on 12 quantitative and 8 qualitative characters. The quantitative characters which were considered were 50 % flowering, plant height, number of branches per plant, number of leaves per plant, leaf length, leaf width, fresh leaf weight, stem diameter, number of fruit per plant, fruit length, fruit diameter and number of seeds per pod and 100 seed weight. Under the qualitative characters, we have stem types, growth habit, and leaflet surface, leaflet type, leaflet margin, fruit shape. The scoring for each of the characters was based on the guidelines stipulated by USDA and Germplasm Resources Information Network (GRIN). The stem type was based on the rating scale of 1–3 where 1=branched, 2=not branched. Crop canopy behaviour was considered as growth habit. The growth will be observed for bushy (score =1) and canopy pattern (score = 3). Leaflet surface was based on a rating scale of 1 – 3, where 1=glabrous and 3=pubescent types. The margin of leaflet was observed for the presence of serrated margin (score=1) and smooth margin pattern (score = 3). The size and shape of the leaflet was recorded as narrow shape (score = 1) and broad (score = 3). The shape and size of the fruit will be observed as short or stout (score = 1) and slim or long (score = 3).

Data collection; gboma eggplant

Flowers from which seeds were collected for further conservation were emasculated. All data were taken using eggplant descriptor. The plant height of each accession was measured after flowering with the meter rule. This was done using the eggplant descriptor. The height was categorized as follows; ≤20 cm = very short, 20-30 cm = short, 30-60 cm = intermediate, 60-100 cm = tall and ≥150 cm = very tall.

All the accessions were upright. The length of the leaf was measured using the meter rule. When the length is within 10 cm, it is classified as short, within 20 cm, it is recorded as intermediate and within 30 cm, it is recorded as long. The width of the leaf blade was measured with a meter rule; when the width is within 5 cm, it is scored as narrow, within 10 cm, it is intermediate and within 15 cm, it is wide. Leaf blade lobing was determined using visual observation. This was categorised as very weak, weak, intermediate, strong and very strong. Leaf prickles determination was done by counting the number of prickles on the upper and the lower surface of the leaf. Where there was no prickle, it was described as none, when the number is within 1-2, it is categorised as very weak, within 3-5, it is considered few, within 6-10, it is intermediate, within 11-20, it is many and greater than 20 is considered very many. Fruit length or breath ratio was determined by visual observation. The shapes of the fruit were recorded as described in the descriptor. These were; broader than long, as long as broad, slightly longer than broad, twice as long as broad, three times as long as broad, and several times as long as broad.

The corolla colour was also determined based on visual observation. These were greenish white (Methuen 30A2), white (Methuen 1A1), pale violet (Methuen 18A3), light violet (Methuen 18A5) and bluish violet (Methuen 18A7). The colours of the fruit at commercial ripeness were observed. When the colour is green, it is recorded as (Methuen 27D8), when it is milk-white, it is recorded as (Methuen 1A2), when it is deep green, it is recorded as (Methuen 3A8). When the colour is fire-red, it is recorded as (Methuen 7A), when it is scarlet-red, it is recorded as (Methuen 9A8), when it is lilac-grey, it is (Methuen 16C3), when it is purple, it is recorded as (Methuen 16D-E8), when it is purple-black, then it is categorised as (Methuen 15F5-8). The curvatures of the fruit were identified based on visual observation. The descriptor was used to determine the shapes of the fruit. The shapes were none, slightly curved, curved, snake shaped, sickle shaped and U shaped. In this case, all the fruits were none in terms of shape. The crosssections of the fruits were also identified by visual observation. They were categorized as no grooves, elliptic no grooves, few grooves, many grooves and very irregular. The apex shape of the fruit in the descriptor was given as protruded, rounded, and depressed. The apex of the fruit shape observed in this study were all rounded based on our observation.

Data analysis; jute mallow and gboma eggplant

Data collected were subjected to Analysis of Variance (ANOVA) using GenStat® statistical software, Version 12 (GenStat, 2009). Principal Components Analysis (PCA) and descriptive statistics were performed using MINITAB® statistical software. Computation of Pearson coefficients of correlation among the various agro-morphological traits was done using the same software. Cluster analysis was carried out using PAST® and GenStat® statistical software.

Conclusion

Core collections provide a wide range of diversity for greater utilization in breeding programmes. Core collection of jute mallow (*Corchorus olitorious*) and that of gboma eggplant (*Solanum macrocarpon*) would be valuable resources for the development of improved cultivars of these indigenous vegetables of Africa.

Acknowledgements

The authors would like to acknowledge the immense contributions of the farmers across the various districts who provided with the opportunity to collect accessions from their farms.

Conflict of Interest Statement

This research article is an account of our own research and has not been published elsewhere.
Work of other researchers which served as references has been duly acknowledged.

References

Abu-Hadid AF, El-Shinawy, M., El-Bethagy AS, Gaafer SA, Medany M (1994) Studies on the production of off-season Jew's mallow (Malokhia) in Egypt. Egy J Hort. 21:187-193.

Adeniyi SA, Ahiagbonare JE, Nwangwu, SCO (2012) Nutritional evaluation of some staple leafy vegetables in Southern Nigeria. Int J Agr Food Sci. 2(2): 37-43.

Adeyeye EI, Adanlawo IG (2011) Amino acid composition of the ripe fruits of *Solanum aethiopicum* and *Solanum macrocarpon*. Int J Pharma Bio Sci. 2(2):40-51.

Agoreyo BO, Obansa ES, Obanor EO (2012) Nutritional and Phytochemical Analyses of Varieties of *Solanum melongena*. Sci W J. 7 (1):23-42

Akinnifesi FK, Kwesiga F, Mhango J, Chilanga T, Mkonda A, Kadu, CAC, Kadzere I, Mithöfer D, Saka JDK, Sileshi G, Ramadhani T, Dhliwayo P (2006) Towards the development of miombo fruit trees as commercial tree crops in southern Africa. For Trees Livel. 16(1): 103−121.

Akinnifesi FK, Sileshi G, Ajayi OC, Chirwa PW, Harawa R (2008) Contributions of Agroforestry research and development to livelihood of smallholder farmers in Southern Africa. 2. Fruit, medicinal, fuelwood and fodder tree systems. Agric J. 3(1): 76−88.

Arnold JEM, Ruiz PM (2001) Can non-timber forest products match tropical forests conservation and development objectives? Ecol Econ. 39: 437−447.

Barku VYA, Opoku-Boahen Y, Owusu-Ansah E, Dayie NTKD, Mensah FE (2013) *In-vitro* Assessment of Antioxidant and Antimicrobial Activities of Methanol Extracts of Six Wound Healing Medicinal Plants. J Nat Sci Res. 3(1): 74-80.

Chweya J.A. and Eyzaguirre, P. (eds) (1999). The biodiversity of traditional leafy vegetables. IPGRI, Rome, 182 p.

Chipurura B, Muchuweti M, Parawira W, Kasiyamhuru A (2011) An assessment of the phenolic content, composition and antioxidant capacity of *Bidens pilosa,Cleome gynandra, Corchorus olitorius, Galinsoga parviflora* and A*maranthus hybridus* ISHS Acta Hort. 911:417-426.

Cunningham AB (1997) Review of the ethnobotanical literature from eastern and southern Africa. Afr Ethnobot Netw Bull. 1: 23−88.

Dansi A, Adoukonou-Sogbajda H, Vodouhe R (2010) Diversity, conservation and related wild species of Fonio millet (*Digitaria* spp.) in the North West of Benin. Genet Resour Crop Evol 57(6):827–839

Dounias E, Rodrigues W, Petit C (2000) Review of the ethnobotanical literature for Central and West Africa. Afr Ethnobot Netw Bull. 2: 5−117.

Dudnik NS, Thorman I, Hodgkin T (2001) The extent of use of plant genetic resources in research – A literature survey. Crop Sci. 41:6-10

Duke JA, Wain KK (1981) Medicinal plants of the world. Computer index with more than 85,000 entries. 85(000):3.

FAO (1988) Traditional food plants. FAO Food and Nutrition Paper. FAO, Rome, No. 42.

FAO (2006) Food and Agriculture Organization of United Nations (FAO) Choice Reviews Online (2) 44-0913-44-0913

Fleurent A (1979) The role of wild foliage plants in the diet: A case study from Lushoto, Tanzania. Ecol Food Nutr. 8: 87–93.

Frankel OH (1984) Genetic perspectives of germplasm conservation. In: W. Arber K, Llimeee WJ, Peacock P, Starlinger (eds.) Genetic Manipulation: Impact on Man and Society. Cambridge University Press, Cambridge. Pp.161-170

Frary A, Doganlar S, Daunay MC, Tanksley SD (2003) QTL analysis of morphological traits in eggplant and implications for conservation of gene function during evolution of solanaceous species. Theor App Genet. 107:359-370.

Freberger CE, Vanderjagt DJ, Pastuszyn A, Glew RS, Garba M, Millson M, Glew RH (1998) Nutrient content of edible leaves of seven wild plants from Niger. Plant Foods Hum Nutr. 53 (1), 57-69.

Furini A, Wunder J (2004) Analysis of eggplant (*Solanum melongena)*-related germplasm. Morphological and AFLP data contribute to phylogenetic interpretation and germplasm utilization. Theor App Genet. 108: 197-208

Furumoto T, Wang R, Okazaki K, Ali MI, Kondo A, Fukui H (2002) Antitumor promoters in leaves of Jute (*Corchorus capsularis* and *Corchorus olitorius*). Food Sci Technol Res. 8: 239–43.

Gockowski J, Mbazo'o J, Mbah G, Moulende TF (2003) African traditional leafy vegetables and urban and peri-urban poor. Food Pol. 28 (3): 221-235.

Godoy RA, Bawa KS (1993) The economic value and sustainable harvest of plants from the tropical forest: Assumptions, hypothesis and methods. Econ Bot. 47(3): 215−219.

Gomez OJ, Blair MW, Frankow-Lindberg BE Gullberg U (2005) Comparative study of common bean (*Phaseolus vulgaris* L.) landraces conserved *ex situ* in genebanks and *in situ* by farmers. Genet Resour Crop Evol. 52:371-380.

Hammer Ø, Harper David AT, Ryan PD (2001) PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palae Elect. 4(1): 9pp., 178kb.

Hazra P, Basu D (2000) Genetic variability, correlation and path analysis in okra. Annal Agri Resources. 21(3): 452-453.

Imungi JK (2002) The brighter side of phenolic compounds abundance in African leafy vegetables in IPGRI. Newsletter for Sub-Saharan Africa. 17:7-13.

Imungi JK, Porter NN (1983) Nutrient content of raw and cooked cowpea leaves. J Food Sci. 48: 1252-1254.

Kadu CAC, Imbuga M, Jamnadass R, Dawson IK (2006) Genetic management of indigenous fruit trees in southern Africa. A case study of *Sclerocarya birrea* based on nuclear and chloroplast variation. SA J Bot. 72: 421−427.

Khan M, Bano S, Javed K, Mueed MA (2006) A comprehensive review on the chemistry and pharmacology of *Corchorus* species - A source of cardiac glycosides, triterpenoids, ionones, flavonoids, coumarins, steroids and some other compounds. J Sci Ind Res. 65: 283–98.

Kimiywe J, Waudo J, Mbithe D (2006) Reducing hidden hunger and malnutrition through traditional foods. Nairobi, IPGRI Newsletter for sub-Saharan Africa. Issue No. 21.

Kumawat BK, Gupta M, Singh TY (2012) Free radical scavenging effect of various extracts of leaves of *Balanites aegyptiaca* (L.) Delile by DPPH method. Asia J Pl Sci Res. 2 (3):323-329

Kwarteng AO, Ghunney T, Amoah RA, Nyadanu D, Abogoom J, Nyam KC, Ziyaaba JZ, Danso EO, Whyte T, Asiedu DD (2017) Current knowledge and breeding avenues to improve upon Frafra potato (*Solenostemon rotundifolius* (Poir.) JK Morton). Genet Resour Crop Evol. pp.1-11

Ladio AH, Lozada M (2004) Patterns of use and knowledge of wild edible plants in distinct ecological environment: A case study of a Mapuche community in Patagonia. Biodiv Conserv. 13(6): 1153−1173.

List PH, Horhammer L (1979) Hager's handbuch der pharmazeutischen praxis. vols 2-6.

Matsufuji H, Sakai S, Chino M, Goda Y, Toyoda M, Takeda M (2001) Relationship between Cardiac Glycoside Contents and Color of *Corchorus olitorius* Seeds. J Hea Sci. 47(2): 89-93.

Maundu PM (1995) The status of traditional vegetable utilisation Kenyan. In: Guarion L (ed) Traditional African Vegetables Proceedings of the IPGRI International Workshop on Genetic Resources of traditional vegetables in Africa: Conservation and Use. 29th–31st, August 1995, Rome, IPGRI

McGregor J (1995) Gathered produce in Zimbabwe's communal areas changing resource availability and use. Ecol Food Nutr. 33(3): 163−193.

Mnzava NA (1997) Comparing nutritional values of exotic and indigenous vegetables. In: Schippers R, Budd L (eds) African indigenous vegetables. ODA, UK, 70-75.

Muok BO, Matsumura A, Ishii T, Odee DW (2009) The effect of intercropping *Sclerocarya birrea* (A. Rich.) Hochst. Millet and corn in the presence of arbuscular mycorrhizal fungi. Afr J Biotechnol., 8(5): 807−812.

Naujeer HB (2009) Morphological diversity in eggplant (*Solanum melongena* L.), their related species and wild types conserved at the National gene bank in Mauritius. Master Thesis No. 57. Swedish Biodiversity Centre.74 p.p.

Nesamvuni C, Steyn NP, Potgieter MJ (2001) Nutritional value of wild, leafy plants consumed by the Vhavenda. SA J Sci. 97(1/2): 51−54.

Nwodo SC, Abayomi CO, Eboji OK, Opeyemi CE, Olajumoke AK, Damilola ID (2011) Proximate and Phytochemical Analysis of *Solanum aethiopicum* L. and *Solanum macrocarpon* L. fruits. Res J Chem Sci. 1(3):436-439.

Nyadanu D, Amoah RA, Kwarteng AO, Akromah R, Aboagye LM, Adu-Dapaah H, Dagadu FK, Kyirika D, Joti KG, Oppong G (2017) Combining ability and genetic analysis of fruit and leaf yield in gboma eggplant. Afr Crop Sci J. 25(1):97-107.

Nyadanu D, Amoah RA, Kwarteng AO, Akromah R, Aboagye LM, 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. Genet Res Crop Evol. 1;64(6):1313-29.

Nyadanu D, Amoah RA, Obeng B, Kwarteng AO, Akromah R, Aboagye LM, Adu-Dapaah H (2017) Ethnobotany and analysis of food components of African locust bean (*Parkia biglobosa* (Jacq.) Benth.) in the transitional zone of Ghana: implications for domestication, conservation and breeding of improved varieties. Genet Resour Crop Evol. 64(6):1231-40.

Nyadanu D, Lowor ST (2015) Promoting competitiveness of neglected and underutilized crop species: comparative analysis of nutritional composition of indigenous and exotic leafy and fruit vegetables in Ghana. Genet. Resour Crop Evol. 1;62(1):131-40.

Paredes CM, Becerra VV, Tay JU, Blair MW, Bascur GB (2009) Selection of a representative core collection from the Chilean common bean germplasm. Chil J Agric Res. 70(1):3-15.

Portis E, Nervo G, Cavallanti F, Barchi L, Lanteri S (2006). Multivariate analysis of genetic relationships between Italian pepper landraces. Crop Sci. 46: 2517-2525.

Rao VR, Hodgkin T (2002) Genetic diversity, conservation, and utilization of plant genetic resources. PCTOC 68:1-19.

Scherrer AM, Motti R, Wecherle CS (2005) Traditional plant use in the areas of Monte Vesole and Ascea National Park (Campania, Southern Italy). J Enthopharmacol. 97(1): 129−143.

Schippers RR (2000) African Indigenous Vegetables. An overview of the cultivated species. Chatham, U.K. Natural Resources Institute/ACP-EU Technical Centre for Agriculture and Rural Cooperation. Pg i–214 2

Shackleton CM, Shackleton SE (2004) The importance of non-timber products in rural livelihood security and as safety-nets: A review of evidence from South Africa. SA J Sci. 100: 658−664.

Shackleton SE, Shackleton CM, Dzerefos CM, Mathabela FR (1998) Use and trading of wild edible herbs in central the Lowveld savanna region, South Africa. Econ Bot. 52(3): 251−259.

Shackleton SE, Shackleton CM, Netshiluvhi TR, Geach BS, Balance A, Fairbanks DHK (2002) Use patterns and value of savannah resources in three rural villages in South Africa. Econ Bot. 56(2): 130−146.

Steyn NP, Olivier J, Winter P, Burger S, Nesamvuni S (2001) A survey of wild, green, leafy vegetables and their potential in combating micronutrient deficiencies in rural populations. SA J Sci. 97: 276-279.

Upadhyaya HD, Thudi M, Dronavali N, Gujaria N, Singh S, Sharma S, Varshney RK (2011) Genomic tools and germplasm diversity for chickpea improvement. Plant Genet Res. 9: 45-58.

Zeghichi S, Kallithraka S, Simopoulos AP (2003) Nutritional composition of molokhi (*Corchorus olitorius*) and stamnagathi (*Cichorium spinosum*). World Rev Nutr Diet. 91: 1–21.