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Domestication Potential of Aromatic Pickle-mango (*Appemidi*) Types in the Central Western Ghats, India

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Aromatic pickle-mango types, locally termed as '*Appemidi*', are extensively collected for household use and for commerce from the wild habitats even today in the central Western Ghats, India. Because of the deep cultural attachment, people have recognized several pickle-mango types from the wild habitats. However, studies on tree-to-tree variation in fruit and stone traits in natural populations are not done, which is a pre-requisite for cultivar development. Unripe fruits collected from 34 wild fruiting trees in two populations, 17 from Sirsi and 17 from Siddapur localities in Central Western Ghats, India were studied for variation in fruit traits and its association traits. Fruits from Sirsi locality were significantly larger than those from Siddapur (84.27 *vs.* 51.26 g) due to their greater green flesh mass (79.91 *vs.* 43.17 g). Tree-to-tree variation was highly significant and continuous in fruit length (Sirsi = 49.45-102.51 mm; Siddapur = 28.23–59.19 mm), stone length (Sirsi=26.97–55.59 mm; Siddapur=20.43–51.47 mm), fruit mass (Sirsi=19.78–84.27 g; Siddapur=15.50–51.26 g) and flesh mass (Sirsi=18.01–79.91 g; Siddapur=13.93–43.17 g), indicating the potential for selection. The strong relationships between fruit mass and green flesh mass in aromatic pickle-mango found in this study indicated that selection for green flesh mass can be based on fruit mass. Based on five important traits preferred by growers/fruit collectors/sellers and four quantitative traits from observations, development of an 'ideal type' and identification of potential superior trees was attempted. These results have important implications for the domestication of pickle-mango genetic resources.

Key Words: Cultivar development, Ideal fruit type, Phenotypic variation, Pickle-mango, Riparian habitat

Introduction

Among the tropical fruits, mango (*Mangifera indica* L.) is highly valued for its tasty fruits. A wide array of products ranging from pickles, jam, jelly, leather, squash, wine, *etc.* are prepared using this fruit. Different stages of fruit development are used to prepare different products. One such unique preparation is pickling of highly aromatic mango types in their tender and unripe stage. In the central Western Ghats of Karnataka state, India, these effervescent fruit types are locally termed as '*Appemidi*' and extensively collected from the wild habitats even today (Vasudeva and Rajeshwari, 2014). Unlike commercial mango, '*Appemidi*' fruits are extremely sour and hence are not used as edible flesh fruits. Traditionally these tender fruits are used in household preparations such as *gojju*, *sasve*, *thambuli* and *chutney*. For a common man of this region, no meal is complete without the extraordinary effervescent taste of these '*Appemidi*' pickles. Because of this deep cultural attachment, people have recognized several hundred pickle-mango types from the wild habitats (Vasugi *et al*., 2012). These types are recognized based on their aroma and taste apart from fruit shape, size, and are generally named after the habitat or hamlet with an '*Appe*' suffix (Tesfayi Ashine, 2011). For instance '*Haladota appe*' is the name given to a specific pickle-type mango found near '*Haladota*' hamlet in the central Western Ghats of India (Vasudeva and Rajeshwari, 2014).

Aromatic pickle-mango types are specifically adapted to riparian habitats, grow lofty to reach over 40 m in

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height and remain standing for several decades. Currently these fruits are sought for their high quality pickle with a long shelf life of 3-4 years. It is estimated that the annual business turn over for aromatic pickle-mango in the state of Karnataka is over 10 million Indian Rupees (about US $ 220,000) (Vasudeva *et al.,* 2011). Due to the commercial importance in pickling industry and their multiple uses in household, farmers of the central Western Ghats have been bringing this wild pickle-mango genetic resource under cultivation. However, the range of phenotypic variation in these types and the trait associations are not yet understood considering that these are natural populations.

Community management and domestication of '*Appemidi'* resources of the central Western Ghats are being addressed under the GEF-UNEP project entitled "Conservation and sustainable use of cultivated and wild tropical fruit diversity: promoting sustainable livelihood, food security and ecosystem services". Being implemented in 18 communities of India along with six communities each in Indonesia, Malaysia and Thailand, the immediate objective of the project is to conserve tropical fruit tree genetic resources *in situ* and on-farm through strengthening capacity of farmers, user groups, local communities and institutions to sustainably apply good practices and to secure benefits. *Appemidi* has been recently provided with the geographical indication (GI) registry by the Government of India (Source: http://ipindia.nic.in/girindia/images/RegGis.gif; Gautam *et al*., 2012).

The aim of the present study is to quantify the phenotypic variation in fruit and stone traits of *'Appemidi'* types; to understand the relationships between different traits of importance such that it is possible to develop a 'ideal fruit type' based on trait combinations. Similar approaches were followed in west and central Africa, where the identification of 'ideal types' (Atangana *et al.,* 2001; Leakey *et al.,* 2002) as a tool within a programme of participatory domestication aimed at the development of Agroforestry Tree Products AFTPs (Leakey *et al.,* 2003) and the identified promising types can be explored for domestication.

Materials and Methods

Present study was conducted in Uttara Kannada district, Karnataka, India (13º55'-15º32' N latitude and 74º05'-75º05' E longitude; 650 m above msl). The two specific study localities (Sirsi and Siddapur) in the central Western Ghats were chosen because of the predominant occurrence of natural populations and the deep knowledge of local people in identification and use of *'Appemidi'* types.

About 25-30 pickling stage (unripe) fruits were collected from 34 randomly selected wild trees. Fruits were carefully collected coinciding with the time of local collections (in the month of March), such that the exact stage of fruit development for pickling purpose was met. Fruits from each tree were separately collected in a bag and immediately brought to the laboratory. Every fresh fruit was weighed using an electronic top balance to the nearest 0.1 g. Length, width and thickness of the fruits was measured using a digital electronic vernier calliper to the nearest 0.01 mm (Make-Afcoset). About 10-15 fruits from each tree were cut open and fresh stone weight was taken using electronic top pan balance and recorded in grams. Total green flesh mass was derived by difference (fruit mass – stone mass = green flesh mass). Stone length, width and thickness were also measured on every fruit. Simple Analysis of Variance (ANOVA) and student's 't-test' were adopted to compare mean values on the raw data on in a range of fruit and stone traits.

Information on the most important traits of interest was collected from farmers (growers), fruit collectors and sellers in the nearby market and the values were summarized and converted into scores to arrive at fruit ideal type characters (Leakey *et al.*, 2002). In order to determine the relationship between different traits, linear and non-linear regression method was adopted.

PCA technique is the most widely used ordination procedure. PCA is basically a multivariate statistical technique that partitions a resemblance matrix into a set of orthogonal (perpendicular) axes or components (Ludwig and Reynolds, 1988). Individual trees were ordinate based on the different traits. The clusters are formed based on the proximity of the points on the graph. The principal components were obtained by adopting statistical programme following Sneath and Sokal (1973).

Web diagrams are the graphical representations of the range of variation present in a set of economically important traits plotted simultaneously for several trees (Leakey and Page, 2006). Based on the farmer's response and observations, a set of economically important traits preferred by growers, fruit collectors and sellers were selected and arranged in to several axes with a common origin following Leakey and Page (2006). Considering the phenotypic values for every economic trait, a web is constructed on the radiating axis by joining the points for the values of an individual tree. Similarly, all the trees would be represented on this web. A population is represented by one such collection of webs. The visual deviation among the population could be compared to get an idea of range of variation that would be used for genetic improvement (Leakey and Page, 2006).

Results and Discussion

Domestication involves accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven and market-led process (ICRAF, 1997). It is a continuous process wherein newer traits are selected to produce desirable products. Assessing domestication potential is an important line of research. This has not been addressed in many tropical tree species. In the present study, considerable tree-to-tree variation in fruit characteristics observed in aromatic pickle-mango is consistent with the results reported in other indigenous fruit trees, such as *Irvingia gabonensis* (Atangana *et al.,* 2001), *Dacryodes edulis* (Anegbeh, 1990; Warhiu, 1999), marula (Leakey, 2005) in west and central Africa and *Garcinia gummi-gutta* in central Western Ghats, India (Bhagyavanth *et al.,* 2010). However, some traits were more variable than others. Green flesh mass per fruit and smaller stone mass per fruit are the two commercially important traits that showed large variations. Hence there are considerable opportunities for phenotypic selection. Similarly qualitative traits such as aroma of the sap also showed variation between trees. However, the all fruits derived from a single tree showed same aroma. This suggests that the trait may be under genetic control and hence offer good opportunities for selection and domestication.

Comparison of Mean Values between the Two Sites

Statistically significant differences in mean fruit traits *viz.* fruit length, thickness, width and skin thickness were observed between the two sites. Significant variation was observed for fruit thickness (t=7.40), fruit width (t=6.44), fruit length (t=5.68) and skin thickness (t=2.99) (Table 1). Among other traits, significant variation was observed for stone: fruit area ratio (t=10.25) and stone width: length ratio (t=2.17) between the two populations. The variation found for other fruit and stone traits *viz.* mean fruit mass, flesh mass, flesh depth, stone length and stone width between the two populations was not significant (Table 1).

Variation in Fruit, Stone and Green Flesh Mass

Tree-to-tree differences in fruit, stone and green flesh mass were highly significant ($P < 0.05$). Continuous tree-to-tree variation was observed in fruit mass in both sites (Fig. 1). High tree-to-tree variation was also observed for stone mass of fruits. The variation for mean stone mass in both sites was not exactly in the same tree order as mean fruit mass (Fig. 2).

Variation in Fruit Length, Width and Thickness

High tree-to-tree differences were observed in fruit length, width and thickness (Fig. 3). This variation

Table 1. Comparison of mean values for fruit and stone traits between the two sites

S.No.	Traits	Sirsi (n= 17) $\bar{x} \pm$ SE	Siddapur (n=17) $\bar{x} \pm$ SE	t-test statistic
1	Fruit mass (g)	39.16 ± 4.08	33.7 ± 2.15	1.18
2	Fruit length (mm)	68.08 ± 3.88	43.07 ± 2.08	5.68*
3	Fruit width (mm)	38.41 ± 1.27	25.13 ± 1.62	6.44*
4	Fruit thickness (mm)	31.42 ± 1.08	17.93 ± 1.47	7.40*
5	Stone mass (g)	4.09 ± 0.55	4.69 ± 0.49	0.82
6	Stone length (mm)	38.51 ± 2.07	36.82 ± 1.75	0.62
7	Stone width (mm)	18.71 ± 0.64	19.52 ± 0.72	1.23
8	Stone thickness (mm)	10.21 ± 0.56	11.29 ± 0.62	1.29
9	Skin thickness (mm)	0.87 ± 0.02	0.97 ± 0.03	2.99*
10	Fruit width: length ratio	0.59 ± 0.03	0.59 ± 0.03	0.11
11	Stone width: length ratio	0.50 ± 0.02	0.55 ± 0.01	2.17*
12	Stone: Fruit area ratio	0.28 ± 0.02	0.67 ± 0.03	10.25*
13	Flesh mass (g)	35.07 ± 3.83	29.01 ± 1.83	1.42
14	Flesh depth (mm)	8.49 ± 0.42	7.83 ± 0.32	1.25

*Significant @ p<0.05

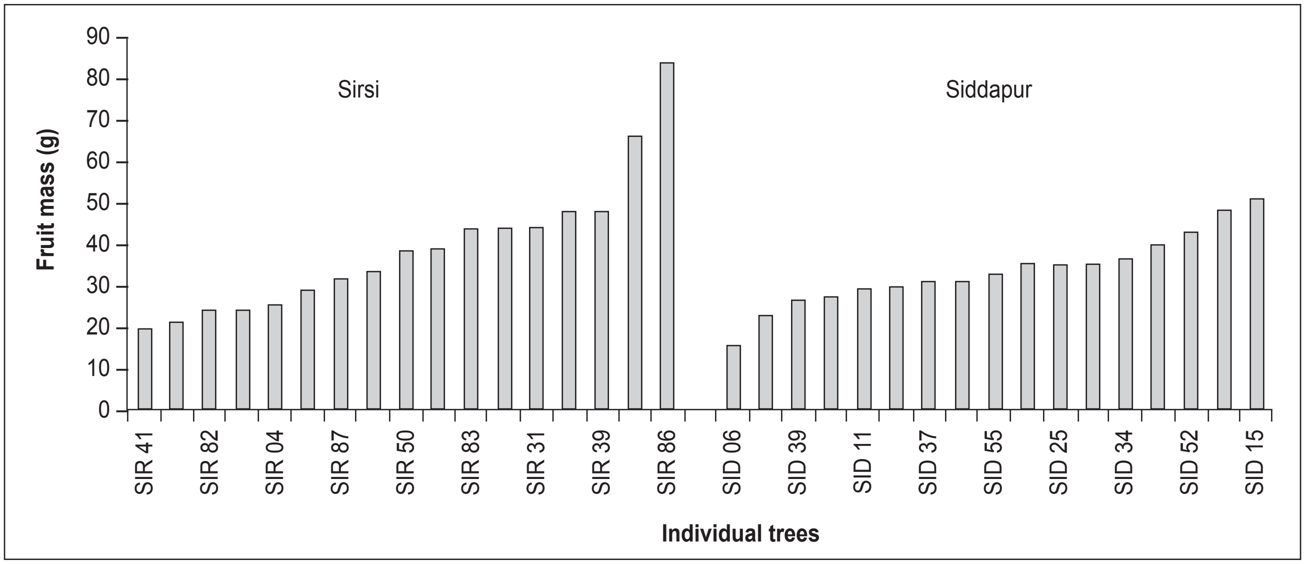

Fig. 1. Continuous tree-to-tree variation in mean fruit mass (g) of wild pickle-mango in two localities of Uttara Kannada, Central Western Ghats. The accessions are arranged in the increasing order of fruit mass

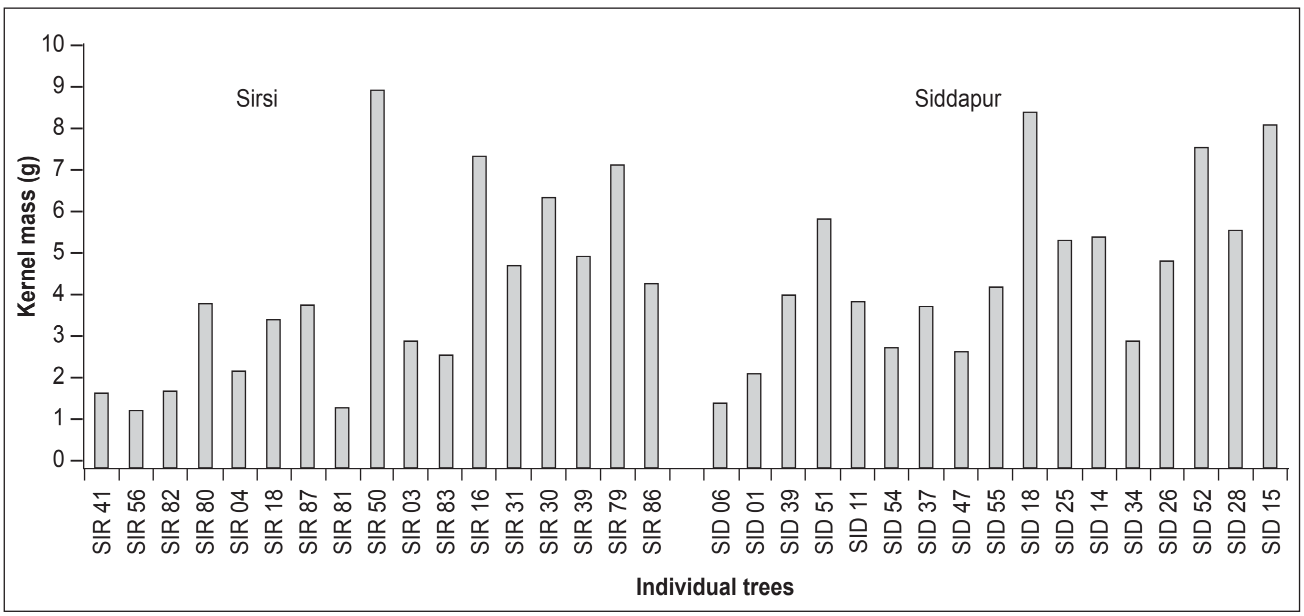

Fig. 2. Tree-to-tree variation in mean stone mass (g) in two localities of Uttara Kannada, Central Western Ghats

was not exactly in same tree order as mean fruit mass. Mean stone length varied from 26.97 mm (SIR 04) to 55.59 mm (SIR 30) in Sirsi while it varied from 20.43 mm (SID 06) to 51.47 mm (SID 52) in Siddapur. Mean stone width varied from 13.07 mm to 22.92 mm in Sirsi whereas the variation was from 20.43 mm to 51.47 mm in Siddapur. The variation for stone thickness was 6.67 mm to 14.00 mm in Sirsi and 6.21 mm to 15.93 mm in Siddapur (Fig. 3).

Variation in Stone Length, Width and Thickness

High tree-to-tree differences were also observed in stone length, width and thickness. This variation was not exactly in same tree order as mean fruit mass. Mean stone width varied from 13.07 mm to 22.92 mm in Sirsi whereas it varied from 20.43 mm to 51.47 mm in Siddapur (Fig. 4).

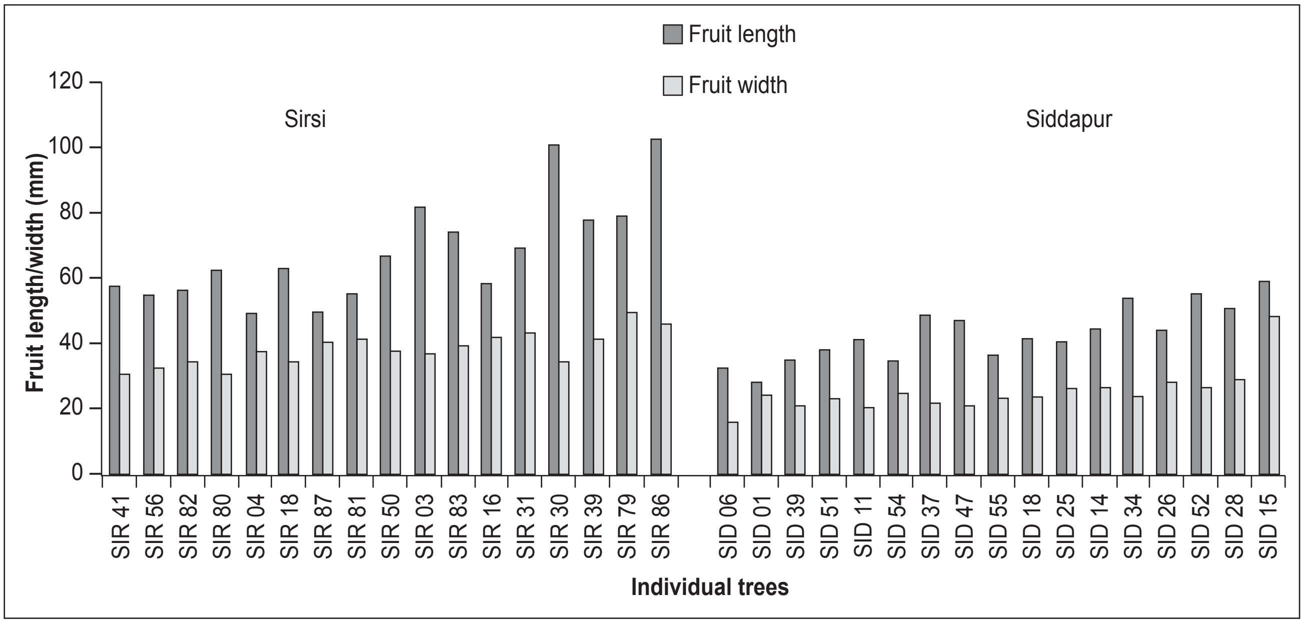

Fig. 3. Tree-to-tree variation in mean fruit length and width (mm) in two localities of Uttara Kannada, Central Western Ghats

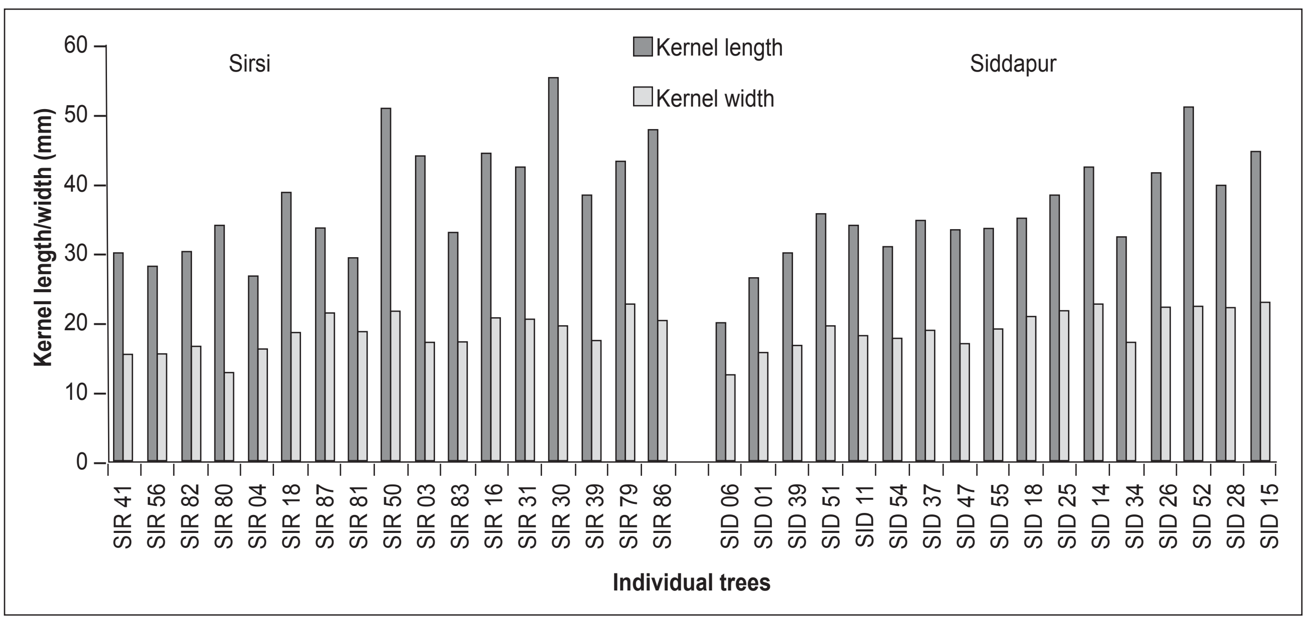

Fig. 4. Tree-to-tree variation in mean stone length and width (mm) in two localities of Uttara Kannada, Central Western Ghats

Variation in Flesh Depth and Skin Thickness

Tree-to-tree differences in flesh depth and skin thickness were highly significant ($P<0.05$). Flesh depth varied continuously from 5.27 mm to 11.40 mm in Sirsi and it varied from 5.31 mm to 11.62 mm in Siddapur. Continuous tree-to-tree variation was observed for skin thickness that ranged from 0.76 mm to 1.07 mm in Sirsi and from 0.79 mm to 1.25 mm in Siddapur.

Variation in Fruit Width to Length and Stone to Fruit Area Ratios

Significant tree-to-tree variation was observed in fruit width: length, stone width: length and stone: fruit area ratio. Fruit width: length ratio ranged from 0.34 to 0.82 in Sirsi, while it varied from 0.44 to 0.85 in Siddapur. The variation for stone length: width ratio was ranged from 0.36 to 0.65 in Sirsi and from 0.04 to 0.62 in Siddapur.

On the other hand stone: fruit area ratio exhibited a significant variation ranging from 0.20 to 0.44 in Sirsi and from 0.37 to 0.84 in Siddapur.

Although tree-to-tree variation in stone mass was high, it was not tightly associated with fruit mass, suggesting the difficulty of predicting stone mass based on fruit mass. This pattern might also arise due to the use of unripe/tender stage of mango fruit for pickle making. Leakey *et al.* (2000) and Atangana *et al.* (2001) have also reported such weak associations between fruit and stone size in bush mango (*Irvingia gabonensis*) in Cameroon. The least fruit and flesh mass in Sirsi site was as heavy as that of the highest in Siddapur site indicating contrasting patterns of variation across sites. Wide tree-to-tree variation in fruit skin thickness was observed in Siddapur than in Sirsi indicating a possibility of selecting genotypes for better shelf-life. Hence it is recommended to sample more number of populations than more number of trees within a population.

Tree-to-tree variation for several fruit traits showed continuous distribution in both the localities as depicted by the histograms (Fig. 1-4). This suggests that the sampling was sufficient to capture a continuous variation (Atangana *et al.,* 2001; Leakey *et al.,* 2005a,b). Such continuous distribution of tree-to-tree variation is also shown in fruit and nut traits in Marula (Leakey *et al.,* 2005a,b) and differences were also significant between the two populations studied.

Relationships between Fruit Traits

There were highly significant and strong positive relationships between fruit mass and flesh mass in both the populations (R^2 = 0.988) in Sirsi and (R^2=0.965) in Siddapur respectively (Table 2). However, the relationships between flesh depth and other fruit characteristics (length/width/thickness) were found to be weak.

Fruit mass exhibited moderate correlation with fruit length (R^2=0.636) and width (R^2=0.682) in Sirsi and Siddapur respectively. However, it exhibited stronger and positive correlation with fruit thickness (R^2=0.720) in Sirsi and (R^2=0.723) in Siddapur (Table 2).

Relationships between Stone Traits

Moderate relationship was found between stone mass and stone length in both sites with (R^2=0.636) and (R^2=0.682) in Sirsi and in Siddapur respectively. Strong relationship (R^2=0.744) was found between Stone width and stone mass in Siddapur but not in Sirsi (Table 3). In contrast strong relationship (R^2=0.859) was found between stone thickness and stone mass in Sirsi (Table 3).

Relationships between Fruit and Stone Traits

There was no considerable and significant relationship between fruit and stone traits considered except the moderate relationship found between stone width and fruit width with (R^2=0.585) in Sirsi and (R^2=0.542) in Siddapur (Table 4). The relationship between fruit mass and stone mass was very weak. Generally the relationship between fruit mass and stone mass were weaker than between fruit mass and flesh mass.

Strong relationships between fruit mass and green flesh mass in aromatic pickle-mango found in this study indicated that selection for green flesh mass can be based

Table 2. Relationships between fruit traits in wild pickle-mango genetic resources in Uttara Kannada, Central Western Ghats

Traits	Sirsi (n=17) Equation	R^2	Siddapur (n=17) Equation	R^2
Fruit mass *v* flesh mass	$y = 0.002x^2 + 0.660x + 4.247$	0.988	$y = 0.000x^2 + 0.794x + 1.478$	0.965
Flesh depth *v* fruit mass	$y = 0.001x^2 - 0.066x + 9.066$	0.238	$y = -0.001x^2 + 0.141x + 4.910$	0.075
Fruit length *v* fruit mass	$y = 0.002x^2 + 0.517x - 6.506$	0.636	$y = 0.000x^2 + 0.780x - 1.511$	0.682
Fruit width *v* fruit mass	$y = 0.095x^2 - 4.892x + 84.02$	0.660	$y = -0.049x^2 + 4.320x - 41.45$	0.780
Fruit thickness *v* fruit mass	$y = 0.139x^2 - 5.739x + 79.26$	0.720	$y = -0.055x^2 + 3.911x - 16.59$	0.723
Flesh mass *v* fruit width	$y = 0.092x^2 - 4.860x + 82.91$	0.647	$y = -0.043x^2 + 3.714x - 35.26$	0.751
Flesh mass *v* fruit length	$y = 0.004x^2 + 0.145x + 4.471$	0.633	$y = 0.002x^2 + 0.506x + 2.317$	0.687

Table 3. Relationships between stone traits in wild pickle-mango genetic resources in Uttara Kannada, Central Western Ghats

Traits	Sirsi (n=17) Equation	R^2	Siddapur (n=17) Equation	R^2
Stone length *v* stone mass	$y = 0.002x^2 + 0.517x - 6.506$	0.636	$y = 0.000x^2 + 0.780x - 1.511$	0.682
Stone width *v* stone mass	$y = 0.111x^2 - 3.525x + 30.30$	0.590	$y = 0.021x^2 - 0.261x + 1.359$	0.744
Stone thickness *v* stone mass	$y = 0.180x^2 - 2.867x + 13.60$	0.859	$y = -0.077x^2 + 2.210x - 10.08$	0.490

Table 4. Relationships between fruit and stone traits in wild pickle-mango in Uttara Kannada, Central Western Ghats

Traits	Sirsi (n=17) Equation	R^2	Siddapur (n=17) Equation	R^2
Stone mass *v* flesh mass	$y = -1.228x^2 + 14.58x + 1.901$	0.310	$y= 0.426x^2 + 6.495x + 9.564$	0.384
Flesh depth *v* stone mass	$y = 0.114x^2 - 1.044x + 10.30$	0.110	$y = -0.129x^2 + 1.342x + 4.869$	0.168
Stone mass *v* fruit mass	$y = -0.002x^2 + 0.339x - 4.247$	0.457	$y = -0.000x^2 + 0.205x - 1.478$	0.414
Stone length *v* fruit length	$y = -0.003x^2 + 0.894x - 6.529$	0.589	$y = -0.018x^2 + 2.198x - 21.86$	0.456
Stone width *v* fruit width	$y = -0.011x^2 + 1.249x - 12.61$	0.585	$y = -0.022x^2 + 1.743x - 8.754$	0.542
Stone thickness *v* fruit thickness	$y = -0.022x^2 + 1.708x - 20.58$	0.307	$y = -0.016x^2 + 0.990x + 0.026$	0.219

on fruit mass. However, the weak relationship between fruit mass and stone mass suggests the difficulty of predicting stone size based on fruit size. Rare trees in the population with big fruits and small stone could be selected for domestication. However, it is also clear that much larger populations will need to be examined if these rare trees worthy of development as cultivars are to be found (Atangana *et al.,* 2001; Leakey *et al.,* 2005a,b).

The results of this study with aromatic pickle-mango have highlighted the extent of tree-to-tree variation at village level in many commercially important traits and suggest the opportunities for multiple-trait selection. Studies from indigenous fruits, being domesticated in West Africa using a participatory domestication approach (Tchoundjeu *et al.,* 2002; Leakey *et al.,* 2003), suggest similar participatory strategy to aromatic pickle-mango domestication could be useful strategy in Central Western Ghats. The participatory domestication of indigenous fruits has been proposed as an appropriate means to alleviate poverty (Leakey *et al.*, 2003), and could also have positive benefits on the environment. The ideal type concept would also assist in identifying the specific trait combinations for best aromatic pickle making.

Principal Component Analysis (PCA) of the Populations

The results of principal component analysis in fruit parameters enabled to identify those traits which contribute maximum to the divergence of the populations. The largest absolute loading values in the first principal component were fruit length (0.631), fruit mass (0.470), flesh mass (0.438) (Table 5). The corresponding values for the second principal component was for fruit length (0.539), fruit mass (0.523) and flesh mass (0.431). The third eigen vector consisted of fruit width (0.590), fruit length (0.497) and thickness (0.483). Among the principal components, the first component accounted for 76.071 per cent variation while the PC2 and PC3 accounted for 12.479 and 6.171% of the variation, respectively. These three components accounted for totally 94.721 per cent of the variation. These traits contribute maximum to the divergence of the two populations.

Table 5. Eigen vectors of Principal Components in the descending order for fruit parameters in wild pickle-mango

S.No.	Parameter	Principal component I	Principal component II	Principal component III
1	Fruit length	0.631	-0.539	-0.497
2	Fruit mass	0.470	0.523	0.096
3	Flesh mass	0.438	0.431	0.126
4	Fruit width	0.273	-0.251	0.590
5	Fruit thickness	0.264	-0.303	0.483
6	Stone length	0.204	0.210	-0.372
7	Stone width	0.038	0.163	0.043
8	Stone mass	0.031	0.092	-0.030
9	Flesh depth	0.019	0.033	0.054
10	Stone thickness	0.016	0.123	-0.050
11	Skin thickness	-0.000	0.002	-0.003
12	Fruit width: Length ratio	-0.001	0.001	0.014
13	Stone width: Length ratio	-0.002	0.001	0.006
14	Stone to fruit area ratio	-0.005	0.015	-0.008

PCA based on fruit traits has suggested that the two populations' ordinate into two distinct clusters indicating diverging natural selection (Fig. 5). It is surprising that such clear categorization has been obtained despite the fact that the two populations are separated by not more than 50 km from each other and fall within high rain fall (2500–4000 mm) and moderate temperature zone (22.8 °C-30.2 °C) as well as occur in similar altitude of about 600 m above mean sea level.

Recognition of Ideal Fruit Types

Based on eight important traits preferred by growers/ fruit collectors/sellers, identification of potential superior trees was attempted. As shown in the Table 6, 'cumin type' was the most preferred in character 'aroma'. The growers/collectors preferred trees that yield less than 3" fruit; with elongated shape; having a keeping quality more than two years. These characters might represent a suite of morphological features that are associated with domestication of wild aromatic pickle mango for a specific purpose.

A score for each trait under each rank was computed by multiplying the number of respondents preferring a trait in a particular rank and the weight given to the rank (first=4, second=3, third 2 and fourth=1). The total score for each trait was then computed by summing up the scores of all four ranks (Table 7).

Almost all respondents identified traits like aroma as important for a better pickle-mango type. This was followed by the traits like keeping quality suggesting that these were ranked second with 60% of the respondents identifying it as the best (Table 7). Other fruit characteristics like fruit size, shape, sourness and quantity of latex were also among the most considered traits. Since these respondents were carefully chosen to include those that are practising the trade/ collection / maintenance their opinion is crucial for the domestication (Fig. 6).

Implications for Cultivar Development and in situ Conservation

Perhaps the restricted gene exchange between the two populations because of their high habitat specificity to valley systems of two different riparian habitats may lead to the population divergence. Further a combination of animal and water dispersal of mango fruits often result in clumped cohorts which may also contribute to higher intra-population similarity than the inter-population

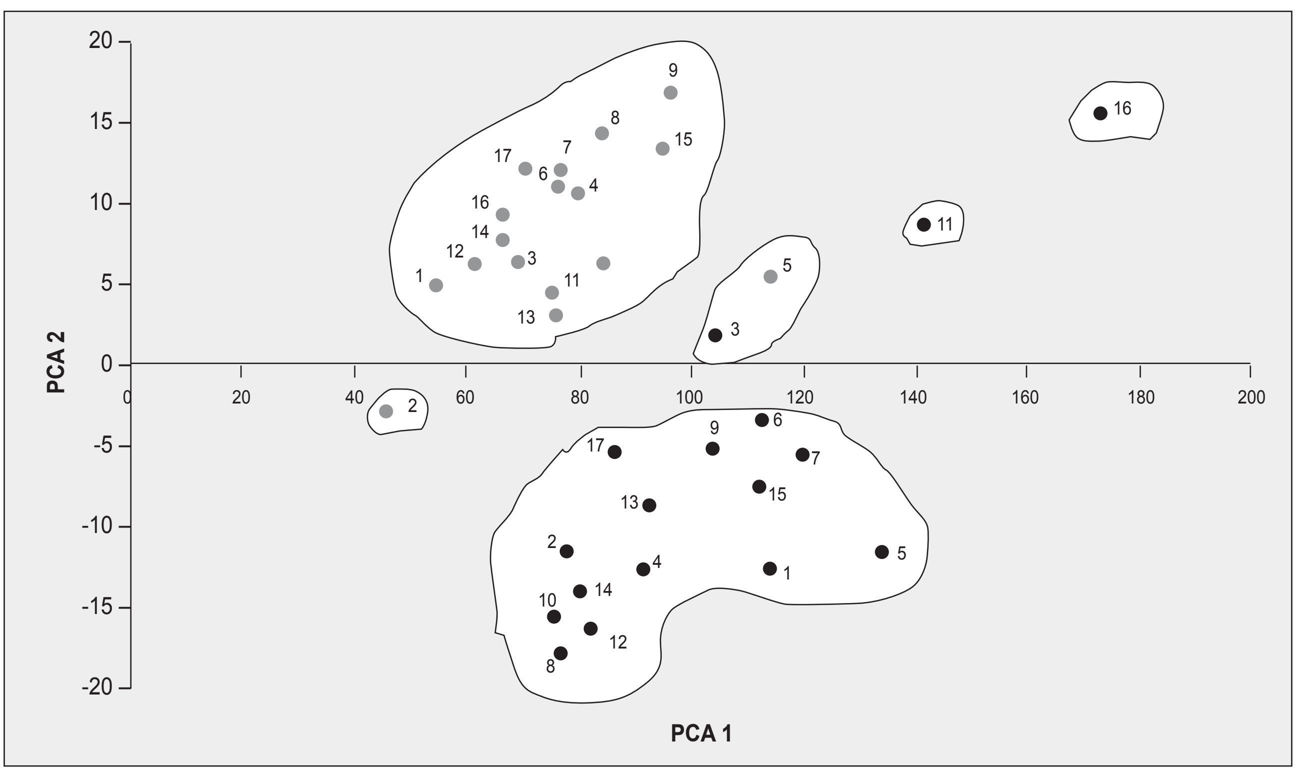

Fig. 5. Configuration of wild pickle-mango accessions from Sirsi (red n=17) and Siddapur (Blue n= 17) site as shown by PC 1 and PC 2 for fruit parameters. Accession number of trees is shown next to dots

Table 6. Typology and number of respondents preferring different fruit traits in aromatic pickle-mango types. Values in the parenthesis is per cent of total respondents (N= 40)

S. No.	Characters	Typology of trait / number of respondents preferring the trait			
		Rank I	Rank II	Rank III	Rank IV
1.	Aroma	Cumin 26 (65%)	Camphor 7 (17.5%)	Orange-mango 4 (10%)	Typical mango 3 (7.5%)
2.	Fruit brittleness	Highly brittle 14 (35%)	Brittle 13 (32.5%)	Moderate 10 (25%)	Non brittle 3 (7.5%)
3.	Quantity of latex	High 14 (35%)	Medium 13 (32.5%)	Low 7 (17.5%)	Very low 6 (15%)
4.	Sourness	Very strong 17 (42.5%)	Strong 12 (30%)	Medium 6 (15%)	Low 5 (12.5%)
5.	Fruit size	Small < 3" 21 (52.5%)	Medium 3"- 4" 10 (25%)	Large > 4" 6 (15%)	Any 3 (7.5%)
6.	Fruit shape	Elongated 16 (40%)	Oblong 14 (35%)	Ovoid 5 (12.5%)	Others 5 (12.5%)
7.	Flesh colour*	White 16 (40%)	Greenish white 11 (27.5%)	Yellowish white 10 (25%)	Any 3 (7.5%)
8.	Keeping quality	>2 years 24 (60%)	1-2 year 7 (17.5%)	6 month-1 year 6 (15%)	< 6 month 3 (7.5%)

Rank assigned to a character is based on the per cent preference
**after at least one year of keeping in brine solution*

Table 7. Order of importance of characters in aromatic pickle-mango types based on total score for each trait

Character	Rank I	Rank II	Rank III	Rank IV	Total score	Order of importance for the character
Aroma	26(104)	7(21)	4(8)	3(3)	136	I
Keeping quality	24(96)	7(21)	6(12)	3(3)	132	II
Fruit size	21(84)	10(30)	6(12)	3(3)	129	III
Fruit shape	16(64)	14(42)	5(10)	5(5)	121	IV
Flesh colour	16(64)	11(33)	10(20)	3(3)	120	V
Quantity of latex	16 (64)	10 (30)	11(22)	3(3)	119	VI
Sourness	17(51)	12(36)	6(12)	5(5)	104	VII
Fruit brittleness	14(42)	13(39)	10(20)	3(3)	104	VIII

Figures in parenthesis are scores of each variable for that rank which is determined by multiplying the number of respondents by the respective scores *i.e.* Rank I=4, Rank II= 3, Rank III= 2, Rank IV= 1

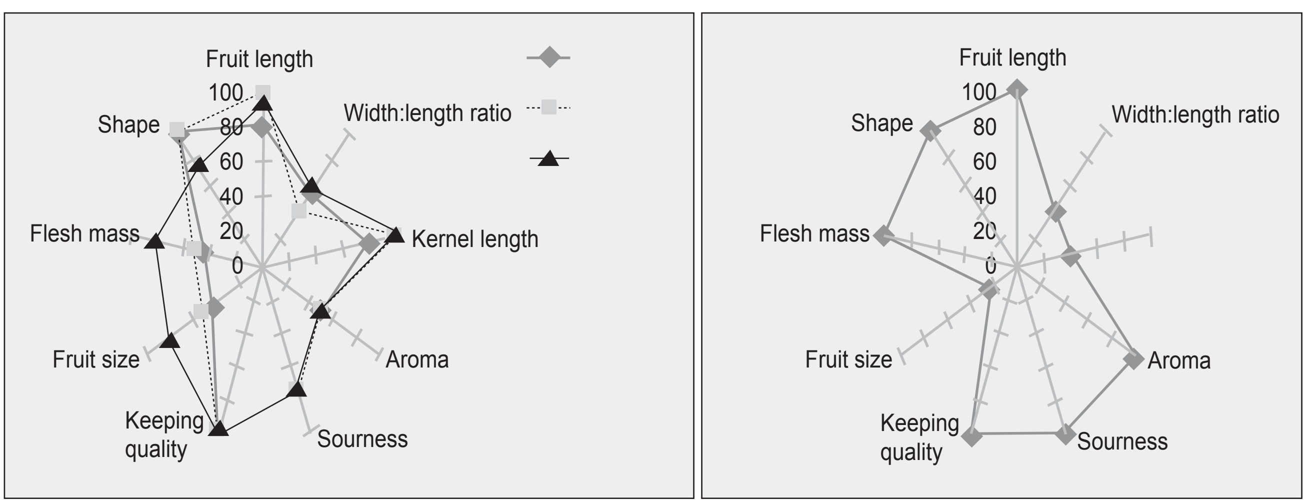

Fig. 6. Web diagrams showing ideal fruit type of wild pickle-mango (a) of three trees that are closest to the ideal type (b) as determined by the respondents and observations

divergence. Hence it may be suggested here that the pickle-mango tree populations occurring in different river valley systems of the central Western Ghats may represent divergent populations each with unique set of traits. Consequently, every riparian pickle-mango population may be regarded as a treasure house of genetic variability. This calls for effective *in situ* conservation of these populations as meta-populations (Sthapit and Rao, 2009). Any effort towards *ex situ* conservation should sample more number of habitats than more number of individuals within a population to capture the range of variations present. Large scale plantings of aromatic pickle-mango may be suggested which would also help to conserve these important genetic resources and to obtain ecological benefits as well. In addition, the move towards cultivation of these genetic resources in an agro-ecosystem may encourage farmers to plant other useful trees, so diversifying the farming system with likely benefits on sustainability, through the creation of agro-ecological succession culminating in a mature or climax phase as suggested by Leakey (2001).

This study has highlighted the extent of tree-to-tree variation in aromatic pickle-mango at village level in many commercially important traits and suggest the opportunities for multiple-trait selection. Similarly qualitative traits such as aroma of the sap also showed variation between trees. However, all the fruits derived from a single tree showed same aroma. This suggests that the trait may be under genetic control and hence it is concluded that there is an opportunity to select cultivars for traditional household uses and for current pickling industries' requirement. This should lead to socio-economic and environmental benefits from the adoption of agro-forestry practices (Leakey, 2001).

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