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MORPHOLOGICAL CHARACTERISATION OF GUAVA BASED ON FRUIT TRAITS IN TAITA TAVETA COUNTY OF KENYA

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ABSTRACT

Guava (*Psidium guajava*) is a minor fruit in Kenya. The fruit exists in various flesh colours. There is, however, limited information on the influence of flesh colour on guava fruit morphological characteristics. Such information would be vital for processing of the fruit into various products and also form a basis for future breeding programmes. The objective of this study was to investigate the effect of guava fruit flesh colour on fruit morphological characteristics. The study was conducted in three sub-counties, which are situated in different agro ecological zones; Wundanyi (Upper midland zone), Mwatate (Lower midland) and Voi (Inner lowland) in Taita Taveta County of Kenya. The various flesh colours domesticated include; red fleshed, white fleshed, pink fleshed and strawberry guava. Majority of the fruits sampled in Wundanyi were white fleshed (20%); while those sampled in Mwatate were red fleshed (29%). Strawberry guava recorded the least (3%). Strawberry guava differed significantly from white, pink and red fleshed in Mwatate and Voi regions recording the lowest values in fruit width, length, weight, endocarp thickness, pericarp thickness and number of seeds. Highest fruit weight was recorded by pink fleshed fruit (84.5 g) from Mwatate region; while the lowest 3.8 g was recorded by strawberry guava from Voi region. These variations are essential for future guava improvement programmes, targeting fruits for fresh consumption and industrial processing as well. Overall, red fleshed guava is fleshier and less seeded compared to the white and pink fleshed guavas thus more suitable for consumption both as a fresh fruit and making processed products.

Key Words: Guava fruit diversity, *Psidium guajava*

RÉSUMÉ

La goyave (*Psidium guajava*) est un fruit mineur au Kenya. Le fruit existe en différentes couleurs de chair. Il existe cependant des informations limitées sur l'influence de la couleur de la chair sur les caractéristiques morphologiques du fruit de la goyave. Ces informations seraient vitales pour la transformation du fruit en divers produits et formeraient également une base pour les futurs programmes de sélection. L'objectif de cette étude était d'étudier l'effet de la couleur de la chair du goyavier sur les

caractéristiques morphologiques du fruit. L'étude a été menée dans trois sous-comtés, qui sont situés dans différentes zones agro-écologiques ; Wundanyi (zone des hauts plateaux), Mwatate (basses terres) et Voi (basses terres intérieures) dans le comté de Taita Taveta au Kenya. Les différentes couleurs de chair domestiquées comprennent; goyave à chair rouge, à chair blanche, à chair rose et goyave fraise. La majorité des fruits échantillonnés à Wundanyi étaient à chair blanche (20 %) ; tandis que ceux échantillonnés à Mwatate étaient à chair rouge (29%). La goyave fraise a enregistré le moins (3%). La goyave fraise différait significativement de la chair blanche, rose et rouge dans les régions de Mwatate et de Voi, enregistrant les valeurs les plus faibles en largeur, longueur, poids, épaisseur de l'endocarpe, épaisseur du péricarpe et nombre de graines. Le poids de fruit le plus élevé a été enregistré par les fruits à chair rose (84,5 g) de la région de Mwatate ; tandis que les 3,8 g les plus bas ont été enregistrés par la goyave fraise de la région de Voi. Ces variations sont essentielles pour les futurs programmes d'amélioration de la goyave, ciblant également les fruits destinés à la consommation fraîche et à la transformation industrielle. Dans l'ensemble, la goyave à chair rouge est plus charnue et moins ensemencée que les goyaves à chair blanche et rose, donc plus adaptée à la consommation à la fois comme fruit frais et pour la fabrication de produits transformés.

Mots Clés : Diversité des fruits de goyave, *Psidium guajava*

INTRODUCTION

Guava (*Psidium guajava* L.) is one of the minor tropical fruit, grown in Kenya (Sisir *et al.*, 2012). The fruit is grown for its nutritional benefits; with the peel containing the highest ascorbic acid content (Lim *et al.*, 2006). Guava fruits are round or oval and are eaten fresh at two stages; mature green and fully ripe (Adel, 2014). At the fully ripe stage, the flesh can be white to bright red, with light to bright yellow skin (Reddy *et al.*, 2016). Leading counties in guava production in Kenya include: Mandera, Makueni, Vihiga, Homabay, Kiambu, Kilifi, Kisii, Nyamira and TaitaTaveta; contributing 35.0, 20.0, 6.8, 5.9, 5.4, 4.8, 3.6, 2.5 and 1.9 percent, respectively (HCDA, 2017).

Kenya has diverse agro- ecological zones that supports production of a wide range of exotic fruits. In most parts of Kenya, guava has been mostly growing wildly. This has been attributed to under-utilisation of the fruit (HCD, 2014).

Morphological characterisation of guava based on leaf qualitative traits have been studied in countries such as Bangladesh and India. From these studies leaf size showed a positive relationship with plant vigour, and the leaf intermodal length differed significantly

ranging between 1.36- 4.76 cm (Shiva *et al.*, 2017; Nusrat *et al.*, 2019). Characterisation and quantification of phytochemicals in the peel and flesh of Costa Rican guava (*Psidium friedrichsthalianum*) revealed phytochemicals such as proanthocyanidins, ellagitannins, flavonolignans, biflavonoids and dihydrochalcones are present in the peel than in the flesh (Carolina *et al.*, 2018).

In Kenya, molecular characterisation for genetic differences of guava leaves have been carried out in Western and South Coast regions and revealed distinct differences among the domesticated guava landraces (Liharaka *et al.*, 2015). The genetic diversity of guava accessions from Coast, Eastern, Rift Valley and Western regions of Kenya recorded genetic diversity of individual accessions, rather than agro ecological zones (Chiveu *et al.*, 2019 a), thus, much variation exists in individual accessions.

Morphological characterisation of guava based on fruit parameters is of great importance since fruit parameters are indicators of yield and quality. Fruit size determined by traits such as fruit length and width is an important indicator of both yield and quality. Guava fruit flesh colour is essential

since various processed products can be made for consumer taste and preference.

Fruit characterisation in Kenya has mainly focused on major fruits such as papaya, mango and passion fruits, focusing mainly in Eastern and central provinces (Asudi *et al.*, 2011; Gitahi *et al.*, 2016; Matheri *et al.*, 2016). There is insignificant on characterisation of guava, thus limited information on the identification of the guava accessions cultivated in Kenya both genetically and morphologically (Kidaha *et al.*, 2014; Chiveu, 2019b). The objective of this study was to investigate the effect of guava fruit flesh colour on fruit morphological characteristics.

MATERIALS AND METHODS

This research was carried out in TaitaTaveta County (Coastal region) of Kenya, within three sub-counties (Mwatate, Voi and Wundanyi). TaitaTaveta county terrain with altitude ranging from 500 - 2228 m above sea level. It receives an average of 440 mm of rain per *annum*; while highland areas (Wundanyi sub-county) receive up to 1900 mm of rainfall (MoALF, 2016).

The three sub-counties are located on different agro-ecological zones; with Wundanyi being on the upper midland zone (UM 3) receiving a rainfall of 900-1200 mm per *annum*; Mwatate in the lower midland (LM 4) zone having a rainfall range of 600-800 mm per *annum* and Voi in the inner lowland zone (IL5) receiving a rainfall of 550- 680 mm per *annum* (ICPAC, 2019).

Stratified systematic sampling was carried out whereby each of the three agro-ecological zones formed a stratum. Within each stratum, was laid a transect along which, sampling was done after every 5th tree; while putting into consideration the fruit flesh colours.

Sampling was carried out in the month of September in the year 2020. Twenty fruits were sampled per tree, having a total of ten trees in each region. Visual assessment of fruit shape was done. Fruit skin colour and pulp colour was evaluated using a RHS (2015)

Colour Chart. Fruit size (length and thickness; pericarp thickness, exocarp thickness and mesocarp thickness) parameters were measured using a vanier caliper, and recorded in centimeters. Fruit weight was measured using a weighing balance. Number of seeds per fruit was also recorded. The data collected were, thereafter, subjected to analysis of variance and means separated by Tukeys. Multiple factor analysis was done for both qualitative and quantitative fruit traits and correlation for quantitative fruit traits using R-software.

RESULTS

During fruit sample collection, guava fruits of various flesh colours were collected. Guava fruit flesh colours ranged from white, pink and red (Fig. 1).

Red fleshed fruits differed significantly in all the three regions; while strawberry guava differed significantly from the other flesh colours in Mwatate and Voi sub-counties. There were no pink fleshed fruits in Voi sub-county as illustrated in Figure 2.

Pink fleshed guava differed significantly in Mwatate and Wundanyi sub-counties. White and red fleshed guava recorded highest endocarp thickness in Voi and Mwatate respectively (Fig. 3).

Red and pink fleshed guava from Mwatate differed significantly from Voi and Wundanyi regions.

Highest mesocarp thickness was registered in strawberry guava from Mwatate compared to Voi sub-county (Fig. 4).

Majority of the fruits sampled from Wundanyi were white fleshed; while those sampled from Mwatate were red fleshed, followed by pink, white and strawberry fleshed was the least. In terms of fruit shape, Voi recorded oval shaped fruits; while Wundanyi and Mwatate regions the fruits were round and pear shaped. Fruit skin colour ranged from yellow for the white, red and pink fleshed guava to purple and orange for straw



Figure 1. Guava fruit flesh colours observed in three sub-counties; Wundanyi, Mwatate and Voi in TaitaTaveta County of Kenya.

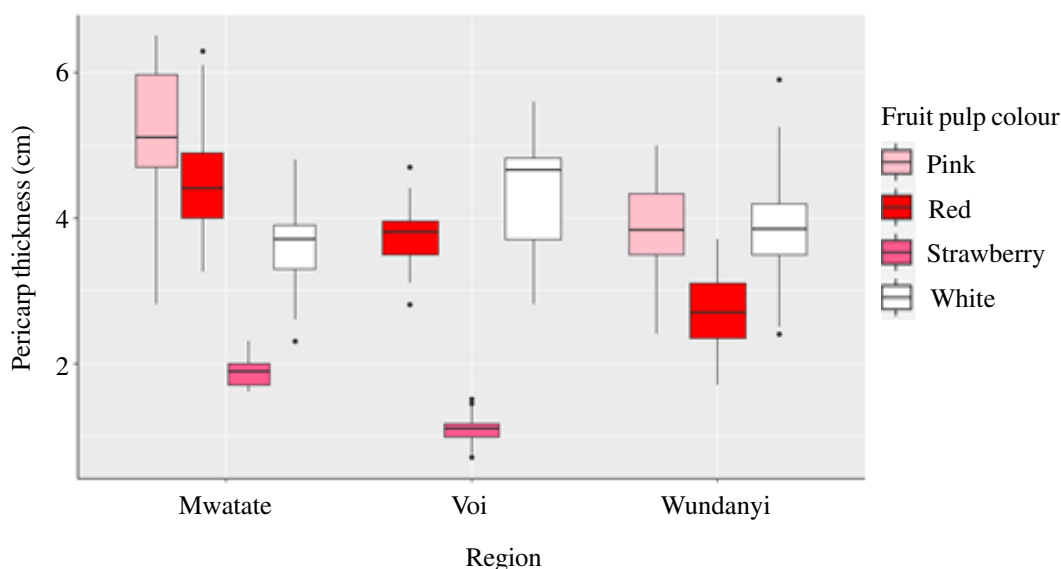


Figure 2. Box and whisker plots for fruit pericarp thickness in three sub-counties of TaitaTaveta County of Kenya.

berry guava as presented in Figure 5 and affirmed by Figure 1.

There were strong positive correlations on different fruit traits evaluated, having equal contribution to the fruit morphology as shown in Figure 6.

Table 1 presents fruit weight, fruit length and number of seeds per fruit for the various fruit flesh colours, across the sampled sites. Pink-fleshed fruits had fruit weight (64.25 g)

that was significantly higher than red (32.48 g), white (38.33 g) and strawberry fruits (4.15 g). However, the average fruit lengths of red, white and pink-fleshed fruits did not differ across the sampled regions. The number of seeds per fruit was significantly higher for white and pink-fleshed fruits across the regions, compared with that of the red-fleshed and strawberry fruits (Table 1).

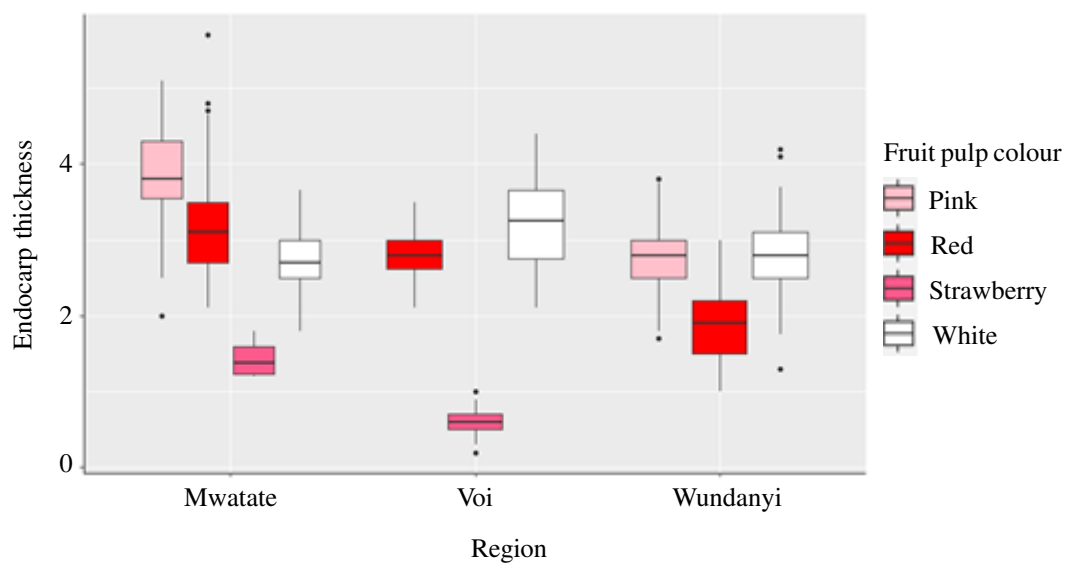


Figure 3. Box and whisker plots for fruit endocarp thickness in three sub-counties of TaitaTaveta County of Kenya.

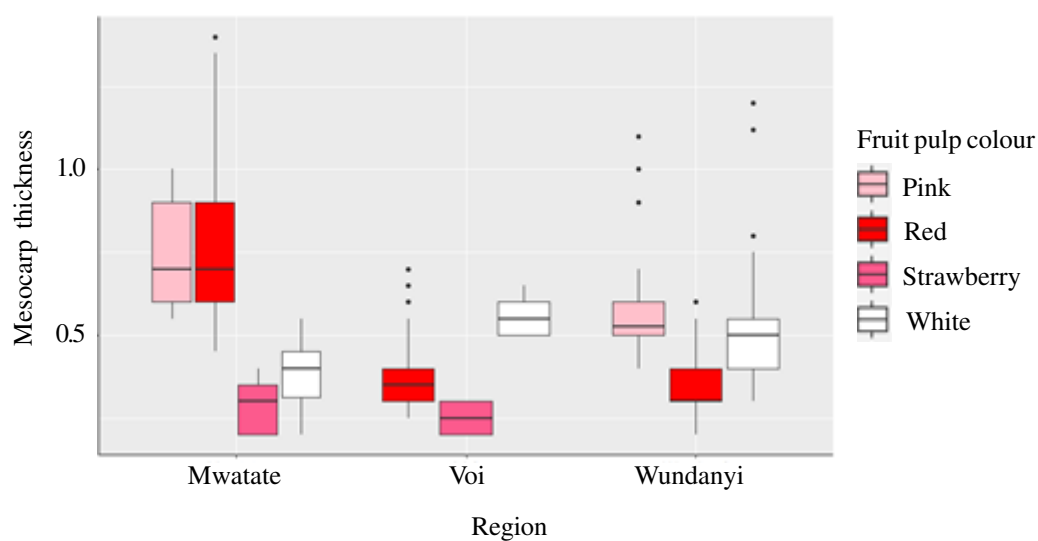


Figure 4. Box and whisker plots for fruit mesocarp thickness in three sub-counties of TaitaTaveta County of Kenya.

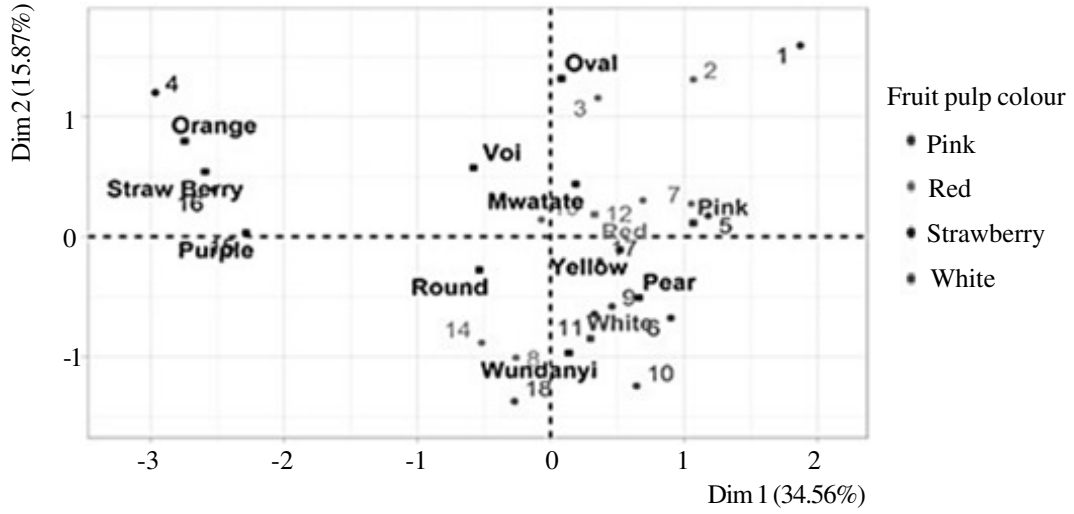


Figure 5. Factor map of guava accessions sampled at TaitaTaveta county of Kenya.

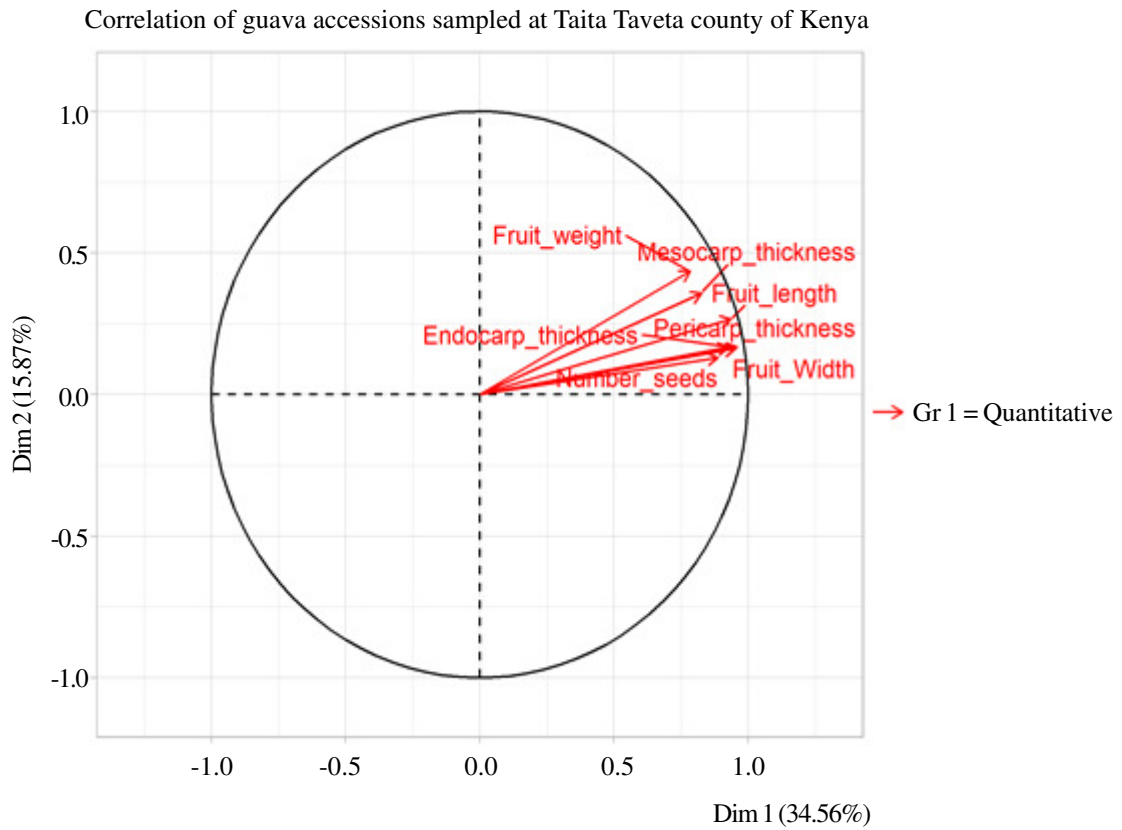


Figure 6. Correlation of guava accessions sampled in TaitaTaveta county of Kenya.

TABLE 1. Fruit weight, length and number of seeds for guava accessions sampled at three sub-counties; Wundanyi, Mwatate and Voi in TaitaTaveta County of Kenya

Region	Fruit weight (g)				Fruit length (cm)				Number of seeds			
	Red	White	Pink	Straw berry	Red	White	Pink	Straw berry	Red	White	Pink	Straw berry
Mwatate	48.75 ^{at}	31.25 ^{bt}	84.5 ^{at}	4.50 ^{a-1}	5.76 ^{at}	4.23 ^{at}	6.07 ^{at}	2.44 ^{a-1}	75.7 ^{ab-1a}	149.2 ^{ab1a}	176.3 ^{at}	13.0 ^{a-1}
Voi	30.0 ^{at}	48.50 ^{at}	-	3.80 ^{a-1}	4.03 ^{bt}	4.84 ^{bt}	-	1.39 ^{a-1}	141.6 ^{at}	182.2 ^{at}	-	4.5 ^{a-1}
Wundanyi	18.70 ^{bt}	35.25 ^{bt}	44.0 ^{bt}	-	2.71 ^{c-1}	4.24 ^{at}	4.51 ^{bt}	-	25.25 ^{b-1}	99.90 ^{bt}	103.25 ^{bt}	-
Means for flesh colour	32.48 ^B	38.33 ^B	64.25 ^A	4.15 ^C	4.19 ^A	4.44 ^A	5.29 ^A	1.91 ^B	80.85 ^B	143.78 ^A	139.78 ^A	8.75 ^C

Values within the same column followed by same letter are not significantly different at $p < 0.05$ according to analysis of variance followed by multiple comparison (Tukey). Greek letter values and alphabetical capital letters are compared across the row for the same trait and same letter indicates no significance. A dash (-) indicates absence of fruit flesh colour within a region.

DISCUSSION

Guava fruit attributes. Flesh colours of domesticated guava included red, white and pink fleshed, in addition to strawberry guava (Fig. 1). Similar guava flesh colours have also been recorded by Wasilwa and Odendo (2018) in Kenya. Most fruits from Wundanyi were white fleshed; while the dominant fruit flesh colour in Mwatate was red. This could be due to preference of some flesh colours in the different regions by the farmers; thus they domesticate the various flesh colours for their own consumption. Another contributing factor could be the means of dispersion for the fruit crop since it is mainly by birds. According to HCD (2014), guava trees grows from seeds dispersed unintentionally.

Similarly, Liharaka *et al.* (2015) found guava fruit flesh colours to vary from pink to cream in western and coastal regions of Kenya. According to findings of Mehmood *et al.* (2014), guava flesh colours ranged from white, cream and pink in Pakistani. These diverse guava flesh colours can be processed into different products for consumer taste and preference

The red, white and pink fleshed guava fruits had a yellow skin colour when ripe; while strawberry guava had purple and orange skin. The fruits exist in various shapes which include; pear, round and oval. Most of the white, red and pink fleshed guava fruits were pear shaped compared to the strawberry guava, whose majority of fruits were round (Fig. 5). This is similar to the findings of Chiveu *et al.* (2016) who recorded the fruit to be round, obovate and ovate having round shaped fruits occupying a bigger percentage (43%), followed by obovate (25%); while ovate recorded the least (14%); in Western, Rift valley, Eastern and Coastal regions of Kenya. Variability in skin colour and shape have also been recorded by Asim *et al.* (2014) for guava germplasm in Pakistani.

Variations in pericarp thickness observed within the white and pink fleshed guava from Voi and Mwatate might be due to the different

agro ecological and edaphic conditions having the dominant soils on the Taita hills ranging from humiccambisols, humicnitisols to dystriregosols of moderate to high fertility which are in Wundanyi region (Table 1). Regosols and orthicrendzinas soils of high fertility occur on the hills. The upper zones comprise of humiccambisols and chromic acrisols. Foothills bordering the mountains and hills have soils of chromic luvisols and rhodicferralsols of low natural fertility (NEMA, 2020). The fertile soils found on the hills might have greatly contributed to higher pericarp thickness, endocarp thickness, mesocarp thickness and fruit weight of the red fleshed fruits and strawberry guava at Mwatate compared to Voi region. This different soil types might have contributed to the fruit diversity because soil mineral composition is among the factors affecting guava fruit diversity (Jaetzold *et al.*, 2009).

Strawberry guava recorded the lowest number of seeds at Voi (4.5); followed by Mwatate (13) and red fleshed fruits (25.25) from Wundanyi region (Table 1). Less seeded guava accessions with higher weight are suitable for processing because the fruits contain a bigger part of the fruit pulp. Such variations in weight and number of seeds were also recorded by Methela *et al.* (2019) in Bangladesh for twelve guava germplasms having Kanchan Nagar being less seeded (196) compared to other guava germplasms analysed. Fruits from the coastal region were recorded to contain many seeds by Chiveu *et al.* (2019b) compared to other regions. These findings were attributed to the heretic structure of the plant which controlled the number of seeds per fruit.

Correlation of traits. The different fruit traits had strong positive correlations as presented in Figure 6 above hence contributed to the fruit characteristic like size, weight and fleshiness, which are useful for the processing industry. Production of less seeded or seedless guava accessions for processing requires breeding

for improvement of the present highly seeded accessions. Variations in fruit length and weight as observed in pink fleshed fruits at Mwatate compared to Wundanyi might be due to the differences in agronomic practices by the farmers and huge variations that exists in the wild where the fruits grow unattended. These variations are essential for improvement programmes in future since vegetative propagation can be done by selecting fruit trees with desired traits and also in breeding programmes where fruits that are large in size can be bred with less seeded accessions to produce fruits which are fleshy. The significant difference observed in fruit length for red and pink fleshed fruits recorded in the three regions is probably due to the different climatic conditions experienced in the different agro-ecological zones having Wundanyi receiving 1220-1520 mm of mean annual rainfall, Mwatate (600-800 mm of mean annual rainfall) while Voi (Inner lowland) region receives the lowest rainfall per *annum* (550-680 mm). Shiva *et al.* (2017) recorded guava fruit length and weight to statistically differ. Strawberry guava recorded no significant differences in fruit weight, length and number of seeds at Mwatate and Voi regions which can be associated with the narrow gene pool that exists for this guava accession.

CONCLUSION

Guava exists in various flesh colours in the region of Kenya, with red fleshed fruits being dominant; while strawberry is the least with the fruits having distinct traits such as fruit weight, length, number of seeds, pericarp thickness and endocarp thickness. Red fleshed fruits are fleshier and less seeded compared to the white and pink fleshed guavas thus more suitable for consumption both as a fresh fruit and making processed products. These important traits should also be explored in future guava breeding programmes for improvement of the crop.

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