

# Morphological characters of guava landraces in Western and Coastal Kenya

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## Abstract

Morphological characters using 13 qualitative and 2 quantitative descriptors were described in guava landraces in Western and Coastal Kenya. Root descriptors between the landraces in the two regions did not show differences while the leaf, fruit, branching of stem showed variations. Leaf shape varied, being oblong, trapezoidal, elliptical and ovate. Branching habits were either axial, erect or irregular. Ripe fruit color varied from pink to cream. Grouping of characters using unweighed neighbour joining (Darwin software) resulted to three clusters. The clusters had landraces within the region and others clustered across the region. The results revealed that Kenyan landraces varied morphologically within and across regions.

**Key words:** Morphological variation; fruit character; Root; Leaf shape; Branching habit

## 1.1 Introduction

Guava (*Psidium guajava* L.) is native to tropical America where it exists as a wild and cultivated plant. In East Africa, guava grows well from sea level to an altitude of about 2000 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 ripe or after being processed; leaves are used in traditional therapy in dysentery, diabetes, acute diarrhea, cough and intestinal spasmodic diseases [3]. Several guava cultivars have emerged as a result of seedling selection. Seedlings have also given rise to several types which are not true to the recognized guava cultivars and vary greatly from the parental populations [4]. Morphological traits are phenotypic markers that can aid in identification of plants [5]. Morphological characteristics such as leaf shape, leaf size, color of leaf veins, color of leaf apex, pubescence on apical leaves, leaf margin, 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 to differentiate plants. Morphological characterization may be useful in improvement of guava [6] in the Western and Coastal Kenyan regions.

## 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 districts and three sites from Coastal region. Western sites included Kisa, Evukambuli, Bumamu, Bukura, Makunga and Sabatia. Temperature in the Western Kenya ranged from 17°C-22°C. Coastal sites included Shimba, Ukunda and Msambweni; the temperature at the Coastal sites had an annual temperature of 24.2°C (Fig.1).

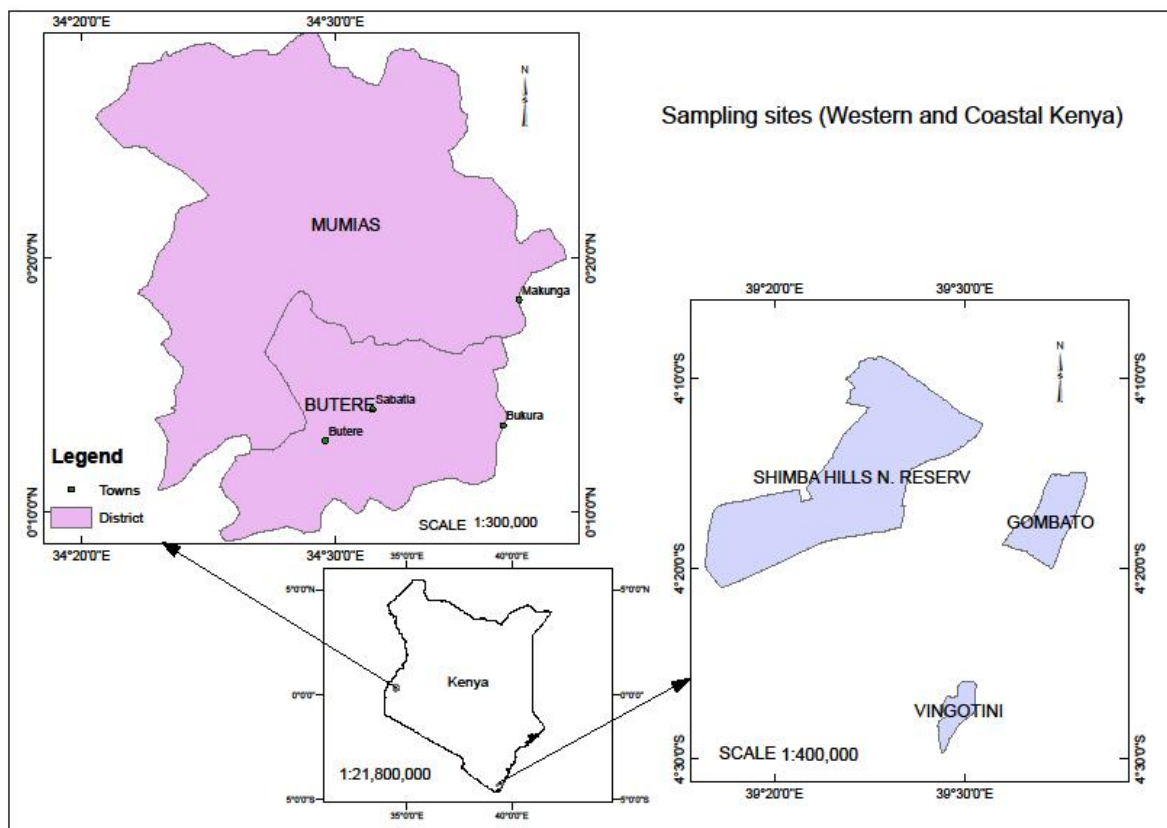


Fig. 1. Collection sites in Kenya

Purposive sampling technique was used and the trees under study were tagged. An average of 6 trees at 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

**Table 1.** Leaf, stem, root and fruit descriptors with scores

| Descriptor                |                                  |                                 |                  |                 |                           |         |
|---------------------------|----------------------------------|---------------------------------|------------------|-----------------|---------------------------|---------|
| Colour of apical leaf     | 1-yellow green with brown margin | 2-light green with brown margin | 3-greenish brown | 4-reddish brown | 5-brilliant reddish brown | 6-green |
| Pubescence on apical leaf | 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 vein      | 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           |                      |                       |           |
| Root                     |                    |                       |                      |                       |           |
| Root hair                | 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                 |           |

## 48 3.0 Results

### 49 3.1 Leaf and stem analysis

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

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

57

58 Table 2: Variation of leaf and stem analysis in Sabatia

| Sample | CAL                           | LR                  | PC           | LS         | SC        | BH        |
|--------|-------------------------------|---------------------|--------------|------------|-----------|-----------|
| SAB001 | light green with brown margin | 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 margin | outstanding         | green        | elliptical | dark grey | axial     |
| SAB009 | light green with brown margin | average             | green        | elliptical | dark grey | irregular |
| SAB01  | greenish brown                | better than average | green        | oblong     | dark grey | axial     |

59 **LR- Leaf retention, PC-Petiole color, CLV- Color of leaf vein, LS-Leaf shape, SC-stem color, BH- Branching**  
60 **habit, RS-Root shape, CRP- Color of root pulp, CRC- Color of root cortex**

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

65 Table 3. Variation in leaf and stem color of guava populations at 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      |

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

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

72 Table 4. Variations in leaf and stem color of guava populations at Makunga

| Sample | CAL                           | LR          | PC    | CLV   | LS          | SC         | BH        |
|--------|-------------------------------|-------------|-------|-------|-------------|------------|-----------|
| MAK001 | light green with brown margin | average     | green | green | elliptical  | dark grey  | irregular |
| MAK002 | greenish brown                | average     | green | green | ovate       | light grey | irregular |
| MAK003 | light green with brown margin | 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     |

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

75 In Evukambuli all apical leaves were light green with brown margin. Leaf retention was average,  
 76 better than average and outstanding. Petiole color and color of leaf veins were green. Leaf shape  
 77 was trapezoidal, oblong and elliptical. Stem color was dark and light grey while branching habits  
 78 was axil, irregular and erect (Table 5)

79 Table 5. Variation in leaf and stem color of guava populations at Evukambuli

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

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

82 In Bumamu, apical leaves were light green with brown margin and greenish brown. Leaf  
 83 retention was average, better than average and outstanding. Petiole color was green Color of leaf  
 84 veins was light green. Leaf shape was oblong and elliptical. Stem color was light grey while  
 85 branching habits was axial, horizontal and erect (Table 6).

86 Table 6. Variations in leaf and stem color of guava populations at Bumamu

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

|        |                |                                   |       |                         |        |            |       |
|--------|----------------|-----------------------------------|-------|-------------------------|--------|------------|-------|
| BUM006 | greenish brown | average<br>better than<br>average | green | green<br>light<br>green | oblong | light grey | erect |
|--------|----------------|-----------------------------------|-------|-------------------------|--------|------------|-------|

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

89 In Kisa apical leaves were light green with brown margin and greenish brown. Leaf retention  
90 was outstanding. Petiole color was green and color of leaf veins was light green. Leaf shape  
91 observed was trapezoidal and oblong. Stem color was light grey while branching habits was axial  
92 and irregular (Table 7).

93 Table 7. Variation in leaf and stem color in guava populations at Kisa

| Sample  | CAL                              | LR          | PC    | CLV            | LS          | SC         | BH        |
|---------|----------------------------------|-------------|-------|----------------|-------------|------------|-----------|
| SHIS001 | greenish brown                   | outstanding | green | light<br>green | trapezoidal | light grey | irregular |
| SHIS002 | greenish brown                   | outstanding | green | light<br>green | oblong      | light grey | irregular |
| SHIS003 | greenish brown                   | outstanding | green | light<br>green | trapezoidal | light grey | irregular |
| SHIS004 | light green with<br>brown margin | outstanding | green | light<br>green | trapezoidal | light grey | axial     |
| SHIS005 | light green with<br>brown margin | outstanding | green | light<br>green | oblong      | light grey | axial     |
| SHIS006 | light green with<br>brown margin | outstanding | green | light<br>green | oblong      | light grey | erect     |

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

96 In Shimba leaf apex was greenish brown and green. Leaf retention was less than average,  
97 average and better than average. Petiole color and color of leaf veins was green. Leaf shape  
98 observed was ovate, elliptical and oblong. Stem color was light grey while branching habits was  
99 erect (Table 8).

100 Table 8. Variations in leaf and stem color of guava populations at 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       | green | green | elliptical | light grey | erect |

|         |       |                     |       |       |        |            |       |
|---------|-------|---------------------|-------|-------|--------|------------|-------|
|         |       | average             |       |       |        |            |       |
| 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 |

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

103 In Ukunda apical leaves were light green with brown margin. Leaf retention was less than  
 104 average, average and better than average. Petiole color was green and yellow green Color of leaf  
 105 veins was green. Leaf shape observed was ovate and oblong. Stem color was light grey and dark  
 106 grey while the branches showed erect habits (Table 9).

107 Table 9. Variations in leaf and stem shape and color in guava populations in Ukunda

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

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

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

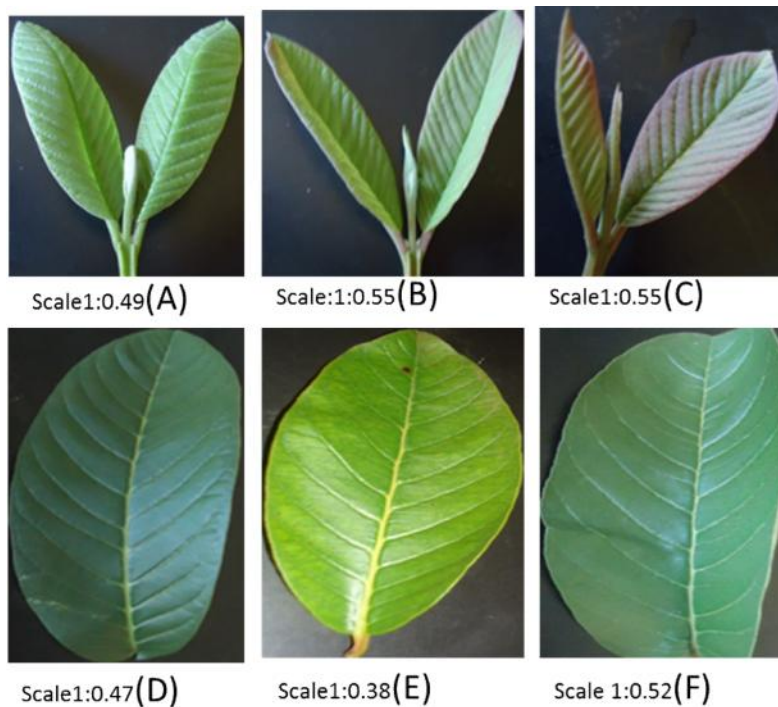
114 Table 10. Variations in leaf and stem color and shape of guava populations in Msambweni

| Sample | CAL                           | LR                  | PC    | CLV   | LS         | SC         | BH    |
|--------|-------------------------------|---------------------|-------|-------|------------|------------|-------|
| MSA001 | light green with brown margin | outstanding         | green | green | oblong     | dark grey  | erect |
| MSA002 | green                         | outstanding         | green | green | oblong     | dark grey  | erect |
| MSA003 | light green with brown margin | better than average | green | green | elliptical | light grey | erect |

|        |                               |                     |              |       |       |            |       |
|--------|-------------------------------|---------------------|--------------|-------|-------|------------|-------|
| MSA004 | light green with brown margin | better than average | yellow green | green | ovate | light grey | erect |
| MSA005 | green                         | better than average | green        | green | ovate | light grey | erect |

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

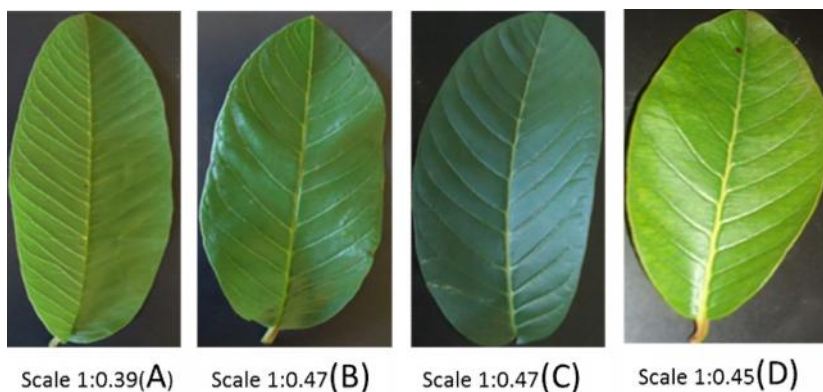
117 The predominant color of young apical leaves was greenish brown, green and light green with  
118 brown margin (Fig.1.A-C) and predominant color of mature leaf varied from dark green, green  
119 and light green (Fig.1. D-F)



120

121 **Fig. 1.** Variation of apical leaf analysis and color of mature leaf analysis; green young apical  
122 leaves(A), light green apical leaves with brown margin(B),greenish brown apical leaves(C),dark  
123 green leaf(D),light green leaf(E),green leaf(F).

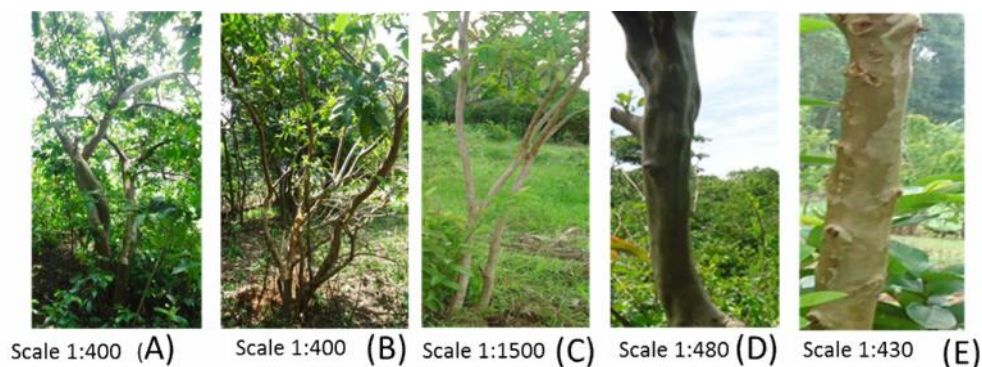
124 Five leaf shape color were observed; trapezoidal, ovate, oblong and elliptical (Fig.2.A-D)



125

126 **Fig. 2.** Variation of leaf shape morphology; trapezoidal leaf shape (A), oblong leaf shape (B),  
 127 ovate leaf shape (C), elliptical leaf shape (D)

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



130

131 **Fig. 3.** Variation of stem branching and color analysis; axial branching (A) irregular (B) Erect  
 132 branching (C), dark gray stem (D) light gray stem (E)

### 133 **Root analysis**

134 In western and Coastal region, all plants had fibrous roots which were many when the plants  
 135 were still young and the propensity reduced as the plants grew in age with pink root cortex, white  
 136 creamy root pulp. All the roots were cylindrical in shape (Fig. 4.A-D).



**Fig.4.** variation of root morphological characters in Western and Coastal regions; fibrous roots (A) pink cortex of young root (B), white pulp (C), pink cortex of mature root (D)

### Fruit characters

In Western region, the fruits at Sabatia site had a green pericarp when unripe and yellow pericarp on ripening. Mesocarp of ripe fruits differed, 4 were cream while 6 were pink. In Coastal region, the fruits had green pericarp, mesocarp varied, 3 had cream while the other 3 had Pink mesocarp (Fig. 5. A-D)

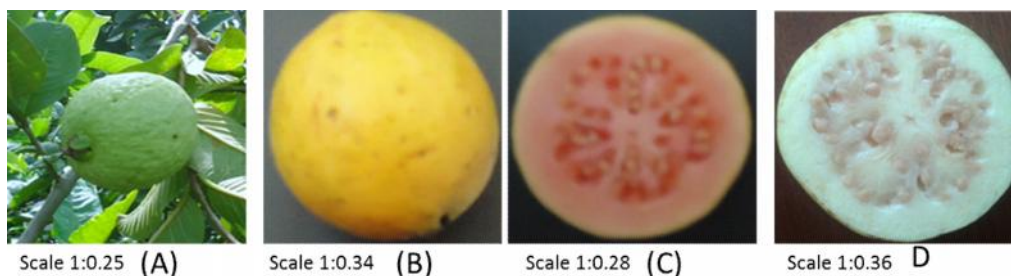


**Fig. 5.** Variations in fruit characters in guava from Western and Coast regions; unripe green pericarp (A), ripe yellow pericarp (B), pink mesocarp (C), cream white mesocarp (D)

### Morphological clustering

DARwin software was used to cluster the accessions based on morphology: three clustered were observed within the Western and Coastal regions (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 and 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

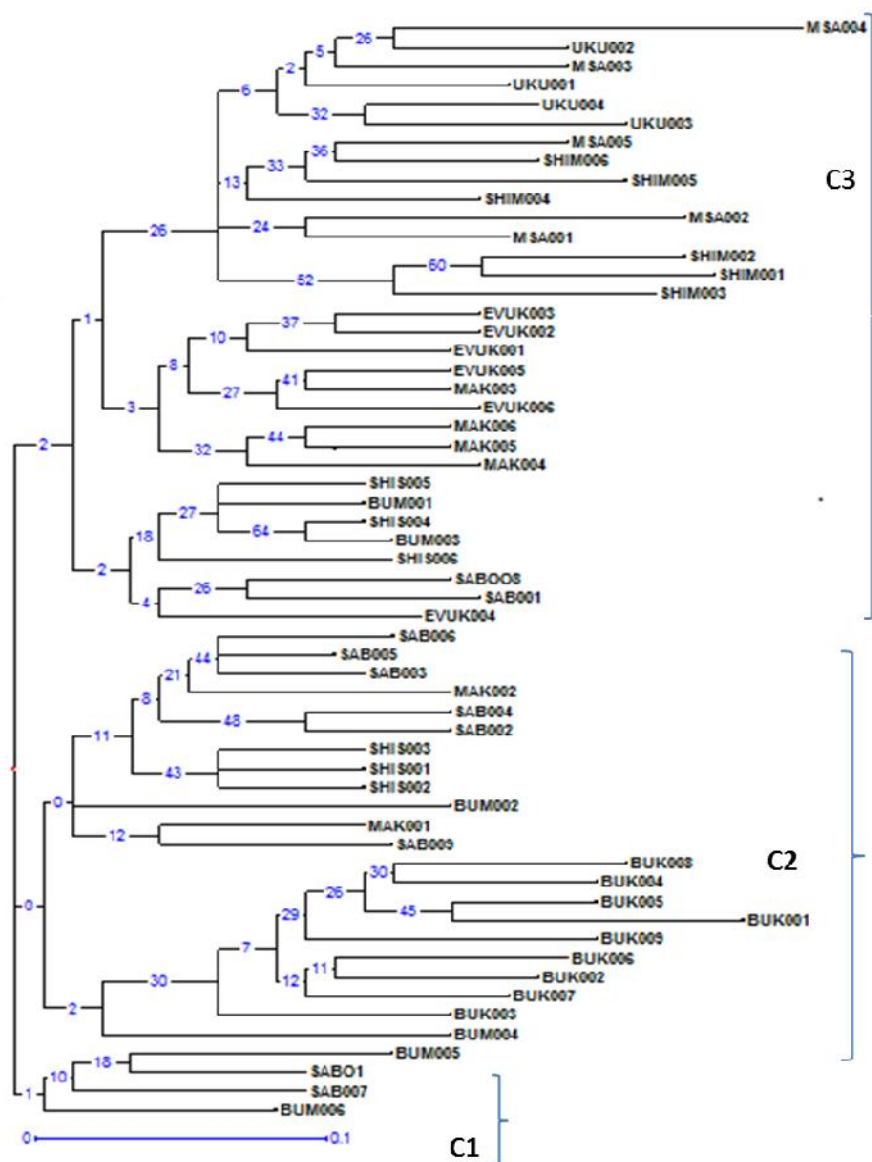


Fig. 6. Clustering of 58 guava landraces based on morphological characters

#### 4.0 Discussion

Differences in morphological descriptors may be attributed to the genetic makeup of the landraces, geographical locations and the climatic conditions of the sites [9, 10]. In this work, morphological differences were reported [11]. Color of young apical leaves of light green with brown margin, greenish brown and green with green margin and branching habits of erect, axial and irregular were reported [4]. Leaf shape: oblong, trapezoidal, ovate, elliptical and lanceolate

similar to those reported earlier [12, 10] .Color of mature leaves: dark green and green were reported [13,10]. All leaves were oriented upwards

Color of stem was green and dark green. Red and green color of stem was reported earlier [9]. Color pigmentation of the stem that varied from brown to green color, light brown and red brown colors were obtained as reported [12]. According to [14] the chest nut red color was common; there was no earlier report on pigmentation of guava stem.

Green fruit pericarp, white cream and pink mesocarp color of guava were reported [13,15,16 and 9]. Guava fruits with pink pulp was very common[17,10]. reported Color of fruit pulp in guava as white and red and that absence of color was considered to be recessive and linked with other traits was reported[12]. Roots showed minor morphological differences. The color of root cortex, shape of the root and color of root pulp was similar in guava from both the regions. This is the first report on root morphology of guava in the region.

Morphological descriptors of 58 landraces were used to generate similarity matrices and were used to generate a dendrogram 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 is 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 margin or greenish brown apical leaves, Evukambuli had light green with brown margin 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

## Authors' contribution

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

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