International Scholars Journals

International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 6 (6), pp. 1048-1058, June, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Phenotypic characterization of selected African eggplant accessions collected from a number of African countries

G. W. Mungai[1], J.J. Giovanonni[3], A.B. Nyende[1], J. Ambuko[2] and W. Owino[1*].

[1]Jomo Kenyatta University of Agriculture and Technology P. O. Box 62000 - 00200 Nairobi, Kenya.
[2]University of Nairobi P.O. Box 29053-00625 Nairobi, Kenya.
[3]Cornell University; Boyce Thompson Institute 533 Tower Road Ithaca, New York14853.

Received 27 April, 2016; Accepted 02 June, 2016; Published 16 June, 2016

Africa is home to a variety of Solanaceae crops including the African eggplant used as food and for income generation. However, African eggplant has not been characterized to show their diversity to inform crop improvement programs. This study was carried out to evaluate the morphological diversity of the African eggplants. Sixty-seven African eggplants accessions collected from the Asian Vegetable Research and development center- regional center for Africa (AVRDC- RCA) in Arusha Tanzania were planted using complete random block design in 18 replicates. The morphological data collected was subjected to Genstat's univariate analysis, bivariate, multivariate and Darwin6 software for statistical analysis. The dendogram grouped the accessions into two main clusters with majority falling in cluster 2 revealing a narrow genetic base in the cluster. Many singletons formed suggest divergent genetic background hence useful for out crossing to other accessions. Clustering was contributed by the plant growth habit, fruit shape and fruit colour. Cluster 1 was constituted by accessions exhibiting prostrate and very prostrate growth habit while cluster 2 was composed of intermediate, tall and very tall. Overlapping accessions in the biplot revealed close relationship between many of the accessions studied as well as a considerably wide diversity for a few accessions. Accessions RV100328, RV100194 and RV100346 clustered far from the rest showing high variation based on morphological characters. Analysis of variance showed significant phenotypic variations in the accessions at P<0.05. Eight of the 14 Principal component (PC) analysis were significant accounting for 70.6% variation. PC-1 accounted for 16.02 %whereas PC-2 accounted for 12.29%. The findings of this study reveal significant variation among the selected African eggplant mainly contributed by plant height, leaf blade length, leaf blade width and fruit width. Substantial variation among the 67 accessions was also observed in fruit colour, fruit shape, fruit texture, leaf base and leaf lade colour.

Key words: Morphological, Solanaceae, Singletons, eggplant accessions.

INTRODUCTION

The African eggplant (*Solanum aethiopicum, S. Macrocarpon and S. anguivi*) is a wild relative of the well known eggplant (*Solanum melongena*) but they are all commonly refered to as eggplant belonging to the solanaceae family (AVRDC, 2002).

Eggplant is ranked 3rd most important crop from Solanaceae family after potato and tomato, with a world production of 32 million tonnes. The greatest produces are China(18 Mtons, India 8.4 M tons, Egypt 1M tons and Turkey at 0.8 M tons, Italy 0.3M tons and Spain 0.2M

*Corresponding author. E-mail: willis@agri.jkuat.ac.ke

tons (FAOSTAT 2007).

Eggplant is a good source of Iron , Calcium, Phosphorous, Potassium, Vitamin B . its fresh weight is composed of 92.% moisture, 1% proteins, 1.3% fibre, 0.3% fat, 0.3% minerals and 4% carbohydrates and vitamins A and C(Haushna et al 2009).

African eggplants are perennial deciduous shrubs with or without prickles on the leaf and stems, they can grow up to 2m tall; they have branched stems, vertical and lateral roots, alternate leaves, up to 12 bisexual flowers, fruit (berries) shape ranges from globular to depressed globular, elliptic in outline, egg-shaped or spindle-shaped, 1-6 cm long, smooth to grooved, and they appear in different colours including red, green, purple, orange, white, yellow among others (Sunseri *et al,.*2010).

African eggplant is mainly found in Asia and tropical Africa. It is also referred to as, the bitter tomato, Ethiopian eggplant or nakati, Ethiopian nightshades, garden eggs, and mock tomato, these names are a result of its varied morphology, with ripe fruit often looking like a cross between an eggplant and a tomato.

The orange-red fruit is eaten boiled, steamed, pickled, or in stews with other vegetables or meats. Young leaves are cut and used in soups. African eggplants leaves are known to have extremely high beta carotene, ascorbic acid, calcium, iron, proteins but, low in fruit. Vitamin E, folic acid, ascorbic acid, calcium, iron, proteins and riboflavin are also found in high quantities in eggplant fruit. Leaves also contain oxalic acid and alkaloids, which possess anti-inflammatory and immunosuppressive properties. The bitter taste in leaves is attributed to furostanol glycosides especially saponins (Sarah and Maina, 2008).

To identify and estimate the genetic diversity of plants, various methods can be used including morphological, biochemical and molecular markers. Morphological markers are important diagnostic features for distinguishing genotypes and are the mostly used to study of genetic variation in plant species (Osei *et al.,* 2014).

Phenotypic variation is important for evolution by natural selection which affects the genetic structure of a population. Genetic diversity is important for determination of organism’s physical form and functions. It also helps the organism in question to cope with environmental variability and reduces potential deleterious effects of breeding among close relatives (Allen et al., 1996).

The aim of present study was to evaluate the morphological diversity within different African eggplants accessions using standard morphological descriptors (INIBAP, 2003). This will allow studying the diversity and identification of potentially interesting accessions for selection and breeding, as well as developing strategies for conservation and management of germplasm.

MATERIALS AND METHODS

African eggplant accessions

Sixty-Seven African eggplant accessions were collected from the Asian Vegetable Center, Regional Center for Africa (AVRDC-RCA), Arusha, Tanzania (Table 1).

Viability check and Pre- germination

Ten seeds of each accession were planted on petri-dishes with wet paper for 10 days ensuring the paper did not dry out during this time. All accessions with 70 to 90 % germination were used for pre-germination on trays containing peat moss media in the greenhouses at Jomo Kenyatta University; Institute of Biotechnology Research laboratory.

After four weeks, Germinated seeds were transplanted in potting bags containing well mixed forest soil, and manure in the ratio of 3:1 and placed in the Institute of Biotechnology Research greenhouse.

Experimental design and layout

A randomized complete block design was used to set up an evaluation plot in an open field at the JKUAT farm.The67 accessions were sown in three blocks each containing 3 x 2 m three plots. Six plants per accession with three replications were grown such that 18 plants per each accession, with a total of 1, 206 plants from all 67 accessions were grown.

Uniform crop management practices (watering, weeding, pruning, labelling application of fungicides and pesticides)were applied to all entries (Table 2.),according to the “guide Agricole 2004” a vegetable cultivation manual. This included labelling, watering daily, weeding was done regularly, pruning was done using secateurs to remove the old lower leaves.

Phenotypic characterization

Measurements and observations were taken from six tagged individual plants selected from 18 plants from each accession. Phenotyping was carried out using nine quantitative and nine qualitative traits to estimate the levels of variation among the eggplant accessions according to IPGRI,1993 (Table 3).

Vegetative data was collected when 50% of the plants had flowered, while the fruit data was collected at mature green, mature breaker and mature red stages. The data was recorded as recommended by IPGRI, 1993 (Table 1).

Data analyses

Analysis of variance (ANOVA) was carried out to determine genetic diversity of themeasured16 quantitative traits. Means for each trait were separated by the least significant difference (LSD)at ($p < 0.001$, 0.01 and 0.05). Phenotypic correlation coefficients were computed to examine the degree of association among the quantitative traits. Multivariate analysis of variance (MANOVA) was conducted to reveal the patterns of phenotypic diversity of quantitative traits studied.

RESULTS AND DISCUSSION

Morphological characterization at vegetative and reproductive stage

Significant differences were observed in the various morphological characteristics evaluated at the vegetative

Table 1. Accession number and scientific name of the African Eggplant used in this study.

S/no	Accession number	Country of Origin	Scientific name	S/no	Accession number	Country of Origin	Scientific name
1	RV100245	Mali	*Solanum aethiopicum*	35	RV100364	Uganda	*Solanum anguivi*
2	RVI00334	Mali	*Solanum aethiopicum*	36	RV100252	Mali	*Solanum aethiopicum*
3	RV100359	Uganda	*Solanum anguivi*	37	RV100263	Mali	*Solanumaethiopicum*
4	RV100352	Uganda	*Solanum aethiopicum*	38	RV100239	Mali	*Solanum aethiopicum*
5	RV100328	Mali	*Solanum aethiopicum*	49	RV100271	Mali	*Solanum aethiopicum*
6	RV100260	Mali	*Solanum aethiopicum*	40	RV100169	Tanzania	*Solanum aethiopicum*
7	RV100330	Mali	*Solanum aethiopicum*	41	RV100268	Mali	*Solanum aethiopicum*
8	RV100264	Mali	*Solanum aethiopicum*	42	RV100241	Mali	*Solanum aethiopicum*
9	RV100432	unknown	*Solanum spp*	43	RV100386	Ivory Cost	*Solanum aethiopicum*
10	RV100445	unknown	*Solanum spp*	44	RV100377	Uganda	*Solanum aethiopicum*
11	RV100333	Mali	*Solanum aethiopicum*	45	RV100248	Senegal	*Solanum aethiopicum*
12	RV100185	Gabon	*Solanum aethiopicum*	46	RV100265	Mali	*Solanum aethiopicum*
13	RV100259	Senegal	*Solanum aethiopicum*	47	RV100261	Mali	*Solanum aethiopicum*
14	RV100250	Mali	*Solanum aethiopicum*	48	RV100217	Mali	*Solanum aethiopicum*
15	RV100453	unknown	*Solanum spp*	49	RV100327	Mali	*Solanum aethiopicum*
16	RV100342	Cameroon	*Solanum aethiopicum*	50	RV100511	Tanzania	*Solanum aethiopicum*
17	RV1001201	Unknown	*Solanum spp*	51	RV100380	Ghana	*Solanum aethiopicum*
18	RV100452	unknown	*Solanum spp*	52	RV100343	Cameron	*Solanum aethiopicum*
19	RV100270	Mali	*Solanum aethiopicum*	53	RV100360	Uganda	*Solanum aethiopicum*
20	RV1002100	Malawi	*Solanum aethiopicum*	54	RV100382	Madagascar	*Solanum aguivi*
21	RV100455	unknown	*Solanum spp*	55	RV100199	Tanzania	*Solanum spp*
22	RV100385	Madagascar	*Solanum spp*	56	RV100274	Mali	*Solanum spp*
23	RV10332	Burkina Faso	*Solanum aethiopicum*	57	RV100384	Madagascar	*Solanum spp*
24	RV100247	Mali	*Solanum aethiopicum*	58	RV100190	Tanzania	*Solanum spp*
25	RV100249	Mali	*Solanum aethiopicum*	59	RV100325	France	*Solanum anguivi*
26	RV100447	Mali	*Solanu spp*	60	RV100346	Rwanda	*Solanum aethiopicum*
27	RV100335	Cameroon	*Solanum anguivi*	61	RV100262	mali	*Solanum aethiopicum*
28	RV100431	Tanzania	*Solanum spp*	62	RV100243	mali	*Solanum aethiopicum*
329	RV100161	Tanzania	*Solanum aethiopicum*	63	RV100456	unknown	*Solanum spp*
30	RV100273	Mali	*Solanum aethiopicum*	64	RV100166	Tanzania	*Solanum aethiopicum*
31	RV100242	Mali	*Solanum aethiopicum*	65	RV100163	Tanzania	*Solanum aethiopicum*
32	RV100234	Mali	*Solanum aethiopicum*	66	RV100356	Uganda	*Solanum anguivi*
33	RV100438	unknown	*Solanum aethiopicum*	67	RV100215	Mali	*Solanum aethiopicum*
34	RV100240	Mali	*Solanum aethiopicum*				

stage and reproductive stages (Table 4). A range of variation was observed at reproductive stage (fruit colour, fruit shape, fruit size and texture) of the African eggplant.

Plant growth habit (PGH):The sixty - seven accessions segregated into five groups i.e. very tall (10), tall (17), intermediate (21), prostrate (13) and very prostrate (5) accessions (Table 4).Accession RV100511 was the tallest (104 cm) while RV100360 (23cm) was the shortest among the 67 African eggplants.

Number of prickles present (PN): Sixty-four percent of all

Table 2. Uniform crop management practices.

Pest	Pesticide	Dosage per Litre of water	Infestation rate	Application frequency per fortnight
Powdery mildew	Microthiol	3g	Mild	Once
Whiteflies	Azatrol, 1-4 yellow stickers (1000 ft)	2ml	Mild	once
Promopsis fruit rot	Mancozeb 80 NP	2 g	Mild	once
Fruit and shoot borer	Lambda-cyhalothrine	0.5ml	Mild	Once
Fertilizer application				
Nursery	Farm yard manure (FYM)	3kg		
	Ammonium sulphate	15g		
	Potassium sulphate	30g		
	Triple super phosphate	9g		
Transplanting	FYM	1kg		
	CAN	10g		
	Triple super phosphate	8g		
	Potassium sulphate	30g		
	Ammonium sulphate	65g		

Table 2. Uniform crop management practices.
Source: Guide Agricole 2004

accessions did not have prickles on the leaf surface, while 3% (RV100185 and RV100247) having more than 20 prickles, others ranged between 16.4, 1.5,7.5 and 6% for 4, 8 and 15 prickles on the leaf surface respectively (Table 4).

Leaf blade length (LBL) and Leaf lobules (LLL): Leaf blade length ranged between 7.7cm (RV100380)-32.5cm(RV100364 and RV100383) while leaf blade width ranged 5.5cm (RV100328 to 21cm (RV100447).The number of leaf lobules was between 5 to 16 (Table 4).

Leaf vein colour (VC) and Leaf blade colour (LBC): Variations on leaf vein colour formed six groups with most accessions having light green and green colour.The leaf blade colour was distributed among 3 groups with most accessions having the green colour (Table 4).

Plant breadth (PB): Plant breath ranged between 3.5 to 6.3 cm while internode length ranged between 2.9 to 7.7 cm (Table 4).

Stem colour (SC): Stem colour formed six groups; light green (10), green (23), dark green (1), green with purple stripes (25) purple (2) and dark purple (6) (Table 4).

Leaf base shape (LB): Only three groups were formed when the shape of the leaf base was considered, with one accession (RV100199) showing the sessile behavior, 40 had asymmetrical and 26 had the heart shape leaf base (Table 4).

Fruit colour (FC):A diversity of fruit shape and colour; the most important trait in a variety in this study was observed (Fig. 1 Table 4). The fruit shape ranged from round, oval, and oblong shapes, the diverse colour included the red (Fig. 1 a,b and c), yellow (Fig.1d), orange, purple (Fig.1h), yellow with green stripes (Fig. 1g) and white (Fig. 1f).

Fruit shape (FSand Texture: Round fruit shape dominated the fruit shape category with 57 accessions (Fig. 1a, c and f); oval had 7accessions (Fig. 1b, 1d, 1gand 1g) while oblong shape had 3 accessions (Fig. 1e and h). Only two types of fruit surface texture were observed; ridged surface (51 accessions - 1a)) and smooth surface (16 accessions) (Fig. 1b, 1c, 1d,1e, 1f, 1g, 1h) .and Table 4).

Fruit size: Fruits variedin length having between 2 to 12cm and the fruit width having between 4 to 22.6 cm (Fig. 1 and Table 4).

Cluster analysis of the African eggplants using Darwin 6 software

Clustering procedure using the Darwin 6 software grouped the 67 accessions into two main groups and many sub-clusters. Cluster 1 had 18 accessions, all with round fruit shape (RV100455, RV100199, RV100380, RV100456, RV100325, RV100432, RV100386, RV100265, RV100270, RV100215, RV100271, RV100334, RV100236, RV100274, RV100330, RV100240, RV100273 and RV100234). Cluster 1 had a main sub cluster in which all eight accessions had a ridged fruit surface structure except accession RV100199 which had a white smooth fruit surface, (RV100334, RV100236, RV10027, RV100330, RV100240 RV100273 and RV100234) (Fig 2. and Table 4).

Accessions in cluster 1 were either prostrate or very prostrate. Most of the accessions clustered very closely

Table 3. Data collected at 50% flowering(according to IPGRI,1993).

	Quantitative Traits Measured		Qualitative traits observed
1	Flower Heads (FH)	1	Plant growth habit - (very tall, tall, intermediate, prostrate, very prostrate.)
2	Fruit Length (FL)	2	Fruit colour – (red yellow, purple, green, yellow with strips, white, orange)
3	Fruit Width (FW)	3	Fruit Shape – (Round, oval, oblong)
4	Internode Height (IH)	4	Fruit texture - (smooth, ridged)
5	Plant Breadth (PB)	5	Leaf base shape - (sessile, asymmetrical, symmetrical)
6	Plant Height (PH)	6	Leaf blade colour – (light green, green, dark green)
7	Leaf Blade Length (LBL)	7	Petiole colour- (light green, green, purple with green stripes, purple)
8	Leaf Blade Width (LBW)	8	Stem colour – (light green, green, dark green, purple with green stripes, purple, dark purple)
9	Number of Leaf Lobules (LLL)	9	Vein colour-(light green, green, dark green, purple with green stripes, purple, dark purple)

Source: (IPGRI, 1993).

showing a narrow diversity amongst the accessions, i.e accessions RV100445and RV100 265, RV100 215 and RV100271, RV100236 and RV100274, RV100273 and RV100234 grouped very closely. (Fig 2 and Table 4).

Cluster 2 had the most accessions (49). the clustering was mainly dictated by the growth habit. in this cluster, the cluster had two main sub clusters, Cluster 2a constituted of 27 accessions with intermediate growth habit. they included (RV100190, RV100352, RV100458, RV100239 RV100382 RV100161, RV100438, RV100364, RV100377, RV100431, RV100447, RV100335, RV1001201, RV100359, RV100456RV100260, RV100343, RV100247, RV100194, RV100332, RV100511, RV100245, RV100169, RV100249, RV100217, RV100343-CN 012, and RV100356) (Table 4 and Fig 2).

Sub cluster 2b comprised of 22 accessions all with tall and very tall growth habit. They included RV100328, RV100241, RV1002100, RV100250, RV100342, RV100327, RV100266, RV100243, RV100185, RV100268, RV100455, RV100259, RV100264, RV100452, RV100248, RV100333, RV100261, RV100242, RV100346, RV100218, RV100453 and RV100263) (Table 4 and fig 2).

Clustering of the selected African eggplants was not dependent on the country of origin, but mainly on the plant growth habit, fruit colour and texture (Table 4).

Biplot display showing relationships among the African eggplant accessions

Overlapping accessions in the two dimensions revealed a close relationship between many of the accessions studied as well as a considerably wide difference between the characters. Similar to the dendogram presentation, closely related accessions overlapped when the factorial analysis was considered at (axes ½) example of overlapping accessions wereRV100445and RV100265, RV100215 and RV100271, RV100236 and RV100274, RV100273 and RV100234. Accessions RV100328, RV100194 and RV100346 separated themselves from the rest showing high variation based on morphological traits (Fig 3).

Morphological descriptors presenting highly significant differences among the accessions. Accessions which plot in different parts of the biplot would be the most informative for distinguishing accessions with narrow and wide diversity. This is in agreement with the findings of Kisua *et al*., 2015 on his research on genetic diversity of sweet sorghum populations.

Morphological variation in African eggplant accessions using quantitative traits

The African eggplant showed significant diversity in the quantitative traits that were selected for their characterization. The means of the quantitative traits, their minimum and maximum values were significant at $P \leq 0.01$. Plant height, leaf blade length, leaf blade width, and fruit width had a significant contribution to the variation among the selected African eggplant with a mean of 75.17±3.59, 19.44±1.50, 14.76±1.69 and 12.37±1.42 respectively (Table 5).

($P \leq 0.01$ significance level)

Principal component analysis of the quantitative traits

The first eight principal components (PC1, PC 2, PC3, PC4, PC5, PC6, PC7 and PC8analysis covered 70.6% variation for eight PC within the 14 dimensions generated

Table 4. Morphological variations in African eggplant accessions based on (IPGRI, 2003).

	Accessions	Plant growth	Plant height	Leaf blade height	Leaf blade width	Princ-kles	Leaf vein colour	Leaf blade colour	Stem colour	Leaf blade shape	Fruit length	Fruit width	Fruit colour	Fruit shape	Fruit texture
1	RV100383	Very Tall	101	31	26	0	L. Green	L. Green	L. Green	Sym	6.6	13.8	Y+G stripes	Oval	Ridged
2	RV100511,	Very Tall	104	24.7	20.4	0	L. Green	Green	L. Green	Asymm	5	7.3	Orange	Oval	Smooth
3	RV100431	Very Tall	102	24	18	0	Purple	D.Green	D.Purple	Asymm	5	13	Red	Round	Ridged
4	RV100364	Very Tall	102	31	21	0	Purple	D.Green	D.Purple	Sym	6	17	Red	Round	Ridged
5	RV100352	Very Tall	100	17.2	16.2	0	L. Green	L. Green	Green	Sym	6	15	Red	Round	Ridged
6	RV100260	Very Tall	101	18.5	15.4	< 3	Green	D.Green	P+G Stripes	Asymm	6.3	17.6	Red	Round	Ridged
7	RV100169	Very Tall	100	21.3	19.5	0	Green	Green	P+G Stripes	Asymm	4.6	8.6	Yellow	Oval	Ridged
8	RV100359	Very Tall	102	23.7	19.7	0	L. Green	Green	L. Green	Asymm	12.6	15.5	Red	Oval	Ridged
9	RV100458	Very Tall	103	12	8.5	0	P+G stripes	D.Green	P+G Stripes	Sym	5.2	10	Red	Oval	Ridged
10	RV100190	Very Tall	101	13	9.9	0	Green	D.Green	Green	Sym	2	4	Red	Round	Smooth
11	RV100335	Tall	94	16	12.2	0	L. Green	Green	Green	Sym	10.2	22.5	Red	Round	Ridged
12	RV100249	Tall	94	22.2	17.5	0	L. Green	Green	Green	Sym	3.5	8	Red	Round	Ridged
13	RV100194	Tall	93	22.3	15	~15	D. Purple	D.Green	D.Purple	Sym	4	12	Red	Round	Ridged
14	RV100356	Tall	95	22.5	18.7	0	Green	Green	Green	Asymm	2	5	Red	Round	Smooth
15	RV100382	Tall	94	12.9	10.1	0	L.Green	Green	Green	Asymm	4	10	Red	Round	Ridged
16	RV100332	Tall	95	23	15	~15	Green	D.Green	P+G Stripes	Asymm	5	11	Red	Round	Ridged
17	RV100239	Tall	96	11.2	10	0	Green	Green	Green	Asymm	5	12	Red	Round	Ridged
18	RV100245	Tall	96	22	17	< 3	L. Green	Green	P+G Stripes	Sym	4	8	Red	Round	Ridged
19	RV100343	Tall	94	21.1	20	0	Green	D.Green	Green	Sym	2.5	5.8	Red	Round	Smooth
20	RV100201	Tall	95	21.2	15	~ 8	L. Green	Green	L. Green	Asymm	11	11.5	Green	Oblong	Smooth
21	RV100447	Tall	99	29	22	~ 8	Purple	D.Green	Purple	Sym	4.5	11	Red	Round	Ridged
22	RV100161	Tall	94	25.9	12.5	0	Green	Green	L. Green	Asymm	5	13.3	Red	Round	Ridged
23	RV100456	Tall	98	23	17.8	~4	Green	D.Green	P+G Stripes	Asymm	6.5	17.4	Red	Round	Ridged
24	RV100377	Tall	96	28.1	19	0	P+G Stripes	D.Green	P+G Stripes	Asymm	5.7	12.4	Red	Round	Ridged
25	RV100247	Tall	92	21	19	>20	Green	Green	P+G Stripes	Sym	4	10.5	Red	Round	Ridged
26	RV100343-C	Tall	90	21.1	20	0	Green	D.Green	Green	Sym	2.5	5.8	Red	Round	Smooth
27	RV100217	Tall	93	21	15	< 3	Green	Green	L. Green	Asymm	3.2	6	Red	Round	Smooth
23	RV100268	Intermediate	75	25.4	19.5	0	D. Purple	3	D.Purple	Asymm	5.6	12.4	Red	Round	Ridged
24	RV100218	Intermediate	77	16.8	11	0	L. Green	Green	L. Green	Asymm	2	7	Red	Round	Smooth
25	RV100346	Intermediate	75	14	10.1	0	L. Green	Green	P+G Stripes	Asymm	2.2	5	Red	Round	Ridged
26	RV100185	Intermediate	74	25.4	19.1	>20	Purple	D.Green	D.Purple	Asymm	5	11	Red	Round	Ridged
27	RV100259	Intermediate	75	20.4	17.5	0	Green	D.Green	P+G Stripes	Sym	7	16	Orange	Round	Ridged
28	RV100248	Intermediate	76	22	17	<3	D.Green	Green	P+G Stripes	Sym	8	14	Red	Round	Ridged
29	RV100452	Intermediate	77	16.7	15.7	<3	Green	D.Green	Green	Asymm	7	15	Green	Round	Ridged

(Table 6),This suggests that after principal component8 more principal components did not describe much variation. Other studies on sorghum genetics showed similar results (Kisua *et al*., 2014). According to Chat field and Collins (1980), components with an eigen value of < 1 were eliminated so that fewer components were dealt with. Moreover, eigen values greater than one is considered significant.

Table 4. Cont.

Table 4. Morphological variations in African eggplant accessions based on (IPGRI, 2003).

	Acc	Plant growth habit	Plant height	Leaf length	Leaf width	Prickles	vein colour	Leaf colour	Stem colour	Leaf base shape	Fruit length	Fruit width	Fruit colour	Fruit shape	Fruit texture
30	RV1002100	Intermediate	78	16.8	11	0	D. Green	Green	Purple	Asymm	7.3	17.3	Red	Round	Ridged
31	RV100333	Intermediate	75	19.2	17.7	<3	L. Green	Green	L. Green	Asymm	5.4	13	Red	Oval	Smooth
32	RV100266	Intermediate	78	14	10.5	0	L. Green	Green	L. Green	Asymm	5.4	13	Red	Round	Ridged
33	RV100327	Intermediate	76	13.3	10.7	0	Green	Green	Green	Asymm	4.8	13	Red	Round	Ridged
34	RV100264	Intermediate	77	18	18	0	P+G Stripes	D.Green	P+G Stripes	Sym	6.7	16.4	Red	Oval	Ridged
35	RV100243	Intermediate	72	13.5	10	<3	L. Green	Green	Green	Sym	5.4	15	Red	Round	Ridged
36	RV100250	Intermediate	70	10.3	8	<3	Green	Green	Green	Asymm	5	12.8	Red	Round	Ridged
37	RV100455	Intermediate	75	24	21.2	0	Green	Green	Green	Asymm	5	13	Purple	Round	Smooth
38	RV100261	Intermediate	67	18.6	15.4	<3	Green	Green	Green	Asymm	6.8	7.5	Purple	Oblong	Smooth
39	RV100453	Intermediate	87	13.7	11	0	P+G Stripes	Green	P+G Stripes	Asymm	2.2	6.3	Red	Round	Smooth
40	RV100241	Intermediate	66	18	12	~8	L. Green	Green	Green	Asymm	8.5	16	Red	Round	Ridged
41	RV100242	Intermediate	65	20	15	0	P+G Stripes	Green	P+G Stripes	Asymm	1	5	Red	Round	Smooth
42	RV100328	Intermediate	76	10	5.5	0	P+G Stripes	D.Green	P+G Stripes	Sym	9	21	Green	Round	Ridged
43	RV100342	Intermediate	72	12.5	10.5	~15	L. Green	D.Green	P+G Stripes	Asymm	6.4	15.6	Red	Round	Ridged
50	RV100386	Prostrate	45	14.8	11.1		L. Green	Green	Green	Asymm	9.8	21.5	Red	Round	Ridged
51	RV100380	Prostrate	42	7.7	5.6	0	Green	Green	P+G Stripes	Sym	5.3	9.8	Yellow	Oval	Ridged
52	RV100240	Prostrate	44	23.5	17	0	L.Green	D.Green	Green	Asymm	5.5	13.3	Red	Round	Ridged
53	RV100325	Prostrate	43	12.8	19	0	L.Green	Green	Green	Asymm	7	17	Red	Round	Ridged
54	RV100445	Prostrate	45	16	13	0	Green	Green	Green	Asymm	5	13	Green	Oblong	Smooth
55	RV100330	Prostrate	45	23	17	<3	Purple	D.Green	D.Purple	Sym	4.8	12.3	Green	Round	Ridged
56	RV100271	Prostrate	45	17.2	16.2	0	L. Green	Green	D.Green	Sym	6	15	Red	Round	Ridged
57	RV100234	Prostrate	42	23	15	0	Green	Green	P+G Stripes	Asymm	6	15	Red	Round	Ridged
58	RV100273	Prostrate	43	22	15.4	0	Green	Green	P+G Stripes	Sym	6.1	16	Red	Round	Ridged
59	RV100265	Prostrate	44	13.4	11.5	0	Green	Green	Green	Asymm	5	13	Red	Round	Ridged
60	RV100215	Prostrate	44	20	17	0	Green	D.Green	Green	Asymm	5.5	13	Green	Round	Ridged
61	RV100334	Prostrate	40	20.8	13.4	0	Green	D.Green	Green	Asymm	7	15	Orange	Round	Ridged
62	RV100270	Prostrate	45	17.3	15	~4	Green	Green	Green	Asymm	5.5	13	Red	Round	Ridged
63	RV100 199	V. prostrate	30	29	19	0	P+G Stripes	Green	P+G Stripes	Sessile	12	15.5	White	Round	Smooth
64	RV100274	V. prostrate	39	20.9	17.7	0	Green	D.Green	P+G Stripes	Asymm	5	12	Red	Round	Ridged
65	RV100360	V. prostrate	23	23.7	19.5	0	L.Green	Green	L. Green	Sym	12.7	15.6	Orange	Round	Smooth
66	RV100432	V. prostrate	30	15	14	0	Green	Green	P+G Stripes	Sym	4	9.6	Red	Round	Ridged
67	RV100236	V. prostrate	37	20.5	18	0	Green	Green	P+G Stripes	Sym	7	17	Yellow	Round	Ridged

Key: L. Green- Light green, D. Green – Dark green, P+G- purple +Green, Asymm- asymmetrical, Sym – Symmetrical.

Fig 1. Variation in fruit shape, colour, size and texture; a) round ridged red, b) oval smooth red, c) round small smooth red, d) oblong ridged yellow, e) oblong smooth green, f) round smooth white, g) oval smooth orange with stripes, h) oblong smooth purple fruit.

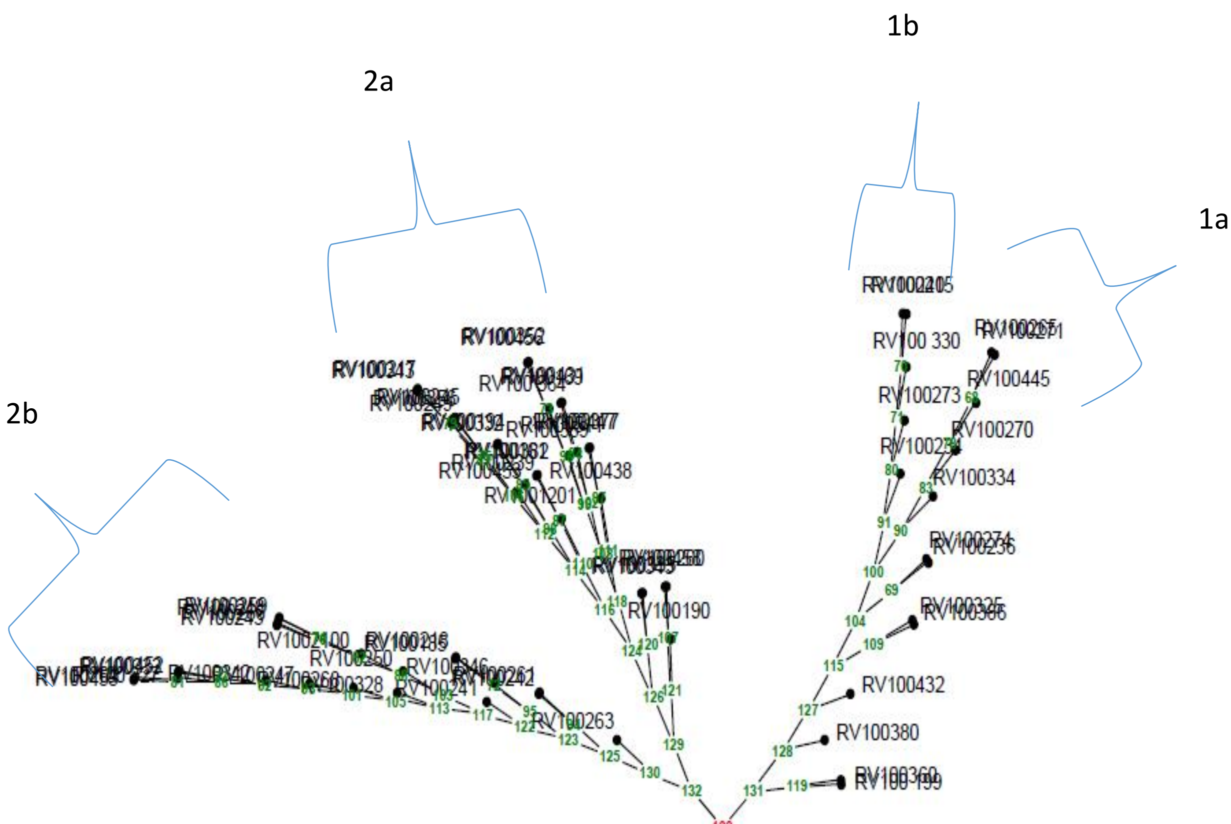

Fig 2. Cluster analysis of Sixty-Seven African eggplants accessions using Darwin's 6 software.

The Eigenvectors decreased significantly from principal component 8from5.34 % to 5.06 % (Table 6). This suggests that after principal component8 more principal components didnot describe much variation. PC-1 accounted for 16.02 % mainly contributed by Plant growth habit fruit colour, fruit width and length, whereas

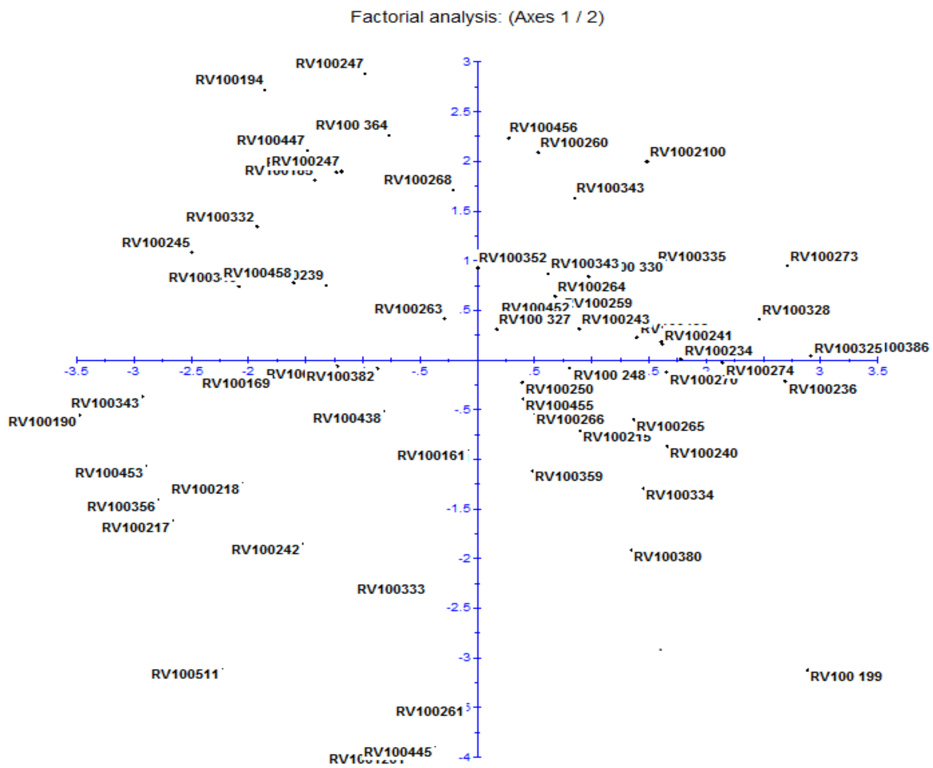

Fig. 3. Interactions between the accessions using the factorial analysis.

Table 5. Coefficient variance percentage, least significant difference, means and mean squares for nine quantitative traits.

Trait	Minimum	Maximum	Mean	Mean square	LSD	F	CV%
Flower Heads	1.00	13.00	4.309±0.48	37.99	0.54	0.23	11.1
Fruit Length	1.50	13.00	5.56 ± 0.72	27.40	0.81	0.51	12.9
Fruit Width	4.00	23.00	12.37±1.42	88.97	1.60	2.02	11.5
Internode Height	1.00	9.30	4.63±0.92	11.10	1.03	0.84	8.5
Plant Breadth	3.00	7.00	4.90±0.46	1.75	0.52	0.22	9.5
Plant Height	22.00	119.00	75.17±3.59	3403.72	4.05	12.94	4.8
Leaf Blade Length	9.00	32.50	19.44±1.50	134.43	1.69	2.26	7.7
Leaf Blade Width	6.30	26.20	14.76±1.69	72.37	1.91	2.87	11.5
Leaf Lobules	5.00	16.00	8.75±0.38	13.13	0.44	0.15	4.4

PC-2 accounted for 12.29% mainly contributed by fruit texture, leaf blade width and length and number flower heads PC-3 was contributed mainly by fruit texture, number of flower heads, plant breadth. PC-4 was contributed by plant growth habit, number of leaf lobules. PC-5 was dictated mainly by leaf blade width, number of prickles and leaf blade length. PC-6 was contributed by number of flower heads, fruit length, and number of prickles PC-7 was accounted by fruit colour, internode height; whereas PC-8 was contributed mainly by fruit shape, number of prickles plant breadth (Table 6).

The first, second and third PCs with a cumulative of 41.03% revealed the most variation among the populations, showing a high degree of correlation among the traits studied. Overall, the PCA analysis under this study shows that phenotypic markers were useful in characterizing the African eggplant. (Table 6).

Morphological characterization using qualitative traits

Phenotypic diversity for individual qualitative traits revealed a high degree of variation among the studied populations (Table 7) using the Shannon - Weaver diversity

Table 6. Eigenvectors, percentage variation, eigenvalues and cumulative variance of nine quantitative traits in African Eggplants.

Traits	PC-1	PC-2	PC-3	PC-4	PC-5	PC-6	PC-7	PC-8
Number of Flower Heads	-0.15897	0.27744	0.11538	-0.21196	0.02384	0.38472	0.10237	-0.18399
Fruit Length	0.28841	-0.20113	-0.39739	0.18032	-0.07939	0.33111	-0.04052	0.08979
Fruit Width	0.18062	-0.43483	-0.35880	0.05968	0.01560	0.15866	0.02196	0.04421
Internode Height	-0.08371	0.12666	-0.22202	-0.20757	-0.51360	-0.05897	0.20670	0.07094
Leaf Blade Length	-0.21312	0.24640	-0.46125	-0.02428	0.16944	-0.16278	-0.17892	-0.02010
Leaf blade width	-0.15968	0.23779	-0.49039	0.00986	0.21654	-0.10560	-0.08740	-0.02063
Number of leaf lobules	0.14892	0.14362	-0.12556	0.24815	-0.28188	-0.00530	-0.58571	0.02506
Plant Breadth	0.03963	-0.20629	0.09199	0.16662	-0.22362	-0.61760	0.04144	0.10840
Plant Height	-0.02030	-0.00653	-0.07088	-0.16291	-0.27069	-0.00309	-0.16444	-0.61130
Eigenvalue	2.802	2.439	2.175	1.495	1.239	1.169	1.086	1.015
% Variation	14.75	12.83	11.45	7.87	6.52	6.15	5.75	5.34
%CumulativeVariation	14.75	27.58	39.03	46.9	53.42	59.57	65.32	70.66

Coloured values indicate the descriptors that contributed most to the specific principal component.

Table 7. Diversity index (H´) values explaining the genetic diversity of the accessions based on qualitative traits.

Qualitative traits	Genetic index(H')
Plant growth habit	1.0
Fruit colour	0.951
Fruit shape	0.988
Fruit texture	0.992
Leaf base shape	0.987
Leaf blade colour	0.995
Petiole colour	1.0
Stem colour	1.0
Vein colour	1.0
Total	**6.040**

index to estimate phenotypic diversity of nine qualitative traits studied.

The highest phenotypic diversity index (H') for traits studied recorded was 1.0 in plant growth habit, petiole colour, stem colour and vein colour with a total mean phenotypic diversity index of 6.0. Substantial variation was observed in fruit colour, fruit shape, fruit texture, leaf base and leaf lade colour (Table 7).

The characterization data and the multivariate analysis performed may be useful to select a subset of accessions that represent most of the morphological diversity of the African eggplants. At the selection and breeding level, considerable phenotypic differenced among and within groups may be used for selecting best accessions or selection of parents in obtaining F1 hybrid herotic for yield or with intermediate or new characteristics (Adeniji and Aloyse, 2012).

CONCLUSIONS

Significant variation among the selected African eggplant was mainly contributed by plant height, leaf blade length, leaf blade width and fruit width.

Substantial variation among the 67 accessions was observed in fruit colour, fruit shape, fruit texture, leaf base and leaf lade colour

RECOMMENDATION

High genetic distance recorded among a number of accessions could be exploited to identify parents for future genetic improvement. Cluster analysis gathered population showing homogeneity of quantitative traits together. Computation of Shannon-Weaver diversity index revealed high genetic diversity based on qualitative traits of the African eggplants.

Next generation sequence should be used to fully characterize and unveil the responsible genes for the unique traits in the African eggplant for breeding purposes.

ACKNOWLEDGMENTS

The support for this research work was provided by U.S. Agency for International Development through the Partnerships for Enhanced Engagement in Research (PEER) program Sub-Grant Number: PGA-2000003426 to Dr. Willis Owino. The authors would like to thank Dr. Tsvetelina Stoilova of AVRDC- World Vegetable Center in Arusha, Tanzania, seed repository for the provision of the African eggplant seeds. We also thank the Boyce Thomson Institute for Plant Research (BTI), Cornell University, USA for being wonderful hosts and technical assistance in the current study.

REFERENCES

Adeniji O, Aloyce A (2012). Farmer's knowledge of horticultural traits and participatory selection of African eggplant varieties (*Solanum aethiopicum*) in Tanzania. Tropicultura 30, 185–191.

Adeniji O, Kusolwa P, Reuben S (2013). Morphological descriptors and micro satellite diversity among scarlet eggplant groups. Afr. Crop Sci. J. 21, 37–49.

Allen G, Antosand HebdaR (1996). Morphological and genetic variation in disjunct populations of the avalanche lily, *Erythronium montanum*. Can. J. Bot. 74 (3):403-.409.

AVRDC (2002). Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. vii + 151 pp.

Bukenya Z, Carasco J (1994). Biosystematic study of *Solanum macrocarpon-S. dasyphyllum*complex in Uganda and relations with S. linnaeanum. East Afr. Agric. Fores. J. 59, 187–204.

Daunay M-C, Hazra P (2012). Eggplant. In: Peter KV, Hazra P, editors. Handbook of Vegetables. Houston: Studium Press, 257–322.

Furbank R, Tester M (2011). Phenomics – technologies to relieve the phenotyping bottleneck.Trends Plant Sci. 16, 635–644.

Gisbert C, Prohens J, Raigón M, Stommel J, Nuez F (2011). Eggplant relatives as sources of variation for developing new rootstocks: effects of grafting on eggplant yield and fruit apparent quality and composition. Sci. Hort. 128, 14–22.

Hurtado M, Vilanova S, Plazas M, Gramazio P, HerraizJ, Andújar I (2013). Phenomics of fruit shape in eggplant (*Solanum melongena* L.) using tomato Analyzer software. *Sci. Hort.* 164, 625–632.

IPPGRI, (1993). Descriptors for Eggplant. Rome: International Board for Plant Genetic Resources

Khan R, Hasnunnahar M, Isshiki S (2013). Production of amphidiploids of the hybrids between *Solanum macrocarpon* and eggplant. HortScience 48, 422–424.

Kisua J, Mwikamba J, Muigai A (2014). Genetic diversity of sweet and grain sorghum populations using phenotypic markers http://www.innspub.net vol. 6, No. 9, 34-46,

Lester R (1986). Taxonomy of scarlet eggplants, Solanum aethiopicum L. Acta Hort. 182, 125–132.

Lester R. N, Daunay M (2003). Diversity of African Vegetable *Solanum* species and its implications for a better understanding of plant domestication. Schriften zu Genetischen Ressour. 22, 137–152.

Maundu P, Achigan-Dako E, Morimoto Y (2009). Biodiversity of African vegetables, in African Indigenous Vegetables in Urban Agriculture, eds Shackleton C. M., Pasquini M. W., Drescher A. W., editors. , (London: Earthscan;), 65

Nyadanu D, Aboagye L, Akromah R, Osei M, Dordoe M (2014). Agro morphological characterization of Gboma Eggplant, an Indigenous fruit and Leafy Vegetable in Ghana. Afr. Crop Sci. J. Vol. 22, No. 4, pp. 281 - 289.

Polignano G, Uggenti P, Bisignano V, Della Gatta C (2010). Genetic divergence analysis in eggplant (*Solanummelongena* L.) and allied species. Genet. Resour. Crop Evol. 57, 171–181.

Prohens J, Plazas M, Raigón D, Seguí-Simarro J. M, Stommel J. R, Vilanova S (2012). Characterization of interspecific hybrids and backcross generations from crosses between two cultivated eggplants (*Solanum melongena* and *S. aethiopicum Kumba group) and implications for eggplant breeding*. Euphytica 186, 517–538.

Sarah M, Maina M (2008). Vegetables in East Africa. Elewa Publications, Farming Resources Series.

Solanum aethiopicum Natural Resources Conservation Service PLANTS Database. USDA. Retrieved 16 November 2015.

Sunseri F, Polignano G. B, Alba V, Lotti C, Visignano V, Mennella G (2010). Genetic diversity and characterization of African eggplant germplasm collection. Afr. J. Plant Sci. 4, 231–24.1.