

Morphological characters of guava landraces in Western and Coastal Kenya

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Abstract

Morphological variations of Kenyan guava to different environments and their corresponding adaptation have not been adequately studied. A study was carried out in 6 sites of Western and 3 sites of Coastal region of Kenya for morphological differences. The aim of the study was to evaluate morphological variations of guava landraces in Western and Coastal Kenya using morphological descriptors. 13 qualitative and 2 quantitative descriptors were studied. Root descriptors in the two regions did not give differences between the landraces. Leaf, fruit, branching habit showed difference. Leaf shape observed included oblong, trapezoidal, elliptical and ovate. Branching habits included axial, erect and irregular. Ripe fruit color of pink and cream was recorded. When grouped using unweighed neighbour joining (Darwin software) resulting to three clusters. The clusters had landraces within the region and others clustered across the region. The results of this study shows that Kenyan landraces vary morphologically within and across regions

Key words; Morphological variation; fruit character; Root; Leaf shape; Branching habits

1.1 Introduction

Guava (*Psidium guajava* L) is native to tropical areas of America where it exists as wild and cultivated. In East Africa, guava grows well from sea level to an altitude of about 2,000 m above the sea level. The tree generally begins bearing 1 or 2 years after planting and continues fruiting for 30 years [1]. The fruit is an excellent source of vitamin C, calcium potassium and iron [2]. It is consumed as ripe or processed into juices; leaves are also used in traditional therapy of dysentery, diabetes, treat acute diarrhea, cough and intestinal spasmodic diseases [3]. Several guava cultivars have emerged as a result of seedling selection. Seedling of the guava cultivars are being commercially exploited through seed propagation which has indirectly given rise to several types which are not true to the commercial type and vary greatly from the parental population [4]. Morphological traits are phenotypic markers that are used to identify plants [5]. Morphological characteristics such as leaf shape, leaf size, color of leaf veins, color of apical leaves, pubescence on apical leaves, margin of the leaves, root hairs, root shape, color of root cortex, color of root pulp, branching habit, color of fruit epidermis, color of fruit endocarp [4] have been used in giving the differences. Morphological study of Kenyan guava has not been carried [6] out and this limits the possibility of improving and exploiting the guava in the region. This study aims at provide morphological differences of guava from Western and Coastal Kenya that can be used in developing the landrace

2.0 Materials and Methods

2.1 Study site and sampling

Samples were collected from 9 sites; 6 sites from Western Kenya in Butere Mumias district and three sites from Coastal region. Western sites included Kisa, Evukambuli, Bumamu, Bukura, Makunga and Sabatia. Temperatures in western ranges from 17°C-22°C. Coastal sites included; Shimba, Ukunda and Msambweni. Coastal sites have an annual temperature of 24.2°C (Fig1).

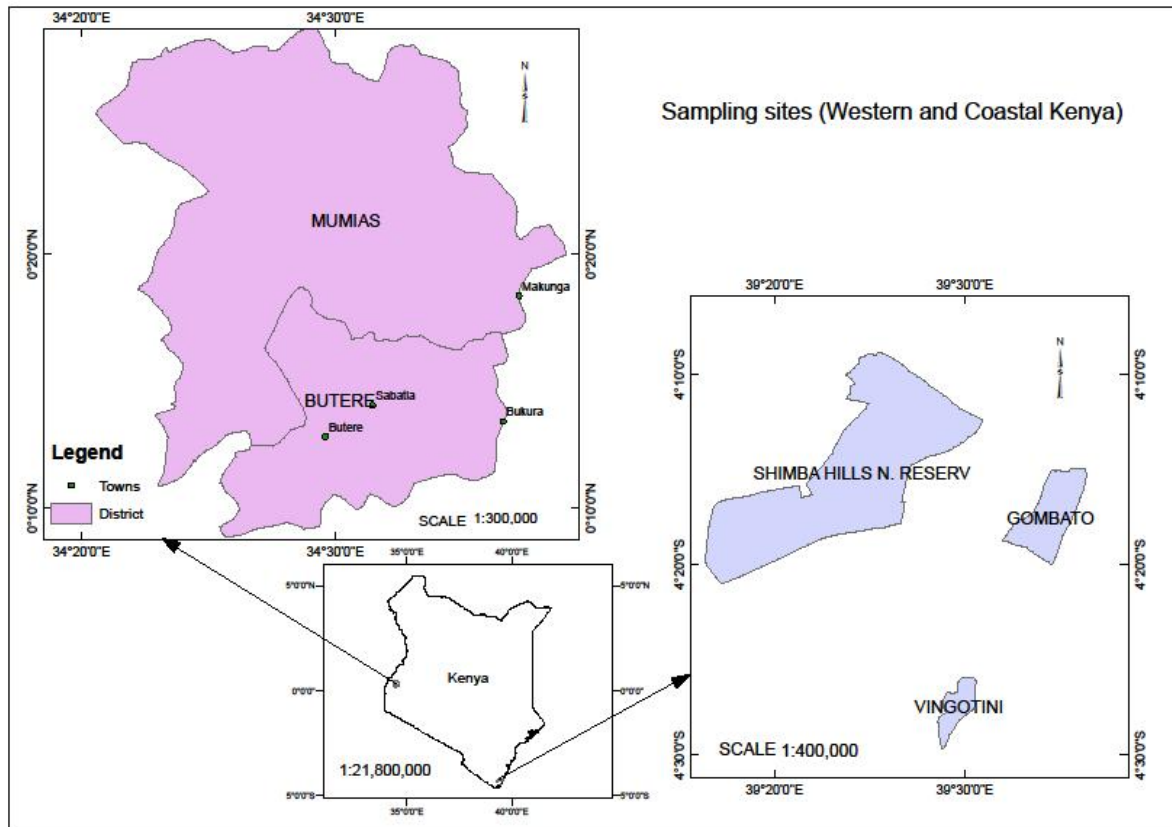


Figure 1: Collection sites in Kenya

Purposive sampling technique was used and the trees under study were tagged. An average of 6 trees in each site was studied. Samples from Kisa were denoted as SHIS001- SHIS006. Evukambuli samples were labeled as EVUK001- EVUK006. Bumamu samples were labeled as BUM001-BUM006. Bukura samples were labeled as BUK001-BUK009. Samples from Makunga were labeled as MAK001-MAK006. Sabatia samples were labeled as SAB001- SAB01. Shimba samples were labeled as SHIM001-SHIM006. Ukunda samples were labeled as UK001-UK004. Msambweni samples were labeled as MSA001-MSA005. Morphological descriptors were based on [7] [8]. The descriptors were scored as in table 1

Descriptor						
Colour of apical leaves	1-yellow green with brown borders	2-light green with brown borders	3-greenish brown	4-reddish brown	5-brilliant reddish brown	6-green
Pubescence on apical leaves	0-Absent	1-present				
Leaf retention	1-very poor	2-less than average	3-average	4-better than average	5-average	
Petiole colour	1-yellow green	2-green	3-Reddish green	4-red		
Colour of leaf veins	1-light green	2-green	3-reddish green	4-red		
Leaf shape	1-ovate	2-trapezoidal	3-oblong	4-elliptical		
Leaf colour	1-light green	2-dark green	3-green	4-green maroon		
Orientation of petiole	1-Inclined upwards	2-horizontal	3-inclined downwards	4-irregular		
Branch colour	1-light grey	2-dark grey				
Roots						
Root hairs	0-absent	1-present				
Root shape	conical	2-Conical cylindrical	3-cylindrical	4-irregular		
Colour of root pulp	1-white	2-cream	3-yellow	4-orange	5-pink	
Colour of root cortex	1-white cream	2-yellow	3-Pink	4-purple		
Fruit						
Colour of fruit	1-green	2-yellow	3-Yellow pink			
Colour of fruit endocarp	1-White	2-yellow	3-Pink	4-red		

3.0 Results

3.1 Leaf and stem analysis

In the nine sites the leaf petiole were oriented upwards, the leaves were dropping. Variation was observed in color of apical leaves, leaf retention, petiole color, leaf shape stem color and branching habit.

In Sabatia the apical leaves were light green with brown borders and greenish brown. Leaf retention varied from very poor, less than average, average, better than average to outstanding. Petiole color observed was yellow green and green. Leaf shape was elliptical and oblong. Stem color was dark grey and branching habit was axial and irregular (Table 2)

Table 2: Variation of leaf and stem analysis in Sabatia

Sample	CAL	LR	PC	LS	SC	BH
SAB001	light green with brown borders	less than average	yellow green	elliptical	dark grey	axial
SAB002	greenish brown	better than average	green	elliptical	dark grey	irregular
SAB003	greenish brown	average	green	oblong	dark grey	irregular
SAB004	greenish brown	average	green	elliptical	dark grey	irregular
SAB005	greenish brown	average	green	oblong	dark grey	irregular
SAB006	greenish brown	average	green	oblong	dark grey	irregular
SAB007	greenish brown	very poor	green	oblong	dark grey	axial
SAB008	light green with brown borders	outstanding	green	elliptical	dark grey	axial
SAB009	light green with brown borders	average	green	elliptical	dark grey	irregular
SAB01	greenish brown	better than average	green	oblong	dark grey	axial

LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH- Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex

In Bukura site color apical leaves observed was green. Leaf retention was better than average, average and outstanding. Petiole color was yellow green. Leaf shape observed was elliptical and oblong. Stem color varied from light grey to dark grey and branching habits were axial irregular and horizontal (Table 3)

Table 3: Variation of leaf and stem analysis in Bukura

Sample	CAL	LR	PC	LS	SC	BH
BUK001	green	better than average	yellow green	elliptical	light grey	irregular
BUK002	green	better than average	yellow green	oblong	light grey	irregular
BUK003	green	better than average	yellow green	oblong	light grey	axial
BUK004	green	outstanding	yellow green	elliptical	light grey	irregular
BUK005	green	better than average	yellow green	elliptical	light grey	irregular
BUK006	green	better than average	yellow green	oblong	dark grey	horizontal
BUK007	green	outstanding	yellow green	oblong	dark grey	irregular
BUK008	green	outstanding	yellow green	elliptical	dark grey	horizontal
BUK009	green	average	yellow green	elliptical	dark grey	erect

LR- Leaf retention, **PC-**Petiole colour, **CLV-** Colour of leaf veins, **LS-**Leaf shape, **SC-**stem colour, **BH-** Branching habit, **RS-**Root shape, **CRP-** Colour of root pulp, **CRC-** Colour of root cortex

In Makunga color of apical leaves observed was light green with brown borders and greenish brown. Leaf retention was average and outstanding. Petiole color was green. Color of leaf veins was green. Leaf shape observed was elliptical, oblong ovate and trapezoidal. Stem color was dark grey and light grey while branching habit was axial and irregular (Table 4)

84 Table 4: Variation of leaf and stem analysis in Makunga

Sample	CAL	LR	PC	CLV	LS	SC	BH
MAK001	light green with brown borders	average	green	green	elliptical	dark grey	irregular
MAK002	greenish brown	average	green	green	ovate	light grey	irregular
MAK003	light green with brown borders	average	green	green	oblong	light grey	irregular
MAK004	greenish brown	outstanding	green	green	trapezoidal	dark grey	irregular
MAK005	greenish brown	outstanding	green	green	trapezoidal	dark grey	axial
MAK006	greenish brown	outstanding	green	green	oblong	dark grey	axial

85 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
86 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

87 In Evukambuli all apical leaves were light green with brown borders. Leaf retention was average,
88 better than average and outstanding. Petiole color and color of leaf veins were green. Leaf shape
89 observed was trapezoidal, oblong and elliptical. Stem color was dark and light grey while
90 branching habits was axil, irregular and erect (Table 5)

91 Table 5: Variation of leaf and stem analysis in Evukambuli

Sample	CAL	LR	PC	CLV	LS	SC	BH
EVUK001	light green with brown borders	outstanding	green	green	trapezoidal	dark grey	axial
EVUK002	light green with brown borders	outstanding	green	green	trapezoidal	light grey	irregular
EVUK003	light green with brown borders	outstanding	green	green	oblong	light grey	irregular
EVUK004	light green with brown borders	better than average	green	green	elliptical	light grey	axial
EVUK005	light green with brown borders	average	green	green	oblong	light grey	erect
EVUK006	light green with brown borders	average	green	green	oblong	light grey	irregular

92 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
93 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

94 In Bumamu apical leaves were light green with brown borders and greenish brown. Leaf
 95 retention was average, better than average and outstanding. Petiole color was green Color of leaf
 96 veins was light green. Leaf shape observed was oblong and elliptical. Stem color was light grey
 97 while branching habits was axial, horizontal and erect (Table 6)

98 Table 6: Variation of leaf and stem analysis in Bumamu

Sample	CAL	LR	PC	CLV	LS	SC	BH
BUM001	light green with brown borders	outstanding	green	light green	oblong	light grey	axial
BUM002	greenish brown	average	green	light green	oblong	light grey	erect
BUM003	light green with brown borders	outstanding	green	light green	oblong	light grey	axial
BUM004	greenish brown	outstanding	green	light green	elliptical	light grey	horizontal
BUM005	greenish brown	better than average	green	light green	elliptical	light grey	axial
BUM006	greenish brown	better than average	green	light green	oblong	light grey	erect

99 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
 100 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

101 In Kisa apical leaves were light green with brown borders and greenish brown. Leaf retention
 102 was outstanding. Petiole color was green and color of leaf veins was light green. Leaf shape
 103 observed was trapezoidal and oblong. Stem color was light grey while branching habits was axial
 104 and irregular (Table 7)

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111 Table 7: Variation of leaf and stem analysis in Kisa

Sample	CAL	LR	PC	CLV	LS	SC	BH
SHIS001	greenish brown	outstanding	green	light green	trapezoidal	light grey	irregular
SHIS002	greenish brown	outstanding	green	light green	oblong	light grey	irregular
SHIS003	greenish brown	outstanding	green	light green	trapezoidal	light grey	irregular
SHIS004	light green with brown borders	outstanding	green	light green	trapezoidal	light grey	axial
SHIS005	light green with brown borders	outstanding	green	light green	oblong	light grey	axial
SHIS006	light green with brown borders	outstanding	green	light green	oblong	light grey	erect

112 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
113 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

114 In Shimba leaf apical were greenish brown and green. Leaf retention was less than average,
115 average and better than average. Petiole color and color of leaf veins was green. Leaf shape
116 observed was ovate, elliptical and oblong. Stem color was light grey while branching habits was
117 erect (Table 8)

118 Table 8: Variation of leaf and stem analysis in Shimba

Sample	CAL	LR	PC	CLV	LS	SC	BH
SHIM001	greenish brown	less than average	green	green	oblong	light grey	erect
SHIM002	greenish brown	less than average	green	green	elliptical	light grey	erect
SHIM003	greenish brown	better than average	green	green	elliptical	light grey	erect
SHIM004	green	average	green	green	ovate	light grey	erect
SHIM005	green	better than average	green	green	ovate	light grey	erect
SHIM006	green	better than average	green	green	oblong	light grey	erect

119 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
120 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

121 In Ukunda apical leaves were light green with brown borders. Leaf retention was less than
122 average, average and better than average. Petiole color was green and yellow green Color of leaf

123 veins was green. Leaf shape observed was ovate and oblong. Stem color was light grey and dark
 124 grey while branch habits was erect (Table 9)

125 Table 9: Variation of leaf and stem analysis in Ukunda

Sample	CAL	LR	PC	CLV	LS	SC	BH
UKU001	light green with brown borders	better than average	green	green	oblong	light grey	erect
UKU002	light green with brown borders	better than average	green	green	ovate	dark grey	erect
UKU003	light green with brown borders	average	yellow green	green	oblong	dark grey	erect
UKU004	light green with brown borders	less than average	yellow green	green	oblong	dark grey	erect

126 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
 127 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

128 In Msambweni apical leaves were light green with brown borders and green. Leaf retention was
 129 outstanding and better than average. Petiole color was green and green yellow. Color of leaf
 130 veins was green. Leaf shape observed was elliptical, ovate and oblong. Stem color was light grey
 131 and dark grey while branch habits was erect (Table 10)

132 Table 10: Variation of leaf and stem analysis in Msambweni

Sample	CAL	LR	PC	CLV	LS	SC	BH
MSA001	light green with brown borders	outstanding	green	green	oblong	dark grey	erect
MSA002	green	outstanding	green	green	oblong	dark grey	erect
MSA003	light green with brown borders	better than average	green	green	elliptical	light grey	erect
MSA004	light green with brown borders	better than average	yellow green	green	ovate	light grey	erect
MSA005	green	better than average	green	green	ovate	light grey	erect

133 **LR- Leaf retention, PC-Petiole colour, CLV- Colour of leaf veins, LS-Leaf shape, SC-stem colour, BH-**
 134 **Branching habit, RS-Root shape, CRP- Colour of root pulp, CRC- Colour of root cortex**

135 The predominant color of young apical leaves was greenish brown, green and light green with
 136 brown borders (fig1A-C) and predominant color of mature leaf varied from dark green, green
 137 and light green (fig1 D-F)

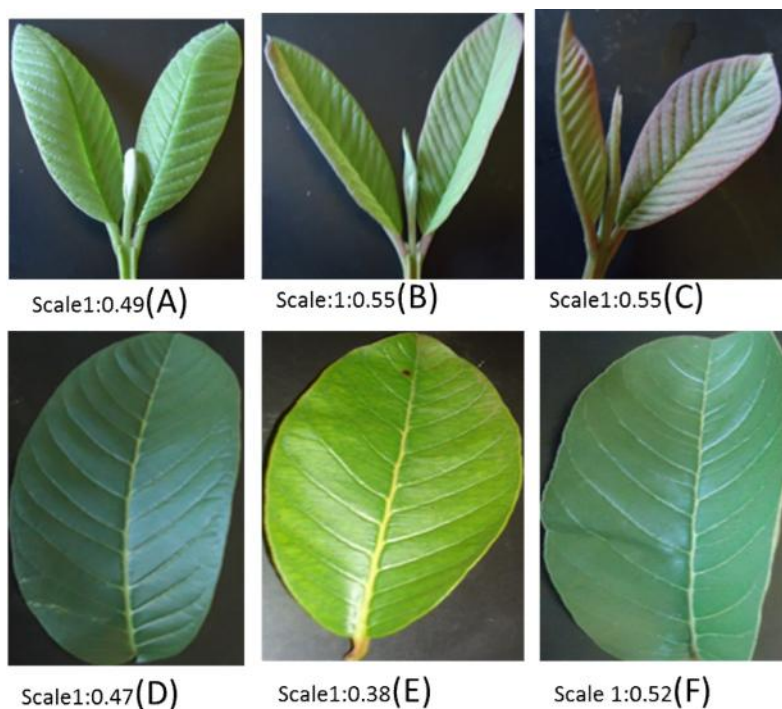


Figure 1: Variation of apical leaf analysis and color of mature leaf analysis; green young apical leaves(A), light green apical leaves with brown borders(B), greenish brown apical leaves(C), dark green leaf(D), light green leaf(E), green leaf(F).

Five leaf shape color were observed; trapezoidal, ovate, oblong and elliptical (fig2A-D)

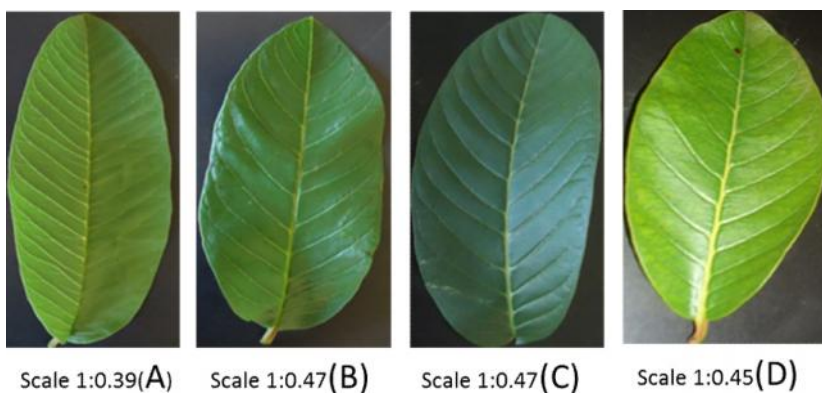


Figure 2: Variation of leaf shape morphology; trapezoidal leaf shape (A), oblong leaf shape (B), ovate leaf shape (C), elliptical leaf shape (D)

Branch habit that was observed were axial, erect branching, irregular branching and two stem colors dark gray and light gray (Fig 3A-E).



Scale 1:400 (A) Scale 1:400 (B) Scale 1:1500 (C) Scale 1:480 (D) Scale 1:430 (E)

Figure 3: Variation of stem branching and color analysis; axial branching (A) irregular (B) Erect branching(C), dark gray stem (D) light gray stem (E)

Root analysis

In western and Coastal region, all plants had fibrous roots which are many when the plant is still young and reduces as the plant ages, pink root cortex, white cream root pulp .All the roots were cylindrical in shape (fig 4A-D).



Figure 4: variation of root morphological analysis in Western and Coast; fibrous roots (A) pink cortex of young root (B), white pulp (C), pink cortex of mature root (D)

Fruit analysis

In Western the fruits were available in Sabatia site. All the fruits had a green pericarp when unripe and yellow pericarp when ripe. Mesocarp of ripe fruits differed where 4 were cream while 6 were pink. In Coast the fruits were present in Shimba hills site. All fruits collected from Shimba hills had a green pericarp. Mesocarp of the fruits varied with 3 having cream mesocarp while 3 had Pink mesocarp (fig 5 A-D)

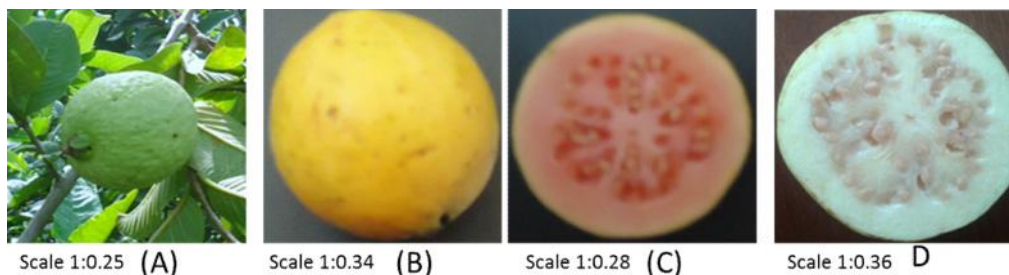


Figure 5: Variation of fruit morphological analysis from Western and Coast; unripe green pericarp (A), ripe yellow pericarp (B), pink mesocarp (C), cream white mesocarp (D)

Morphological clustering

DARwin software was used to cluster the accessions based on morphology and three clustered were observed within the Western and Coastal region (Fig 6). Cluster 1 comprised of BUM006, SAB007, SAB001 and BUM005. Cluster 2 comprised of BUM004, BUK003, BUK007, BUK002, BUK006, BUK009, BUK001, BUK005, BUK004, BUK003, SAB009, MAK001, BUM002, SHIS002, SHIS001, SHIS003, SAB002, SAB004, MAK002, SAB003, SAB005 and SAB006. Cluster 3 comprised of EVUK004, SAB01, SAB008, SHIS006, BUM003, SHIS004, BUM001, SHIS005, MAK004, MAK005, MAK006, EVUK006, MAK003, EVUK005, EVUK001, EVUK002, EVUK003, SHIM003, SHIM001, SHIM002, MSA001, MSA002, SHIM004, SHIM005, SHIM006, MSA005, UKU003, UKU004, UKU001, MSA003, UKU002 and MSA004

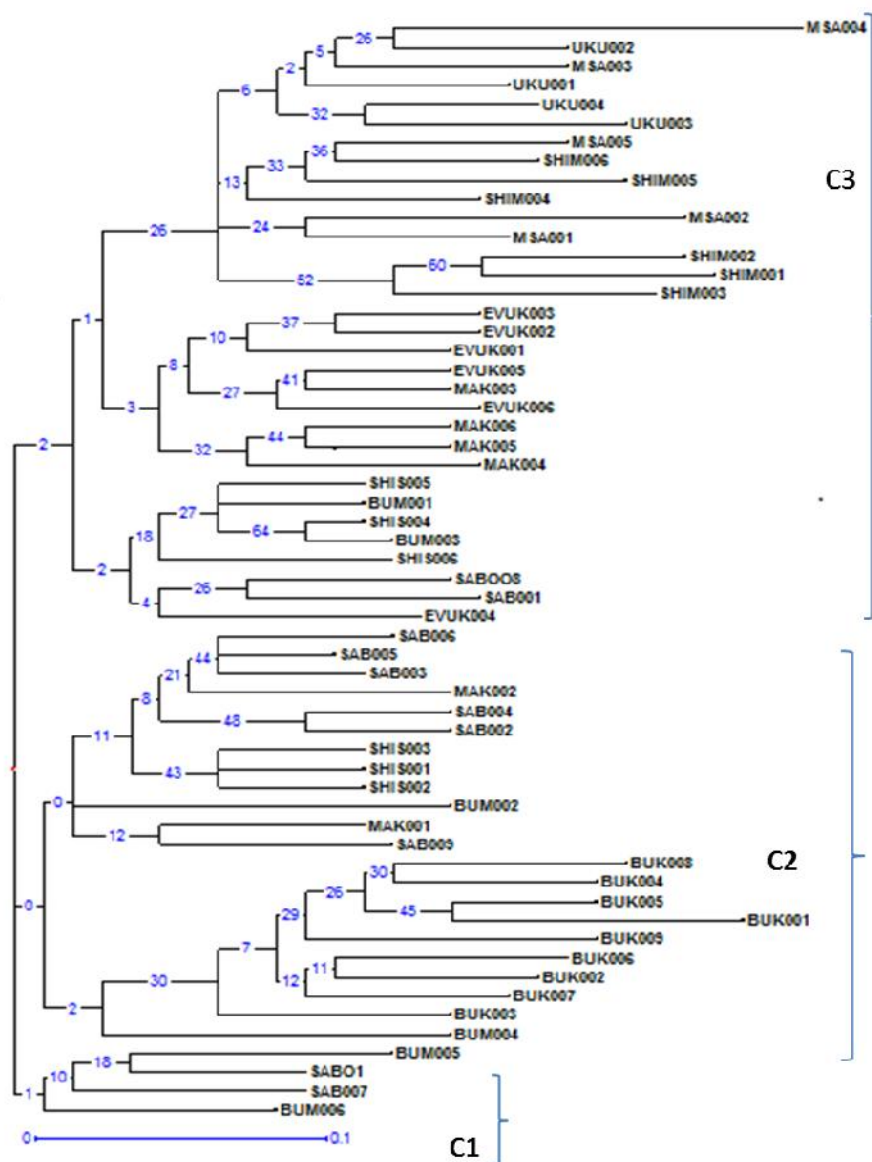


Figure 6; morphological clustering of 58 guava landraces

4.0 Discussion

Differences observed in morphological descriptors may be associated with the differences in genetic makeup of the landraces, geographical deposition and the climatic conditions of the site [9] [10]. In this work, morphological difference was reported in this study which was similar [11]. Color of young apical leaves of light green with brown borders, greenish brown and green with green borders and branching habits of erect, axial and irregular were reported by [4]. Leaf shapes observed in this study; oblong, trapezoidal, ovate, elliptical and lanceolate were similar to

those reported by [12] [10] .Color of mature leaves dark green and green were reported by [13] [10]. All leaves were oriented upwards

Color of stem in this study was recorded as green and dark green. Red and green color of stem was reported by [9] .[12] reported different color pigmentation of the stem that varied from brown to green color, light brown and red brown colors were also obtained. According to [14] the chest nut red color is common but no studies have been done in regard to pigmentation of guava stem

Fruit pericarp color of green and mesocarp color of white cream and pink were also reported by [13] [15] [16] [9]. [17] [10] also reported high frequencies of guava fruits with a pink pulp. [12] reported color of fruit pulp as white and red and that absents of color to be recessive and linked with other traits. In this study roots had low morphological difference. The color of root cortex, shape of the root and color of root pulp was similar in all the two regions. Studies on root morphology have not been reported.

Morphological descriptors of 58 landraces were used to generate similarity matrices and were used to generate a dendrogram by using by using unweighted neighbour joining to reveal morphological relationship between the landraces. The cluster tree analysis based on morphological characterization divided the guava landraces into 3 major classes (Fig 6). Cluster 1 comprised of landraces from Western region (14.04%). Cluster 2 comprised of 46.51% landraces from Western Kenya. Cluster 3 had landraces from both regions 100% of Coastal landraces and 39.45 % of Western landraces. Cluster one and two clustered based on the region as the region has most climatic conditions similar while cluster 3 had most landraces from Western Kenya. Despite of the region cluster three showed more similarity as this could have been caused by seed dispersal and agents of pollination retaining their genetic make-up.

Conclusion and recommendation

There exists morphological diversity among guava landraces in Western and Coastal Kenya. Coastal landraces have erect branching, Shimba had green apical leaves, Msambweni with yellow green petiole color, Ukunda had leaf retention less than average, Bukura had yellow green petiole color, Bumamu had horizontal branching, Makunga had either irregular or axial branching habits, Sabatia the landraces had either light green with brown borders or greenish brown apical leaves, Evukambuli had light green with brown borders apical leaves, Kisa had outstanding leaf retention. To the recommendation is that morphological information to be used in guava improvement through breeding programs and in gene banks

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Competing interests

Authors of this work have no competing interests

224 **Authors' contribution**

225 LMK- did sampling, did characterization and prepared draft, AAE supervised the study from
226 field to manuscript preparation, ABN supervised the work and corrected publication manuscript

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