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Motivation for On-farm Conservation of Mango (*Mangifera indica*) Diversity in India – A Case Study

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Studies were carried out to investigate the reasons underlying farmers' motivation to conserve mango diversity particularly of indigenous varieties. At four project sites, *viz*., Chittoor, Malihabad, Pusa and Sirsi, 48 custodian farmers were identified. The results of the analysis indicated that it is not only the economic factors (market value, 79%), but also other factors such as personal (63%), social (52%), cultural/religious (14%), natural (48%) factors and biological traits (52%) which motivate farmers to conserve specific varieties while maintaining mango diversity. Further, while all the custodians maintained the diversity, some others (34%) also promoted and adapted the diversity. For promotion of mango diversity conservation, value addition to diversity and linking mango diversity to markets through diversity fairs, stakeholders' meeting, and roadside stalls will have to be given priority. National policy support in the form of establishing a network of custodian farmers and skill up gradation (grafting, management of genetic resources) and registration of farmers' varieties will go a long way in ensuring conservation of mango diversity on sustainable basis.

Key Words: Custodian farmer, Mango diversity, Motivation, On-farm conservation, Tropical fruit tree resources

Introduction

Many farmers maintain a large number of fruit tree species or varieties on their farms and a wide variability in intra and interspecific richness can be found between households. Despite the availability of preferred commercial fruit varieties, farmers around the world have been maintaining, promoting and adapting a wide range of indigenous fruit tree varieties on their farms and homesteads (Bhag Mal *et al*., 2010). Such male and female farmers, 'who actively maintain, adapt and promote agricultural biodiversity and related knowledge over time and space at farms and community level and are locally recognised for these efforts', have been defined as custodian farmers (Sthapit *et al*., 2013). The factors that motivate farmers to maintain indigenous varieties in their farm lands have been subjected to recent scientific scrutiny (Subedi *et al*., 2003; Jarvis *et al.*, 2011). Earlier studies have indicated that farmers benefit from conserving crop diversity and several factors have been shown to motivate them (Perrings and Gadgil, 2003; Bellon, 2004; De Boef *et al.*, 2012). Brush and Meng (1998) and Brush (2000) identified three different types of values of crop varieties: direct, indirect and option value. Direct or use value refers to harvest and uses of crop varieties. Indirect value refers to environmental services or ecological health to which crop varieties contribute though farmers may not observe or notice the relationship. Option value refers to the future use of crop varieties. These values accrue to fruit tree diversity based on personal, social, economical, cultural and biological source of motivation (Sthapit *et al.*, 2013). It would be useful to understand the underlying reasons for the farmer's motivation and to know how the farmers benefit from such a decision. In order to gain such insights, the present study was carried out to get an answer to a few key questions such as: (i) what varieties such farmers maintain? (ii) who

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maintains them and what is their socio-economic context? (iii) what factors motivate the farmers to conserve diversity? (iv) what are the commercial implications of diversity conserved by them?

A clear understanding of the type of farmers who maintain diversity on their farms and of the relative importance of motivational factors shaping such on-farm conservation practices, is fundamental to guide conservation interventions and to create an enabling policy environment. This study has the following objectives:

- To understand the socio-economic profile of custodian farmers and assess if they had a distinct profile compared with other fruit farmers
- To identify different factors that motivated the farmers to conserve mango diversity
- To assess the relative importance of these motivational factors and their association with the level of diversity
- To examine whether there existed variety-specific motivation

Materials and Methods

The present study was conducted at four ecologically diverse sites (Chittoor, Malihabad, Pusa and Sirsi) across India (Table 1 and Fig. 1), where community management of tropical fruit tree (TFT) resources is 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 amongst 18 communities of India along with six communities each in Indonesia, Malaysia and Thailand, the immediate objective of the project was to conserve TFT genetic resources *in situ* and on- farm through strengthening capacity of farmers, user groups, local communities and institutions to sustainably apply good practices and secure benefits (Sthapit *et al*., 2013). Based on the focus group discussion especially, Four Cell Analysis, the mango-richness of the communities at each site was ascertained. Later, baseline data that was collected at the beginning of the TFT project, was used to identify farmers who typically maintained higher number of varieties of TFT than those who maintained the average (4-5) in that community. Further, the farmers who maintained more than 10 varieties of mango were included in the initial list of Custodian Farmers (CF) in the present study. Additional custodians were identified based on the recommendations from TFT project field staff and fellow farmers based on the aforementioned description of custodian farmers. A total of 48 custodian farmers who conserved more than 10 varieties of mango and also maintained 'un-named' seedling types, were identified at the respective sites – Chittoor (17), Malihabad and Pusa (10 each), and Sirsi (11). Subsequently, data were collected from these custodian farmers based on a questionnaire and or semi-structured interview with respect to personal characteristics like age, education, farm characteristics and motivational factors for analysing the reasons for conservation of mango diversity.

The following typology of motivational factors driving the custodian farmers to maintain agro-biodiversity, provided earlier by Sthapit *et al*. (2013), was adopted in this study.

1. Personal (hobby, personal interest to collect)
2. Social value (heritage value and legacy-respect for parents/forefathers, for exchange with relatives/ friends)
3. Economic considerations (good income, risk management)
4. Cultural significance (traditions, customs, beliefs or because of its use in cultural or religious functions)
5. Natural / virtues of a variety (disease-or pest-resistant or adapted to local climate and soil conditions, provision of eco-system services, regular bearer)
6. Biological (taste, varietal preference)

Results and Discussion

Profile of Custodian Farmers

As shown in Table 2, there were no significant differences in the profiles of custodian farmers and the average

Table 1. Study sites, their geographic details and number of custodian farmers at each site

Site	State	Broad agro-ecological region	Farming system	Latitude	Longitude	Altitude	No. of custodian farmers
Chittoor	Andhra Pradesh	Hot, arid eco-region	Orchard	13°13	79°08	183 m	17
Malihabad	Uttar Pradesh	Hot, moist semi-arid region	Orchard	26°55	80°43	127 m	10
Pusa	Bihar	Hot, sub- humid eco-region	Orchard and home garden	25°46	86°10	53 m	10
Sirsi	Karnataka	Humid hill zone	Home garden and orchard	14°37	74°50	605 m	11

Fig. 1. Study sites in India

farmers except their education and the farm size. This suggested that factors other than the age and family size of the farmers motivate farmers to conserve the mango diversity, on-farm (Table 3). Clearly, all custodian farmers possessed significantly larger farm size (thrice as that of other farmers) and higher education than the non-custodian farmers.

Table 2. Socio-economic profile of custodians and general mango farmers

Characteristics	Custodian farmers (n=48)	Average mango grower (n=824)
Farm size (ha)	6.43* (±9.01)	1.83* (±3.09)
Age (years)	52.35 (±12.12)	53.25 (±13.24)
Education (%, > high school)	54.16	18.12
Family size (No.)	6.18 (±3.41)	5.33 (±2.70)

*Significant @1% level of probability; Figures in parentheses are SD

Motivational Factors

As shown in Table 3, farmers conserve mango diversity for a variety of reasons. Though economic benefit (79%) is the major driver of conservation, other non-economic factors like prestige for being the owner of diversity (63%), exchange of specific varieties and their products with neighbours, relatives and family friends (52%), biological traits (52%) like taste, colour and/or specific use (pickling) also motivate farmers to maintain and promote conservation of mango diversity. Further, adaptability of certain seedling types (*Naati/Bijju/Tukmi*) to adverse climatic conditions including other abiotic and biotic stresses, regular and heavy bearing also contributed to on-farm conservation of rich mango diversity (48%). The motivational factors differed across sites clearly implying the importance of these factors while making efforts to support conservation.

Choice of Varieties

Specific varieties chosen by the farmers for conservation

were driven by the motivational factors (Table 4). It is evident from the table that choice of varieties by farmers varied with respect to sites and also the motivating factors. It was also observed that the same variety was conserved for different reasons at a particular site. For example, *Imam Pasand* is conserved due to its good marketability as well as for being a pollinator attractant thus helping in better fruit-set in the mango orchards. Similarly, some *Appe* varieties are conserved for their biological traits (specific aroma) and also for the economic considerations. Varieties such as *Royal Special* and *Atimadhuram* are conserved mainly for their rarity in the region and also for social reasons like exchange among the friends and relatives. Besides, the *Naati* varieties are mostly regular bearers and thus contribute to tide over the economic risk associated with other commercial varieties. The farmers have also identified the superior biological traits of certain varieties like *Chakkaraguttulu, Ali Pasand, Gaddemar, Reddy Pasand* and *Sukul* (pickling types); *Lalbaba* and *Manoranjitam* being suitable for long distance transport due to their better keeping quality besides having attractive colour. Choicest varieties conserved by custodian farmers have been described by Rajan *et al.* (2014).

Type of Custodians

Custodian farmers, apart from playing a critical role in conserving the rare varieties, act as local guides to disseminate the good practices and also as providers of scions of local varieties and traditional knowledge associated with TFT. Such roles have been earlier reported

Table 3. Relative importance of economic and non-economic motivational factors for the conservation of local mango varieties across four study sites in India

Site and number of respondents	Motivating factors						No. of varieties (Range)
	Economic (%)	Non-economic (%)					
		Personal	Social	Cultural	Natural	Biological	
Chittoor (n=17)	82.36	47.06	58.82	11.76	64.75	64.75	10-28
Malihabad (n=10)	80.00	70.00	80.00	–	40.00	40.00	25-135
Pusa (n=10)	80.00	90.00	60.00	20.00	50.00	40.00	10-36
Sirsi (n=11)	72.72	45.45	9.09	9.09	36.36	63.64	18-72
India (n=48)	78.77	63.12	51.98	13.62	47.77	52.09	

The percentages do not add up to 100 because of multiple responses

Table 4. Motivating factors and specific varieties conserved across sites

Motivating factors	Chittoor	Malihabad	Pusa	Sirsi
Economic	*Kalepadu, Imam Pasand*	*Dashehari, Gulab Khas, Husnara, Fakira, Mohan Bhog, Rangeen Gola, Jard-Amin*	*Calcuttia Malda Bathua Safeda Malda Lal Malda, Sukul Sipia*	*Varate Guduga, Malanji, Nandagara, Adderi jeerige*
Personal	*Kudadut, Royal Special*	*Surkhi, Sundari, Pauda Gaj, Deshi Bombaiya, Machhli, Pan,*	*Calcuttia Malda Safeda Malda Lal Malda Sukul*	*Genesina kuli*
Social	*Royal Special, Atimadhuram*	*Surkhi, Amin, Taimuriya, Fakira, Mohan Bhog, Rangeen Gola, Jard-Amin*	*Bathua, Belwa, Sipia, Hajipur Mithui, Sukul*	*Manadur Katte*
Cultural	*Chakkaraguttulu* – Pickle served during functions	–	*Bijju* – traditional belief not to cut mango trees of seedling origin	*Appe varieties* for a sweet sour drink *(Appehuli)* to be served during functions
Natural	*Imam Pasand, Mittigeri, Naati-3, Nauzak Pasand, Bogum Rangasani, Gadiyaram, Poonsa* (bears twice a year), *Royal Special* (bears twice a year)	*Biju Tukmi, Deshi Chausa, Tukmi Chausa, Gulab Jamun*	*Sukul, Bathua*	*Chouti Appe* because of late bearing
Biological	*Lalbaba* (attractive colour), *Peddarasam, Atimadhuram* (taste), *Manoranjitam* (shelf life), *Gaddemar* and *Ali Pasand* (pickle), *Thorappadu* and *Kudadat* (large fruits), *Kuddus, Gadiyaram, Seeri* (juicy)	*Acharwala, Peela Gola, Khubsurat Lamboi, Thuhuru* (pickle)	*Bijju* (colour), *Belwa, Shukulia*	All *Appe* varieties (aroma)

Table 5. Description of custodian farmers by their roles (%)

Type of custodian farmer	Chittoor	Malihabad	Pusa	Sirsi	India
Maintain	100.00	100.00	100.00	100.00	100.00
Maintain + Adapt	35.29	60.00	60.00	54.55	52.46
Maintain + Promote	41.17	50.00	100.00	63.64	63.70
Maintain + Adapt + Promote	29.41	30.00	60.00	18.18	34.40

The total does not add up to 100 as there are multiple responses

by Sthapit *et al*. (2013). However, not all the custodians play all the roles. In this study, attempts were made to identify the roles of custodians and typify each of them. The results of the analysis are presented in Table 5. It may be observed that all the farmers maintain diversity for one reason or the other (100%). However, about 64% of them maintain and also promote specific varieties by giving scions to nursery men or other interested farmers in the community, *Royal Special* and *Lalbaba* being the notable ones. *Royal Special* is a locally appreciated variety in Chittoor which flowers twice a year. About 52 % of the farmers maintain as well as adapt certain varieties of their choice. For example, *Atimadhuram* and *Lalbaba* are adapted by the Chittoor farmers. Interestingly, about 34 % of the farmers play all the roles of a custodian i.e. maintain, adapt and promote the diversity. It means that about a third of the custodian farmers identified in the study had the highest impact on conservation and use of TFT. Hence, it may be possible to move the two thirds of CF who only maintain and/or adapt, into the most effective group (those who maintain, adapt and promote) through active support and suitable education

Conclusions

One of the strategies of conserving diversity, on-farm, is identification of custodians and extending support to them as these farmers have maintained the diversity without any formal support. The results of the study indicated that it is not only the economic factors (market value) which motivated the farmers to conserve mango diversity but also personal, social and cultural/religious factors. Biological traits with reference to specific varieties played an equally important role. The farmers also chose varieties for conservation depending upon the type of motivation. Further, while all custodians just maintained the diversity, a good number of them (50-60%) also promoted and adapted the diversity. The latter role is important for sustainability of conservation efforts made by the farmers. The custodian farmers are *de facto* the primary actors in *in situ* conservation, on-farm, for which they deserve full recognition and appreciation from the community. Further, for continuation of mango diversity conservation on a sustainable basis, farmers need to be made aware of the value of their rich diversity by linking them to R&D sector for characterization and evaluation of the elite types, grafting of superior types in their farm and by distribution of plants. Value addition to diversity and linking mango diversity to markets through diversity fairs, stakeholders' meet and roadside stalls, will have to be given priority. The demonstration (valuation), capturing and sharing the benefits of biodiversity conservation as proposed by Pascual and Perrings (2007) may be of interest in sustainable conservation of mango diversity. National policy support in the form of establishing a network of custodian farmers and skill up gradation (grafting, management of genetic resources) and registration of farmers' varieties will go a long way in ensuring conservation of mango diversity on a sustainable basis.

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References

Bhag Mal, V Ramanatha Rao, RK Arora, PE Sajise and BR Sthapit (2010) Conservation and sustainable use of tropical fruit species diversity: Biodiversity's efforts in Asia, the Pacific and Oceania. *Indian J. Plant Genet. Resour.* **24**: 1-22.

Bellon M (2004) Conceptualizing interventions to support on-farm genetic resources conservation. *World Dev.* **32**:159-172.

Brush S and E Meng (1998) Farmers' valuation and conservation of crop genetic resources, *Genet. Resour. Crop Evol.* **45**:139-150.

Brush SB (2000) The issues of *in situ* conservation of crop genetic resources. In: SB Brush (ed) *Genes in the field. On-*

farm conservation of crop diversity, IPGRI, Rome: IDRC, Ottawa: Lewis Boca Raton.

Jarvis D, T Hodgkin, BR Sthapit**,** C Fadda and I Lopez-Noriega (2010) A heuristic framework for identifying multiple ways of supporting the conservation and use of traditional crop varieties within the agricultural production system. *Critical Rev. Plant Sci.* **30**:1-49.

De Boef WS, MH Thijssen, P Shrestha, A Subedi, R Feyissa, G Gezu, A Canci, MAJDF Ferreira, T Dias, S Swain and BR Sthapit (2012) Moving beyond the dilemma: Practices that contribute to the on-farm management of agro biodiversity, *J. Sustainable Agri.* **36**: 788-809.

Perrings C and M Gadgil (2003) Conserving biodiversity: Recognizing local and global public interests. In: I Kaul, P Conceicao, K Le Goulven and RU Mendoza (eds) *Providing Global Public Goods*: *Managing Globalization*, New York, UNDP, pp 532-555.

Rajan S, MR Dinesh, KV Ravishankar, A Bajpai, I Ahmad, A Singh, SK Singh, IP Singh, R Vasudeva, BMC Reddy, VA Parthasarathy and BR Sthapit (2014) Heirloom Varieties of Important Tropical Fruits: A Community Initiative to Conservation. TFT Project, Bioversity International, Indian Institute of Horticultural Research, Bangalore, 34 p.

Subedi A, P Chaudhary, BK Baniya, RB Rana, RK Tiwari, DK Rijal, BR Sthapit and DI Jarvis (2003) Who maintains crop genetic diversity and how?: Implications for on-farm conservation and utilization. *Cult. Agric.* **25**: 41-50.

Sthapit B, H Lamers and V Ramanatha Rao (2013) *Custodian farmers of agricultural biodiversity: Selected Profiles from South and South East Asia.* Proceedings of Workshop on Custodian Farmers of Agricultural Biodiversity, 11-12 February, 2013, New Delhi, India.

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Farmers' Perception on On-farm Conservation of Mango and *Citrus* Diversity in Indonesia

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A study was conducted in 2014 to measure Indonesian farmers' perception of mango and *Citrus* conservation, to analyse which non-behavioural factors affect the farmers' perceptions and to analyse the impact of farmers' participation in project activities based on their perception. Eighty respondents were selected randomly from two sub districts in South Kalimantan and two sub-districts in East Java, and a questionnaire was administered. Simple linear regression showed that farmers' participation in *on-farm* conservation programs positively affect their perceptions about *on-farm* conservation. Multivariate regression analysis indicated furthermore that the following non-behavioural factors do affect farmers' perceptions significantly a) the accessibility of mango and *Citrus* planting materials, b) farmers' knowledge about conservation benefits, c) the level of government support, and d) farmers' knowledge about conservation purposes. Farmers suggest that the Indonesian government should focus on creating access to qualitative saplings, access to farm inputs and assistance to improve their skills in bio-fertilizer and bio-pesticide production. The community biodiversity management approach, as used in the project, seems an appropriate approach to influence farmers' perceptions and behaviour related to conservation activities, especially when incentives and needs of farmers are recognised and addressed.

Key Words: Agricultural biodiversity, Behaviour, *On-farm* conservation, Perception, Tropical fruit trees

Introduction

As an archipelagic country, with its thousands of islands scattered between two continents (Asia and Australia) and two oceans (Pacific and Indian), Indonesia is endowed with very rich and unique biological resources. More than 329 native and introduced fruit species have been documented and described in Indonesia as potential sources of food, nutrition and medicine (Uji, 2007). The Indonesian Ministry of Agriculture (2010) has prioritized mango and *Citrus* as commodities and has targeted production of some 2.5 million tonnes of mango and 2.3 million tonnes of *Citrus*. However, the programmes are threatened by farm land conversions. The rate of farm land conversions in Indonesia is around 100.000 hectares per year and caused by the rapid population growth in the last 15 years that increased around 1.49% per year (Indonesian Statistic Agency, 2014).

Diversifying the agricultural sector has become now an important strategic interest for the Indonesian Government, which requires also a conservation strategy to maintain a viable population of species and the intra-specific diversity within species as the fundamental source for improved planting material. To diversify and improve the agricultural sector, the conservation of fruit trees is urgently needed by the Indonesian government (Hanani *et al.*, 2009), especially for fruit trees which have recalcitrant seeds and can not be conserved in cold storage. The prevention of erosion of native fruit genetic resources should be highlighted as a national priority. Loosing plant genetic resources means that Indonesia will lose national assets to develop new products or compete in the global market, whereas the competitiveness level of Indonesian fruits in Asia is already low.

On-farm conservation entails the active participation of local communities in the documentation, multiplication, utilization and safeguarding of unique species and varieties found on their farms. *In situ* and *on-farm* conservation is ineffective without local community participation (Isager *et al.*, 2001). Community-based Biodiversity Management (CBM), is an example of a conservation approach that empowers the community through participation so that their access to and control over genetic resources are secured (Rechlin *et al.*, 2008). Sthapit *et al.* (2008) described CBM method entails several steps and type of interventions. Firstly sites and

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communities are selected with high level of unique inter or intra-specific diversity, followed by full understanding of the local context to determine if *on-farm* conservation is appropriate and feasible. The next steps are: raising awareness, set-up institutional modalities, strengthen capacities and skills, development and implementation of action plans for utilization and conservation, mobilize CBM funds, and facilitating social learning in which local stakeholders lead and drive the CBM process (Sthapit *et al.*, 2008).

On-farm conservation activities and interventions include the organization of diversity fairs, the documentation and description of local species and varieties in a catalogue or register, establishment of nurseries for multiplication and distribution of unique plant or seed material, the promotion of nutritional values and traditional recipes, the development of enterprises and market linkages for the sales of products or services based on local unique crop diversity and the protection/ conservation of most important source trees or seed material (Arsanti, 2013). The successful implementation of *on-farm* conservation projects or interventions is dependent on many inter-related endogenous and exogenous factors. Results are often considered context specific and thus attributed to external factors, providing little recognition for the effectiveness of specific or several associated interventions. This study strives to provide insights which factors do contribute most to the successful participation of farming households in *on-farm* conservation activities, using the model of Green (1994) which evaluates factors that influence behavioural change.

Behaviour and perception are connected with causal relationship (Riding *et al.*, 2001). Perception is a part of human's cognitive and affective area, while behaviour is a part of psychometrics area. Farmers' perceptions on conservation could be affected by *n*on-behavioural factors such as farmers' age, gender, education level, knowledge on conservation purposes and benefits, and external factors such as availability of mango and *Citrus* seed material and also government endorsement and support. Our hypothesis is that the more positive the farmers' perception on mango and *Citrus* conservation activities are, the more chance they will adopt and continue *on-farm* conservation practises within their communities and on their farms. These insights might help to improve the implementation and planning of *on-farm* conservation projects and programmes and also to identify the type of assistance programmes that the government should prioritize to raise the farmers' participation and influence their perceptions ensure the sustainability of existing conservation efforts.

Methodology

Green (1994) developed a model or framework to better understand how to improve health education and treatment programmes (for asthma) that take into account additional factors such as lifestyle, behavioural factors and social or environmental factors besides the medical treatment. The model strives to understand how to facilitate and achieve behavioural change of the patient to adopt the suggested therapy. The model has been applied and adapted in former studies to assess which factors influence the implementation of land conservation and soil degradation programs (Ratnada 2002; Kurniasih 2007). Model was used to analyse the factors crucial for the adoption of *on-farm* conservation programmes (Green, 1994). The model describes that the sustainable adoption of therapies (or programs) entails the facilitation of behavioural change of the target individual or group which is strongly affected by people's perceptions. In this study we identified 7 non-behavioural factors which influence perceptions related to *on-farm* conservation which are grouped as follow: (a) predisposing factors (farmers' age, gender, farmers' educational level, farmers' knowledge on conservation purposes and benefits), (b) enabling factor (mango and *Citrus* planting materials availability), (c) reinforcing factors (government support).

Key Variables or Concepts Used in the Model

On-farm conservation entails the implementation of a range of activities involving community members in the documentation, dissemination, utilization and safeguarding of mango and *Citrus* species and varieties. In this study *on-farm* conservation means the development of a community biodiversity register (fruit catalogue), establishment of community nurseries, conducting diversity fairs, establishment of a diversity block, producing and popularizing informative flyers about good practices in conservation and other publications, training on grafting, fruits processing and marketing.

Farmers' perception regarding *on-farm* conservation was determined by the opinion of farmers about the importance of a range of activities for *on-farm* conservation. Respondents were asked about the

importance of the following activities; *i.e.* community biodiversity register, community nursery, conducting diversity fair, diversity block, producing fruit catalogues and other publications, training on grafting, fruits processing and marketing). Respondents could choose between 5 options ranging from 1. Strongly Disagree, 2. Disagree, 3. Doubt, 4. Agree, 5. Strongly agree. Subsequently the sum of all scores for each respondents were categorized in three equal groups, those with high score (38-50), medium score (24-37) and low score (10-23). High scores were interpreted as a positive perception towards *on-farm* conservation and low scores with a negative perception towards *on-farm* conservation.

Farmers' participation was determined by the frequency of participation in each of the seven listed *on-farm* conservation activities. Respondents could choose between 5 options ranging from (1. Never, 2. Very rarely, 3. Rarely, 4. Often, 5. Always). Similarly, the sum of all scores determined the frequency of participation, which was clustered in three categories; low, medium and high participation.

Predisposing factors in this study were described as the factors that facilitate or predispose the farmers' perception on *on-farm* conservation of *Citrus* and mango. The predisposing factors determinated in this study were farmers' age, gender, farmers' educational level, farmers' knowledge on conservation purposes and farmers' knowledge on conservation benefits. The last two variables were calculated based on the sum of scores from several questions asking them to confirm their awareness about several purposes and benefits related to conservation of mango and Citrus diversity in a Likert scale of five options. This study used those factors as they have been proven to affect farmers' perception and behaviour (Kurniasih, 2007).

Enabling factors described as the external factor that enable or facilitate the farmers' perception on *on-farm* conservation of *Citrus* and mango. The enabling factor determined in this study is mango and *Citrus* planting materials availability. The variable was calculated based on the sum of scores for several questions asking about the distance, number and type of nurseries and the number of varieties that are available to them.

Reinforcing factors in this study described as the factors that encourage and reinforce the farmers' perception on *on-farm* conservation of *Citrus* and mango. The reinforcing factor selected in this study was government support.

Study Site and Sampling Method

The study was carried out in four districts: Sukomoro and Tiron sub-district in East Java province, Pembantanan and Kandangan sub district in South Kalimantan province. The locations were selected out of six sites which have been part of the UNEP/GEF funded project 'sustainable use of wild and cultivated tropical fruit tree diversity, improving livelihoods, ecosystem services and food security', which used the CBM approach to strengthen local *on-farm* conservation practises for mango and *Citrus* species and varieties in selected villages. South Kalimantan and East Java are major production regions of mango and *Citrus* respectively in Indonesia and harbouring a wide range of inter- and intra-specific diversity. Based on baseline survey was reported by Winarno *et al.* (2013), Tiron had 4 species of mango, Pembantanan and Telaga Langsat had 11 species of mango, and Sukomoro had 6 different species of *Citrus*. The details of varieties for each species can be seen in Table 1.

Data were collected by enumerators using pen and paper questionnaire including multiple choice questions and few open questions regarding their participation and perceptions of project interventions. Respondents were selected by simple random sampling, selecting 20 people from each of the four locations. Heads of households were selected for interview and if not available the person available that could represent the household, ensuring equal representation of male and female respondents. In total 80 respondents consisting of 47 male farmers and 33 female farmers were interviewed. Interviews were conducted at the end of the UNEP/GEF project for *on-farm* conservation after completion of all field activities.

Data Analysis

Descriptive statistics was used to describe the basic features of the variables used in the study (See Table 2). To categorize the variables in respondents with high, medium and low scores proportions where calculated as described in Dajan (1986) for the following variables; i.e. farmers' knowledge on conservation purposes, farmers' knowledge on conservation benefits, mango and *Citrus* planting materials availability, government support, farmers' perception and participationon mango and *Citrus on-farm* conservation Subsequently the study used simple linear regression analysis to study the relationship between participation and perceptions.

Table 1. The species and varieties identified at the study location

Location	Scientific name	Varieties (local name)
Tiron	*M. indica*	Podang Urang, Golek, Gadung, Madu, Lanang, Santok Buto, Kopyor, Santok Kapur, Bader, Jempol, Manalagi, Dodonilo, Beruk, Sengir Empok, Apel, Gajih, Gurih, Ireng, Dasa Muko, Cantek, Lulang, Cantrik
	M. foetida	Jaran
	M. odorata	Pakel, Kweni
	M. lalijiwo	Lalijiwo
Pembantanan and Telaga Langsat	*M. indica*	Hampalam Nagara, Mangga Golek, Mangga Gadung, Hampalam Hambuku, Hampalam Biasa, Apel
	M. foetida	Hambawang Biasa, Hambawang Kalambuai, Hambawang Tapah
	M. odorata	Kuini
	M. torquenda	Hambawang Pulasan
	M. griffthii	Rawa-Rawa Humbut, Rawa-Rawa Biasa
	M. applanata	Palipisan Sak Hirang, Palipisan Sak Hijau
	M. havilandii	Hampalam Damar
	M. rufocostata	Tandui
	M. casturi	Kasturi
	M. caesia	Binjai Manis, Binjai Asam
	M. pentandra	Asam Pauh
Bibis	*C. grandis*	Adas, Adas Duku, Nambangan, Sri Nyonya, Bali Merah, Bali Putih, Jeruk Gulung, Jeruk Jowo, Pamelo Magetan
	C. sinensis	Sunkis
	C. hystrix:	Jeruk Purut
	C. reticulata	Keprok Gulung Keprok Siem
	C. aurantifolia	Jeruk Pecel
	C. limon	Sitrun

Table 2. Descriptive table

Variables	Mean	Standard deviation	Score max	Score min
Farmers' age	44.68	12.04	80	20
Farmers' educational level	8.68	4.11	0	17
Knowledge of conservation purposes	47.78	5.10	63	37
Knowledge of conservation benefits	20.72	3.38	25	5
Mango and *Citrus* richness within the village	15.50	3.03	21	5
Government support	24.13	3.04	31	16
Farmers' participation	37.96	4.37	47	27
Farmers' perception	20.43	2.95	25	10

Besides, the study used multiple linear regression analysis to assess which non-behaviour factors do influence perceptions of farmers.

A simple linear regression analysis was used to analyse the impact of farmers' participation in project activities on their perceptions on mango and *Citrus* conservation.

$Y = a_0 + b\ X + e$

Where:

Y : Farmers' perception on mango and *Citrus* conservation;
a_0 : constant;
b : regression coefficient;
X : farmers' participation on mango and *Citrus* conservation.

Whereas a multiple linear regression analysis was used to analyse non-behavioural causes that dominantly affecting the Indonesian farmers' perception on mango and *Citrus* conservation.

$Y = a_0 + a_1\ Di + b_1X_1 + b_2X_2 + b_3X_3 + ...+ b_6X_6 + e$

Where:

Y : Farmers' perception on mango and Citrus conservation (Z score);
a0 : constant;
a1 : regression coefficient of dummy variable;
b1–b13 : regression coefficients;
Di : Gender (dummy variable);
X1 : Farmers' age;
X2 : Farmers' education level;
X3 : Knowledge of conservation purposes;

X4 : Knowledge of conservation benefits;
X5 : Mango and Citrus richness within the village;
X6 : Government support; and
e : Error.

X_1 was determined by asking of farmers' age, X_2 was determined based on number of years of farmers' education, X_3 was determined by asking about the farmers' knowledge about conservation purposes (i.e. ecological purposes, economical purposes, and social purposes). Variable X_4 was based on farmers' respons about conservation benefits (i.e. ecological benefits, economical benefits, and social benefits). Whereas X_5 was determined by several questions about the availability of saplings in the village. X_6 was determined by asking the farmers' about the number of government programs they participated that contribute to the *Citrus* and mango *on-farm* conservation such as technical assistance programs for fruit tree cultivation. This was converted into a number by calculating a total score (interval score 1, 2, 3, 4, 5) from each question in each variable.

Results

People's perception is influenced by participation (in the program activities) and non-behavioural factors (Fig. 1). Green (1994) differentiated non-behavioural factors into three categories, (a) predisposing factors include knowledge, attitudes, beliefs, personal preferences, existing skills, and self-efficacy towards the desired behaviour change, (b) enabling factors are skills or physical factors such as availability and accessibility of resources, or services that facilitate achievement of motivation to change behaviour, (c) reinforcing factors include factors that reward or reinforce the desired behaviour change, including social support, economic rewards, and changing social norms.

Ratnada (2002) reported that non-behavioural causes that consist of predisposing factors (*i.e.* farmers' motivation to reach success, farmers' knowledge on land conservation, and farmers' initiatives to get information), enabling factor (*i.e.* farmers' income), and reinforcing factor (extension intensity), influenced farmers' behaviour in land conservation. Kurniasih (2007) also reported that predisposing factors (*e.g.* farmers' age, conservation knowledge, motivation, activity in group), enabling factors (*e.g.* non-agricultural income and availability of organic input), and reinforcing factors (e.g. government endorsement and policy support) affected farmers' perceptions and behaviour regarding wetland conservation.

The variables used for this analysis are presented in Fig. 2. The results indicated that 53% of the farmers fall into non-productive age group (*i.e.* 60 years and older) while 47% into productive age group (*i.e.* between 16 and 60 years). Farmers interviewed included just as much young as older farmers, showcasing equal distribution of age. This is interesting as often it is assumed that farmers are generally getting older as less and less young farmers take up farming. Most of them have more than six years of formal education, which means they have

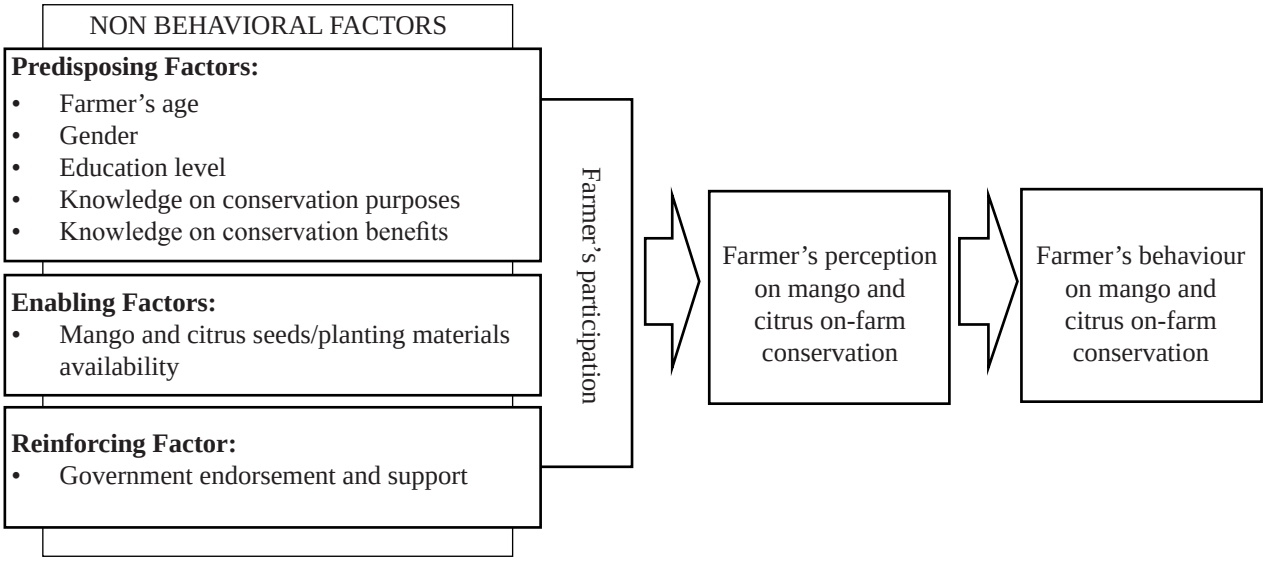

Fig. 1. Logical frame of the study

Table 3. Regression analysis result of causal relationship between farmers' participation and farmers' perception about *on-farm* conservation activities by SPSS.16 operation

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.575[a]	0.331	0.322	2.43614	1.289

a. Predictors: (Constant), Farmer participation
b. Dependent Variable: Farmer_perception

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.675	2.393		2.371	0.020
	Farmer participation	0.389	0.063	0.575	6.209	0.000

a. Dependent Variable: Farmer participation

finished secondary school, which will influence the ability to understand concepts of *on-farm* conservation. The respondents were having high knowledge about social, ecological and economic benefits of conservation activities (88% of respondents fall in highest tertile), and substantial knowledge on the purpose of conservation activities (56% of respondents fall in highest tertile). While government support and access to saplings is medium (respectively 83% and 74% respondents fall in middle tertile), the participation in activities and perception about conservation activities is very high (87% and 89% respectively in highest tertile).

Farmers participated most in diversity fair (32.5% farmers participated always), training on grafting (15%), training on processing fruits (12.5%), community nursery (10%), training on marketing (10%), diversity block and producing fruit catalogue (7.5%) and community biodiversity register (5%). Based on their participation, farmers gave highest importance to the following activities as part of *on-farm* conservation activities; conducting diversity fair (36.25% farmers were agree), training on grafting (17.5%), training on processing fruits (16.25%), and establishing community nursery (11.25%). Other activities were considered less important such as producing fruit catalogue and other publication (6.25%), training on marketing (5%), community biodiversity register and diversity block (3.75%). Results show that activities in which respondents participated most are evaluated sequentially also as most important for *on-farm* conservation with diversity fairs as clearly most mentioned activity as stated by Arsanti and Kurniasih (2013).

The results of the simple regression equation showed that farmers' participation in activities does affect farmers' perceptions with an R^2 of 0.322, which means 32.2% of the change in perceptions is explained by their participation in project activities (see Table 3). This means a larger share is explained by other factors; however frequent participation in project activities does play a major role in influencing perceptions about the importance of activities for *on-farm* conservation. The regressor is estimated to be 0.389 (significant at the 0.01 level) showcasing a substantial effect on perception when the frequency of participation changes.

The results of multiple linear regression analysis presented on Table 4 showed that R^2 value is high (0.901). This means that 90.1% variation in the farmers' perception on mango and *Citrus* conservation activities could be explained by the independent variables observed. The regression equation is:

$$Y = a_0 + a_1 Di + b_1X_1 + b_2X_2 + b_3X_3 + ...+ b_6X_6 + e$$

$Y = 0.338 - 0.003Di - 0{,}044\ X_1$ (Farmers' age) $+ 0.031X_2$ (Farmers' education) $+ 0.084X_3$ (Farmers' knowledge on conservation purpose)** $+ 0.163X_4$ (Farmers' knowledge on conservation benefits)** $+ 0.753X_5$ (Farmers' access of mango and *Citrus* planting materials)** $+ 0.160X_6$ (Government support)** + error

Checking the model on heteroskedasticity (scatter plot), autocorrelation (Durban-Watson test) and multicollinearity (Variance Inflation Factor test) shows no pattern in residuals (model seems fit) or disturbing correlations between error terms or independent variables. Variables (significant at 0.01 level) with largest (standardized) effect on a change in perceptions are respectively seed availability (0.753), knowledge about conservation benefits (0.163), government support (0.160) and knowledge about purpose of *on-farm*

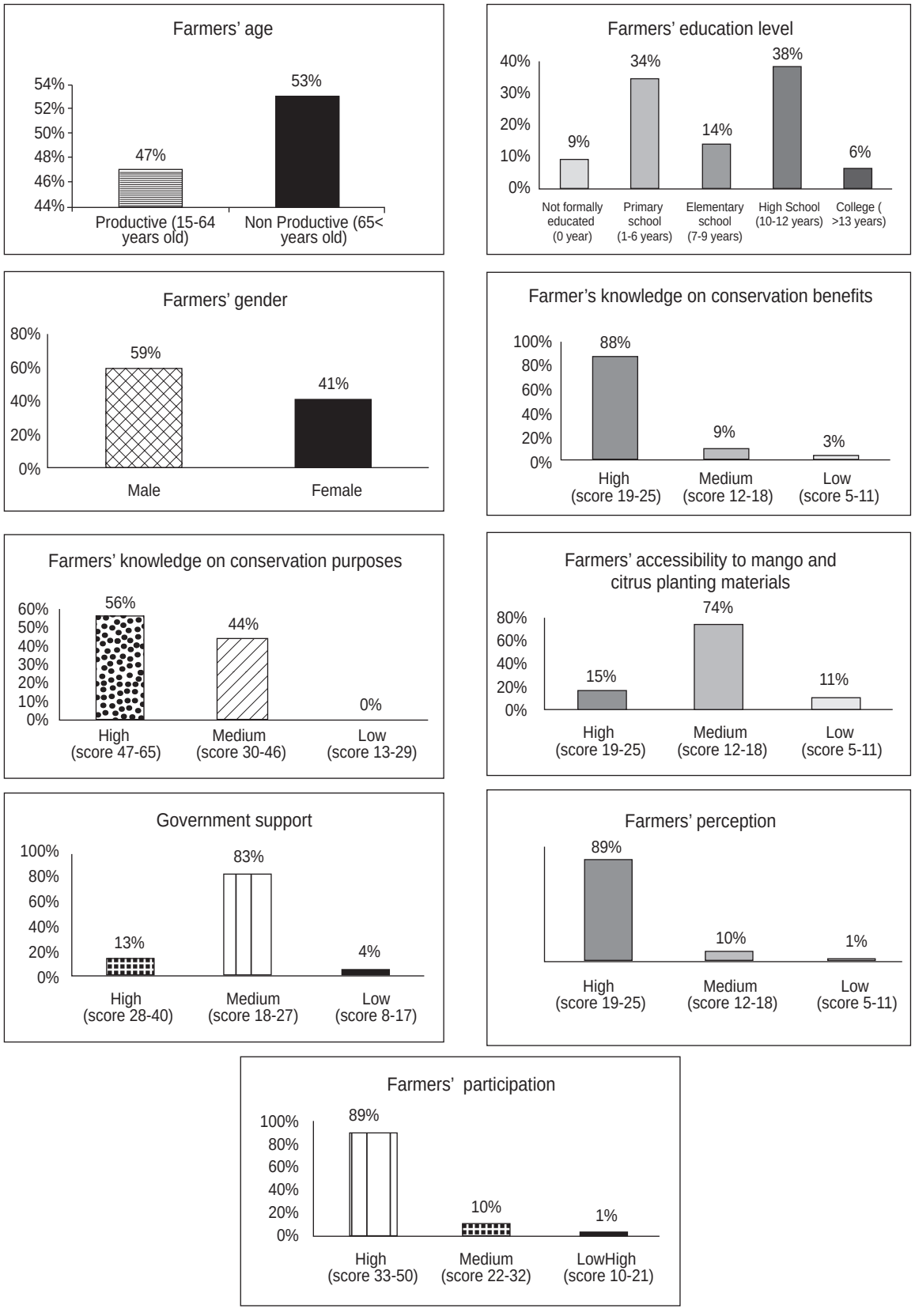

Fig. 2. Distribution of non-behavioural factors, farmers' participation and perception (Primary data, 2014)

conservation (0.084). Gender, age and education years were not significant. The results show that improving the availability of saplings has a major positive effect on perceptions, and thus subsequently ismost likely to facilitate a change in behaviour and the successful adoption of *on-farm* conservation practices. Knowledge about the purpose and benefits of conservation and government support, have a significant but smaller effect.

Discussion

The Influence of Predisposing, Enabling, and Reinforcing Factors

Age is an intrinsic factor that is believed to affect the acceptance and adoption of new information (Jogiyanto, 2007). The result of this study showed that, farmers' perception was not affected by farmers' age. This study identified that 53% of the farmers are more than 65 years old. Nevertheless, they still actively worked in their farm to cultivate paddy, vegetable, fruit, and also raised cattle. They also still involved in the farmers group activities. By interacting with the other farmers they benefitted from the information related to their mango and *Citrus* farming. Therefore, despite the fact that they are included in non-productive age group, their level of perception is still high.

Gender is an important issue and involving woman farmers in conservation programmes is necessary as they have significant knowledge on conservation issues and hence should have the same right as men to be involved in any decision making process regarding *on-farm* conservation activities (Kurniasih, 2007). Unfortunately, often traditional and culturally embedded taboos prevent them to play an active role in such processes. The result of this study showed that, gender did not affect the farmers' perception. In total, 59% of respondents are male and 41% female farmers. In this case, the woman farmers were also actively involved in the farmer group activities, conservation activities and the training workshops provided by government agencies or Non-Government Organizations (NGOs). Women also got involved through a woman farmer group that established a business unit for the processing of mango and *Citrus* fruits.

Education strengthens capacities and gives knowledge and ideas to the participants to access more information and technologies that are useful to improve their farming system. The result of this study showed that educational level did not affect the farmers' perception. Most of the respondents did not have higher level education such as pursuing a bachelor or master's degree. About 57% of the respondents were formally educated (up to 9 years), meaning they finished high school or a vocational school after secondary school. However, even farmers with limited formal education have a high perception on conservation activities. It is possible that they may be getting information about mango and *Citrus* conservation from informal institution like farmer groups. Conservation is usually a long term effort and may not always be a profitable activity. Often, farmers were not interested in conservation programmes because they did not directly benefit from it. Government has to change the farmers'

Table 4. Regression analysis result of causal relationship between non behavioural factors and farmers' perception by SPSS.16 operation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.954[a]	0.910	0.901	0.92868	1.413

Coefficients[a]

Model	Unstandardized coef.		Standardized coef.	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	0.338	1.407		0.240	0.811		
Age	-0.011	0.010	-0.044	-1.145	0.256	0.828	1.208
Gender	-0.016	0.227	-0.003	-0.070	0.944	0.866	1.155
Year_of_Education	0.022	0.027	0.031	0.823	0.413	0.876	1.142
Seed_availability	0.733	0.047	0.753	15.659	0.000	0.539	1.854
Knowl_conserv_ purposes	0.049	0.023	0.084	2.116	0.038	0.783	1.278
Knowl_conserv_ benefits	0.143	0.042	0.163	3.414	0.001	0.546	1.832
Government_support	0.155	0.037	0.160	4.243	0.000	0.880	1.136

Dependent Variable:Farmer_perception

mind set about conservation and its purposes. In this study, the farmers' knowledge about the different uses and purposes of mango and *Citrus* conservation significantly affected the farmers' perception. The study suggested that the project activities have been effective to increase the knowledge of farmers regarding the purpose of conservation and its benefits. The study also suggests that targeted activities regarding these topics are important to influence opinions and perceptions regarding the importance of *on-farm* conservation activities.

Conservation of mango and *Citrus* depend on planting materials availability as enabling factor, especially for wild species that recently have been difficult to find. Mostly, only commercial varieties are available. In this study, 85% of farmers indicated to have difficulties to access mango and *Citrus* planting materials, especially for wild varieties. The result of this study showed that farmers' access to mango and *Citrus* planting materials has a large influence on their perception on conservation. The farmers got the mango and *Citrus* planting materials from community nursery that were established by the project. Unfortunately, community nurseries have not been able to fulfill the planting materials demand because of its limitation of rootstocks. This issue should be taken by the government and it should develop faculties so that the access to seedlings of species/varieties by farmers is improved. This may be done through establishing nurseries by formal sector or by promoting community nurseries.

This study also indicated that the support by the government to conservation programmes influenced the farmers' perception on mango and *Citrus* on farm conservation. This reinforcing factor already proven affected the farmers' behaviour on conservation (Ratnada, 2002; Kurniasih, 2007). About 89% farmers' stated that the role of government in *on-farm* conservation is crucial. The role of the government, to empowering communities in the management of genetic resources, is critical. In the case of the mango and *Citrus* conservation project, the government was responsible to educate, facilitate, and empower the communities by providing information, technology, and assist them to secure economic benefits from conservation activities. However, such interventions need to be cost efficient, effective and sustainable, as a dominant role of the government can also disempower communities. Farmers identified that the government should help the community by providing mango and *Citrus* seed and seedling production technology, farm inputs such as fertilizers and pesticides, harvesting and post-harvest technologies (fruits processing : pure, juice, dodol, manisan), and market linkages (see Table 5).

Conclusions

This study conducted in the final phase of a community-based *on-farm* conservation project showed that farmers' participation in project activities had a major positive effect on their perceptions about *on-farm* conservation, and thus increased the likelihood that practises are adopted and continued within their farming system. Multivariate regression analysis indicated furthermore that the following non-behavioural factors do affect farmers' perceptions significantly a) the accessibility of mango and *Citrus* planting materials, b) farmers' knowledge about conservation benefits, c) the level of government support, and d) farmers' knowledge about conservation purposes. The organization of diversity fairs was considered most important and most often attended by the farmers among all activities. Furthermore, farmer suggested that the Indonesian government should provide assistance in the creation of access to qualitative saplings, access to farm inputs and assistance to improve their skills in production of bio-fertilizer and bio-pesticide, as part of *on-farm* conservation activities.

The community biodiversity management approach and its activities, as used in the project, seems an appropriate approach to influence farmers' perceptions related to conservation activities, especially when incentives and needs of farmers are recognised and addressed. Creating access to planting material of unique fruit species and varieties, the provision of additional agronomic and technical support and the creation of benefits through income generation seem all important aspects for a community-based biodiversity management approach.

With efficient and effective government assistance, farming communities in high diversity areas may be able to position themselves as agent of change to ensure the sustainable utilization and conservation of fruit tree diversity. Some outcome that emerge from this study that could be implemented by stakeholders are:

The importance of identifying and working through custodian households within the community as entry point for interventions and agents of change to document and spread knowledge, practises and saplings across the community.

Table 5. The rank of community needs for the following government programmes

Community needs	Positive confirmations (%)	Rank
Providing the mango and *Citrus* planting materials	90	1
Providing the production input (fertilizer and pesticide)	86	2
Assistance on cultivation and pest control technology	83	3
Providing a micro finance	80	4
Assistance on harvest and post-harvest assistance	75	5
Assistance to build marketing linkage	71	6
Training on seedling technology	60	7

The importance of having a long timeframe of 5-8 years of *on-farm* conservation projects to understand the context, identify key stakeholders, plan interventions to be able to influence and change perceptions and behaviours regarding the utilization and safeguarding of local fruit tree species.

The existing conservation activities that are part of the CBM approach, such as biodiversity block or garden, community biodiversity register or fruit catalogue, community nursery, diversity fair, processing product of mango and *Citrus*, and marketing training, are effective to encourage farmers' participation and perception on conservation of mango and *Citrus*. Therefore, these activities should be continued to get increased participation not only in the project location but also in the other places in Indonesia.

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References

Arsanti IW and Dian Kurniasih (2013) Putting theories into practices: community based biodiversity management on podang urang *(Mangifera indica)* in Kediri, East Java. *Proc. of Int. Con. on Trop. Hor*., October 2-4, 2013, ICHORD, Jakarta, Indonesia.

Dajan A (1986) *The Introduction of Statistical Methods*. LP3ES, Jakarta, Indonesia.

Green, LW (1994) *Health Education Planning a Diagnostic Approach*. Manfield Publishing Company, New York, United States of America.

Indonesian Ministry of Agriculture (2010) *Indonesian Ministry of Agriculture Strategic Plan*. Jakarta, Indonesia.

Indonesian Statistic Agency (2014) *Trends of Selected Socio Economic Indicators of Indonesia*. Jakarta, Indonesia.

Isager L, I Theilade and L Thomson (2001) People's participation in forest conservation: considerations and case studies. *Proc. of the Southeast Asian Moving Workshop on Conservation, Management and Utilization of Forest Genetic Resources*, 25 February-10 March, 2001, FAO.

Jogiyanto HM (2007) *Behavioural Information System*. Andi Publisher, Yogyakarta, Indonesia.

Kurniasih D (2007) *The Analysis of Land Carrying Capacity and Non Behavioural Causes Effects to Farmers' Behaviour on Wet Land Conservations in Kulon Progo Regency*. Thesis, Faculty of Agriculture Gadjah Mada University, Yogyakarta, Indonesia, (Unpublished).

Hanani N, R Hartono and LPA Ratnadi (2009) Competitivenes analysis of indonesian fruits export level. *J. Agris E*. **9**: 1-8.

Ratnada YM (2002) *Farmers' Behaviour in Land Conservation on Irrigated Lowland Rice Farming System in Bantul Regency*. Thesis, Faculty of Agriculture Gadjah Mada University, Yogyakarta, Indonesia, (Unpublished).

Rechlin MA, D Taylor, J Lichatowich, P Hoon and B Leon (2008) *Community-Based Conservation. is it More Effective, Efficient and Sustainable?*, The Gordon and Betty Moore Foundation.

Riding RJ and GR Stephen (2001) *Self Perception: International Perspectives on Individual*. Greenwood Publishing Group, Wesport, USA.

Sthapit BR, PK Shrestha, A Subedi, P Shrestha, MP Upadhyay and P Eyzaguirre (2008) Mobilizing and empowering communities in biodiversity management. *In:* MH Thijsen, Z Bishaw, A Beshir and WS de Boef (Eds.). Farmers, seeds and varieties: Supporting informal seed system in Ethiopia. Wageningen, Wageningen International.

Uji T (2007) Review: The diversity of Indonesian indigenous fruits and its potency. *J. Biodiversity* **8**: 157-167.

Winarno BA Kuntoro and R Achmad (2013) *Baseline Report: UNEP-GEF Project on "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security and Ecosystem Services.* Jakarta, Indonesia (Unpublished).

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Use Values and Cultural Importance of Major Tropical Fruit Trees: An Analysis from 24 Village Sites Across South and South-East Asia

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Native communities of South and South East Asia, a centre of diversity of tropical fruit trees (TFT), share a common cultural heritage associated with tropical fruits. Unfortunately, there is a dramatic loss of traditional knowledge associated with TFTs. This comparative study was undertaken in 24 village communities spread across India, Indonesia, Malaysia and Thailand using structured questionnaires and multiple approaches to document use-value of TFTs. Considering only four focal genera of TFT species *viz*., *Mangifera*, *Garcinia*, *Citrus* and *Nephelium*, an amazing diversity of 56 species was reported to be utilized by the communities. Ranking of species based on the number of use-categories and based on the cultural importance value showed differences. *Mangifera indica*, *Citrus aurantifolia* and *C. reticulata* were the three extensively used TFTs as food and for processing. As revealed by Jaccards' index, three South East Asian countries showed a higher similarity among themselves than India. *M. indica*, *M. pajang*, *M. foetida*, *G. morella*, *G. atroviridis*, *G. mangostana*, *C. hystrix*, *C. aurantifolia* and *C. grandis* were culturally the most significant TFTs and hence may be conserved with high priority.

Key Words: Tropical fruit trees, Use value, Cultural significance, South and South-East Asia

Introduction

Fruit trees are important components of stable agro-ecosystems and provide valuable resources as well as broad range of forest products in the form of food supplements to the rural communities (Ramanatha Rao and Bhagmal, 2002). Environmental services provided by fruit trees such as protecting and, providing habitats for pollinators, and storing carbon are valued in the tens of billions of dollars annually. Fruit trees provide important adaptive values and tend to be more resilient to climate change due to their perennial nature (Sthapit *et al*., 2012). Hence diverse native fruit trees are used by farming communities to improve nutrition in their food and augment the farm ecology, hence farmers also hold valuable information on the diversity and its uses. World over, there is a renewed interest in documenting the use values of fruit trees. Use of tropical fruit species is a part of the Traditional Knowledge (TK), which is a rational and reliable knowledge developed through generations of intimate contact with the nature by the local people

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(Mauro and Hardison, 2000). Knowledge about the identification and use of tropical fruits is an integral part of the local food tradition and indigenous knowledge systems and practices that have been developed over many generations (Vinceti *et al*., 2013). The TK is generally associated with biological resources and is invariably an intangible component of such a biological resource. However, there is a dramatic loss of traditional knowledge associated with tropical fruits. Key to the conservation of tropical fruit resources and of the associated TK is the scientific documentation of knowledge relating to their uses and assessing the cultural significance. Based on the role that species plays as food, shelter, medicine, *etc*. in a specific culture, its cultural significance is assessed (Pieroni, 2001). Native communities of South and South-East Asia share a common cultural heritage of use of tropical fruits for diversified purposes and their associated traditional knowledge. Use of native tropical fruits is perhaps most conservative aspect of any culture but highly vulnerable to loss. However there is a paucity of a comparative study of use values of tropical fruit trees across this region. With this background, the study was aimed at the following: (a) document local specific uses of four focal genera of tropical fruit trees *viz*., *Mangifera*, *Garcinia*, *Nephelium* and *Citrus* in 24 village sites, set in diverse agro ecosystems in four nations of South and South-east Asia; (b) to compare the cultural significance of the use values of focal species in these countries and (c) to understand the cultural significance and abundance of these species. Here, we report the salient results of a larger study under the UNEP/GEF-supported regional project titled "Conservation and sustainable use of cultivated and wild tropical fruit diversity: promoting sustainable livelihoods, food security and ecosystem services", implemented in India, Indonesia, Malaysia and Thailand.

Materials and Methods

Tropical fruit tree (TFT) species occurring around 24 village sites in India, Indonesia, Malaysia and Thailand were studied with an objective of documenting their local uses and assessing their cultural importance (CI) value under the UNEP/GEF-supported regional project. The geographic details, agro-ecosystems and general features of each site are provided in Table 1. The landscapes included a mosaic of agricultural land, tree plantations, tree gardens, meadows, and forests. All 24 sites were biologically rich areas comprising of focal TFT species. In India, study sites consisted of home gardens, commercial, semi-commercial orchards, set in agricultural ecosystems and forest ecosystems. The eight sites of Indonesia consisted of home gardens, commercial, semi-commercial orchards located in agricultural ecosystems, forest ecosystems, and island ecosystems. The sites of Malaysia were located in hilly zones, along the coast which consisted of orchards as the major production systems. In Thailand, sites were consisted of multi-species orchards, home gardens in low lands, river bank that flood annually (Table 1).

Over a period of five years, multiple sources of information such as participatory rural appraisals, baseline surveys, focal group discussion on TK documentation, fruit diversity fairs, community fruit catalogues and key informant surveys of custodian farmers were used to document the locally specific uses of four focal genera *viz*., *Mangifera*, *Garcinia*, *Nephelium* and *Citrus*. Information was obtained from the respondents through personal interviews and field observations through structured questionnaires prepared for the purpose, following a prior informed consent. For the purpose of this study the data on uses were grouped into 14 use-categories based on folk perceptions such as consumption, processing as food, use as medicine, use as cosmetic, use as bio-pesticide, use as timber, *etc*. A short description of each of the use-category is provided in Table 2.

The identified respondents in each village (about 20 to 50 households in each community) were interviewed personally to collect data related to aspects as detailed in research questionnaires. The individual household survey involved questions on tropical fruit species diversity, their frequency, use and marketing aspects. In home-gardens, the number of tropical fruit tree species, their frequency and density, varieties, average tree age, economic parts of the tree species, consumption patterns, area under fruit tree cultivation and total landholding size were recorded.

To estimate the cultural significance of each species, CI value was computed, which was introduced by Philips and Gentry (1993) and adopted by Pardo-de-Santayana *et al.* (2007). This index measures the use-value of a plant by including the number of informants citing a given use-value. It was computed using the following formula:

$$CI = \sum_{i=1}^{i=NU} \frac{URi}{N}$$

Table 1. Localities, number of households visited, agro-ecosystems and general features across four countries

S. No.	Country/ province (State)	Localities/ site names	Agro-eco system/forest types	General features
1	India, Uttar Pradesh	Malihabad	Orchards	Commercial oriented mango belt with high intra specific diversity and old orchards with seedling types.
2	India, Bihar	Pusa	Orchards, Home gardens	Semi-commercial with some old orchards with seedling types, potential to strengthen home gardening
3	India, Maharashtra	Amravati	Orchards	Commercial oriented citrus belt with active farmer association and nurseries. Mango seedling types exist; Unique area as citrus trees flowers twice a year
4	India, Karnataka	Sirsi	Orchards, Home gardens, Forest Ecosystem	Forested area including collection from wild to semi commercial gardens
5	India, Andhra Pradesh	Chittoor	Orchards	Commercial mango orchards with variety diversity
6	Indonesia, East Java	Kediri	Home gardens, Orchards	Semi-commercial area with high inter specific diversity in home gardens, some orchards and a communal forest ecosystem
7	Indonesia, East Java	Magetan	Orchards, Home gardens	Commercial oriented area with citrus orchards and home garden
8	Indonesia, South Kalimantan	Telaga Langsat	Forests, Home gardens	Located in the hills with trees found in home garden, along paddy field and in community forest
9	Indonesia, South Kalimantan	Pembantanan	Along paddy fields	Low wetland and trees mostly found along paddy fields
10	Indonesia, South Kalimantan	Sungai Kambat	Orchards	Low wetland area, commercial oriented with active farmer groups
11	Indonesia, South Kalimantan	Sungai Tuan Hilir	Orchards	Low wetland area, semi-commercial oriented
12	Indonesia West Sumantra	Kampung Dalan	Forested community	Community forests with buffer zones
13	Indonesia West Sumantra	Latang	Forested community	Community forests with buffer zones
14	Malaysia, Sabah	Kota Belud	Home gardens	Home gardens mainly producing for home consumption located at the foot of the hills
15	Malaysia, Sabah	Papar	Home gardens	Traditional home garden system with high inter species diversity for semi-commercial use in low lands
16	Malaysia, Sarawak, Miri	Sibuti	Home gardens	Home gardens and fields in the hills close to the coast line
17	Malaysia, Sarawak, Kuching	Serian	Forest	Community forest system in lower mountains, mainly for home consumption
18	Malaysia, Peninsular, Kedah	Yan	Orchards	Semi-commercial orchards along the coast line
19	Malaysia, Peninsular, Perak	Bukit Gantang	Home gardens	Semi-commercial home gardens with active/responsive community
20	Thailand	Huaithaptha, Srisaket	Home gardens, Community forests	Multi species, low land home gardens producing the TFTs Natural habitat along the river bank, annually flooded
21	Thailand	Trok Nong Chantaburi	Home Gardens, Orchards	Home gardens with intercropping. Mangosteen, Durian are mainly grown in the coastal region
22	Thailand	Banmae -o- nai Chiang Mai	Home Gardens, Orchards	Home gardens produce TFTs for the household purposes. Multi-varietal commercial orchards for Mango and Litchi in the hill side region
23	Thailand	Nhongtrea	Home gardens	Home gardens with multi-species TFTs producing TFTs at the foot-hill
24	Thailand	Kiriwong Nakorn, Srithammar	Home Gardens, Orchards	Home gardens with multi species trees on the mountain terrain

TFTs = Tropical fruit trees

where 'N' is the number of sites (number of sites within a country where the species is reported), 'NU' is the number of different use-categories and 'UR' is the number of different uses mentioned by site *i*. When all the sites cite a specific use, the ratio UR/N would be 1. The upper value of the CI is equal to the total number of use-categories (15).The CI value was computed for each country separately. This additive index takes into

Table 2. Use-categories and their short description

Use-category	Description
Aesthetic value	Any part used for decoration of self/homes/temples/ambience/ landscape
Bio pesticide	Used to control the insects and diseases of plants
Consumption	Fruit/leaf/root/stem parts are eaten raw/routinely cooked
Cosmetic use	Any part used for cosmetic purposes
Fodder	Leaves used as fodder
Handicraft	Handicrafts are made from any part
Medicine	Any part used as medicine/local health care
Mulch	Used for soil cover
Processing	Any part processed as juice/jam/pickle/pappad/sauce/wine *etc.*
Timber/small timber	Used for house-hold timber purposes
Soil Protection	Planted to protect the soil
Used in ritual	Any part used in ritual/festival/offered to Gods/spirits
Used for dye	Any part used to extract the dye
Wind break	Planted as wind break
Other uses	Any other major category such as root stock/butter extraction etc.

account the spread of use (number of sites) for each species and number of uses. The theoretical maximum value of the index is the total number of different edible use-categories. Culturally most significant species were identified as those with top ten ranks. The similarity between two countries was computed using Jaccards' index.

Results and Discussion

South and South East Asia has been recognized as a centre of diversity of tropical fruits and boasts of over 500 TFT species. Because of varying agro-ecological conditions and varying cultural milieu of the communities, a large array of intra specific variation has been accumulated among the TFTs. These variations have been efficiently recognized and used by the local communities. However, this knowledge associated with TFTs is highly vulnerable for loss than the TFTs resource *per se*. Hence there is a need for the documentation of the locally specific uses and to assess the cultural significance objectively. Evaluation of various uses of tropical fruits across a regional level considering different cultural contexts is important to compare intercultural variations/similarities in resource use. Such comparisons would ultimately lead to the insights on prioritizing the species for conservation and in developing new drugs/food additives, *etc*.

In this study, considering only four focal genera of the TFT species *viz*., *Mangifera, Garcinia*, *Citrus* and *Nephelium*, an amazing diversity of 56 species were reported to be utilized by the communities (Table 3). Among the four countries, highest numbers of 26 species were used by the communities in Indonesia and Thailand, while those of Malaysia and India were dependent on 18 species and 17 species, respectively (Table 3). At a regional scale, communities dependent on the genus *Citrus* to a great extent with 20 species and then on genus *Garcinia* (17). The focal tropical fruits were used in a variety of uses that ranged from simple eating raw fruit, to be used as bio-pesticide and used in religious rituals. A complete list of specific uses of the species is appended as annexure I. Very interesting uses of TFTs have been documented. The sticks of *G. fusca* (Madan) in Thailand, are used to grill chicken for special culinary preparation that imparts a well-liked flavour. Young leaves of the same species are used as additives in many Thai dishes. The bark of *M. pentandra* is used in Malaysia to boost men's virility; while the fruits of *G. forbesii* are used in birth control.

Table 3. Total number of species of four tropical fruit tree genus found to be used by the communities in different countries

Country	*Mangifera*	*Garcinia*	*Citrus*	*Nephelium*	Total
India	1(1)	3(3)	13(6)	0(0)	17
Indonesia	12(4)	4(3)	8(2)	2(0)	26
Malaysia	9(4)	4(3)	3(1)	2(2)	18
Thailand	7(7)	8(2)	10(1)	0	26
Overall number of species*	15	17	20	4	56

Values in the parentheses indicate the number of culturally important species as determined by the top ten ranks of the CI value
*not a simple column total, since there are overlapping occurrence of species among the countries

In Sabah, Sarawak and South Kalimantan, fruits of *M. odorata* and *M caesia* are used for fresh consumption, while *M. pajang* (Bambangan) is mainly processed into pickle alone or with fish. In the Western Ghats of India, acrid sap from young fruits of aromatic pickle mango (*appemidi*) varieties are collected and preserved to be used to spice-up several dishes. Various types of aroma ranging from cumin to camphor are identified by the communities and used in different dishes. The wood of *G. speciosa* is used for making handle of agricultural implements and for hoe, knife, and sticks for fencing in Thailand. The tree resinous exudates of several species of *Garcinia* are used in fabric colouring in India, Indonesia and Thailand. Surprisingly, several species of *Citrus* are associated with rituals/black magic in every country while mango is associated with other religious purposes, suggesting that non-biological factors are also important in computing the cultural significance of a species.

Cultural Importance (CI) Value of Tropical Fruits Across Different Countries

Ranking of species based on the number of use-categories and based on the CI value showed differences. Since CI is more robust in truly assessing the significance, more emphasis could be placed on this.

In India, mango showed highest number of uses and cultural importance value suggesting its deep cultural value. *G. morella* and *C. limon* were next best in terms of CI (Table 4). Further, all the other species of the four target genera also showed relatively high values of CI. These major TFT genetic resources are part and parcel of the home-gardens and farmland suggesting the domestication of these valuable TFT genetic resources for household consumption from the growers. This is because farmers tend to domesticate only those local varieties that are most likely to satisfy their specific needs and preferences.

Communities of Indonesia valued *C. hystrix* and *C. grandis* higher over all other species (Table 5). These two species were on the top both with respect to the number of uses as well as with CI. *G. atroviridis* was also reported to be having a higher use value and CI value. *M. indica* and *M. odorata* were next best in terms of CI. All most every species reported had relatively high values of CI.

In Malaysia, considering the number of use-categories, *G. mangostana* ranked first, however, the CI value revealed that *M. pajang* was at the top (Table 6). The top ranking of species based on the two measures were different. Interestingly *G. atroviridis* with only two reported use-categories ranked second in terms of CI values. Geographically, the top two species with the highest value of CI in Malaysia were distantly located from each other; with *M. pajang* was endemic to East Malaysia region, in the Borneo Island while *G. atroviridis* can only be found in Peninsular Malaysia. This showed that both species were culturally important to different communities of different region.

Communities of Thailand valued *G. mangostana* the most as revealed by both number of use-categories and CI value. *C.hystrix, C. aurantifolia* and *M. foetida* were also in the top ranking category (Table 7).

Culturally Most Significant Species Across Different Countries

There were substantial differences among the uses of species across the four countries suggesting differences in the cultural base. *M. indica, C. aurantifolia* and *C. reticulata* were extensively used as food and used for processing and were culturally significant species in all the four countries. Perhaps wide spread commercial interest along with cultural importance could be the reason for the same. *C. medica* (as the name implies) was reported to be used for medicinal purposes and was a culturally significant species in all the countries except Malaysia. Among the three South East Asian countries, *G. atroviridis* and the genus *Citrus* were common suggesting a shared cultural thread. As revealed by Jaccards' index, there was a higher similarity of communities of India with that of Thailand and least with Malaysia (Table 8). The three South East Asian countries showed a higher similarity among themselves perhaps because India is geographically isolated from these three nations.

In India, only one species of mango, *M. indica*, and all the three species of *Garcinia* reported by the communities were within the top 10 ranks and hence were designated as culturally most significant. In Indonesia, four out of 12 reported species of *Mangifera*, three species of *Garcinia* out of four, two species of *Citrus* out of eight reported were culturally most significant. In Malaysia, nearly half of the species belonging to *Mangifera* and about 75% of the species of *Garcinia* and both the species of *Nephelium* were culturally highly significant. The communities of Thailand reported that the genus *Mangifera* which had the largest number (n=7) of species as culturally the most significant (Fig.1). In general,

Table 4. Comparative list of ranks of species according to the number of use categories reported and cultural value index computed for five sites of India

Rank	Species	Number of use categories	Species	Cultural importance value
1	*Mangifera indica*	9	*M. indica*	7.20
2	*Citrus aurantifolia*	7	*G. morella*	5.00
3	*Garcinia gummi-gutta*	6	*C. limon*	4.60
4	*G. indica*	6	*C. aurantifolia*	4.00
5	*G. morella*	6	*G. gummi-gutta*	4.00
6	*C. limon*	5	*G. indica*	4.00
7	*C. medica*	4	*C. medica*	3.25
8	*C. grandis*	3	*C. sinensis*	3.00
9	*C. maxima*	3	*C. reticulata*	2.50
10	*C. reticulata*	3	*Citrus sp.*	2.00
11	*C. sinensis*	3	*C. decumana*	2.00
12	*C. aurantium*	2	*C. maxima*	1.75
13	*C. decumana*	2	*C. grandis*	1.25
14	*Citrus* sp.	2	*C. jambhiri*	1.00
15	*C. jambhiri*	1	*C. pseudolimon*	1.00
16	*C. pseudolimon*	1	*C. reshni*	1.00
17	*C. reshni*	1	*C. aurantium*	0.75

Table 5. Comparative list of ranks of species according to the number of use categories reported and cultural value index computed for eight sites of Indonesia

Rank	Species	Number of use categories	Species	Cultural value index
1	*Citrus hystrix*	9	*C. hystrix*	8.00
2	*C. grandis*	8	*C. grandis*	7.00
3	*C. limonia*	8	*G. atroviridis*	7.00
4	*Garcinia atroviridis*	8	*M. indica*	7.00
5	*C. microcarpa*	7	*M. odarata*	6.50
6	*C. reticulata*	7	*G. griffithii*	6.00
7	*C. sinensis*	7	*Garcinia sp.*	6.00
8	*G. griffithii*	7	*G. xanthochymus*	6.00
9	*Garcinia sp.*	7	*M. applanata*	6.00
10	*Mangifera casturi*	7	*M. casturi*	6.00
11	*M. griffithii*	7	*M. griffithii*	6.00
12	*M. indica*	7	*M. laurina*	6.00
13	*M. odarata*	7	*M. torquenda*	6.00
14	*C. aurantifolia*	6	*Nephelium* spp.	6.00
15	*G. xanthochymus*	6	*C. reticulata*	5.67
16	*M. applanata*	6	*C. sinensis*	5.67
17	*M. torquenda*	6	*C. microcarpa*	5.50
18	*Nephelium* sp.	6	*M. pentandra*	5.00
19	*C. medica*	5	*N. maingayi*	5.00
20	*M. laurina*	5	*C. aurantifolia*	4.67
21	*M. rufocostata*	5	*M. rufocostata*	4.50
22	*N. maingayi*	5	*C. medica*	4.00
23	*M. foetida*	4	*M. havilandii*	4.00
24	*M. havilandii*	4	*C. limonia*	4.00
25	*M. caesia*	3	*M. caesia*	3.00
26	*M. pentandra*	3	*M. foetida*	3.00

species yielding edible fruits are generally valued high by the communities. For instance, Manuel *et al*. (2007) has shown that all the domesticated and wild edible fruit species in six regions of Spain and Portugal were in the top 10 places. Further, there could be a strong association of cultural importance value and the frequency of TFTs in a community. In a recent study, Hegde (2014) has shown positive correlation between the CI value of a species and the log frequency of the TFT species in the two village sites of the Western Ghats of India. However, Pieroni (2001) has shown that wild greens were more valued in Italy than the wild fruits hence other factors

Table 6. Comparative list of ranks of species according to the number of use categories reported and cultural value index computed for six sites of Malaysia

Rank	Species	Number of use-categories	Species	Cultural value index
1	*Garcinia mangostana*	6	*M. pajang*	4.25
2	*Nephelium lappaceum*	5	*G. atroviridis*	3.50
3	*G. parvifolia*	4	*M. caesia*	3.25
4	*M. caesia*	4	*N. lappaceum*	3.20
5	*M. pajang*	4	*G. mangostana*	3.17
6	*M. pentandra*	4	*C. aurantifolia*	3.00
7	*G. forbesii*	3	*Mangifera* sp.	3.00
8	*M. indica*	3	*N. ramboutan-ake*	3.00
9	*M. odorata*	3	*G. forbesii*	2.67
10	*M. quadrifida*	3	*M. pentandra*	2.25
11	*Citurs aurantifolia*	2	*M. griffithii*	2.00
12	*G. atroviridis*	2	*G. parvifolia*	1.75
13	*N. ramboutan-ake*	2	*M. odorata*	1.67
14	*C. microcarpa*	1	*M. indica*	1.33
15	*Citrus* sp.	1	*C. microcarpa*	1.00
16	*M. griffithii*	1	*Citrus* sp.	1.00
17	*M. laurina*	1	*M. laurina*	1.00
18	*Mangifera* sp.	1	*M, quadrifida*	1.00

Table 7. Comparative list of ranks of species according to the number of use categories reported and cultural value index computed for five sites of Thailand

Rank	Species	Number of use-categories	Species	Cultural value index
1	*Garcinia mangostana*	7	*G. mangostana*	5.25
2	*Citrus hystrix*	5	*M. duperreana*	5.00
3	*Mangifera foetida*	5	*M. foetida*	4.00
4	*M. indica*	5	*C. aurantifolia*	4.00
5	*C. aurantifolia*	4	*Garcinia sp.(Son kandari)*	4.00
6	*G. atroviridis*	4	*M. cochinchinensis*	4.00
7	*Garcinia* sp. (Son kandari)	4	*M. hypoleucum*	4.00
8	*M. cochinchinensis*	4	*M. lagnifera*	4.00
9	*M. duperreana*	4	*M. odorata*	4.00
10	*M. hypoleucum*	4	*M. indica*	3.60
11	*M. lagnifera*	4	*G. atroviridis*	3.50
12	*M. odorata*	4	*C. hystrix*	3.40
13	*C. maxima*	3	*N. lappaceum*	2.70
14	*G. speciosa*	3	*C. maxima*	2.50
15	*N. lappaceum*	3	*G. speciosa*	2.25
16	*C. aurantium*	2	*C. aurantium*	2.00
17	*C. medica*	2	*C. medica*	2.00
18	*C. reticulata*	2	*C. reticulata*	2.00
19	*C. madurensis*	2	*C. madurensis*	2.00
20	*G. cowa*	2	*G. cowa*	2.00
21	*G. hanburyi*	2	*G. hanburyi*	2.00
22	*G. schomburgkiana*	2	*G. schomburgkiana*	2.00
23	*G. fusca* (Madan)	2	*G. fusca* (Madan)	2.00
24	*Citrus* sp. (Junkra)	1	*Citrus* sp. (Junkra)	1.00
25	*Citrus* sp. (Makrud)	1	*Citrus* sp. (Makrud)	1.00
26	*Citrus* sp. (Somjangkra)	1	*Citrus* sp. (Somjangkra)	1.00

such as availability, multi functionality, medicinal and/or ritual characteristics may contribute to the importance of a species.

Thus in summary, this study identifies *M. indica, M. pajang, M. foetida, G. morella, G. atroviridis, G. mangostana, C. hystrix, C. aurantifolia* and *C. grandis* as culturally the most significant and hence deserve higher priority in efforts to conserve TFT genetic resources. Culturally most significant species identified in the current study through CI values across South and South East Asia need to be focused for conservation and utilization. Many authors have reported the same view

Table 8. Similarity among tropical fruit species of focal genera among four countries as revealed by the Jaccards' index expressed (%)

Country	Indonesia	Malaysia	Thailand
India	9.0	5.0	15.0
Indonesia		21.0	14.0
Malaysia			13.0

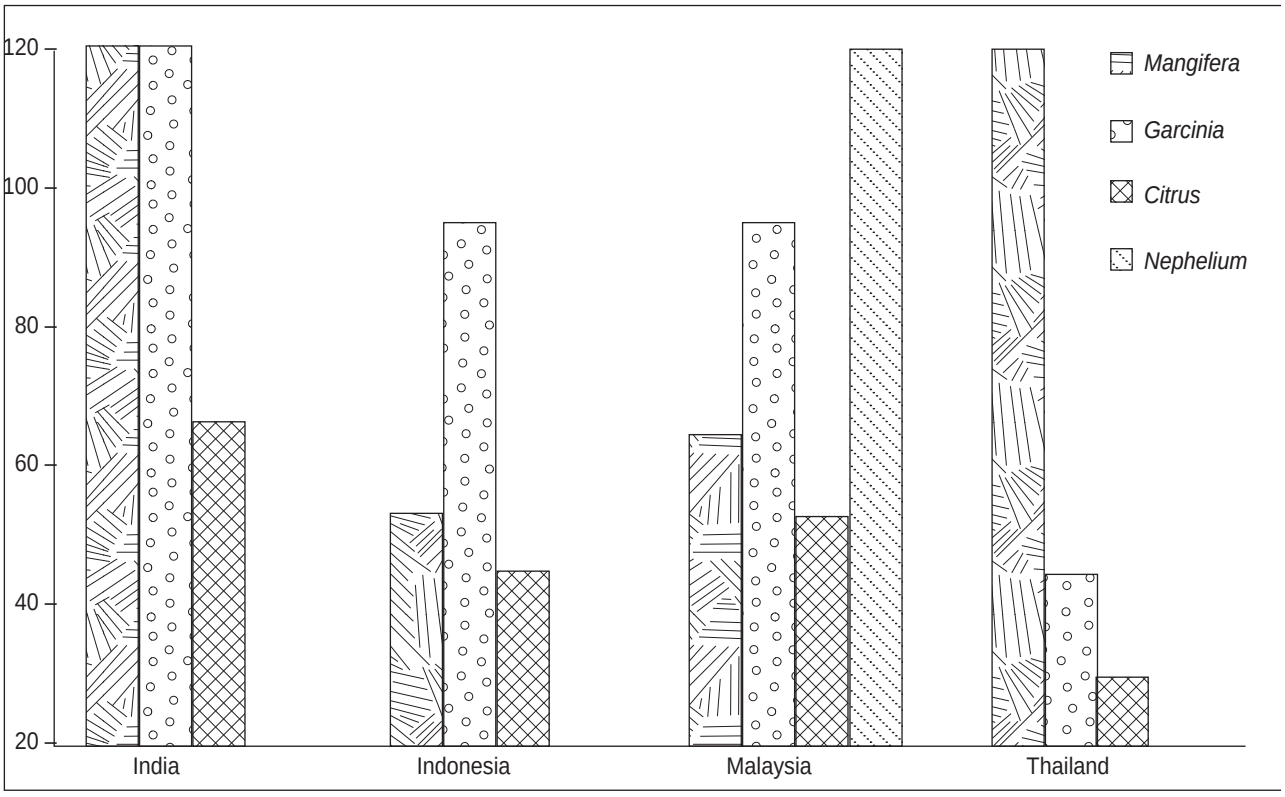

Fig. 1. Per cent species of four important genera of tropical fruit trees that are culturally most significant in India, Indonesia, Malaysia and Thailand

earlier (Dawson *et al*., 2011; Leakey and Ajayi, 2007; Sthapit *et al*., 2007; Gavali and Sharma, 2004). This analysis also provides a good starting point for further inter-cultural comparisons using multivariate analyses.

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References

Dawson IK, B Vinceti, JC Weber, H Neufeldt, J Russell, AG Lengkeek, A Kalinganire, R Kindt, JPB Lilleso, J Roshetko and R Jamnadass (2011) Climate change and tree genetic resource management: maintaining and enhancing the productivity and value of small holder tropical agro-forestry landscapes, a review. *Agroforest. Syst*. **81**: 67-78.

Gavali D and D Sharma (2004) Traditional knowledge and biodiversity conservation in Gujarat. *Indian J. Trad. Knowl.* **3**: 51-58.

Hegde Vanishree M (2014) Documenting diversity to develop community biodiversity register (CBR) for tropical fruit tree (TFT) genetic resources in central Western Ghats. M.Sc. thesis in Forest Genetic Resources submitted to the University of Agricultural Sciences, Dharwad.

Leakey RRB and OC Ajayi (2007) Indigenous fruit trees in the tropics: Domestication, utilization and commercialization. In: RRB Leakey and OC Ajayi (eds.) CAB International Publishing, Wallingford, United Kingdom, pp 94-96.

Manuel P, T Javier, B Emilio, MC Ana, JL Juan, SM Elia and M Ramon (2007) Traditional knowledge of wild edible plants used in the northwest of the Iberian Peninsula (Spain and Protugal): a comparative study. *J. Ethnobiol. Ethnomed*. **3**: 27.

Mauro F and PD Hardison (2000) Traditional knowledge of indigenous and local communities: international debate and policy. *Ecol. Appl*. **10**: 1263-1269.

Pieroni A (2001) Evaluation of the cultural significance of wild food botanicals traditionally consumed in north-western Tuscay, Italy. *J. Ethnobiol.* **21**: 89-104.

Pardo-de-Santayana M, J Tardío, E Blanco, AM Carvalho, JJ Lastra, ES Miguel and R Morales (2007) Traditional knowledge of wild edible plants used in the northwest of the Iberian Peninsula (Spain and Portugal): a comparative study. *J. Ethnobiol. Ethnomed.* **3**:27 doi:10.1186/1746-4269-3-27.

Phillips O and AH Gentry (1993) The useful plants of tambopata, Peru.1. Statistical hypotheses tests with a new quantitative technique. *Econ. Bot.* **47**: 15-32.

Ramanatha Rao V and M Bhag Mal (2002) Tropical fruit species in Asia: Diversity and conservation strategies. *Acta Hort.* **575**: 179-190.

Sthapit BR, ES Percy, VR Ramanatha, P Quek, F De Cruz, F Kruijssen and M Bellon (2007) Good practices of *in-situ* conservation of TFT species diversity: Linking conservation and livelihood. In: *International Seminar on Utilization of Diversity in Land use Systems, Sustainable and Organic Approaches to Meet Human Needs.* Tropentag, Octber 9-11, 2007, Witzenhausen.

Sthapit BR, V Ramanatha Rao and SR Sthapit (2012) *Tropical Fruit Tree Species and Climate Change.* Bioversity International, New Delhi, India.

Vasudeva R and N Rajeshwari (2014) *Appemidi*: Wild aromatic pickle mango of the central Western Ghats, India. Information Brochure, GEF/UNEP/Bioversity International.

Vinceti B, C Termote, A Ickowitz, B Powell, K Kehlenbeck and D Hunter (2013) The contribution of forests and trees to sustainable diets. *Sustainability* **5**: 4797-4824. doi:10.3390/su5114797.

Appendix I

A. List of uses of different species of focal TFT, recorded in study sites of India

Species	Uses
Mangifera indica	Leaves used in folk festivals Timber is useful for making traditional boats Ripe fruits edible Raw fruits used in making traditional dishes like *chutney, Tambuli* etc. Pulp of the fruit used in making jams, syrups, leather*etc*. A traditional dish '*Mamla'* prepared by drying pulps Tender fruits of special Mango variety (*Appe*) made into pickles Raw fruits made into cut pickles The resin from the tender mango of special variety are collected and stored and it is used as a flavouring agent for special soup called '*Appehuli'*
Garcinia gummi-gutta	Dried rind used as souring material for fish and other non-vegetarian curries Gamboge a gum resin is obtained from the peeled bark used as colouring pigment Butter or oil extracted from seeds used in making confectionary items Unripe fruit rind is pickled Ripen fruit rind used in cleaning utensils, gold and silver fruit pulp used as medicine to cure acid reflux
G. indica	Ripe fruit is eaten raw Pulp and rind used in making summer refreshing drink (*Kokum*) Pulp and rind used in making traditional soups (*Tambuli, Solkadi*) Rind used as condiments instead of tamarind Rind powder used in making soft drinks soups Butter extracted from seeds used in making culinary items Butter used as ointments as lip guards Butter used as medicine for gastrointestinal disorder Rind and pulp used for acidity
G. morella	Colouring pigments obtained from seed coats used in painting traditional arts and also for painting house walls Butter extracted from seeds employed in local medicines and also for making traditional dishes
Citrus aurantifolia	fruit juice used in making soft drinks (*Sherbat*) fruits used for pickling and lime chutney fruit juice used in cleaning products essential oil extracted from rind used for making perfumes and as a flavoring agent juice used in making soups juice for medicine fruits used in folklore arts as a '*Tantra'* for removing evil spirits

Contd.

Species	Uses
C. aurantium	Leaf, flower, fruit peel and fruit juice used as medicine for skin diseases, gastrointestinal disorder, anemia and also for weight loss Essential from the fruit used as flavouring agent Dried fruit peel used as seasoning Fruit used in pickling Unripe fruit used cuisine
C. decumana	Ripen fruit eaten raw Juice used in making soft drinks Flowers used as perfume industry Wood is used in making tool handles Fruit juice medicinal (ulcers, diabetes and good urinary flow)
C. grandis	Ripen fruit eaten raw Juice used in making soft drinks Flowers used as perfume industry Wood is used in making tool handles Fruit juice medicinal (ulcers, diabetes and good urinary flow)
C. jambhiri	Fruit juice used common lime juice Slices of the fruit used to garnish fish and meat Pickles made from fruits
C. limon	Ripe and unripe fruit edible raw Fruit juice used in making soft drinks Fruits are pickled Essential oil extracted from leaves used in perfumery Juice used in making soups Dried fruit peel used as seasoning fruits used in folklore arts as a '*Tantra*' for removing evil spirits fruits used in folk medicines fruit juice used in cleaning products Juice to cure acidity and stomach disorder
C. maxima	Ripen fruit eaten raw Juice used in making soft drinks Flowers used as perfume industry Wood is used in making tool handles Fruit juice medicinal (ulcers, diabetes and good urinary flow) Juice used in curing bronchitis Leaves mixed with bitter guard, *Anthocephalus cadamba* bark and make paste to treat chickenpox
C. medica	Fruits and fruit juice used as medicine for cold, stomach disorder and also for anemia Fruit juice make into sweet jams Plant is used as root stock for grafting other *Citrus species*
C. pseudolimon	Fruit edible raw Juice for making soft drink Fruits pickled
C. reshni	Fruit used as common lime Juicy fruits used for making refreshing drinks Pickles made from fruits
C. reticulata	Fruits edible Raw fruits used as condiments Fruit juice used in making Sherbet (refreshing soft drink) Essential oil used in bathing Fruits used in making confectionary items
C. sinensis	Ripe fruit eaten Soft drinks made from juice

B. List of uses of different species of focal TFT, recorded in study sites of Indonesia

Species	Uses
Mangifera applanata	Fruits are eaten raw Tender fruits are used as pickle Wood is used as timber
M. caesia	Fruits are eaten raw Fruits are used as hot spices mixture Wood is used as small timber Used as fodder for animal
M. casturi	Fruits are eaten raw, fruit juice is made into jam, juice, taffy Wood is used as small timber Bark /sap is use as dye Leaves are used as fodder to animal
M. foetida	Fruits are eaten raw Fruit are locally processed (tampuyak)
M. griffithii	Fruits are eaten raw Tolerant to drought, floods, and pest diseases
M. havilandii	Fruits are eaten raw, juice used in beverage preparation Wood is used as timber
M. indica	Fruits are eaten raw Use for taffy, use for pickle Leaves are used in rituals Leaves used as fodder Use as medicine (antioxidant)
M. laurina	Fruits are eaten raw Tender fruits are used as pickle Use for medicine Wood is used as timber
M. odorata	Fruits are eaten raw Bio-pesticide (fragrant fruit; susceptible to stem borer) Use for medicine Use as ritual
M. pentandra	Fruit are eaten raw, Adaptable to swampy area,
M. torquenda	Fruits are eaten raw, Tolerant to drought, floods, and pest diseases, Wood is used as small timber, Use for dye, Leaves are used for rituals
M. rufocostata	Fruits are eaten raw Wood is used as timber Root and bark used as diabetic medicine, Susceptible to floods
Garcinia atroviridis	Fruits are dried for used in seasoning Fruits are used as a cure for cough Leaves are used as bio-pesticide Wood is used as timber Used as fodder for animal
G. griffithii	Fruits are used in seasoning Fruit juice is extracted Fruits are used for cosmetic Wood is used as small timber
Garcinia sp.	Fruits are eaten raw Fruit juice is used for seasoning Wood is used as small timber

Contd.

Species	Uses
G. xanthochymus	Fruits are used raw Fruit are used for seasoning Wood is used as timber, Used as fodder for farm animal
C. aurantifolia	Fruits are eaten raw, juice is used in cooking Used as medicine Fruits used as cosmetic use
C. grandis	Fruits are eaten raw Fruits are used for making taffy, jelly, juice, oven rind for prepare candies Leaves used as bio-pesticide Wood is used as timber
C. hystrix	Fruit juice is used as beverage drink with sugar Fruit juice is used for seasoning Fruit used for medicinal purposes Fruit used as shampoo, dried fruit for steam-bath Leaves are used for food seasoning Leaves are used as bio-pesticide Fruits are usedin rituals Used as fodder
C. limonia	Fruits are eaten raw Used for seasoning Fruit juice used as beverage drink Leaves used as bio-pesticide Fruits used in ritual
C. medica	Fruits are used for medicinal purposes Fruits are used in rituals
C. microcarpa	Fruits are eaten raw Fruits used in hot spices mixture Cosmetic use Leaves uses as bio-pesticide
C. reticulata	Fruits are eaten raw Used for seasoning Fruit juice used as beverage drink Leaves used as bio-pesticide Cosmetic use
C. sinensis	Fruits are eaten raw Fruit juice used as beverage drink Fruits are used for medicinal purposes for animal
Nephelium maingayi	Fruits are eaten raw Wood is used as timber Leaves are used as fodder
Nephelium sp.	Seeds are boiled or processed for food, Wood is used as timber Use for dye Leaves are used as fodder

C. List of uses of different species of focal TFT, recorded in study sites of Malaysia

Species	Uses
Mangifera caesia	Fruits are consumed with fresh. Used as food additives. Help increase appetite. Treating cold, body itchiness, high blood pressure and bronchitis Standing trees are worshiped as a ritual to treat itchiness Wood is of good quality and used as building structure, furniture and other woodwork Leaf litter is used as good mulch and fertilizes soil
M. griffithii	Fruits are eaten raw and processed into pickles
M. indica	Fruits are eaten raw, Juice is extracted. Increases appetite. Treat digestion problem

Contd.

Species	Uses
M. laurina	Leaves are used in the treatment of shingles
M. odorata	Fruits are eaten raw, used as food additives. Processed into pickle, jam Wood is used as timber
M. pajang	Fruits are eaten fresh, juice is extracted, processed into pickle and as food additive Bark is used to treat scabies. Fibbers are extracted Wood is used as timber Roots are used to treat winds Sap is used to treat ulcer Seeds are consumed fresh or processed into pickles
M. pentandra	Fruits are processed into pickle, jam and chutney. Used as food additives. and to treat piles Bark is used to treat gastric pain and haemorrhoids. Strengthen men's virility
M. quadrifida	Fruit are consumed fresh. Juice is used in beverage making. Food additives
Mangifera sp.	Fresh fruits are consumed, used as food main cooking ingredients and additives. Removes fish slime and oil-stain Treat itchiness and winds in babies
Garcinia atroviridis	Bark and roots are used in treating high blood pressure Flower is used in treat diabetes Leaves and Fruit are used as Food additive Processed into pickle. Juice is used as a dye mixture Food conditioner Cleaning fish. Brass cleaning To treat itchiness, high blood pressure, fever, diabetes, wounds and venomous sting Relieve dizziness and coughs Feminine intimate part cleansing Post-natal treatment Weight control Leaves are used as Food additives (Tea) Treat high blood pressure Consumed with fresh Seeds are used to treat high blood pressure
G. forbesii	Fruits are used as food additives Fruits used in treating stomach ache, body swelling, relief from sore throat, post natal treatment, family planning, henna mixture, and treat smallpox Flowers are used in body cooling Leaves are consumed fresh Wood is used as timber
G. mangostana	Fruits are used to treat vomiting blood and piles. Family planning Bark is used to treat high blood pressure, haemorrhoids and diabetes Leaves are used as food additives
G. parvifolia	Fruits are consumed fresh. Used as cooking additives. Pickles To treat cough, sore throat and swelling. Post-natal treatment Wood is used for building structure
Citrus aurantifolia	Fresh fruits are consumed raw / made into a beverage used as food additives Leaves are used in bathing to eliminate body odour It is a basic ingredient for rituals /spiritual barrier from bad spirits
C. microcarpa	Fruits used to minimize smell of fish Leaves are also used to minimize fishy smell of fish
Citrus sp.	Fruit is used in treating headache
N. lappaceum	Fruits are processed into pickles and jam. Eaten fresh Wood is used as firewood Leaves are used in the treatment of sore eyes
N. ramboutan-ake	Fresh fruits are consumed and used as food additive Tree sap is used in the treatment of scabies Leaves are used to treat itchiness

D. List of uses of different species of focal TFT, recorded in study sites of Thailand

Species	Uses
Mangifera foetida	Fruits are eaten raw both green and ripe, ripen fruits used in making candy, green fruits used in making salad, used as vegetable in curry and give the sour taste /seasoning Wood is used as timber
M. indica	Green, mature and ripen fruits are eaten raw; Juice is extracted from ripen fruits, made into candy/leather Un-ripen fruits are used in pickle making salad, seasoning (to give sour taste) Green mature fruits are dried-salted, dehydrated and used as condiments Young leaves are used as vegetable
M. cochinchinensis	Fruits are eaten raw both green and ripen Used as root-stock Wood is timber, wood is used for making craft
M. Duperreana	Fruits are eaten raw both green and ripen Used as root-stock Wood is timber, wood is used for making craft
M. hypoleucum	Fruits are eaten raw both green and ripen Used as root-stock Wood is timber, wood is used for making craft
M. lagnifera	Fruits are eaten raw both green and ripen Used as root-stock Wood is timber, wood is used for making craft
M. odorata	Fruits are eaten raw both green and ripen Used as root-stock Wood is timber, wood is used for making craft
Garcinia mangostana	Fruits are eaten raw (green mature, ripen), used for making juice, wine, vinegar, mangosteen candy, cosmetics, dropping fruit (young)-making charcoal, compost Leaves are used to extract dye Seeds are used as medicine
G. atroviridis	Leaves- for cooking Fruit raw and dried for cooking (give the sour taste), juice, tea, pickle, candy medicine
G. cowa	Leaves are eaten as fresh vegetable, young leaves are used for cooking (in soup/curvy)
G. hanburyi	Fruits are used for dying purposes
G. schomburgkiana	Young leaves are used for cooking, Fruits are eaten raw, used in cooking, and pickle making
G. speciosa	Fruits are eaten raw Bark is used for dye making Wood is used for making handle of agricultural implements and for hoe, knife, stick for fencing
Garcinia sp. *(Madan)*	Twigs are specially used in cooking chicken to provide good taste and flavour
Garcinia sp. *(Son kandari)*	Fruit for cooking give the sour taste, juice, tea, medicine, cosmetic
Citrus aurantium	Fruit juice is soup / curry; used medicine
C. hystrix	Leaves are used in seasoning, eaten raw and cooked Fruit / fruit juice used in curry (masman), juice making used as detergent, skin of the fruits put in curvy paste, medicine
C. aurantifolia	Leaves -seasoning Fruit-making juice, juice for cooking (giving sour taste), juice for medicine, preserved, (the whole fruit) pickle
C. maxima	Fruits are eaten raw and used as salad Fruit peel is used in making sweets
C.medica	Fruit juice is used in cooking and as medicine
C.reticulata	Fruits are eating raw, juice is extracted. Fruit peel is used as insect repellent.
C. madurensis	Fruits are eaten raw, juice is extracted, used in cooking, salted-dried fruit
Citrus sp. *(Junkra)*	Fruit juice is used for cooking
Citrus sp. *(Makrud)*	Fruit juice is used for cooking
Citrus sp. *(Somjangkra)*	Fruit juice is used for cooking
Nephelium lappaceum	Fruits are eaten raw, canned, sweet making, fruit husk is used for dye making, Leaves are used in rubber latex setting

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Preliminary Studies on Morphological and Molecular Characterization of Wild *Garcinia* in Sijunjung, West Sumatra

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A total of 18 samples of five *Garcinia* species from two sites in Sijunjung district, West Sumatra were evaluated using morphological traits and molecular markers. The species comprised four wild species, *G. xanthocymus, G. atroviridis*, *G. nervosa* and *G. macrophyla,* and one cultivated species, *G. mangostana.* Morphological variability was observed with respect to flower and fruit position, leaf size, flower colour, fruit shape and size, the existence of stigma lobe, calyx, and the corolla in ripe fruit. Using RAPD markers, highest inter-specific diversity was observed in *G. xanthocymus* with genetic similarity coefficient ranging from 0.75 to 0.88, while the three other species exhibited similar range from 0.80 to 0.88. The genetic similarity coefficient among species was from 0.60 to 0.88. There are two types of each species based on their sites of occurrence and also their morphological and molecular characters. The information generated will be of use in devising *in situ* conservation strategy and sustainable use of *Garcinia* species.

Key Words: *In situ* conservation, Molecular markers, Morphological traits, Wild *Garcinia* species

Introduction

Indonesia is an important agrobiodiversity centre for tropical fruit species and their wild relatives. Sumatran lowland rain forests is an important center of biodiversity (Stolton *et al.,* 2006); majority of fruit species currently being cultivated in this area are indigenous and have wild relatives. Four genera of indigenous fruits are recommended to be developed in Indonesia, *i.e. Durio, Mangifera, Garcinia* and *Nephelium* (Uji, 2007). There are 77 *Garcinia* species in Indonesia of which 22 are grown in Sumatra, comprising cultivated, wild, edible and timber species. In Borneo, there are 20 *Garcinia* species native to Indonesia, four of which are cultivated while others grow wild in the forest (Uji, 2004; Uji 2007).

A study to assess the diversity of wild *Garcinia* at eight locations in West Sumatra and Jambi Provinces indicated rich diversity in Nagari Latang, and Nagari Kampung Dalam, at Sijunjung district, West Sumatra. Five *Garcinia* species occuring in the above areas, include *G. atroviridis* (asam gelugur), *G. xanthocymus (*asam kandis*), G. macrophyla* (manggis jepang) and one unidentified *Garcinia* (manggis hutan). All the above species grow in the forest interior and in the buffer zone (Winarno *et al*., 2013).

It is well known that the Sumatran lowland rain forests are under great risk, with high levels of habitat conversion (66%) and low levels of protection (4.9%). Wild and cultivated fruit species diversity in Asia is threatened by rapid genetic erosion due to habitat destruction, extension of agriculture, filling up of wetlands, conversion of biodiversity rich sites for human settlement and industrial development. Deforestation and land use conversion have put immense pressure on wild fruit tree resources leading to their loss and its relatives (FAO, 2003).

There is an urgent need to develop and upscale successful strategies to conserve both cultivated and wild relatives of tropical fruit species in Asia for economic, cultural, and ecological reasons (IPGRI, 2003). *In situ* conservation and on-farm conservation protects threatened plants in their natural habitat and takes into account social and cultural factors such as farmers' perceptions and knowledge (Maxted, 2006). Before implementing *in situ*/on-farm conservation activities, knowledge of the levels of genetic diversity is important for planning, managing and monitoring *in situ* conservation activities. Hence, the objective of the present study was to determine the level of genetic diversity in the target populations of cultivated and wild *Garcinia* species occuring at Sijunjung, West Sumatra using morphological and molecular methods.

Materials and Methods

The experimental material consisted of 18 trees belonging to five, wild and cultivated *Garcinia* species, collected

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Table 1. Details of *Garcinia* species used in the present study

Samples	Code	Vernacular name	Botanical name	Habitat	Source of sample/Origin
1	X1	Asam kandis	*Garcinia xanthocymus*	Forest	Mother tree/Latang
2	X2	Asam kandis	*Garcinia xanthocymus*	Forest	Mother tree/Latang
3	X3	Asam kandis	*Garcinia xanthocymus*	Forest	Mother tree/Latang
4	X4	Asam kandis	*Garcinia xanthocymus*	Forest	Mother tree/Latang
5	X5	Asam kandis	*Garcinia xanthocymus*	Forest	Seedling/Latang
6	X6	Asam kandis	*Garcinia xanthocymus*	Forest	Seedling/Latang
7	X7	Asam kandis	*Garcinia xanthocymus*	Forest	Seedling/Latang
8	A1	Asam gelugur	*Garcinia atroviridis*	Forest	Mother tree/Latang
9	A2	Asam gelugur	*Garcinia atroviridis*	Forest	Mother tree/Latang
10	A3	Asam gelugur	*Garcinia atroviridis*	Forest	Seedling/Latang
11	A4	Asam gelugur	*Garcinia atroviridis*	Forest	Seedling/Latang
12	A5	Asam gelugur	*Garcinia atroviridis*	Forest	Seedling/Latang
13	G1	Manggis Jepang	*Garcinia macrophyla*	Forest	Seedling /Kampung Dalam
14	G2	Manggis Jepang	*Garcinia macrophyla*	Forest	Seedling/Kampung Dalam
15	G3	Manggis Jepang	*Garcinia macrophyla*	Forest	Mother tree/Latang
16	H1	Manggis Hutan	*Garcinia nervosa*	Forest	Mother tree/Latang
17	H2	Manggis Hutan	*Garcinia nervosa*	Forest	Seedling/Latang
18	M	Manggis	*Garcinia mangostana*	Home Garden/ Orchard	Mother tree/Latang

from Nagari Latang and Kampung Dalam, Lubuk Tarok subdistrict, Sijunjung district, West Sumatra. The location was selected based on previous survey of *Garcinia* species diversity found in this region (Winarno *et al.*, 2013). The five species comprised four wild species (*G. xanthocymus*, *G. atroviridis*, *G. macrophyla* and *G. nervosa*, and one cultivated species (*G. mangostana*) (Table 1).

Morphological Evaluation

All the 18 samples were evaluated for 25 morphological traits based on descriptors developed by IPGRI (2003) (Table 3). The main traits studied were the branching system, leaves, flowers and fruits position. The flower characters included the colour of inner and outer calyx and corolla, and the existence of calyx and corolla in the ripe fruits. Fruit characters included shape, size, pedicel length, colour, fruit surfaces, number of segments, the existence of stigma lobe, seed number and latex colour (Table 3).

Molecular Evaluation

DNA Extraction

About 0.1 mg fresh leaflets of 18 *Garcinia* species (Table 1) were ground for DNA extraction. Total DNA was extracted according to the modified CTAB protocol (Doyle and Doyle, 1990) using 1% PVPP (polyvinyl polypyrrolidone). DNA concentration was determined with electrophoresis in agarose gel, ethidium bromide staining solution and visualization on UV transilluminator.

DNA Amplification

DNA was PCR-amplified by using eight RAPD primers (Table 2) in a 96-well Applied Biosystems 2720 thermal cycler. Reactions were carried out in a total volume of 25 µl consisting of 2 µl (20 ng) of template DNA, 12.5 µl Go Taq Green Master Mix (Promega M7122), 1 µl primer (20 µM), and 9.5 µl free nuclease water. Amplification was performed under the following conditions: 4 min at 94°C for 1 cycle, followed by 0.5 min at 94°C, 0.5 min at annealing temperature (depending on the primer used), and 1 min at 72°C for 35 cycles, and 5 min at 72°C for final extension. Forty five cycles were repeated with initial denaturation at 94°C for 30 sec. Primer annealing temperature was 37°C for 45 sec and extension at 72°C for 2 min. The final extension step was carried out at 72°C for 7 min. The amplification products were electrophoresed on 2% agarose gel in 1X TAE buffer.

Data Analysis

The DNA banding pattern was observed under UV light after staining with ethidium bromide (0.1µg/ml of gel solution) and photographed in Gel-Doc (Biometra). PCR

Table 2. Primers used for the molecular characterization of *Garcinia* species

Primer	Sequence (5'----------3')
OPH13	CACGCCACAC
OPH18	GAATCGGCCA
P1	GGTGCGGGAA
P2	GTTTCGCTCC
P3	GTAGACCCGT
P4	AAGAGCCCGT
P5	AACGCGCAAC
P6	CCCGTCAGCA

Table 3. Morphological variability for different traits in *Garcinia* species from Sijunjung, West Sumatra

Characters	*G. xanthocymus*		*G. atroviridis*		*G. macrophyla*		*G. nervosa*		*G. mangostana*
	Type 1 (site 1 and 2)	Type 2 (site 1 and 2)	Type 1 (site 1)* Type 2	Type 2 (site 2)** Type 2	Type (site 1) Type 2	Type 2 (site 2) Type 2	Type 1 (site 1) Type 2	Type 2 (site 2) Type 2	
Tree									
Branch position	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite
Leaf									
Leaf position	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite	Opposite
Leaf length (cm)	7-10	4-5	25-30	25-30	30-35	30-35	50-60	50-60	25-30
Leaf width (cm)	4-5	2-3	10-16	10-16	15-20	15-20	20-25	20-25	15-20
Flower									
Flower/fruit position	Terminal	Terminal	Terminal	Terminal	Axillary	Axillary	Axillary	Axillary	Terminal
Colour of outer calyx	Absent	Absent	Green	Green	Green	Green	Green	Green	Green
Colour of inner calyx	Absent	Absent	Red	Red	Red	Red	Yellow	Yellow	Red
Corolla	Light Yellow	Light Yellow	Red, remains attached until ripe	Red, remains attached until ripe	Red	Red	Light Yellow	Light Yellow	Red margin, yellowish in the centre, fall after full bloom
Fruit									
Outer calyx	Absent	Absent	Green	Green	Absent	Absent	Absent	Absent	Green
Colour of inner calyx	Absent	Absent	Green	Green	Absent	Absent	Absent	Absent	Green
Corolla	Absent	Absent	Red	Red	Absent	Absent	Absent	Absent	Absent
Stigma lobe	Not prominent	Not prominent	Prominent	Prominent	Prominent	Prominent	Not prominent	Not prominent	Prominent
Stigma lobe diameter (cm)	–	–	2-2.5	2-2.5	0.3-0.5	0.3-0.5	–	–	1.5-2
Fruit weight (gram)	10-20 (Big)	5-10 (Small)	200-600	200-400	55-100	55-100 gram	250-300	250-300	50-300
Calyx	Absent	Absent	Present	Present	Absent	Absent	Absent	Absent	Present
Fruit shape	Round	Oblong	Flattened	Flattened	Flattened	Flattened	Round	Oblong	Round and Flattened
Fruit surface	Smooth	Smooth	Corrugated	Corrugated	Stripes	Smooth	Smooth	Smooth	Smooth
Mature fruit colour	Orange	Orange	Orange	Orange	Yellow	Yellow	Yellow	Yellow	Deep Purple
Pedicel length (cm)	None	None	None	None	None	None	1-2	3-4	1.5-3.0
Pericarp thickness (cm)	2-3	2-3	4-5	4-5	3-4	3-4	1-1.5	1-1.5	0.5-1.0
Flesh colour	Orange	Orange	Light Yellow	Light Yellow	Light Yellow	Light Yellow	Yellow	Yellow	White
Taste	Sour	Sour	Sour	Sour	Sour	Sour	Sour, Astringent	Sour, Astringent	Sweet-sour
Number of fruit segment	7-8	7-8	8-13	13 or more	9-11	9-11	–	–	4-8
Number of seed	2-4	2-4	2-6	2-6	1-8	1-8	3-5	3-5	1-2
Latex colour	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow

* Nagari Latang, Sijunjung district, West Sumatra

** Nagari Kampung Dalam, Sijunjung district, West Sumatra

products were then scored as present (1) or absent (0) for the 18 samples analysed in the present study. Genetic diversity and the relationship between samples were calculated through Jaccard's coefficient and a sequential, agglomerative, hierarchical and nested (SAHN) cluster analysis was carried out. This analysis was performed using the un-weighted pair group method with arithmetic means (UPGMA) algorithm computed by NTSYS-pc *(*Numerical Taxonomy and Multivariate Analysis) software version 2.1 (Rohlf, 2000).

Results and Discussion

Morphological Evaluation

Garcinia species have a characteristic feature of opposite position of the branches and leaves. Amongst species there was profound variability in flower and fruit position, leaf size, flower colour, fruit shape and size, the existence of stigma lobe, calyx and the corolla in the ripe fruit (Table 3). The flower and fruit of *G. mangostana* and *G. atroviridis* are terminal buds, while in the three others, these are borne as axillary buds. Two species, *G. xanthocymus* and *G. nervosa* have no stigma lobe, while three others have the stigma lobes but of different sizes. The stigma lobe diameter of *G. atroviridis, G. mangostana* and *G. macrophyla* are 2-2.5 cm, 1.5-2.0 cm and 0.3-0.5 cm, respectively. The species *G. xanthocymus* has the smallest leaves and fruits with leaf length varying from 5-7 cm and fruit weight ranging from 10-20 g. The species *G. nervosa* has the largest leaves, about 50-60 cm in length, whereas *G. atroviridis* and *G. mangostana* have medium leaves, 25-30 cm in length.The calyx and corolla are present in the ripe fruit of *G. atroviridis*, whereas in *G. mangostana* there is only a calyx as the corolla falls when the flowers are in full bloom. Three other species have no calyx and corolla in the ripe fruits. The general morphological traits of the five species are the leaves and branching system which are born in pairs and have yellow latex in all parts of the plant.

Based on these morphological characters each of the wild species could be divided into two types which were separated into different sites. It was observed that the *G. atroviridis, G. macrophyla* and *G. nervosa* from Nagari Latang (site1) were different from those of Nagari Kampung Dalam (site 2), while the two types of *G. xanthocymus* occuring at each site differed with respect to leaf and fruit shape. The first type has bigger leaves, (12 cm long and 3.5 cm wide) with round fruits. The leaves of the second type are about 8 cm long and 2.5 cm wide, with round fruits.

G. atroviridis showed variability in the number of fruit segments. The first type found at site 1 has 8 to 13 segments, and the second type present at site 2 has more than 13 segments. The key character which differentiates the two types of *G. macrophyla*, is the type of stripes on the fruit surface. The fruit skin surface of *G. macrophyla* from site 1 has longitudinal stripes while that from site 2 has a smooth skin with no stripes on pericarp. The two types of *G. nervosa* differ in fruit shape and pedicel length. The first type has round fruits with a short pedicel and the second type has an oblong fruit with a long pedicel. Comparative morphological variation within species can be observed from data presented in Table 1 and from Figure 1.

Molecular Characterization

Polymorphism of RAPD Markers

It is clear from Table 4 that there is polymorphism amongst 18 trees of five *Garcinia* species. Eight RAPD primers yielded a total of 152 bands, with a maximum of 26 for P3 (AAGAGCCCGT) and a minimum of 15 for P2 (GTAGACCCGT) and P4 (AACGCGCAAC). The

Table 4. The amplification products by eight RAPD primers in 18 *Garcinia* plants

Primer code	Primers sequence (5'----------3')	Total scorable bands	Polymorphic bands	Monomorphic bands
OPH13	GAATCGGCCA	22	22	0
OPH18	GGTGCGGGAA	24	24	0
P1	GTTTCGCTCC	16	16	0
P2	GTAGACCCGT	15	15	0
P3	AAGAGCCCGT	26	26	0
P4	AACGCGCAAC	15	15	0
P5	CCCGTCAGCA	18	18	0
P6	CACGCCACAC	16	15	1
	Total	152	151 (99.003%)	1(0.007%)
	Average	19	18,875	0,11

Fig. 1. The two types of *G. macrophyla*: (a) fruit surface with stripes in pericarp, (b) smooth surface with no stripes in pericarp, (c) two types of *G. nervosa*: short pedicel and round fruits, (d) long pedicel and oblong fruits

Table 5. Morphological variations within *Garcinia* species from Sijunjung, West Sumatra

Species	Main morphological characters	Locations
G. xanthocymus		
Type 1	Large leaves (10 to 12 cm in length and 3 to 3.5 cm in width), oblong fruits	Site 1 and 2
Type 2	Small leaves (8 to 9 cm in length and 2-2.5 cm in width), round fruits	Site 1 and 2
G. atroviridis		
Type 1	Fruit segments 8 to 13	Site 1
Type 2	Fruit segment more than 13	Site 2
G. macrophyla		
Type 1	fruit surface with stripes in pericarp	Site 1
Type 2	Smooth surface with no stripes in pericarp	Site 2
G. nervosa		
Type 1	Short pedicel, round fruit	Site 1
Type 2	Long pedicel, oblong fruit	Site 2

152 markers consisted of 151 (99.003%) polymorphic bands and 1 (0.007 %) monomorphic band, and these ranged in size from 250 to 2500 bp. This result indicates the wide genetic variation among the species.

Amplification products of eight RAPD primers produced several DNA fragments and DNA banding patterns that were unique to certain samples. Part of PCR products of *Garcinia* species by primer OPH 13, OPH 18, P1 and P5 are presented in Figure 2. The arrows indicate the unique DNA fragments and DNA banding patterns. *G. xanthocymus* and *G. atroviridis* exhibited considerable variability in molecular data. Among the seven samples of *G. xanthocymus* the tree number 4 (X4) exhibited very different and unique banding pattern for each primer used. Morphologically, the X4 tree belongs to type 2 (small leaves) while the other trees belong to type 1 (large leaves).

Similar to *G. xanthocymus*, the DNA banding pattern of *G. atroviridis* samples were variable indicating the wide genetic variability in this species. The RAPD analysis showed that the offsprings differ in genetic diversity from the mother plant. This condition is related to the cross-pollinated reproduction system of *G. atroviridis*. The *G. atroviridis* is gynodioecoius plant in which female and hermaphrodite individuals co-occur (Pangsuban *et al*., 2007).

The aditional bands, OPH 13/1600 bp, OPH 18/ 250 bp, P1/250 bp and 1000 bp, were present in *G. macrophyla* collected from site 1 (G3) and these were absent in two others samples from site 2 (G1 and G2). The bands indicated by the arrow in Figure 2. The G3 plants are morphologically unique due to presence of stripes in fruit skin. The unique morphology (Figs. 1a, 1b) of this sample correlates with the unique banding patterns (Fig. 2).

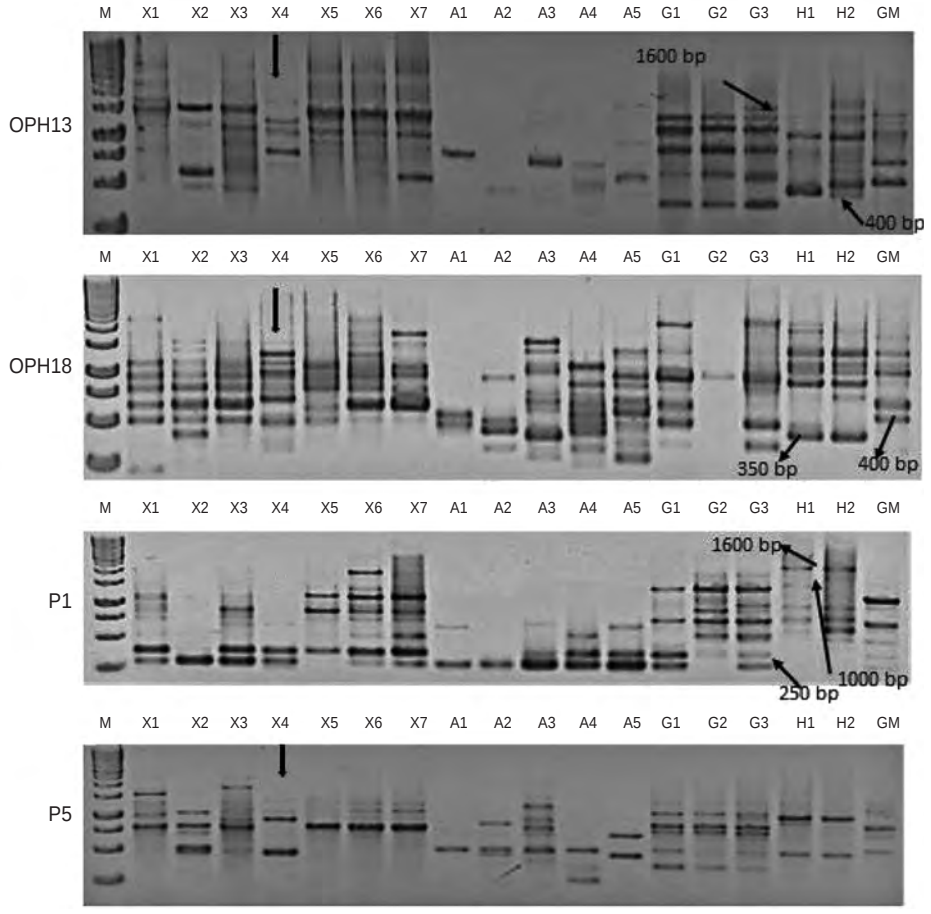

Fig. 2. Part of PCR products of *Garcinia* species by primer OPH 13, OPH 18, RAPD1 and RAPD 5

It is clear from the amplification pattern in *G. nervosa* that the two samples, mother tree (H1) and the offspring (H2) exhibit genetic differences. The PCR products of *G. nevosa* also displayed a number of unique bands. The bands produced by primer OPH13 at 400 bp are present in H2 and absent in H1 whereas OPH-18/400 bp and P1/1600 bp are present in H1 and absent in H2.

From these analyses, all the samples could be differentiated using the eight RAPD markers. This indicates that RAPD markers can be used to distinguish between and within species of *Garcinia*. Random Amplified Polymorphic DNA (RAPD) technique is a simple and quick method to determine the level of genetic diversity. This technique requires less DNA 10-25 ng, does not require DNA sequence information, not radioactive, its implementation is relatively easy, and produce higher estimates for interspecific similarity (Powell *et al.*, 1996; Gupta *et al*., 1996). Nevertheless, RAPD technique has some limitations, among others, cannot distinguish homozygous and heterozygous individuals for being as dominant markers (Williams *et al.*, 1990). Small changes in the reaction conditions can significantly alter the amount and intensity of the amplification products so that reproducibility is difficult to be maintained. (Hallden *et al*., 1996). Further research is needed using more samples of *Garcinia* and better molecular methods such as microsatellite or Simple Sequence Repeat (SSR)

Genetic Relationships among Samples

Genetic similarity coefficient among the 18 *Garcinia* trees based on RAPD analysis varied from 0.60 to 0.88 (Fig. 3.). These results are similar to genetic diversity among 11 *Garcinia* spp. using ISSR (Inter Simple Sequence Repeat) markers which was 0.61 to 1.0 in similarity coefficient (Sobir *et al*., 2011). Isozyme analysis of *G. mangostana* and 10 related species showed genetic similarity coefficient of 0.14 to 0.97 (Sinaga *et al*., 2010). According to Ramage *et al.* (2004) regarding genetic diversity among nine *Garcinia* spp. using Randomly

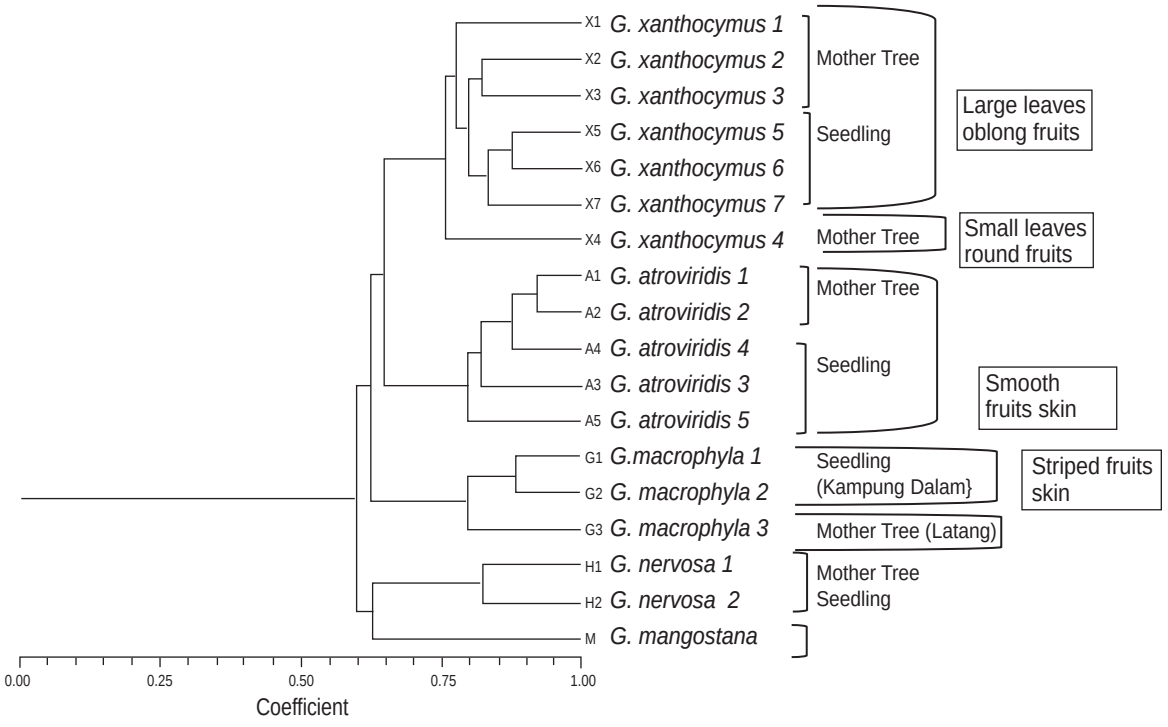

Fig. 3. Dendrogram of 18 *Garcinia* samples based on eight RAPD primers along with morphological correlates

Amplified DNA Fingerprinting (RAF), there was wider diversity with similarity index from 0.20-0.88. The variations in the genetic similarity coefficient were caused by different markers and the samples used.

The 18 *Garcinia* trees were clustered into four distinct groups which represented different species. *G. xanthocymus* displayed the greatest genetic variation with the genetic similarity coefficient varying from 0.75 to 0.88. The four other species exhibited similar range from 0.80 to 0.88. The sequence of the species groups on dendogram (Fig. 3) based on similarity coefficient value from the largest to smallest are *G. xanthocymus*, *G. atroviridis*, *G. macrophyla* and *G. nervosa*, and *G. mangostana*.

The first group contained seven *G. xanthocymus* samples, divided into two sub-clusters which were different in morphology as well as in the banding patterns. The first sub-cluster consisted of the trees with large leaves and oblong fruits (X1, X2 and X3), and three seedlings (X5, X6 and X7); the second sub-cluster contained one *G. xanthocymus* tree with small leaves and round fruits. The second group, *G. atroviridis* species, consisted of five trees which could be separated into two sub-clusters. The two mother trees were in the same sub-cluster and the three seedlings within the other sub-cluster.

The third group consisted of three *G. macrophyla* samples. This group is divided clearly into two sub-clusters *i.e*., *G. macrophyla* 1 and 2 (G1 and G2) from Nagari Latang and *G. macrophyla* 3 (G3) from Nagari Kampung Dalam, having 0.80 in genetic similarity. The two sub-clusters were different in their origin and morphology, and were separated by the unique DNA fragments OPH13/1600 bp, OPH18/350bp, P1/1600bp and P5/250 bp. Two samples of *G. nervosa* and one of *G. mangostana* were clustered within the group four. The cluster analysis showed that *G. nervosa* is very close to *G. mangostana*. The mother tree of *G. nervosa* (H1) was also genetically different from its offsprings (H2)**.**

It is clear from the present study that there is high genetic diversity among and within the five *Garcinia* species. The diversity was exhibited at both morphological and molecular levels. The variations occur among species, within species and between the seedlings and their mother tree. Based on these results, it is suggested to propagate the *Garcinia* vegetatively by grafting. Such different forms or genotypes need to be domesticated and conserved on-farm and in orchards to reduce human pressure to the natural and community forest. These results can be used as a basis for *in situ* conservation

activities of *Garcinia* in Sijunjung, West Sumatra and for educating the community for better management plans. Since the species come from the forest, it is necessary to domesticate and conserve them at home gardens or orchards to maintain their existence together with their utilization.

Acknowledgments

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References

Doyle JJ and Doyle JL (1990) Isolation of plant DNA from fresh tissues. *Focus* **12**: 13-15.

FAO (2003) State of the World's Forests, FAO, Rome, Italy, 126 pp.

Gupta PK, HS Balyan, PC Sharma and B Ramesh (1996) Microsatellites in plants : A new class of molecular markers. *Curr. Sci.* **70**: 45-54.

Hallden C, M Hansen, NO Nilsson, A Hjerdin and T Sall (1996) Competition as a source of errors in RAPD analysis. *Theor. Appl. Genet.* **93**: 1185-1192.

IPGRI (2003) Descriptors for Mangosteen (*Garcinia mangostana*). International Plant Genetic Resources Institute, Rome, Italy, 67 p.

Maxted N, JG Hawkes, BV Ford-Lloyd and JT Williams (1997) A practical model for *in situ* genetic conservation, In: Maxted N, Ford-Lloyd BV, and Hawkes JG (eds.), *Plant Genetic Conservation:* the *In Situ Approach*, Chapman and Hall, London, pp 69-87.

Pangsuban S, N Bamroongrugsa, K Kanchanapoom and C Nualsri (2007). An evaluation of the sexual system of *Garcinia atroviridis* L. (Clusiaceae), based on reproductive features. *Songklanakarin J. Sci. Technol*. **29:** 1457-1468.

Powell W, M Morgante, C Andre, M Hanafey, J Vogel, S Tingey and A Rafalski (1996) The comparison of RFLP, RAPD, AFLP, and SSR (microsatellite) markers for germplasm analysis. *Mol. Breed.* **2**: 225–238.

Rohlf JF (2000) NTSYSpc Numerical Taxonomy and Multivariate Analysis System, Version 2.1. User Guide. Departement of Ecology and Evolution, State University of New York. Stony Brook, NY.

Ramage CM, L Sando, CP Peace, BJ Carroll and RA Drew (2004) Genetic diversity revealed in the apomictic fruit species *Garcinia mangostana* L. (mangosteen). *Euphytica* **136**: 1–10.

Sinaga S, Sobir, R Poerwanto, H Aswidinnoor and D Duryadi (2010) Genetic Diversity and The Relationship Between The Indonesian Mangosteen (*Garcinia mangostana*) and The Related Species Using Isozyme Markers. *J. Natur. Indonesia* 13: 53-58.

Sobir R Poerwanto, E Santosa, S Sinaga and E Mansyah (2011) Genetic variability in apomictic mangosteen (Garcinia mangostana) and its close relatives (*Garcinia* spp.) based on ISSR markers. *Biodiversitas* **12:** 59-63.

Stolton S, N Maxted N, B Ford-Lloyd, S Kell S and N Dudley (2006) Arguments for Protection Food Stores: Using Protected Areas to Secure Crop Genetic Diversity. A research report by WWF, Equilibrium and the University of Birmingham, UK, 137 p.

Uji T (2004) Keanekaragaman Jenis, Plasma Nutfah, dan Potensi Buah-buahan Asli Kalimantan. (Species diversity, genetic resources, and potential of the indigenous fruits in Kalimantan). *BioSMART*, Vol 6, No 2 Oktober 2004. Halaman: 117-125. ISSN: 1411-321X.

Uji T (2007) Diversity, distribution and potential of genus *Garcinia* in Indonesia. *Hayati* **12**: 129-135.

Williams JGK, AR Kubelik, KJ Livak, JA Rafalski and SV Tingey (1990) DNA polymorphysms amplified by arbitrari primers are useful as genetic markers. *Nucleic Acid Res.* **18**: 6531-6535.

Winarno M MP Yufdy, IW Arsanti, AM Kiloes, E Mansyah and Edison HS (2013) Locating *Garcinia* and *Nephelium spp* in West Sumatra and Jambi. International Conference on Plant Genetic Resources, Food Security and Climate Change, July 1-4, 2013, Bandung, Indonesia.

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Value Addition of Wild Madan Tree (*Garcinia fusca* Pierre) in Sisaket, Thailand

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Wild madan tree is a native fruit tree commonly found along the river banks in Sisaket, Thailand. The wooden stick from tree stem has been traditionally used as a chicken skewer since over 50 years. The community earns about 1.5 million baht per year from the madan skewer production. This enterprise generates a lot of peeled wild madan bark as a by-product. The present investigation was aimed at assessing whether natural dyes can be extracted from wild madan tree (used traditionally as chicken skewer) bark. Employing four mordants to intensify the colour of the extract, it was concluded that dyeing three times with dye from fresh bark resulted in highest percentage (68) of satisfaction. Thus, using wild madan tree bark for dyeing cotton cloth would provide additional incentive to farmers for conserving this nature fruit tree.

Key Words: Chicken skewer, *Garcinia fusca*, Mordants, Natural dye, Wild madan

Introduction

Wild madan (*Garcinia fusca* Pierre) belongs to the Clusiaceae, the same family with mangosteen. In Thailand, it is commonly found growing in wild along the rivers, streams and swamps in dry evergreen forests (Subhadrabandhu, 2001; Shu *et al*., 2007). The young leaf can be used in many traditional dishes like sour soup whereas the fruit can be used in chili paste. The local people in Sisaket have discovered a unique way of using the wild madan stem. The wooden stick from wild madan stem are used as a skewer for grilled chicken, called "Kai Yang Mai Madan". Whilst grilling the chicken, stick exudes fluid which imparts special flavour to grilled chicken which consumers prefer (Sthapit *et al*., 2013). About 1,000 tons of madan sticks are consumed every day. The bark has to be peeled from the wild madan stem for making skewer. This results in the by-products of plenty of peeled wild madan bark that was wasted traditionally.

A plant usually contains a mixture of natural dyes. This mixture is often extracted and used to dye textiles. Recent environmental awareness has created an interest in the products made from natural dyes. Natural dyes are considered eco-friendly as these are renewable, biodegradable, are skin friendly and also provide health benefits to the wearer (Saxena and Raja, 2014). Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic dyes (Samanta and Konar, 2011). The natural dye extract from *Garcinia* bark (*G. dulcis*) has been reported (Nakpathom *et al*., 2012). The present study was aimed at producing natural dye from the extract of wild madan bark and exploring the function of mordants in the dyeing process. Four mordants were used to intensify the colour of the extract for dyeing cotton cloth. Mordants play a very important role in imparting colour to the cotton cloth. The wild madan extracted was stabilized by all mordants used. The colour fastness to washing and rubbing was tested with dyed cotton cloth for different duration. Cotton cloth dyed three times showed very good colour fastness. The satisfaction evaluation of dyed cotton cloth was evaluated with fifty samples. This study thus aimed at exploring new avenues for enhancing the income and job opportunity for the community.

Materials and Methods

Extraction of Dyes

Plant parts from various *Garcinia* spp. were used for the extraction of dyes. Leaves were used from "Cha muang" (*G. cowa*), mangosteen (*G. mangostana*) and wild madan (*G. fusca*). Bark from wild madan and mangosteen husk were used in the experiment. The chopped plant materials were boiled with 3 l of water in a pot for 1 h. One kilogram of each material was used for dye extraction except for madan bark for which only 300 gms were used. The dye thus extracted was filtered to remove the remaining residue and kept till further use

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(Nakpathom *et al.*, 2014; Office of Sericulture Research and Development, 2013).

Testing Dyes for Dyeing with Cotton Clothes

The cotton clothes were washed in commercial detergent at room temperature and washed with tap water. Dyeing was performed in an open bath. Salt (5g/l) was added to assist in absorption of the dye. The wet cotton clothes were placed into the dye bath and simmered for 1 h. The clothes were completely submerged in the dye solution during the entire dyeing period (Office of Sericulture Research and Development, 2013).

Mordanting

Mordanting was carried out in the post-stage. Four mordants were used in this experiment. One chemical mordant namely alum (0.5g/l) and three natural mordants were used. Natural mordants were lime water (10g/l) and mud and rice husk ash in the ratio of 1:3. After dyeing, the cotton clothes were submerged in mordants for 15 min followed by washing and drying in the shade (Anonymous, 2014).

Comparison of the Dyes from Fresh and Dried Wild Madan Bark

Experiments were performed with respect to dyeing of cotton clothes with dyes from fresh and dried madan bark one, two or three times for 1 h. Fresh and dried madan bark dyes were prepared using 300 gms of bark with 3 l of water as described above. Mordant used in this study was lime water.

Colour Fastness Testing

Colour fastness to washing and rubbing were tested. The dyed cotton clothes were washed and rubbed manually with detergent (5g/l) and rinsed with tap water. The testing was repeated five times. The colour change of the dyed cotton clothes was assessed using a rating scale of 1 =very poor, 2=poor, 3=fair, 4=good and 5=very good (Napathom *et al*., 2012).

Evaluation of Satisfaction

Dyeing cotton clothes with dye extracted from fresh and dried wild madan bark one, two or three times was used for satisfaction evaluation. The experiment was performed in Ise subdistrict. Fifty villagers comprising 27 males and 23 females were chosen as evaluators. The satisfaction was evaluated by satisfaction rating scale ranging from 1 (very dissatisfied), 2 (somewhat dissatisfied), 3 (neither satisfied nor dissatisfied), 4 (somewhat satisfied) to 5 (satisfied). The rating scale was calculated on per cent bars.

Results and Discussion

Dyeing and Mordanting

It is evident from the results that dye extracted from various *Garcinia fusca* produced different dye solution colours; greenish yellow from "*Cha Muang*" leaves, brown from wild madan leaves, brownish yellow from wild madan bark, red brown from mangosteen leaves and dark brown from mangosteen husk. Dyeing of cotton clothes with these natural dyes yielded different colour shades (Fig. 1). Mordants played a very important role in imparting colour to the cotton cloth. The different mordants and different ratios gave varying shades. Results showed that natural dyes extracted were stabilized by all mordants.

Comparison of Dyes Extracted from Fresh and Dried Wild Madan Bark

The result indicated that dye extracted from fresh and dried wild madan bark imparted brown colour. The dye extracted from fresh bark gave darker colour than that extracted from the dried bark. Dyeing for different durations yielded different colour shades. Dyeing cotton cloth three times resulted in darker shade than dyeing one or two times. (Fig. 2).

Colour Fastness

Colour fastness to washing and rubbing of the dyed cotton cloth for different duration had different fastness properties (Fig. 3). Dyeing with dye from fresh wild madan bark showed better fastness properties. Dyeing for one time with dye from fresh and dried wild madan bark showed mostly poor rating between 1 and 2 scale. Repeat dyeing for three times with dye from fresh and dried wild madan showed good to very good rating between 4-5 scale.

Evaluation of Satisfaction

Satisfaction testing of dyed cotton cloth with dye from fresh and dried wild madan bark is shown in Figure 4. The greater satisfaction was from repeated dyeing using fresh wild madan bark three times and two times. They gave the satisfaction percentage were 68% and 46%, respectively. The highest satisfaction percentage from using dried wild madan bark was 42. The results also indicated that repeat dyeing was more popular.

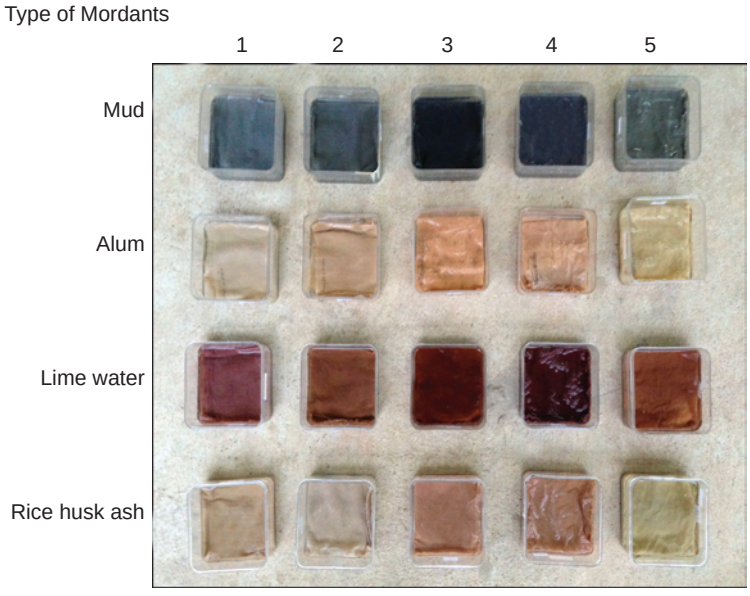

Fig. 1. Comparison of cotton cloth dyed with dyes extracted from various *Garcinia* spp. (1 to 5) using different mordants; 1 = "Cha Muang" leaves, 2 = Wild madan leaves, 3= Wild madan bark, 4 = Mangosteen leaves, 5 = Mangosteen husk

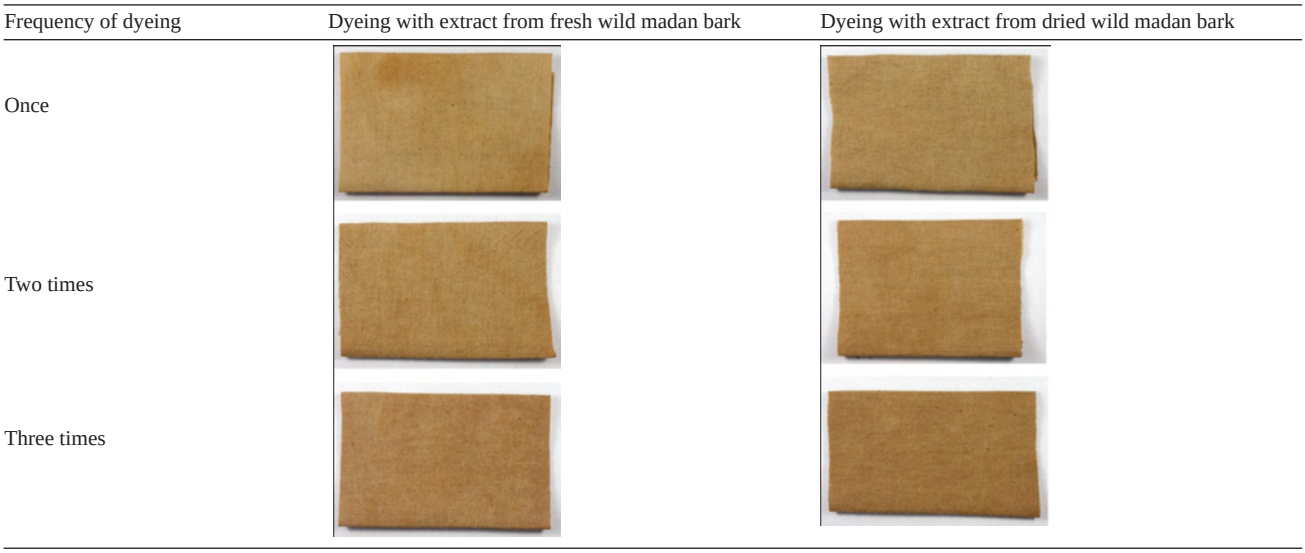

Fig. 2. Comparison of cotton clothes dyed with extracts from fresh and dried wild madan bark

Based on the results of present study, four on-site trainings, on dyeing process of cotton cloth with wild madan dyes, were conducted for the people in Ise subdistrict, Sisaket province. The idea for such a study was stimulated when site coordinator and farmers visited Kiriwong community in Thailand and used similar techniques in locally available materials.

Conclusion

There is an increasing interest in the application of natural dyes following environmental awareness and public concern about increasing pollution. The study concluded that dyeing of cotton clothes with dyes from wild madan bark yielded brown and brownish yellow colour depending on the mordant used. Mordants cotton fiber help absorb the dye give better, brighter and more permanent colours to the cloth. Many chemicals used as mordants are very poisonous. The most common mordants are alum, copper sulfate, potassium dichromate (VI), iron (II), sulfate and tannins. Often two mordants are mixed together for the best results.

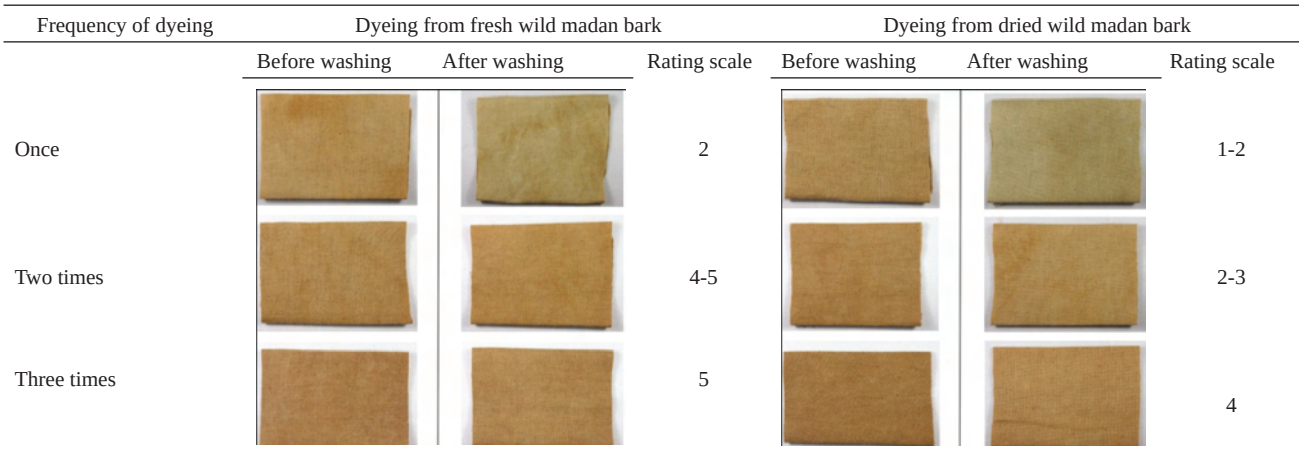

Fig. 3. Comparative colour fastness to washing and rubbing of dyed cotton cloth

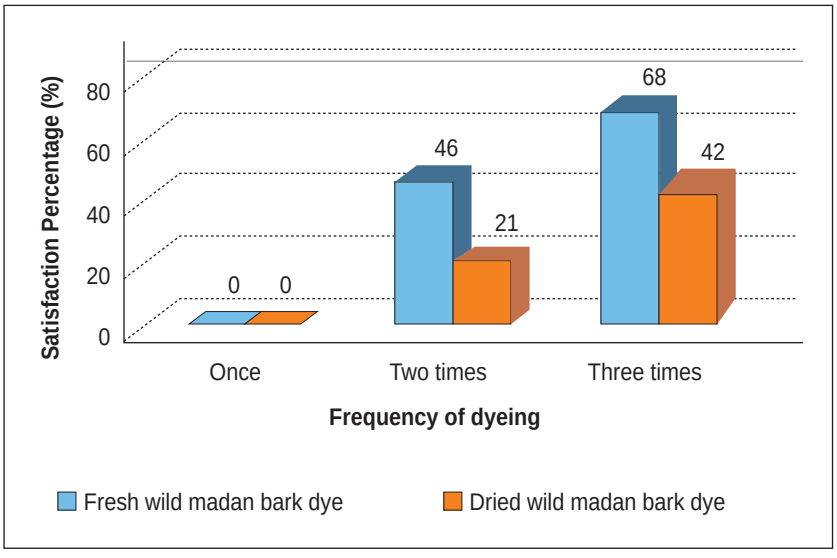

Fig. 4. Comparative satisfaction percentage (%) of dyeing cotton cloth with dyes extracted from fresh and dried wild madan bark

Colour fastness to washing and rubbing of the dyed cotton clothes was mostly good. This is the first report of dyeing cotton cloth with dyes extracted from wild madan bark. Training and setting up of women groups similar to Kiriwong village as small business enterprises might generate income and encourage the community for conservation of wild madan trees along river banks and cultivation around the fence of fields.

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References

Anonymous (2014) *Natural dyeing*. http://www.ist.cmu.ac.th/cotton/ naturalColor_Human.php?subnav=3 Accessed 1 Apr 2014.

Office of Sericulture Research and Development (2013) *Silk dyeing with natural dyes.* http://www.qsds.go.th/osrd_new/inside_page.php?pageid=19 Accessed 15 Nov 2013

Shu TH, L Xiwen, L Jie and PF Stevens (2007) *Garcinia L.*, sp. *Flora of China* **13**: 40–47.

Subhadrabandhu S (2001) *Under-Utilized Tropical Fruits of Thailand*. Food and Agriculture Organization of the United Nation, Regional Office for Asia and the Pacific, Bangkok, Thailand, 70 p.

Sthapit B, H Lamers and VR Rao (2013) *Custodian farmers of agricultural biodiversity: Selected profiles from South and*

South East Asia. Proceedings of the workshop on "Custodial farmers of agricultural biodiversity", 11-12 February 2013, New Delhi, India.

Nakpathom M, B Somboon, N Narumol and S Pinmanee (2012) *Natural dyeing of hemp yarns*. RMUT International Conference: Textiles & Fashion 2012, 3-4 July, 2012, Bangkok, Thailand.

Saxena S and ASM Raja (2014) Natural dyes: Sources, chemistry, application and sustainable issues. In: Muthu SS (ed). *Roadmap to Sustainable Textiles and Clothing*. Springer Science, Singapore, pp 37-79.

Samanta AK and A Konar (2011) Dyeing of textiles with natural dyes. In: Kumbasar EA (ed) *Natural Dyes*. Croatia, Intech, China, pp 29-56.

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Pummelo [*Citrus grandis* (L.) Osbeck] Diversity in India

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An extensive survey was conducted in parts of Bihar, Karnataka, Tamil Nadu, North-East Region and Andamans during 2012-14 to know the existing variability of largest sized *Citrus* spp. fruit, pummelo [*Citrus grandis* (L.) Osbeck]. The aim was to select the best genotypes suitable for large scale plantation and domestic markets. *Devenhalli* pummelo from Karnataka got GI status, indicating its importance in the region as it has small size (525 g), low acidity and high TSS (>10^0B) with red pulp. Pummelo from Yarcaud, Tamil Nadu had highest juice content (22.60 %) followed by fruits from Nagaland (21.65 %) which are larger in size (1,232.30 g). In Bihar, pummelo is valued for *Chhat Puja* and farmers maintain at least one plant in their home gardens to get fruits during festival season without any maintenance cost, and fortunately many good quality pummelo are available in some home gardens of the state. Pummelo from Bihar as Clone No. 8, 28, 31, 35, and 39 had high TSS (>10^0B) confirmed its potential for better consumer acceptance than others. The fruits of Clone No. 33 were completely seedless, were easy to serve and Clone No. 26 was suited for better consumption as it had soft cell sacs. Clone No. 1 had maximum fruit size (2,420 g) and number of segments per fruit (22.00) may be suited for better yield. The fruits of Clone No. 25, 37 and 13 are easy to peel as it has very thin rind (0.80, 1.00, 1.01 cm). Port Blair pummelo has low acidity, but due to low TSS (6.90 ^{0}B), may not be liked by consumers. *Devanhalli* pummelo from Karnataka, Manipur pummelo, Clone No. 31 and seedless pummelo of Bihar may be suited for commercial plantation and large scale consumption. If all these germplasm are propagated through air-layering and distributed to the farmers, better quality pummelo may fetch better price in national and international markets. Livelihood security will thus improve for the grower and subsequently diversity will also be maintained.

Key Words: Diversity, Home garden, Nutritional security, Pummelo

Introduction

Citrus fruits are recognized as an important component of the human diet, being sodium and cholesterol free, rich in vitamin C, folic acid, potassium, flavonoids, coumarins, pectins and dietary fibres (Dugo and Di Giacomo, 2002; Roy *et al.*, 2014). 'Pummelo' a member of Rutaceae family, grown as a tropical citrus fruit, has generally been identified with the wild species *Citrus maxima* (Burm.) Merr. on the basis of morphology and molecular markers.

Pummelo is now gaining popularity in India due to its high nutritional value and antioxidant property. The pummelo plants are mostly maintained in home gardens and no commercial plantation has been started yet. The quality of pummelo in India is not homogeneous across the regions and morphological characteristics are very different and the genetic variability has not been fully reported. It has played an important role as a parent of many citrus fruits, such as lemon, oranges and grapefruits (Youseif *et al.*, 2014).

Pummelo is distributed in Bangladesh, Cambodia, Chile, India, Indonesia, Japan, Laos, Malaysia, Philippines, Thailand and Vietnam (Orwa *et al.*, 2009) and, is also grown in China (Vinning and Moody, 1997; Zhang and Shaolin, 2000), Srilanka and Nepal. In India, it is grown in home gardens in all states of India and maximum diversity is reported from North-East (NE) Region (Singh and Singh, 2003; Roy *et al*., 2014), Bihar and Bengal. Though it is the largest fruit of citrus group, it has not attained the commercial importance despite its health and nutritional benefits. The use of pummelo is more as a fresh fruit and it is valued in Bihar during *Chhat Puja*, while the high antioxidants content and other nutritional values have medicinal uses (Panmanas

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and Theamprat, 2012). In fact, popularity of pummelo lies in its greater tolerance to insect and diseases than other citrus fruits. However number of trees with good quality fruit is very negligible in comparison to the inferior ones, and even then, large variability exists in different parts of the country (Karnataka, Bihar, West Bengal, NE region, Tamil Nadu, Andaman and Nicobar Island etc.).

There is potential in India for the development of this fruit as an export crop because its thick rind makes it easy to handle and transport (suitable for distant market), and thin rind is easy to peel (suited for local consumption). According to Wen *et al.* (2010), there is an urgent need for pummelo conservation due to a decline in varietal diversity owing to loss of natural habitat, elimination of unwanted phenotypic characters and artificial selection during domestication process. *Chhat Puja*, a festival of Bihar for which pummelo is valued for, is the main sink of fruit consumption and people of Bihar who are residing in other parts of the country, purchase the fruits at any cost, during the festival which motivates farmers to conserve the diversity. Once the suitable germplasm is identified, it can be used not only during *Chhat Puja* but also as a table fruit. Further, it's red colour segments are attractive and have potential for large scale processing, juice extraction etc.

Across the country, many good quality pummelo are available in home gardens, descriptive orchards and recently *Devenhalli* pummelo from Karnataka got GI protection. Characterization of pummelo using morphological traits will help in selecting genetically potential genotypes for cultivation (increased production), marketing and their use in plant breeding programmes. The present study was, therefore, undertaken for morphological and quality characterization of pummelo germplasm grown in homestead across the country and to select germplasm of better quality for consumption, marketing and conservation.

Materials and Methods

The study was conducted at two places in India, NRC for Citrus (NRCC), Nagpur (for *Amrawati* cluster) and NRC for Litchi, Muzaffarpur, Bihar (for *Pusa* cluster) under UNEP-GEF/ TFT Project during 2012-14. At both the places as well across the country, pummelo diversity was observed, mostly in home gardens and street plantations.

To know about the pummelo variability available in the country, information was collected from the records of ADB (Asian Development Bank) and National Agricultural Technology Project (Plant Breeding) project completed at NRCC, Nagpur. Accordingly, different areas of India were surveyed and first hand information was collected from farmers to identify their preferred phenotypes, and above all, to obtain pointers to the genetic diversity. Traits, such as tree age, fruit bearing frequency, flowering, maturity period and fruit yield, were assessed based on information collected from growers. As per information provided by the community/pummelo grower, individual plants were observed. Three fully mature and healthy fruits from each tree were collected randomly from different directions of the canopy, at different locations.

The physical (fruit weight, fruit length, fruit width, rind thickness, number of segments/fruit, number of seeds/fruit) and chemical (TSS, acidity percentage) characters of fruits were recorded after thorough washing with tap water to remove adhering impurities. Fruit and seed weights were measured using electronic (digital) balance whereas fruit rind thickness was measured by slide callipers. The juice was extracted from the pulp by straining through a muslin cloth and total soluble solid content of fruits was determined with the help of a hand held refractometer and expressed in terms of degree brix and values were corrected at 20 °C. Juice acidity was estimated by titrating 2 ml juice against 0.1 N NaOH using phenolphthalein as an indicator (AOAC, 1990). The data was analyzed as per Gomez and Gomez (1984).

Result and Discussion

Large variability was observed in fruits of pummelo collected across India. All the eight quantitative characters showed significant variation indicating the strength of genetic base of the crop. Among different regions where pummelo are grown, one of the areas is Bihar, wherein pummelo with only red flesh was found, indicating the preference for red flesh over white ones. However, in other parts of the country, both white and red flesh pummelo are maintained by the community, in their home gardens. Pummelo diversity existing in different regions, based on fruit characters and their potential for commercialization, is mentioned below.

Variability of Pummelo in Bihar

Based on the information available at the community level in Muzaffarpur, Samastipur and Darbhanga districts

of Bihar, a total of 43 seedling plants of pummelo were marked and fruits were analysed for fruit physico-chemical characters (Table 1). The wide variation in physico-chemical composition of fruits, offers wide scope for breeding desirable hybrids or variants.

Large variability was observed in clones collected from Bihar and based on fruit characters, four clones (clone no. 8, 28, 31 and 35) were found superior with high TSS (> 10.50°B). These four clones had red flesh and tasted better due to sweetness.

Table 1. Physico-chemical characteristics of pummelo fruits collected from Muzaffarpur, Samastipur and Darbhanga districts of Bihar

Place of collection of fruits	*Clone no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Rind thickness (cm)	No. of segments per fruit	No. of seeds per fruit	TSS (^{0}B)	Acidity (%)	Pulp colour
Muzaffarpur and Darbhanga	1.	2420.00	19.50	18.60	1.52	22.00	111.00	10.10	1.10	-
	2.	468.00	9.94	10.42	1.21	11.00	52.00	8.40	1.00	-
	3.	1481.00	15.20	16.30	2.34	15.00	95.00	8.30	1.30	-
	5.	1415.00	14.60	15.80	1.36	16.00	85.00	8.80	1.20	-
	6.	542.00	10.40	9.50	1.04	16.00	8.00	10.30	1.10	-
	7.	1063.00	12.70	15.80	1.53	14.00	80.00	8.50	1.40	-
	8.	1380.00	14.05	14.78	1.82	14.00	64.00	11.50	1.60	-
	9.	1490.00	15.60	16.04	1.94	14.00	43.00	8.90	1.50	-
	10.	1838.00	17.50	19.50	3.16	14.00	36.00	8.10	1.60	-
	12.	1594.00	14.00	16.00	1.44	19.00	108.00	10.10	1.60	-
	13.	1557.00	13.50	16.02	1.01	16.00	98.00	9.60	1.40	-
	14.	1378.00	15.00	14.88	1.17	12.00	111.00	8.70	1.60	-
	15.	1358.00	14.00	13.50	1.84	15.00	112.00	9.90	1.30	-
	17.	1560.00	14.60	14.50	1.20	16.00	115.00	9.30	1.60	-
	18.	1641.00	16.80	13.60	1.06	19.00	62.00	8.00	1.40	-
	19.	2006.00	15.20	16.70	1.64	19.00	125.00	9.20	1.60	-
Pusa, Samastipur	20	1231.67	15.17	14.50	1.63	12.00	76.00	9.30	3.14	Light red
	21	1289.33	15.33	14.53	2.10	12.33	38.00	8.23	3.48	Pink
	22	2064.00	21.83	17.50	4.00	15.67	128.33	9.63	3.39	Light pink
	23	1056.00	14.83	15.13	2.50	14.67	104.67	8.63	3.27	Light red
	24	1701.33	14.33	15.23	1.50	18.00	125.67	9.00	3.59	Dark red
	25	862.67	11.03	11.83	0.80	14.08	125.33	9.17	3.43	Dark red
	26	1088.67	15.07	13.40	2.10	17.33	108.00	8.50	2.93	Light red
	27	1208.67	13.07	15.17	1.90	14.00	151.33	8.00	3.34	Light pink
	28	644.67	10.73	10.63	1.13	12.00	96.00	10.50	3.34	Light red
	29	1283.33	15.57	15.67	2.70	17.67	60.67	7.40	3.92	Light red
	30	1110.00	15.17	13.07	2.07	13.67	58.67	9.00	3.55	Very light red
	31	2238.67	16.50	17.03	1.97	14.67	82.67	11.13	3.40	Red
	32	1738.67	15.00	16.77	2.00	17.00	98.00	9.60	3.41	Red
	33	498.00	11.53	11.87	2.00	10.00	0.00	8.60	-	Light red
	34	1774.67	16.97	16.73	2.90	13.67	139.33	8.10	3.13	Red
	35	602.00	12.00	12.67	1.30	14.33	124.00	11.10	3.21	Dark red
	36	638.00	10.73	11.03	1.20	12.33	112.00	8.20	3.50	Light red
	37	750.67	12.67	11.67	1.00	13.67	54.00	9.67	3.39	Red
	38	868.67	13.33	10.67	1.07	15.67	82.00	8.80	3.54	Light red
	39	493.33	10.50	10.10	1.10	13.33	47.00	10.17	3.06	White
	40	1334.00	11.75	13.75	1.35	15.00	68.00	9.55	3.41	Dark red
	41	789.33	10.67	12.50	1.50	13.33	23.33	9.40	3.26	Dark red
	42	1207.00	16.33	14.33	2.77	14.67	19.67	8.00	3.62	Red
	43	1358.67	11.50	13.67	1.93	18.00	78.00	8.10	3.33	Light pink
	Mean	1275.58	14.10	14.28	1.74	14.98	82.64	9.13	2.58	-
	Range	468.00-2420.00	9.90-21.80	9.50-19.50	0.80-4.00	10.00-22.00	0.00-151.00	7.40-11.50	1.00-4.00	-
	SEm ±	78.34	0.40	0.38	0.10	0.39	5.93	0.15	0.16	-
	Variance	245510.30	6.62	5.77	0.46	6.05	1408.43	0.93	1.00	-
	SD	495.49	2.57	2.40	0.68	2.46	37.52	0.96	1.00	-

For better yield, fruit size is more important and clone nos. 1, 31, 22 and 19 had fruit weight more than 2000 g *i.e.*, 2420, 2238.67, 2064 and 2006 g, respectively over other genotypes. The fruit of clone no. 33 was comparatively small (498 g) but completely seedless and may be best for fresh fruit consumption by children. Clone no. 33, also had least number of segments (10.00) and clone no. 26 was tender as it had very soft cell sacs (Table 1).

Present findings indicated significant variation in number of seeds/fruit (0-151) with clone no. 6, 42, 41 and 10 of Bihar having few seeds/fruit (8, 19.67, 23.33 and 36, respectively). Clone no. 1, 24, 43, 29 had more than 17 segments/fruit. Hazarika *et al.* (2013) also reported less number of seeds (12.67-37.50) among germplasm of pummelo from Mizoram. Thin rind was observed in clone no. 25 (0.80 cm), 37 (1.00 cm), 13 (1.01 cm) and 18 (1.06 cm) whereas thick rind was found in clone no. 22 (4.00 cm) and 10 (3.16 cm). Clone no. 31 with higher fruit weight, red flesh, thin rind, high TSS (11.13°B), moderate acidity and less number of seeds per fruit can be considered a promising clone of pummelo from Bihar. The pulp of pummelo from Bihar is mostly red or dark red and may fetch better price in the market for attractive appearance and high antioxidant content. Additionally, in three pummelo collections, fruit bearing was thrice in a year *viz*., during flowering, fruit development and fruit maturity. These plants can be used in breeding programmes for availability of fruits throughout the year for consumption and other uses.

Variability of Pummelo in South India, NE Region and Andamans

In North-East region, pummelo are grown mostly in home gardens and best quality of pummelo is produced in Agartala (Tripura), Mamit (Mizoram) and Dimapur (Nagaland). In Tripura, the maximum demand was observed during *Vishwakarma Puja* (in September) and *Durga Puja* (in October), as it is offered (as *prasad*) to god. In Bihar and West Bengal, large quantity of pummelo fruits are consumed during *Chhath* and *Durga Puja* (September-October) as mature pummelo are available in these states. This creates a huge market for this fruit during the season. Like Bihar, in every household of Dimapur area of Nagaland, pummelo is grown in home gardens and is mostly maintained for domestic consumption. Best quality of pummelo is produced in villages near *Medziphema*, due to better climate and soil conditions. All accessions were seedy in nature.

Table 2 gives the physico-chemical characters of pummelo collected from NE region, Southern India and, Andaman and Nicobar Islands. The highest fruit weight (1232.30 g) was recorded in Nagaland clone with high acidity (2.52). Most of the fruits were concave with pulp colour varying from white to reddish white. Fruit juice percentage was maximum in Yercaud pummelo (22.60%) followed by Nagaland pummelo (21.65%). Least acidity (%) was observed in Port Blair pummelo (0.80) but due to low TSS (6.90 °B), small fruit size (491.80g) and high rind thickness, it is not preferred by traders or consumers.

Table 2. Physico-chemical characters of pummelo fruits from NE region, Southern India and, Andaman and Nicobar Islands

Place of collection of fruits	Region	*Clone no.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Rind thickness (cm)	Juice (%)	TSS (˚B)	Acidity (%)	Pulp colour
Salem	Tamilnadu	-	741.70	11.86	12.64	1.30	19.54	7.50	1.36	-
Yercaud		-	925.00	12.36	11.48	1.44	22.60	9.00	2.10	-
Chettalli, Coorg	Karnataka	-	1023.20	13.58	14.48	1.80	20.15	7.20	1.44	White
		-	938.90	14.15	13.27	1.40	17.66	6.20	1.60	Red
Devanahalli, Bengaluru,		-	754.10	11.64	11.25	1.40	20.32	10.90	1.37	Red
		-	525.40	11.58	10.84	1.60	21.45	10.20	2.12	Red
Jonapotha,	Nagaland	-	1232.30	13.50	13.08	1.80	21.65	9.80	2.52	White
Tamenglang,	Manipur	-	999.50	12.45	11.86	1.70	19.20	12.50	1.44	Red
Port Blair	Andaman and Nicobar Island	-	491.80	10.46	10.25	2.70	18.80	6.90	0.80	Red
		Mean	847.99	12.39	12.12	1.68	20.15	8.91	1.63	-
		Range	491.80-1232.30	10.46-14.15	10.25-14.48	1.30-2.70	17.66-22.60	6.20-12.50	0.80-2.52	-
		SEm ±	80.50	0.39	0.44	0.14	0.51	0.70	0.17	-
		Variance	58323.96	1.37	1.80	0.18	2.40	4.45	0.27	-
		SD	241.50	1.17	1.34	0.42	1.55	2.10	0.52	-

*****all the clones are maintained and conserved by community in home gardens at various locations

In Southern India, best quality of pummelo is produced near BIAL (Bengaluru International Airport Limited), Bengaluru, Karnataka as *Devanhalli* pummelo. Although, fruit weight is 525.40 g but it has higher TSS (>10 °Brix), moderate rind thickness and juice percentage, may be most suitable for peninsular region. Besides this, Coorg region of Karnataka also has good pummelo diversity in home gardens and in the areas of coffee plantations. It is used for home consumption due to which very less quantity is sold in the local market. Large plantation of pummelo is also maintained at IIHR Regional Centre, CHES, Chettalli and Coorg. Pummelo from Salem, Tamil Nadu has thinnest rind among pummelos of southern India and exhibits higher productivity due to tropical humid climate which facilitates marketing in nearby cities. There is a need to popularize the pummelo in southern India by highlighting the nutritive value and other benefits.

Pummelo is also grown in North-western part of India, Doon Valley of Uttarakhand and Poanta Valley of Himachal Pradesh wherein it is mostly maintained in home gardens. Limited number of fruits are sold in the local market for consumption. However, there is a need to increase consumption of fruits by generating more awareness about its health and nutritional benefits.

Present investigations revealed that there was a wide range of variation among assessed germplasm and few may be exploited for various attributes. Some like *Devenhalli* pummelo of Karnataka (for better juice percentage, high TSS and moderately thin rind with red pulp) is best for fruit consumption in peninsular region, Nagaland pummelo (for better juice percentage) and Manipur pummelo (with high TSS) may be promoted for large scale plantations in NE regions. Regarding pummelo from Bihar, clone no. 1 for yield and, clone no. 31 and 33 for fruit quality (better sized fruit, moderately thin rind, high TSS and seedlessness) may be promoted among community, orchardist of northern and eastern parts of the country for better consumption, yield and fruit quality. Despite presence of a strong genetic base, serious effort must be made to conserve the germplasm and popularize the crop both from health point of view and for livelihood security.

The present study, clearly established that many superior pummelo clones are managed by local farming communities inhabiting various agro-eco-niche as *on-farm* conservation, may help to identify best parental lines for pummelo improvement and potential clones for livelihood security. Further, breeding programme and effective management of genetic resources may help in growing the crop along with competing cash crops.

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References

Association of Official Agricultural Chemists (1990) *AOAC Official Methods of Analysis*. (15th edition). 1230 p.

Dugo G and Di Giacomo (2002) *Citrus: the genus Citrus, medicinal and aromatic plants-industrial profiles*, Taylor and Francis group, London.

Gomez KA and AA Gomez (1984) *Statistical Procedures for Agricultural Research*. 2nd edition, John Wiley and Sons, New York, 680 p.

Hazarika TK, M Lalbiakngheti and BP Nautiyal (2013) Genetic variability in physico-chemical characteristics of some pummelo collections from Mizoram. *Indian J. Hort.* **70:** 431-434.

Orwa C, A Muta, R Kindt, R Jamnads and A Simons (2009) Agro-forestry Database: a tree, reference and selection guide version 4.0. http://www.orldagrofrestry.org/aftredb/

Panmanas S and C Theamprat (2012) Physico-chemical and textural properties of pomelo (*Citrus maxima* Merr. cv. Kao Nam Pueng) fruit at pre-harvest, post-harvest and during the commercial harvest period. *Philipp. Agric. Scientist*. **95**: 43-52

Roy D, S Kundu, B Ghosh, P Dutta and R Pal (2014) Performance of pummelo germplasm in new alluvial zone of West Bengal. *J. Crop. Weed.* **10**:179-182

Singh IP and Shyam Singh (2003) *Exploration, Collection and Mapping of Citrus Genetic Diversity in India*. Technical Bulletin No. 7, NRC for Citrus, Nagpur, Maharashtra, 230p.

Vinning G and T Moody (1997) Pommelo. *In: A market compendium of tropical fruits.* RIRDC Research Report No. 97/74. Rural Industries Research and Development Corporation, Canberra, Australia, pp 212-220.

Youseif SH, AE Halwagi, HA Sayed and A El Itriby Hanaiya (2014) Chemical analyses, antibacterial activity and genetic diversity assessment of some Egyptian *Citrus* spp. cultivars. *African J. Biotech.* **13**:2626-2636.

Zhang Taipin and Shaolin Peng (2000) Introduction to the origin and evolution of pomelo and its distribution in China [J]. *cje*, **5**: 58-61.

Wen B, C Cai, R Wang, Y Tan and Q Lan (2010) Critical moisture content windows differ for the cryopreservation of pomelo (*Citrus grandis*) seeds and embryonic axes. *Cryo Lett*. **31**: 29-39.

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Phytochemical Evaluation of Pummelo Fruits (*Citrus grandis*) in India for Enhancing Marketing Opportunities

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Pummelo *(Citrus maxima*) is a nutrient-rich citrus fruit that helps to preserve human health and provide nutritional security. The objective of the study was to investigate the effect of different sites on the phytochemicals content in eight accessions collected across India. Different varieties of pummelo were collected and analysed for their physico-chemical, biochemical and phytochemical properties, mainly total soluble solids (TSS), acidity, total phenols, limonoids, hesperidin and naringin. Results revealed that individual phytochemicals, flavonoids showed unique characteristics. Considerable differences were observed regarding the naringin (51.42-129.66 mg/l) and hesperidin (0.44-3.35 mg/l) contents among the different accessions. Naringin the predominant flavonone glycoside along with hesperidin was recorded highest in Pummelo from Salem (Tamil Nadu) as compared to the other accessions.

Key Words: *Citrus grandis*, Pummelo, Citrus fruits, Phytochemicals, Flavonoids

Introduction

Citrus fruits are one of the most traded horticultural crops in the world. They are considered as an important component of human diet because of their nutritional values. Pummelo (*Citrus grandis* Osbek.) native to South East Asia is the largest citrus fruit and many cultivars are grown all over the world. The health benefits of citrus fruits have mainly been attributed to the presence of bioactive compounds, such as phenolics (e.g. flavonoids, hydroxycinnamic acids) and ascorbic acid. Flavonoids have a wide range of biological effects including prevention and control of coronary heart disease and they have anti-inflammatory and antimicrobial activities (Silberberg *et al.*, 2006). Phenolic compounds naturally exist as secondary metabolites in fruits, and their accumulation is determined by genotypes as well as regional cultivation conditions. For a particular variety of fruit, different regional cultivation characteristics have been reported to regulate the flavonoid metabolism gene expressions and enzyme activities, and therefore play a very important role in affecting the accumulation of phenolic compounds. Therefore, understanding the impact of the cultivation regions on the pattern and content of phenolic compounds in pummelo is useful for the conservation of pummelo of better quality and nutritional value. Limonoids are a group of chemically related triterpene derivatives present in citrus fruit. The most prominent of this group are limonin and nomilin (Girard and Mazza, 1998). Hence the present study on the nutritional value of pummelo is very important as it will help in popularizing this crop from a nutraceutical point of view. In recent years, the pummelo has received much attention because of its nutritional and antioxidant properties, especially flavonoids in Asia *i.e*. Thailand, China, Taiwan and Japan (Wattanasiritham *et al*., 2005; Nagata *et al*., 2006; Wang *et al*., 2007; Xu *et al.*, 2008). Such studies have not been conducted on pummelo fruits in India and very meagre information is available regarding its physico-chemical, biochemical and phytochemical properties. In the present work, a comparative study among the different accessions grown under diverse climate conditions was carried out, which will enhance the marketing opportunities of pummelo diversity in India and in turn the conservation. Hence, this study is aiming to answer the phytochemical status of pummelo fruit grown in different climatic conditions and its place of origin.

Geographically, Chettalli (Karnataka) and Salem (Tamil Nadu) regions belong to the South India, whereas the Nagaland and Manipur regions are located in the North-East, pummelo cultivation area, respectively. Whereas, Andaman and Nicobar Islands belong to the South East region of India. The climate of Karnataka and Tamil Nadu regions possess a sub-tropical monsoon climate with average annual precipitation approximately 1200 mm (Table 1). The Andaman and Nicobar Island region possesses similar climate characteristics. It should

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Table1. Cultivation region, climate and regional characteristics of pummelo collection from different sites of India

Cultivation region	Climate	Regional characteristics
Karnataka	Sub- tropical monsoon	12.9702° N, 77.5603° E; average annual rainfall of 1248 mm
Tamil Nadu	Sub- tropical monsoon	13.0900° N, 80.2700° E; average annual rainfall of 1145 mm
Nagaland	Sub- tropical humid monsoon	25.6700° N, 94.1200° E; average annual rainfall of 1800–2500 mm
Manipur	Sub- tropical humid monsoon	24.8170° N, 93.9500° E; average annual rainfall of 1467 mm
Andaman and Nicobar Islands	Sub- tropical monsoon	11.6683° N, 92.7378° E; average annual rainfall of 3180 mm

be noted that the Nagaland and Manipur regions are located in the sub-tropical humid monsoon climate. This indicates that the microclimate of the regions might significantly alter the accumulation of flavonoids.

Materials and Methods

In this study, samples of eight indigenous accessions of pummelo (*C. grandis*) were collected from orchards in distinct sites. The most popular accessions grown in each province were selected and five fully ripened fruits were randomly picked. The accessions were from Salem, Tamil Nadu; Chettalli, Karnataka; Jonapotha, Nagaland; Tamenglang, Manipur; Port Blair, Andaman and Nicobar Islands and Devanahalli, Bengaluru, Karnataka and these accessions were analysed for their physico-chemical, biochemical and phytochemical properties at the laboratory of the National Research Centre (NRC) for Citrus, Nagpur (Table 2). Since GI has been given to Devanahalli pummelo, it is referred for the comparison. The fruits were analysed after seven days of harvesting. The fruits were washed and cleaned with distilled water to remove surface residues. The pulp and peel were separated and after that juice was squeezed manually from the fruits.

The total soluble solids (TSS) of pummelo juice was determined by using digital refractometer at temperature 25˚C and expressed as ºBrix. The titratable acidity was determined by the method given by Association of Analytical Chemists (AOAC, 1990) using Phenolphthalein (1%) as an indicator by titrating against N/10 NaOH. The acidity was expressed in gram of citric acid per 100 ml of juice. Ascorbic acid was estimated as per the method given by Association of Analytical Chemists (AOAC, 1990). Limonin (ppm) was estimated from juice by the method given by Wilson and Cruthchfield (1968). Total phenols content (mg/100ml) in the pummelo juice and peel was determined by the Folin-Ciocalteu method (Singleton *et al.*, 1999). Naringin (mg/l) and hesperidin (mg/l) were estimated from juice by the method given by Hendricson *et al*. (1958).

Results and Discussion

Results indicate that there were clear differences between the accessions for all the chemical constituents evaluated (Table 3). The TSS ranged from 6.2 to 12.5˚Brix. The TSS was found lower as compared to the Devanahalli pummelo in all the accessions except in red-fleshed pummelo from Tamenglang, Manipur. The juice acidity was in the range of 0.80-2.52%. Acidity was found maximum (2.52 %) in juice from white fleshed pummelo from Jonapotha, Nagaland and minimum in red-fleshed pummelo from Port Blair, Andaman and Nicobar Islands (0.80%) (Table 3). The limonin content ranged between 12.73 and 18.89 ppm. Ohta and Hasegawa (1995) reported that the total limonoid content in pummelo juice was 7-71 ppm. Limonin content was found maximum (18.89 ppm) in red-fleshed pummelo from Chettalli, Karnataka. However, in most of the fruits the limonin content was around 14 ppm. Ohta and Hasegawa (1995) reported the average limonin content in the pummelo juice of sixteen cultivars as 18 ppm. Wattanasiritham *et al.* (2005) found that the limonin concentration in the juice of eight pummelo cultivars averaged 21.07 ppm. The results

Table 2. Details of the pummelo accessions collected from different sites of India

Accession/ Collectors No.	Plant type	Colour of fruit flesh	Collection site	Sample size (No.)
Pummelo 1	Seedling	Red fleshed	Salem, Tamil Nadu	5
Pummelo 2	Seedling	White fleshed	Chettalli, Karnataka	5
Pummelo 3	Seedling	Red fleshed	Chettalli, Karnataka	5
Pummelo 4	Seedling	White fleshed	Jonapotha, Nagaland	5
Pummelo 5	Seedling	Red fleshed	Tamenglang, Manipur	5
Pummelo 6	Seedling	Red fleshed	Port Blair, Andaman and Nicobar Islands	5
Pummelo 7	Seedling	Red fleshed	Devanahalli, Karnataka	5
Pummelo 8	Seedling	Red fleshed	Devanahalli, Karnataka	5

Table 3. Comparative physico-chemical and phytochemical analysis of fruit juice of various accessions of pummelo

Pummelo types	Juice (%)	TSS (°B)	Acidity (%)	TSS Acidity ratio	pH	Limonin (ppm)	Total phenol (mg/100ml)
Pummelo, Salem, Tamil Nadu	19.54	7.5	1.36	5.36	2.94	14.72	7.86
White-fleshed pummelo, Chettalli, Karnataka	20.15	7.2	1.44	5.00	4.25	14.88	7.88
Red-fleshed pummelo, Chettalli, Karnataka	17.66	6.2	1.60	3.87	3.58	18.89	7.25
Red-fleshed, Devanahalli 1 pummelo, Bengaluru, Karnataka	20.32	10.9	1.37	7.95	4.44	12.73	5.10
Red-fleshed, Devanahalli 2 pummelo, Bengaluru, Karnataka	21.45	10.2	2.12	4.63	4.19	14.03	5.28
White-fleshed pummelo, Jonapotha, Nagaland	21.65	9.8	2.52	3.79	2.58	14.80	7.5
Red-fleshed pummelo, Tamenglang, Manipur	19.20	12.5	1.44	8.68	3.04	15.31	10.16
Red-fleshed pummelo, Port Blair, Andaman and Nicobar Islands	18.80	3.9	0.80	4.75	3.82	15.08	5.59

TSS= Total soluble solids

from other studies indicated that the limonin content in our pummelo is in the same range as in other cases. Total phenols were maximum (16.57 mg/100ml) in peel of white-fleshed pummelo from Jonapotha, Nagaland and were maximum (10.16) in juice from Red-fleshed pummelo, Tamenglang, Manipur. The phenol content in other accessions were either lower or equal to the phenol content in Devanahalli pummelo juice and peel. The peel showed the higher amount of phenol, as compared to the juice in accordance with previous studies and expressed as mg catechin equivalent per 100 ml. Total phenols have reportedly been linked with the antioxidant capacity of fruits. Increasing the total phenol content also increased the antioxidant efficacy in fruits (Proteggente *et al*., 2003). Total phenols were reported to be the major antioxidant of citrus fruits. Tsai *et al.* (2007) showed that pink pummelo juice had higher total polyphenol content and antioxidant ability than white pummelo juice due to pigments. Fig. 1 and 2 shows considerable differences regarding the naringin and hespiridin contents among the different cultivars; naringin content ranged between 51.42 and 129.66 mg/l. The naringin content in the pummelo from Manipur and Nagaland was also higher as compared to the Devanahalli pummelo. The hespiridin content ranged between 0.44 and 3.35 mg/l. Pummelo from Salem, Tamil Nadu had the highest naringin and hesperidin contents (129.66 mg/l and 3.35mg/l), followed by pummelo from Andaman and Nicobar Islands (Figs. 1 & 2). This indicates that there was a variation in naringin content in the local accessions of pummelo in India. Factors such as environment, production area, cultivation and cultural practices might cause the divergence. Xu *et al.* (2008) also reported that naringin was the major flavanone followed by hesperidin in cultivars. The antioxidant power of flavanones (hesperidin, naringin, neohespiridins) was also reported by Majo *et al.* (2005). It has been proposed that the expressions of genes and activities of enzymes related to flavonoid biosynthesis and metabolism can be regulated and altered in different cultivation regions under different temperatures, precipitations, and sunshine exposures, which eventually impact the accumulation of the flavonoids in fruits

The observations in the present study indicate higher phenolic contents which indicate potent antioxidant ability. Similar findings were reported by other workers who found high correlation of the total phenolic and antioxidant activity of citrus extracts (Gorinstein *et al.*, 2004). It has been found that composition and level of metabolites in fruits varied greatly between cultivars and was independent of species and geographical locations similar to the report of Wahyuni *et al*. (2011).

The content of flavanones in each accession of pummelo juice could be used to identify pummelo accessions. Strategy to conserve fruit diversity while exerting a positive influence on rural livelihoods would be the development of local value-added products that would capitalize on the many nutritional and medicinal properties of pummelo. The unique and significant traits as summarized in Table 4 can help to create added value and increase profit margins for all actors in the pummelo value chain from farmer to retailer through product differentiation, targeting specific consumer segments and explore fresh sales and novel products based on unique traits for local and distant markets.

The expression of unique nutritional and health traits as found in this study due to distinct climate and cultivation practices in different sites suggest the

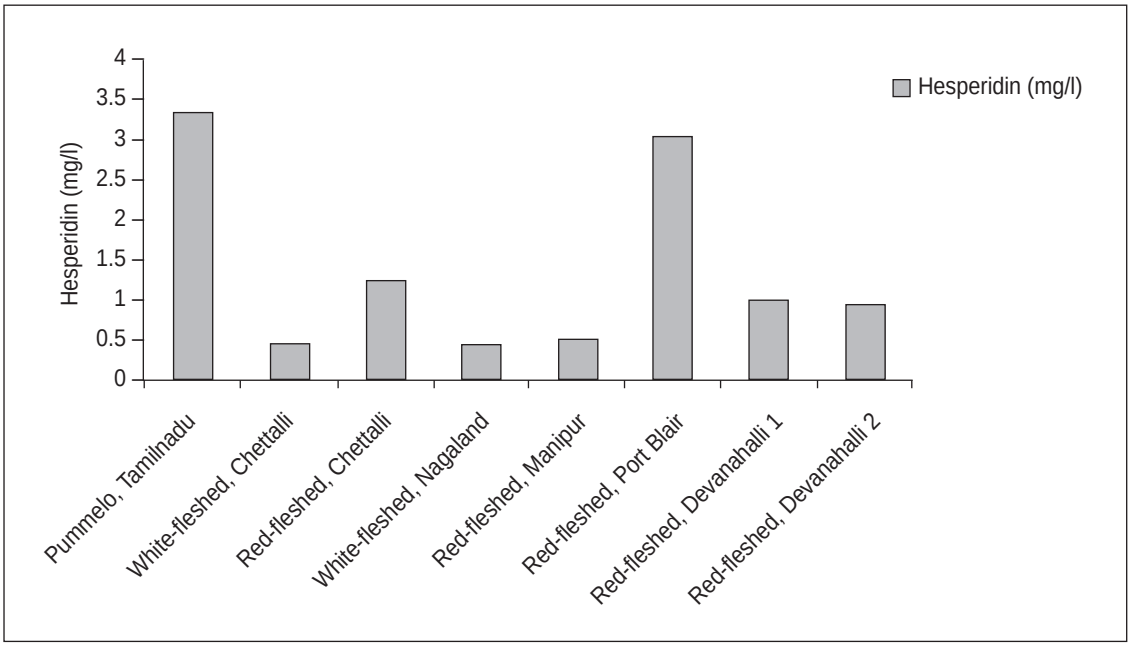

Fig. 1. Hesperidin content of juice from collected accessions of pummelo

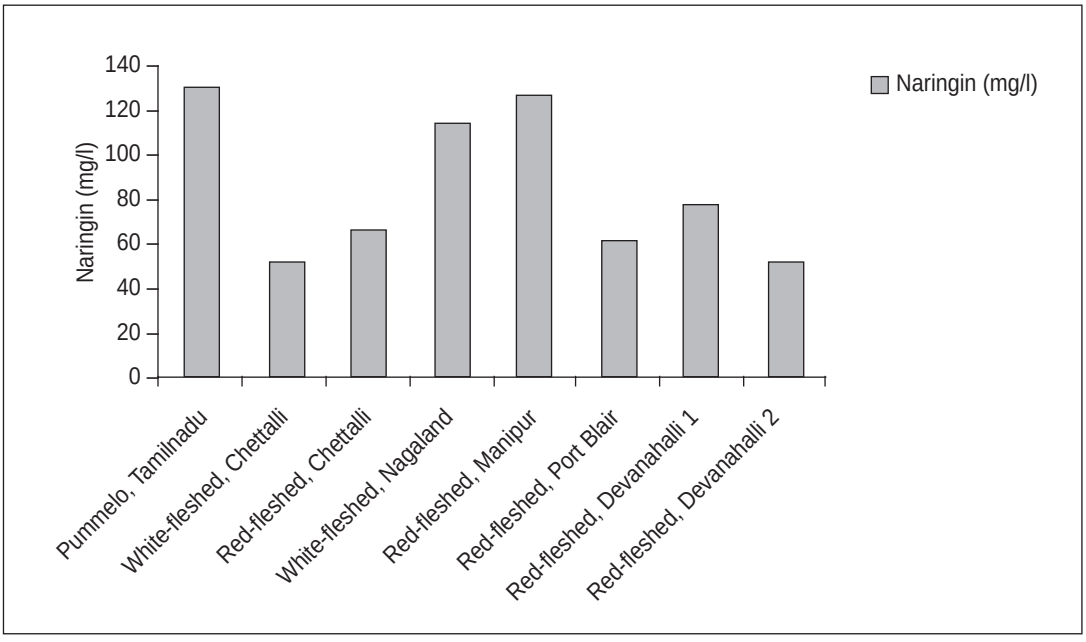

Fig. 2. Naringin content of juice from collected accessions of pummelo

Table 4. Unique traits and potential markets of the collected accessions of pummelo

Various pummelo types	Unique and significant nutritional traits	Potential consumer and market interest
Pummelo, Tamil Nadu	High hesperidin and naringin	Health-aware consumers
Red-fleshed, Devanahalli 2	High juice content	Juice industry
Red-fleshed, Chettalli	High limonin	Health-aware consumers
Red-fleshed, Manipur	High phenols, naringin and TSS	Health-aware consumers
White-fleshed, Nagaland	High naringin, high juice content	Juice industry and health-aware consumers
Red-fleshed, Port Blair	High hesperidin	Health-aware consumers

potential of a marketing strategy for specific accessions based on area of origin (geographic indication). Innovative marketing approaches based on unique traits that combines traditional knowledge with global or local economic trends, are key when pursuing market development strategies based on unique crop diversity and can help to ensure the on-farm conservation of pummelo diversity in India.

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References

AOAC (1990) Official Methods of Analysis. Association of Analytical Chemists, 15th Ed. Washington DC.

Girard B and G Mazza (1998) Function grape and citrus products, pp. 139-191. In: Mazza G. (ed.). *Functional Foods* Technomic publishing company, Inc. USA.

Gorinstein, S, Z Zachwieja, E Katrich, E Pawelzik, R Haruenkit and S Trakhtenberg (2004) Comparison of the contents of the main antioxidant compounds and the antioxidant activity of white grapefruit and his new hybrid. LWT–*Food Sci. Technol.* **37**: 337–343.

Hendricson R, JW Kesterson and GJ Edwards (1958) Ultraviolet absorption the technique to determine the naringin content of grape fruit juice. *Proc. Fla. Sta. hortis*. *So* **71:** 194-198.

Majo D, DM Giammano, ML Guardia, E Tripoli, S Giammanco and E Finotti (2005) Flavanones in citrus fruit: antioxidant activity relationships. *Food Res. Inter.* **38:** 1161-1166.

Nagata Y, K Sakamoto, H Shiratsuchi, T Ishii, M Yano and H Otha (2006) Flavonoid composition of fruit tissue of Citrus species. *Biosci. Biothechnol. Biochem*. **70**: 178-192.

Ohta H and S Hasegawa (1995) Limonoids in Pummelos *Citrus grandis* (L.) Osbeck *J. Food Sci.* **60:** 1284-1285.

Proteggente AR, A Saija, A De, AD Pasquale and CA Rice-Evans (2003) The compositional characterisation and antioxidant activity of fresh juices from sicilian sweet orange [*Citrus sinensis* (L.) Osbeck] varieties. *Free Radical Res*. **37:** 681-687.

Silberberg M, A Gil-Izquierdo, L Combaret, C Remesy, A Scalbert and C Morand (2006) Flavanones metabolism in healthy and tumor bearing rats. *Biom. Pharm*. **60**: 529-535

Singleton V, LR Orthofer and RM Lamuela-Raventos (1999) Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Meth. Enzymol.* **299:** 152-178.

Tsai HL, KCC Sam and C Sue-Joan (2007) Antioxidant content and free radical scavenging ability of fresh red pummelo [*Citrus grandis* (L.) Osbeck] juice and freeze- dried products. *J. Agric. Food Chem*. **55:** 2867-2872.

Wahyuni Y, AR Ballester, E Sudarmonowati, RJ Bino and AG Bovy (2011) Metabolite biodiversity in pepper (Capsicum) fruits of thirty-two diverse accessions: variation in health-related compounds and implications for breeding. *Phytochemistry* **72:** 1358-70.

Wang YC, YC Chuang and YH Ku (2007) Quantitation of bioactive compound in citrus fruits cultivated in Taiwan. *Food Chem*. **102:** 1163-1171.

Wattanasiritham L, K Taweesuk and B Ratanachinakorn (2005) Limonin and Naringin in Pummelos (*Citrus grandis* (L.) Osbeck) In 31st Congress on Science and Technology of Thailand, 18-20 October 2005, Suranaree University of Technology, Thailand.

Wilson KW and CA Cruthchfield (1968) Spectrophotometric determination of limonin in orange juice. *J. Agri. Food Chem.* **16:** 118-124.

Xu G, D Liu, J Chen, X Ye, Y Ma and J Shi (2008) Juice components and antioxidant capacity of citrus varieties cultivated in China. *Food Chem*. **106:** 545-51.

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Diversity in Cultivated and Wild *Nephelium* species in South-East Asia

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The diversity of *Nephelium* species in the home gardens, orchards and forests from 12 selected sites in Malaysia, Thailand and Indonesia were studied. A total of 20 *Nephelium* species including four unidentified species were recorded in the three countries. The highest number of species was recorded in Malaysia (12 including one unidentified species), followed by Thailand and Indonesia each with six species, with two unidentified species in Thailand and three unidentified species in Indonesia. Most of the *Nephelium* species were found in the forest: Malaysia (seven), Thailand (four) and Indonesia (five). Using the four cell analysis, Shannon Diversity Index was highest at Sijunjung (*H'*=1.386) followed by Sibuti, Serian and Papar each with *H'*= 1.099; and followed by Nakhon Sithamarat and Sisaket, *H'*=0.693. Although Sibuti and Papar had three species each but the Shannon Diversity Index was higher in Sibuti (*H'*=0.558) compared to Papar (*H'*=0.400) due to the uneven number of the trees for the species. In Sisaket and Nakhon Sithamarat, Shannon Diversity Index showed highest *H'*=0.693. Lambir Forest Reserve showed the highest number of species (seven), followed by Sijunjung (five) and Kota Belud (three). Similarly, Shannon Diversity Index was highest at Lambir Fores Reserve *H'*=1.946, followed by Sijunjung (Sumatera) *H'*=1.609 and Kota Belud *H'*=1.099. The commercial species, *N. lappaceum* is widely cultivated in all the three countries. *N. ramboutan-ake* and *N. maingayi* can be considered as rare while the other species are threatened. In order to capture enough genetic variability for conservation it requires to select many home gardens and large areas of forest reserves. It is recommended to intensify the survey of the cultivated and wild *Nephelium* species in other areas in order to obtain comprehensive data pertaining to species diversity and distribution. The genetic materials of the wild *Nephelium* species also need to be collected and planted in the field genebank at various government institutions for *ex situ* conservation.

Key Words: ***Nephelium ramboutan-ake, N. maingayi, N. cuspidatum* var. *robustum*, Species richness, Shannon diversity index**

Introduction

The genus *Nephelium* (Sapindaceae) consists of 22 species, with 20 species occurring in Malaysia (Yap, 1989; Leenhouts, 1986), six in Thailand (Van Welzen, 1999) and 16 in Kalimantan, Indonesia (Siebert, 1991). The genus is distributed in South East Asia from Yunnan and Assam to Hainan, Peninsular Malaysia, Sumatra, Jawa, Borneo, the Phillippines, Sulawesi and Maluku

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(Yap, 1989; Leenhouts, 1986). Among these species only *N. lappaceum* locally known as 'rambutan' in Malaysia and Indonesia, or 'Ngo' or 'Phruan' in Thailand is commonly and widely cultivated in the home gardens and orchards in the three countries. Another species which can be considered rare, *N. ramboutan-ake* locally known as pulasan (Malaysia) and kapulasan (Indonesia) is rarely cultivated and the fruits are sold in the local markets. Many other species are very rare and wild and mostly can be found in the forest. The fruits of some of the wild species such as *N. cuspidatum* var. *robustum, N. cuspidatum* var. *eriopetalum, N. maingayi, N. hypoleucum* and *N. unicatum* are edible and normally they are harvested from the forest and sold in the local markets by the farmers.

Diverse fruit tree species including *N. lappaceum* are cultivated in home gardens and orchards in Malaysia (Salma *et al*., 2006; Raziah *et al*., 2006). Similarly, Tahan Uji (2007), reported that many of the fruit species were cultivated in the home gardens in Indonesia, while Siregar (2006) stated that many *Nephelium* species were found cultivated and also in the wild in Kalimantan (Indonesia). Likewise in Thailand, of the five *Nephelium* species found in the wild, the fruits of *N. hypoleucum* are normally harvested by the locals and sold in the local markets.

N. lappaceum exhibits a wide range of genetic variation within the species. The seedling progeny of *N. lappaceum* is heterogenous and shows a great variability in fruit characters such as fruit size, shape and colour, sarcotesta taste, thickness, juiciness, flavour and adherence to the seed (Salma, 1986). Clonal selection of *N. lappaceum* was carried out in Malaysia, Indonesia and Thailand. Malaysia has a great diversity of *N. lappaceum* clones and till to date more than 200 *N. lappaceum* clones were registered by the Department of Agriculture (DOA, 1995), and the recommended clones include R 160, R 161, R 162, 'anak sekolah' and 'jarum mas'. In Thailand the common *N. lappaceum* clones include 'Rongrian', 'Seechompoo',and 'Bangyeekkhan', while in Indonesia the main commercial cultivars are 'Lebakbulus', 'Binjai' and 'Simacan' (Lye *et al*., 1987).

However, the diversity present in most of the *Nephelium* species has been not fully exploited. These species are rapidly declining and in danger of being lost forever due to development, land conversion, planting of modern and superior crop varieties and more profitable crops. Further, the potential value of many of these fruit species which are well adopted to currtent climate and local conditions is enormous and can provide the local communities with food security and as a source of nutrition (Amin *et al*., 2004; Emmy Hainida, *et al*., 2007; Mohd Shukri *et al*., 2008).

Currently, a very few accessions of *Nephelium* species were collected for conservation. There were four *Nephelium* species *viz*. *N. ramboutan-ake, N. cuspidatum* var. *robustum, N. maingayi* and *N. milliferum* conserved at MARDI field genebank in Serdang, Malaysia. In Indonesia the collection of wild *Nephelium* is scattered at several institutions. Indonesian Tropical Fruit Research Institute (ITFRI) has *N. mutabile* (kapulasan) collection planted in Subang Experimental Farm, West Java. While *N. maingayi* (ridan) collection is at Balai Benih Induk (BBI) Padang Marpoyan, Riau Province, *N. jugladifolium* (rambutan hutan) planted in Bogor Botanical Garden and *N. cuspidatum* (sibau) at Assessment Institute for Agricultural Technology (AIAT) of South Kalimatan. In Thailand, *Nephelium.* sp. var. *paunmuang*, *N. hypoleucum* var. *kholan,* were planted at Chanthaburi Horticultural Research Center, Chanthaburi province whereas *Nephelium.* sp. var. *ngo bant* and *N. ramboutan-ake* var. *pakonsan luklek* were conserved at Trang Horticultural Research Center, Trang province.

The current knowledge on the variation and diversity of *Nephelium* species is lacking and thus the objective of the present study is to assess the inter and intra-specific diversity of the species from the genus *Nephelium* in the home gardens, orchards and forests in the selected sites from the three countries using rapid participatory methods and structured survey as well as to determine the common, rare and threatened species (*i.e*. common and rare in term of use and threatened not in cultivation particularly as a species is rarely or seldom used) so as to identify the type of interventions for conservation of these fruit species *ex situ* or on farm.

Materials and Methods

Study Sites

A total of 12 provinces or states were selected based on the richness of the target species in the areas. In Malaysia six districts that had high richness of the target species in the areas were obtained from the results of site selection analysis. These sites were Yan (Kedah) and Bukit Gantang (Perak) in Peninsular Malaysia; Serian and Sibuti in Sarawak; and Papar and Kota Belud in Sabah. Similar selection analysis was carried out in Thailand and Indonesia, and provinces with high target species

Table 1. Study sites from the three countries

Country	State/ Province	District	Habitat
Malaysia	Kedah	Yan	HG, ORC
	Perak	Bukit Gantang	HG, ORC, FOR
	Sabah	Papar	HG, ORC
		Kota Belud	HG, ORC, FOR
	Sarawak	Serian	HG, ORC
		Sibuti	HG, ORC, FOR
Thailand	Chiang Mai		HG, ORC
	Si Sa Ket		HG, ORC
	Chanthaburi	Klong Narai, Muang, Trok Nong, Klung	HG, ORC, FOR
	Trang	Nong Bua, Rasda	HG, ORC, FOR
	Nakhon Si Thammarat	Kiriwong, Lanska	HG, ORC, FOR
Indonesia	West Sumatra	Sijunjung	HG, FOR

HG – Home garden; ORC – Orchard; FOR – Forest

were selected (Table 1). Five provinces were selected in Thailand and these were Chiang Mai, Si Sa Ket, Chanthaburi, Trang and Nakhon Sri Thammarat while in Indonesia Sijunjung in West Sumatra was chosen.

Two types of surveys were carried out at these sites to gather *Nephelium* species and their varietal richness at household or community level in the home gardens, orchards as well as forest. Fruit species studied were all the *Nephelium* species including their landraces, varieties and clones.

Four Cell Analysis

Four Cell Analysis (FCA) is a participatory approach where it involved the participation of the farmers at the sites in the three countries. This method is a rapid assessment technique to determine the diversity and distribution of the fruit species in the home gardens or orchards (de Boef and Thijssen, 2007). It involved a focus group discussion among the farmers, men and women, from various villages. The farmers were requested to distinguish the fruit species available in their villages into four categories and place them in the appropriate quadrants. The tree species or varieties are categorized into many or a few fruit trees when grown in many or in a few households; or a few few trees in many or a few households.

Structured Survey

A systematic survey of the fruit trees in the home gardens and orchards was carried out in Malaysia and Thailand only while the survey in the forest was carried out in all the three countries. In Malaysia, 240 home gardens including orchards in the six districts while in Thailand 200 home gardens were surveyed. Initially the farmer was requested to draw the layout of the fruit tree species or varieties available in his home gardens and orchards on a paper and followed up by field walk to verify the species. Among other parameters recorded include home garden size, species name, local name, number of trees per species, age of fruit tree, yield, fruit taste, marketing and pest and disease. Besides, information on the source of fruit trees and those species that have commercial value from farmer's perspective were also recorded.

In Thailand, the wild species in the forest were surveyed in the sampling plots constructed. Three sampling plots of 20×20 m area at the edge of Kaolung Park covering 9,000 ha in Nakhom Sri Thammarat Province, ten plots of 40×40 m area at Khao Bantat wild life sanctuary covering 127,752 ha in Trang Province and six sampling plots of 40×40 m at Plew waterfall National Park covering11,250 ha at Chantaburi were made. *Nephelium* species encountered in these plots were recorded. In Malaysia wild *Nephelium* species at Bukit Bintang Hijau near Bukit Gantang were surveyed along transcects that covered an area of 10 ha. While at Kota Belud the *Nephelium* species were surveyed along 30 transects of 1000 m length and 10 m width at Crocker range. At Lambir Forest reserve in Sarawak a 52 ha plot was made and *Nephelium* species in the plot were scored. While in Sumatra, data on the *Nephelium* species in the nearby forest near Sijunjung were recorded.

Results and Discussion

Diversity and Richness of Nephelium Species

A total of twenty *Nephelium* species including four unidentified species were recorded in the three countries (Table 2). The highest number of species was recorded in

Table 2. Summary of *Nephelium* species identified from four cell analysis, genetic diversity analysis and forest survey

No.	Species	FCA			GDA			FOREST		
		Mal	Thai	Ind	Mal	Thai	Ind	Mal	Thai	Ind
1	*Nephelium aculeatum*							+		
2	*N. costatum*							+		
3	*N. cuspidatum*							+		
4	*N. cuspidatum* var. *robustum*	+			+					
5	*N. daedaleum*							+		
6	*N. hypoleucum*		+			+			+	
7	*N. lappaceum*	+	+	+	+	+		+		+
8	*N. maingayi*	+		+				+		+
9	*N. melliferum*								+	
10	*N. ramboutan-ake*	+			+			+		
11	*N. subfalcatum*							+		
12	*N. uncinatum*							+		
13	*N. xanthoides*							+		
14	*N. xerospermoides*			+						+
15	*Nephelium* sp.1 (Bantut)	+								
16	*Nephelium* sp.2 (Oge)			+						
17	*Nephelium* sp.3								+	
18	*Nephelium* sp.4								+	
19	*Nephelium* sp.5									+
20	*Nephelium* sp.6									+

Mal = Malaysia, Thai = Thailand, Ind = India, + = present

Malaysia (12 including one unidentified species), followed by Thailand and Indonesia each with six species, with two unidentified species in Thailand and three unidentified species in Indonesia. Most of the *Nephelium* species were found in forests, Malaysia (seven), Thailand (four) and Indonesia (five).

Participatory Identification and Diversity of Nepehelium Species

Based on the Four Cell Analysis, six identified *Nephelium* species and two unknown *Nephelium* species locally known as 'Bantut' in Sibuti (Malaysia) and 'Oge' in Sijunjung (Sumatera) were reported (Table 2). Sijunjung in Indonesia was reported to have the highest species richness (S=4) *i.e. N. lappaceum, N. maingayi, N. xerospermoides* and one unidentified species (Oge), followed by Sibuti, Serian and Papar in Malaysia where S=3, and Nakhon Sithammarat and Sisaket in Thailand with each S=2, (*N. lappaceum* and *N. hypoleucum*) (Tables 2 and 3). Like-wise, Shannon Diversity Index was highest at Sijunjung (*H'*=1.386) followed by Sibuti, Serian and Papar each with *H'*= 1.099; and followed by Nakhon Sithamarat and Sisaket, *H'*=0.693 (Table 3). However, by comparing all the study sites among the three countries, Malaysia recorded the highest number of *Nephelium* species with a total of five *i.e. N. lappaceum, N. ramboutan-ake, N. cuspidatum* var. *robustum, N. maingayi* and one unidentified species (Bantut). The high number of *Nephelium* species could be due to the fact that Malay Peninsular being the centre of origin of the genus *Nephelium* (Van Welzen (1999). The commercial fruit of *N. lappaceum* is common and found to be cultivated in the three countries.

Diversity of Nephelium Species in Home Gardens and Orchards

The genetic diversity analysis from the baseline data (Syauqi, 2015) showed that only four *Nephelium* species were recorded in the home gardens and orchards in Malaysia and Thailand. The number of species found during the survey was less compared to the information given by the farmers during the focussed group discussion. This situation happened because during the FCA, the farmer will narrate the list of species that appears to his mind but in reality during the actual survey the species are not encountered due to several reasons, either the plant has been cut down, died or probably growing in other areas not included in the surveyed area. The commercial species, *N. lappaceum* is widely cultivated in all the sites except in Sisaket (Thailand) only one tree was recorded. Chantaburi in Thailand showed the highest number of trees *i.e.*750 planted followed by Bukit

Table 3. Shannon diversity index, evenness and species richness of *Nephelium* species based on four cell analysis

Country	Site	Shannon diversity index (H')	Evenness (E)	Species richness (S)
Thailand	Chanthaburi	0.000	0	1
	Chiangmai	-	-	0
	Nakhon Sithammarat	0.693	1	2
	Sisaket	0.693	1	2
	Trang	0.000	0	1
Malaysia	B. Gantang	0.000	0	1
	K. Belud	0.000	0	1
	Papar	1.099	1	3
	Serian	1.099	1	3
	Sibuti	1.099	1	3
	Yan	0.000	0	1
Indonesia	Sijunjung	1.386	1	4

Table 4. Number of trees in each *Nephelium* species in eleven locations

Country	Site	*Nephelium cuspidatum* var. *robustum*	*Nephelium lappaceum*	*Nephelium ramboutan-ake*	*Nephelium hypoleucum*
Thailand	Chanthaburi	0	750	0	0
	Chiang Mai	0	0	0	0
	Nakhon Si Thammarat	0	520	0	5
	Sisaket	0	1	0	1
	Trang	0	354	0	0
Malaysia	B.Gantang	0	728	9	0
	K.Belud	0	230	0	0
	Papar	19	334	25	0
	Serian	0	224	0	0
	Sibuti	2	503	150	0
	Yan	0	321	2	0

Gantang in Malaysia (728 trees) (Table 4). *N. ramboutan-ake* which is a close relative of *N. lappaceum* was only recorded at Sibuti, Papar, Bukit Gantang and Yan in Malaysia. Although *N. ramboutan-ake* was not found in the surveyed home gardens and orchards in Kota Belud and Serian, but it was found to be grown in other areas in these two districts. However, there was no record of *N. ramboutan-ake* in the surveyed sites in Thailand. Therefore *N. ramboutan-ake* can be considered as a rare species. The wild species, *N.cuspidatum* var. *robustum* was only located at two sites *i.e.* Papar (19 trees) and Sibuti (two trees). This species normally occurs as a single individual formerly grown by the older generation or left uncut during land clearing for developing an orchard or building houses. While *N. hypoleucum* was only recorded from Nakhon Sithammarat (five trees) and Sisaket (one tree). This species was reported to be cultivated in Thailand (Tindall, 1994).

Sibuti and Papar possessed three species each but Shannon Diversity Index is higher in Sibuti (H'=0.558) compared to Papar (H'=0.400) due to the uneven number of the trees for the species (Table 5). The same situation is shown in Sisaket and Nakhon Sithamarat where Shannon diversity index showed highest H'=0.693 due to the same number of trees for both species. There was no rambutan trees growing in Chiang Mai.

Comparison of the various communities at the different sites showed that the Malay community in Yan and Bukit Gantang (Malaysia) has maximum number of *N. lappaceum* trees in their home gardens and orchards (Table 6). Normally the farmers in Malaysia planted the recommended clones given by the Department of Agriculture (R 156, 'lekang nyiur' or 'anak sekolah') or they bought the seedlings from the private nurseries. Similarly in Thailand the commercial cultivars of *N. lappaceum* planted are Ngo Rongrian, Ngo Si Chompu or Ngo Ban. The Kadazan Dusun and Kedayan in Papar and Sibuti simultaneously still maintained the wild *N. cuspidatum* var. *robustum* in their orchards for their own consumption.

Diversity of Wild Nephelium Species in Selected Forests

Many *Nephelium* species were found in the forest as

Table 5. Shannon diversity index, evenness and species richness of *Nephelium* species based baseline data

Country	Site	Shannon diversity index (H')	Evenness (E)	Species richness (S)
Thailand	Chanthaburi	0	0	1
	Chiang Mai	-	-	0
	Nakhon Si Thammarat	0.054	0.078	2
	Sisaket	0.693	1.000	2
	Trang	0.000	0.000	1
Malaysia	B. Gantang	0.066	0.095	2
	K. Belud	0.000	0.000	1
	Papar	0.439	0.400	3
	Serian	0.000	0.000	1
	Sibuti	0.558	0.508	3
	Yan	0.038	0.054	2

Table 6. *Nephelium* species and number of trees owned by the different communities

Site	Community	*Nephelium cuspidatum* var. *robustum*	*Nephelium lappaceum*	*Nephelium ramboutan-ake*	*Nephelium hypoleucum*	Grand Total
Chanthaburi	Trok Nong		750			750
Chiang-Mai	Banmaeya		0			0
	Banmae-onai		0			0
Kota Belud	Bajau		230			230
Nakhon Si Thammarat	Kiriwong		520		5	525
Papar	Kadazan Dusun	19	334	25		378
Serian	Bidayuh		224			224
Sibuti	Kedayan	2	503	150		655
Sisaket	Nongsingyai		1		1	2
Trang	Banchongphli		61			61
	Banlongnam		117			117
	Bannakhao		72			72
	Bannamtok		52			52
	Banthamphraphut		74			74
Yan / Bukit Gantang	Malay		1049	11		1060

recorded during the survey made. The density of trees for each *Nephelium* species varies greatly from 1-20 trees per species. A total of 13 identified and four unidentified species were recorded in three countries with Malaysia showing the highest number of species (10) followed by Indonesia (six) and Thailand (four) (Table 2). Lambir Forest Reserve showed the highest number of species (seven), followed by Sijunjung (five) and Kota Belud (three) (Table 7). Similarly, Shannon Diversity Index was highest at Lambir Forest Reserve *H'*=1.946, followed by Sijunjung (Sumatra) *H'*=1.609 and Kota Belud *H'*=1.099. The high number of species found at Lambir Forest Reserve was probably due to the larger area surveyed compared to the other sites. In Thailand, two species were found in Trang and another two unidentified species were found in Nakhon Sithammarat. In Thailand, the fruits of *N. hypoloceum* eventhough of inferior quality were normally harvested and sold in local markets. However at Sijunjung, Sumatera, of the five species recorded, only three species were identified (Table 1). In general, the wild *Nephelium* species produce sarcotesta which is thin, sour and adhered to the seed. However, through selection and domestication or participatory breeding the fruit quality can be improved.

Conclusion and Recommendations

Based on the number of trees per species and their occurence at the studied sites, *N. ramboutan-ake* and *N. maingayi* can be considered as rare while the other species are threatened besides *N. lappaceum* which is

Table 7. Shannon diversity index, evenness and species richness of *Nephelium* species in selected forests

Country	Site	Shannon diversity index	Evenness	Species richness
Malaysia	Bukit Gantang	0.000	0	1
	Kota Belud	1.099	1	3
	Lambir FR	1.946	1	7
Thailand	Nakhon Si Thammarat	0.693	1	2
	Trang	0.693	1	2
Indonesia	Sijunjung	1.609	1	5

common to all the three countries. Home gardens and forest reserves have the potential for maintaining and conserving *Nephelium* species. Since the occurence of the number of trees for each species either in the home garden or forest is small at each site, therefore, in order to capture enough genetic variability for conservation it requires to select many home gardens and large areas of forest reserves. Besides, it is recommended to intensify the survey of the cultivated and wild *Nephelium* species in other areas in the country in order to obtain comprehensive data pertaining to species diversity and distribution. In addition, the genetic material of the wild *Nephelium* species also need to be collected and planted in the field genebank at various governmental institutions as *ex situ* conservation. Besides exploration on the value addition of the *Nephelium* species in the home gardens and linking them with market should be an important strategy for *in situ* conservation. Research programmes on selection and breeding for crop improvement of the wild *Nephelium* species should be enhanced.

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References

Amin I, MD Norzatol Akmar, I Salma, K Madzlan and I Khatijah (2004) Antioxidant capacity and polyphenol content of Malaysian indigenous fruits. In: Conference and Annual General Meeting. Nutrition Society of Malaysia, Kuching.

de Boef W and Thijssen (2007) Participatory tools working with crops, varieties and seeds.Wageningen International, pp 68-69.

DOA (1995) Registered fruit clones of the Department of Agriculture. Kuala Lumpur, Cawangan Pengeluaran Tanaman. Jabatan Pertanian.

Emmy Hainida KI, HE Khoo, MJ Abbe Maleyki, I Amin, I Salma, A Azrina, MN Halimatul Saadiah, MD Norzatol Akmar and MM Ruzaidi Azli (2007) Antioxidant capacity and phenolic content of Malaysian underutilized fruits. In: 7th International Food Data Conference, October 22-24, 2007, Sao Poulo, Brazail.

Leenhouts PW (1986) A taxonomic revision of *Nephelium* (Sapindaceae). *Blumea* **31**: 373-436.

Lye TT, LDS Laksmi, P Maspol and SK Yang (1987) The commercial rambutan cultivars in ASEAN. In: PF Lam and S Ksiyachinda (eds.) *Rambutan. Fruit Development, Post Harvest Physiology and Marketing in ASEAN*. ASEAN Food Handling Bereau, Kuala Lumpur, Malaysia, pp 9-15.

Maya Izar K, I Salma, and A Adam Haris Gerten (2011) Site selection Malaysia. Poster presented during Regional Project Steering Committee Meeting at Bangalore, India.

Mohd Shukri MA, I Salma, N Mohd Shukor, P Mansor, Y Musa, and AR Site Norzuraini (2008) Biodiversity and health: when tradition meets enjoyable and nutritious rich food. *In:* Seminar on Agriculture and Biodiversity: New Challenges and Emerging Issues in conjuction to The International Biodiversity Day, 22 May 2008, MTBIC, MARDI.

Raziah ML, I Salma, M Abd Rahman, MS Samsuddin, A Mohd Nazri and MS Abd Manaf (2006) On-farm conservation of indigenous fruits in Ulu Cheka, Jerantut, Pahang: Socio-economic and ethnobotanical studies using the Participatory Rural Appraisal (PRA) technique. MARDI Report No. 204.

Salma I (1986) *Rambutan (Nephelium lappaceum L.) Clones and Their Classification*. MARDI Report No. 107. Malaysian Agricultural Research and Development Institute, Kuala Lumpur.

Salma I, A Mohd. Nor, H Masrom and ML Raziah (2006) Diversity and use of traditional fruit species in selected home gardens or fruit orchards in Malaysia. *J. Trop. Agric. Food Sci.* **34:** 149-164.

Seibert B (1991) *Nephelium* L. In: EWM Verheij and RE Coronel (eds.) *Plant Resources of South-East Asia No. 2: Edible fruits and nuts*. Pudoc, Wageningen, The Netherlands, pp 233-235.

Siregar M (2006) Species Diversity of Local Fruits Trees in Kalimantan: Problems of Conservation and its Development. *Biodiversitas* **7**: 94-99.

Syauqi N (2005) Impact assessment survey report, Malaysia (Unpublished). MARDI, Serdang.

Tahan Uji (2007) Species diversity of indigenous fruits in Indonesia and its potential. *Biodiversitas* **8**: 157-167.

Tindall HD (1994) *Rambutan cultivation* FAO plant production and protection paper 121. FAO Rome 162 p.

Van Welzen, PC (1999) Sapindaceae. In: S Thawatchai and K Larsen (eds.) *Flora of Thailand* 7. The Forest Herbarium, Royal Forest Department, Bangkok, Thailand, pp 169-250.

Yap SK (1989) Sapindaceae. In: FSP Ng (ed.) Tree Flora of Malaya. Vol. **4**. Longman, Malaysia, pp 434-461.

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A Preliminary Appraisal of Mango Biodiversity in Kerala, India

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Mango (*Mangifera indica* L.) is a keystone species in homestead gardens across Kerala, India. This study was conducted in two village sites in Kerala to assess their richness and evenness values of mango diversity, document farmers' motivations for maintaining this diversity, and record pertinent indigenous traditional knowledge (ITK). Four Cell Analysis (FCA) in the context of Focus Group Discussions (FGDs) was used to generate biodiversity data and gauge farmer rationale for cultivation. The average household (HH) richness in the Erippadam village was r=6.29 and the average HH evenness was λ=0.64, whereas the average HH richness in the Maruthampadam village was r=2.84 and the average HH evenness was λ=0.40. These variations were attributed to the presence of different forms of agricultural commercialization in the two village sites. Drawing on FGD results, several suggestions were offered that may serve to enhance and maintain mango biodiversity in the Kerala region.

Key Words: Agricultural biodiversity, *In situ* (on-farm) conservation, Mango biodiversity, Home gardens, Kerala

Introduction

South Asia in its entirety contains more than 500 different species of fruits, and the Indian subcontinent itself is home to over 300 of them (Malik *et al*., 2010). This vast reservoir of genetic resources is a vital asset for future global food and nutritional security as well as maintaining ecosystem health. A combination of trends including deforestation, the proliferation of monoculture farming systems, and the economic incentives commercialized agriculture offers has contributed to the worldwide erosion of valuable genetic resources and associated traditional knowledge. This loss of agricultural biodiversity threatens world food security, ecosystem health, and the economic security of more than one billion people who rely on agriculture for a means of livelihood (FAO Statistical Yearbook, 2013).

Two primary conservation strategies – *in situ* (on-farm) and *ex situ* (external storage of seeds in seed banks, research facilities, *etc*.) conservation have been adopted by the international community as a means of safeguarding this wealth of genetic diversity. That said, the capacity, availability, and long-term sustainability of *ex situ* conservation efforts are constrained by a host of factors that make sole reliance on them unreliable at best. As such, in recent years *in situ* or on-farm conservation has begun to grow in popularity and importance due to its global applicability, relatively low capital input requirement, and its ability to build, maintain and strengthen relationships between the formal scientific research sector and rural communities worldwide.

Mango, hailed as "the most important fruit crop in India" (Dinesh *et al*., 2012), is no exception to this global trend of genetic erosion. However, not only does mango play an important economic role in India as a cash crop sold domestically and internationally, it has also penetrated and influenced the country's culinary, religious, and ethnic culture for thousands of years. Furthermore, this fruit exhibits a startling array of diversity, with over 1000 recognized varieties of the *M. indica* species alone in India (Dinesh *et al*., 2012). In Kerala, a province located in the southwestern corner of the Indian subcontinent, a wide variety of mango species and cultivars are maintained by local communities for commercial and domestic purposes (Kumar and Nair, 2006). Many locals keep mango trees in home-gardens and semi-commercial orchards, and the fruit figures prominently in the area's food culture.

Notwithstanding its importance to local communities and markets, there is a marked research gap concerning the status of mango biodiversity in south India in general and in Kerala in particular. This current study is both descriptive and normative. It strives to fill the current lack of participatory research devoted to this topic by

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assessing the state of mango biodiversity in two village sites in Kerala. Furthermore, it investigates the reasons for richness and distribution values of mango diversity and the state of associated indigenous traditional knowledge (ITK) on mango biodiversity in the region. Lastly, this study concludes by providing suggestions for good practices that will help maintain and enhance mango diversity in Kerala in the context of increasingly widespread agricultural commercialization.

Materials and Methods

Site Description

Two villages were selected as research sites for this study, both located in the state of Kerala, India. Maruthampadam village is located in Thrissur District, Pazhayannur gramapanchayat (GP, term for a smaller local administrative unit). The total geographical area of Pazhayannur GP is 59 sq. km with altitudes ranging from 30-220 m. The average annual rainfall is 2972 mm, and the climate type is monsoon tropical. The average yearly temperatures range from a high of 36°C in April to a low of 19°C in December and January. The area is known for its lush green tropical landscape characterized by red lateritic soil. The lowlands of this GP are cultivated with a range of fruit crops such as coconut, areca nut, and banana while the commercial cultivation of teak and rubber is rapidly spreading.

Erippadam village is located in Palakkad District (which borders Thrissur District to the west), Muthalamada GP. The total geographical area of Muthalamada GP is 67 sq. km, with an altitude range of approximately 75-250 m. Though displaying nearly identical average temperature patterns, this GP exhibits a drier climate than Pazhayannur GP, with an average annual rainfall of 2269 mm. The soil types vary across the GP, from black soil with clay content to red soil to lime rocks, etc. The plain regions of Muthalamada GP are characterized by the cultivation of paddy, groundnut, coconut, and an increasingly semi-commercialized mango industry. Though showing slight variations in terms of geography, climate, and agriculture preference, the cultural makeup of the two GPs is relatively similar and no drastic differences in custom or way of life were noted.

Selection of Participating Farmers

Data on local mango biodiversity and the target communities' ITK was collected by means of participatory collaboration between researchers and locals. Village notables were initially reached externally in order to establish baseline contacts in the target sites. Representative homesteads thought to maintain rich mango varietal diversity were then contacted via a socio-metric survey employing the snowball sampling method. This method operates by having existing study subjects (*i.e.* those with whom initial village contact was established) recruit future subjects with whom they are personally or professionally acquainted at the village level, thus creating an expanding web of interlinking participants.

Participatory Identification of Local Biodiversity

Focus group discussions (FGDs) were held with selected farmers in the two target villages. FGDs were held in Maruthampadam and Erippadam villages on 10/11/2010 and 27/12/2010, respectively. In these FGDs, four-cell analysis (FCA) was used as the primary means of gauging local biodiversity via accessing the ITK resources possessed by the farmers. Four-cell analysis is a participatory method that engages with knowledgeable local populations in order to: (1) identify common, unique, and rare crop varieties, (2) document the reasons why these crops/varieties are found in a dynamic state, and (3) devise and identify conservation strategies that can be implemented at the village level to conserve local biodiversity (Sthapit *et al*., 2012a).

In this study's two project sites, the FCA technique conducted during FGDs consisted of several steps. Prior to the discussions, farmers were asked to assess the types of mango species and varieties maintained in their home-gardens and orchards and to bring this information with them to the planned FGDs. The discussions were then initiated on an introductory note stressing the importance of maintaining *in situ* varietal diversity. Participating farmers were subsequently asked the following four questions that form the basis of the FCA technique: (1) what are the mango types cultivated in large areas in many homesteads, (2) what are the mango types cultivated in large areas in few homesteads, (3) what are the mango types cultivated in small areas in many homesteads, and (4) what are the mango types cultivated in small areas in a few homesteads? The parameters of what constitutes a small *vs.* large area and many *vs.* few homesteads are a qualitative measure agreed upon by farmers during the FGD, thus differing slightly between the two research sites. These research questions are critical for developing deeper understanding of farmer's decision on choice of mango varieties and their conservation efforts.

Once these questions were fielded and a set of local parameters mutually agreed upon, farmers assigned the mango species and varieties found in their home-gardens into the specific cells of the FCA grid (Table 1). This was done interactively and visually in order to keep the farmers engaged and aware of the ongoing process. Following the placement of local mango species and varieties into the aforementioned FCA grid, the different characteristics and qualities of these types were discussed and analyzed by the group. The different varieties were classified as common, other distinct, or rare depending on their placement in the grid (Table 1). The FGD was concluded with remarks regarding the diversity status of the local mango population and various strategies that could help to preserve and enhance this diversity in the future.

Diversity Estimates

Richness and evenness are two measures useful for gauging the biodiversity of a given site (Jarvis *et al.*, 2008). Richness describes the total number of genotypes (in terms of this study, species or varieties) found within a specified area. Richness was determined at the household level and was calculated by counting the total number of different farmer-named mango varieties per household unit.

Likewise, evenness details the frequency of given types within a total population. For instance, a low evenness value indicates the dominance of an agricultural system by one or few species or varieties, whereas a high value indicates a more uniform distribution of types in a given unit area (which, in this study, was the household unit). Evenness was calculated using the Simpson Diversity Index defined as:

$$\text{Evenness } (\lambda) = 1 - \frac{\sum_{k=1}^{n} V_k^2}{N^2}, V_k = \text{Number of trees per variety k, } N = \text{Total number of trees}$$

Results

Choice of Fruit Crop

FCA is also used to measure the importance of crops to the community. The importance value is measured by the number of households (HHs) growing given crops and/or varieties (Fig. 2a and 2b) in a project site. In both villages, mango was recognized as the most important crop (cultivated by 21-29 HHs). With respect to other locally grown commercial and food crops, rubber, coconut, rice, vegetables and banana were important in Maruthampadan village whereas coconut and rice were other important crops in Erippadam village.

FCA Classification Status of Mango Diversity

Mango varietal data collected from the FCAs performed at the two village sites were organized into the above-specified categories, namely common, other distinct or rare varieties. Table 2 displays the data collected from the Maruthampadam and Erippadam village sites. Though Maruthampadam village showed a relatively low richness value for common mango varieties (r=3), nine different rare varieties were maintained in the home gardens and orchards, and six other distinct varieties were recorded during the session. Erippadam village maintained more than twice the number of common varieties than Maruthampadam village, with a richness value of r=7. Conversely, only four rare varieties were recorded during the FCA held in Erippadam village, less than half the number was recorded in Maruthampadam. Overall, Maruthampadam village displayed a tendency to maintain a greater number of rare varieties and other distinct varieties, while Erippadam village exhibited a preference for common varieties at the expense of rare varieties. Both villages contained similar numbers of other distinct mango varieties. Lastly, popular varieties common across Kerala such as Olour, Bapakai, and Kurukan were not reported in these two villages.

Richness and Evenness Diversity Values

The overall varietal richness of the Maruthampadam village site was r=17 with a household level range of 1-13 varieties. The average richness per household in the village was r=2.84 while the average evenness per household was λ=0.40. Evenness values for this site of each recorded mango variety are presented in Fig. 3a.

Table 1. Participatory four-cell analysis diversity grid

Mango Types	Considered as
Mango types grown in large areas (many trees) in many households	Common type
Mango types grown in small areas (few trees) in many households	Culturally important but endangered type
Mango types grown in large areas (many trees) in few households (few orchards)	Other distinct commercial type
Mango types grown in small areas (few trees) in few households (few home gardens)	Rare or unique type

Table 2. Comparative mango varietal distribution status and key traits in project sites

Variety	Village	Conservation Status*	Notable Traits
Gomanga	Maruthampadam	Common	Regular bearer
Muvandan	Maruthampadam	Common	Regular bearer, good for processing, disease tolerant and good for marketing
Pulimanga	Maruthampadam	Common	Acidic variety, tender mango pickling purpose, regular bearer
Kilimook	Maruthampadam	Other Distinct	Widely grown in south India, regular bearer, preferred for processing
Nadasala	Maruthampadam	Other Distinct	Regular bearer, dual purpose variety
Neelum	Maruthampadam	Other Distinct	Pollinizer for orchards and used for table purposes
Priyur	Maruthampadam	Other Distinct	Profuse bearer
Puliyan	Maruthampadam	Other Distinct	Culinary purpose, pickling purpose, high fiber content
Chandrakaran	Maruthampadam	Rare/Unique	Popular variety of Kerala, used in traditional households for making *mambazha pulissery*
Ganapatimookan	Maruthampadam	Rare/Unique	Big fruit, sour taste
Karpuramanga	Maruthampadam	Rare/Unique	Turpentine flavor, regular bearer, pickling purposes
Kilichundan	Maruthampadam	Rare/Unique	Local seedling, used for pickling purposes
Kottamavu	Maruthampadam	Rare/Unique	Local land race, regular bearer, pickling purposes
Marathakam	Maruthampadam	Rare/Unique	Dark green color
Mundappa	Maruthampadam	Rare/Unique	Attracts fruit flies when rains; best before rainfall
Sindhura	Maruthampadam	Rare/Unique	Deep reddish tinge, different taste and texture, early bearer
Alphonso	Erippadam	Common	Export quality, retains quality good, alternate bearer, firm pulp, fibreless and of excellent quality
Banganapalli	Erippadam	Common	Early variety cultivated widely in southern states, moderate and regular bearer, high quality fruit
Kilichundan	Erippadam	Common	Local seedling, used for pickling purposes
Muvandan	Erippadam	Common	Regular bearer, good for processing, disease tolerant and good for marketing
Nadasala	Erippadam	Common	Regular bearer, dual purpose variety
Neelum	Erippadam	Common	Regular bearer, heavy yielder, late season variety with wide adaptability
Sindhuram	Erippadam	Common	Taste good, good keeping quality
Gomanga	Erippadam	Other Distinct	Common variety of North Kerala, dual purpose, used for instant pickling
Gudadath	Erippadam	Other Distinct	Culinary purposes, regular bearer
Himapasanth	Erippadam	Other Distinct	Taste good, table type
Kalepad	Erippadam	Other Distinct	Regular bearer, popular in Kerala, fruit small to medium, fibreless flesh
Mulgoa	Erippadam	Other Distinct	Late season variety, shy bearer, pulp very sweet, melting and with pleasant flavor
Nadanmanga	Erippadam	Other Distinct	Tangy taste, not eaten ripe, used for curry preparation
Priyur	Erippadam	Other Distinct	Profuse bearer
Chandrakaran	Erippadam	Rare/Unique	Poly-embryonic variety
Kilimook	Erippadam	Rare/Unique	Widely grown in south India, regular bearer, preferred for processing
Mallika	Erippadam	Rare/Unique	Hybrid
Mundappa	Erippadam	Rare/Unique	Attracts fruit flies when rains; best before rainfall

*In terms of FCA analysis, 'Common' denotes mango varieties grown in large areas (many trees) by many households (home gardens); 'Other Distinct' represents mango varieties grown in large areas (many trees) by few households (few orchard); 'Rare/Unique' represents mango varieties grown in small areas (few trees) by few households (few home gardens).

Similarly, the overall varietal richness of the Erippadam village site was r=18 with a household level range of 1-15 varieties. The average richness per household in the village was r=6.29 while the average evenness per household was λ=0.64. Evenness values for this site of each recorded mango variety are presented in Fig. 3b. Overall, Erippadam displayed higher total richness, average richness per household, and average evenness per household values than Maruthampadam village.

Relationship between Plot Size and Mango Diversity

During the FGD and data collection process, home-garden plots were divided into four distinct categories: a) >1 acre, b) 1 – <5 acres, c) 5 – <7 acres, and d) 7≤ acres. Average varietal richness was then plotted against home-garden size for the two villages (Fig. 4). Maruthampadam village showed a direct positive relationship between richness and plot size for size categories a) through c). However, richness decreased dramatically in the largest size category, dropping from r=14 to r=5. Erippadam village showed a consistent direct positive relationship for all size categories, though the most significant jump in richness was between size categories b) and c).

Discussion

Potential Reasons for Mango Diversity Differences

With the exception of an approximately 25% difference in annual average rainfall between Maruthampadam

Fig. 1. Map of Kerala state showing the location of the selected gram panchayats

and Erippadam villages (2972 mm *vs*. 2269 mm, respectively), the most significant distinction between the two sites is that while the former village is located in an area dominated by commercial rubber and teak cultivation, the latter is located in an area dominated by semi-commercial mango cultivation. This difference in the areas' commercial agricultural foci may be one factor that explains the mango diversity disparity between the two sites. With respect to the FCA diversity categories (*i.e.* common, other distinct, and rare), as was noted above, the Maruthampadam village maintained a total of nine rare mango varieties compared to only three common varieties. In Erippadam village, where commercial mango cultivation has become increasingly widespread, seven common varieties were maintained as opposed to only four rare varieties. These figures seem to imply that commercialized mango farming and common varietal diversity are directly positively related, whereas subsistence mango farming and rare varietal diversity are inversely related. In other words, the data suggests that in areas where common varietal diversity dominates, specific types are cultivated to cater to wider consumer and market preferences, whereas areas dominated by rare varietal diversity are more focused on raising the crops for household and local use. Such a conclusion would be expected, as commercialized mango cultivation places emphasis on a limited number of common varieties that have broader consumer demand, fetch higher market prices, and maintain stable production potential.

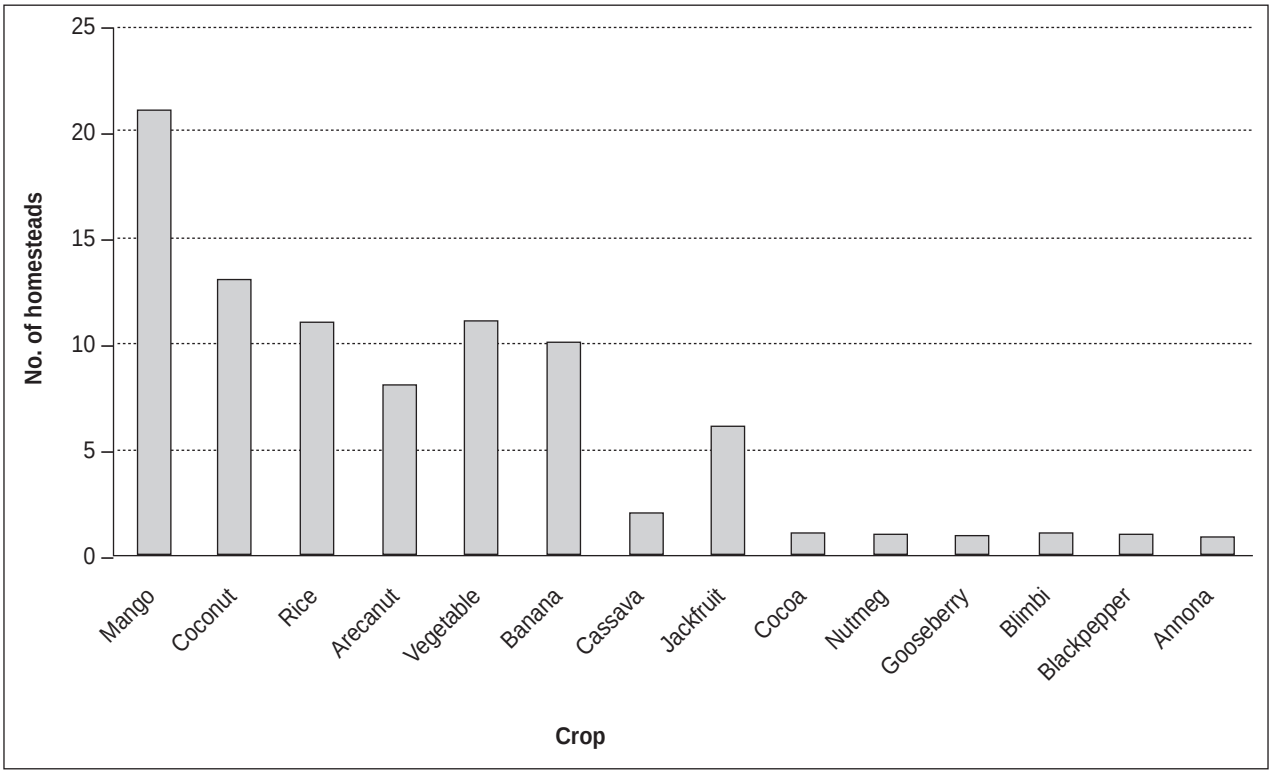

Fig. 2a. Crop diversity status of Maruthampadam village (Pazhayannur GP)

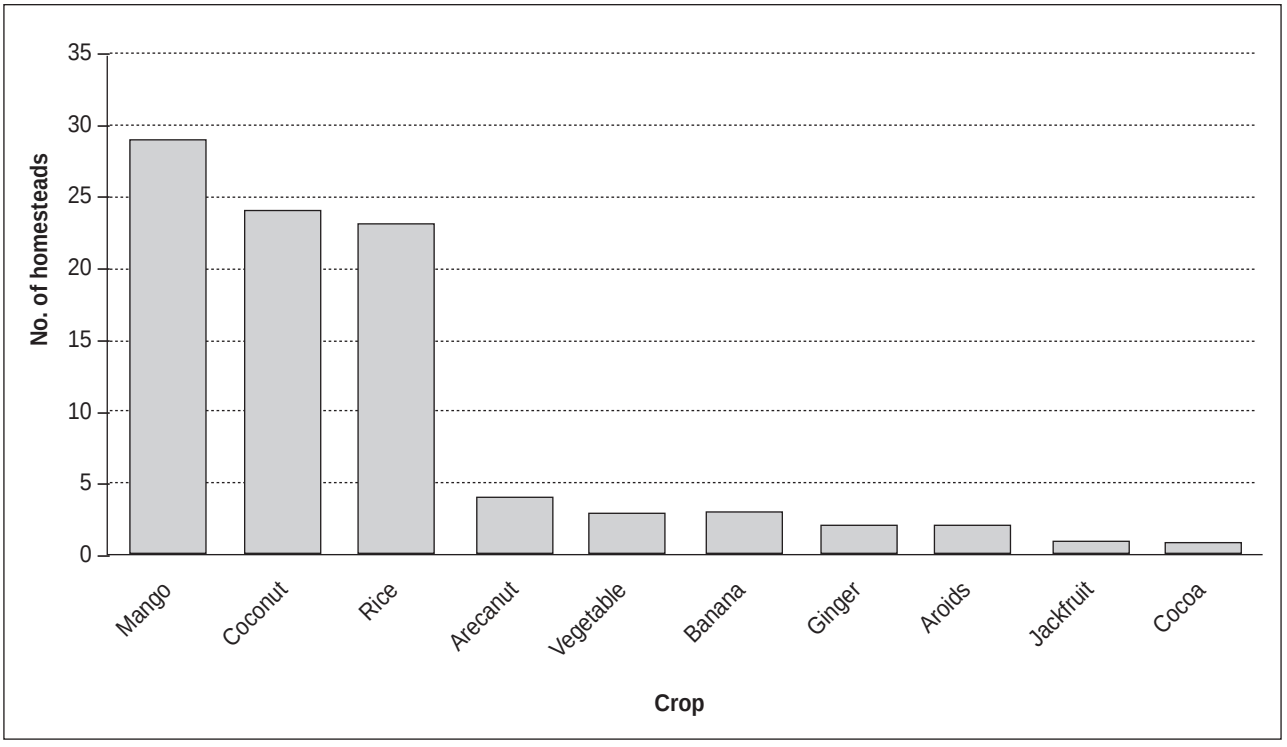

Fig. 2b. Crop diversity status of Erippadam village (Muthalamada GP)

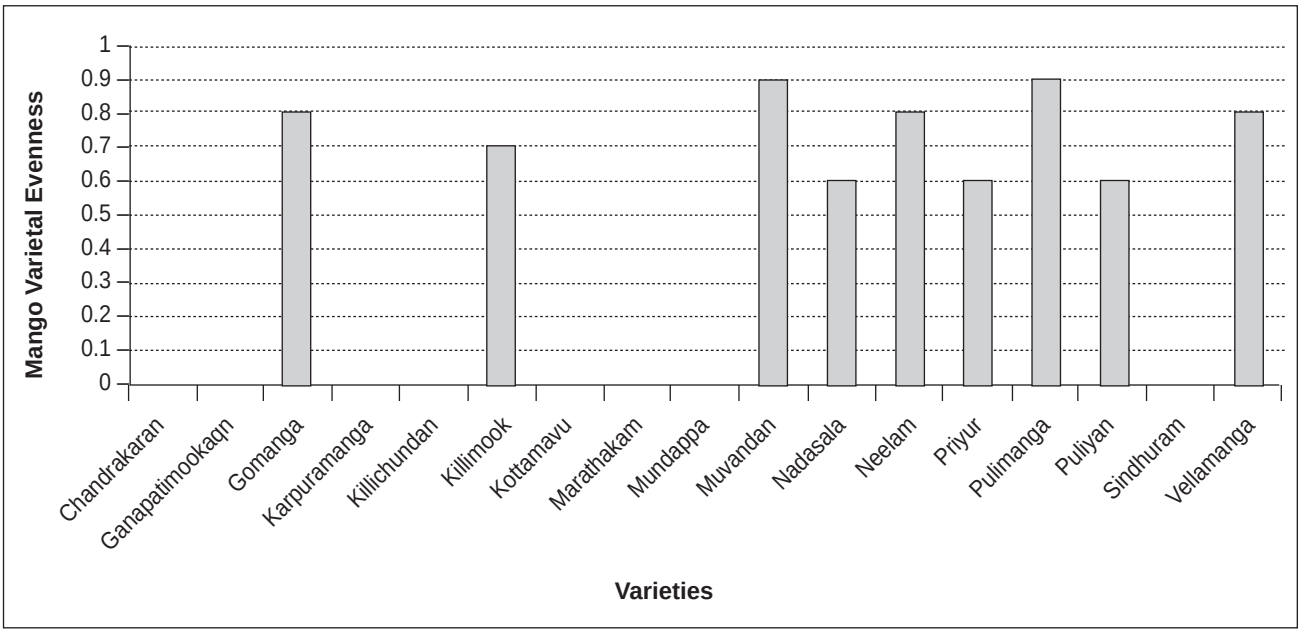

Fig. 3a. Varietal evenness for Maruthampadam village

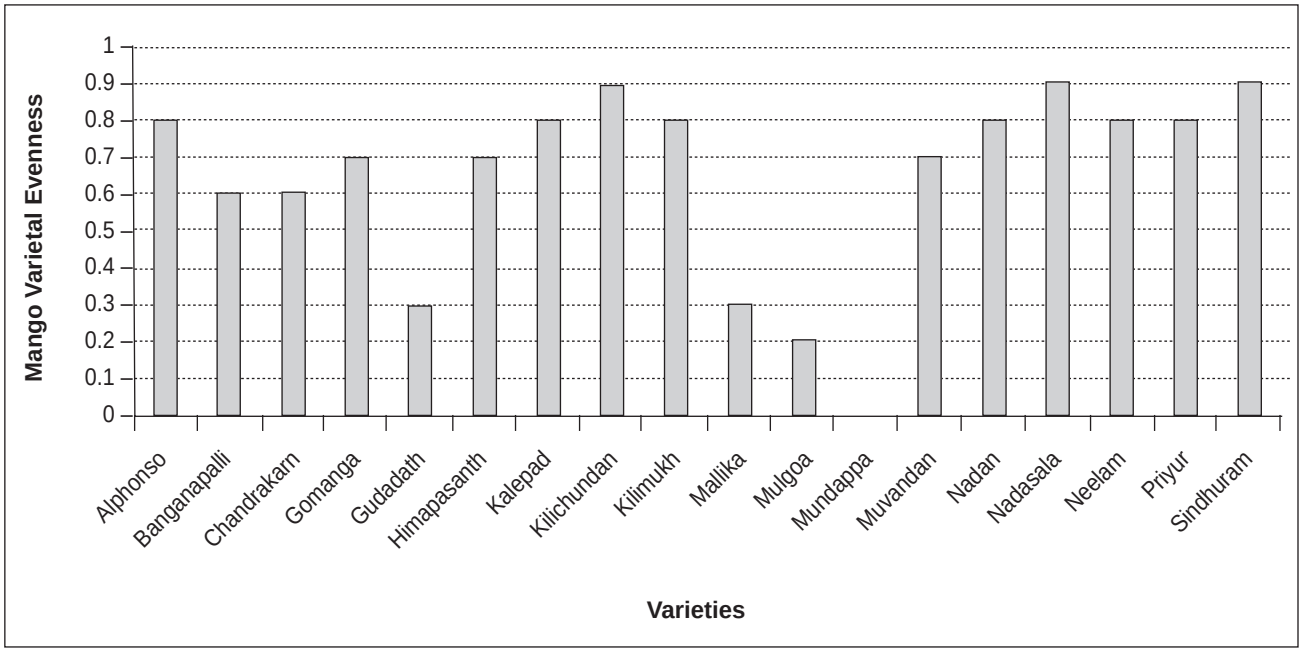

Fig. 3b. Varietal evenness for Erippadam village

In addition, the two villages displayed significant differences with respect to average HH varietal richness and average HH evenness (r=[2.84 cf. 6.29], λ=[0.40 cf. 0.64] for Maruthampadam and Erippadam, respectively). Erippadam village was richer in mango diversity and the varieties were distributed relatively evenly, likely in order to enhance resilience capacity. In Maruthampadam village, on an average only two to three mango varieties were grown in homestead gardens for home consumption. One potential explanation for this marked variation in average HH richness and evenness is that in areas where agricultural commercialization including

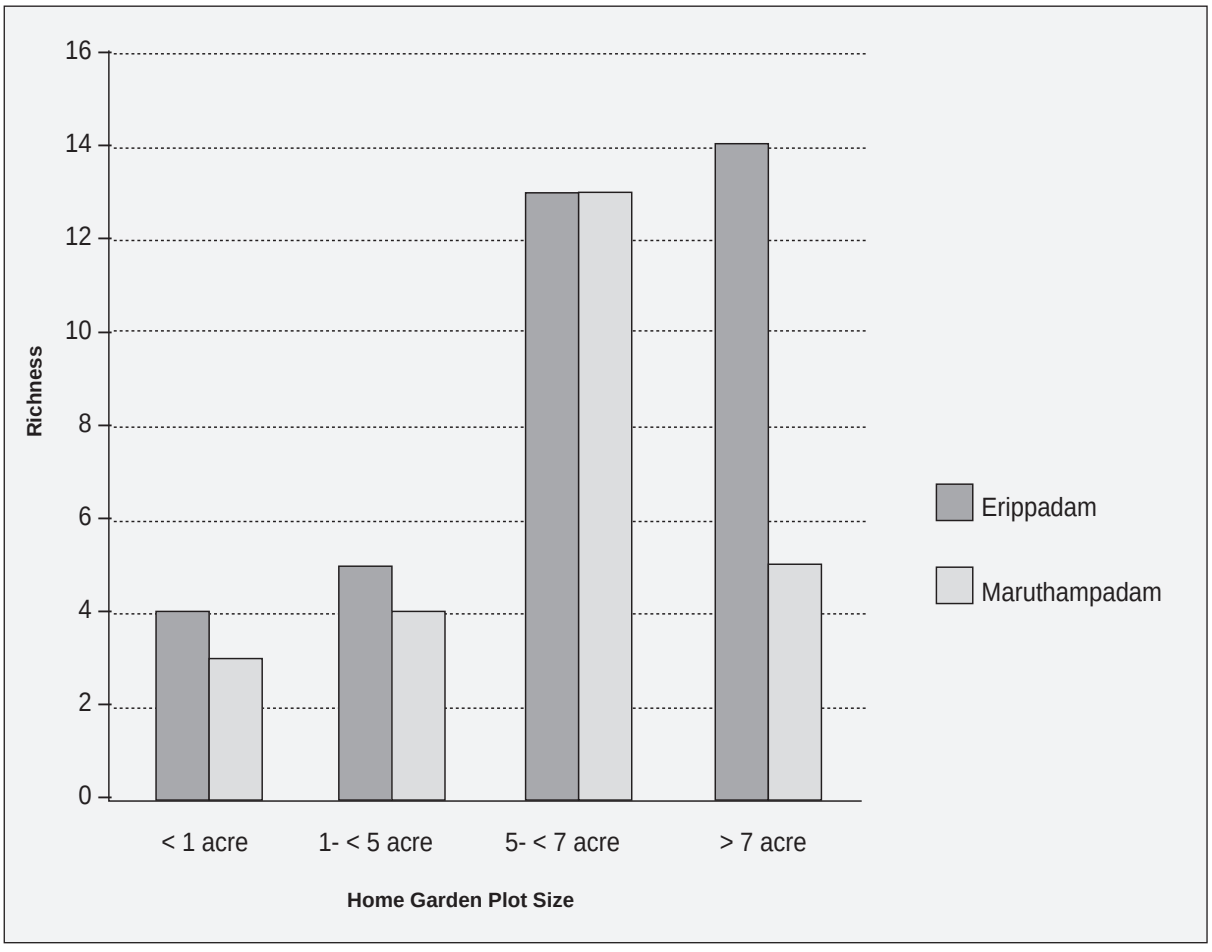

Fig. 4. Relationship between home-garden size and average varietal richness

of a non-food crop is rapidly spreading, the result is the overall erosion of food-crop diversity including mango. In Maruthampadam, where teak and rubber monocropping is an established and spreading industry, average household richness and evenness are markedly lower than in Erippadam village, where the primary commercial agricultural industry is mango cultivation. It thus appears that though commercial mango cultivation has a negative impact on the conservation of rare mango varieties, it is an effective means for maintaining common varietal diversity. Furthermore, in areas where commercial cultivation of non-food is dominant, average household varietal richness and evenness values will be lower than those of households located in areas where commercial food-crop cultivation is more common, due to general food-crop genetic erosion. This speculation calls for additional study, due to the fact that the degree of commercial mango cultivation in a given area may be influenced by factors not discussed in this study, such as proximity to markets and the strength of local commercial linkages.

This set of inferences could also explain the significant difference in overall varietal richness values between both villages for the largest home-garden size category, *i.e.* $\leq$7 acres. In both sites, it is highly probable that the largest home-gardens were used not simply as a supplement for kitchens and household use, but rather were for commercial purposes as well. As such, in Maruthampadam, rubber and teak may have come to dominate these large holdings, leading to the observed drop in varietal richness in larger plots. In Erippadam, where large gardens most likely served as semi-commercial mango orchards, varietal richness continued to increase.

Strategies for Future Diversity Management

As Malik (2010) argues, "*in situ* on-farm conservation would be an ideal approach for conserving local natural

selections, cultivars, and farmer's varieties." Given that the practice of maintaining home-gardens is a deeply entrenched cultural tradition in South India, the village sites of this study proving no exception, the most productive method of promoting *in situ* mango diversity in the region would be to focus on the home-gardens of local villagers. In an area such as Kerala, where genetic diversity is already threatened, home-gardens would provide an ideal setting for the maintenance of rare and unique varieties (Gautam *et al*., 2008; Watson and Eyzaguirre, 2002). The first step towards maintaining and enhancing mango diversity in local home-gardens would be to conduct further FGDs with target communities about the cultural, environmental, and economic importance of conserving rare landraces and varieties. If not already in place, the creation of a village diversity register that would record the different species and varieties maintained by the community could aid this campaign of raising local awareness on the importance of varietal diversity (Dinesh *et al*., 2014). Likewise, an assessment of the local informal seed-exchange system would be undertaken in order to track the flow of genetic material between farmers and correspondingly optimize its functioning.

Lastly, the promotion of local value-added processing industries has been shown to have a positive impact on both rural livelihoods and biodiversity (Sthapit *et al*., 2012b). Using the above mentioned local fruit diversity register, village level value-added processing could create a range of products that could be stored for long term use and supplement the communities' diets year-round. In addition, it would help to preserve ITK on mango diversity and the ways that different varieties can be used, which is an invaluable asset for the ensuring the perpetuity of traditional life and culture as well as maintaining local mango diversity (Boef *et al*., 1993). Products could also be sold in local markets to help increase incomes and improve local livelihoods. If wider market connections were established by means of a value chain analysis, the villages could even manufacture products for export to neighboring districts or states. This would provide villagers with an economic incentive to maintain and enhance mango diversity, as a range of varieties are required for specific value-added products. That said, there a number of constraining factors on the development of value-added processing at the local level. Small-volume production using inputs from home gardens carries a high transaction cost. Generally speaking, such ventures require initial capital investment from external sources that may be difficult or impossible for the target communities to access. Also, the performance of a value chain analysis could be potentially costly and logistically problematic, and its conclusions regarding market potential uncertain.

Recommendations for Future Research

Though the FGD held in Maruthampadam village touched on relevant and interesting ITK covering topics such as customary fruit processing techniques, recipes, and cultivation methods, the discussions held in Erippadam village did not yield significant information on the state or nature of ITK in the village. As was mentioned previously, ITK is an important asset for villages wishing to preserve local fruit diversity by means of *in situ* conservation and value-added processing. Understanding local motivations for the cultivation of specific varieties is critical for the continued maintenance of useful mango trees in home gardens. As such, one area of future research would be to comprehensively document ITK on fruit diversity (mango in particular) from the two project sites. This data could subsequently be employed by future researchers and market actors focusing on a value chain assessment of mango value-added products in Kerala, how this industry draws on ITK, and the manner in which it affects varietal diversity.

This study has hoped to draw attention to the state of mango varietal diversity in Kerala, India through data collected from two village sites. Though no definitive conclusions can be drawn without confirmation by future studies, this study suggests that agricultural commercialization effects local mango diversity in different ways depending on the specific cash crop(s) under cultivation. Nonetheless, the preservation of ITK, raising local awareness regarding the multifold importance of fruit genetic diversity, and the implementation of strategies such as the creation of a local diversity register and the promotion of value-added processing can contribute to the maintenance and enhancement of mango varietal diversity for use by current and future generations.

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References

Boef Wd, K Amanor, K Wellard and A Bebbington (1993) *Introduction Cultivating Knowledge*. Intermediate Technology Publications, London, UK.

Dinesh MR, C Vasugi, K Ravishankar and Y Reddy (2012) Mango in India *Mango Catalogue*. Indian Institute of Horticultural Research, Banglore, India.

FAO Statistical Yearbook (2013) Retrieved on July 23, 2014, http://www.fao.org/docrep/018/i3107e/i3107e.PDF.

Gautam R, B Sthapit, A Subedi, D Poudel, P Shrestha and P Eyzaguirre (2008) Home gardens management of key species in Nepal: a way to maximize the use of useful diversity for the well-Being of poor farmers. *Plant Genet. Resour.* **7:** 1-12.

Jarvis DI, AHD Brown, PH Cuong, L Collado-Panduro, L Latourniere-Moreno, S Gyawali, T Tanto, M Sawadogo, I Mar, M Sadiki, NTN Hue, L Arias-Reyes, D Balma, J Bajracharya, F Castillo, D Rijal, L Belqadi, R Rana, S Saidi, J Ouedraogo, R Zangre, RO Keltoum, JL Chavez, D Schoen, B Sthapit, P de Santis, C Fadda and T Hodgkin (2008) A global perspective of the richness and evenness of traditional crop genetic diversity maintained by farming communities. *Proc. Nat. Acad. Sci.* **1-6:** www.pnas.org/cgi/doi/10.1073/pnas.0800607105.

Kumar BM and PKR Nair (2006) *Tropical Homegardens: A Time-Tested Example of Sustainable Agroforestry*, Springer, UK.

Malik S, R Chaudhury, O Dhariwal and D Bhandari (2010) Genetic Resource Management. *Genetic Resources of Tropical Underutilized Fruits in India*. National Bureau of Plant Genetic Resources, New Delhi.

Sthapit B, P Shrestha and M Upadhyay (eds) (2012a) Participatory Four-Cell Analysis (FCA) for Understanding Local Crop Diversity. *On-Farm Management of Agricultural Biodiversity in Nepal: Good Practices* (Revised Edition ed.). NARC/LI-BIRD/Bioversity International, Nepal.

Sthapit B, P Shrestha and M Upadhyay (eds) (2012b) Value Addition of Local Crop Diversity. *On-Farm Management of Agricultural Biodiversity in Nepal: Good Practices* (Revised Edition). NARC/LI-BIRD/Bioversity International, Nepal.

Watson J and P Eyzaguirre (2002) *Home Gardens and In Situ Conservation of Plant Genetic Resources in Farming Systems*.International Plant Genetic Resources Institute, Rome, Italy.

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Antioxidant and Nutritional Values of Selected Under-utilised *Mangifera* Species in Malaysia

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Antioxidant properties and nutritional constituents of selected *Mangifera* species namely, *M. caesia, M. foetida, M. laurina, M. longipetiolata, M. odorata, M. pajang, M. pentandra* besides some landraces and commercial clones collected from four different sites in Malaysia, were studied. Results showed that *M. caesia* was the most potential source of antioxidant as evidenced by its most active scavenging activity with 92.09 ± 0.22% radical inhibition or IC_{50} value of 8.14 ± 0.17 mg/ml. *M. pajang* showed the greatest amount of total phenolic (7055.65 ± 101.89 mg/100 g) and ascorbic acid (403.21 ± 46.83 mg/100 g) content. Highest protein content was observed in *M. odorata* var. Kuini KL with 6.02%, while the highest calcium content was found in *M. pentandra* and *M. odorata* var. Kuini KR with 140 mg/100 g. *M. pentandra* was also found to be the best source of potassium with 1930 mg/100 g. In addition to being the potential antioxidants, *M. caesia* and *M. pajang* also showed the highest magnesium (130 mg/100 g) and iron (7.31 mg/100 g) content, respectively. The present study indicates that underutilised *Mangifera* species are a potential source of antioxidants and nutrition with some of them being even better than common mango and other popular fruits.

Key Words: *Mangifera*, Underutilised, Antioxidant, Proximate, Mineral

Introduction

Malaysia possesses a rich diversity of many traditional under-utilised fruits that can be explored for their potential health and nutritional value. These fruits are usually grown in orchards and home gardens and some can be found in the wild and forests of Peninsular Malaysia, Sabah and Sarawak. In Malaysia, underutilised fruits are important for better nutritional status and food security especially for rural and farm communities. As they are usually maintained by cultural preferences and traditional practices, some of them are neglected in research and conservation. Low attention from formal research could be due to lack of knowledge of their potential value. Therefore, information about their health and nutritional components is critical to increase the value of neglected species and varieties and for sustaining and strengthening food, nutrition, health and livelihood security.

Information about food composition of different cultivars, regions and countries is extremely important and needs to be more widely disseminated in order to guarantee the preservation and sustainable use of biodiversity in enhancing food security and human nutrition programmes (de Menezes, 2009). The availability of compositional information will support countries in promoting their local species and varieties to improve health and nutrition status by increasing food diversity from the local surroundings and through planting more foods with higher micronutrient content (Stadlmayr *et al.*, 2011).

Mangifera belongs to the order Sapindales in the family Anacardiaceae which comprises 73 genera and about 830 species, mainly in tropical regions. Previous studies (Bompard and Schnell, 1997) indicate that the centre of origin and diversity of the genus *Mangifera* is mostly restricted to Southeast Asia. Yamanaka *et al.* (2006) listed 58 species in the genus *Mangifera*, with the highest diversity occurring in Malaysia, Java and Sumatra (Kostermans and Bompard, 1993) of which 12 were cultivated, of which eight were found in the wild. Salma *et al.* (2006) listed 30 cultivated and wild *Mangifera* species occurring in Malaysia with three endemic species.

M. indica L., the popular mango, is the most commonly studied by researchers and widely cultivated throughout the world. Mango is a popular and economically important tropical fruit due to its excellent

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eating quality and nutritional composition. Mango is also rich in antioxidants and is reported to contain various classes of polyphenols, carotenoids and ascorbic acid, which scavenge free radicals that have been associated with the beginning of many disorders, such as cancer and cardio- and cerebro-vascular diseases. Antioxidants, may therefore contribute to different health-promoting properties (Kim *et al.,* 2009).

While extensive research has been carried out on *M. indica*, there is lack of information on the other *Mangifera* fruit species. Other *Mangifera* fruit species, commonly referred to as wild and underutilised, are less popular even though they have consumption value. Ikram *et al.* (2009) reported that *M. foetida*, *M. odorata* and *M. pajang* had higher antioxidant capacity than *M. indica*. This finding has shown that underutilised fruits could be better sources of antioxidants than the popular commercial fruit and therefore, should not be neglected. Antioxidants have gained increasing interest in health, nutrition and food science in recent years due to their claimed health benefits (Stadlmayr *et al.,* 2011). Antioxidants scavenge reactive free radicals and oxidants which have been associated with the beginning of many disorders, such as cancer and cardio- and cerebro-vascular diseases (Liu *et al.,* 2000). Almost all organisms posses antioxidant defences and repair systems to protect them against oxidative damage. However, these systems are insufficient to prevent the damage entirely. Thus, exogenous addition of dietary antioxidants is beneficial in assisting the human body to neutralise free radicals, help reduce the harmful effects of oxidative damage and protect against various diseases (Mau *et al.,* 2002). However, scientific information on the antioxidant and nutritional value of other underutilised *Mangifera* fruit species and some of their landraces and commercial clones is still scarce. This information is pertinent in promoting these underutilised fruit species to the public.

Thus, the major objectives of this study were; (i) to evaluate the antioxidant properties and (ii) to determine proximate and mineral composition as indicators of nutritional values of the fruits of selected underutilised *Mangifera* species, landraces and clones collected from various locations in Malaysia.

Materials and Methods

Fruit Samples

Mangifera species, landraces and clones were collected from four different sites in Malaysia (Table 1). Only ripe *Mangifera* fruits were used in this study.

Table 1. *Mangifera* species and their collection sites in Malaysia

Species	Common name	Collection site
Mangifera caesia	Binjai	Papar, Sabah
M. foetida	Bacang	Yan, Kedah
M. laurina	Mempelam air	Papar, Sabah
M. longipetiolata	Sepam	Yan, Kedah
M. odorata	Kuini	Yan, Kedah
M. pajang	Bambangan	Kota Belud, Sabah
M. pentandra	Mempelam bemban	Bukit Gantang, Perak

Preparation and Extraction of Fruit Samples

Fruit samples were washed with running tap water before being weighed for the whole and edible portion parts. Then, the edible portions of the fruits were cut into small pieces and freeze-dried using a bench-top freeze dryer (Virtis, USA). The freeze-dried samples were finely ground and kept in an airtight container prior to extraction.

For antioxidant analysis, the samples were extracted using methanol (1:10) and shaken for approximately 1 h before centrifugation for 10 min. at 10,000 rpm. The residue was separated from the supernatant and the procedure was repeated twice. The two resulting supernatants were mixed together to obtain the crude extracts which were stored at -80°C prior to analysis.

For ascorbic acid analysis, the extraction was performed according to Yurena *et al.* (2006) and Patric *et al.* (2006) with some modifications. The freeze-dried fruit samples were weighed and mixed with extract buffer (100 µg/ml Tris (2-carboxyethyl)-phosphine hydrochloride (TCEP-HCl), 3% MPA, 8% acetic acid and 1 mM ethylenediaminetetraacetic acid disodium salt (EDTA). The mixture was homogenized in a Virtishear homogenizer (Virtis, USA) in ice for 1 min. and then centrifuged at 10,000 rpm (refrigerated at 4°C) for 10 min. The supernatant was filtered through a 0.45 µm cellulose membrane and stored at -80°C until further use.

Determination of Antioxidant Activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) Free Radical Scavenging Assay

Scavenging activity of the fruit extracts on DPPH radicals was assayed according to Molyneux (2004) with some modifications. Various concentrations of the crude extracts in methanol were prepared to give

a final volume of 7 µl and were mixed with 280 µl of methanolic solution containing DPPH (Sigma, USA) radicals resulting in a final concentration of 0.06 mM. The mixture was vigorously shaken and left to stand for 30 min. in the dark. The absorbance was measured at 517nm and ascorbic acid (Sigma, USA) was used as the positive control. The assays were carried out in triplicate and the results were expressed as mean values ± standard deviations. The scavenging effect on DPPH free radicals was calculated as follows:

$$\text{Inhibition (\%)} = \frac{A_{Control} - A_{Extract}}{A_{Control}} \times 100\%$$

$A_{Control}$ is the absorbance of the control reaction (containing all reagents except the test compound), and $A_{Extract}$ is the absorbance of the test compound.

Determination of Total Phenolic Content

Total phenolic content of the extracts was estimated by a colorimetric assay as described by Singleton and Rossi (1965) with some modifications. Briefly, 50 µl of the crude extracts were mixed with 100 µl of Folin Ciocalteau's phenol reagent (Merck, Germany). After 3 mins, 100 µl of 10% sodium carbonate (Na_2CO_3) (Sigma-Aldrich, USA) was added to the reaction mixture and allowed to stand in the dark for 60 mins. The absorbance was measured at 725 nm and the total phenolic content was obtained from a calibration curve using gallic acid (0–10 µg/ml) as a standard reference. Estimation of the phenolic content was carried out in triplicate. The results were mean values ± standard deviations and expressed as mg gallic acid per 100 g samples. All procedures were carefully carried out with minimum exposure of light.

Determination of Total Flavonoid Content

Measurement of flavonoid concentration of the extracts was based on the method described by Kim *et al*. (2003) with some modifications. An aliquot of 100 µl of fruit extract was diluted with 400 µl of distilled water. Afterwards, 30 µl of 5% sodium nitrite ($NaNO_2$), (Sigma, USA) solution was added and allowed to react for 5 min. Following this, 20 µl of 10% aluminium chloride ($AlCl_3.6H_20$) (Sigma, USA) was added and left to stand for 5 min. Finally, 200 µl of sodium hydroxide (NaOH) (Sigma, USA) was added and the mixture was well-mixed with a vortex. All samples were analyzed in triplicate and the absorbance was measured immediately at 510 nm. Rutin (Sigma, USA) was used to calculate the standard curve and the results were expressed as mg rutin per 100 g samples.

Determination of Ascorbic Acid Content

The analysis was carried out using a Waters High Performance Liquid Chromatography (HPLC) system equipped with a Waters E600 pump controller and Waters 2996 PDA detector (Waters, USA) based on Yurena *et al*. (2006) Empowers software was used for controlling the analytical system and data processing. The separation was carried out on a symmetry C18 column (5 µm particle size, 250 × 4.6 mm I.D.) as a stationary phase with a symmetry C18 guard column. Detection wavelength was set at 200 to 700 nm of which the UV spectrum of ascorbic acid is 245 nm. The standard solutions and extract samples were filtered through a 0.45 µm nylon membrane before introduced onto the column through a Waters 717 plus autosampler. The mobile phase employed was a 25 mM phosphate buffer (pH 2.5) adjusted with orthophosphoric acid at 25°C. Flow rate of the mobile phase was 1 ml/min. and an injection volume of 10 µl was used for quantitative analysis. The commercial external standard, ascorbic acid was used to identify and quantify the level of ascorbic acid in the samples by comparing their spectral characteristics and retention time.

Determination of Proximate Composition

Protein, fat and ash contents were determined using the routine chemical analytical methods of the Association of Official Analytical Chemists (AOAC) official method (AOAC, 1984). Protein content was determined by weighing 0.2 g of homogenized sample into a Kjeldahl digestion flask of capacity 30–35 ml. Potassium sulphate (1.2 g), mercuric solution (1 ml) and concentrated sulphuric acid (2.5 ml) were added. The mixture was then heated on a top pan heater in a fume cupboard. After heating, 10 ml of alkali mixture was added, and the steam was passed through the apparatus until the volume of liquid was 50–100 ml. Finally, the liquid was titrated with 0.02 N HCl.

In the method described by Tee *et al*. (1986), fat content was determined by directly extracting 10–40 g of dried ground sample with 150 ml petroleum ether in a Soxhlet extraction apparatus. The residue in the extraction flask after solvent removal represented the fat content of the sample.

The ash content was determined by drying the homogenized sample in a dish in an oven at 130 °C for 24 h. The dried sample was charred until it ceased smoking. The dish was placed in a cold muffle oven until

the temperature reached 550 °C. Total ash content was obtained after the weight of the sample was constant.

The carbohydrate content was calculated by the formula: [100–(moisture+protein+fat+ash)]. Meanwhile, the energy was calculated as: Energy, kcal/100g = [Fat] × 9 + [Protein] × 4 + [Carbohydrate] × 4.

Determination of Mineral Content

Calcium (Ca), iron (Fe), potassium (K), magnesium (Mg) and zinc (Zn) content of the selected underutilised fruit species were determined using inductively coupled plasma-mass spectrometry (ICP-MS) according to AOAC official method (AOAC, 1990). The freeze-dried samples were sent to Technical Service Centre, MARDI for analysis.

Results and Discussion

Antioxidant Capacity of Selected Mangifera Fruit Species

Results of the antioxidant activity of the edible portions of selected underutilised *Mangifera* species are presented in Table 2. The antioxidant activity was determined by DPPH free radical scavenging assay (FRSA) which measures the ability of the extracts to scavenge the harmful free radicals. The results were compared to the popular mango, *M. indica*. Different *Mangifera* species were observed to have varying degrees of free radical scavenging activities. Two underutilised *Mangifera* species were found to exhibit higher FRSA as compared to *M. indica*. *M. caesia* was the strongest potential source of antioxidant as evidenced by its most active FRSA with 92.09 ± 0.22% radical inhibition or IC_{50} value of 8.14 ± 0.17 mg/ml. *M. longipetiolata* ranked second with 90.08 ± 0.15% radical inhibition or IC_{50} value of 8.33 ± 0.08 mg/ml. The antioxidant properties are inversely proportional to the IC_{50} values and values lower than 10 mg/ml are indicative of the effective antioxidant activity (Lee *et al.*, 2007).

Table 2. Free radical scavenging activity (FRSA) of selected *Mangifera* species as compared to *M. indica*

Species	% of inhibition at 15 mg/ml	IC_{50} (mg/ml)
Mangifera caesia	92.09 ± 0.22	8.14 ± 0.17
M. foetida	17.35 ± 0.10	43.22 ± 0.29
M. laurina	56.31 ± 0.03	13.32 ± 0.11
M. longipetiolata	90.08 ± 0.15	8.33 ± 0.08
M. odorata	37.19 ± 0.59	20.16 ± 1.31
M. pajang	19.77 ± 0.53	37.94 ± 1.29
M. pentandra	56.54 ± 1.36	13.27 ± 0.81
M. indica	73.44 ± 0.40	10.21 ± 0.32

Values are mean ± standard error mean (SEM) of mean of triplicate analyses; IC_{50}: inhibitory concentration at which 50% radicals are scavenged

Table 3 shows the total phenolic content (TPC), total flavonoid content (TFC) and ascorbic acid content (AAC) of the selected underutilised *Mangifera* species. From the results, *M. pajang* showed the greatest amount of TPC (7055.65 ± 101.89 mg/100g) as followed by *M. foetida* (2917.92 ± 155.35 mg/100g) and *M. caesia* (2637.35 ± 178.92 mg/100g). This is in accordance to Ikram *et al.* (2009) who reported that *M. pajang* and *M. foetida* showed higher TPC value than *M. indica*. It is also interesting to note that all the underutilised *Mangifera* fruits tested in this study demonstrated higher TPC than *M. indica*. Meanwhile, *M. caesia* was also observed to have the highest TFC (550.67 ± 19.78 mg/100g) as compared to other underutilised *Mangifera* species tested. This explained its strong free radical scavenging activity as mentioned earlier (Table 2). However, the TFC was not comparable to *M. indica*. Phenolics and flavonoids have been the main phytochemicals responsible for the antioxidant capacity of fruits. They are important for human health because of their activities as radical scavengers (Hertog *et al.*, 1993). On the other hand,

Table 3. Total phenolic content (TPC), total flavonoid content (TFC) and ascorbic acid content (AAC) of selected underutilised *Mangifera* species as compared to *M. indica*

Species	TPC (mg /100g)	TFC (mg/100g)	AAC (mg/100g)
Mangifera caesia	2637.35 ± 178.92	550.67 ± 19.78	270.22 ± 12.79
M. foetida	2917.92 ± 155.35	282.88 ± 71.75	122.13 ± 32.84
M. laurina	144.33 ± 23.88	176.71 ± 25.78	135.74 ± 30.33
M. longipetiolata	263.31 ± 35.53	129.11 ± 56.39	322.75 ± 32.55
M. odorata	257.17 ± 27.72	202.33 ± 32.19	47.32 ± 9.73
M. pajang	7055.65 ± 101.89	256.42 ± 17.52	403.21 ± 46.83
M. pentandra	676.24 ± 40.13	118.82 ± 24.83	400.94 ± 71.74
M. indica	125.21 ± 19.11	853.98 ± 24.53	125.23 ± 81.26

Values are mean ± standard error mean (SEM) of mean of triplicate analyses; TPC: total pehenolic content; TFC: total flavonoid content; AAC: ascorbic acid content

M. pajang was found to exhibit the highest AAC (403.21 ± 46.83 mg/100g) followed by *M. pentandra* (400.94 ± 71.74 mg/100g). Most of the underutilised *Mangifera* fruits were also shown to have higher AAC than *M. indica.* Ascorbic acid or commonly known as vitamin C is one of the important antioxidants found in fruits and important for human nutrition. The vitamin C content in *M. pajang* reported in the current study is also higher than the vitamin C content of oranges (171.4 mg/100g) (Mirfat *et al.*, 2009) and guava (322.33 mg/100g) (Mirfat *et al.*, 2010). Meanwhile, Yahia *et al.* (2011) demonstrated that oranges and guava had 142 mg/100 g and 270 mg/100g vitamin C content, respectively. These results, may therefore suggest that some of the underutilised fruits have strong antioxidant properties compared to the popular fruits.

Antioxidant Capacity of Selected Mangifera Fruit Species, Landraces and Commercial Clones

Table 4 shows the results of antioxidant capacity of selected of underutilised *Mangifera* species and their landraces and commercial clones collected from Yan, Kedah. It was observed that different fruit samples showed different trend in the antioxidant activity and properties. Even within the same species, the landraces and commercial clones were shown to exhibit great variability. From the results, the commercial clone *M. indica* var. Chokanan Arau showed the strongest antioxidant activity (95.29 ± 4.09%) as compared to other *Mangifera* species, landraces and commercial clones tested. Another commercial clone, *M. indica* var. Harumanis had the highest TFC (885.11 ± 19.82 mg/100g). On the other hand, *M. odorata* var. Kuini KL demonstrated the highest TPC (2688.24 ± 307.99 mg/100g). All these results are consistent with the earlier findings (Table 2 and 3) that *M. indica* fruit showed higher free radical scavenging activity (FRSA) and TFC as compared to *M. foetida* and *M. odorata.* The variation of the antioxidant capacity of the selected *Mangifera* species, landraces and commercial clones is in agreement with previous studies which reported that the variation of antioxidant properties of *Mangifera* are strongly affected by the type of fruit (species and variety within species) and cultivation conditions of the plant (environmental and cultivation techniques) (Ma *et al.*, 2011). Other contributing factors to the variations may be expected from different location, ripening stage, season (Kubola *et al.*, 2011), agronomical differences, genomics, method of extraction and standards used (Imeh and Khokhar, 2002).

Nutritional Constituents of Selected Mangifera Species, Landraces and Commercial Clones

Other than the antioxidant phytochemicals, fruits also provide other nutrients which are good for health. The proximate composition of selected *Mangifera* species, landraces and commercial clones was shown in Table 5. From the results, considerable differences were found among the fruit samples tested. The commercial clones of *M. indica* were revealed to be a good source of fat,

Table 4. Free radical scavenging activity (FRSA), total phenolic content (TPC) and total flavonoid content (TFC) of selected *Mangifera* fruit species, landraces and commercial clones collected from Yan, Kedah

Species/landraces/clones		FRSA (%)	TPC (mg /100g)	TFC (mg/100g)
Mangifera foetida				
Landraces	Lada	64.12 ± 2.11	916.77 ± 19.92	295.43 ± 0.48
M. odorata				
Landraces	Kuini KL	45.86 ± 5.6	2688.24 ± 307.99	568.16 ± 10.99
	Kuini KR	63.76 ± 1.32	722.75 ± 10.22	206.98 ± 42.5
M. indica				
Landraces	Ciku	41.00 ± 0.89	792.61 ± 13.21	111.16 ± 9.65
	Enam Kati	27.66 ± 1.25	774.94 ± 11.3	450.22 ± 12.16
	Paragon Bangkok	24.00 ± 6.77	902.88 ± 71.1	221.72 ± 1.55
	Pipi Merah	37.91 ± 2.23	799.98 ± 12.18	804.03 ± 16.73
	Sawa	22.45 ± 1.87	2140.92 ± 109.61	302.80 ± 10.76
	Tok Nus	47.49 ± 0.66	862.89 ± 12.45	479.71 ± 1.54
	Pedal Ayam	67.49 ± 1.45	813.66 ± 3.98	442.85 ± 17.87
Commercial clones	Chokanan Arau	95.29 ± 4.09	904.99 ± 11.32	30.07 ± 0.78
	Chokanan	68.82 ± 10.11	869.00 ± 17.91	155.38 ± 14.11
	Epal	45.27 ± 2.35	851.96 ± 46.11	575.53 ± 52.1
	Harumanis	22.58 ± 1.89	736.22 ± 9.87	885.11 ± 19.82
	Sala	42.32 ± 5.76	756.21 ± 61.12	442.85 ± 7.88

Values are mean ± standard error mean (SEM) of mean of triplicate analyses**;** FRSA: free radical scavenging activity; TPC: total phenolic content; TFC: total flavonoid content

carbohydrate and energy. *Mangifera indica* var. Sala contained the highest fat and energy with 2.21% and 421 kcal, respectively. Meanwhile, *M. indica* var. Chokanan Arau exhibited the highest carbohydrate content with 95.43% (Table 5). The contribution of energy content in fruits may come from fat, other than protein and carbohydrate (Umi Kalsum and Mirfat, 2014). The energy content of *Mangifera* species, landraces and commercial clones in this present study ranged from 312.04-421.00 kcal and was higher than that of avocado (145-198 kcal) and banana (81-185 kcal) (Yahia *et al.*, 2011). *Mangifera foetida* var. Lada was observed to have the highest ash content with 4.53%. Ash content is a direct indicator of the total amount of minerals present in fruits. The higher ash content may indicate the higher minerals in the fruits. Determination of the ash in foods is important for nutritional labelling, quality assessment, microbiological stability, nutrition aspect and processing (McClements and Decker, 2009). On the other hand, protein predominated in the *M. odorata* var. Kuini KL with 6.02%. Protein is also a major source of energy, as well as containing essential amino acids, such as lysine, tryptophan, methionine, leucine, isoleucine and valine, which are essential for human health (Umi Kalsum and Mirfat, 2014).

In addition to proximate, mineral composition is also important for reliable nutritional information and necessary to evaluate diets for nutritional adequacy. Minerals are also required for normal cellular function and provide additional protection to the human body. In this study, five selected major trace elements; calcium (Ca), iron (Fe), potassium (K), magnesium (Mg) and zinc (Zn) were determined (Table 6). Some of these minerals have a function in the mechanism of preventive defense against free radicals performed by antioxidant enzymes (Yahia *et al.*, 2011). From the results, both *M. pentandra* and *M. odorata* var. Kuini KR showed the highest Ca content with 140 mg/100 g. In addition, *M. pentandra* fruit species was also found to be the best source of potassium with 1930 mg/100g. This value is much greater than the popular potassium-enriched fruit, banana with only of 348-370 mg/100g (Yahia *et al.*, 2011). *M. caesia* and *M. pajang* which were earlier revealed to be good antioxidants had the highest Mg (130 mg/100 g) and Fe (7.31 mg/100g) content, respectively. Meanwhile, *M. foetida* showed the highest Zn content with 3.26 mg/100 g. The Fe and Zn content of *Mangifera* species, landraces and commercial clones in this study was notably higher than all the tropical and sub-tropical fruits tested by US Department of Agriculture (USDA,

Table 5. Proximate composition of selected *Mangifera* species, landraces and commercial clones collected from Yan, Kedah

Species/landraces/ commercial clones	Fat (%)	Ash (%)	Protein (%)	Carbohydrate (%)	Energy (kcal)
	(% dry basis)				
Mangifera caesia	0.82	2.25	4.12	75.35	325.21
M. laurina	0.33	2.44	1.89	80.55	332.72
M. pajang	0.28	2.38	3.24	74.15	312.04
M. pentandra	2.21	2.15	2.61	84.28	367.51
M. foetida					
Landraces					
Lada	0.43	4.53	3.43	91.43	383.29
M. odorata					
Landraces					
Kuini KL	1.22	2.48	6.02	89.71	393.87
Kuini KR	1.16	2.97	4.35	91.05	392.01
M. indica					
Landraces					
Ciku	0.59	1.58	3.06	94.43	395.29
Enam Kati	0.56	3.01	4.79	90.98	388.13
Paragon Bangkok					
Pipi Merah	0.28	1.87	2.75	87.74	364.48
Sawa	1.14	1.32	3.73	92.51	395.26
Tok Nus	0.68	1.70	2.46	94.15	392.54
Pedal Ayam	0.08	1.81	2.81	94.69	390.70
Commercial clones					
Chokanan Arau	0.78	1.76	1.72	95.43	395.66
Chokanan	0.29	2.95	4.07	92.37	388.37
Epal	1.02	2.14	2.79	93.09	392.75
Harumanis	0.97	1.87	3.26	93.49	395.73
Sala	6.08	1.79	3.58	87.99	421.00

2005). In particular, Fe and Zn content of the tropical and sub-tropical fruits ranged from 0.09-3.4 mg/100g and 0.06-0.64 mg/100g, respectively (Yahia *et al.*, 2011). The variations in the nutritional composition of these fruits may be attributed to maturity, climate, soil type, fertility and agricultural practices (Lee and Kader, 2000; Forster *et al.*, 2002). Even within a cultivar, there could also be large plant-to-plant and within plant variation in nutrient composition for fruit harvested from the same field (Shewfelt, 1990).

Conclusions

The present study indicates that underutilised *Mangifera* fruit species, landraces and commercial clones are potential sources of antioxidants and nutrition with some of them being even better than *M. indica* (mango) and other popular fruits. This information is also pertinent to help neglected species and varieties be valued for better health and nutritional status especially for rural and farm communities. More studies should be conducted to explore their functional and nutraceutical benefits. This study adds valuable information to the current knowledge of health and nutritional properties of the selected *Mangifera* species, landraces and commercial clones, serves as a guideline and selection criteria for their further consumption in diet and can inform potential product developments in the future.

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References

AOAC (1984) Official Methods of Analysis. 14th ed. (S Williams ed.). Arlington, VA: Association of Official Analytical Chemists. Washington DC, USA.

AOAC (1990) Official Methods of Analysis, 15th ed. Arlington, VA: Association of Official Analytical Chemists. Washington DC, USA.

Table 6. Major mineral composition of selected *Mangifera* fruit species, landraces and commercial clones collected from Yan, Kedah

Fruit sample	Ca	Fe	K	Mg	Zn
			mg/100g		
Mangifera caesia	30	4.85	1060	130	1.23
M. laurina	130	4.38	1040	100	1.21
M. longipetiolata	90	5.06	1600	130	1.69
M. pajang	70	7.61	1120	110	2.27
M. pentandra	140	3.27	1930	90	1.54
M. foetida					
Landraces					
Lada	110	4.04	1600	120	3.26
M. odorata					
Landraces					
Kuini KL	50	2.08	610	80	1.64
Kuini KR	140	4.26	660	70	2.76
M. indica					
Landraces					
Ciku	30	1.83	480	40	2.48
Enam Kati	30	2.28	830	80	2.26
Paragon Bangkok	90	1.76	860	60	1.11
Pipi Merah	40	3.22	540	60	2.13
Sawa	80	2.76	370	40	2.04
Tok Nus	40	3.47	470	50	2.90
Pedal Ayam	30	2.52	610	40	1.42
Commercial clones					
Chokanan Arau	40	3.56	450	40	1.89
Chokanan	50	3.44	980	60	2.79
Epal	70	2.04	580	40	2.19
Harumanis	40	2.22	470	40	1.41
Sala	50	2.47	530	70	2.13

Bompard JM and RJ Schnell (1997) Taxonomy and systematics. *In: RE* Litz (ed.) *The Mango: Botany, Production and Uses.* CAB International, Wallingford, UK.

de Menezes EW (2009) 7th International Food Data Conference: Food composition and biodiversity. *J. Food Compos. Anal.* **22**: 359-360.

Forster MP, E Rodriguez, JD Martin and CD Romero (2002) Statistical differentiation of bananas according to their mineral composition. *J. Agri. Food Chem.* 50: 6130-6135.

Hertog MGL, PCH Hollman and B Van de Putte (1993) Content of potentially anticarcinogenic flavonoids of tea infusions, wines and fruit juices. *J. Agri. Food Chem.* **41**: 1242-1246.

Ikram, EHK, KH Eng, AMM Jalil, A Ismail, S Idris, A Azlan, HSM Nazri, NAM Diton and RAM Mokhtar (2009) Antioxidant capacity and total phenolic content of Malaysian underutilized fruits. *J. Food Compos. Anal.* **22**: 388-393.

Imeh U and S Khokhar (2002) Distribution of conjugated and free phenols in fruits: Antioxidant activity and cultivar variations. *J. Agri. Food. Chem.* **50**: 6301-6306.

Kim D, O Chun, Y Kim, H Moon and C Lee (2003) Quantification of phenolics and their antioxidant capacity in fresh plums. *J. Agri. Food. Chem.* **51**: 6509-6515.

Kim Y, AJ Lounds-Singleton and ST Talcott (2009) Antioxidant phytochemical and quality changes associated with hot water immersion treatment of mangoes (*Mangifera indica* L.). *Food Chem*. **115**: 989-993.

Kostermans AJGH and JM Bompard (1993) *The Mangoes: Their Botany, Nomenclature, Horticulture and Utilization.* Academic Press Limited, London.

Kubola J, S Siriamornpun and N Meeso (2011) Phytochemicals, vitamin C and sugar content of Thai wild fruits. *Food Chem.* **126**: 972-981.

Lee YL, Y Ming Tsung and JL Mau (2007) Antioxidant properties of various extracts from *Hypsizigus marmoreus. Food Chem.* **104**: 1-9.

Lee SK and AA Kader (2000) Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biol. Tech.* **20**: 207-220.

Liu S, JE Manson, IM Lee, SR Cole, CH Hennekens, WC Willett and JE Buring (2000) Fruit and vegetable intake and risk of cardiovascular disease: The women's health study. *Am. J. Clin. Nutr.* **72**: 922-928.

Ma X, H Wu, L Liu, Q Yao, S Wang, R Zhan, S Xing and Y Zhou (2011) Polyphenolic compounds and antioxidant properties in mango fruits. *Sci. Hort.* **129**: 102-107.

Mau JL, HC Lin and CC Chen (2002) Antioxidant properties of several medicinal mushrooms. *J. Agri. Food Chem.* **50**: 6072-6077.

McClements DJ and EA Decker (2009) *Designing Functional Foods.* Woodhead Publishing, Cambridge, UK.

Mirfat AHS, I Salma and M Razali (2009) Ceri Terengganu: Potential source of antioxidant for health benefits. Proceedings of National Conference on New Crops and Bio-resources 2009, 15–17 December 2009, The Royale Bintang Resort & Spa Seremban, Negeri Sembilan, Malaysia, 302 p.

Mirfat AHS, I Salma and M Razali (2010) Evaluation of antioxidant properties and mineral contents of selected underutilized fruits in Malaysia. The 2nd International Biotechnology and Biodiversity Conference, 6-8 July 2010, Johor Bahru, Johor, Malaysia, 97 p.

Molyneux P (2004) The use of the stable free radical diphenylpicryl-hydrazyl (DPPH) for estimating antioxidant activity. *Songklanakarin J. Sci. Technol.* **26:** 211-219.

Patric F, K Tamara and H Olivier (2006) HPLC-UV determination of total vitamin C in a wide range of fortified food products. *Food Chem.* **94**: 626-631.

Salma I, A Mohd. Nor, H Masrom and ML Raziah (2006) Diversity and use of traditional fruit species in selected home gardens or fruit orchards in Malaysia. *J. Trop. Agric. Food. Sci.* **34**: 149-164.

Shewfelt RI (1990) Sources of variation in the nutrient content of agricultural commodities from the farm to the consumer. *J. Food Quality.* **13**: 37-54.

Singleton VL and JA Rossi (1965) Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *Am. J. Enol. Vitic.* **16**: 144-158.

Stadlmayr B, E Nilsson, B Mouille, E Medhammar, B Burlingame and UR Charrondiere (2011) Nutrition indicator for biodiversity on food composition–A report on the progress of data availability. *J Food Compos. Anal.* **24**: 692-698.

Tee ES, S Siti Mizura, R Kuladevan, SI Young, SC Khor and SK Chin (1986) Laboratory procedures in nutrient analysis of foods. IMR Kuala Lumpur.

Umi Kalsum HZ and AHS Mirfat (2014) Proximate composition of Malaysian underutilised fruits. *J. Trop. Agric. Food. Sci.* **42**: 63-72.

USDA (2005) U.S. Department of Agriculture, Agricultural Research Service. 2005. USDA National Nutrient Database for Standard Reference, Release 18. Nutrient Data Laboratory Home Page, http://www.nal.usda.gov/fnic/foodcomp.

Yahia EM, J De Jesus Ornelas-Paz and GA Gonzalez-Aguilar (2011) Nutritional and health-promoting properties of tropical and subtropical fruits. In: EM Yahia (ed.) Postharvest Biology and Technology of Tropical and Subtropical Fruits. Woodhead Publishing Series in Food Science, Technology and Nutrition, Cambridge UK, pp 21-78.

Yamanaka N, H Masrom, HX Dong, H Tsunematsu, I Salma and T Ban (2006) Genetic relationship and diversity of four *Mangifera* species revealed through AFLP analysis. *Genet. Resour. Crop Evol.* **53**: 949-954.

Yurena HM, L Gloria and G Mo´nica (2006) Determination of vitamin C in tropical fruits: A comparative evaluation of methods. *Food Chem.* **96**: 654-664.

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Fruit Diversity Fair and On-farm Conservation–An Indian Experience

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As many as 18 diversity fairs were organised on *Mangifera, Citrus* and *Garcinia* species during the last five years in five sites selected in India with the objectives of creating public awareness about tropical fruit tree (TFT) diversity, using it as a participatory tool for locating trait specific indigenous varieties and to enable marketing the diversity. The research questions revolved around the methodology used for organizing the diversity fairs, display of rich diversity by the farmers and success/failure of diversity fair (DF) in locating the trait specific variety among the vast diversity. The diversity fairs also provided a platform for discussion on linking farmers to market, recognizing the custodians of diversity by honouring them and distribution of elite grafts and harvesting tools. Mango was prominent with more number of diversity fairs as well as identification of varieties in four of the five sites. In case of *Citrus*, Amravati and Pusa organized diversity fairs whereas Sirsi organized *Garcinia* diversity fair as three species of *Garcinia* were located in this site. The success of the diversity may be judged by the indicators such as number of varieties characterized and evaluated, number of varieties registered/sent for registration, number of varieties linked to market, value addition possibilities implemented based on the diversity fair besides meeting the primary objectives of creating awareness and locating the trait specific diversity.

Key Words: Diversity Fair, Conservation, Indigenous variety, Sustainable use

Introduction

Diversity fair is considered a good practice among diverse actors in a wide range of geographical and institutional settings as it provides a good forum that over time and space maintains, enhances and creates crop genetic diversity and ensures their availability to and from farmers and other actors for improved livelihoods on a sustainable basis. Although the diversity fair is started as a popular tool for raising public awareness on the value of conserving local landraces (Tapia and Rosa, 1993), it is now used for many different purposes.

Diversity fairs are organised for different purposes such as creating awareness about diversity in landraces, promoting exchange of knowledge and seed and planting materials amongst farmers (Adhikari *et al.*, 2012; Sthapit *et al.*, 2003), recognition of diversity/custodian farmers, locating trait specific indigenous varieties, identifying the elite materials using characterisation and evaluation and to link diversity to markets. A tropical fruit tree (TFT) project on "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihood, Food Security and Ecosystem Services" has been in operation in four Asian countries *viz.* India, Indonesia, Thailand and Malaysia for the last five years. As part of the project, 18 diversity fairs were organized in the five project sites [Amravati in Maharashtra, Malihabad in Uttar Pradesh, Pusa in Bihar, Chittoor in Andhra Pradesh and Sirsi in Karnataka] in India on *Mangifera, Citrus* and *Garcinia* species. It would be useful to analyze success or failure of these fairs in achieving the objectives. With this background, a study was taken up to document the Indian experience in organising fruit tree diversity fairs.

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Material and Methods

A total of 18 diversity fairs were organised [mango (13), citrus (4), and garcinia (1)] at different sites over a period of five years under the TFT project "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihood, Food Security and Ecosystem Services". The diversity fairs were organized at different places for creating awareness about the prevailing diversity, exchange of produce (fruits/products) and planting material, locating trait specific indigenous varieties, linking the farmers to markets, distribution of elite planting materials developed at the research organisations to the farmers, promote characterisation, evaluation and at a later stage, registration of varieties with PPV & FRA.

Organizing the Diversity Fair

The main steps in organising the diversity fairs include:

i. Conduct focus group discussion (FGD), four cell analysis (FCA), resource mapping and baseline survey to assess fruit tree diversity (genetic and species)

ii. Ascertain the available diversity in the respective communities of the sites, hold discussions with the groups to decide the venue, material to be displayed, timing and other logistics of the diversity fair.

iii. Plan and implement the event with participation of local institutions, research organisations, development departments, non-governmental organisations (NGO), Krishi Vigyana Kendra (KVK) etc.

iv. Display of farmers' diversity, followed by stake-holders' meeting.

Normally, the diversity fairs coincided with the harvesting of fruits enabling display of maximum number of varieties. In majority of the cases, diversity fair involved showcasing the diversity of the targeted crops by the community and a stakeholders' meeting involving research scientists, horticulture/agriculture department, KVK, NGO and traders. The event also helped to identify farmers who hold unique and diverse material and provided opportunity to recognize and honour such farmers. Sthapit *et al.* (2003) report that diversity fairs in the region get incorporated into conventional fairs and farmers are recognized for conserving maximum diversity and are awarded prizes. Distribution of superior planting materials, implements like fruit harvesting tools and fruit fly traps (mango), marketing of diversity also took place in these fairs.

Results and Discussion

Crop-wise Diversity Fairs

A total of 18 diversity fairs were organized across five selected sites in India. Crop wise and site wise break up of this is presented in Table 1. As may be seen from the table, 13 diversity fairs were organised for mango alone, 4 for citrus and only one for *Garcinia* species. Further, it is interesting to note that four of the five sites organized mango diversity fairs and Amravati (Mandarins) and Pusa (Pummelo) sites organized citrus diversity fairs. Only site *i.e.* Sirsi where *Garcinia* diversity was located could organize one diversity fair for *Garcinia* species.

Participation and Display of Diversity by the Farmers

A number of species and varieties were displayed during the different diversity fairs. The list of such fairs, participation of farmers and the diversity displayed are presented in Table 2. The results are discussed species wise *i.e. Mangifera, Citrus* and *Garcinia*.

Mango

Mangifera was the most dominant species which found place in four of the five sites in India and as many as 13 diversity fairs organized with different objectives. As regards the display of diversity and participation of farmers also, mango was prominent. The display of varieties ranged from 28 varieties to as high as 460 varieties. Further, it is interesting to note that a large number of farmers also participated in the diversity fair while displaying their mango diversity. The diversity fairs were organized at national level as well as at the village level to locate the mango diversity over time and

Table 1. Species/crop wise diversity fairs organized by the sites in India

Sites	Crop-wise No. of Diversity Fairs			Total
	Mango*	Citrus**	Garcinia	
Amravati	-	3	-	3
Chittoor	4	-	-	4
Malihabad	5	-	-	5
Pusa	1	1	-	2
Sirsi	3	-	1	4
India	13	4	1	18

* at Sirsi site, diversity fairs focusing on aromatic pickle mango (*Appemidi*) was conducted.

** At Pusa site, diversity fair focusing on Pummelo was conducted

Table 2. List of diversity fairs organized by different sites, diversity displayed and participation of farmers

Sites	Name of Diversity Fair	No. of species/varieties displayed	No. of farmers displaying diversity	No. of farmers visiting DF
Amravati	Citrus diversity fair in NEH Region (Tura, Meghalaya), October 24, 2010	15 species 19 varieties	65	200
	Citrus Diversity Fair in Central India, Warud, India), March 8, 2013	10 varieties and 8 species	72	620
	National Citrus diversity fair in Central India at Nagpur, Maharashtra October 30-31, 2014	22 species 105 varieties	70	1145 and 98 students
Chittoor	Mango diversity fair and Stakeholders' meeting in Chittoor, June 7, 2014	125 varieties	145	200
	Mango diversity fair and Stakeholders' meeting in Bangalore, June 3, 2014	460 varieties	118	140
	Mango diversity fair, Chittoor, June 13, 2011	78 varieties		200
	Mango diversity fair, Bangalore, May 30,2010	125 varieties		400
Malihabad	Community fruit diversity fair, Kasmandi Kalan, June 18, 2011	235 varieties	300	
	All India Mango Show during Global Conference on Augmenting Production and Utilization of Mango in Emerging Scenario of Biotic and Abiotic Stresses, Lucknow, June 21- 23, 2011	250 varieties	50	
	Mango exhibition at Kasmandikalan, July 22, 2012	425 varieties	300	
	Pickle making competition from different varieties, July 2013.	83 varieties	42	
	Custodian Farmers' Workshop at Lucknow, June 28-29, 2014	600 varieties	150	
Pusa	Mango diversity fair, Samastipur, July 4, 2013	147 seedling types	176	235
	Citrus Biodiversity fair, Mahamda, November 5, 2011	9 species 127 types	109	260
Sirsi	Diversity Fair of *Garcinia indica*, College of Forestry, SIRSI, May 8-9,2010	45 varieties of mango, 5 species of Garcinia	40	150
	Diversity Fair of Wild- Pickle Mango, College of Forestry, SIRSI, April 9,2011	150 *Appemidi* types	61	380
	Diversity Fair of Tropical fruits, on the occasion of National Symposium on "People and Forestry". May 29,2012	35 varieties of mango, 48 species	24	129
	Village level diversity fair at Menasi (Sunkkatti) hamlet in association with Dhan Foundation, June 10, 2014	28 varieties of mango	15	65

space. While the mango diversity of 250 varieties were showcased at the All India mango show in Delhi, about 460 varieties were displayed at the mango diversity fair in Bangalore. It is to be noted that while the sole objective of mango fair in Delhi was showcasing the rich mango diversity to create awareness i.e. to let the public/consumers know that a vast range of diverse mango fruits were available to meet the needs and tastes of a variety of consumers .

The objective of fair organised in Bangalore was not only to create awareness about the rich mango diversity, but also to bring scientists and farmers face to face to understand the problems associated with the mango diversity and its maintenance. But, the interesting part of the diversity fair is about locating the trait specific diversity of indigenous mangoes. The diversity fairs conducted at Chittoor (2011, 2014), Malihabad (2011, 2013), Pusa (2013) and Sirsi (2011) focused on specific types of diversity. Indigenous varieties in Chittoor, pickling types in Malihabad, seedling types in Pusa and aromatic pickle mango types in Sirsi. Aromatic pickle mango varieties (*Appemidi*) are very unique, provided with Geographic Indication (GI) tag, and have a deep cultural value associated with communities in the Western Ghats. Display of over 150 types of *Appemidi* types collected by the farming communities had huge impact on popularizing these unique and rare types. It is also interesting to note that the communities were empowered to organize the diversity fairs on their own which reflects on the capacity building part of the project. The diversity fair organized by farmers of Kasmandi Kalan is a case in point.

Citrus

In the citrus diversity fair organized at Tura, Meghalaya, 15 species and 19 varieties of *Citrus* were displayed and farmers from Amravati site participated in the fair. The farmers from Amravati site for the first time were exposed to the vast array of diversity present in *Citrus* species. One of the objectives was to send a strong message to the Amravati farmers who are facing the threat of genetic erosion as they are dependent on only one species *i.e. Citrus reticulata* and also to motivate them to conserve the citrus diversity for their livelihood. The other diversity fair at the Amravati site was to create awareness at the community level and also exchange of superior rootstocks for posterity. One mega citrus diversity fair at National level was organized at NRCC, Nagpur where a total of 105 varieties of citrus belonging to mandarin (15), sweet orange (22), acid lime (7), grapefruit (8) pummelo (10), lemon (5), wild species (4), rootstocks (35) were displayed at the site. As many as 1145 farmers and 98 students from 3 colleges of Nagpur visited the fair.

An exclusive diversity fair on Pummelo was organized at Mahamda community in Pusa site and 127 types of pummelo and as many as 8 species of citrus were displayed. The pommelo types were later evaluated for elite types. Subsequently, 13 pummelo types were selected for multiplication and distribution to the community.

Garcinia

The only site where *Garcinia* diversity was located was in Sirsi, in the Western Ghats. Three species *Garcinia indica, G. gummi-gutta* and *G. morella* were identified in the different communities of Sirsi site. A specific variant of *G. indica*, yellow morpho-type (popularly called as 'bili murugalu' in Kannada) was the most popular among the local healers and Ayurveda. About 25 products prepared out of *Garcinia* were displayed at the fair. This was the first ever large scale diversity fair on *Garcinia*. A large number of stakeholders of *Garcinia* growers/gatherers/users were provided with an opportunity to exchange their views.

Involvement of Other Agencies

The involvement of policy makers such as National Horticulture Board (NHB), National Bank for Agriculture and Rural Development (NABARD), development departments like State Horticulture/Agriculture Departments (SHD, SAD), research organisations like Indian Council of Agriculture Research (ICAR), State Agriculture/Horticulture Universities (SAU), nursery men, custodian farmers, extension agencies like Zonal Project Directorates (ZPD), KVK and NGO become crucial in taking forward the outcomes of the diversity fairs. Accordingly, the involvement of these agencies was observed in all the diversity fairs organised by different sites. Social learning happens in such fairs as the participant farmers benefit by direct social interaction with many groups of people to share information and gain access to new planting materials. They learn of each other, NGOs, government departments and research organizations (May *et al*., 2014).

Recommendations of Diversity Fairs

The species wise recommendations/ requirements/ suggestions of the farmers are discussed below:

Mango

The diversity fairs on mango organized by different sites resulted in showcasing the huge diversity available at the community levels, exchange of the elite planting materials, identification of indigenous varieties (Chittoor), different *Appemidi* types (Sirsi), seedling diversity (Pusa and Malihabad), requirements of the farmers for maintaining and promoting diversity. The diversity fairs also facilitated the need to further evaluate the indigenous types for various desirable traits. For example, the seedlings of Dhobgama had the sweetest taste and they also possess the late bearing habits (September).

Broad suggestions emerging are:

- Multiplication of farmers' varieties and their distribution among the other community farmers
- The farmers of Sirsi site required capacity building programmes on pickle making from *Appemidi* mangoes.
- Farmers also wanted literature and training on plant propagation, plant protection and linkage with the markets especially for indigenous and seedling types.
- Creation of *in situ* conservation areas for wild aromatic pickle mango through a policy
- Establishment of network of grafting experts for promoting diversity conservation and popularization of *Appemidi* in non-traditional areas
- Popularization of local varieties of fruit-mango

- Diversity fairs should be an annual event
- Recognition to the progressive farmers who maintain high diversity and awarding them
- Policy environment for the registration of the varieties – Fee structure for registration of varieties and benefits to the farmers by registration of their varieties
- Besides, farmers demanded introduction of new fruit species like Custard Apple (Annona) and Cashew in Chittoor, plant protection trainings in Malihabad and Chittoor, value addition possibilities from mango diversity of the region (Pusa, Sirsi, Chittoor and Malihabad).

Citrus

- Development and distribution of better rootstocks like *Alemow* for mandarins and better lime and pummelo varieties
- Training on preparation of value added products (RTS beverage, *Santra Burfi*, Orange Squash, RTE Slices of pummelo) from different citrus species–Nagpur Mandarins, Pummelo, lime, sweet orange
- Linking Pommelo farmers to market

Garcinia

- Trainings on hygienic processing of *Garcinia* products through self-help groups, Village Forest Committees, *etc*.
- Strengthen association between industries and producers
- Awareness on medicinal importance of *Garcinia* species must be enhanced among farming communities and in the metropolitan cities.
- Driers should be provided to all the farmers to dry the rinds of especially *Uppage* (*Garcinia gummi-gutta*)
- Documentation of important Garcinia resources of Western Ghats should be done.
- Popularize the use of *Garcinia* based value added products like butter, kokum juice/concentrate, candles. Since the *Garcinia* species is still under domestication by the farmers, more than the diversity of species, product diversity should be focused. Awareness on medicinal importance of *Garcinia* species must be enhanced among farming communities and in the metropolitan cities.

Success Indicators

A diversity fair (DF) may be considered a success if it meets the objectives with which it was organised. Considering this criterion, though, on the whole, the diversity fairs were able to meet the objectives; it would be naïve to say that all of them were successful. While creating awareness and locating trait specific diversity were the primary objectives of diversity fairs (Sthapit *et al.*, 2003), characterization and evaluation of identified indigenous varieties, linking the diversity to market, value addition to diversity and registration of varieties are crucial to declare diversity fair a success. While all the diversity fairs fulfilled the primary objectives, only a few of them were successful in enabling registration of varieties, linking the diversity to markets and facilitating value addition possibilities to diversity. While a good number of mango varieties were registered or sent for registration only one citrus variety and none of the *Garcinia* species was sent for registration. Further, as regards market linkage and value addition, road side stalls for sale of indigenous mango varieties (Chittoor), distant market sale of pummelo (Pusa), formation of Society for Conservation of Mango Diversity (SCMD) in Malihabad, value addition to Nagpur mandarin – *Satpuda Santra Burfi* (GI) in Amravati, value added garcinia products like kokum juice, butter, candles from seed, HCA in Sirsi site are to be noted.

Efforts were made in the project to address the concerns of the farmers of different communities and as a result, publications were brought out and distributed to the communities, need based training programmes were organized for conservation of diversity, plant protection, organic cultivation of mango, value addition to mango, citrus and garcinia fruits (Table 3), initiatives on linking farmers' varieties to market, formation of groups and capacity building etc. It is to be noted that the number of training programmes and the aspects covered are almost on par with the requirements and these programmes enabled the community farmers to organize the diversity fairs themselves in Malihabad, Sirsi, Pusa sites.

Publications: Important outcomes based on the recommendations of DF are the publications like National Fruit Catalogue, Custodians of fruit tree diversity, Appeyemba Aparanji (Kannada), Custodian Farmers' Workshop Proceedings, Flyers, TK documentation, Technical Bulletins.

Table 3. Number of training/workshops organized based on the recommendations of diversity fairs

Sites	No. of trainings/ interaction meeting	Aspects covered
Amravati	12	Management of Mrig and Ambia crop of Nagpur mandarin Production of disease-free planting material of Citrus. Identification of Citrus Rootstock, Mother Block Development Product Development from Local Fruit Diversity and Their Marketing - Squash, *Satpuda Santra Burfi* Good practices
Chittoor	12	1. Disease and pest control in mango Organic farming in mango 2. Sensitization workshop on "Mainstreaming of mango biodiversity, September 30, 2014
Malihabad	4	1. Organizing diversity fair 2. Harvesting, ripening and packaging of mango 3. Value addition in mangoesPropagation of mango varieties
Pusa	8	Pickle making from Seedling mango for Value Addition' Propagation methods in Mango and Pummelo '*Good Agricultural Practices'* (GAPs) for Mango diversity, livelihood and ecosystem services"
Sirsi	25 +	Grafting Techniques, Garcinia products – Jam, Candles, Butter extraction Good practices and marketing

Linking of Farmers to Market: Formation of SCMD in Malihabad, linking of indigenous mango varieties with markets through Roadside Stalls in Chittoor and distant market sale of Pummelo fruits in Hyderabad are some of the marketing initiatives taken based on the suggestions of the diversity fairs.

Value Addition Possibilities: Some of the value addition possibilities explored are pickle making from *Appemidi* by SHGs in Sirsi, from *Sukul* mango in Pusa, from indigenous varieties in Malihabad, juice making from indigenous mango varieties like *Atimdhuram* and blending in Chittoor, Preparation of *Satpuda Santra Burfi* in Amravati.

Conservation of Diversity: Steps were taken for conserving the fruit tree diversity and among them, formation of network of grafting experts leading to conservation of elite *Appemidi* mangoes in Sirsi, establishment of diversity blocks in Sirsi, establishment of diversity parks in Chittoor, participation of custodian farmers and awareness creation about mango diversity conservation are noteworthy.

Capacity Building: Capacity building was one of the requirements of the farmers who participated in the diversity fairs and efforts were made in this direction in the form of formation of groups and financial transaction, empowering the farmers to organize the diversity fairs at community level, exposure visits and participation in diversity fairs organized in other sites enabling cross learning and interaction meetings with custodian farmers, scientists, traders, NGO.

Recognition of Custodians: Farmers were recognized for their efforts in maintaining and promoting diversity conservation in the form of awarding them with certificates, prizes, taking them on exposure visits to Workshops in India and Thailand.

Identification, Characterization and Registration of Indigenous/Farmers' Varieties

The most crucial aspect of follow up of diversity fairs recommendations is identification of indigenous types, characterization and evaluation of elite types for specific traits and finally registration of varieties. The details are given in Table 4.

Table 4. Number of indigenous varieties identified, characterized and registered across sites

Sites	No. of indigenous varieties identified	No. varieties characterized	No. of varieties registered/sent for registration
Amravati	Mango (12), Citrus (8)	Mango (12), Citrus (8)	2, 1
Chittoor	Mango (44)	Mango (38)	10
Malihabad	Mango (42)	Mango (42)	37
Pusa	Mango (17), Pummelo (13)	Mango (17), Pummelo (13)	15, 0
Sirsi	Mango (52), *Garcinia* (3)	Mango (52), *Garcinia* (2)	4, 0

Identification and characterization of indigenous varieties, the success may be rated high. However, with respect to registration of evaluated varieties, the success rate may be a bit lower. It may be noted at this juncture that the stringent procedures and guidelines required for registration with PPV & FRA acted as a stumbling block in the process of registration of farmers' varieties. This calls for introducing flexibility in the registration norms.

Conclusions and Recommendations

Mango was prominent both in terms of number of diversity fairs and also the number of varieties displayed. Some of the lessons learnt over time and space were overcoming the problems of logistics to bring farmers, arrange the display of good diversity, timing of the diversity fairs and involvement of the other agencies while organising the diversity fairs. May *et al.* (2014) suggested, after an exhaustive literature review, that gender consideration-participation of women in diversity fairs, timing of diversity fairs – which may be optimized with prior consultation and discussion with farmers and involvement of custodians, development department and policy makers for improved social interactions and promoting conservation of diversity on sustainable basis are the important lessons learnt while organising the diversity fairs. Useful suggestions/recommendations of the diversity fairs are followed up with implementation to a larger extent. The success of the diversity fairs may be judged by the indicators such as number of varieties identified, characterized and evaluated, number of varieties registered/sent for registration, number of varieties linked to market, value addition possibilities implemented based on the diversity fairs besides meeting the primary objectives of creating awareness about diversity and locating the trait specific diversity. There is ample scope for fine tuning the organization of diversity fairs. One of the roles of diversity fairs of identifying the custodians of diversity was effectively demonstrated and supporting these diversity conservers with a policy would strengthen the diversity conservation efforts. Further, though the objective of diversity fairs was not registration of varieties, it is to be mentioned here that the diversity fairs in India facilitated registration of some of the evaluated elite varieties despite stringent procedures and there is a need to introduce flexibility in registration norms.

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References

Adhikari Anu, R Rana, R Gautam, A Subedi, MP Upadhyaya, P Chaudhary, D Rijal and B Sthapit (2012) Diversity fair: promoting exchange of knowledge and germplasm. In: B Sthapit, P Shrestha and M Upadhyay (ed) *On-farm Management of Agricultural Biodiversity in Nepal: Good Practices*, NARC/ LI-BIRD/Bioversity International, Nepal.

May C, S McClelland, H Scrafford and K Safarli (2014) *Seed and Diversity Fairs–A Literature Review*, Cornell University, USA.

Sthapit B, D Rijal, NN De and D Jarvis (2003) A role for diversity fairs: experiences from Nepal and Vietnam In: CIP-UPWARDS 2003 (ed). *Conservation and Sustainable Use of Agricultural Biodiversity: A Source Book* Vol II: Strengthening Local Management of Agricultural Biodiversity. International Potato, pp 271-276.

Tapia, ME and A Rosa (1993) Seed fairs in the Andes: A strategy for local conservation of plant genetic resources. In: de Boef W Amanor, K Wellard and A Beddington (ed) *Cultivating Knowledge: Genetic Diversity, Farmer Participation and Crop Research*. IT Publications, UK, pp 111-118.

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Diversity of Tropical Fruits in the Farmlands of Central Western Ghats, India and its Contribution to the Household Income

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Diversity of tropical fruit tree (TFT) species, their occurrence and relationship with cultivated species in home-gardens and their use by humans has rarely been studied systematically in Central Western Ghats. Among all the nine villages sampled in three bioclimatic zones, a total of 10,202 individuals belonging to 55 species were recorded. *Mangifera indica* was the predominantly (n=4,496) found TFT species in the home-gardens and farmlands of Uttara Kannada district. Richness was highest in up-ghat zone (10.92) and substantial lower in coastal zone (5.95) and lowest in eastern plains (4.04). Major factors contributing to low richness is the increasing replacement with exotic commercial crops (cashew) in coastal zone and the low rainfall and varied climatic conditions in eastern zone. Villages of the up-ghat zone, on an average, showed richness index of 10.92 while its value reduced nearly by half when villages of the coastal zone were considered (5.95). The lowest average richness index was found among the villages of the eastern plains (4.04). Overall, nearly one third of all TFT species (36.36 per cent) were non-native to the Western Ghats which was similar in all three zones. However, non-native trees were dominant in coastal zone (54.96%) and less prominent in up-ghat (31.58%) and eastern zone (13.42%). Average family income derived from TFT was Rs 9.595 in coastal zone, Rs 4.207 in up-ghat zone and Rs 10,591 in eastern zone. Contribution of native and non-native TFT species to total household income is low in all three zones, highest contribution was measured in eastern zone (8.18% of the total family income) and coastal zone (7.56%) and even lower in up-ghat zone (2.27%). Correlation analysis showed a positive relationship between diversity and total household income. Regression analysis showed that total family income postivily contributes to the level of TFT diversity found on farmlands, this contribtion was most significant in coastal and up-ghat zone.

Key Words: Central Western Ghats, Household Income, Tropical fruit diversity

Introduction

Tropical Fruit Tree (TFT) species are intricately associated with the culture of peoples, their livelihoods and food security in South, South-east and East Asia. A rich diversity of over 500 species of TFT, of which about 90% are perennial, found in this region provide for a broad range of livelihood options to local people in the form of food supplements, better nutrition, household income and employment (Bhag Mal *et al*., 2011). Several TFT species are also used for their medicinal value, as timber and as livestock fodder. It is a well-established fact that biodiversity conservation and the maintenance of associated ecosystem services are vital for human well-being (Beaumont *et al*., 2011). TFT species provide vital forest products that are important for rural livelihoods and play a crucial role in forest eco-systems as forage crop for animals. The Asian fruit production system ranges from collecting/gathering of fruit from forest to well-developed home-gardens to intensive commercial plantations. Home-gardens are the most prevalent production system for cultivated fruits in Asia (Anupunt *et al*., 2002). The diversity of tropical fruits is also higher in India because of the affinity to grow variety of fruits in home-gardens and marginal lands (Ajay and Pratap, 2009).

Being a part of the central Western Ghats of India, Uttara Kannada district in Karnataka has some striking diversity of TFT species (Vasudeva *et al*., 2011). The district falls under tropical belt of rich forests well suited for diverse wild fruit yielding trees (Varadaranganatha and Madiwalar, 2010; Bhat and Ravindranath, 2011). TFT species are also found commonly in home-gardens and

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planted around home-gardens as well as in farmlands. As various analyses and summary reports have repeatedly indicated (Kumar and Nair, 2004), food plants (food crops and fruit trees) are the most common species in most home-gardens throughout the world. Farming communities and rural settlements of Uttara Kannada district have an age old history of maintaining home-gardens (Bhat and Ravindranath, 2011) and well known for deriving livelihood means from diversified sources. Growing TFT species has been a part of the culture of the farming communities. However, diversity and composition of TFT species and its relationship with family income has rarely been studied systematically in the central Western Ghats. Community management of TFT resources is being addressed under the GEF-UNEP project titled "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 (Sthapit *et al.*, 2013).

Material and Methods

The study was carried out during 2012-13 to assess the patterns of tropical fruit tree species (TFT) diversity in home-gardens and farmlands as well as to assess the extent of contribution of TFT to the livelihood of local farming community of Uttara Kannada district, Karnataka. The district lies between 14°71' N latitude and 74°78' E longitude. Study area was divided into three bio-climatic zones *viz*., coastal, up-ghat and eastern plains based on following Pascal (1984).

The coastal zone is characterized by fairly level lands almost at the sea level with an altitude of 20-300 m above Mean Sea Level (MSL). The major soil types in this zone are red clay loam, red lateritic soils and coastal alluvial soil in thin narrow strips; the soils are yellowish brown, brown to grey and acidic in nature. The area receives on an average annual rainfall of 3537mm. The up-ghat bioclimatic zone falls in the crest-line of the Western Ghats and receives an average annual rainfall of around 2800 mm and situated at an altitude of around 650 m. The major soil types in the up-ghat zone are red lateritic, loam, sandy loam to clayey. The mean maximum temperature ranges from 25-32^{0}C. Evergreen and semi-evergreen formations are fragmented in the crest-line of the Ghats. The eastern plain area lies in the eastern part of the district with an elevation of 550 to 650 m. The major soil types in this zone are clay loams. The area receives on an average annual rainfall of 922 mm. The mean maximum temperature ranges from 26.6-38.6°C.

Three typical villages in each of the three distinct bioclimatic zones namely Marugadde, Devgiri and Kotakhanda in coastal; Nilkunda, Chavatti and Bisgod in up-ghat and Kalakardi, Santholli and Koppa in the eastern plain region are included in the study. The background information on altitude, soil types and weather data of the Uttara Kannada district was collected by visiting the district statistical office. Geo co-ordinates of the village were recorded through GPS (Global Positioning System). Table 1 and Fig. 1 show the latitude, longitude, and climatic details of the focal villages selected for the study under different bio-climatic zones of Uttara Kannada district.

In every village 25 households were selected representing all the three sections of farmers on the basis of land-holding (Smallholder farmer = <0.88 hectare land; Medium farmer = 0.88-2 hectares land; Large farmer = >2 hectares land). Hence the data comes from 225 households; 75 households in each of the bioclimatic zone. The identified respondents in each village were interviewed personally using a questionnaire covering several topics. The household survey involved documenting tropical fruit species diversity found on farmlands and assessing their income level among other household characteristics such as family size, education level, ownership of consumer goods and productive assets. The data on the extent of land-use patterns such as home-gardens, orchards and fields were recorded. In home-gardens, the number of tropical fruit tree species, frequency and density, varieties, average age of trees, economic parts of the tree species, consumption pattern *i.e.* for household and sale purpose, area under fruit tree cultivation and size of the field *etc.*, were recorded. The diversity of TFT species was determined using species richness index, Shannon's index, Simpson's index to understand inter- and intra-cluster variability (Magurran and McGill, 2010).

The study evaluated the differences in diversity levels, the occurrence of non-native and native species and income levels between the three classified household groups and three agro-ecological zones using general

Table 1. Latitude, longitude, and climatic details of the focal villages selected for the study under different bioclimatic zones of Uttara Kannada district

Villages	Latitude °N	Longitude °E	Average Rainfall (mm)	MSL (m)	Average Farm Size (ha)
COASTAL ZONE					
Kotakhanda	14° 00' 25.47"	74° 35' 35.61"	3625	58	1.5± 1.70
Devgiri	14° 21' 15.82"	74° 24' 33.25"	3540	17	1.3±0.90
Marugadde	14° 44' 12.72"	74° 24' 44.28"	3450	138	1.59±1.07
UP GHAT ZONE					
Nilkunda	14° 26' 59.48"	74° 42' 02.34"	3530	528	1.39±0.25
Chavatti	14° 46' 11.9"	74° 48' 49.80"	2540	515	1.63±1.16
Bisgod	15° 01' 56.30"	74° 38' 55.53"	2420	561	1.37±1.68
EASTERN PLAINS					
Kalakaradi	14° 35' 51.00"	75° 00' 18.57"	900	575	3.83±6.59
Santholli	14° 38' 57.5"	75° 02' 18.15"	925	592	1.90 ±1.86
Koppa	14° 47' 23.15"	75° 02' 14.68"	945	609	1.74±1.33

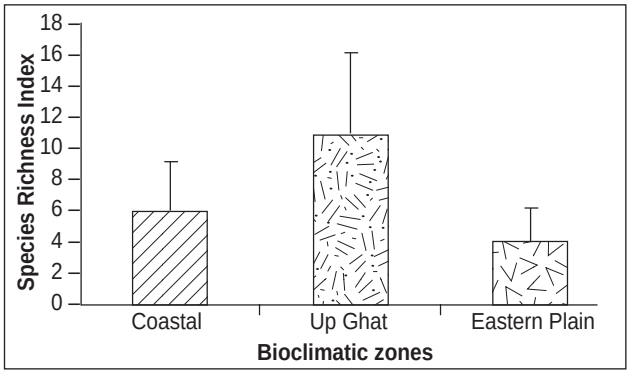

Fig. 1. Species richness index of TFT species (pooled over all home-gardens of a zone) across three bio-climatic zones in Uttara Kannada district (error bars indicate standard deviation)

statistics and assessed the relationship between diversity indicators and welfare indicators using correlations and two stage least squares regression procedure.

Results and Discussion

Patterns of Diversity of TFT across Bioclimatic Zones of the Central Western Ghats

Among the home-gardens and farmlands of nine villages sampled in three bioclimatic zones of the central Western Ghats, a total of 10,202 individuals belonging to 55 TFT species were recorded (Table 2). Mango was the predominantly (n=4,496) found TFT species. Two introduced species (non-native species) *viz.* cashew nut, *Anacardium occidentale* (n=1,363) and sapota, *Achras zapota* (n=502), respectively were in second and third positions. Overall, nearly one third of all TFT species found in the study area (29.09%) were non-native to the Western Ghats. Considering the number of individuals, about 27.76% of them, were non-native. *Garcinia intermedia*, an introduction from the South America, was the rarest TFT species represented by a single individual in a home-garden of up-ghat zone. The top ten species included cashew, sapota, jackfruit, guava, lemon and papaya. *Kokam* (*Garcinia indica)* and *uppage* (*G. gummi-gutta*) were also predominantly found species in the coastal and up-ghat bioclimatic zones but not in the eastern plains. Tamarind (*Tamarindus indicus*) was restricted to the eastern plain zone.

Earlier reports have also shown similar levels of tree diversity in home-gardens. For instance, Kumar and Nair (2004) have reported 69 different species among the home-gardens in Kerala. Mendez *et al.* (2001) have reported 40 fruit trees out of 324 plant species in home-gardens of Nicaragua. Home-gardens of West Java have been shown to possess astounding diversity of species, 56 species of plants in a single home-garden and about 272 species in a hamlet of 41 households (Soemarwoto and Conway, 1991). Styger *et al*. (1999), Pandey *et al.* (2006), Varadaranganatha and Madiwalar (2010), Zaman *et al.* (2010), Bardhan *et al.* (2012) and Saikia *et al.* (2012) also reported that mango species are predominant in home-garden system. Home-garden agroforestry systems in the tropics are structurally complex and hence possess a great diversity of tree species (Nair and Shreedharan, 1986). Such diversified trees on farm lands is generally regarded as a strategy meet the subsistence/cash needs as well as to stabilise yield. Further, different traditional agroforestry systems of the tropics also characteristically possess dominant tree species. For instance, 'enset-coffee agroforestry' home-gardens of Southern Ethiopia, 'shade-coffee based agroforestry' of Kodagu in Southern India.

Table 2. List of TFT species and their frequency in nine representative villages of Uttara Kannada district belonging to three bio-climatic zones. The species are organized in descending order of their frequency

S.No.	Botanical name	Family	Exotic/ Native	Coastal			Up-Ghat			Eastern Plain			Total
				Kot	Dev	Mar	Nil	Chv	Bis	Kal	San	Kop	
1	*Anacardium occidentale* L.	Anacardiaceae	Exotic	436	217	169	117	72	217	34	44	57	1363
2	*Achras zapota* (L.) P. Royen	Sapotaceae	Exotic	48	15	0	78	62	54	19	44	182	502
3	*Psidium guajava* L.	Myrtaceae	Exotic	11	8	15	38	36	57	21	79	69	334
4	*Carica papaya* L.	Caricaceae	Exotic	24	6	18	31	27	48	4	10	8	176
5	*Artocarpus incisa* L.	Moraceae	Exotic	28	6	11	15	15	26	3	1	4	109
6	*Theobroma cacao* L.	Malvaceae	Exotic	0	0	0	8	62	7	0	0	0	77
7	*Myristica fragrans* Houtt.	Myristicaceae	Exotic	31	19	0	0	0	21	0	0	0	71
8	*Averrhoa bilimbi* L.	Oxalidaceae	Exotic	11	11	6	4	10	21	0	0	0	63
9	*Annona squamosa* L.	Annonaceae	Exotic	12	9	0	8	10	6	0	6	0	51
10	*Annona reticulate* L.	Annonaceae	Exotic	0	1	3	12	7	8	3	0	4	38
11	*Averrhoa carambola* L.	Oxalidaceae	Exotic	1	3	2	3	9	9	0	0	0	27
12	*Syzygium samarangense* (Blume) Merril & Perry	Myrtaceae	Exotic	7	0	0	7	3	8	0	0	0	25
13	*Syzygium jambos* (L.) Alston	Myrtaceae	Exotic	0	2	0	7	9	6	0	0	0	24
14	*Ficus carica* L.	Moraceae	Exotic	6	0	0	5	8	3	0	0	0	22
15	*Citrus sinensis* (L.) Osbeck	Rutaceae	Exotic	0	0	0	4	7	0	6	0	4	21
16	*Punica granatum* L.	Punicaceae	Exotic	0	0	0	4	5	9	0	0	0	18
17	*Citrus reticulata* Blanco	Rutaceae	Exotic	0	0	0	4	6	0	0	1	0	11
18	*Prunus avium.* (L.) L.	Rosaceae	Exotic	0	0	0	0	0	3	0	0	0	3
19	*Garcinia intermedia* (Pittier) Hammel	Clusiaceae	Exotic	0	0	0	0	0	1	0	0	0	1
46	*Citrus grandis* Burm.	Rutaceae	Exotic	5	8	0	0	0	0	0	2	0	15
20	*Mangifera indica* L.	Anacardiaceae	Native	157	57	166	175	283	290	1135	884	1349	4496
21	*Artocarpus integrifolia* Lamk.	Moraceae	Native	46	14	22	56	157	105	7	14	36	457
22	*Citrus limon* Burm.f.	Rutaceae	Native	14	23	18	47	77	52	19	24	22	296
23	*Tamarindus indica* L.	Fabaceae	Native	4	2	0	3	16	6	88	69	104	292
24	*Garcinia indica* (Thouras) Choisy.	Clusiaceae	Native	28	23	38	76	14	88	0	0	0	267
25	*Garcinia gummi-gutta* (L.) N. Robson	Clusiaceae	Native	0	0	2	222	17	3	0	0	0	244
26	*Carissa carandas* L.	Apocynaceae	Native	60	0	0	32	0	30	0	21	0	143
27	*Aporosa lindleyana* (Wt.) Baill.	Euphorbiaceae	Native	8	5	2	39	37	35	3	2	2	133
28	*Emblica officinalis* Geartn.	Phyllanthaceae	Native	0	0	6	11	30	32	4	17	28	128
29	*Spondias mangifer* (L.f.) Kurz.	Anacardiaceae	Native	11	9	10	11	28	15	2	2	5	93
30	*Syzygium cumini* (L.) Skeels	Myrtaceae	Native	7	6	7	19	7	14	7	8	5	80
31	*Citrus medica* L.	Rutaceae	Native	6	0	2	16	35	15	2	0	2	78
32	*Artocarpus lakoocha* Roxb.	Moraceae	Native	3	0	6	12	8	25	0	0	0	54
33	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	Native	0	0	0	53	0	0	0	0	0	53
34	*Aegle marmelos* (L.) Correa	Rutaceae	Native	5	3	2	5	14	20	0	3	0	52
35	*Ziziphus rugosa* Lamk.	Rhamnaceae	Native	1	5	2	6	13	20	0	3	0	50
36	*Phyllanthus acidus* (L.) Skeels.	Phyllanthaceae	Native	4	3	2	9	10	4	4	2	7	45
37	*Flacourtia montana* J. Graham	Flacourtiaceae	Native	12	0	2	6	0	20	0	0	0	40
38	*Gardenia gummifera* L.	Rubiaceae	Native	0	0	0	16	0	14	0	0	0	30
39	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	Native	0	0	5	0	0	24	0	0	0	29
40	*Buchanania lanzan* Spreng	Anacardiaceae	Native	0	0	0	15	0	6	2	0	3	26
41	*Ficus glomerata* L.	Moraceae	Native	0	1	1	6	7	10	0	0	0	25
42	*Elaeagnus conferta* Roxb.	Elaeagnaceae	Native	0	0	0	23	0	0	0	0	0	23
43	*Grewia tiliaefolia* Vahl.	Tiliaceae	Native	0	0	0	0	0	21	0	0	0	21
44	*Syzygium operculatum* Gamb.	Myrtaceae	Native	0	0	0	4	0	15	0	0	0	19
45	*Morus alba* L.	Moraceae	Native	6	0	0	0	0	12	0	0	0	18
47	*Ziziphus mauritiana* Lamk.	Rhamnaceae	Native	0	0	0	0	0	0	4	4	6	14
48	*Semecarpus anacardium* L.f.	Anacardiaceae	Native	0	0	0	0	0	12	0	0	0	12
49	*Grewia microcos* L.	Tiliaceae	Native	0	0	0	0	0	6	0	0	0	6
50	*Terminalia catappa* L.	Combretaceae	Native	6	0	0	0	0	0	0	0	0	6
51	*Mammea suriga* (Buck.-Ham. ex Roxb.) Kosterm.	Clusiaceae	Native	0	0	0	0	0	5	0	0	0	5
52	*Mimusops elengi* L.	Sapotaceae	Native	0	0	0	0	0	5	0	0	0	5
53	*Citrus* sps.	Rutaceae	Native	0	0	0	0	0	4	0	0	0	4
54	*Terminalia chebula* Retz.	Combretaceae	Native	0	0	1	0	0	0	2	0	1	4
55	*Zanthoxylum rhetsa* (Roxb.) DC.	Rutaceae	Native	0	0	0	2	0	1	0	0	0	3
	Total			998	456	518	1209	1101	1413	1369	1240	1898	10202

Perhaps the highest use-values associated with these species have made them to be a part of these systems.

Higher diversity of TFT species in these systems is generally regarded to contribute to the conservation of native species. However, the present study shows that substantial number of non-native species do occur. Such displacement of indigenous trees by the exotic trees has been shown to occur at intermediate altitudes around Mount Kenya, because of the proportion of indigenous species increased with increasing aridity and temperature. Dominance of exotic species was found at farms of humid, mid- and high lands. Exotic species contributed to the separation of farms in the high lands and upper mid lands, where as indigenous species in the lower mid lands and low lands. As the frequency of most indigenous trees were low, only parts of surveyed farms can contribute to conservation of tree genetic resources, particularly the less intensively managed farms of more arid lands (Kehlenbeck *et al*., 2011).

The level of diversity and the composition of TFT species showed marked differences across three bioclimatic zones studied. In the coastal zone, 36 TFT species belonging to 18 families were recorded; among these, Moraceae contributed a maximum of six species. A total of 1,972 individuals were sampled in which cashew was the most predominant one (n=822; 41.68 %); mango was the second predominantly found species (n=380; 19.25 %). Interestingly, as much as 30 per cent of the TFT species and little over 50 per cent of the individual trees were non-native in the coastal zone.

In the up-Ghat zone 51 TFT species belonging to 24 families were recorded. Among these, family Rutaceae contributed to a maximum of 7 species (n=309). A total of 3,723 individuals were sampled in the survey and a large number (n=748; 60.27 %) of them were *Mangifera indica*; cashew was the second predominantly found TFT in the up-ghat zone (n=406; 32.71 %). Little over 31 per cent of the TFT species and individual trees were not native in the up-Ghat zone.

In the eastern-plain zone, 26 TFT species belonging to 13 families were recorded. Among these, Rutaceae contributed a maximum of 6 species (n=85). A total of 4,507 individuals were sampled and of which *Mangifera indica* was the predominant TFT (n= 3,368; 74.72 %); *Tamaridus indica* was in the second position (n=261; 5.79 %). Interestingly, as much as 26.92 per cent of the TFT species and little over 13% of the individual trees were non-native to the eastern plain zone.

Species richness index (Fig. 1) and Shannon's index (Fig. 2) computed for TFT species differed across the three bioclimatic zones. Pooled over all households in a zone, average species richness index (10.92) and average Shannon's index (1.73) were the highest for the up-ghat zone. While the richness index in the coast zone was reduced to half (5.95) with an average Shannon's diversity index of (1.25), the lowest average richness index was found in the eastern plains (4.04; Fig. 1) with a lowest average Shannon's diversity index of 0.87 (Fig. 2).

The diversity of TFT species at the village level has been described on several parameters in the Table 3. Even at the village level the zonal patterns were up-held. In every respect of diversity descriptors, the home-gardens and farmlands of up-ghat zone fared better than other zones. Consistently the villages of the eastern plains showed lower values for the diversity. Among the nine villages studied, the home-gardens and farmlands of Bisgod village recorded the highest species richness index (1.27) and Shannon's index (3.07). The species density *i.e.*, mean number of species per unit area of home-garden (8.84) and tree density *i.e.*, mean number of individuals per unit area (26.75) were also found to be the highest in Bisgod.

Average Income from TFT Species Pooled over Three Bio-climatic Zones

Pooled over all the households of the a bioclimatic zone (n=75), highest average annual income of Rs 10, 591=00 was obtained from TFT species in the eastern plain zone. This, on an average, is about 8.18 % of the total family income (SD ± 15.07 %). In the coastal zone the average annual income generated per family

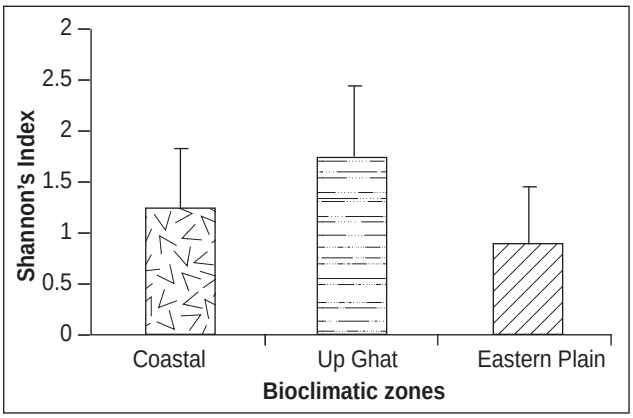

Fig. 2. Shannon's diversity index for TFT species (pooled over all home-gardens of a zone) across three bio-climatic zones in Uttara Kannada district

Table 3. Descriptors of TFT species diversity in nine representative villages of Uttara Kannada district belonging to three bio-climatic zones

S. No.	Village/ Bioclimatic Zone	No. of TFT species	No. of individuals belonging to TFT species	Species Richness Index[1]	Simpson's Index	Shannon's Index	Species density[2]	CV associated with species density	Tree density[3]	CV associated with tree density
1	Kotakhanda / Coastal	29	998	0.92	0.22	2.18	3.62	0.59	22.95	0.71
2	Devgiri/ Coastal	24	456	1.12	0.25	2.10	2.86	1.71	9.51	1.54
3	Marugadde/ Coastal	25	518	1.09	0.22	2.03	1.79	0.75	6.22	0.77
4	Nilkunda / Up-Ghat	40	1209	1.15	0.08	2.94	4.73	1.19	19.12	1.42
5	Chavatti/ Up-Ghat	32	1101	0.96	0.10	2.75	3.92	1.34	14.44	0.88
6	Bisgod/ Up-Ghat	48	1423	1.27	0.08	3.07	8.84	1.19	26.75	0.92
7	Kalakardi / Plains	20	1369	0.54	0.69	0.83	1.13	0.84	8.51	0.89
8	Santholli / Plains	21	1240	0.60	0.51	1.27	1.55	0.84	10.12	1.12
9	Koppa / Plains	20	1898	0.46	0.52	1.20	1.48	1.01	13.62	1.01

*1= Menhenick's Index
*2= Mean no. of species per area of home-garden/farmland
*3= Mean number of individuals per area of home-garden/farmland

by TFT was at Rs 9,595=00 (which is 7.56 % of the total annual family income with a SD of ± 12.65 %); while the least average income from TFT to was accrued in the up-ghat zone with an average of Rs 4,207=00 (2.27 % ± 2.73 % of the total family income). Mean per cent income contribtion by TFT species across the villages of three bio-climatic zones represented in Fig. 3, also confirms the general trend. In the eastern plains zone popular varieties mango are raised as commercial plantations, hence contributes maximum to the family income. In addition, slightly drier conditions prevailing in the eastern plains are congenial to mango plantations compared to the up-Ghat zone where heavy rainfall may reduce yields. Mango in the up-Ghat zone is more used for preparation of house-hold pickles (aromatic pickle mango) rather than for table purpose (Vasudeva and Rajeshwari, 2014). In contrast, in coastal areas of Uttara Kannada district cashew cultivation is preferred because of its commercial value and established marketing channel (Panda, 2013).

Income as a Driver of TFT Species Diversity

In the present study, association between total family income and number of TFT species per home-garden (avarage1.8 ha landholding) was statistically significant for Coastal zone (r=0.234; P<0.005 at 73 df) and for Up-Ghat zone (r=0.202; P<0.05 at 73 df). However, the association was poor in the Eastern-plain zone (r=0.151; NS) of central Western Ghats. This suggests that the species diversity does increase with the total family income. However, an exception to this is the eastern plains zone, where the relationship was not significant perhaps because of focus is on a few commercially important varieties/species. Apart from total family income, several motivational factors such as the value attached to the TFT, social factors such as heirloom varieties, are regarded as strong drivers of the diversity of the tropical fruit tree species. The results of the present study do not provide proof for the direction of the relationship or influence of other factors such as land size or household characteristics. Farmers could maintain more diversity simply because of having more space. Other way round, the utilization of diversity could have contributed also to higher incomes. Similar results were reported by Esipisu (2005) where number of varietal richness was positively associated with income of the household. However, the R^2 values were lower.

Conclusions

Clear differences in the composition and diversity of TFT species existed across the bioclimatic zones of the study area. Largest diversity of TFT was found among the up-ghat zone where traditional agroforestry was more prevalent. Introduction of cash crops such as cashew (as in the case of coastal zone) or increased commercialization of a native TFT such as mango (as in the case of eastern-plain) contributed to the decrease in the diversity. This calls for an urgent revial of interest in use of the traditional varieties of mango and their registration (Gautam *et al*., 2012). Pooled over all the

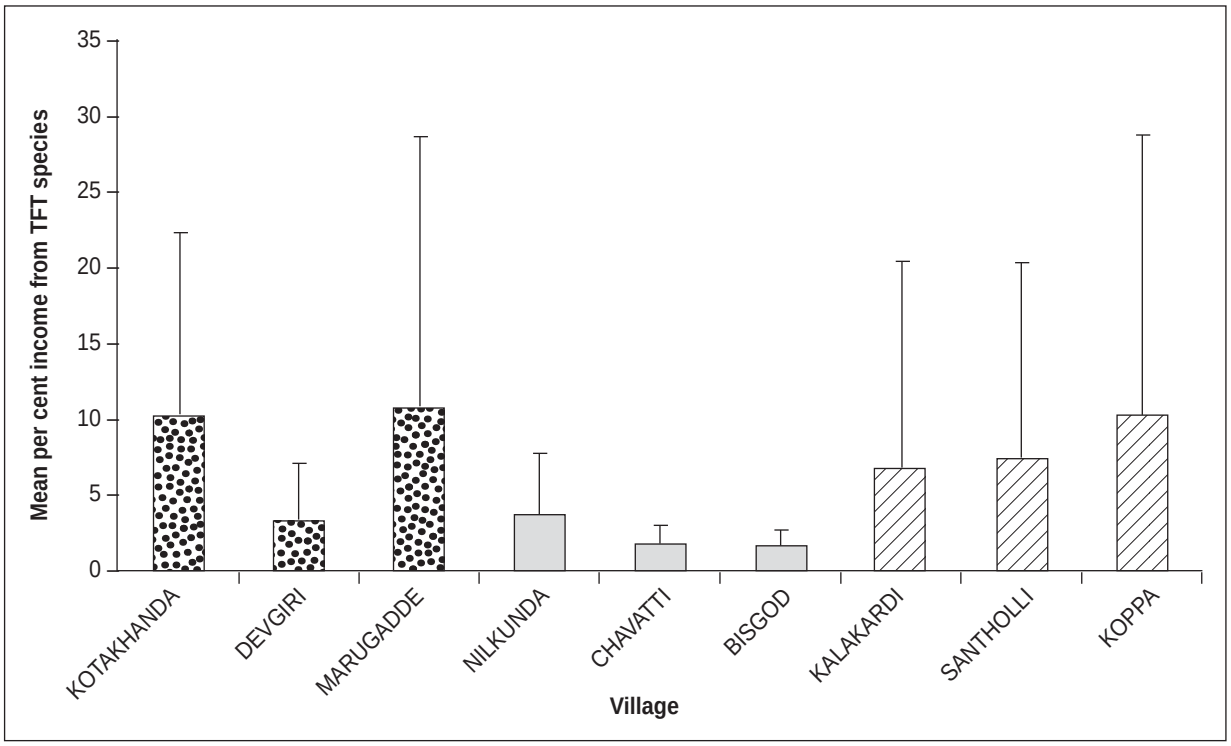

Fig. 3. Average per cent family income contributed by TFT in nine focal villages across three bio-climatic zones of Uttara Kannada district. The error bars indicate the ± 1 S.D. The first three villages *viz*. Kotakhanda, Devgiri and Marugadde belong to coastal bioclimatic zone; Nilkunda, Chavattti and Bisgod belong to up-ghat zone; the eastern plain is represented by Kalakardi, Santholli and Koppa village

households of the a bioclimatic zone, highest average annual income was obtained from TFT species in the eastern plain zone (8.18 % of the total family income). In the coastal zone it was 7.56 % of the total annual family income; while the least average income from TFT to was accrued in the up-Ghat zone (2.27 %). However, regression analysis showed that total family income postivily contributes to the level of TFT diversity found on farmlands, this contribtion was most significant in Coastal and up-Ghat zone.

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References

Ajay KM and CP Pratap (2009) *Wild Edible Fruit Plants of Eastern India.* Odhisha: Regional Plant Resource Centre, pp 20-25.

Anupunt P, S Somsri, S Chaikiattiyos and U Kumscha (2003) Native Tropical Asian Fruits. *Acta Hort. (ISHS)* **620**:151-159.

Bardhan S, S Jose, S Biswas, K Kabir and W Rogers (2012) Home-garden agroforestry systems: an intermediary for biodiversity conservation in Bangladesh. *Agrofor. Syst.* **85**: 29-34.

Beaumont LJ, A Pitman, S Perkins, NE Zimmermann, NG Yoccoz and W Thuiller (2011) Impacts of climate change on the world's most exceptional eco-regions. *Proc. Natl. Acad. Sci. USA* **108**: 2306–2311.

Bhag Mal, V Ramnatha Rao, RK Arora, PE Sajise and Bhuwon Sthapit (2011) Conservation and sustainable use of tropical fruit species diversity: Bioversity's efforts in Asia, the Pacific and Oceania. *Indian J. Plant Genet. Resour.* **24**: 1-22.

Bhat DM and NH Ravindranath (2011) Above-ground standing biomass and carbon stock dynamics under a varied degree of anthropogenic pressure in tropical rain forests of Uttara Kannada district, Western Ghats, India. *Taiwania* **56**: 85-96.

Esipisu E (2005) Mango Production Survey and Cluster Analysis. USAID, Kenya Business Development Services Program (Kenya BDS).

Gautam PL, Ajay Kumar Singh, Manoj Srivastava and PK Singh (2012) Protection of plant varieties and farmers' rights: a review. *Indian J. Plant Genet. Resour*. **25**: 9–30

Kehlenbeck K, R Kindt, FL Sinclair, AJ Simons and R Jamnadass (2011) Exotic tree species displace indigenous ones on farms at intermediate altitudes around Mount Kenya. *Agrofor. Syst*. **83**:133-147.

Kumar BM and PKR Nair (2004) The enigma of tropical home-gardens. *Agrofor. Syst.* **61:** 135-152.

Magurran AE and McGill BJ (2010) *Biological Diversity: Frontiers in Measurement and Assessment*. Oxford University Press.

Mendez VE, L Kok and E Somarriba (2001) Interdisciplinary analysis of home-gardens in Nicaragua: micro-zonation, plant use and socioeconomic importance. *Agrofor. Syst.* **51**: 85- 96.

Nair MA and C Sreedharan (1986) Agroforestry farming systems in the homesteads of Kerala, Southern India. *Agrofor. Syst.* **4**: 339-363

Panda H (2013) *The Complete Book on Cashew (Cultivation, Processing and By-products)*. Asia Pacific Business Press Inc., Delhi.

Pandey CB, K Lata, A Venkatesh and RP Medhi (2006) Diversity and species structure of home-gardens in South Andaman. *Trop. Ecol.* **47**: 251-258.

Pascal JP (1984) *Bio-climates of Western Ghats*. Institut Français de Pondicherry. Publications du department d'écologie 38.

Saikia P, BI Choudhury and ML Khan (2012) Floristic composition and plant utilization pattern in home-gardens of Upper Assam, India. *Trop. Ecol*. **53**: 105-118.

Soemarwoto O and GR Conway (1991) The Javenese Home-garden. *J. Farming Systems Research-Extension* **2**: 95-117

Sthapit BR, H Lamers and VR Rao (2013) *Custodian Farmers of Agricultural Biodiversity: Selected Profiles from South and South East Asia*. Proc. of the Workshop on Custodian Farmers of Agricultural Biodiversity, 11-12 February 2013, New Delhi, India.

Styger E, JEM Rakotoarimanana, R Rabevohitra and ECM Fernandes (1999) Indigenous fruit trees of Madagascar: Potential components of agroforestry systems to improve human nutrition and restore biological diversity. *Agroforest. Syst.* **46**: 289-310.

Varadaranganatha GH and SL Madiwalar (2010) Studies on species richness, diversity and density of tree/shrub species in agro-forestry systems. *Karnataka J. Agric. Sci.* **23**: 452-456.

Vasudeva R and N Rajeshwari (2014) *Appemidi*: *Wild Aromatic Pickle Mango of the Central Western Ghats. India.* Information Brochure, UNEP/GEF project on Tropical Fruit Trees.

Vasudeva R, AA Abebe, NR Hegde and GS Deepa (2011) Documenting fruit trait diversity of aromatic pickle mango in the humid tropics of central Western Ghats. *In*: Proc. of *'Augmenting Production and Utilization of Mango: Biotic and Abiotic Stresses'* organized by the Society for Development of Subtropical Horticulture. Central Institute for Subtropical Horticulture (ICAR), Lucknow.

Zaman S, U Siddiquee and M Katoh (2010) Structure and diversity of home-garden agroforestry in Thakurgaon district, Bangladesh. *The Open For. Sci. J.* **3**: 38-44.

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Traditional Knowledge Associated with Tropical Fruit Tree Genetic Resources: Comparison of Upper-Ghat and Coastal Situation of Central Western Ghats, India

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The study was taken up in two representative villages each from upper-Ghat and coastal bioclimatic zones of Uttara Kannada district, Karnataka, India with an objective to document the total tropical fruit tree species diversity and the associated traditional knowledge. About 43 tropical fruit tree (TFT) species, were recorded. Seventy four traditional knowledge associated with TFTs were recorded from the study sites. It was noted that traditional knowledge related to culinary uses and processing of TFTs were practised even today. However, traditional knowledge related to medicinal uses showed a decreasing trend, where traditional medicines are being replaced with modern medicines. Cultural Importance (CI) value was calculated for all the 42 TFT genetic resources recorded. Mango showed highest value for CI when considered for each bioclimatic zone as well as when the data was pooled over all the village. Further, other two species that showed relatively higher values of CI were jack fruit and *Garcinia indica*. There was a positive association of the frequency of TFTs and their CI values. Documentation of such invaluable traditional knowledge would establish the rights of local communities over their traditional knowledge and its use. It is suggested that community biodiversity register (CBR) could be effectively adopted to empower local people.

Key Words: Central Western Ghats, Cultural importance value, Traditional knowledge, Tropical fruits

Introduction

Asia is a treasure house of tropical fruit tree (TFT) genetic resources harbouring over 500 species (Ramanatha Rao and Bhag Mal, 2002). In India, central Western Ghats is a rich repository of TFTs housing hundreds of native TFT species such as *Mangifera indica*, *Artocarpus heterophyllus*, *Garcinia indica* etc. Naturally, TFTs form a major part of culture and livelihood of local indigenous people. Being a part of Central Western Ghats, Uttara Kannada district, Karnataka state, has high diversity of TFT species spread in several production systems such as home-gardens, farmlands, *etc*. Nearly a hundred TFT species form an important source of livelihood, medicine and income of local indigenous people (Bhat *et al*., 2013). Several wild TFT genetic resources have been partially domesticated and deployed into farming systems. For instance, several varieties of wild aromatic pickle mango (*Mangifera indica*) popularly known as *'Appemidi'*, an important commodity of commerce, have been identified by the farmers from the riverine habitats and have been deployed under various agro-forestry systems (Vasudeva abnd Rajeshwari, 2014). Hence these indigenous people possess knowledge on the use-value of TFTs as food, medicines and other uses (Bhat, 2013). For instance, *Garcinia indica* and *G. gummi-gutta* are used for beverage making from the fruit rind/extracting an edible butter from seeds to be used also for cosmetic/therapeutic benefits which are also mentioned in *Ayurveda* and many other folk systems (Baliga *et al.*, 2011). Many traditional as well as recent medicinal literature have shown the usefulness of Indian gooseberry (*Phyllanthus emblica*) in the treatment of cold, influenza, diabetes, lung problems and also as an immune restorative agent under cancer conditions. *Phyllanthus emblica* is also a rich source of Vitamin C, Iron, Calcium and many other minerals and anti-oxidants (Sampath Kumar *et al.*, 2012).

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Worldwide, the knowledge developed over many generations has supported the local communities to sustainably live and utilize the biodiversity for improved livelihood and health (Kiene, 2006; Maharouf, 2003; Idris, 2003; Delacruz, 2003). In Vietnam, litchi has been used for its medicinal property (Hue, 2003). Documentation of traditional knowledge (TK) on mango and jackfruit in Sri Lanka indicated specific species are used for the treatment of specific ailments (Maharouf, 2003). TK[1] refers to the rational and reliable knowledge, practice and belief of indigenous people developed through generations of intimate contact with the nature by the local people (Mauro and Hardison, 2000). It would include detailed information on species of a locality, use-values of local biodiversity, harvesting and management practices and manipulation of disturbance regimes (Berkes, 1993). This knowledge is unique to a specific community and their culture.

Such knowledge has strong links with TFT genetic resources of India (Ajay and Pratap, 2009). However, TK is constantly under threat due to its mode of transmission and cultural erosion from one generation to another. It is mostly orally transferred, through folklore, songs, practices, rituals *etc.* (Kiene, 2006; Sthapit and Quek, 2006; Huntington, 2000). In addition, rapid agricultural expansion, changing land use pattern and with other social pressures have led to the depletion of TFT genetic resource diversity. Therefore, it is essential that this knowledge is documented and the genetic resources are regularly monitored for their conservation status. There are several international efforts to recognize the importance of protection of TK. World Intellectual Property Organization (WIPO) and UNESCO have adopted a model law on folklore in 1981 and the Convention on Biological Diversity (CBD) highlighted the need to promote and preserve traditional knowledge in 1992. Despite these efforts, universally acceptable solutions for the protection and promotion of TK have yet to emerge.

Documentation is primarily a process by which TK is identified, collected, organized, registered and recorded in order to constantly maintain, manage, use, disseminate and protect against bio-piracy. Bio-piracy is a situation where indigenous knowledge of nature, originating with indigenous people, is used by others for profit, without permission from and with little or no compensation or recognition to the indigenous people themselves (Pandey, 2014). In the recent past, it is said that many commercial companies had exploited indigenous knowledge, where original knowledge holder was not given due credit. The examples of turmeric, neem and ayahuasca illustrate such issues that arise when patent protection is granted to inventions relating to traditional knowledge which is already in the public domain. In these cases, invalid patents were issued because the patent examiners were not aware of the relevant traditional knowledge. India had many bitter experiences where our traditional knowledge (related to turmeric, neem, basmati rice *etc.*) had been patented by outside parties as their own innovations (www.tkdl.res.in). Such instances prompted the international community to take stand on the exploitation of indigenous knowledge access, and Benefit Sharing (ABS) provisions of the CBD. The provisions outline the frame work for the development of legal and ethical bio-prospecting agreements between the 'provider' (host country / community) and 'user' (party outside to the community/country) of TK. National Biodiversity Authority in India is one such national organization involved in the protection of TK and its use which encourages documentation. Under the GEF-UNEP funded project titled "Conservation and sustainable use of cultivated and wild tropical fruit diversity: promoting sustainable livelihood, food security and ecosystem services" TK associated with TFTs were documented adopting multifarious methods. Being implemented in 18 communities of India along with six other 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. With this background, the current study was carried out with an aim of documenting the traditional knowledge associated with TFT and to describe their cultural significance while comparing the two bioclimatic zones of central Western Ghats of India.

Materials and Methods

Two typical villages of upper-Ghat (Salkani and Killara) and two of the coastal zone (Murur and Kallabbe) in the central Western Ghats, Karnataka were selected for the

[1] **Traditional knowledge** (TK) is **knowledge**, know-how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity. www.wipo.int/tk/en/tk/ (accessed on 05092014)

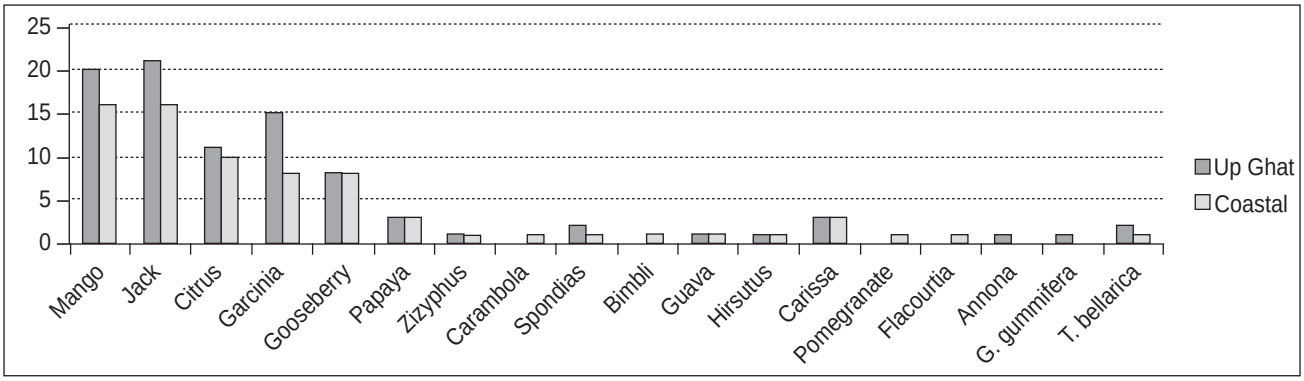

Fig. 1. Comparison of number of TK recorded for different use-values in Upper Ghat and Coastal villages of central Western Ghats

study. These sites are biologically rich but differ with respect to bio-climate and the cultural milieu (Bhat, 2013). The geographical details of the study sites, number of respondents in each village is provided in the Table 1. The coastal zone is situated at an altitude of 20-300 m and receives an average annual rainfall of 3537 mm. The mean maximum temperature ranges from 25-36°C. The upper-Ghat bioclimatic zone is in the crest-line of the Western Ghats hill chain at 400-600 m. The area receives an average annual rainfall of 2830 mm. The mean maximum temperature ranges from 25-32°C.

Villages were surveyed for documenting tropical fruit tree genetic resources and associated TK through personal interview at the household level. The focus was on documenting the TFT diversity in each village, essentially on local varieties. Traditional knowledge in the form of cultivation practices, uses (medicinal, culinary and other uses) and knowledge about species diversity in their village *etc*. were documented. Household was the unit of primary data collection. A pre-tested structured questionnaire was used to collect data on household information, TFT diversity and traditional knowledge associated after taking the Prior Informed Consent (PIC) from the respondents. The criteria for salient difference between varieties/species, as perceived by the farmers, were arrived at through the interviews. This essentially comprises of farmers' descriptors of the local varieties. Farmers' descriptors are those traits used by farmers of a given location to distinguish varieties of a species. Some of the farmers' descriptors used in distinguishing the varieties were fruit colour, skin texture, taste, aroma and fruiting season. This formed the major knowledge base on traditional classification of TFTs. Interviews of the local communities were recorded through audio-recording devices.

Cultural Importance (CI) Index of each species was computed following Philips and Gentry (1993). This index measures the use-value of a plant by considering the number of informants citing a given use-value.

$$CI = \sum_{i=1}^{i=NU} \frac{URi}{N}$$

Where 'N' is the number of informants, 'NU' is the number of use-values cited and 'UR' is the number of different uses mentioned by each informant *i*.

Results and Discussion

A total of 43 TFT species were recorded from different production systems such as home-gardens, forests, orchards and *bettaland* (a kind of usufruct forest patch provided by the State Forest Department as an incentive to the betel nut farmers in the district of Uttara Kannada) within the study sites (Appendix 1). The villages in the upper-Ghat region recorded 42 TFTs, the coastal villages recorded about 31 TFT species. Each species

Table 1. Geographic features, number of households visited in two bioclimatic zones of central Western Ghats

Village/site	Bioclimatic zone	Latitude	Longitude	Altitude (m above msl)	No. of households interviewed
Salkani	Upper-Ghat	14º39'31"N	74°43'22"E	543 m	40
Killara	Upper-Ghat	14º17'33.1"N	74°53'18.3"E	560 m	40
Kallabbe	Coast	14º23'11.7"N	74°28'46.6"E	25 m	40
Murur	Coast	14º26'54.02"N	74°28'47.3"E	25 m	40

Table 2. Use values of tropical fruit tree genetic resources in four typical villages of Uttara Kannada district

S.No.	Species	Uses*													Total no. of uses
		1	2	3	4	5	6	7	8	9	10	11	12	13	
1	*Artocarpus heterophyllus*	✔	✔	-	✔	✔	✔	✔	-	✔	✔	-	✔	✔	10
2	*Mangifera indica*	✔	-	-	✔	✔	✔	✔	-	-	✔	✔	✔	✔	09
3	*Phyllanthus emblica*	✔	-	-	✔	✔	✔	-	-	✔	-	✔	✔	✔	08
4	*Citrus limon*	-	-	-	✔	✔	✔	-	-	✔	-	-	✔	✔	06
5	*Anacardium occidentale*	✔	✔	-	✔	✔	-	-	✔	-	-	-	-	-	05
6	*Garcinia indica*	-	✔	-	✔	✔	-	-	-	✔	-	-	✔	-	05
7	*Psidium guajava*	✔	-	-	✔	-	-	-	-	✔	-	-	✔	✔	05
8	*Carissa carandus*	✔	-	-	✔	✔	✔	-	-	✔	-	-	-	-	05
9	*Citrus maxima*	✔	-	-	✔	-	✔	-	-	✔	-	-	-	-	04
10	*Garcinia gummi-gutta*	-	-	✔	✔	✔	-	-	-	✔	-	-	-	-	04
11	*Gardenia gummifera*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	03
12	*Carica papaya*	✔	-	-	-	✔	-	-	-	✔	-	-	-	-	03
13	*Citrus aurantifolia*	-	-	-	✔	✔	-	-	-	✔	-	-	-	-	03
14	*Zizyphus rugosa*	✔	-	-	-	✔	-	-	-	✔	-	-	-	-	03
15	*Averroha bilimbi*	-	-	-	✔	-	✔	-	-	✔	-	-	-	-	03
16	*Syzygium cumini*	-	✔	-	-	-	-	-	-	✔	-	-	-	-	02
17	*Anona reticulata*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
18	*Flacourtia montana*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
19	*Theobroma cacao*	✔	-	-	-	✔	-	-	-	-	-	-	-	-	02
20	*Artocarpus altilis*	-	-	-	✔	✔	-	-	-	-	-	-	-	-	02
21	*Spondias pinnata*	✔	-	-	✔	-	-	-	-	-	-	-	-	-	02
22	*Tamarindus indica*	✔	-	-	✔	-	-	-	-	-	-	-	-	✔	02
23	*Semecarpus anacardium*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
24	*Terminalia bellerica*	-	-	-	-	✔	-	-	-	✔	-	-	-	-	02
25	*Citrus limetta*	✔	-	-	-	✔	-	-	-	-	-	-	-	-	02
26	*Ficus glomerata*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
27	*Punica granatum*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
28	*Phyllanthus acidus*	✔	-	-	-	-	-	-	-	✔	-	-	-	-	02
29	*Aporosa lindleyana*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
30	*Citrus sinensis*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
31	*Achras zapota*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
32	*Syzygium jambos*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
33	*Ziziphus oenoplea*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
34	*Elaeagnus conferta*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
35	*Citrus paradisi*	-	-	-	-	✔	-	-	-	-	-	-	-	-	01
36	*Syzygium malaccense*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
37	*Averroha carambola*	-	-	-	✔	-	-	-	-	-	-	-	-	-	01
38	*Buchanania lanzan*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
39	*Rourea santaloides*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
40	*Syzygium caryophyllatum*	✔	-	-	-	-	-	-	-	-	-	-	-	-	01
41	*Arocarpus hirsuta*	-	-	-	✔	-	-	-	-	-	-	-	-	-	01
42	*Artocarpus lakoocha*	-	-	-	✔	-	-	-	-	-	-	-	-	-	01

**** Code for uses:***

1. Fresh fruit consumed *2. Seeds consumed* *3. Seed butter extracted* *4. General culinary use* *5.Special dish*
6. Pickle making *7. Papad /chips-making* *8.Wine making* *9. Medicinal purpose* *10.Timber*
11. Used as mulch *12. Wind break* *13. Religious purpose*

was categorized into thirteen broad use-values (Table 2). It was found that *Artocarpus heterophyllus* (jackfruit), *Mangifera indica* (mango) and *Phyllanthus emblica* (gooseberry) were used for higher number of uses.

Traditional knowledge was recorded for tropical fruit tree species under four broad use-values *viz.*, related to culinary use, medicinal use, processing and preservation and related to nursery and maintenance. Seventy four traditional knowledge associated with TFTs were recorded from the study sites (shown as the Appendix 2). It was noted that traditional knowledge related to culinary uses and processing of TFTs were practised even today.

Table 3. Cultural Importance Value index of TFT species (the species that are considered under the TFT project are in bold); the species have been organized according to the overall CI value

S.No.	Species	Cultural index values		
		Pooled over all the Upper-Ghat villages	Pooled over all the Coastal villages	Overall CI
1	*Mangifera indica*	5.475	4.54	4.64
2	*Artocarpus heterophyllus*	5.65	2.185	3.90
3	*Garcinia indica*	3.05	2.28	2.74
4	*Anacardium occidentale*	2.15	1.93	2.005
5	*Citrus limon*	1.7	0.65	1.225
6	*Averroha bilimbi*	0.75	1.01	1.0
7	*Citrus sinensis*	1.0	1.0	1.0
8	*Citrus aurantifolia*	0.9	0.1	0.9
9	*Carissa carandus*	0.8	0.1	0.8
10	*Zizyphus rugosa*	0.625	1.25	0.75
11	*Tamarindus indica*	1.0	0.5	0.75
12	*Achras zapota*	0.81	0.5	0.66
13	*Aporosa lindleyana*	0.88	0.43	0.64
14	*Zizyphus oenoplea*	0.7	0.65	0.61
15	*Carica papaya*	0.975	0.55	0.603
16	*Psidium guajava*	0.7	0.6	0.53
17	*Citrus maxima*	0.625	0.5	0.5
18	*Syzygium cumini*	0.45	0.36	0.48
19	*Syzygium caryophyllatum*	0.78	0.25	0.48
20	*Flacourtia montana*	0.78	0.38	0.42
21	*Buchanania lanzan*	0.41	-	0.41
22	*Ficus glomerata*	0.38	0.44	0.41
23	*Artocarpus hirsuta*	0.6	0.32	0.40
24	*Phyllanthus emblica*	1.35	1.31	0.35
25	*Rourea santaloides*	0.38	-	0.35
26	*Annona reticulata*	0.65	0.5	0.35
27	*Artocarpus altilis*	0.2	0.44	0.34
28	*Garcinia gummi-gutta*	1.4	0.25	0.33
29	*Gardenia gummifera*	0.638	-	0.32
30	*Artocarpus lakoocha*	0.125	0.025	0.31
31	*Avverroha carambola*	-	0.05	0.25
32	*Elaeagnus conferta*	0.20	-	0.20
33	*Garcinia morella*	0.375	-	0.19
34	*Syzygium malaccense*	0.325	-	0.163
35	*Spondias pinnata*	0.25	1.0	0.14
36	*Citrus paradisi*	0.12	-	0.12
37	*Citrus macroptera*	0.1	-	0.1
38	*Syzygium jambos*	0.125	-	0.07
39	*Terminalia bellerica*	0.1	0.1	0.05
40	*Theobroma cacao*	0.15	0.2	0.03
41	*Semecarpus anacardium*	0.275	0.02	0.03
42	*Phyllanthus acidus*	0.01	-	0.01

However, traditional knowledge related to medicinal uses showed a decreasing trend, where traditional medicines are being replaced with modern medicines. Home remedies followed for common ailments such as cold, fever, bile reflux and cough were found to be out of practice. However, the knowledge was still held by the community members.

Out of the 43 TFT species recorded from the four villages, about 20 species were used for their culinary use. Out of the 41 species surveyed in the upper-Ghat villages over 15 were used for culinary use, while the coastal villages with 33 TFT species surveyed about 17 species were used for culinary purposes as mentioned in Table 3. Jackfruit was the most widely used fruit species, with more than 8 dishes prepared. Maximum number of informants (85 per cent) responded about the use of jackfruit for culinary uses. However, upper-Ghat villages recorded more number of dishes/cuisines and more uses (number of households) of TFT genetic resources in culinary use when compared to the coastal villages.

Pickle making was one of the common-most use of the TFTs (N=60) wherein tender mango was used for pickle preparation. People in the upper-Ghat villages showed larger involvement in identifying the better varieties of pickle mango than those from the coastal region.

Out of the 42 species surveyed in two villages of upper-Ghat and coastal zones of Uttara Kannada 16 TFT species were used for medicinal purpose. Lemon juice was prominently used in both bioclimatic zones for medicinal purpose; as many as 14 species were used in the upper-Ghat villages, while 13 species were used in the coastal villages for the same purpose. Use of Indian gooseberry in combination with other plants is a useful medicine for controlling diabetes. Several contemporary literatures support the evidence of use of Indian gooseberry in treating diabetes, inflammatory ailments and asthma etc. (Sampath Kumar *et al.*, 2012; Hussain *et al.*, 2008). The dried fruits are used by the local communities of Uttara Kannada in controlling diabetes and other ailments like breathing problems. Dried jackfruit seeds are used like almond or cashew seeds after frying in oil.

Out of the total 43 species of TFT genetic resources recorded, processing and preservation is done mainly for two species *viz*. *'Appemidi'* and *Garcinia* species. Relatively more number of households in the upper-Ghat villages showed participation in processing of both of these fruits. *'Appemidi'* (aromatic pickle mango type) has been recently provided with the geographic indication registry by the Government of India (Source: http://ipindia.nic.in/girindia/images/RegGis.gif; Gautam *et al*., 2012).

Cultural Importance (CI) Index is an additive index that takes into account the spread of use (number of informants) for each species and the diversity of uses (number of use) (Manuel *et al.*, 2007). The total number of uses for each species is added to understand the importance of different species found in a particular region. CI was calculated for all the 42 TFT genetic resources recorded from the four typical villages of upper-Ghat and coastal zones. The theoretical highest value of CI is the number of its uses. When the number of uses and the number of users increase, CI value also increases.

Mango showed highest value for CI when considered for each bioclimatic zone as well as when the data was pooled over all the villages (Table 3). Further, the other two species that show relatively higher values of CI are jackfruit and *Garcinia indica*. Rest of the species showed CI value of less than one. The major TFT genetic resources grown in the home-gardens and farmlands such as *Anacardium occidentale*, *Citrus* species, *Achrus zapota*, *Phyllanthus emblica*, *Carissa carandus* and *Averroha bilimbi* showed more number of uses for culinary and medicinal values. Preference of a species by farmers seems to be positively associated with the use of that species for household consumption. CI value of a species showed strong correlation with the frequency of occurrence of a species.

The use of *Garcinia indica* is popular among the local communities of Uttara Kannada. Its fruit rind and seeds are used in treating wide range of ailments like fever, cough, bile reflux, obesity, skin problems and for culinary uses. Butter extracted from the seeds is an excellent skin moisturizer used by the local communities. Juice is extracted from the fruit rind are stored in the form of squash for a period of 6-12 months. The juice is served during the hot summers, which is a coolant. Another *Garcinia* species available in the locality *Garcinia gummi-gutta* is also used in extracting butter. *Garcinia* species are preferred for their medicinal uses (Baliga *et al.*, 2011; Jena *et al.*, 2002).

Conclusions

The present study showed that a significant level of TK on the use of TFTs exists in both upper-Ghat and coastal zone of central Western Ghats. The difference in traditional knowledge associated with TFTs is not very prominent between the two bioclimatic zones. However, practice of traditional knowledge was higher in the upper-Ghat villages. Large scale migration of rural youth has been observed in the coastal villages when compared to the upper-Ghat villages is the perceived reason for the same. Rapid documentation of TK needs to be done and such documents should be made available at the local institutions such as village *panchayat*. This could lead to the empowerment of local communities. Creating awareness is important by involving young children so that traditional knowledge evolved over centuries is transferred adequately to the next generation. Documentation of traditional knowledge not only ensures its protection against theft but also ensures financial benefits to the knowledge holder when commercial sectors exploit the knowledge. Community biodiversity register

is an effective tool to officially document the TK and to empower local people (Rijal *et al*., 2003).

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References

Ajay KM and CP Pratap (2009) *Wild Edible Fruit Plants of Eastern India.* Orissa: Regional Plant Resource Centre, pp 20-25.

Baliga MS, HP Bhat, RJ Pai, R Boloor and PL Palatty (2011) The chemistry and medicinal uses of the underutilized Indian fruit tree *Garcinia indica* choisy (kokum): a review. *Food Res. International* **44**: 1790-1799.

Berkes F (1993) Traditional ecological knowledge in perspective. In: Inglis JT (ed.). *Traditional Ecological Knowledge: Concepts and Cases*. Canadian Museum of Nature, Ottawa, Ontario, Canada, pp 1-9.

Bhat V (2013) *Assessment of Tropical Fruit Tree Species Diversity in Home-gardens and Farmlands of Uttara Kannada district*. M.Sc. Thesis in Forest Genetic Resources. University of Agricultural Sciences, Dharwad.

Bhat V, T Abebe, R Vasudeva, GV Nayak, MR Dinesh, S Rajan, B Sthapit and Ramanatha Rao (2013) *Status and Diversity of Aromatic Wild Pickle Mango (Appemidi) in Home Gardens and Farmlands of Central Western Ghats.* Technical unpublished report UASD, GEF/Bioversity, ICAR.

Delacruz FS (2003) Conservation and utilization of germplasm of mango, *Citrus* spp. and *Garcinia* spp. in the Philippines. In: *Final Country Report for Philippines submitted to IPGRI under the ADB-funded project on 'Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia*'. National Plant Genetic Resources Laboratory, Institute of Plant Breeding, College of Agriculture, University of the Philippines, Los Banos (UPLB), Laguna, Philippines, pp 11-13.

Gautam PL, Ajay Kumar Singh, Manoj Srivastava and PK Singh (2012) Protection of plant varieties and farmers' rights: a review. *Indian J. Plant Genet. Resour*. **25**: 9–30.

Hue NTN (2003) Conservation and use of diversity in citrus, mango and litchi in Vietnam. In: *Final Country Report for Vietnam submitted to IPGRI under the ADB-funded project on "Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia*". Vietnam Agricultural Science Institute, Thanh Tri, Hanoi, Vietnam, 12p.

Huntington HP (2000) Using traditional ecological knowledge in science: methods and applications. *Ecol. Appl*. **10**: 1270-1274.

Hussain SZ, RN Malik, M Javaid and S Bibi (2008) Ethnobotanical properties and uses of medicinal plants of Morgah Biodiveristy Park, Rawalpindi. *Pak. J. Bot.* **40**: 1897-1911.

Idris S (2003) Genetic conservation and utilization of *Nephelium ramboutan-ake* and *Mangifera odorata* in Malaysia. In*: Final Country Report for Malaysia submitted to IPGRI under ADB-funded Project on ''Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia''*. Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia.

Jena BS, GK Jayaprakash, RP Singh and KK Sakariah (2002) Chemistry and biochemistry of hydroxycitric acid from *Garcinia. J. Agric. Food Chem.* **50**: 10-22.

Kiene T (2006) Traditional knowledge in the European context. In: *Resources Naturelles*. de l'OMPI Europe, **2**: 26-29.

Mahrouf ARM (2003) Socio-economic dimensions in conservation and use of mango species biodiversity in Sri Lanka. In: *Final Report on Socioeconomic Aspects studied under IPGRI-ADB-TFT Project 'Conservation and Use of Native Tropical Fruit Species Biodiversity in Asia*'. Socio-economics & Planning Centre, Department of Agriculture, Peradeniya, Sri Lanka, 75p.

Manuel P, T Javier, B Emilio, MC Ana, JL Juan, SM Elia and M Ramon (2007) Traditional knowledge of wild edible plants used in the northwest of the Iberian Peninsula (Spain and Protugal): a comparative study. *J. Ethnobiol. Ethnomed*. **3**: 27.

Mauro F and PD Hardison (2000) Traditional knowledge of indigenous and local communities: international debate and policy. *Ecol. Appl*. **10**: 1263-1269.

Pandey S (2014) Traditional knowledge and bio-piracy. In: *Workshop on Securing and Exploiting Intellectual Property Rights in Bioscience Sector,* 6th March 2014, Mohali, India.

Phillips O and AH Gentry (1993) The useful plants of Tambopata, Peru 1. statistical hypotheses tests with a new quantitative technique. *Econ. Bot.* **47**:15-32.

Ramanatha Rao V and Bhag Mal (2002) Tropical fruit species in Asia: diversity and conservation strategies. *Acta Hort.* (ISHS). **575**: 179-190.

Rijal DK, A Subedi, MP Upadilla, RB Rana, P Chaudhary, RK Tiwari, BR Sthapit and D Gauchan (2003) Community biodiversity register: developing community based database for genetic resources and local knowledge of Nepal. In: BR Sthapit, MP Upadhyay, BK Baniya, A Subedi, and BK Joshi (eds.). *On farm Management of Agricultural Biodiversity in Nepal*, Proc. National Workshop 24-26 April.

Sampath Kumar KP, D Bhowmik, A Dutta, A Yadav, S Paswan, S Srivastava and L Deb (2012) Recent trends in potential traditional Indian herbs *Emblica officinalis* and its medicinal importance. *J. Pharmacognosy Phytochem.* **1**: 24.

Sthapit BR and P Quek (2006) Community biodiversity registers: overview, concepts and some systematic approaches. *Paper presented at the National Workshop of Community Biodiversity Register*, 27-28 Oct 2005, Khumaltar, NARC, Nepal.

Vasudeva R and N Rajeshwari (2014) *Appemidi*: W*ild Aromatic Pickle Mango of the Central Western Ghats, India*. Information Brochure, UNEP/GEF project on Tropical Fruit Trees.

Appendix 1

Tropical fruit tree species recorded in four typical villages belonging upper-Ghat and coastal bioclimatic zones of Uttara Kannada district

S. No.	Scientific Name	Common Name	Family	Native/ Introduced	Villages				Production system
					Salkani	Killara	Murur	Kallabbe	
1.	*Anacardium occidentale*	Geru	Anacardiacea	I	✔	✔	✔	✔	Orchard and *Bettaland*
2.	*Mangifera indica*	Mavu	Anacardiaceae	N	✔	✔	✔	✔	Home-garden and orchard
3.	*Garcinia indica*	Murugalu	Clusiaceae	N	✔	✔	✔	✔	Forest/orchard
4.	*Artocarpus heterophyllus*	Halasu	Moraceae	N	✔	✔	✔	✔	Home-garden
5.	*Garcinia gummi-gutta*	Uppage	Clusiaceae	N	✔	✔	-	✔	Orchard
6.	*Achras zapota*	Chikku	Sapotaceae	I	✔	✔	✔	✔	Home-garden
7.	*Citrus limon*	Nimbu	Rutaceae	N	✔	✔	✔	✔	Home-garden
8.	*Carica papaya*	Papaya	Caricaceae	I	✔	✔	✔	✔	Home-garden
9.	*Phyllanthus emblica*	Nelli	Euphorbiaceae	N	✔	✔	✔	✔	*Bettaland* and Home-garden
10.	*Theobroma cacao*	Cocoa	Sterculiaceae	I	✔	-	✔	✔	Home-garden
11.	*Artocarpus altilis*	Beru halasu	Moraceae	N	✔	✔	✔	✔	Home-garden
12.	*Citrus aurantifolia*	Huli Kanchi	Rutaceae	N	✔	✔	-	✔	Home-garden
13.	*Psidium guajava*	Perale	Myrtacea	N	✔	✔	✔	✔	Home-garden
14.	*Averroha bilimbi*	Bimbli	Oxalidaceae	N	-	-	✔	✔	Home-garden
15.	*Citrus maxima*	Sakkare Kanchi	Rutaceae	N	✔	✔	✔	✔	Home-garden
16.	*Anona reticulata*	Ramaphala	Anonaceae	N	✔	✔	✔	✔	Home-garden
17.	*Citrus paradisi*	Panaka Nimbu	Rutaceae	I	✔	-	✔	✔	Home-garden
18.	*Syzygium malaccense*	Jambe	Myrtaceae	N	✔	✔	-	-	Home-garden
19.	*Citrus sinensis*	Kittale	Rutaceae	N	✔	✔	-	-	Home-garden
20.	*Syzygium jambos*	Pannerale	Myrtaceae	N	✔	✔	✔	✔	Home-garden
21.	*Avverroha carambola*	Dare Huli/ Karimadala	Oxalideraceae	N	-	-	✔	✔	Home-garden
22.	*Spondias pinnata*	Amte	Anacardicaeae	N	-	✔	✔	✔	Home-garden
23.	*Phyllanthus acidus*	Rajanelli	Euphorbiaceae	N	✔	-	-	✔	Home-garden
24.	*Tamarindus indica*	Hunase	Fabaceae	I	-	✔	✔	✔	Home-garden
25.	*Citrus macroptera*	Dadli	Rutaceae	N	✔	✔	-	-	
26.	*Artocarpus hirsuta*	Hebbalasu	Moraceae	N	✔	✔	✔	✔	Forest
27.	*Phyllanthus emblica*	Nelli	Euphorbiaceae	N	✔	✔	✔	✔	Bettaland
28.	*Syzygium cumini*	Nerale	Myrtaceae	N	✔	✔	✔	✔	Forest/ *Bettaland*
29.	*Ziziphus rugosa*	Mulle Hannu	Rhamnaceae	N	✔	✔	✔	✔	Forest / *Bettaland*
30.	*Aporosa lindleyana*	Challe Hannu	Euphorbiaceae	N	✔	✔	✔	✔	Forest/ *Bettaland*
31.	*Buchanania lanzan*	Nurukalu	Anacardiaceae	N	✔	✔	-	-	Forest/ *Bettaland*
32.	*Flacourtia montana*	Sampige Hannu	Flacourtiaceae	N	✔	✔	✔	✔	Forest
33.	*Rourea santaloides*	Hulinajjige Hannu	Connaraceae	N	✔	✔	-	-	Forest
34.	*Ziziphus oenoplea*	Parage Hannu	Rhamnaceae	N	✔	✔	-	-	Forest/ *Bettaland*
35.	*Carissa carandus*	Kaulikayi	Apocynaceae	N	✔	-	✔	✔	Forest
36.	*Elaeagnus conferta*	Halage Hannu	Elaeagnaceae	N	✔	✔	-	-	Forest
37.	*Gardenia gummifera*	Bikke	Rubiaceae	N	✔	✔	-	-	Forest
38.	*Semecarpus anacardium*	Guddegeru	Anacardiaceae	N	✔	✔	✔	✔	Forest
39.	*Syzygium caryophyllatum*	Kuntanerale	Myrtaceae	N	✔	✔	✔	✔	Forest/ *Bettaland*
40.	*Terminalia bellerica*	Anale	Combretaceae	N	✔	✔	✔	✔	Forest
41.	*Garcinia morella*	Arishina Gurage	Cluciaceae	N	-	✔	-	-	Forest
42.	*Artocarpus lakoocha*	Vate	Moraceae	N	✔	✔	✔	✔	Forest
43.	*Ficus glomerata*	Attihannu	Moraceae	N	✔	✔	-	-	Home-gardens

Appendix 2

Traditional knowledge associated with tropical fruit trees recorded in the study locations

a. Culinary uses

S.No.	Species/variety	Use	Part used	Brief procedure	Remarks
1.	Jackfruit	*Kadabu*/*idli*	Fruit rind	Grind the flakes. Add milled rice flour, jaggery, salt and bake in a banana leaf.	Special sweet dish
		Papad	Fruit	Separate the flakes from seeds. Boil in water, grind and apply the paste on a cocoa leaf.	This papad is usually roasted on open flame or else can be cooked in coconut oil.
		Holige	Seeds	Boil the seeds in water, add jaggery. Grind them & make them into tiny balls. Add water and turmeric powder to wheat flour. Stuff grinded seeds into flour balls.	A traditional sweet dish
		Neeragojju	Flakes and seeds	Boil the flakes and seeds in water. Add salt, lemon juice and season with green chili, cumin seeds, asafoetida, mustard & coriander.	It is a type of gravy, usually mixed with rice for taste
		Finger chips	Flakes	Cut the flakes in finger-shape. Fry them. Add salt, red chili powder, cumin powder, asafoetida whilst still hot.	Flakes are expected to be less sweet and crispy
		Genasale	Flakes	Grind the fruit flakes with rice flour, grated coconut, jaggery and salt. Wrap in a banana leaf and bake.	A type of sweet
		Gudna	Seeds	Remove the seed coat and boil. Add salt, jaggery, grated coconut,	
2.	Mango	*Gojju*	Pulp	Soak the fruit in salt water for some time. Then season it with oil, mustard seeds, green chilli and garlic. Add butter milk after some time.	A type of gravy
		Appehuli	*Appe* (unripe mango) sap	Add few drops of sap to water. Add salt and jaggery to it. Then season with mustard seeds & green chili.	It improves digestion. It is also taken after major meal
		Pickle	*Appe* varieties	Mix the appe with salt in layers for 5- days. Dry thoroughly and add the pickle masala. Keep in an air-tight container for few months before it is ready for use.	Pickle from different varieties can be stored from 6 months to 2-3 years. The shelf life depends on the mango variety and procedure
		'*Halwa*'	Fruit	Juice is extracted from the fruit rind. Boil it after adding sugar. Allow to cool for some time.	It is a type of dessert
3.	White *Garcinia indica*	Juice	Fruit skin	Soak the skin overnight in water. Season with mustard seeds, cumin seeds, chili and add a pinch of salt.	It has medicinal property. Good for acidity, *kapha* and bile problems
		Curry	Fruit skin	Soak the fruit in water. Add red chili, clove, black pepper, cinnamon and grind well. Season with cumin and coriander leaves. Add salt.	
		Fish curry	Dried fruit rind	Sun-dry the fruit for few days.	Added as a flavouring agent
	Garcinia indica (Kokum)	Butter	Seeds	Extracted butter is used as cooking oil and for roasting *dosa*.	Garcinia butter has excellent crack-healing property. It is used as skin moisturizer during winter
4.	*Ziziphus rugosa* (Bili-Mullehannu)	Juice	Fruit	Separate the fruit from seeds. Add jaggery and grind well.	Acts as a coolant. Keeps the body hydrated
5.	Cashew & Jackfruit	Dry fruits	Seeds	Roast the seeds and eat.	The seeds are roasted and eaten like almond
		Wine	Fruits (cashew)	Juice is extracted and kept in a container below the ground for few days until fermentation process occurs. The juice is processed and wine is obtained.	People followed a crude method for wine preparation
6.	*Artocarpus hirsuta* (Wild Jack)	Curry	Fruit	This fruit is used as vegetable.	
8.	*Spondias pinnata (Amte)*	Curry	Fruit	Flavouring agent and adds sour taste to curry.	

b. Medicinal purposes

S. No.	Species	Problem	Part used	Brief procedure	Remarks
1.	Mango	Dysentery	Fruit juice	Mix few drops of mango juice with lemon juice. Make a paste from mango bark using the juice.	Works best for mild form of the problem
	Huli (sour) mango variety	Severe dysentery	Fruit juice	Prepare paste from the bark of '*Huli* mango' variety in water	Not in practice these days
	Tender mango (*appe*)	Intestinal worm problem	Tender endocarp	Eat fresh endocarp of tender mango	Works like a tablet
2.	*Syzygium cumini* (Jamun)	Bark	Diabetes	Make a paste with water and take regularly.	This treatment keeps a check on sugar level in diabetic patients if good care taken on diet
3.	Gooseberry	Fruits	Diabetes	Roast the fruits in ghee and add fenugreek, jaggery, butter milk and drink regularly.	Gooseberry and fenugreek can be made into powder and stored. This mixture can be used as and when needed
4.	*Garcinia indica*	Fruit rind	Dysentery	*Garcinia* butter is mixed with garlic.	For mild dysentery
		Fruit rind	Severe dysentery	*Garcinia* butter is taken in tea decoction. It can also be taken with rice.	Still used in the villages for dysentery in kids
		Fruit rind (juice)	Bile	Soak the dried fruit rind in water overnight. Drink in the morning before breakfast.	
5.	Papaya	Seeds	Intestine worm	Dry the seeds, powder them. One spoon per one glass of water is recommended.	It is a knowledge held by the local community but not in practice these days
		Fruits	Obesity	Regularly eating papaya fruits is helpful in reducing the weight in overweight persons.	
6.	*Citrus limon*	Juice	Headache	Put a few drops of lemon juice into hot water and inhale the vapour.	
			Cough	Add some sugar to lemon juice and drink.	
7.	*Annona reticulata*	Seeds	Head lice	Crush the seeds, add coconut oil and apply during night time. Wash the hair in the morning.	Highly effective
8.	*Terminalia bellerica*	Fruits	Dysentry	Dry the fruits and powder them. Add water and drink.	It is not advisable to pregnant women, which could result in abortion
9.	*Gardenia gummifera*	Leaf	Indigestion in cattle	Crush the leaves. Add water and feed it to cattle.	

c. Processing and preservation of TFT

S.No.	Species	Part	Use	Brief procedure	Remarks
1.	Mango	Tender mango	Pickle	Separate the waste from the fruits. Soak them in salt water until they shrivel and turn to light brown.	They can be kept for few months
		Sap collection from tender mango	Flavouring agent	Cut the stalk and keep the fruit inverted in a bottle until all the sap is collected.	Stored for a long time (1 year) if kept in air-tight bottle
		Fruits	Ripening	Mango unripe fruits are kept in paddy straw.	It is believed to accelerate ripening process
2.	Jackfruit	Seeds	Eaten like badam, almond	Mix termite soil with the seeds. Keep the seeds in copper vessels.	Shelf life is up to 4-5 months
		Flakes	Edible	Preserved in brine solution	Can be stored up to 7-8 months
3.	*Garcinia indica*	Seeds	Butter	Separate the seeds from fruit dry them and mix them with ash to get rid of the slime. Fry them until they start giving off oil. Powder and boil in water. Oil floats on the surface. Remove them and it turns to solid at room temperature.	It has excellent medicinal properties and is also used as a natural skin moisturizer, especially during winter
		Seeds	Preservation	Seeds are separated from the fruits. The seeds are mixed with ash. Mixing with ash makes the seeds slime-free and extends the shelf life.	The ash-mixed seeds can be used for sowing as well for other uses like butter extraction
4.	*Garcinia indica* (White fruit type)	Fruit rind	Squash	Extract juice, add sugar and dry in sun.	It can be stored up to 6 months

d. Pest and disease management

S.No.	Species	Treatment	Brief procedure	Remarks
1.	Mango	Lime water	Mango fruits are dipped in lime water once to protect from pest and diseases.	It is also supposed to accelerate ripening
		Light burning	Arecanut husk is burnt underneath the tree. The smoke is helpful to ward off sucking pests.	
2.	Jackfruit	Coating with red soil	Jackfruit seeds are coated with red soil and sun-dried. Then the seeds are stored in mud pots which are stored in muddy pits.	The area should be dry so as to avoid water logging condition. Seeds could be preserved up to 6 months

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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 @ $p<0.05$

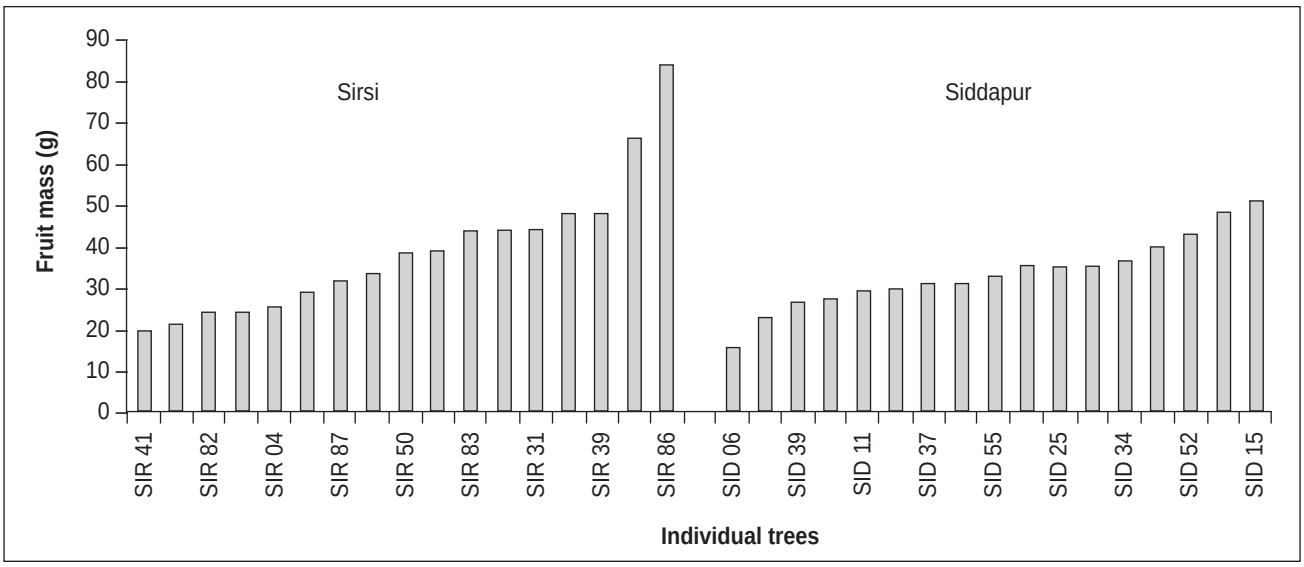

Fig. 1. Continuous tree-to-tree variation in mean fruit mass (g) of wild pickle-mango in two localities of Uttara Kannada, Central Western Ghats. The accessions are arranged in the increasing order of fruit mass

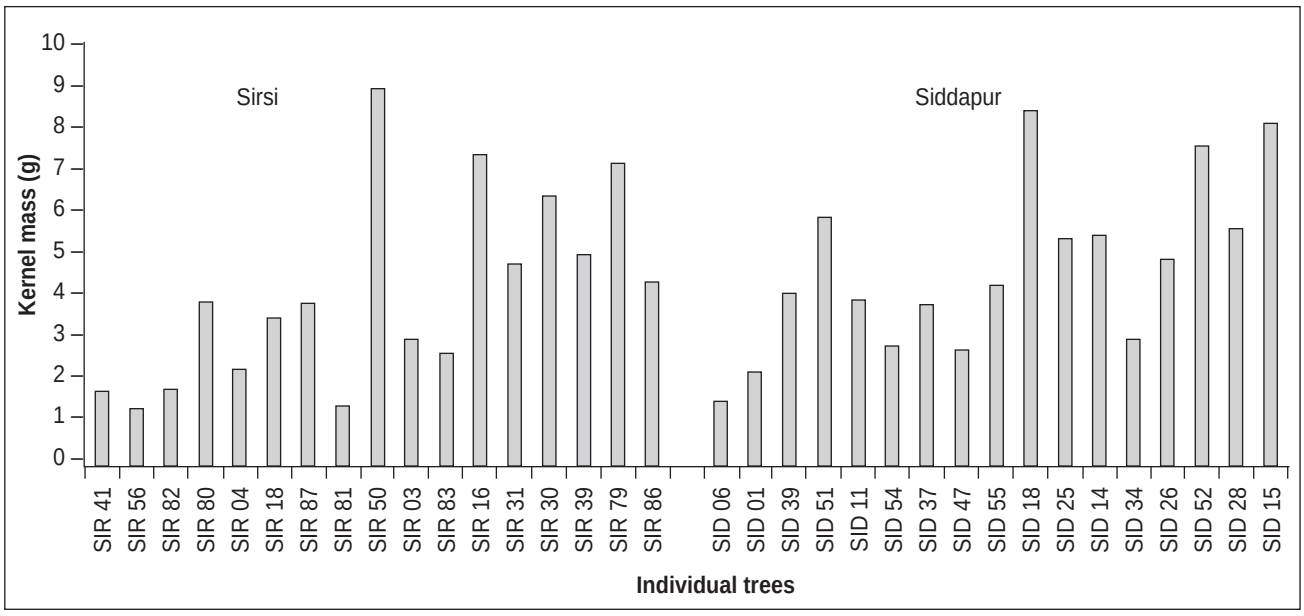

Fig. 2. Tree-to-tree variation in mean stone mass (g) in two localities of Uttara Kannada, Central Western Ghats

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).

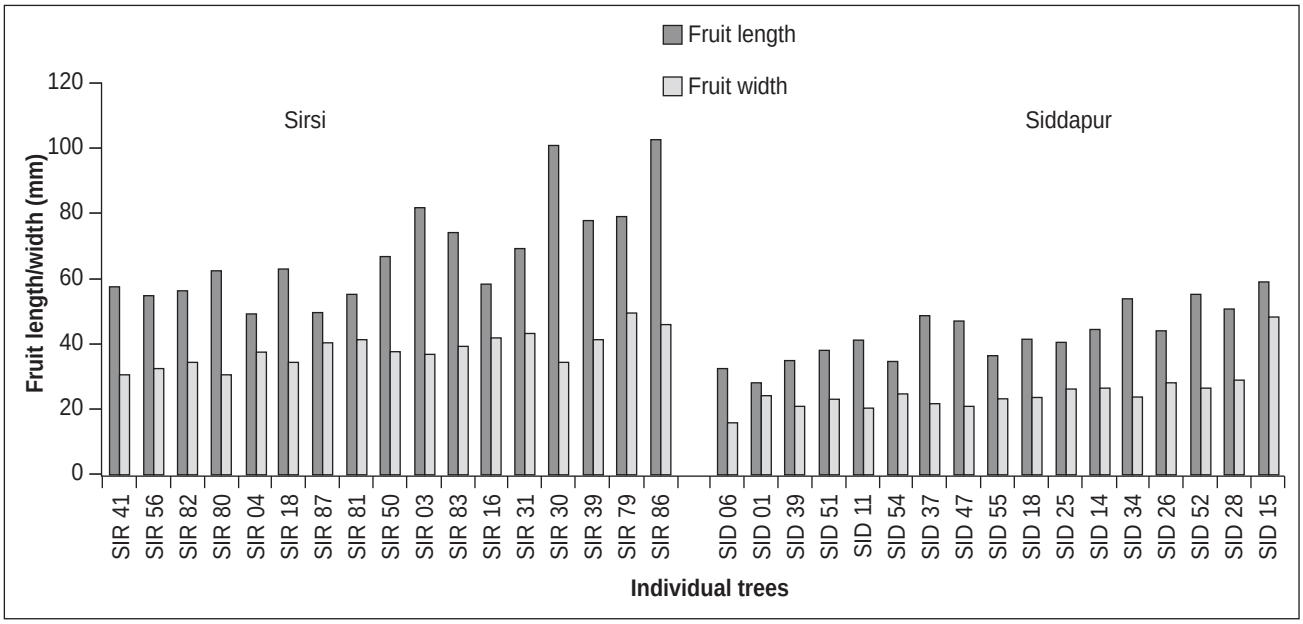

Fig. 3. Tree-to-tree variation in mean fruit length and width (mm) in two localities of Uttara Kannada, Central Western Ghats

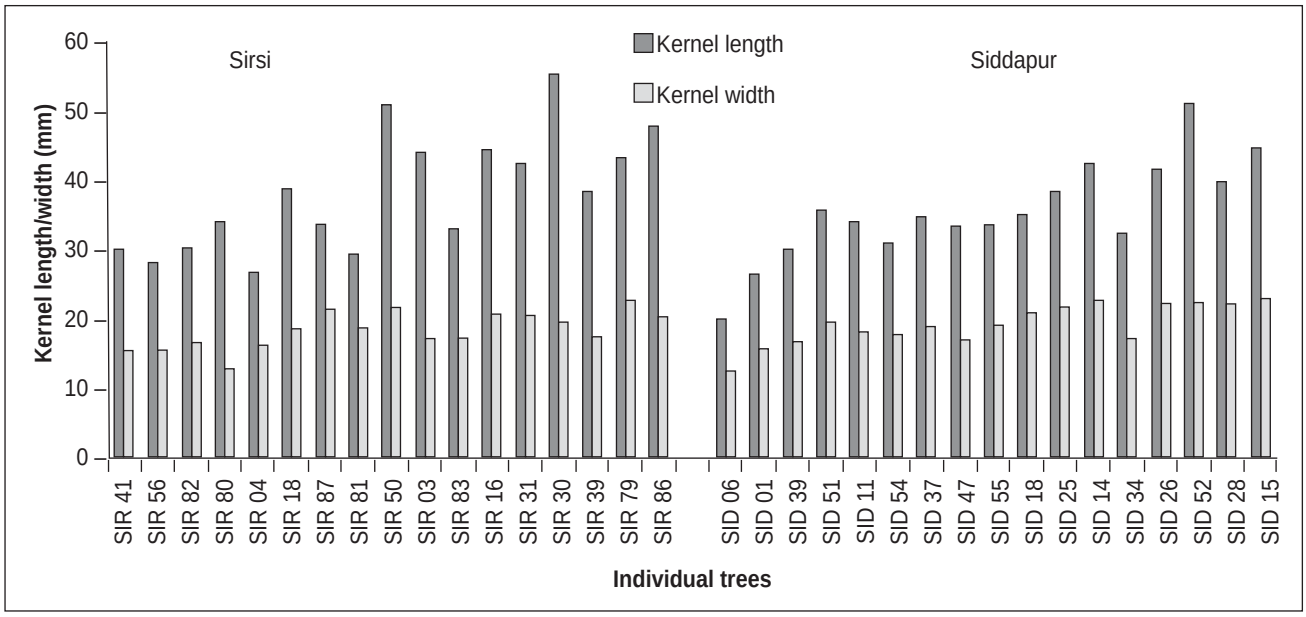

Fig. 4. Tree-to-tree variation in mean stone length and width (mm) in two localities of Uttara Kannada, Central Western Ghats

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

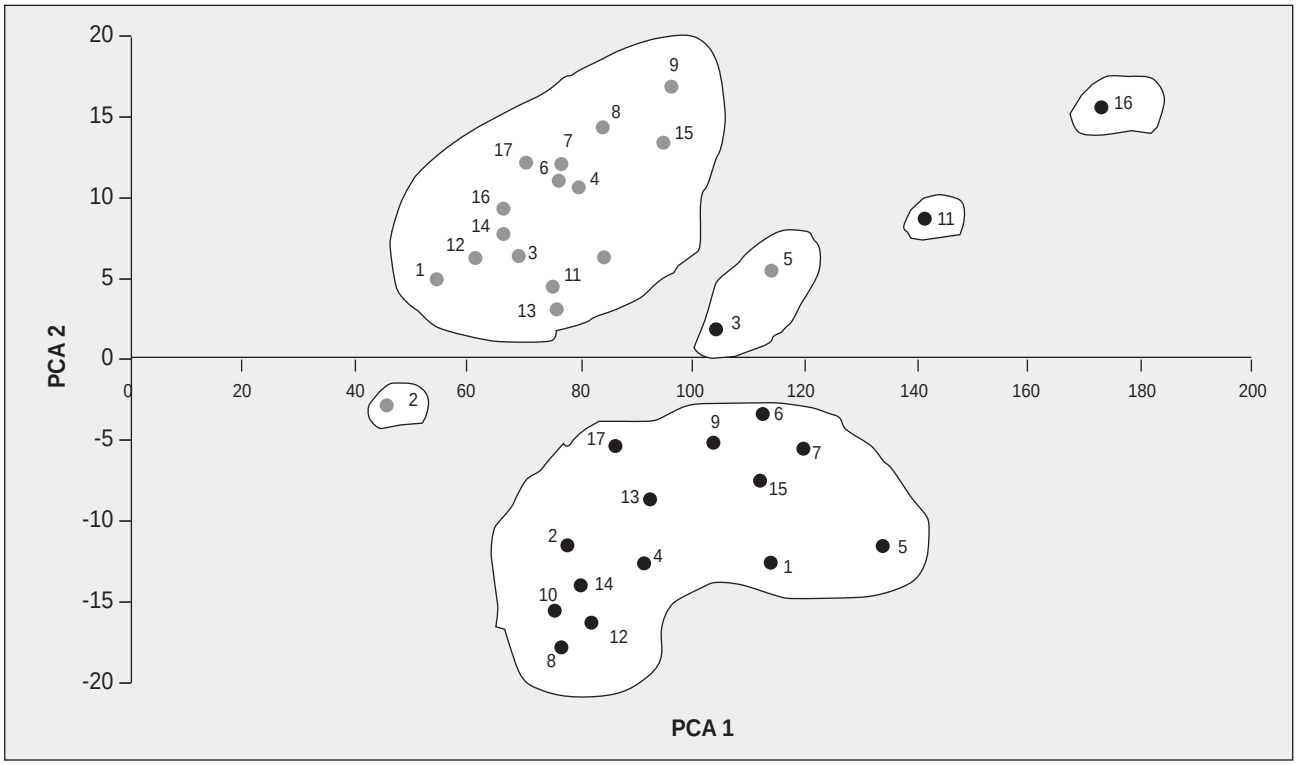

Fig. 5. Configuration of wild pickle-mango accessions from Sirsi (red n=17) and Siddapur (Blue n= 17) site as shown by PC 1 and PC 2 for fruit parameters. Accession number of trees is shown next to dots

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

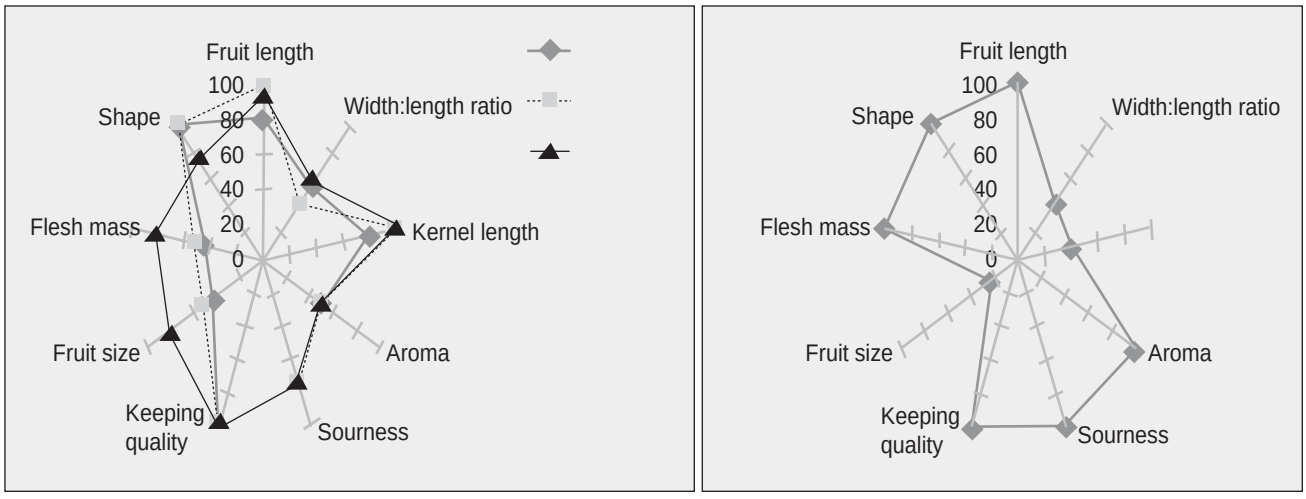

Fig. 6. Web diagrams showing ideal fruit type of wild pickle-mango (a) of three trees that are closest to the ideal type (b) as determined by the respondents and observations

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).

Acknowledgements

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References

Anegbeh PO (1990) Variation in *Newbouldia laevis* P. Beauv. Seeman ex Bureau from some sources in Southwestern Nigeria. M.Sc. Thesis, University of Ibadan, Nigeria.

Atangana AR, Z Tchoundjeu, J-M Fondoun, E Asaah, M Ndoumbe and RRB Leakey (2001) Domestication of *Irvingia gabonensis*: 1. Phenotypic variation in fruits and kernels in two populations from Cameroon. *Agrofor. Syst.* **53**: 55-64.

Bhagyavanth N Masudi, Rajesh P Gunaga, Pradeep Damle and R Vasudeva (2010) Development of fruit and seed descriptors in *Garcinia gummi-gutta* (L.) Robsn.: Implications for domestication. *In*: R Vasudeva, BS Janagoudar, BMC Reddy, Bhuwon Sthapit and HP Singh (eds). *National Symposium on Garcinia Genetic Resources: Linking Diversity, Livelihood and Management*, May 8-9, 2010, College of Forestry, Sirsi.

Gautam PL, Ajay Kumar Singh, Manoj Srivastava and PK Singh (2012) Protection of plant varieties and farmers' rights: a review. *Indian J. Plant Genet. Resour*. **25**: 9-30.

ICRAF (1997) Annual Report 1996, ICRAF, Nairobi, Kenya.

Leakey RRB (2001) Win:win land use strategies for Africa: 2. Capturing economic and environmental benefits with multi-strata agroforests. *Int. Forestry Rev.* **3**: 11-18.

Leakey RRB (2005) Domestication potential of marula (*Sclerocarya birrea* subsp. *caffra*) in South Africa and Namibia: 3. Multiple trait selection. *Agrofor. Syst.* **64**: 51-59.

Leakey RRB, J-M Fondoun, A Atangana and Z Tchoundjeu (2000) Quantitative descriptors of variation in fruits and seeds of *Irvingia gabonensis*. *Agrofor. Syst.* **50**: 47-58.

Leakey RRB, K Pate and C Lombard (2005b) Domestication potential of marula (*Sclerocarya birrea* subsp. *caffra*) in South Africa and Namibia: 2. phenotypic variation in nut and kernel traits. *Agrofor. Syst.* **64**: 37-49.

Leakey RRB and T Page (2006) The 'ideo type concept' and its application to the selection of 'AFTP' cultivars. *For. Trees Liveli.* **16:** 5-16.

Leakey RRB, S Shackleton and P Plessis (2005a) Domestication potential of marula (*Sclerocarya birrea* subsp. *caffra*) in South Africa and Namibia: 1. phenotypic variation in fruit traits. *Agrofor. Syst.* **64**: 25–35.

Leakey RRB, AR Atangana, E Kengni, AN Waruhhiu, C Usora, PO Anegbeh and Z Tchoundjeu, (2002) Domestication of *Dacryode edulis* in west and central Africa: characterization of genetic variation. *For. Trees Liveli.* **12:** 57-72.

Leakey RRB, K Schreckenberg and Z Tchoundjeu (2003) The participatory domestication of West African indigenous fruits. *Int. Forestry Rev.* **5**: 338-347.

Ludwig JA and JF Reynolds (1988) *Statistical Ecology: A Primer on Methods and Computing*, John Wiley and Sons, New York, pp 85-106.

Sneath PHA and R Sokal (1973) *Numerical Taxonomy.* Freeman, San Francisco, pp 92-98.

Sthapit BR and VR Rao (2009) Consolidating community's role. In: local crop development by promoting farmer innovation to maximize the use of local crop diversity for the well-

being of people. *Acta Hort*. (ISHS) 806: 669-676 (http://www.actahort.org/books/806/806_83.htm).

Tchoundjeu Z, J Kengue and RRB Leakey (2002) Domestication of *Dacryodes edulis*: state-of-the-art. *For. Trees Liveli.* **12**: 3-13.

Tesfaye Ashine (2011) *Mapping, Regeneration Assessment and Development of Quantitative Descriptors for Wild Pickle-Mango Genetic Resources of Central Western Ghats.* M.Sc. (Forestry) Thesis in Forest Genetic Resources, submitted to the University of Agricultural Sciences, Dharwad, Karnataka, India.

Vasudeva R, AA Abebe, NR Hegde and GS Deepa (2011) Documenting fruit trait diversity of aromatic pickle mango in the humid tropics of central Western Ghats. In: Proc. of '*Augmenting Production and Utilization of Mango: Biotic and Abiotic Stresses*' organized by the Society for Development of Subtropical Horticulture, Central Institute for Subtropical Horticulture (ICAR), Lucknow, Uttar Pradesh, India.

Vasudeva R and N Rajeshwari (2014) *Appemidi*: *Wild Aromatic Pickle Mango of the Central Western Ghats, India*. Information Brochure, UNEP/GEF project on Tropical Fruit Trees.

Vasugi C, MR Dinesh, K Sekar, KS Shivashankara, B Padmakar and KV Ravishankar (2012) Genetic diversity in unique indigenous mango accessions (*Appemidi*) of the Western Ghats for certain fruit characteristics. *Curr. Sci.* **103**:199-207.

Warihiu AN (1999) *Characterization of Fruit Traits Towards Domestication of an Indigenous Fruit Tree of West and Central Africa: A Case Study of Dacryodes edulis in Cameroon.* M.Sc. Thesis, University of Edinburgh.

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Morphological Characterization of a Few Farmers'-Identified Unique Aromatic Pickle Mango (*Appemidi*) Varieties of the Central Western Ghats

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Aromatic pickle mango (locally called *'Appemidi'*) is a special type of mango (*Mangifera indica* L.) harvested and semi-domesticated from riverine habitats of the central Western Ghats, India. Recently, it has been provided with the geographical indication (GI) tag. These types are recognized by the local people based on their aroma and taste apart from fruit shape and size. In spite of its commercial importance, there are very few attempts to formally characterize these types for further use. Twelve farmers' identified varieties collected from a fifteen-year-old mango orchard were characterized adopting standard mango descriptors developed by the IPGRI. In the present study 12 varieties of aromatic pickle mango were characterized through a set of distinguishing traits and delineated adopting simple forking method to individual varieties unambiguously.

Key Words: *Appemidi,* Aromatic pickle mango, Descriptors, Farmers' varieties, Morphological traits

Introduction

India is the regarded as the centre of origin and the primary centre of diversity of mango harboring perhaps the largest gene pool with over 1500 mango cultivars (Mukherjee, 1985). Apart from eating fresh fruits, a wide array of products ranging from jam, jelly, leather, squash, wine, *etc.* are prepared using this fruit. Different stages of fruit development are used to prepare these products. One such unique preparation is pickles of highly aromatic mango types in their tender, un-ripen 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 up to today (Vasugi *et al*., 2012; Bhat *et al*., 2013; Vasudeva *et al*., 2011). Unlike commercial mango, "*appemidi*" fruits are extremely sour and far from sweet taste and hence are not used as edible fresh fruits, but are valued for its aroma. *Appemidi* fruits are processed into pickle which is a widely used and appreciated side dish of almost every single meal in the Central Western Ghats. For a common man of this region, no meal is complete without the extraordinary effervescent taste of these *'appemidi'* pickles (Vasudeva and Rajeshwari, 2014). Because of this deep cultural attachment, people have recognized several hundred pickle-mango types from the wild habitats. These types are recognized by the local people based on their aroma and taste apart from fruit shape, size. Unique types of *'appemidi'* have been identified and domesticated/introduced in home gardens by many households and were extensively collected by farmers. It is distinct from other cultivated fruit varieties with respect to morphological characters such as fruit size, shape, taste, aroma, crown shape, height, and resistance to pest and diseases. The immature fruits are especially suitable for pickling and are in more demand in the market. Very recently, Government of India has also accorded a "geographical indication (GI)" tag to *'appemidi'* types (Source: http://ipindia.nic.in/girindia/images/RegGis.gif; Gautam *et al*., 2012). Despite being a valued local commodity and commonly used side dish, with multiple distinctive types and varieties locally recognized, as well as high importance in rural people's livelihoods little research has been done to systematically characterize the range of available types (Vasugi *et al*., 2012).

Characterization of wild types and semi-domesticated

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types is necessary as it forms the basis for discerning farmers' varieties, subsequent registration of the same and further genetic improvement. Community management and domestication of *'Appemidi'* resources are being addressed under the GEF-UNEP project titled "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 (Sthapit *et al.*, 2013).

Materials and Methods

The study material was collected from a fifteen-year-old mango orchard of a custodian farmer (Sthapit *et al.*, 2013) located at *Salkani* village, situated at about 17 km away from the College of Forestry, Sirsi (14^0 37' N latitude and 74^0 51'E longitude; 650 msl), India. The area falls in the central Western Ghats eco-region, which is one of the hotspots of biological diversity of the world. This farmer has scrupulously maintained dozens of aromatic pickle mango types in his 7 acre orchard obtained through grafting of the original mother trees from natural habitats. The orchard has been raised on a fairly plain land with a uniform spacing of 5m between rows and between trees. He has been recognized as a custodian farmer of *'appemidi'* recently by the Bioversity International (Sthapit *et al*., 2013). Twelve farmers' identified varieties considered in the study and their special uses are shown in the Table 1. These varieties have been selected from the natural populations of *'appemidi'* by the custodian farmer for multiple uses as whole fruit pickle, cut pickle, propagated through vegetative grafting and today well accepted by the farming communities for their good qualities (Vasudeva and Rajeshwari, 2014).

The morphological characterization was done adopting standard mango descriptors developed by the IPGRI (IPGRI, 2006). Three ramets (*i.e*. vegetatively propagated saplings of the mother tree) per variety were considered for the observations. Only when traits were consistently expressed by all the three ramets, the variety was selected for evaluation. The morphological characterization is carried under four broad category such as i) Tree descriptors, ii) Leaf descriptors, iii) Flower descriptors, and iv) Fruit descriptors as prescribed by the IPGRI (IPGRI, 2006). All the varieties focused in the study are 'grafted' types, had similar trunk circumference and crown diameter facilitating the comparison for other characteristics. From every tree, a minimum of 10 leaves, five inflorescences, and 20 fruits were considered to take the observations on quantitative traits. The data on qualitative traits were observed for two seasons.

Results and Discussion

Tree Descriptors

Tree growth habit, foliage density and crown shape were considered under the tree morphological descriptors (Table 1). With respect to tree growth habit, except

Table 1. Characterization of selected farmers' varieties of aromatic pickle mango using tree morphological descriptors

S. No.	Name of the Farmers' varieties	Specific use	Tree type	Tree growth habit	Foliage density	Crown shape
1	*Malangi*	Whole tender mango pickling	Grafted	Spreading	Intermediate	Broadly pyramidal
2	*Mavinakatta*	Whole tender mango pickling	Grafted	Spreading	Dense	Oblong
3	*Dannalli*	Whole tender mango pickling	Grafted	Spreading	Intermediate	Oblong
4	*Kalkai*	Whole tender mango pickling	Grafted	Spreading	Dense	Semi circular
5	*Haldota*	Whole tender mango pickling	Grafted	Erect	Dense	Oblong
6	*Nandgar*	Whole tender mango pickling	Grafted	Spreading	Dense	Oblong
7	*Ananth bhatta*	Whole tender mango pickling	Grafted	Spreading	Sparse	Oblong
8	*Purappe mane*	Whole tender mango pickling	Grafted	Spreading	Intermediate	Semi circular
9	*Kadigai*	Sliced mango pickling	Grafted	Spreading	Intermediate	Semi circular
10	*Karolla*	Sliced mango pickling	Grafted	Spreading	Sparse	Semi circular
11	*Mudgar kosgai*	Sliced mango pickling	Grafted	Spreading	Dense	Semi circular
12	*Gadehalli kuchagai*	Sliced mango pickling	Grafted	Spreading	Dense	Oblong

'*Haldota*' variety, which showed an 'erect' type, all other varieties were categorized as 'spreading' type. Except '*Ananthabhatta*' and '*Karola*' varieties, all others showed 'intermediate' to 'dense' foliage. '*Malanji*' variety recorded 'pyramidal crown' while others were either 'oblong' or 'semi-circular'. However it is likely that the crown shape might have been slightly altered through the management.

Leaf Descriptors

The aromatic pickle mango varieties considered in the study did not differ with respect to leaf lamina shape and showed 'oblong' leaf shape (Table 2). Leaf apex shape was generally 'acute' except in '*Kalkai*', '*Kadigai*' and '*Gadihalli Kuchagai*' varieties. The leaf base shape showed only two variants *viz*. 'acute' and 'obtuse'. Similarly leaf margin was either 'wavy' type or 'entire' type. The colour of the matured leaves ranged from 'pale green' to 'dark green' colour. The most distinctive trait used by the farmers to identify '*Nandagar*' variety was the slight reddish tinge on the leaf petiole.

The range of leaf blade length varied from 16.98 to 25.03 cm (Table 2). This is perhaps much smaller than the fruit varieties. '*Kadigai*' variety showed the largest leaf blade length (25.03 cm), while a minimum was observed in '*Malangi*' (16.98 cm). Characteristically '*Dannalli*' and '*Kadigai*' varieties had a very good shininess of leaves; while strong leaf fragrance was observed in '*Anantabhatta*' and '*Mudgar kosagai*' varieties. With respect to fragrance, '*Ananthabhata*' variety showed the strongest aroma in the leaf.

Flower Descriptors

Among the floral traits, variety '*Purappe mane*' recorded a slight 'pinkish' shade which was distinctive from all other varieties evaluated.

Fruit Descriptors

For the purpose of pickling, farmers harvest aromatic fruit types of different varieties at different stages. 'Whole fruit pickle varieties' are harvested at very immature stage while the 'sliced pickle' varieties are harvested at mature but unripe stage (Table 1). It is at these stages distinctive traits are observed by the farmers to recognize the varieties. Hence it is important to evaluate them at appropriate stages to determine the best characters for pickling. For this reason, morphological characterization of the aromatic pickle mango varieties has been done at two different stages of fruit development. For all the whole pickle mango varieties (S.No. 1-8; Table 3), tender stage was considered while for the ''sliced pickle mango' types (S.No. 9-12; Table 3) fully developed but immature stage was considered. All 'sliced pickle mango' types were 'roundish' with 'round' fruit apex and 'smooth surface texture'. Variety '*Haldota*' showed 'Serpentoid' fruit shape which is one of most preferred varieties by farmers. With respect to fruit beak type 'pointed' and 'perceptible' types were predominant, and 'prominent type' of fruit beak was observed in only two varieties '*Haldota*' and '*Anantabhatta*'. Among all the varieties it was observed that there were an equal proportion of 'waxy' and 'non-waxy' fruits. There were no specific

Table 2. Characterization of selected farmers' varieties of aromatic pickle mango using leaf morphological descriptors

S. No.	Name of the Farmers' varieties	Leaf blade shape	Leaf apex shape	Leaf base shape	Leaf margin	Colour of fully developed leaf	Leaf blade length (cm)	Leaf blade width (cm)	Petiole length (mm)	Shininess*	Leaf fragrance**
1	*Malangi*	Oblong	Acute	Acute	Wavy	Green	16.98	4.45	3.31	0	1
2	*Mavinakatta*	Oblong	Acute	Acute	Wavy	Dark green	20.48	4.69	3.74	1	1
3	*Dannalli*	Oblong	Acute	Acute	Wavy	Dark green	18.49	4.34	3.32	2	1
4	*Kalkai*	Oblong	Obtuse	Obtuse	Entire	Pale green	18.24	5.66	2.83	1	1
5	*Haldota*	Oblong	Acute	Obtuse	Entire	Green	19.37	6.81	3.55	1	1
6	*Nandgar*	Oblong	Acute	Acute	Entire	Pale green	20.19	4.81	3.67	1	1
7	*Ananth bhatta*	Oblong	Acute	Acute	Entire	Pale green	19.08	4.39	2.83	1	2
8	*Purappe mane*	Oblong	Acute	Acute	Wavy	Dark green	17.51	5.09	2.46	1	1
9	*Kadigai*	Oblong	Acuminate	Acute	Wavy	Dark green	25.03	6.37	3.62	2	1
10	*Karolla*	Oblong	Acute	Obtuse	Wavy	Green	21.63	6.39	2.99	1	0
11	*Mudgar kosgai*	Oblong	Acute	Obtuse	Entire	Green	18.5	4.26	2.96	0	1
12	*Gadehalli kuchagai*	Oblong	Acuminate	Acute	Wavy	Green	20.25	4.86	4.64	0	0

* 0= no shine; 1 = moderate shine 2 = good shine

** 0 = Not fragrant; 1 = moderately fragrant; 2 = strongly fragrant

Table 3. Characterization of selected farmers' varieties of aromatic pickle mango using qualitative fruit morphological descriptors

S. No.	Varieties	Fruit shape	Shape of fruit apex	Skin colour of the fruit	Fruit-beak type	Skin waxiness	Depth of fruit-stalk cavity	Fruit-neck prominence	Pulp aroma	Mature fruit colour
1	*Malangi*	Oblong	Obtuse	Green	Perceptible	Non-waxy	Absent	Slightly prominent	Strong	Greenish yellow
2	*Mavinakatta*	Oblong	Obtuse	Dark green	Pointed	Non-waxy	Absent	Absent	Strong	Greenish yellow
3	*Dannalli*	Oblong	Obtuse	Green	Pointed	Non-waxy	Absent	Absent	Intermediate	Yellow
4	*Kalkai*	Roundish	Round	Dark green	Perceptible	Waxy	Absent	Very prominent	Intermediate	Greenish yellow
5	*Haldota*	Serpentoid	Acute	Green	Prominent	Waxy	Absent	Slightly prominent	Intermediate	Yellow
6	*Nandgar*	Oblong	Obtuse	Greenish yellow	Pointed	Waxy	Absent	Slightly prominent	Intermediate	Greenish yellow
7	*Ananth bhatta*	Extra oblong	Acute	Green	Prominent	Non-waxy	Absent	Absent	Strong	Yellow
8	*Purappe mane*	Oblong	Round	Dark green	Perceptible	Waxy	Absent	Slightly prominent	Intermediate	Greenish Yellow
9	*Kadigai*	Roundish	Round	Dark green	Perceptible	Waxy	Shallow	Absent	Mild	Reddish Yellow
10	*Karolla*	Roundish	Round	Greenish yellow	Perceptible	Waxy	Medium	Prominent	Mild	Yellow
11	*Mudgar kosgai*	Roundish	Round	Green	Pointed	Non-waxy	Shallow	Absent	Mild	Yellow
12	*Gadehalli kuchagai*	Roundish	Round	Greenish yellow	Pointed	Non-waxy	Shallow	Absent	Mild	Yellow

associations among the six evaluated fruit characteristics as presented in Table 4.

As shown in the Table 4, all 'whole-fruit pickle' varieties (S.No. 1-8) showed smaller diameter (ranging from 2.87 to 4.29 cm) and fruit length (ranging from 4.84 to 7.62 cm); while the 'sliced-pickle' varieties (S.No. 9-12) recorded larger diameter (ranging from 5.07 to 8.22 cm) and larger length (ranging from 6.30 to 10.4 cm). All 'whole-fruit pickle varieties' did not show any stalk cavity.

For the general characterization of the aromatic pickle mango varieties, the observations are also recorded after fully ripening of fruits of all the varieties (Table 4). Varieties used for 'sliced pickles' generally possessed larger mass and mild aroma than those used as 'whole-fruit pickle'. Matured fruit colour of all the 'sliced pickles' varieties was 'yellow'. In general the 'whole fruit pickle' varieties showed greenish yellow colour.

In the era of IPR issues, characterization of varieties assumes greater importance. The application of morphological markers is the simplest of the methods of characterization that could be repeatedly done and effective used for IPR issues (Lyngdoh *et al*., 2007). Since the published descriptor lists are readily available for the morphological markers, it can be carried out *in situ*, is relatively low-cost and easy to perform.

Table 4. Characterization of selected farmers' varieties of aromatic pickle mango using quantitative unripe and mature fruit morphological descriptors

S. No.	Varieties	Fruit diameter (cm)	Fruit length (cm)	Fresh fruit weight (g)	Mature fruit diameter (cm)	Mature fruit length (cm)	Mature fresh fruit weight (g)
1	*Malangi*	3.68	4.76	25.73	4.82	6.49	70.20
2	*Mavinakatta*	3.63	6.00	26.11	5.49	8.06	110.13
3	*Dannalli*	4.29	6.78	42.97	5.48	8.81	122.12
4	*Kalkai*	3.96	4.84	20.02	5.57	6.39	88.91
5	*Haldota*	2.87	7.62	23.76	3.94	9.74	68.00
6	*Nandgar*	3.63	4.87	24.47	5.19	6.98	93.60
7	*Ananth bhatta*	3.17	7.26	53.79	4.12	9.52	121.22
8	*Purappe mane*	3.92	5.10	26.20	6.40	8.25	154.00
9	*Kadigai*	8.22	10.4	348.26	8.22	10.4	348.2
10	*Karolla*	8.26	9.35	286.13	8.26	9.35	286.13
11	*Mudgar kosgai*	5.54	6.43	108.43	5.54	6.43	108.43
12	*Gadehalli kuchagai*	5.07	6.30	78.26	5.07	6.30	78.26

Morphological characterization is the first step that should be done before more profound biochemical or molecular studies are carried out (Hoogendijk and Williams, 2001). Historically mango genotypes have been characterized using morphological markers (Singh, 1969; Vasugi *et al*., 2012).The strength of the descriptors lays in its ability to delineate genotypes without redundancy. It is shown in the present study that of 12 varieties of aromatic pickle mango could be delineated adopting a set of fruit traits (Fig.1). The simple forking method adapted to individual varieties was designed in a way that traits where unambiguous categories could be made were considered first and subjective traits were considered towards the end. Such a pattern of varietal identification has not been reported for any of tree species even though morphological characterization has been done in case of *Populus* spp. (Mohanty and Khurana, 2003) and *Santalum album* (Bagchi and Veerendra, 1985). Leaf descriptors were earlier adopted to describe inter-provenancial (Rawat *et al*., 1998) or to describe inter-clonal variation (Gunaga and Surendran, 2002) in teak. Gunaga and Surendran (2002) stressed the importance of morphological characterization as a cheaper tool for quick identification of clones based on their observation of eight leaf characters. Adopting these morphological markers, it is easy to delineate the farmers' varieties both at the nursery level and at adult tree level. These descriptors are also helpful in varietal registration processes. Further, at the field level, morphological characterization offers much scope to ascertain the fidelity of varieties and help in roughing operations.

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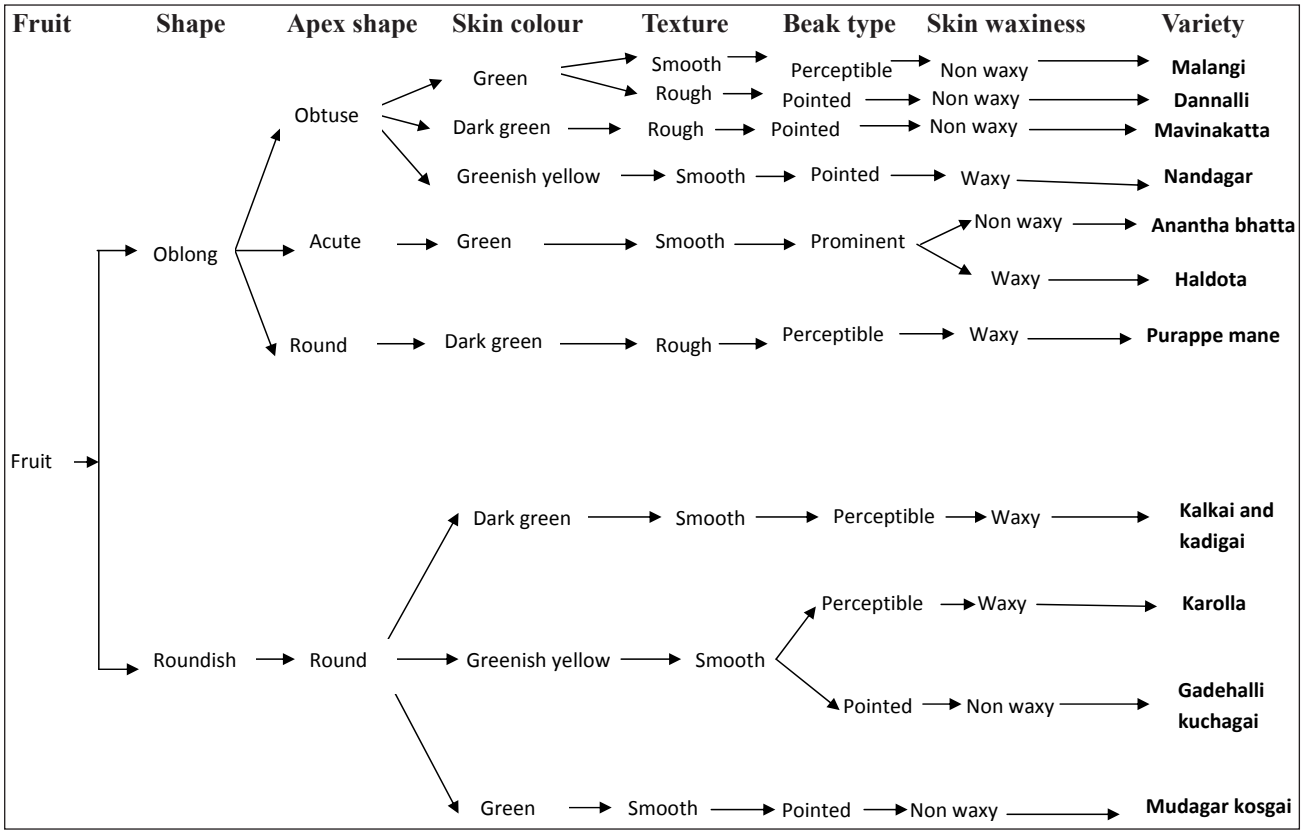

Fig. 1. Fruit-descriptors based key for the delineation of wild pickling mango varieties of the Central Western Ghats

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References

Bagchi SK and HGS Veerendra (1985) Study on intra tree and inter tree variation in leaves of *Santalum album* Linn. *Myforest* **21**: 33-39.

Bhat V, T Abebe, R Vasudeva, GV Nayak, MR Dinesh, S Rajan, B Sthapit and Ramanatha Rao (2013) Status and diversity of aromatic wild pickle mango *(Appemidi)* in home gardens and farmlands of central Western Ghats. Technical unpublished report UASD, GEF/Bioversity, ICAR.

Gautam PL, Ajay Kumar Singh, Manoj Srivastava and PK Singh (2012) Protection of plant varieties and farmers' rights: a review. *Indian J. Plant Genet. Resour.* **25**: 9-30.

Gunaga R and T Surendran (2002) Leaf morphological variation in teak (*Tectona grandis* L.f.*)* clones. *Evergreen* **48**: 8-9.

Hoogendijk M and D Williams (2001) Characterizing the genetic diversity of home garden crops: Some examples from Americas. *2nd International Home Gardens Workshop, July 17-19,2001*, Witzenhausen, Federal Republic of Germany. pp 34-40.

IPGRI (2006) Descriptors for Mango (*Mangifera indica* L.). International Plant Genetic Resources Institute, Rome, Italy, pp 36-44.

Lyngdoh Nicolee, Rajesh P Gunaga and R Vasudeva (2007) Delineation of teak (*Tectona grandis* Linn. F.) clones through leaf descriptors. *Indian J. For.* **30**: 21-28.

Mohanty TL and DK Khurana (2003) Morphological analysis of selected clones of *Populous ciliate* × *Populus maximowiczii* hybrid. *Indian J. For.* **26**: 83-89.

Mukherjee SK (1985) Systematic and eco-geographic studies on crop genepools in *Mangifera* L. IPGRI, Rome, 86 p.

Rawat MS, DP Uniyal and SL Sharma (1998) Identification of provenances based on leaf morphology in *Tectona grandis*. *Ind. For.* **124**: 248-251.

Singh LB (1969) Mango. In: Ferwerda FP & Wit F (eds) *Outlines of Perennial Crop Breeding in the Tropics*. Veenman and Zonem, Wageningen, Netherlands, 309 p.

Sthapit BR, H Lamers and VR Rao (2013) *Custodian Farmers of Agricultural Biodiversity: Selected profiles from South and South East Asia*. Proceedings of the Workshop on Custodian Farmers of Agricultural Biodiversity, 11-12 February 2013, New Delhi, India.

Vasudeva R and N Rajeshwari (2014) *Appemidi*: W*ild Aromatic Pickle Mango of the Central Western Ghats. India*. Information Brochure, UNEP/GEF project on Tropical Fruit Trees.

Vasudeva R, TA Abebe, NR Hegde and GS Deepa (2011) Documenting fruit trait diversity of aromatic pickle mango in the humid tropics of central Western Ghats. *In*: *Proc. of 'Augmenting Production and Utilization of Mango: Biotic and Abiotic Stresses*' organized by the Society for Development of Subtropical Horticulture, Central Institute for Subtropical Horticulture (ICAR), Lucknow, Uttar Pradesh, India.

Vasugi C, MR Dinesh, K Sekar, KS Shivashankara, B Padmakar and KV Ravishankar (2012) Genetic diversity in unique indigenous mango accessions (*Appemidi*) of the Western Ghats for certain fruit characteristics. *Curr. Sci.* **103**:199-207.

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Genetic Diversity in Seedling Populations of Mango

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The genetic improvement of mango (*Mangifera indica* L.), a native of India, has been largely through selection among seedling populations or propagating elite clones and such efforts have resulted in the identification and cultivation of improved commercial varieties. Development of better cultivars by traditional method using morphological traits, although highly heritable, is slow because of long juvenility and being expensive. Farmers of Pusa, Bihar have been conserving high levels of intraspecific diversity of mango in old orchards mostly located along the *Gandak* River. These orchards are often poorly maintained as revenues obtained are small compared to income from other farm activities; however these old orchards harbour a highly diverse population of traditional mango varieties and seedlings, with trees over 80 years old. Hence a survey was conducted in five communities for documenting the mango diversity found in native landraces. Sixteen superior mango varieties of endemic value and importance were evaluated for table, sucking and pickling purposes on the basis of physical appearance and chemical attributes. Out of these, six were found suitable for table, five for sucking, three for pickle and two for dual purpose (sucking and table). Studies revealed a clone from *Bhuskaul* community with fruit weight up to 420.0 g with TSS 27.40^0B and having very thin stone and maturing by the end of August. The present study highlights the need for and demands of diversity rich areas of *Pusa* community in Bihar to conserve and protect seedling mangoes for the benefit of posterity with high value traits for future promotion. Furthermore, the characterization work was captured in fruit catalogues and shared back with the farming community, which might have increased the awareness, interest and appreciation of the available mango diversity and the interest in the continuation of these old highly diverse mango orchards for home use and to explore the commercial potential of these orchards and various types.

Key Words: Accession, Elite materials, Mango, Morphological characterization, Multivariate analysis, Pusa

Introduction

Genetic diversity available in existing germplasm determines the success of any crop improvement programme (Harlan, 1976; Moose and Mumm, 2008). Mango is one of the important fruit crops of India grown on plantations, orchards, and home gardens. Knowledge about the extent of genetic diversity/relatedness in mango germplasm is vital for developing strategies for future gains in productivity. Its improvement through modern methods takes much time and clonal selection, selection from chance seedling and other breeding efforts may results for identification of elite and improved commercial ones. Although, development of better cultivars by conventional method is slow but identification of superior clones on the basis of phenotype, which are generally highly heritable, equally expressed in all environments may shorten breeding cycle. Fruit traits have been the major descriptors for identification of different varieties of fruit crops. However, even in their absence, farmers, breeders and interested stakeholders require to distinguish characters between varieties. Further, while geneticists and plant breeders are particularly interested with diversity at the molecular level (Dempsey, 1996), farmers are more concerned with visible morphological and agronomic variation, which helps them to identify cultivars that are productive and do well in their location specific environment (narrow adaptation as they are unfamiliar

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with the characteristics of the many different cultivars of mango that are now grown and available across the country(Griesbach, 2003).

Agriculturally important place of Pusa, Bihar has diversity of many commercial cultivars of mango *viz.* Kanchan (*Bathua*), *Malda* (Langra), Sukul, *etc.* grown on large scale, Sipia and Bombai are grown by many farmers, and on smaller scale mango varieties like *Paharpur Sinduria*, Fazli, Sunder Langra, Krishanbhog, *Zarda*, *Kerwa*, *Mir Zaffar*, *Zardalu*, *Chinia*, Neelam, Dasheri, Mallika, *Kapuria* and Romani are grown (Baseline Report, 2014). In addition to these varieties, a large population of seedlings of mango is also available in these villages and their number is about 2200 and this is a very good source for the selection of superior clones of mango. It was also thought that selection from superior clones from large number of local variants may have better adaptability and acceptability to the community (Akinnifesi *et al.*, 2007). The variant may be used for different purposes like table, sucking or for pickle preparation.

Morphological characterisation is the first step that should be done before advanced biochemical or molecular studies are carried out (Hoogendijk and Williams, 2001). Hence an effort was made to assess diversity of seedling mangoes in 5 villages of Pusa, Samastipur for selection of superior clones for sucking purposes, table purposes, pickle making or both. The objective of investigation was to document extent of mango diversity found in native land races/farmer's field, its nature and assessment of genetic variability for suitability for table, sucking and pickling purposes based on physical appearance and chemical attributes. Further an assessment of variants grown by the community may lead to identification of promising accession/clone for better quality and late or early maturity over locally acceptable varieties.

Materials and Methods

Based on preliminary baseline survey of 18 villages of Pusa Block of Bihar and going through Four-cell analysis (Sthapit *et al.*, 2006) of four villages, *viz. Mahmada*, *Jagdishpur*, *Dhobgama* and *Murliyachak* were identified as project communities. Additionally, two more villages namely *Bhuskaul* and *Dighra* were selected as control communities. The villages were surveyed for assessment of on farm mango diversity and motivations for their continued cultivation by the farmers. Four cell analysis showed that majority of farmers have seedling mango besides local commercial ones (*Kanchan*, *Malda* and *Sukul, etc.*).

These identified mango cultivars were evaluated on site using some of the IPGRI (2006) descriptors for mango. Seventy seven selected trees of seedling mango were analysed from these communities based on popular fruit characters like fruit size, suitability for pickles, sucking and table purposes, peel colour, flesh colour, flavour and storability. The fruits of selected trees were collected from each seedling trees at ripening stage for recording fruit length (cm), fruit width (cm), fruit thickness (cm), fruit weight (g), peel (%), pulp (%), stone weight and total soluble solids (TSS) (°Brix). Physical qualitative characters *i.e.* fruit skin colour (surface colour of ripened fruit was recorded matching with the Royal Horticultural Society, Colour Chart, 1969), flavour and aroma, organoleptic test, and marketability were recorded based on opinion of panel of 5 judges who scored according to hedonic scale suggested by Amerine *et al.* (1965). In addition, the fruit samples were also characterized for other qualitative traits like peel thickness, peel texture, pulp colour, and quantity of fibre and eating quality. Percent peel, pulp and stone were calculated by the weight of the peel, pulp and stone, respectively divided by total weight of the fruit multiplied by 100. In each sample, quantitative traits like TSS was recorded with hand refractometer. Juice acidity was estimated by titrating 2 ml juice against 0.1 *N* NaOH using phenolphthalein as indicator (AOAC, 1980).

Based on phenotypic suitability, feedback from local villagers, organoleptic test, (including taste, sight, colour, smell, and touch etc,) domestic uses and its sensory evaluation, 16 superior seedlings were identified for further evaluation with farmer's descriptors. Genetic divergence among selected trees (accessions) subjected to Principal Component (PCA) and Cluster analysis using the XLSTAT 2012 statistical package. Cluster analyses were carried out on the principal components using the hierarchic ascendant analysis and Euclidian average distance.

Results and Discussion

The results presented in this study are particularly important because they represent morphological traits, which are highly heritable. The use of the trait of fruits obtained from mango seedling plants resulted in the

identification of 77 variants for fruit weight, fruit and pulp colour, TSS, pulp and seed content, utilization purposes *etc.* The data pertaining to physico-chemical characters of mango seedling along with common vernacular name indicates a great diversity exiting at the site (Table 5, 6).

Based on characterization of the 77 mango seedling trees revealed that a large amount of genetic diversity of mango exists in the selected communities. This characterization will result in the identification, conservation and utilization of mango genetic diversity, which in turn will help in maintaining the sustainability of fruit production in the target areas.

Eigen values of principal component axis, percent of total variation and cumulative variation accounted for them obtained from principal component analysis are presented in Table 3. The first four component were identified as major based upon their Eigen values and explained 71.72% of the total variation among seven characters. The first component (fruit weight) has 25.11 % share in total variation, whereas second component contributes 17.79 % (fruit length), third contributes (fruit width) to 14.61 %. The characters contributed the maximum to the divergence should be given greater emphasis for selection in breeding (Jagadev *et al*., 1991).

The clustering pattern revealed that the varieties collected from same localities did not cluster together. Cluster analysis of 77 accessions using major parameters resulted in 7 clusters (Table 1). 4 clones of mango having TSS more than 25 ^{0}B were identified. These are clone No. 77 (27.40), 56 (27.20), 71 (26.10), 63 (25.30) and 65 (25.00). Mango clone no. 22 has maximum edible portion and pulp: (peel and stone) ratio was recorded up to 3.44. As far as highest fruit weight (more than 420 g) was concerned, the largest mango was found in the clone no. 57 (644.0 g) followed by clone no. 29 (485.2 g), 26 (477.2 g), 54 (470.0 g) and 77 (420.0 g). Twelve mango clones with absolutely no fibre content were identified. They are clone no. 9, 13, 29, 34, 43, 50, 55, 56, 57, 60, 61 and 77. On the basis of cluster analysis of 77 variants, No. 57 was completely different for highest fruit weight (644.00 g) (Fig. 1). The varieties belonging to different clusters with high to moderate genetic distances might be recommended for use in crossing programs to produce new recombinants with desired traits (Majumder *et al*., 2013).

On the basis of cluster analysis of 16 superior clones of mango (Table 2), five clusters were obtained, Pusa mango 1 differs for highest fruit weight, Pusa mango 7 for lightest weight, Pusa mango 12, 4, 1 differs for minimum fruit length, Pusa mango 6, 10, 15, 9 differs for minimum fruit width. Pusa mango 7, 10 had TSS above

Table 1. Cluster formed after assessment of various parameters of 77 varieties

Cluster	Clone No.
I (14)	38, 61, 34, 14, 8, 51, 11, 7, 71, 25, 31, 17, 15, 1
II (11)	48, 64, 45, 74, 5, 46, 65,72, 10, 36, 2
III (12)	62, 44, 39, 16, 56, 55, 12, 19, 40, 27, 13, 9
IV (11)	41, 33, 70, 30, 6, 35, 20, 49, 53, 47, 43, 4
V (14)	68, 58, 42, 46, 69, 66, 50, 24, 75, 60, 52, 32, 18, 8
VI (9)	77, 22, 21, 67, 63, 59, 73, 37, 3
VI (4)	57, 19, 54, 26

Table 2. Cluster analysis of 16 superior clones of mango

Cluster	Clone No.
I (3)	Pusa mango 12, 4, 1
II (5)	Pusa mango 6, 10, 15, 9
III (1)	Pusa mango 7
IV (3)	Pusa mango 16,11, 3
V (4)	Pusa mango 13, 8, 14, 5

Table 3. Principal component analysis (PCA) performed using the XLSTAT (2012) statistical package showing the correlations of the first seven principal components with the variables observed on mango accessions

Principal Component	Varieties	Eigen value (%)	Variation (%)	Cumulative variation (%)
PC1	Fruit weight	1.75	25.10	25.10
PC2	Fruit colour	3.00	17.78	42.89
PC3	Pulp colour	4.02	14.61	57.50
PC4	Pulp: (peel + stone)	5.02	14.21	71.72
PC5	TSS	5.80	11.20	82.93
PC6	Fibre content	6.52	10.27	93.20
PC7	Purpose for suitability (Table, Sucking or Pickle)	7.00	6.79	100.00

Eigen vectors of the most descriptive traits

Table 4. Details of promising clones of mango out of 77 variants of seedling mango

Mango clones	Place of collection	Local name	Longitude	Lattitude	Altitude (m)	Farmer descriptors
Pusa mango 1	*Jadishpur*, Pusa, Samastipur	Biju mango, Lal Pari	N25^{0}56'47.5"	E085^{0}38'44.8"	14	Very sweet in taste, sucking type, mid maturity. The stone is large and a person can eat many fruits. It has red flesh on maturity. The plant is a regular bearer.
Pusa mango 2	*Jadishpur*, Pusa, Samastipur	Biju mango, Madhukupia	N25^{0}56'56.2"	E085^{0}39'11.1"	152	Very sweet in taste as the name suggests (*Madhu*= honey), big sized fruits for table purpose. Matures by end July. It is not a regular bearer.
Pusa mango 3	*Jadishpur*, Pusa, Samastipur	Biju mango, Sukulia	N25^{0}56'56.3"	E085^{0}39'17.9"	149	Fruit matures after local *Sukul* but fruits are bigger and tastier. Regular and heavy bearer.
Pusa mango 4	*Jadishpur*, Pusa, Samastipur	Biju mango, Sukulia	N25^{0}56'51.1"	E085^{0}39'17.9"	149	Medium size fruit, Red colour at maturity, regular and heavy bearer, Matures by mid July.
Pusa mango 5	*Bhuskaul*, Pusa Samastipur	Biju mango	N26^{0}05'44.6"	E85^{0}26'38.7"	144	Medium sized fruit with a lot of fibre, very sweet and attain red colour at maturity. The skin of the fruits is also edible. It is not a regular bearer and the fruit matures by mid July.
Pusa mango 6	*Jagdishpur*, Pusa, Samastipur	Biju mango	N25^{0}56'47.3"	E085^{0}38'45.1"	145	The fruits are medium sized, very sweet with small stone suitable for table purpose. Shelf life of the fruits is good and the fruits attain an attractive orange colour after maturity. Biennial bearer and the fruit maturity is mid July.
Pusa mango 7	*Jagdishpur*, Pusa, Samastipur	Alphonso biju	N25^{0}56'51.1"	E085^{0}39'70.7"	149	Medium sized fruits, very sweet in taste with lot of fibre and are used for sucking. The fruit attains an attractive red colour after maturity. The fruit shape is similar to *Alphonso*. Biennial bearer and the fruit maturity is mid July.
Pusa mango 8	*Bhuskaul*, Pusa, Samastipur	Malda biju	N25^{0}58'32.3"	E085^{0}38'49.1"	145	The fruits are similar to *Malda* in size and colour, but the maturity is very late, i.e. the latest mango to mature in the month of August-September. The fruits are susceptible to fruit diseases due to the rainy season. Medium sized fruits are very sweet in taste, used for sucking as well as table purposes. It is not a regular bearer and prone to theft due to its late maturity.
Pusa mango 9	*Mahamada*, Pusa, Samastipur	Sona Malda, Malda biju	N26^{0}00'27.8"	E085^{0}41'30.1"	171	The fruits are similar to *Malda* in size and colour, but are elongated and mature in June. The fruits are very shining with orange coloured flesh, not much sweet in taste and are suitable as table fruits. Biennial bearer.
Pusa mango 10	*Mahamada*, Pusa, Samastipur	Sipia biju	N25^{0}59'58.8"	E085^{0}39'05.7"	174	The fruits are similar to *Sipia* in size and colour, but are elongated and mature by July. It is very sweet with almost nil fibre and is suitable for table purpose. Biennial bearer.
Pusa mango 11	*Mahmadpur Kothi*, Muraul, Muzaffarpur	Sukul biju	N26^{0}03'12.9"	E085^{0}31'19.9"	146	The fruits are similar to *Sukul* with lot of fibres, dark yellow colour. Suitable for pickle making and sucking purposes. The fruits can be kept for about a week even after the complete maturity.
Pusa mango 12	*Malinagar*, Pusa, Samastipur	Sipia biju	N26^{0}00'27.8"	E085^{0}41'30.1"	165	The fruits are similar to *Sipia* in size and colour, but are somewhat round in shape and mature in the month of July. The fruits are sweet in taste and are suitable as table fruits. It is not a regular bearer.
Pusa mango 13	*Dhobgama*, Pusa, Samastipur	Biju mango	N25^{0}57'32.7"	E085^{0}38'17.7"	161	The fruits are very attractive and bears colour like *Zarda* mango. Fibre content is very less and the fruits are suitable for sucking and table purpose. The taste is good and sweet.
Pusa mango 14	*Jagdishpur*, Pusa, Samastipur	Sukul biju	N26^{0}00'27.8"	E085^{0}41'30.1"	165	The fruits are similar to *Sukul* in all respects but are having dark yellow or reddish colour on full maturity.
Pusa mango 15	*Jagdishpur*, Pusa, Samastipur	Malda biju	N26^{0}00'27.8"	E085^{0}41'30.1"	165	The fruits are similar to *Malda* in size and colour, but matures by end June. The fruits are sweet in taste, suitable as sucking fruits due to their more fibre content. Biennial bearer and may be suitable for making mango juice.
Pusa mango 16	*Jagdishpur*, Pusa, Samastipur	Mango biju	N25^{0}58'09.6"	E085^{0}38'16.0"	172	The fruits are similar to *Malda* in size and colour, but not much sweet. The fruit are tasty, attractive and are suitable as table fruits due to their almost nil fibre content. It is not a regular bearer and the plant is quite young.

Table 5. Physico-chemical character of 16 superior clones of mango

Clone No.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Length : Breadth	Fruit colour	Flesh colour	Fibre content	Skin weight (g)	Pulp (%)	Acidity (%)	Seed weight (g)	TSS (°Brix)	Eating Quality	Special features
Pusa mango 1	140.00	7.66	5.62	1.36	11	8	3	30.00	58.20	0.32	30.00	18.16	3	Attractive fruit and bearing
Pusa mango 2	510.00	12.10	8.50	1.42	1	9	3	60.00	77.00	0.47	50.0	16.40	3	Highly fibrous with small stone
Pusa mango 3	250.00	9.00	6.90	1.30	2	4	3	33.00	71.20	0.75	31.00	18.22	4	Suitable for pickles
Pusa mango 4	160.00	7.60	6.26	1.22	11	2	3	30.00	58.60	0.32	30.00	17.48	1	Attractive appearance
Pusa mango 5	306.00	11.20	7.18	1.56	10	4	4	52.00	68.42	0.32	45.00	15.55	3	Peel is edible
Pusa mango 6	184.00	8.60	6.20	1.39	11	4	5	30.00	63.84	0.23	36.00	19.70	1	Very tasty fruit and attractive fruit appearance
Pusa mango 7	120.00	6.70	5.58	1.19	4	8	2	30.00	43.00	0.32	44.00	21.34	1	Taste is not good
Pusa mango 8	308.00	10.66	6.91	1.56	11	4	5	59.00	64.20	0.23	49.00	19.64	1	Thick peeled
Pusa mango 9	168.00	9.35	6.15	1.15	11	5	5	28.00	68.87	0.32	24.00	12.83	3	Less sweet
Pusa mango 10	170.00	9.83	5.33	1.85	11	4	5	40.00	57.25	0.23	30.00	21.50	1	Suitable for table purposes
Pusa mango 11	243.00	11.32	6.60	1.72	6	5	2	46.00	71.39	0.37	43.00	15.70	1	Suitable for pickle
Pusa mango 12	150.00	7.30	6.16	1.18	11	4	4	30.00	58.00	0.40	30.00	17.06	1	Suitable for juice making
Pusa mango 13	300.00	10.13	7.48	1.36	11	5	5	60.00	61.25	0.20	50.00	18.55	1	Colour is very attractive
Pusa mango 14	300.00	11.42	6.92	1.65	10	3	3	47.00	74.20	0.45	40.00	17.40	1	Good blend of sugar and acids
Pusa mango 15	170.00	8.38	6.00	1.40	1	8	3	40.00	57.40	0.37	40.00	18.44	3	Suitable for sucking
Pusa mango 16	240.00	9.65	6.60	1.46	11	4	6	80.00	70.00	0.43	40.00	17.50	1	Suitable for table purpose

Table 6. Scores for the various quality parameters given to 77 variants of seedling mango

Qualitative parameters	Scores
Fruit colour	1: Green; 2: Greenish yellow; 3: Reddish green, 4: Red, 5: Reddish Orange, 6: Orange, 7: Dark Orange, 8: Light Yellow, 9: Orange Yellow, 10 : Red Yellow, 11: Yellow, 12: Dark Yellow
Pulp colour	1: Red, 2: Reddish Orange, 3: Light Orange, 4: Orange, 5: Dark Orange, 6: Yellow White, 7: Dull Yellow, 8: Yellow, 9: Dark Yellow
Fibre contents	1:Very High, 2: High, 3: Medium, 4: Less, 5: Very Less, 6: Nil
Eating quality	1:Excellent, 2:Very Good, 3:Good, 4:Average
Suitability for purposes	1: Table, 2: Juice or Sucking, 3: Pickle, 4: Table and sucking, 5: Pickling and Sucking

Table 7. Best accessions for the important horticultural traits

S.No	Traits	Accessions
1.	Fibre contents	Pusa mango 3, 11, 12, 14, 15
2.	Eating quality	Pusa mango 2, 4, 5, 6, 8, 9, 10, 16
3.	Suitability for purposes	Pickles (Pusa mango 3, 14); Table (Pusa mango 2, 4, 5, 6, 8, 9, 10,16); Sucking (Pusa mango 1, 7); Table and sucking (Pusa mango 13); Sucking and pickles (Pusa mango 11); Sucking and juice making (Pusa mango 12, 15)

21^0B, least stone weight (<30.0 g) was found in Pusa mango 1, 3, 9, 10 and 12 and highest pulp percentage (> 70.0 %) was available with Pusa mango 2, 3, 11, 14 and 16 (Table 6, Fig. 3).

Clone no. 77 (*Malda* seedling) (Fig. 1) from *Bhuskaul* community had almost similar fruit characteristics to *Malda* with very late maturity (August end). This is potentially a high value trait as by this time fruits from other varieties would have already stopped coming to market. It had a maximum of six desirable characteristics

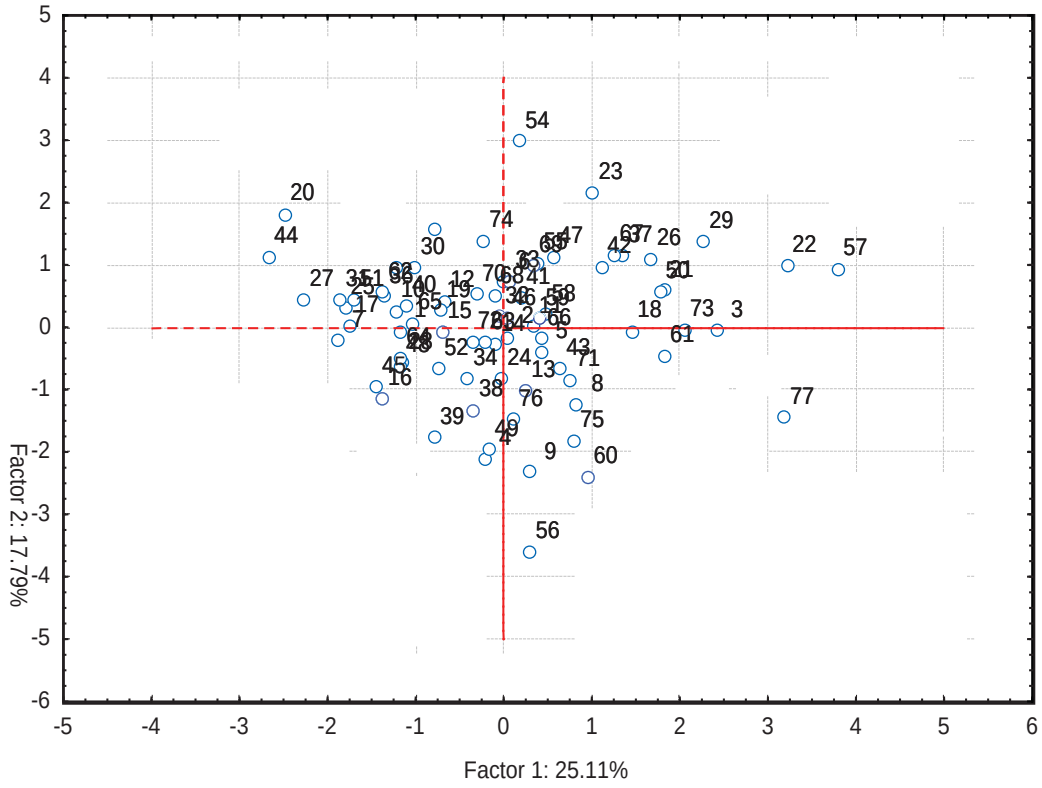

Fig. 1. Distribution of varieties in PC1 (Fruit weight) and PC2 (Fruit colour), 25.11% and 17.79%, respectively

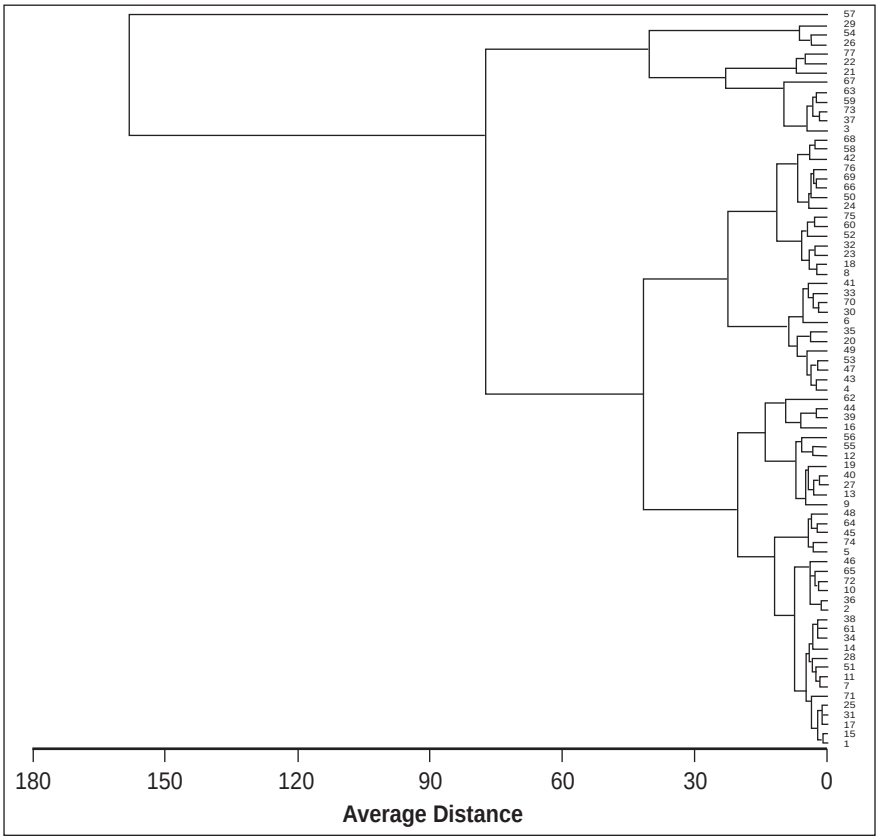

Fig. 2. Dendrogram based on morphological characters of 77 mango accessions from the Pusa, Bihar

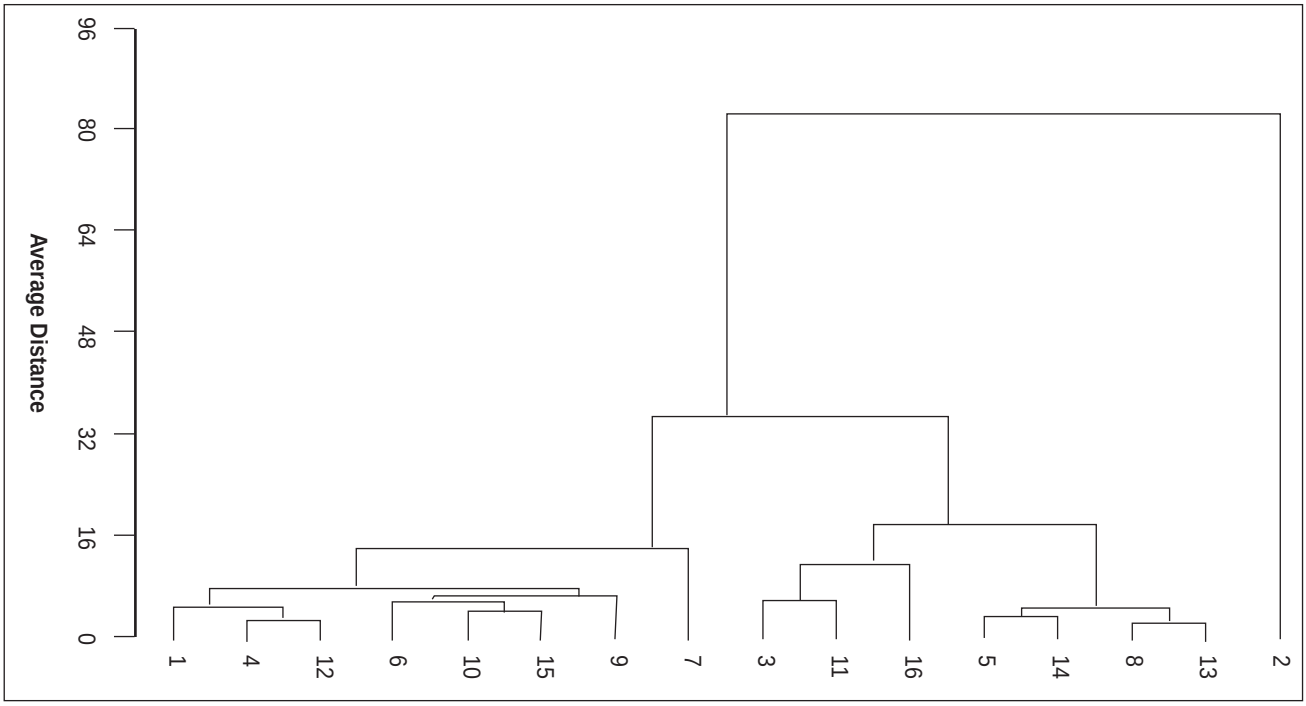

Fig. 3. Dendrogram constructed based on morphological characters of 12 mango superior clones of *Pusa*, Bihar

Fig. 4. Clone 77 matures by September, other parameters are similar to popular *Malda* mango (whole and cut fruit)

of mango such as better fruit weight (420.0 g), dark orange peel and pulp colour, pulp: peel and stone ratio (2:23) with highest TSS (27.40 °B) without any fibre. This is most suited for table purpose; very late maturity may lead to staggered availability. The clone no. 50 and 60 were also at par with clone no. 77 but had lesser fruit weight (300 g, and 159 g) and less sweet (22.20 and 21.30 °B). The clone no. 2, 3, 6, 47 and 76 were observed as having four desirable fruit characteristics. Similarly, nine clones viz. 29, 34, 43, 53, 55, 57, 58, 60 and 73) were possessing three desirable characteristics.

According to Genu and Pinto (2002), in the majority of tropical developing countries, the natural abundance of fresh mango fruits frequently brings an excess in local demand, which is true in the case of Pusa site as well. In fact, mango fruit used for processing should have firm texture, high yield, medium size, high sugar content, bright colour, good flavour and aroma after

ripening, low acid content, no fibre and low tannin content. In this investigation, on the basis of uses of fruits, mango varieties were classified into four groups *i.e.*, table, sucking, pickling, table and sucking varieties. Out of sixteen superior strains of mango (enjoying local importance) and evaluation based on physical appearance and chemical attributes, eight were found suited for table, two for pickling, two for sucking, one for table and sucking, one for sucking and pickle, two were suited for sucking and juice making purposes (Table 7). Kundu *et al*., (2009) also found lot of variation among less known mango varieties grown in West Bengal, India *viz. Nabab bhog, Mithua and Khota Lagga* mango for yield and fruit quality and *Baro Langra Guti, Subodh Guti, Dudh Kumar, Ghia, Gour* and *Durgabhog* as table variety for good quality.

The characterization of the Clone no. 77 (Fig. 4) from mango seedlings indicated, a large amount of genetic diversity is available in the selected communities. This characterization of seedling population helps in the identification, conservation and utilization of mango genetic diversity, and also encourages growers to maintain the sustainability of fruit production.

This study revealed that great variability exists among different mango seedling progenies and this can be exploited for the selection of elite genotypes in future after evaluating their performance.

In the present survey, it was felt that demand for table, sucking and pickles type has been escalated in the region due to decrease in seedlings mango population and awareness about indigestion problems generally experienced after consumption of grafted mangoes.

Therefore, 16 identified clones can be used for table, sucking, juice making and pickling purposes. These accession's characterisation and evaluation inculcate the communities to go for conservation and development efforts required for conservation of unique varieties.

These accessions can be subjected to further selection procedures so that superior planting materials can be made available to the growers. Those who are maintaining maximum number of unique varieties may be nominated for plant saviour community awards. The registration of farmer's varieties with PPVFRA, New Delhi may lead to strengthening our genetic resources of mango and can be future breeding options either for one or more quality attributes.

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References

Akinnifesi FK, OC Ajayi, G Sileshi, I Kadzere and AI Akinnifesi (2007) Domesticating and Commercializing Indigenous Fruit and Nut Tree Crops for Food Security and Income Generation in Sub-Saharan Africa. *In*: Paper presented at the New Crops International Symposium, 3-4 September 2007, Southampton, UK.

Amerine MA, RM Pangborn and EB Rossessler (1965) Principles of sensory evaluation of food. *Acadamic Press inc*., New York USA, pp 366-374.

AOAC (1980) *Official Methods of Analysis*. 12th ed. *Association of Official Analytical Chemists*, Washington, DC, USA.

Baseline Report (2014) UNEP-GEF/TFT project, Bioversity International Regional Office, New Delhi.

Dempsey G (1996) CIMMYT Natural Resources Group Paper, CIMMYT, Mexico.

Genu PJ and AC Pinto (2002) *A cultura da Mangueira.* Brasilia: CIP-Brasil-Embrapa, pp 452.

Griesbach J (2003) Mango Growing in Kenya. ICRAF, Nairobi, Kenya.

Harlan (1976) Genetic resources in wild relatives of crops. *Crop Sci*. **16**: 329-333.

Hoogendijk M and D Williams (2001) Characterizing the genetic diversity of home garden crops: Some examples from Americas. In: *2nd International Home gardens workshop*, July 17-19, 2001, Witzenhausen, Federal Republic of Germany, pp 34-40.

International Plant Genetic Resourcces Institute (IPGRI) (2006) Descriptors for mango (*Mangifera indica* L). *International Plant Genetic Resources Institute*, Rome, Italy.

Jagadev PN, KM Samal and L Lenka (1991) Genetic Divergence in rape mustard. *Indian J. Genet. Plant Breed*. **51**: 465-466.

Kundu SL Sanyal L and P Datta (2009) Studies on potentiality of some mango varieties in West Bengal. *J. Crop Weed* **5**: 68-71.

Majumder, DAN, L Hassan, MA Rahim and MA Kabir (2013) Genetic diversity in mango (*Mangifera indica* L.) through multivariate analysis. *Bangladesh J. Agril. Res*. **38**: 343-353.

Moose Stephen P and Rita H Mumm (2008) Molecular plant breeding as the foundation for 21st century crop improvement. *Plant Physiol*. **147**: 969–977.

Sthapit B, P Shrestha, KP Baral, A Subedi, J Bajracharya and RB Yadav (2006) Diversity block: Assessing and demonstrating local crop diversity. In: good practices: On-farm management of agricultural biodiversity in Nepal In: BR Sthapit, PK Shrestha and MP Upadhyay (ed.) *NARC*, *LI-BIRD*, *IPGRI* and *IDRC*, Nepal.

The Royal Horticultural Society Colour Chart (1969) The Royal Horticultural Society London.

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Pummelo in Homestead Garden: Conservation through Family Farming

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The pummelo (*Citrus grandis* Merr.), the largest fruit size in citrus species, is an underutilized fruit in India. Pummelo in Bihar is mostly grown as homesteads and this fruit is to be developed as potential table fruit because of thick rind, easy to handle and transport. Genetic diversity is an important factor in any crop improvement programme for obtaining high yielding cultivars. Variation among seedling progenies is a rule in pummelo since it is monoembryonic *Citrus* spp. This study was conducted through four cell analysis in the five project communities under the UNEP-GEF project at the Pusa Site, Bihar during 2012 with aim for estimation of genetic diversity for physico-chemical traits, selection of superior clones and to draw the interrelationships between observations for precise characterization of pummelo seedling. Superior plants were also identified based on the highest yield *i.e.* number of fruits/ plant (> 300). Statistical analysis for physico-chemical parameters revealed significant differences among the selected plants for the 12 horticultural traits indicating the higher variability. Principal Component Analysis (PCA) and cluster dendrogram performed on the basis of studied parameters showed continuous variation in the fruit physico-chemical traits and many groups were formed, indicating existence of large and continuous variation. The first four PCs contributed 68.30% of the variability for fruit quality and PC1 accounted for 30.44% (acidity percentage) followed by fruit length (PC2), fruit width (PC3) etc. The maximum coefficient of variation was found in in case of rind thickness, 100 seed weight and acidity percentage. A large number of variability of pummelo with seedling origin and monoembryonic helps in identification of 4 pummelo clones for pulp colour (2 each for dark red flesh and pink flesh) with excellent eating quality, 9 superior clones were identified for profuse bearing with red fleshed and early. The above variation in the selected pummelo seedlings can be exploited for development of superior varieties, marketing and maintenance of exiting superior clone and above all grower can be ensured livelihood security through homestead farming practices in the community.

Key Words: Characterization, Citrus diversity, Evaluation, Homestead, Pummelo seedling

Introduction

Pummelo (*Citrus maxima* (J. Burman) Merrill or *Citrus grandis* Merr.) is a tropical fruit plant species originated from South East Asia. Pummelo is considered to be one of the three true *Citrus* species along with *C. medica* and *C. reticulata*. Pummelo as plant species with long history of cultivation is facing a risk of decreasing variability as a result of artificial selection. Many home gardens, as an ecosystem, contain multiple levels of diversity, including cultural, genetic and agronomic diversity (Engels, 2001) found at Pusa, Bihar and pummelo is necessarily grown there. It is mostly grown in the homesteads in India and the ripe fruit is rich in vitamin C, many important phytochemicals, consumed for its medicinal properties. The pummelo is an underutilized fruit with a potential for commercialization. Currently in India, there are several pummelo seedling types with interesting horticultural traits, but little information is available about their genetic diversity. The high phenotypic variability of the Indian pummelo resulted in the existence of various strains or landraces.

Historically, citrus cultivar improvement started when humans began domestication of this crop by preferential selection and preservation of individuals found among wild plant populations (Barrett, 1977). Clonal selection, identification of chance seedlings or bud-sport mutations has been the major force in the development of citrus cultivars as they possessed some superior trait relative to previously existing cultivars. Most of the present day cultivated citrus scion and rootstocks, originated through

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chance seedlings or bud sport mutations and only a few originated through planned breeding programmes (Hodgson, 1967).

Although genetic diversity of citrus has got immense potential to raise the quality fruit production and productivity, the conservation especially through homestead gardening has not been assessed in depth. These indigenous citrus genotypes like pummelo must be identified, conserved and utilized otherwise loss of valuable genotypes is bound to occur. Therefore, identification of elite valuable genotypes, their proper use and conservation as unique resource is essential. It helps growers to go for quality production not only for internal consumption but also for distant markets. This investigation evaluates the morphological diversity existing at Pusa Site, Bihar with exploration of the opportunities for the growers/farmers, traders and consumers, thereby reduce poverty and enhance food security in the rural areas in the country. Pummelo is a tropical fruit species with a high morphological variability for fruit characters including shape, size, and thickness of peel, flesh colour and taste (Susandarini *et al*., 2013). Cultivated pummelos have been reported to be highly diverse based on phenotypes of their fruits (Chonchalow, 1984; Dass, 1990; Spiegel Roy and Goldschmidt, 1996).

The quality of pummelo is not homogenous among different seedlings, even in small village or a single house. Clonal selection is considered for pummelo an effective method for genetic improvement and the selection of new genotypes. To select a superior genotype, investigation on genetic variability of fruit characters is considered important. Grouping or classification of genotypes based on suitable scale is essential to understand the usable variability. The greatest impediment to the development of large-scale pummelo production is the lack of thin-skinned, high quality cultivars. Pummelo, like most other *Citrus*, produces seedlings that are genetically different from the mother parent. Morphological properties have been the main character used for recognition and description of plant taxa (Duminil and Michele, 2009; Dwari and Mondal, 2011).

Keeping all these points in view, the present study was taken up with pummelo natural seedlings with the main objectives to understand how households grow and conserve pummelo in home gardens in Bihar, the extent and distribution of morphological variability in pummelo at Pusa, Bihar for better conservation of pummelo, its marketability and contribution to livelihood and to identify any variability for useful attributes within the population for potential marketable traits.

Materials and Methods

This study was conducted to assess the phenotypic variation of pummelo in the unexplored areas of *Muzaffarpur* and *Samastipur* districts of Bihar in order to identify the superior phenotypes (seedling trees) with respect to fruit quality and yield. Based on Four cell analysis, survey was carried out in five communities of Pusa Site under UNEP-GEF project *viz.*, *Mahmada*, *Jagdishpur*, *Dhobgama*, *Murliyachak* and *Bhuskaul*, during the fruiting season of 2012. Focus group discussions, interview with individual fruit growers and *in situ* observation of trees and fruits were also carried out in each site to obtain information. The superior plants were identified based on yield as the number of fruits/plant (> 300 fruits/plant). A sample of five fruits was collected from each tree and two fruits were analyzed in the laboratory of National Research Centre on Litchi, Muzaffarpur. Fruits, fruit peel and seed weight was measured with the help of an analytical balance. Fruit length and width were measured with a graduated scale. Peel thickness was recorded using a Vernier Calliper and total soluble solids (TSS) was recorded by a hand-held digital refractometer. The acidity was measured by the titration method (AOAC, 1989). Based on phenotypic suitability, feedback from local villagers, organoleptic taste, domestic uses and its characterization, 13 superior seedlings were identified for further evaluation with respective co-ordinates and farmer's descriptors. Genetic divergence among selected trees (clones) subjected to Principal Component (PCA) and Cluster analysis was performed to examine the grouping of accessions and to assess the taxonomic affinity using the XLSTAT 2012 statistical package. Cluster analyses were carried out on the principal components using the hierarchic ascendant analysis and Euclidean average distance. Fruit quality attributes of pummelo for consumption and marketing was drawn based on feedback of growers, consumers and traders gathered in 'Citrus Biodiversity Fair' 2011 organised at the community level.

Results and Discussion

During investigation and survey it was found that there is close relationship between pummelo in home gardens and holy festival celebrated in surrounding community *i.e. Chhat Puja* (on 6th day after *Diwali* in *Kartik* month),

and in fact the two are completely interwoven. One very striking aspect related to the traditions of a family as part of a larger community, is the key role of women in managing the garden and utilizing its produce, either for *Chhat Puja* or for domestic consumption or exchange or distribution of fruits to devotees or by selling it in the market before the *Puja*. It was also found that pummelo does not have commercial orchard in the community.

Fruit Physico-chemical Characters in the Selected Pummelo Clones

Analysis of variance revealed statistically significant differences between selected plants for the 12 examined characteristics indicating the high variability in the physico-chemical properties of their fruit. Principal Component analysis and cluster dendrogram (Fig. 1) performed on the basis of studied parameters showed a distribution of selected seedling plants of pummelo, independently of their origin and continuous variation in their fruit's physical and chemical traits.

A wide variation for fruit physico-chemical characters was observed in different selected clones of pummelo (Table 1, 2). Mean, range and coefficient of variability for various traits are presented in Table 3. The fruit weight varied between 0.60 kg to 2.50 kg, fruit length and width varied between 10-24 cm and the peel thickness between 1-4 cm. Similarly, there were large differences for number of segments and number of seeds/ fruit. The range of TSS among different pummelo clones varied between 9-13 ^{0}Brix. A large variation for 100 seed weight was recorded among the selected pummelo clones. On the basis of coefficient of variation, maximum variation was recorded for peel thickness (CV=17.032 %) followed by 100-seed weight (CV=13.728 %) and acidity (CV=12.536 %). This variation is a clear cut indication that the superior pummelo clones can be identified from the existing variation.

Desirable Attributes of Pummelo for Better Marketability and Identification of Superior Clones

While interaction with growers, traders, scientists and consumers during diversity fair on citrus at *Pusa* Site, Bihar in 2011, it was found that pummelo fruits must have appropriate shape, size (*i.e.* round in shape with fruit weight 900-1000g for better packaging and transport), dark red segments (rich in antioxidants, attractive in colour), high total soluble solids (>12 ^{0}Brix, improve taste), less acidic (to have more consumption; better sugar: acid blend attract many consumers),thin rind (as thick rind is very difficult to peel it and increase unwanted wastes, thick rind fruits are less juicy), uniformity of segments (helps in better serves or packaging in *punnets*), high

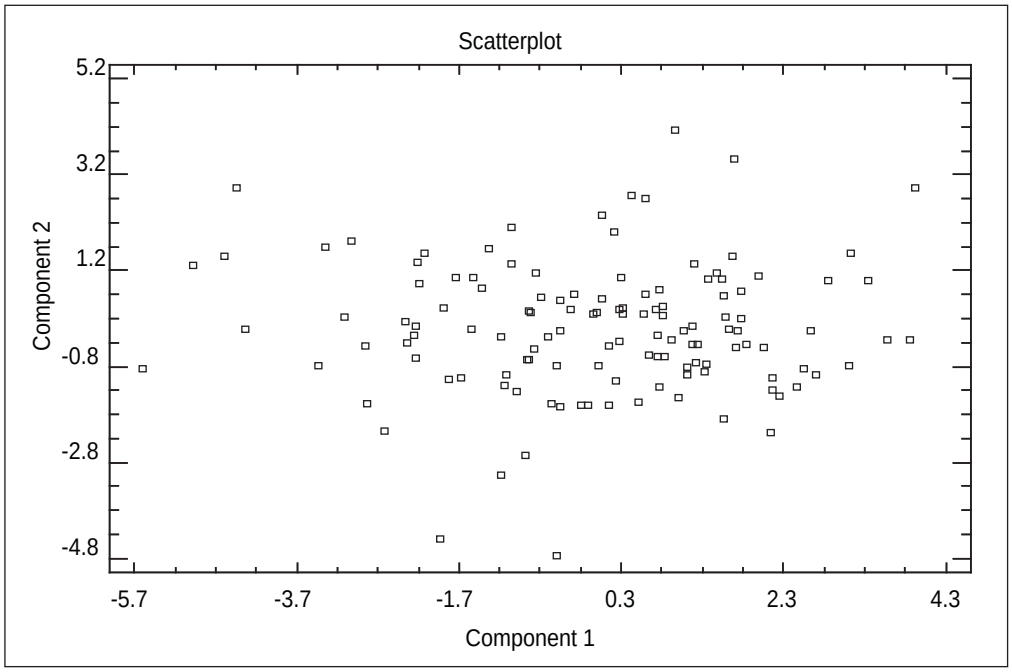

Fig. 1. Scattered distribution of 127 pummelo genotypes based on the principal component score (PC1 contributed 30.44 % and PC2 contributed 15.74 %)

Table 1. Site details and morphological characters of certain pummelo seedlings

Pummelo Clones	Place of collection	Longitude	Latitude	Altitude (m)	Plant habit	Fruit shape	Pulp colour	Fruit size	Fruit colour	Nature of segment	Eating quality
Pusa Pummelo 1	*Narayanpur*, Pusa, Samastipur	N25^{0}57’55.0”	E085^{0}39’0.18”	36	Spreading	Round	Red	Medium	Yellow colour	Hard	Excellent
Pusa Pummelo 2	*Narayanpur*, Pusa, Samastipur	N25^{0}56’47.6”	E085^{0}38’44.8”	39	Spreading	Round	Dark Red	Large	Yellow	Hard	Very Good
Pusa Pummelo 3	*Malinagar*, Pusa, Samastipur	N26^{0}00’03.8”	E085^{0}41’30.0”	28	Spreading	Round	Dark Red	Large	Yellow	Soft	Very Good
Pusa Pummelo 4	*Mahamada*, Pusa, Samastipur	N25^{0}59’33.2”	E085^{0}38’46.1”	31	Spreading	Flattened	Dark Red	Large	Yellow	Soft	Very Good
Pusa Pummelo 5	*Govindpur Chhapra*, Kalyanpur, Samastipur	N26^{0}04’00.6”	E85^{0}26’52.8”	40	Spreading	Elongated	Dark Red	Medium	Dark yellow	Soft	Excellent
Pusa Pummelo 6	*Govindpur Chhapra*, Kalyanpur, Pusa Samastipur	N26^{0}04’01.3”	E085^{0}36’52.8”	28	Spreading	Flattened	Red	Large	Yellow	Soft	Very good
Pusa Pummelo 7	*Narayanpur*, Pusa, Samastipur	N25^{0}57’54.0”	E085^{0}39’01.6”	37	Spreading	Flattened	Red	Large	Dark Yellow	Hard	Good
Pusa Pummelo 8	*Mahamada*, Pusa, Samastipur	N25^{0}59’34.1”	E085^{0}38’37.7”	31	Spreading	Elongated	Red	Medium	Dark yellow	Soft	Very good
Pusa Pummelo 9	*Malinagar*, Pusa, Samastipur	N26^{0}00’01.4”	E085^{0}41’13.1”	29	Spreading	Elongated	Pink	Large	Yellow	Soft	Very Good
Pusa Pummelo 10	*Malinagar*, Pusa, Samastipur	N25^{0}59’98.4”	E085^{0}41’10.9”	28	Spreading	Round	Pink	Large	Yellow	Soft	Good
Pusa Pummelo 11	*Bhuskaul*, Pusa, Samastipur	N25^{0}58’43.2”	E085^{0}38’44.2”	27	Spreading	Flattened	Dark red	Medium	Dark yellow	Soft	Excellent
Pusa Pummelo 12	*Malinagar*, Pusa, Samastipur	N25^{0}59’33.1”	E085^{0}38’45.9”	25	Spreading	Elongated	Red	Medium	Dark yellow	Soft	Very Good
Pusa Pummelo 13	*Mahmadpur*, Muraul, Muzaffarpur	N25^{0}58’45.6”	E085^{0}39’37.6”	32	Spreading	Flattened	Dark red	Medium	Yellow	Hard	Excellent

Table 2. Fruit characters of selected superior clones of pummelo

Clone No.	Fruit weight (kg)	Fruit length (cm)	Fruit width (cm)	Number of seed/ fruit	Number of segments	Peel thickness	Acidity (%)	TSS (°Brix)	100-Seed weight (g)	Fruit length: Breath ratio	TSS: acidity ratio
Pusa Pummelo 1	0.979	12.00	13.05	78.00	14.00	1.55	0.80	11.10	46.99	0.92	20.53
Pusa Pummelo 2	1.613	16.35	17.65	152.50	14.00	1.20	0.70	12.65	51.09	0.92	17.97
Pusa Pummelo 3	1.215	14.75	14.75	81.50	13.50	1.85	0.536	12.30	41.77	1.00	22.95
Pusa Pummelo 4	1.322	14.50	16.25	94.00	17.50	1.75	0.576	12.15	42.57	0.89	22.95
Pusa Pummelo 5	1.048	14.95	14.50	80.50	12.00	0.90	0.488	11.95	29.80	1.03	24.49
Pusa Pummelo 6	0.917	11.25	15.05	91.50	15.00	1.05	0.448	12.30	33.25	0.747	27.45
Pusa Pummelo 7	1.780	15.00	18.15	128.00	18.00	1.995	0.448	10.20	44.25	0.825	20.54
Pusa Pummelo 8	0.991	14.15	12.85	70.50	14.50	1.70	0.632	11.45	41.77	1.10	18.12
Pusa Pummelo 9	1.367	17.00	15.85	90.50	15.00	2.55	0.520	11.10	57.52	1.07	221.35
Pusa Pummelo 10	1.265	14.55	14.75	52.00	16.50	2.55	0.584	10.40	50.51	0.985	17.81
Pusa Pummelo 11	1.037	11.75	13.75	97.00	13.50	1.15	0.472	12.50	34.48	0.85	26.48
Pusa Pummelo 12	0.862	13.80	13.30	72.00	13.00	1.55	0.624	12.55	51.26	1.035	20.11
Pusa Pummelo 13	1.186	16.55	17.40	45.00	13.50	2.65	0.480	11.00	39.49	0.91	22.92

Table 3. Variability parameters in pummelo for certain fruit characteristics

Traits	Range	Mean	SEm±	STDEV	CV
Fruit weight (g)	0.586-2.497	1.264	0.108	0.153	12.132
Fruit length (cm)	10.250-23.300	15.068	0.746	1.055	7.002
Fruit width (cm)	9.90-23.900	15.654	0.767	1.085	6.932
Flesh colour	1.00-6.00	4.693	0.125	0.177	3.814
Skin thickness (cm)	0.800-4.100	1.686	0.203	0.287	17.032
No. of segments/ fruit	11.50-19.50	14.827	0.808	1.143	7.711
TSS (^{0} Brix)	8.90-13.15	10.791	0.265	0.375	3.455
No. of seeds/fruit	17.50-168.00	91.256	5.804	8.208	8.994
Nature of juice sacs (soft/hard)	1.00-2.00	1.976	0.109	0.154	9.079
Acidity (%)	0.320-1.056	0.588	0.052	0.074	12.536
Fruit length: Breadth	0.700-1.275	0.965	0.043	0.061	6.325
100-seed wt. (g)	23.140-68.47	44.479	4.318	6.106	13.728

SE: Standard error of the means; CV: Coefficient of variation

juiciness, and less contents of *limonoids* (once oxidise led to throat congestion).

Amongst these selected clones of pummelo, thirteen were showing better fruit quality in terms of peel thickness, colour of segments, high TSS, number of seeds/fruit and titrable acidity etc. (Table 2). The clones having high TSS (>12.0 ^{0}Brix) in addition to other desirable attributes were finally selected for vegetative propagation and further evaluation. These clones were considered superior because of sweetness (as most of the pummelo grown in the locality is bitter in taste, reduces marketability and consumption), a very desirable trait for pummelo. The cultivation of these high TSS clones will certainly improve the consumption of pummelo in India and particularly in Bihar state.

Pusa Pummelo 5 had excellent eating quality due to dark yellow fruits, thin rind, high TSS, soft segments and small seeds (100-seed weight is 29.80 g) (Table 1, 2). It is also true that excessively thin-skinned fruits are liable to be damaged in the long distance transport and a compromise has to be made for these characters in such a way that no other character is affected. These need further studies to help selection process for increased TSS and reduced rind thickness so that improved pummelo varieties can be developed for the benefit of the growers.

Pusa Pummelo 1 is early maturing, red fleshed suited for table purposes. Pusa Pummelo 2, 3, 4 were large sized, red fleshed and have very good eating quality. Most of the pummelo clones (Pusa Pummelo 3, 4, 5, 6, 8, 9, 10. 11, 12) have soft segments mostly liked by consumers and less content of limonoids. Pusa Pummelo 5, 6, 7, 8, 9, 12 are profuse bearer, red fleshed and large sized suited for table purposes. Pusa Pummelo 9, 10 has large sized fruits, pink fleshed, with profuse bearing. Pusa Pummelo 11, 13 have dark red flesh with excellent eating quality. Various clones may be multiplied by the community and diversity of pummelo will increase. Pusa Pummelo 1, 5, 11, 13 can be encouraged for marketing in domestic *mandis*, once growers get better income, they will conserve and maintain the diversity with interest and can pass on to next generation.

Principal Component Analysis (PCA) and Grouping of Genotypes

PCA is a way of identifying the patterns in the data, and expressing the data in such a way as to highlight their similarities and differences (Winterocea *et al*., 2008). It has been used previously to establish the relationships among genotypes, *i.e.* cultivars and to study the correlation between physico-chemical and other characteristics within sets of genotypes. The PCA used in the present study showed that more than 30% variability observed in the first components (Table 4). The PC1, PC2 and PC3 accounted for 30.44, 15.74 and 11.15, respectively. Though first three (acidity, fruit weight and fruit length) are the most important, but account only for about 60 % of the variability and hence selection pressure may not be enough to get the desired type. The Eigen value of each morphological character in PCA is given in table 4, indicating the contribution in characters in the group formation. Here contribution of various morphological parameters were indicated by high Eigen value (>1.0) as criteria for marking characters with high diagnostic function (PC1, PC2, PC3 and PC4).

Plot analyses are able to create 2 or 3 dimension diagrams that each dimension of them is considered as a principal discriminator factor. In this study a two dimensional scatter plotting diagram constructed using component score 1 on X axis and component score 2 on Y axis exhibited 46.15 % of total variance. The genotypes fall into several clusters (Fig. 1) indicated most of the seedling of pummelo belongs to different source of origin. This result suggests that the factor(s) other than geographical separation is responsible for divergence, and the genotypes that have originated from the same place may have different genetic architecture or vice versa (Majumder *et al*., 2013).

These selected accessions might be important breeding material for the development of improved varieties and need further study. Selecting superior varieties became easy due to genetic characteristics of pummelo as seeds are zygotic (they contain one embryo and subjects to genetic segregation) and give rise to plants with entirely new horticultural traits); the seeds of other *Citrus* spp. tend to reproduce the characters of the mother plant. This produces a wealth of varieties to choose. Here the seedlings were evaluated in field conditions and wide range of variation in physico-chemical characters of pummelo indicated the great scope of individual plant selection based on these characters for future genetic improvement programme.

Table 4. Principal component scores for 12 morphological traits in germplasm lines of pummelo seedling

Principal component	Variates	Eigen value (%)	Variation (%)	Cumulative variation (%)
PC1	Acidity	3.65	30.44	30.44
PC2	Fruit length	1.88	15.74	46.15
PC3	Fruit width	1.43	11.91	58.11
PC4	Fruit weight	1.22	10.19	68.30
PC5	Length: Breadth	0.91	7.62	75.93
PC6	Nature of juice sacs	0.77	6.44	82.38
PC7	No. of seeds/fruit	0.74	6.19	88.57
PC8	No. of segment	0.55	4.59	93.17
PC9	Peel thickness	0.37	3.12	96.29
PC10	Pulp colour	0.33	2.81	99.11
PC11	TSS	0.09	0.77	99.88
PC12	100-seeds wt.	0.01	0.11	100.00

Eigen vectors of the most descriptive traits

The result of this study also suggested fruit morphological characters provides a practical approach in distinguishing seedling groups within pummelo and thus applicable for common people and breeder in selecting favourable clones. Moreover, Shrestha *et al*. (2012) demonstrated the role of morphological characters in distinguishing five landraces of *Citrus aurantifolia* and subsequently used those characters as the main basis in genotype selection for breeding programs. Morphological characterization on 20 cultivars of Indonesian *Citrus nobilis* by Martasari and Reflinur (2012) highlighted contribution of morphology in recognizing major differences among cultivars. The variability of fruit characters in pummelo may arise by hybridization or selection pressure, which resulted in the occurrence of adaptive phenotypic variation. Each group is representing highly variable assembly of seedlings/cultivars and deserve attention for their conservation. Physico-chemical variability in pummelo seedlings was adequately fulfilling criteria as gene-pools, as they represented accessions from different areas. They warrant consideration for conservation properly in order to protect loss of potential plant resources.

References

AOAC (1989) *Official Methods of Analysis* (14th ed.) of the Association of Analytical Chemists, Washington.

Barrett HC (1977) Intergeneric hybridization of *Citrus* and other genera in citrus cultivar improvement. *Proceed. International Soc. Citriculture* **2**: 586-589.

Chomchalow N (1984) Citrus germplasm in Southeast Asia. *IBPGR Newslett*. **28:** 3.

Dass HC (1990) Citrus germplasm of India. In: Huang BY, Yang Q (eds.). *Proceed. Int. Citrus Symposium, Beizing*, pp 65-69.

Duminil J and MD Michele (2009) Plant species delimitation: A comparison of morphological and molecular markers. *Plant Biosyst*. **143**: 528-542.

Dwari S and AK Mondal (2011) Systematic studies (morphology, anatomy and palynology) of economically viable grass *Brachiaria mutica* (Forsskil) in Eastern India. *African J. Plant Sci*. **5**: 296-304.

Engels J (2001) Home gardens and *in situ* conservation of plant genetic resources in farming systems In: Home gardens–a genetic resources perspective, *Proceedings of the Second International Home Gardens Workshop, July 17-19, 2001*, (Eds: JW Watson and PB Eyzaguirre) *Witzenhausen, Federal Republic of Germany.*

Hodgson RW (1967) Horticultural Varieties of Citrus. *In:* Reuther, HW, HJ Webber and LD Batchelor (eds.). *The Citrus Industry* **1**. Univ. California Press, Berkeley, pp 431-591.

Majumder DAN, L Hassan, MA Rahim and MA Kabir (2013) Genetic diversity in mango (*Mangifera indica* L.) through Multivariate Analysis. *Bangladesh J. Agric. Res*. **38**: 343-353.

Martasari CK and Reflinur (2012) Characterization of Indonesian 'Siam' cultivar (*Citrus nobilis* Lour.) by morphological and ISSR markers. ARPN *J. Agri. Biol. Sci*. **7**: 830-835.

Shrestha RL, DD Dhakal, DM Gautum, KP Paudyal and S Shrestha (2012) Study of fruit diversity and selection of elite acid lime (*Citrus aurantifolia* Swingle.) genotypes in Nepal. *Am. J. Plant Sci*. **3**: 1098-1104.

Spiegel-Roy P and EE Goldschmidt (1996) *The Biology of Citrus Cambridge* Cambridge University Press, 41p.

Susandarini R, S Subandiyah, Rugayah, BS Daryono and LL Nugroho (2013) Assessment of taxonomic affinity of Indonesian pummelo (*Citrus maxima* (Burm.) Merr.) based on morphological characters. *Amer. J. Agri. Bio. Sci*. **8**: 182-190.

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Heirloom/Seedling Mango Varieties of India – Potentialities and Future

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Mango is very widely distributed in India with more than one thousand varieties throughout the tropical and subtropical regions. Most of these varieties are of Seedling origin and are found to be growing as heirloom varieties from generation to generation. Survey carried out under the UNEP-GEF TFT project in the four sites *viz.*, *Chittoor, Amravathi, Pusa* and *Malihabad* resulted in the documentation of Seedling types, which showed desirable traits in them. These varieties evaluated *in situ, ex situ* resulted in indicating the desirable traits, which would help in introgression through breeding. The promising among them were registered. Some of these heirloom varieties can be directly adopted for commercial cultivation. The diversity analysis based on the morphological characteristics showed similar trend as the molecular characterization.

Key Words: Diversity, Heirloom, Indigenous, Mango, Variability

Introduction

The mango in India has more than one thousand varieties belonging to *Mangifera indica* and is spread throughout the country (Mukherjee, 1963). Many of today's commercial varieties *viz.*, *Alphonso, Imam pasand* etc., are heirloom varieties, which indicates that these are inherited from their ancestors. Survey carried out under the UNEP-GEF TFT project in the four sites *viz.*, *Chittoor, Amravathi, Pusa and Malihabad* resulted in the documentation of Seedling types, which showed desirable traits. The Seedling progenies were observed to be growing in large numbers in these regions. These were located, evaluated and registered. The information gathered from the selected community indicated that farmers are maintaining these varieties for different purposes *viz.*, pickling and for use during various occasions. These varieties evaluated *in situ*, *ex situ* resulted in indicating the desirable traits, which would help in introgression through breeding. The inter-site diversity studied for certain fruit characteristics showed that the Seedling types followed the diversity trend in recording the variability. This would not only help the farmers in conservation but also help in deriving benefit out of these by registering them as farmer's variety.

Materials and Methods

A total of 68 indigenous types spreading across the villages in the four sites viz., were identified through a participatory four-cell analysis and baseline survey in the three communities to assess on-farm community diversity. In this survey 1175 households were interviewed in the communities to locate the seedling types *(naati)*. Out of these 38 indigenous types, 10 elite types having unique fruit quality traits were identified by evaluating these accessions *ex situ* in five replications during the second year. The varieties once identified in the farmers' orchard were evaluated *in situ* by interviewing the farmers. Those of the Seedling varieties, which had desirable morphological traits *viz.*, peel colour, good shape and size were selected when they were mature and the ripe fruits were evaluated for eating quality, appearance and pulp quality *in situ.*

During the second season, the varieties were evaluated *ex situ* for the fruit quality parameters, which are distinct, unique and stable *viz.*, fruit weight, fruit

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length, fruit breadth, TSS, peel thickness, pulp colour, pulp percentage, keeping quality, total carotenoids and were also characterized using molecular tools to confirm that they are different from other varieties. It was also ensured that there are no duplicates in these Seedlings. Taking all these parameters, the varieties were selected for different purposes.

Thirty-eight indigenous mango varieties from *Chittoor* region, 70 varieties from *Pusa*, 12 varieties from *Amravati* and 115 varieties from *Malihabad* were evaluated for fruit characteristics and the trait specific characteristics for each of the varieties was indicated. Diversity analysis for the indigenous varieties from the four sites was carried out and cluster diagram was drawn using the Ward's method using PAST software. For each of the sites commercial varieties of different regions *viz.*, *Alphonso, Neelum* and *Totapuri* for *Chittoor*, *Dashehari* and *Langra* for *Malihabad* region, *Alphonso* and *Mankurd* for *Amravati* and *Sukul* and *Langra* for *Pusa* region were taken for comparison.

Results and Discussion

The indigenous varieties cultivated by farmers over decades, which are basically of Seedling origin and which are restricted to a particular region and termed as heirloom varieties were studied from four regions of India *viz., Amravati, Chittoor, Malihabad* and *Pusa.*

Indigenous Varieties of Amravati

The evaluation of the varieties showed that Amravati Amba-6 recorded the maximum fruit weight (202.1 g), the minimum fruit weight was observed in the variety Amravati Amba-5 (46.24 g). The TSS was observed to be maximum in the variety Amravati Amba-7 (20.24°Brix), the minimum TSS was observed in the variety Amravati Amba-12 (14.2°Brix). The pulp recovery was observed to be maximum in the variety Amravati Amba-12, which recorded 75.85%. All the selected elite varieties recorded more than 28.7% pulp recovery.

Indigenous Varieties of Chittoor

The evaluation of the varieties showed that Baitpalli V. Ranga Reddy Naati 1 recorded the maximum fruit weight (530.7 g), the minimum fruit weight was observed in the variety P. Reddyvaripalle K. Rajasekara Reddy Naati 2 (114 g). The TSS was observed to be maximum in the variety P. Reddyvaripalle V. Ramamurthy Reddy Naati 2 (21^0 Brix). The pulp recovery was observed to be maximum in the variety Talapulapalle Sreeramulu Achari Naati 4, which recorded as 82%. All the selected elite varieties recorded more than 60% pulp recovery. Wide variation was observed for the total carotenoid content among the varieties. The total carotenoid content was found to be maximum in the variety P. Reddyvaripalli V. Ramamoorthy Reddy Naati 3 (26.44 mg/100g), minimum was seen in the variety Palamakulapalli K. Ravindranath Naati 4 (3.0 mg/100 g).

Indigenous Varieties of Malihabad

The evaluation of the varieties showed that Goal Bhadaiya recorded the maximum fruit weight (945 g), the minimum fruit weight was observed in the variety Johri Safeda (85 g). The TSS was observed to be maximum in the variety Nisar Pasand (25^0Brix) and minimum was observed in the Baramasi Malihabad (11.44^0Brix). The pulp recovery was observed to be maximum in the variety Mahesh Pasand, which recorded 90.97%. All the selected elite varieties recorded more than 46.58% pulp recovery.

Indigenous Varieties of Pusa

The evaluation of the varieties showed that Vinod Rai Jagdishpur Seedling Madhukpia and Pusa Mango 2 recorded the maximum fruit weight (510 g), the minimum fruit weight was observed in the variety Durga Thakur Dhobgama Seedling (22 g). The TSS was observed to be maximum in the variety Sambhu Pd. Thakur Dhobgama Kishanbhog Seedling (22.8°Brix), the minimum TSS was observed in the variety Dinesh Pathak Maruabad Kishanbhog Seedling (8.6°Brix). The pulp recovery was observed to be maximum in the variety Gauri Shankar Jagdishpur Kishanbhog Seedling, which recorded 83%. All the selected elite varieties recorded more than 43% pulp recovery.

Morphological, agronomical as well as biochemical parameters (Rick and Holle, 1990; Weber and Wricke, 1994 and Kraemmer *et al*., 1995) have been widely used in the evaluation of various crops. Exploitation of such traits increases our knowledge on the genetic variability and strongly facilitates breeding for wider geographic adaptability. The vast diversity in mango has given rise to several indigenous varieties. Similar to the study conducted here several workers have studied the morphological descriptions of mango from time to time (Burns and Prayag, 1921; Mukherjee, 1948; Naik and Gangolly, 1950; Singh and Singh, 1956; Gangolly *et al*., 1957; Rajan *et al*., 1999; Yeshitela and Nessel, 2003; Desai and Dhander, 2000; Dinesh and Vasugi,

Table 1. Fruit characteristics of indigenous varieties of Chittoor

S.No.	Variety	F. wt. (g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
1	Talapulapalle Sreeramulu Achari Naati 4	419.55	9.97	8.50	18.37	37.38	82.86
2	Talapulapalle Sreeramulu Achari Naati 6	206.83	9.03	6.93	18.97	37.03	64.85
3	Talapulapalle Sreeramulu Achari Naati 8	82.82	5.77	5.27	18.10	23.35	55.45
4	Talapulapalle Babu Reddy Lalbaba	292.34	9.27	7.90	15.80	35.56	65.00
5	Talapulapalle Babu Reddy Dilpasand	296.69	11.17	7.70	18.80	42.68	71.08
6	Talapulapalle Babu Reddy Thorappadi Variant 2	674.41	14.33	9.50	18.73	46.98	79.56
7	Talapulapalle Babu Reddy Naati 2	576.93	14.00	9.27	19.87	53.04	76.74
8	Talapulapalle Babu Reddy BogamRangasani	393.58	10.33	7.77	21.37	51.11	74.07
9	Talapulapalle Babu Reddy Chittithotha	306.81	11.00	7.63	17.93	45.05	70.45
10	Talapulapalle Sreeramulu Pillai Naati 1	139.53	9.20	5.23	17.53	19.11	67.36
11	Talapulapalle Sreeramulu Pillai Naati 2	423.35	10.73	8.77	16.07	44.26	78.82
12	Kalepalle Rajendra Reddy Naati 2	218.00	8.13	6.90	18.87	24.72	68.65
13	Kalepalle Subramanyam Chetty Najoka	197.47	9.23	6.50	18.50	32.79	71.98
14	Kalepalli P. Govinda Chetty Naati 1	455.76	13.03	8.70	19.90	50.79	70.56
15	P. Reddyvaripalle K Rajasekara Reddy Naati 2	114.26	7.53	5.23	16.33	24.67	61.72
16	P. Reddyvaripalli V Ramamoorthy Reddy Naati 3	433.16	12.40	8.80	13.53	35.39	76.60
17	P. Reddyvaripalle V Ramamurthy Reddy Naati 2	256.42	8.33	7.20	21.00	39.92	70.21
18	Gandlapalle K Gurappa Chetty Naati Khader	217.33	8.67	6.50	18.80	33.60	70.40
19	Gandlapalle Sreeramulu Reddy Naati 3	321.29	9.53	7.67	18.20	35.50	69.22
20	Gandlepalle Sreeramulu Reddy Naati 4	441.89	13.13	8.10	19.63	32.81	82.77
21	Gandlapalle Sreeramulu Reddy Naati 5	157.68	10.60	5.80	18.93	23.56	69.10
22	Gandlapalle Sreeramulu Reddy Naati 1	144.57	7.60	6.33	15.53	41.90	38.65
23	Gandlapalle Sreeramulu Reddy Naati 2	178.23	10.00	5.83	13.90	27.18	69.69
24	Thumbavaripalle K. Subramanyam Reddy Naati 3	116.73	8.27	5.37	21.07	13.12	76.80
25	Thumbavaripalle Munirathnam Reddy Manoranjitham	262.21	9.13	7.87	24.90	41.35	61.14
26	Thumbaripalle Munirathnam Reddy Punasa	172.83	7.53	6.43	21.17	19.95	65.83
27	Thumbavaripalle K Subramanyam Reddy Naati 1	484.01	12.44	8.53	19.76	40.13	82.68
28	Thumbavaripalle K Subramanyam Reddy Naati 2	150.00	8.27	6.01	21.04	26.75	57.13
29	Thumbavaripalle K Subramanyam Reddy Naati 4	186.56	8.90	6.53	22.17	24.28	66.82
30	Palamakulapalle K Ravindranath Naati 1	422.50	10.00	9.10	13.03	54.67	71.13
31	Palamakulapalle K Ravindranath Naati 2	549.51	14.87	8.40	13.73	82.19	63.71
32	Palamakulapalle K Ravindranath Naati 3	274.19	8.25	7.85	18.05	43.72	70.96
33	Palamakulapalle K Ravindranath Green Baneshan	464.41	12.97	8.43	8.77	70.75	68.06
34	Baitpalle V Ranga Reddy Naati 1	541.20	12.13	9.10	15.07	42.47	77.26
35	Baitpalle V Ranga Reddy Naati 2	337.78	9.73	8.20	16.30	41.63	73.70
36	Baitpalle V Ranga Reddy Gadiyaram	441.81	12.23	8.03	13.53	58.25	74.47
37	Gudipalle K Surendra Reddy Naati 1	162.10	8.83	5.70	18.33	35.43	65.38
38	Gudipalle K Surendra Reddy Naati 2	360.83	10.97	8.30	19.10	45.36	68.77

Table 2. Fruit characteristics of indigenous varieties of Amravati

S.No.	Variety	Frt. wt. (g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
1	Amravati Amba - 1	145.3	7.82	6.18	17.4	28.9	60.2
2	Amravati Amba - 5	46.24	5.28	4.14	16.3	15.6	36.1
3	Amravati Amba - 6	202.1	11.8	6.55	15.78	32.5	64.2
4	Amravati Amba - 7	70.52	6.62	5	20.24	16.85	55.8
5	Amravati Amba - 8	94.22	7.2	5.22	16.5	26.4	44.2
6	Amravati Amba - 9	70.25	6.22	4.8	18.2	28.58	28.7
7	Amravati Amba - 10	118.4	7.35	6.15	17.2	28.3	46.4
8	Amravati Amba - 11	78.1	6.45	5.3	16.2	25.5	45.2
9	Amravati Amba - 12	58.2	5.12	4.3	14.2	15.58	75.85
10	Amravati Amba - 13	128.2	7.5	5.65	18.4	30	62.2
11	Amravati Amba - 15	85.2	6.85	4.9	19.2	18.2	62.6
12	Amravati Amba - 17	155.12	7.25	6.2	19.6	27.28	75.2

Table 3. Fruit characteristics of indigenous varieties of Pusa

S. No.	Variety	Frt. wt.(g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
1	Pusa mango 2	510.0	12.1	8.5	16.4	50.0	77.0
2	Pusa mango 3	250.0	9.0	6.9	18.2	31.0	71.2
3	Pusa mango 4	160.0	7.6	6.3	17.5	30.0	58.6
4	Pusa mango 5	306.0	11.2	7.2	15.6	45.0	68.4
5	Pusa mango 6	184.0	8.6	6.2	19.7	36.0	63.8
6	Pusa mango 7	120.0	6.7	5.6	21.3	44.0	43.0
7	Pusa mango 8	308.0	10.7	6.9	19.6	49.0	64.2
8	Pusa mango 9	168.0	9.4	6.2	12.8	24.0	68.9
9	Pusa mango 10	170.0	9.8	5.3	21.5	30.0	57.3
10	Pusa mango 12	150.0	7.3	6.2	17.1	30.0	58.0
11	Pusa mango 13	300.0	10.1	7.5	18.6	50.0	61.3
12	Pusa mango 14	300.0	11.4	6.9	17.4	40.0	74.2
13	Pusa mango 15	170.0	8.4	6.0	18.4	40.0	57.4
14	Pusa mango 16	240.0	9.7	6.6	17.5	40.0	70.0
15	Prashant Chandra Jagdishpur Sipia Seedling	218.0	11.2	6.4	15.4	53.0	56.2
16	Vinod Rai Jagdishpur Malda Seedling	170.0	8.4	6.0	18.4	40.0	57.4
17	Prashant Chandra Jagdishpur Sukulia	290.0	10.7	7.3	11.0	40.0	61.0
18	Vinod Rai Jagdishpur Malda Seedling Chapariya	179.0	8.6	6.6	19.0	41.0	50.5
19	Prashant Chandra Jagdishpur Malda Seedling	273.0	9.7	7.2	17.8	38.0	65.5
20	Vinod Rai Jagdishpur Bhemha Biju	149.0	7.7	5.9	16.5	38.0	46.7
21	Bipin Rai Jagdishpur Kishanbhog Biju	279.0	9.2	7.5	16.4	33.0	67.5
22	Vinod Rai Jagdishpur Alphonso Seedling	121.0	6.64	5.4	20.2	32.0	43.9
23	Surya Kant Mishra Dhobgama Seedling	250.0	9.1	6.9	16.7	41.0	61.3
24	Ram Rekha Thakur Dhobgama seediling	300.0	10.1	7.5	18.6	50.0	61.3
25	Kapildev Prasad Singh Rohua, Muzaffarpur Malda Seedling	270.0	9.8	7.2	12.0	33.0	68.4
26	Chandra Kant Jagdishpur Kishanbhog Seedling	210.0	8.2	6.5	18.0	37.0	60.4
27	Rajesh Kumar Harpur Pusa Seedling Lal Mohia	500.0	11.3	8.9	14.6	58.0	72.7
28	Durga Thakur Dhobgama Seedling	22.0	9.2	6.1	15.7	15.7	59.5
29	Kedar Rai Basuari Samastipur Sipia Seedling	230.0	11.0	6.1	13.9	36.0	62.4
30	Vinod Rai Jagdishpur Seedling Lal Mohia	130.0	6.7	5.8	14.8	24.0	59.2
31	Tribhuwan Thakur Malinagar Kerwa Seedling	280.0	11.5	6.7	15.8	35.0	71.8
32	Manoj Kumar Singh Rohua, Muzaffarpur Malda Seedling	240.0	8.9	7.1	14.2	36.0	66.4
33	Sambhu Pd. Thakur Dhobgama Kishanbhog Seedling	150.0	9.1	5.5	22.8	34.0	65.0
34	Ramji Mahto Mahmada Sipia Seedling	170.0	9.8	5.3	21.5	30.0	57.2
35	Rajesh Thakur Malinagar Sipia Seedling	150.0	7.3	6.2	17.1	30.0	58.0
36	Daya Nand Thakur Dhobgama Sipia Seedling	160.0	9.1	5.5	22.8	34.0	65.0
37	Ramji Mahto Mahmada Sipia Seedling	150.0	9.1	5.4	20.2	30.0	64.0
38	Ram Upek Thakur Malinagar Sipia Seedling	170.0	8.4	6.0	21.3	30.0	65.8
39	Vinod Rai Jagdishpur Seedling Chapahia	160.0	7.9	6.3	20.0	30.0	63.2
40	Vinod Rai Jagdishpur Sipia Seedling	320.0	11.6	7.5	17.3	35.0	66.5
41	Ram Shankar Thakur Dhobgama Kishanbhog Seedling	270.0	8.4	7.8	15.5	28.0	79.0
42	Vijay Kumar Chaudhry Mhamda Sipia Seedling	260.0	10.2	7.0	18.0	30.0	71.8
43	Vinod Rai Jagdishpur Seedling Lal Pari	167.0	8.0	6.3	17.3	40.0	52.4
44	Rajneshwar Thakur Dhobgama Bombay Seedling	240.0	9.7	6.6	17.5	40.0	70.0
45	Sanjay Thakur MalinagarKishanbhog Seedling	190.0	8.6	6.5	21.8	30.0	66.0
46	Prashant Chandra JagdishpurMalda Seedling	273.0	9.7	7.2	17.8	43.0	65.5
47	Alok Kumar JagdishpurSukul Seedling	290.0	11.0	6.7	12.5	38.0	75.0
48	Chandrakant Rai Jagdishpur Unknown Seedling	402.0	11.8	7.6	16.6	44.0	75.5
49	Chandrakant Rai Jagdishpur Unknown Seedling Kishanbhog Seedling	180.0	9.0	6.1	17.8	33.0	64.3
50	Sambhu Pd Thakur Dhobgama Kishanbhog Seedling Sipia Seedling	270.0	9.8	6.9	17.7	31.0	74.2
51	Prashant Chandra Jagdishpur Sipia Seedling	190.0	9.2	6.4	17.0	30.0	66.6
52	Vinod Rai Jagdishpur Seedling Madhukpia	510.0	12.1	8.5	16.4	50.0	77.0
53	Gauri Shankar Jagdishpur Kishanbhog Seedling	450.0	11.8	8.3	16.4	34.0	83.0
54	Gaya Prasad Sharma Bhuskul Malda Seedling	308.0	10.7	6.9	19.6	49.0	64.2
55	Murlidhar Sharma Shahjadpur, Kanti, Muzaffarpur Zarda Seedling	281.0	9.8	7.4	16.6	50.0	60.2
56	Md Abu Jaffar Rampur, Samastipur Jarda Seedling	180.0	8.6	6.3	16.3	27.0	66.0

Contd.

Table 3 Contd.

S. No.	Variety	Frt. wt.(g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
57	Raghupati Pd.Singh Mahmada Malda Selection	168.0	9.4	6.2	12.8	24.0	68.9
58	Ramakant Singh Rampur Bombai Green Seedling	247.0	8.9	6.3	20.6	27.0	66.0
59	Chandeshwar Pd. Singh Sukul Seedling	243.0	11.3	6.6	15.7	43.0	71.4
60	Kailash Pd. Rai Jagdishpur Malda Seedling	184.0	8.6	6.2	17.7	36.0	63.8
61	Dinesh Pathak Maruabad Kishanbhog Seedling	244.0	8.6	7.4	8.6	35.0	70.4
62	Satish Pathak Maruabad Sinduria Seedling	148.0	8.1	5.8	13.8	31.0	48.1
63	Nagendra Pd. Mishara Maruabad Kishanbhog Seedling	107.0	6.6	5.7	15.0	32.0	47.4
64	Parmanand Chaudhary Maruabad Dashahri Seedling	227.0	10.4	6.2	14.7	37.0	59.9
65	Bhikhari Singh Rampur Teknari Kishanbhog Seedling	256.0	9.1	7.7	13.4	56.0	58.6
66	Devendra Singh Rampur Teknari Zarda Seedling	169.0	8.3	6.1	14.6	29.0	63.1
67	Upender Thakur Bhuskaul Sinduria Seedling	306.0	11.2	7.2	15.6	45.0	68.4
68	Chandeshwar Pd. Singh Paterha Buzurg Dashahri Seedling	287.0	12.3	6.3	16.7	16.7	62.5
69	Chulbul Shahbajpur Kishanbhog Seedling	197.0	9.0	6.4	13.2	13.2	49.9
70	Upender Pandey Katarmala Zarda Seedling	365.0	10.8	8.4	16.5	51.0	69.4

Table 4. Fruit characteristics of indigenous varieties of Malihabad

S. No	Name	Frt. wt.(g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
1	Ahan Pasand	193.50	10.40	5.60	17.00	30.00	84.50
2	Alif Laila	247.00	11.00	6.73	21.55	31.25	69.98
3	Allahabadi Chausa	276.50	11.75	6.75	17.00	35.00	68.90
4	AmanAngoori	405.00	10.58	8.60	19.80	24.50	78.14
5	Aman Ibrahimpur	196.00	9.20	6.80	21.00	16.80	70.99
6	Amim Musaidabad	139.00	10.20	5.00	18.20	16.00	88.49
7	Amin	247.00	11.35	6.65	20.33	37.00	61.40
8	Aamin Abbasi	99.50	7.85	4.60	12.80	15.00	65.85
9	Aamin Abdul Ahad Khan	357.40	12.26	7.52	18.60	41.00	72.58
10	Aamin Tehsil	313.80	11.78	7.26	20.12	34.25	72.69
11	Aman Khurd	156.00	9.96	5.96	21.40	22.12	64.64
12	Amin (MTN)	212.00	10.20	6.10	18.20	42.00	63.21
13	Amin Dofasla	446.00	12.97	8.57	16.20	56.00	72.53
14	Amin Mohammad Yunus Khan	119.75	6.70	6.10	21.20	32.25	53.53
15	Amin Prince	315.20	12.12	7.04	19.80	32.40	73.28
16	Amit Deshi 2	97.50	6.80	4.70	16.69	27.00	72.31
17	Amrita	157.50	8.70	6.00	18.00	27.00	82.86
18	Amrita Pasand	116.25	7.70	5.00	18.00	23.40	79.87
19	Anil Pasand	175.75	9.40	6.00	18.25	43.00	75.53
20	Aslam Pasand	88.00	7.00	4.50	18.00	26.20	70.23
21	Baramasi Malihabad	154.00	10.32	5.60	11.44	26.48	62.83
22	Benazir	268.40	11.90	6.86	18.20	33.02	70.46
23	Benazir Sandilla	197.40	9.74	6.02	17.60	20.40	71.91
24	Bhadaila	370.33	9.80	8.03	18.70	46.00	76.15
25	Bhagwanta	193.20	9.34	6.84	20.00	44.00	56.94
26	Darbare Kalan	276.20	11.86	7.42	19.88	25.60	72.67
27	Dashehari (Improved)	297.00	12.40	6.80	20.20	32.00	68.35
28	Deshi (Karhile)	224.80	10.06	6.46	16.00	30.00	68.86
29	Deshi (Suresh)	352.00	12.73	7.50	20.00	36.00	69.89
30	Deshi Ram Kela	153.66	7.20	6.10	19.20	31.67	61.33
31	Deshi Chausa (Dina)	176.75	9.28	5.88	22.30	25.00	67.75
32	Deshi Chausa (Kanhaiya Lal, SAR)	128.00	9.40	4.95	22.00	26.00	60.94
33	Deshi Chausa (Karunesh, GM)	196.75	10.65	6.40	18.00	11.50	78.65
34	Deshi Gola	267.50	9.05	7.55	20.00	26.00	78.21
35	Deshi Gola SG	108.00	7.00	5.30	16.00	22.00	79.63
36	Deshi Lambui (Chhote Lal)	152.20	9.42	5.68	21.00	46.00	46.58
37	Deshi Lambui (Jagganath)	198.25	9.70	5.98	23.00	35.00	53.95
38	Deshi Naresh	117.50	7.60	4.70	17.40	17.00	85.53

Contd.

Table 4 Contd.

S. No	Name	Frt. wt.(g)	Frt. length (cm)	Frt. width (cm)	TSS (°Brix)	Stone wt. (g)	Pulp (%)
39	Deshi Radhey	126.50	9.20	5.00	24.00	26.00	79.45
40	Deshi Safeda	176.50	9.50	7.00	18.00	35.00	54.67
41	Deshi Safeda K2	185.00	9.50	5.80	18.40	24.00	87.03
42	Deshi T.B.	143.50	8.30	4.90	19.00	24.00	83.28
43	Desi Chausa G	185.50	10.00	6.20	18.32	25.00	86.52
44	Dudhiya Gola	317.75	10.58	7.58	20.00	42.00	66.33
45	Dudhiya Safeda N	280.67	11.60	7.00	18.00	53.00	81.12
46	Gilas	108.33	6.10	5.43	21.00	25.00	56.62
47	Goal Bhadaiya	945.00	14.20	10.40	18.00	55.00	77.78
48	Gola	195.00	9.65	6.10	18.60	22.50	72.05
49	Gola (Sarsanda)	111.00	7.00	6.60	19.00	35.00	68.47
50	Gulab Jamun	187.75	8.32	6.57	18.20	25.00	68.65
51	Hardil Aziz	253.00	9.50	7.72	18.40	30.50	69.51
52	Heere Hayat	174.33	9.33	6.03	18.00	45.00	48.37
53	Hushnara	183.00	10.85	5.90	16.30	36.50	65.03
54	Jalal Pasand	187.50	11.30	5.30	19.00	30.40	83.79
55	Jamun	235.33	10.73	6.67	19.23	30.00	63.63
56	Jauhari	104.00	7.48	4.98	20.00	21.00	63.46
57	Johri Safeda	85.00	7.20	4.70	22.12	14.67	63.00
58	Kachcha Meetha Gola	355.00	10.75	7.45	21.00	26.00	75.21
59	Kaliya Gola	99.00	6.38	5.46	19.00	15.00	63.64
60	Karwa Sagar	309.80	10.82	7.52	17.48	34.60	72.57
61	Khasulkhas	256.00	9.25	7.00	21.00	25.00	73.83
62	Khurd Amin	152.00	8.40	6.00	20.65	30.00	80.26
63	Kiran B	171.50	10.00	5.60	16.35	30.00	82.51
64	Kism	270.00	10.07	7.00	19.00	45.00	72.47
65	Kism (OriLal)	291.50	12.33	6.83	16.00	34.00	75.99
66	Kism Safeda	177.00	10.70	5.00	20.25	36.00	79.66
67	Krishana 2	164.00	9.40	5.60	20.00	32.00	80.49
68	Lakhnawwa Safeda	153.00	8.54	5.00	18.56	33.32	63.31
69	Lambauri	182.00	12.60	5.70	19.25	25.00	86.26
70	Lambi Amin	145.33	11.00	5.80	18.56	22.36	84.61
71	Lambori	184.67	10.03	5.97	24.00	30.00	64.26
72	Laumbauri Safeda	324.00	12.60	6.70	19.00	42.00	87.04
73	Madhurima	425.00	12.27	7.83	17.00	47.00	71.29
74	Mahesh Pasand	155.00	9.90	5.40	17.20	14.00	90.97
75	Makhan	175.00	9.20	5.30	21.80	32.40	65.87
76	Markeara	186.20	8.12	6.84	23.10	43.00	59.29
77	Matka Gola	322.50	10.45	7.90	19.40	35.00	70.54
78	Munjjar Aamin	645.00	16.50	8.50	18.20	65.00	75.97
79	Muzzar Amin	645.00	16.50	8.50	18.20	65.00	75.97
80	Nawaab Pasand	584.00	16.00	8.00	18.32	64.00	89.04
81	Nayab	158.20	9.06	5.78	21.00	28.20	63.55
82	Nazir Pasand	465.00	12.15	8.40	18.60	35.00	79.81
83	Nisar Pasand	273.00	11.80	7.08	25.00	32.20	70.59
84	Paan	354.00	10.50	8.60	19.56	36.00	89.83
85	Phool Psasnd	171.50	11.50	5.30	18.35	36.00	79.01
86	Poon N-H	303.50	10.30	8.30	18.00	40.00	86.82
87	Priti Pasasnd	222.50	11.20	5.60	18.00	44.00	80.22
88	Raja Pasand	160.75	10.10	5.85	19.50	25.00	84.45
89	Rajrani	226.67	10.23	6.10	20.00	44.00	65.15
90	Rani Gola	367.00	11.40	8.30	18.00	50.00	86.38
91	Rani Pasand	280.00	10.10	6.80	19.00	42.00	85.00
92	Sadafar	210.67	8.87	6.33	17.00	40.00	65.82
93	Sadafer Mithulal	211.00	8.75	6.75	19.60	41.00	57.58
94	Sadaphal Malihabad	214.25	9.30	6.57	22.50	38.00	65.37
95	Safeda Amin	181.67	11.67	5.47	20.30	36.00	58.41
96	Safeda D	176.50	9.70	5.70	17.25	47.00	73.37
97	Safeda Daun	207.50	11.15	5.85	23.20	35.00	65.30

Contd.

Table 4 Contd.

S. No	Name	Frt. wt.(g)	Frt. length (cm)	Frt. width (cm)	TSS (° Brix)	Stone wt. (g)	Pulp (%)
98	Safeda Deshi	172.50	9.60	6.00	18.25	44.00	74.49
99	Sanjay Pasand	328.00	12.00	7.20	19.32	34.00	89.63
100	Sawanha	162.50	9.65	6.00	19.00	31.00	62.15
101	Serehayat	264.50	11.15	7.00	22.30	37.50	68.86
102	Sheredar	461.80	10.88	7.70	19.40	38.62	78.57
103	Shobha	118.67	8.30	4.70	19.00	26.00	78.09
104	ShorabSah	243.00	11.90	6.70	19.00	28.50	69.90
105	Shweta	373.00	12.15	7.05	20.66	31.00	77.75
106	Surkha Burma	221.60	10.18	6.40	22.00	42.20	64.03
107	Surkha Gola M	173.00	10.30	5.80	18.00	43.00	75.14
108	Surya Amim	184.00	9.30	6.20	22.52	43.00	76.63
109	Surkha Jafarbagh	146.40	7.52	5.86	20.12	23.80	65.95
110	Taimuria	198.50	12.25	5.75	21.00	18.00	70.53
111	Tukmi Heera	214.00	9.76	6.30	19.00	35.00	71.50
112	Tukmi Lamba	196.00	10.50	5.70	18.20	27.00	86.22
113	Vilasita	178.00	9.40	5.50	21.00	36.00	79.78
114	Zafrani Shahabad	280.40	11.72	6.84	20.67	36.00	70.12
115	Zardalu (Seedling)	171.33	10.27	5.83	18.20	38.50	61.48

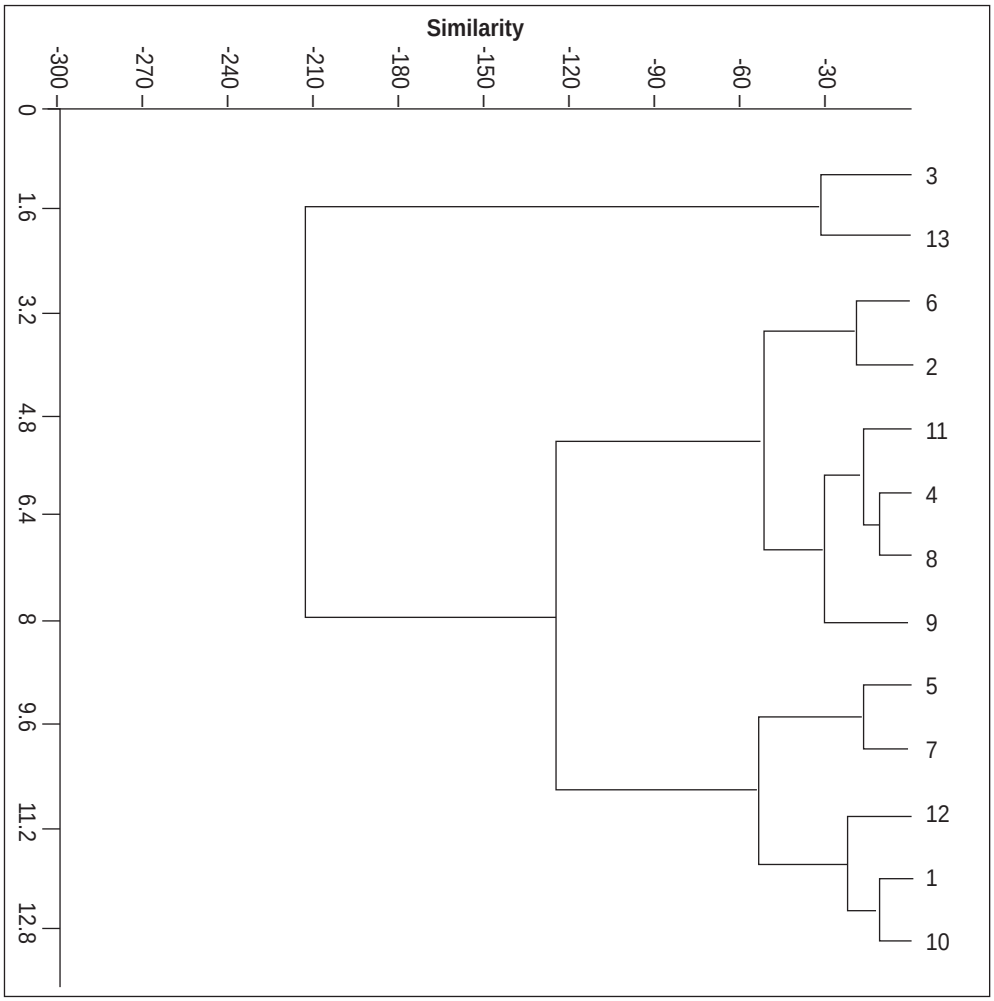


Fig. 1. 1. AmravatiAmba-1, 2. Amravati Amba–5, 3. Amravati Amba– 6, 4. AmravatiAmba– 7, 5. Amravati Amba- 8, 6. Amravati Amba–9, 7. Amravati Amba–10, 8. Amravati Amba–11, 9. Amravati Amba–12, 10. AmravatiAmba–13, 11. Amravati Amba–15, 12. Amravati Amba-17, 13. Alphonso.

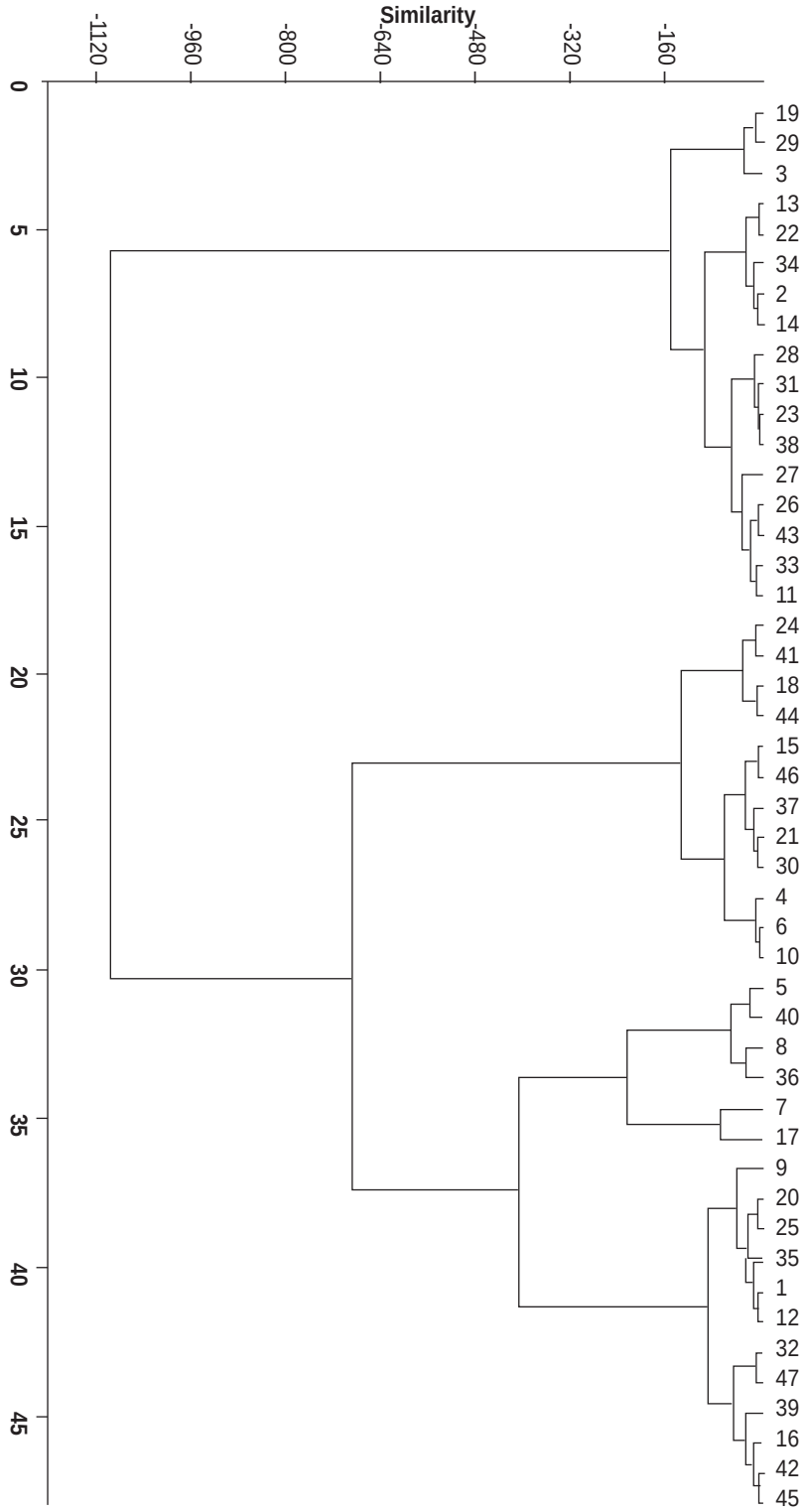


Fig. 2. 1. TSAN4, 2. TSAN6, 3. TSAN 8, 4. TBRLB, 5. TBRN1, 6. TBRD, 7. TBRT, 8. TBRN 2, 9. TBRBR, 10. TBRC, 11. TSPN1, 12. TSPN2, 13. KRRN2, 14. KSCN, 15. KPSN1, 16. KGCN1, 17. KRRN3, 18. RKRRN1, 19. RKRRN2, 20. RVRRN 3, 21. RVRRN2, 22. GGNK, 23. GPJN 2, 24. GSRN3, 25. GSRN4, 26. GSRRN5, 27. GSRRN1, 28. GSRRN2, 29. THKSN 3, 30. THMRM, 31. THMRP, 32. THKSRN1, 33. THKSRN2, 34. THKSRN4, 35. PKRN1, 36. PKRN2, 37. PKRN3, 38. PKRN4, 39. PKRNGB, 40. BVRRN1, 41. BVRRN2, 42. BVRRG, 43. GKSRN1, 44. GKSRN2, 45. Banganpalli, 46. Alphonso, 47. Totapuri

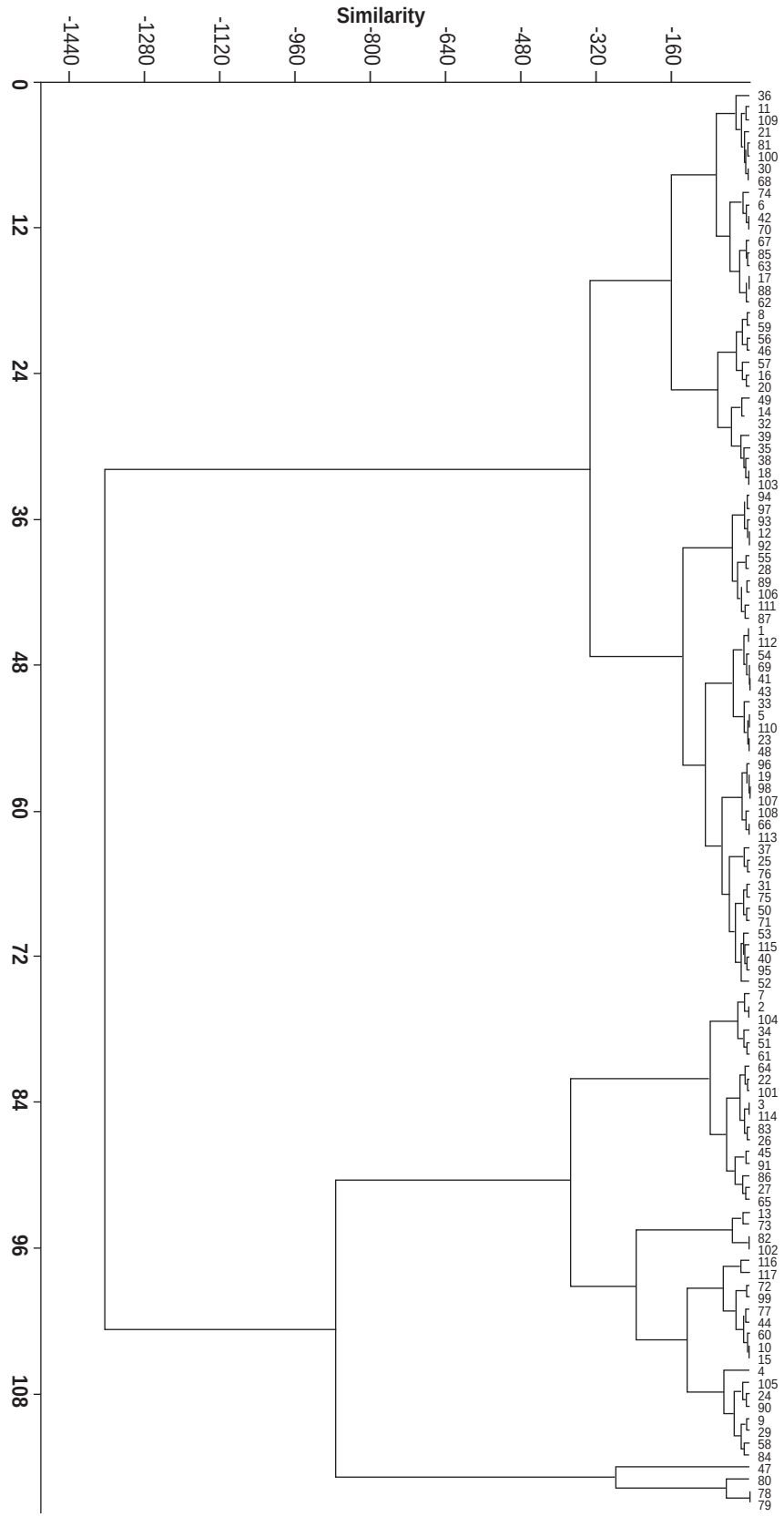


Fig. 3. MALIHABAD: 1. Ahan Pasand, 2. Alif Laila, 3. Allahabadi, Chausa 4. Aman Angoori, 5. Aman Ibrahimpur, 6. Amim Musaidabad, 7. Amin, 8. Aamin Abbasi, 9. Aamin Abdul Ahad Khan, 10. Aamin Tehsil, 11. Aman Khurd, 12. Amin (MTN), 13. Amin Dofasla, 14. Amin Mohammad Yunus Khan, 15. Amin Prince, 16. Amit Deshi 2, 17. Amrita, 18. Amrita Pasand, 19. Anil Pasand, 20. Aslam Pasand, 21. Baramasi Malihabad, 22. Benazir, 23. Benazir Sandilla, 24. Bhadaila, 25. Bhagwanta, 26. Darbare Kalan, 27. Dashehari (Improved), 28. Deshi (Karhile), 29. Deshi (Suresh), 30. Deshi Ram Kela, 31. Deshi Chausa (Dina), 32. Deshi Chausa (Kanhaiya Lal, SAR), 33. Deshi Chausa (Karunesh, GM), 34. Deshi Gola, 35. Deshi Gola SG, 36. Deshi Lambui (Chhote Lal), 37. Deshi Lambui (Jagganath), 38. Deshi Naresh, 39. Deshi Radhey, 40. Deshi Safeda, 41. Deshi Safeda K2, 42. Deshi T.B., 43. Desi Chausa G, 44. Dudhiya Gola, 45. Dudhiya Safeda N, 46. Gilas, 47. Goal Bhadaiya, 48. Gola, 49. Gola (Sarsanda), 50. Gulab Jamun, 51. Hardil Aziz, 52. Heere Hayat, 53. Hushnara, 54. Jalal Pasand, 55. Jamun, 56. Jauhari, 57. Johri Safeda, 58. Kachcha Meetha Gola, 59. Kaliya Gola, 60. Karwa Sagar, 61. Khasulkhas, 62. Khurd Amin, 63. Iran B, 64. Kism, 65. Kism (Ori Lal), 66. Kism Safeda, 67. Krishana 2, 68. Lakhnawwa Safeda, 69. Lambauri, 70. Lambi Amin, 71. Lambori, 72. Laumbauri Safeda, 73. Madhurima, 74. Mahesh Pasand 75. Makhan, 76. Markeara, 77. Matka Gola, 78. Munjjar Aamin, 79. Muzzar Amin, 80. Nawaab Pasand, 81. Nayab, 82. Nazir Pasand, 83. Nisar Pasand, 84. Paan, 85. Phool Pasand, 86. Poon N-H, 87. Priti Pasand, 88. Raja Pasand, 89. Rajrani, 90. Rani Gola, 91. Rani Pasand, 92. Sadafar, 93. Sadafer Mithulal, 94. Sadaphal Malihabad, 95. Safeda Amin, 96. Safeda, 97. Safeda Daun, 98. Safeda Deshi, 99. Anjay Pasand, 100. Swanha, 101. Seehayat, 102. Sheedar, 103. Shoba, 104. Shora Sah, 105. Shweta, 106. Surkha Burma, 107. Surkha Gola M, 108. Surya Amim, 109. Surkha Jafarbagh, 110. Taimuria, 111. Tukmi Heera, 112. Tukmi Lamba, 113. Vilasita, 114. Zafarani Shahabad, 115. Zardalu (Seedling), 116. Dashehari, 117. Langra.

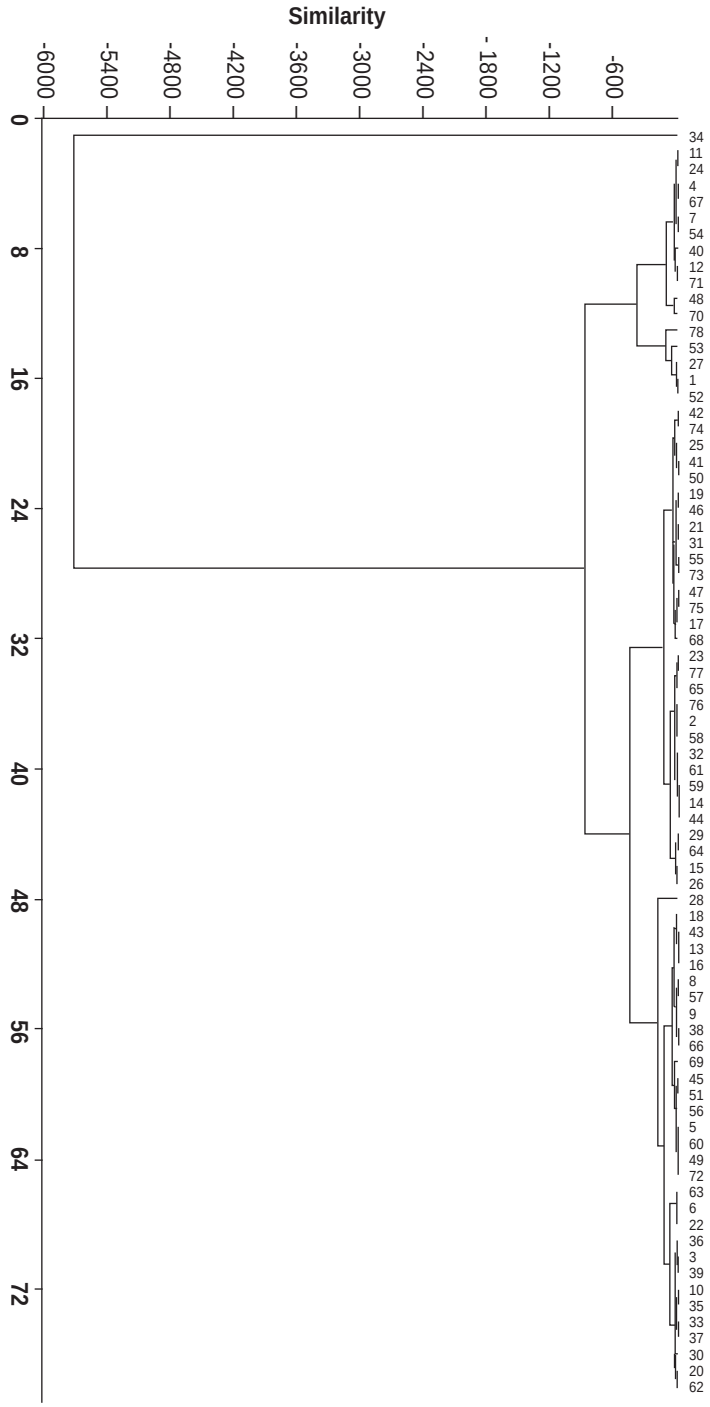


Fig. 4. PUSA: 1. Pusa Mango 2, 2. Pusa Mango 3, 3. Pusa Mango 4, 4. Pusa Mango 5, 5. Pusa Mango 6, 6. Pusa Mango 7 7. Pusa Mango 8, 8. Pusa Mango 9, 9. Pusa Mango 10, 10. Pusa Mango 12, 11. Pusa Mango 13, 12. Pusa Mango 14, 13. Pusa Mango 15, 14. Pusa Mango 16, 15. Prashant Chandra Jagdishpur Sipia Seedling, 16.Vinod Rai Jagdishpur Malda Seedling, 17. Prashant Chandra Jagdishpur Sukulia, 18. Vinod Rai Jagdishpur Malda Seedling Chapariya, 19. Prashant Chandra Jagdishpur Malda Seedling, 20.Vinod Rai Jagdishpur Bhemha Biju, 21. Bipin Rai Jagdishpur Kishanbhog Biju, 22. Vinod Rai Jagdishpur Alphonso Seedling, 23. Surya Kant Mishra Dhobgama Seedling, 24. Ram Rekha Thakur Dhobgama Seedling, 25. Kapildev Prasad Singh Rohua, Muzaffarpur Malda Seedling, 26. Chandra Kant Jagdishpur Kishanbhog Seedling, 27. Rajesh Kumar Harpur Pusa Seedling Lal, Mohia, 28. Durga Thakur Dhobgama Seedling, 29. Kedar Rai Basuari Samastipur Sipia, Seedling, 30. Vinod Rai Jagdishpur Seedling Lal Mohia, 31. Tribhuwan Thakur Malinagar Kerwa, Seedling, 32. Manoj Kumar Singh Rohua, Muzaffarpur Malda Seedling, 33. Sambhu Pd. Thakur Dhobgama Kishanbhog Seedling, 34. Ramji Mahto Mahmada Sipia Seedling, 35. Rajesh Thakur Malinagar Sipia Seedling, 36. Daya Nand Thakur Dhobgama Sipia Seedling, 37. Ramji Mahto Mahmada Sipia Seedling, 38. Ram Upek Thakur Malinagar Sipia Seedling, 39. Vinod Rai Jagdishpur Seedling Chapahia, 40. Vinod Rai Jagdishpur Sipia Seedling, 41. Ram Shankar Thakur Dhobgama Kishanbhog Seedling, 42. Vijay Kumar Chaudhry Mhamda Sipia Seedling, 43. Vinod Rai Jagdishpur Seedling Lal Pari, 44. Rajneshwar Thakur Dhobgama Bombay Seedling, 45. Sanjay Thakur Malinagar Kishanbhog Seedling, 46. Prashant Chandra Jagdishpur Malda Seedling, 47. Alok Kumar Jagdishpur Sukul Seedling, 48. Chandrakant Rai Jagdishpur Unknown Seedling, 49. Chandrakant Rai Jagdishpur Unknown Seedling Kishanbhog Seedling, 50. Sambhu Pd. Thakur Dhobgama Kishanbhog Seedling Sipia Seedling, 51. Prashant Chandra JagdishpurSipia Seedling, 52. Vinod Rai Jagdishpur Seedling Madhukpia, 53. Gauri Shankar Jagdishpur Kishanbhog Seedling, 54. Gaya Prasad Sharma Bhuskul Malda Seedling, 55. Murlidhar Sharma Shahjadpur, Kanti, Muzaffarpur Zarda Seedling, 56. Md. Abu Jaffar Rampur, Samastipur Jarda Seedling, 57. Raghupati Pd. Singh Mahmada Malda Selection, 58. Ramakant Singh Rampur Bombai Green Seedling, 59. Chandeshwar Pd. Singh Sukul Seedling, 60. Kailash Pd. Rai Jagdishpur Malda Seedling, 61. Dinesh Pathak Maruabad Kishanbhog Seedling, 62. Satish Pathak Maruabad Sinduria Seedling, 63. Nagendra Pd. Mishara Maruabad Kishanbhog Seedling, 64. Parmanand Chaudhary Maruabad Dashahri Seedling, 65. Bhikhari Singh Rampur Teknari Kishanbhog Seedling, 66. Devendra Singh Rampur Teknari Zarda Seedling, 67. Upender Thakur Bhuskaul Sinduria Seedling, 68. Chandeshwar Pd. Singh Paterha Buzurg Dashahri Seedling, 69. Chulbul Shahbajpur Kishanbhog Seedling, 70. Upender Pandey Katarmala Zarda Seedling, 71. Malda (Langra), 72. Sipia, 73. Zarda, 74. KishenBhog, 75. Sukul, 76. Paharpur Sinduria 77. Kanchan (Bathua), 78. Fazli.

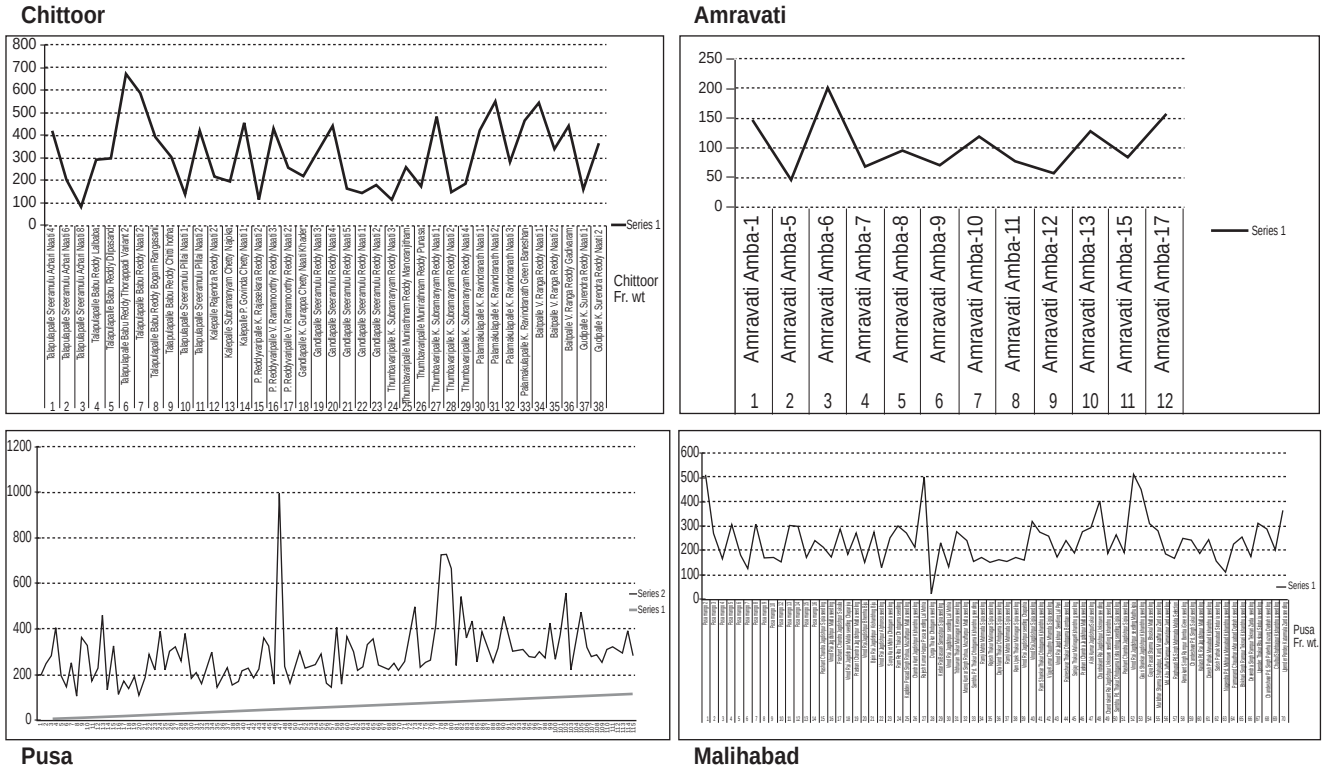


Fig. 5. Fruit weight pattern in different sites

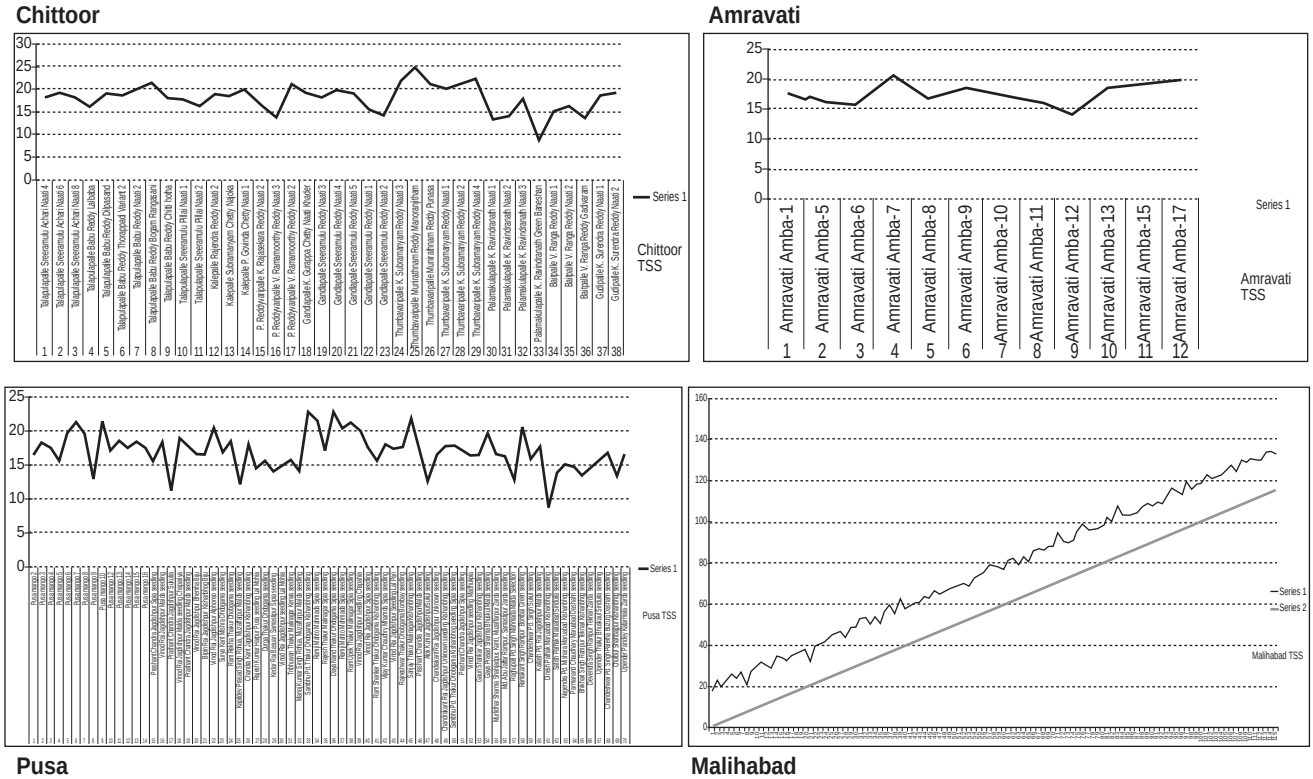
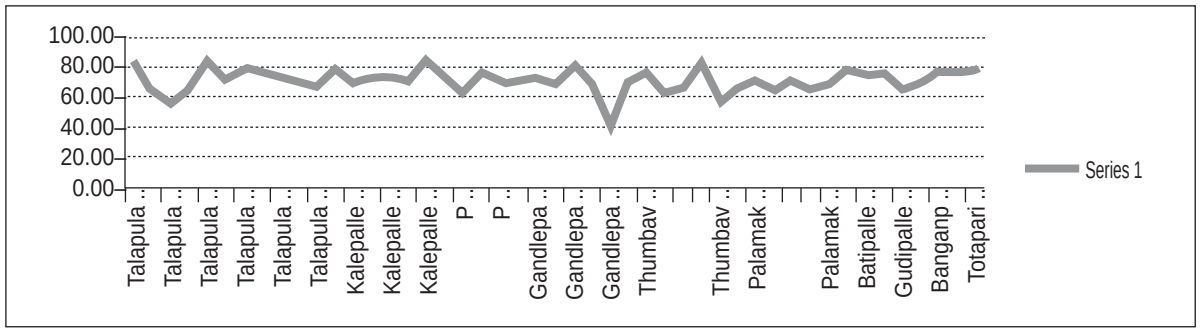
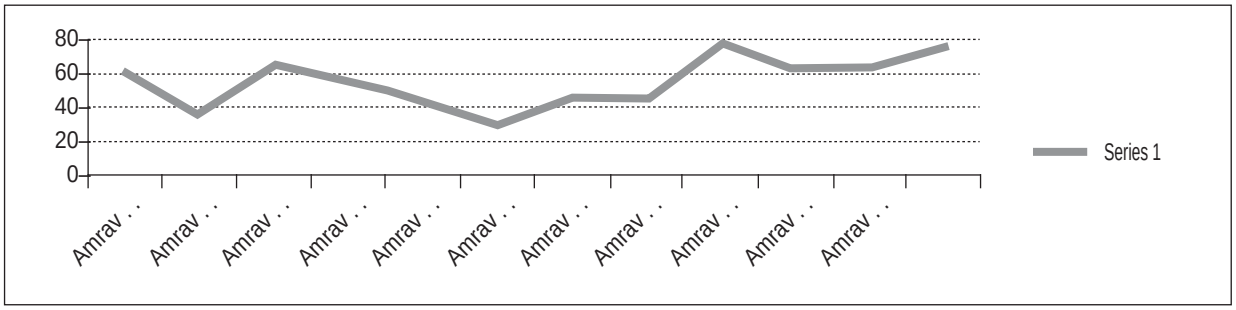


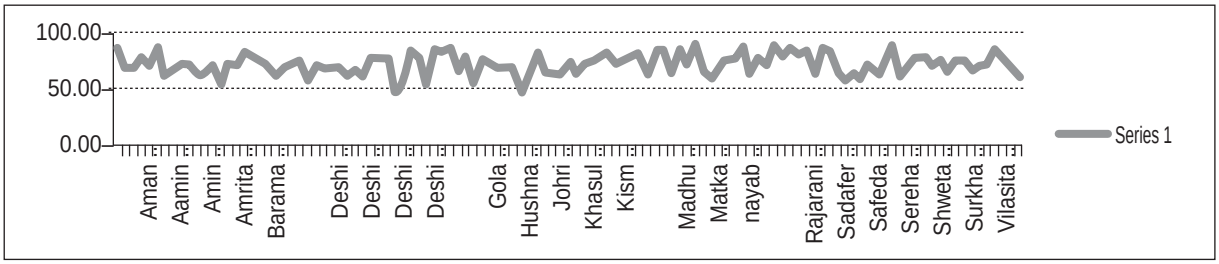
Fig. 6. TSS pattern in different sites



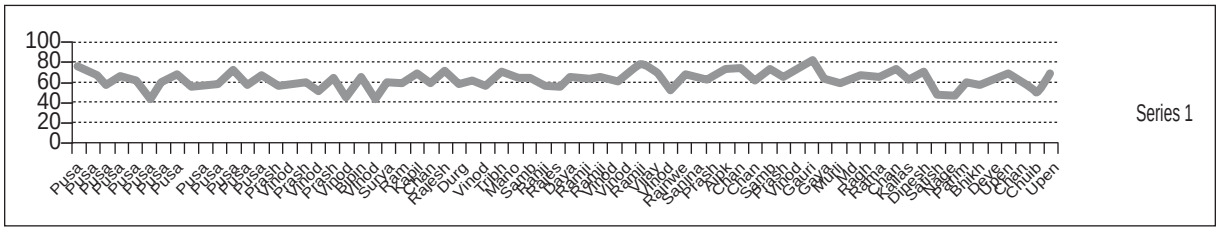
Chittoor



Amravati



Malihabad



Pusa

Fig. 7. Pulp percentage in different sites

2002). Yadav and Singh (1985) opined that South and North Indian varieties belong to two different ecotypes of *M. indica* based on physiology of flowering. In such situations diversity analysis based on morphological characters are likely to show inconsistencies. The inter site comparison of various heirloom varieties for important traits viz., fruit weight, TSS and pulp percentage showed variation between the sites (Fig. 5 to 7). With regard to fruit weight, the variability present in the diversity rich regions of *Malihabad* and *Pusa* is very high, whereas in *Amravati* the variability is less for this trait. The characteristics TSS follow the same pattern but in the case of *Malihabad* there is clear-cut gradation starting from low to high. The pulp recovery expressed as percentage is observed to be similar in all the four sites. Ravishankar *et al* (2000), studied the genetic diversity in eighteen commercial varieties of mango grown in India using RAPD analysis, they observed two major groups; one consisting of northern, eastern and western varieties, another consisting of southern cultivars, their study also indicated that the variety *Kesar* from western region of India was associated with *Neelum* and *Rumani*. The cluster analysis was carried out using past software separately for each site along with the commercial cultivars to see their relationship. In the case of the *Amaravati* site, cluster was developed using the indigenous varieties of *Amaravati* and commercial variety *Alphonso*. Two main clusters were observed, in one of the clusters Alphonso and indigenous variety Amba-6 were grouped together, which shows that this indigenous variety is similar to Alphonso and probably is a Seedling descent. The second cluster was divided into two-sub clusters containing 11 indigenous varieties of the same region. Vasugi *et al.* (2012) concluded that genotypes belonging to different geographic region might have evolved from the existing mango gene pool from which they were selected by local people to domesticate them indifferent areas for cultivation.

In the Chittoor site 2 main clusters were observed. In the 1st cluster, 17 Chittoor indigenous varieties were grouped together. The second cluster was sub divided into two sub clusters and this again is divided into 2 sub clusters where in one sub cluster has the varieties Alphonso and KPSN1. In the second sub cluster Totapuri and THKSRN1, Banganpalli and BVRRG are grouped together, which shows that these varieties are Seedlings derived from the present day commercial varieties.

The cluster diagram of *Malihabad* indicates two main clusters. The 1st group represents only indigenous varieties and in the second group the cultivars *Dashehari, Langra* are grouped with *Laumbauri Safeda, Anjay Pasand, Matka Gola, Karwa Sagar, Dudhiya Gola, Aamin Tehsil* and *Amin Prince* in the 1st sub cluster. In the 2nd sub cluster remaining indigenous varieties are grouped together. Hence, selection of indigenous varieties from the pool of 1st sub-cluster may help in developing varieties or pre-breeding lines similar to *Langra* and *Dashehari.*

With regard to the clustering in the indigenous varieties of *Pusa*, first cluster contains only one indigenous Ramji Mahto Mahmada, *Sipia* seedling, which shows that this variety is distinctly different. The second cluster is subdivided into two sub clusters in which *Langra* and Pusa Mango-12 are grouped together and in the second sub cluster remaining indigenous varieties grouped.

Heirloom varieties have been conserved and grown for various reasons. Perales *et al.* (2003a) opines that farmers play an important, role in the maintenance of crop genetic diversity, farmers do experiment with new plant materials and adopt them if they turn out to be superior to traditional varieties or landraces. This is so in the case of high-altitude region in Mexico where traditional varieties of maize are still grown in spite of the lack of marginality. In this region, local maize varieties are advantageous because they are higher-yielding, resist infestation by weevils better, and are more tolerant to drought and lodging than modern cultivars. This is similar to the Seedling originated mango varieties, which are being grown in spite of quality not very superior. However, farmers have varied uses for these varieties.

Heirloom Varieties, Characteristics and their Utility

The heirloom varieties are of Seedling origin and most of them are regular bearers. These are observed to be growing as individual plants in several orchards of the mango-growing farmers. They have great potentiality as several of them have desirable traits *viz*., keeping quality and high nutritive value for like *naati* variety P. Reddyvaripalli V. Ramamoorthy Reddy Naati 3 recorded high total carotenoids (26.44 mg/100g). Similar studies carried out by Dhander and Desai (2000) resulted in the selection and isolation of *Cardozo Mankurd*. These Seedling selection scan be registered as farmers' varieties, which would benefit the farmer by ensuring the rights. These varieties will be of immense value to a researcher as they can be used in the breeding programme, also they

can be used by the farmers for other value added products and due to their regularity in bearing help the farmer in getting better income when the commercial varieties are not in fruiting. Another important characteristic feature is the bearing season – in these Seedling types early season, mid-season and late season varieties are noticed.

Acknowledgements

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References

Burns W and SH Prayag (1921) *The Book of Mango*. Dept. Agric. Bull. Bombay, Govt. Cent. Press.

Desai AR, Dhandar DG (2000) Variation in physico-chemical and morphogenetic characters of some mango varieties of Goa. *Acta Hort*. **509:** 243-249.

Dinesh, MR and C Vasugi (2002) *Catalogue of mango germplasm*. Published by IIHR.

Gangolly SR, Ranjit Singh, SL Katyal and Daljit Singh (1957) The *Mango*. ICAR Publication, New Delhi.

Kraemer D, K Weising, B Beyemann, T Bomer, JT Epplen and G Kahl (1995) Oligonucleotide fingerprinting of tomato Dann. *Plant Breed.* **114:** 12-17.

Mukherjee SK (1948) The cultivars of mango (*M. indica* L.) and their classification. *Bull. Bot. Soc. Bengal* **2:** 101-33.

Mukherjee SK (1963) Cytology and breeding of mango. *Punjab Hort. J*. **3:** 107-115.

Naik KC and SR Gangolly (1950) *Monograph on Classification and Nomenclature of South Indian Mangoes*. Madras, Supt. of Government Press.

Perales H, SB Brush and CO Qualset (2003) *A Landraces of Maize in Central Mexico: An altitudinal transect*. *Econ. Bot.* **57:** 7-20.

Rajan S, SS Negi and Ram Kumar (1999) *Catalogue of mango germplasm, Central Institute for Subtropical Horticulture*. Lucknow, India.

Ravishankar KV, Lalitha Anand and Dinesh MR (2000) Assessment of genetic relatedness among mango cultivars of India using RAPD markers. *J. Hort. Sci. Biotech.* **13:** 26-28.

Rick CM and M Holle (1990) *An Indian Lycopersicum esculentum* var. *cerasiformie*. *Genetic variation and its evolutionary significance*. *Ecol. Bot.* **44:** 69-78.

Singh LB and RN Singh (1956) *A Monograph on the Mangoes of Uttar Pradesh. Vol. I and II, Superintendent of Printing*. Lucknow.

Vasugi C, MR Dinesh, K Sekar, KS Shivashankara, B Padmakar and KV Ravishankar (2012) Genetic diversity in unique indigenous mango accessions (Appemidi) of the Western Ghats for certain fruit characteristics. *Curr. Sci.* **103:** 199-207.

Weber, WE and G Wricke (1994) Genetic markers in plant breeding In: Advances in breeding. *J. Plant. Breed, Suppl*., pp 16.

Yadav IS and HP Singh (1985*)* Evaluation of different ecological groups of mango cultivators for flowering and fruiting under subtropics. *Prog. Hort*. **17:** 165-75.

Yeshitela T, PJ Robbertse and PJC Stassen (2003) The impact of panicle and shoot pruning on inflorescence and yield related developments in some mango cultivars. *J. Applied Horti.* **5:** 69-75.

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DOI 10.5958/0976-1926.2015.00019.4

Genetic Diversity Studies in Certain Indigenous Mango (*Mangifera indica* L) Varieties

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The large seedling diversity of mango has not been fully evaluated. The evaluation of seedling diversity was carried out for morphological traits in the Chittoor area of Andhra Pradesh in India. The statistical analysis carried out for fruit characteristics showed significant differences among the varieties for various fruit characteristics. Molecular characterization was carried out using microsatellite markers. Most of the indigenous varieties from Kalepalli region are grouped in the same cluster. It is interesting to note that the morphological characterization and molecular characterization follow almost the same pattern suggesting the genetic control of these fruit characters. The study shows that the diversity observed within a geographic region is derived from the varieties that are being grown in that region. The promising seedling varieties selected with desirable traits would help the farmer in benefit sharing as and when they are registered. In addition it would help in 'on farm conservation' and use of these varieties in crop improvement programmes.

Key Words: Characterization, Clusters, Conservation, Diversity, Landraces

Introduction

The mango (*Mangifera indica* L) originated in northeastern India, the Indo-Myanmar border region and Bangladesh (Chittagong Hill tract), where it is still found in feral state, with very small fruits and it is under cultivation in India for at least 4000 years with over 1000 varieties recognized (Mukherjee, 1953). Almost all of them are selections made from naturally occurring open-pollinated seedlings. Seven centers of diversity have been recognized in India (Yadav and Rajan, 1993). In the Peninsular Indian region, Chittoor is one of the main centers of mango growing, wherein several indigenous landraces were observed under cultivation. These indigenous varieties are known as 'naati' types in local language. Most of these seedling types are regular bearers having desirable traits, which were located by survey under the "UNEP/GEF project on "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security and Ecosystem Services". The genetic variability studies were conducted utilizing these seedling originated naati types utilizing microsatellite markers. Molecular tools including both nuclear marker and cytoplasmic markers are currently playing major role in population studies, phytogeography, mapping, parentage analysis. Many different molecular markers have been used in mango for cultivar identification, such as RAPD (Rajwana *et al.*, 2008; Marcela *et al.*, 2009), ISSR (Sagar *et al*., 2007; Pandit *et al*., 2007), AFLP (Yamanaka *et al*., 2006), and SSR (Schnell *et al*., 2005, 2006) for clonal identification and for roughly estimating genetic relationships among genotypes. *Mangifera* germplasm has been collected and analyzed using simple sequence repeat (SSR) markers recently by Dillon *et al*. (2013, 2014). Microsatellites has greater importance due to their abundant occurrence throughout the genome of all the eukaryotes due to their co-dominant nature high level polymorphism because of it variation in repeat lengths (Ravishankar *et al*., 2011). Hence, a study was undertaken to assess genetic variability of naati (seedling) mango varieties in Chittoor, Andhra Pradesh of India for seedlings of desirable traits for further commercialization

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or for home garden conditions or for crop improvement could be selected.

Materials and Methods

The Polakala, Talupulapalle and Bangarupalyam regions of Chittoor district in Andhra Pradesh has a dry and hot climate with low temperatures of 12-18° C in winter and high temperatures of 38-46° C during summer and an average rainfall of 918.1 mm/year. The soil of the region is generally red sandy loam and in some places clayey soils are also seen. A total of 44 naati types spreading across the villages of three communities belonging to 21 farmers were identified through survey. The genetic diversity studies were conducted utilizing these 44 *naati* (indigenous) types.

The 44 indigenous varieties were evaluated for fruit characteristics *viz.,* fruit weight, fruit length, fruit width, skin weight, stone weight, TSS and pulp percentage using 'Bioversity International Descriptors (2006). Evaluation was carried out by taking fruit samples in five replicates. The variance analysis (ANOVA) was carried out using RCBD. The total carotenoids were determined colorimetrically as per the method described by AOAC (1995). The clustering was carried out using the UPGMA method.

The molecular characterization was carried out using SSR markers, which comprised of DNA isolation and polymorphism analysis. The genetic analysis was carried out based on the data generated. Total genomic DNA was extracted from the leaf material using the modified CTAB method (Ravishankar *et al.,* 2000). The concentration of DNA was determined by spectrophotometer at 260nm. The integrity was determined by agarose gel electrophoresis (0.8%).

PCR and Polymorphism Analysis

The fluorescence based PCR method proposed by Schuelke (2000) was used to amplify the microsatellites in a quick, accurate and efficient manner. PCR amplification was performed in a 20µl volume containing 75-100 ng pomegranate DNA, Taq Buffer 10X (Tris with 15mM $MgCl_2$, pH-9)-2.85µl, 1mM dNTPs- 3.5 µl, locus labeled forward specific primer (5µM)- 2.0µl, reverse primer (5µM)- 2.0µl, Nuclease free water-5.65µl and 1.0 unit of Taq DNA polymerase. PCR was performed on Life Pro Thermocycler with the following temperature profile: 94°C for 2 min followed by 35 cycles at 94°C for 30s, 30s at optimal annealing temperature of 55°C and 72°C for 1min. A final extension reaction was allowed to proceed at 72°C for 5min. Amplified products were initially separated on 3% agarose gel for confirmation of the amplification. These samples were separated on the automatic 96 capillary automated DNA Sequencer.

The raw data generated was analyzed and compiled using Peak Scanner V1.0 software for detecting the alleles**.** This produces a size curve based on the known size standard fragments, with the help of which the unknown fragment sizes are determined. The results obtained were used for genetic analysis using Cervus 3.0 software (Kalinowski *et al*., 2007) for determining the number of alleles, observed heterozygosity (Ho), expected heterozygosity (He) and Polymorphic Information Content (PIC). The genetic similarity and genetic distance between 44 genotypes was estimated by the Neighbour Joining method using Darwin software (Perrier *et al*., 2003; Perrier and Jacquemoud-Collet., 2006).

Results and Discussion

Chittoor in Andhra Pradesh is one the main centers of mango growing in the peninsular region of India. The survey carried out under the UNEP/GEF project "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security and Ecosystem Services" resulted in the identification of 44 *naati* varieties (indigenous) having varied size, shape and color (Fig.1), which were utilized for conducting genetic diversity studies. The statistical analysis carried out showed significant differences among the varieties for fruit characteristics (Table 1) thereby pointing out that the varieties are different. The evaluation of the indigenous varieties showed that the variety Thumbavaripalli Munirathnam Reddy Manoranjitham has high total carotenoids (29.0 mg/100g) and high TSS (24^0Brix). Another naati variety P. Reddyvaripalli V. Ramamoorthy Reddy Naati 3 also showed high total carotenoids (26.44 mg/100g). The pulp recovery in most of the seedling types was observed to vary between 54 to 98%, with most of the varieties having > 65%. Selection of seedlings in Israel has resulted in new mango cultivars with excellent peel color *viz.*, 'Naomi' and Tango (Lavi *et al.,* 1997). The seedling (*naati*) types observed in this study *viz.*, TSAN4 and VRR3 were observed to have excellent peel color, indicating that good diversity exists for desirable traits in the seedlings. In a similar study carried out with seedling progenies in Goa,

Fig. 1. Variation for shape, size and colour in the *Naati* types of Chittoor

Nagabhushan and Mathew (1994) reported excellent peel colour in certian seedling type's *viz*., Mankurad, Salcete Mussarat, Malgesh, Xavier, Udgo, Saccrchi, Colaco, Furtado and others. Uttar Pradesh region of India is one of the diversity centres for seedling mango types. The evaluation of seedling types carried out by Teaotia and Srivastava (1979) showed that the variety Gaurjit is a good sucking type and the variety Kare-Ka-Fazli is a very high yielder having good fruit size. In the Chittoor seedling types also it was noticed that they are regular and heavy bearers. Hence, the evaluation and conservation of '*naati'* seedlings can be a very viable method in the improvement of a heterozygous crop like mango. The diversity analysis carried out using morphological characteristics showed two main clusters (Fig. 2). In the first cluster the commercial varieties Kalapadi, Sindhura, Khuddus, Athi Madhuram and Alphonso are grouped with the naati varieties of Talupulapalli. The varieties TBRBR, and TBRLB, both of which have good peel colour is grouped with the commercial variety Khuddus, which has attractive peel colour. The other coloured variety Totapuri is grouped with the coloured variety RVRRN3, which also is similar to Totapuri in shape. The interesting feature is that probably the coloured varietis are descendants of today's commercial variety Khuddus. The clustering to a large extent is based on the location of the seedling in a particular region. The seedlings of Talupulapalli are grouped in the same cluster to a large extent and that of Palamakulapalli and Reddyvaripalli are also grouped in the same cluster. In a study on morphological characterization vis-à-vis molecular characterization, Vasugi *et al.* (2013) have opined that morphological characterization of quantitative characteristics would follow the pattern of molecular characterization in mango.

The diversity analysis carried out from the molecular data showed 3 main clusters (Fig. 2). It can be seen from the diagram that varieties from Talupulapalli and Gandlapalli, which are from nearby places are grouped in the same cluster to a large extent. Similarly majority of the indigenous varieties from Kalepalli are grouped in the same cluster. It also shows that some of the commercial varieties like Neelum are grouped with these varieties, which shows that they may be open pollinated seedlings of Neelum. The variety Khuddus, a colored variety is grouped with Talupulapalli varieties, which also have good peel color. This gives an indication that these seedling varieties would have developed from the same pedigree as Khuddus. The phylogenetic tree shows Gandlapalli Sreeramulu Reddy Naati 5, Talapulapalli Sreeramulu Pillai Naati 2 are closely related varieties. The two indigenous colored varieties RVRRN3 and

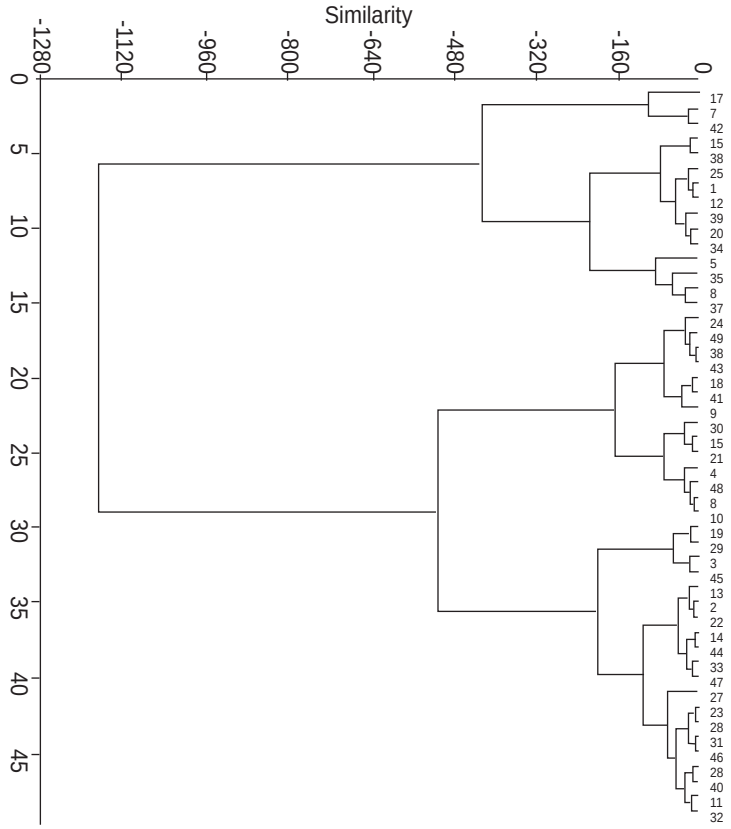

Fig. 2. Cluster diagram based on morphological characteristics

TBRT7 are grouped together. Similar to the evaluation of naati seedlings the 'Appemidi' types from the Western Ghats regions were studied by Vasugi *et al.* (2012), who concluded that genotypes belonging to different geographic region might have evolved from the existing mango gene pool from which they were selected by local people to domesticate them in different areas for cultivation. Karibasappa *et al.* (1999) observed by canonical analysis and cluster analysis eleven clusters in sixty-nine genotypes of mango. They concluded that geographic diversity might not necessarily be related with genetic diversity. Ravishankar *et al.* (2000), studied the genetic diversity in eighteen commercial varieties of mango grown in India using RAPD analysis, they observed two major groups; one consisting of northern, eastern and western varieties, another consisting of southern cultivars, their study also indicated that the variety Kesar from western region of India was associated with Neelum and Rumani. This study showed that genetic diversity within a particular region. Karihaloo *et al.* (2003) in a similar study by RAPD analysis in 29 Indian mango cultivars found that the varieties irrespective of the number of embryos they possessed were grouped together based on the region and genetic diversity existed within the regions. The population in one region need not follow the same pattern as that of the other.

The success of molecular markers in characterizing and analyzing genetic diversity in mango has been demonstrated by a number of studies. Valdomiro and Paulo Sarmanho (2004) used RAPD markers to detect genetic polymorphism in the mango germplasm, suggesting that this technique may be useful tool for germplasm evaluation and management and also for directing crossings in the breeding programmes. SSR analysis has great potential for mango improvement and can be performed for variety identification, validation of parentages, and estimation of genetic variation in existing populations and characterization of intra-cultivar diversity. Ravishankar *et al.* (2011) observed that microsatellites have greater importance due to the abundant occurrence throughout the genome of all the eukaryotes, their co-dominant nature, high level polymorphism as a result of the variation in repeat lengths. Begum *et al*. (2013) observed that the PIC value provides approximation by taking into account the number of alleles at a locus and the relative frequencies

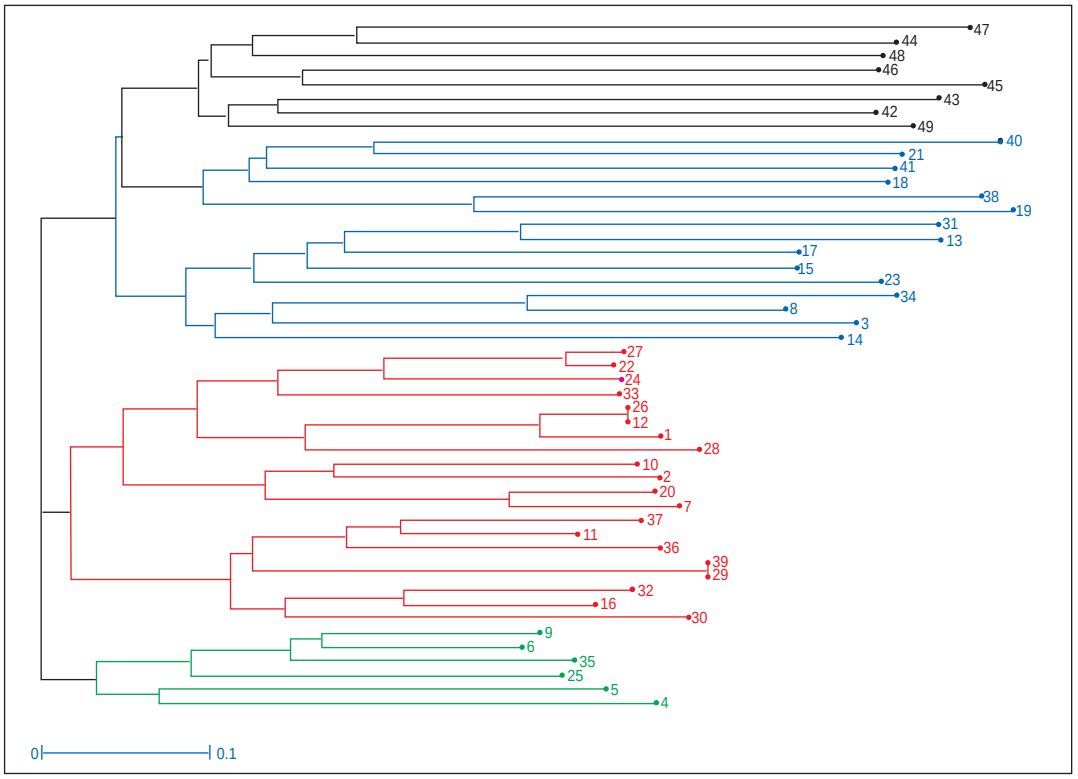

Fig. 3. A dendrogram based on NJ method, summarizing the data on differentiation between 44 naati varieties according to microsatellite analysis

1. TSAN4	2.TSAN6	3.TSAN 8	4.TBRLB	5.TBRN1	6.TBRD	7.TBRT	8.TBRN2	9.TBRBR
10.TBRC	11.TSPN1	12.TSPN2	13.KRRN2	14.KSCN	15.KPSN1	16.KGCN1	17.KRRN3	18.RKRRN1
19.RKRRN2	20.RVRRN 3	21.RVRRN2	22.GGNK	23.GPJN 2	24.GSRN3	25.GSRN4	26.GSRRN5	27.GSRRN1
28.GSRRN2	29.THKSN 3	30.THMRM	31.THMRP	32.THKSRN2	33.THKSRN4	34.PKRN1	35.PKRN2	36.PKRNGB
37.BVRRN1	38.BVRRN2	39.BVRRG	40.GKSRN1	41.GKSRN2	42.Totapuri	43.Neelum	44.Sindhura	
45.Chakkaraguthulu	46. Kalapadi	47.Khuddus	48.Atimadhuram	49.Alphonso				

of these alleles. In this study the polymorphic information content (Table 2) ranged from 0.667(MiIIHR23) to 0.869 (MiIIHR26), average PIC value of 0.76975 for all loci indicated the moderate discriminatory power of the 8 polymorphic SSRs. Marker with high PIC value such as MiIIHR26 and MiIIHR17 could be effectively used in intra-cultivar genetic diversity studies. The observations made here are in agreement with the studies conducted in mango (Duval *et al*., 2005; Honsho *et al*., 2005).

Microsatellite markers have proven useful in assessing intra-cultivar genetic diversity and identifying accessions of 'Chittoor' cultivar. Various mechanisms are responsible for genomic polymorphism between the accessions when two or more different phenotypes exist in the same population of a species and the occurrence of more than one form might be due to single nucleotide changes, deletions, insertions and variable numbers of simple sequence are several different mechanisms responsible for genomic polymorphism between accessions (Begum *et al*., 2013). The 8-labeled SSR markers employed in this study detected 97 alleles in 44 genotypes. The number of alleles for each locus ranged from 9 to 19, with a mean number of alleles per locus being 12.13. Observed heterozygosity (Ho) and expected heterozygosity (He) for each locus ranged from 0.364 to 0.674 and 0.693 to 0.889 respectively (Table 2). The data obtained is useful for working out the diversity and would help in choosing the parents for a hybridization programme. The high heterozygosity that is present in mango comes in the way of clearly pointing out the lineage of the existing naati varieties (indigenous).

Diversity Studies and Core Collection

In a highly heterozygous crop like mango wherein large variability is observed for several traits, core collection becomes extremely important. The wider the range of choice a breeder will have in selecting the appropriate kind of diversity, the better will be the chances for his

Table 1. Fruit characteristics of the Naati mango varieties

S. No.	Local Name	Code Name	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit thickness (cm)	Skin weight (g)	Stone weight (g)	TSS (°Brix)	Pulp (%)	Carotenoids mg/100 g
1	Talapulapalle Sreeramulu Achari Naati 4	TSAN4	370.68	9.44	8.30	7.30	32.57	33.83	18.3	82.09	11.91
2	Talapulapalle Sreeramulu Achari Naati 6	TSAN6	201.82	8.84	6.90	5.96	34.68	38.28	18.98	63.85	-
3	Talapulapalle Sreeramulu Achari Naati 8	TSAN 8	84.00	5.76	5.26	4.74	14.88	23.63	17.78	54.15	-
4	Talapulapalle Babi Reddy Lalbaba	TBRLB	268.09	8.90	7.66	6.90	63.05	32.57	16.8	64.33	6.99
5	Talapulapalle Babi Reddy Naati 1	TBRN1	542.00	14.83	9.80	7.68	33.73	52.7	26.08	84.05	-
6	Talapulapalle Babi Reddy Dilpasand	TBRD	302.70	11.28	7.66	6.36	42.48	41.65	18.46	72.21	6.85
7	Talapulapalle Babi Reddy Thorappadi Variant 2	TBRTV2	662.05	14.08	9.16	8.36	91.71	46.82	19.04	79.08	21.04
8	Talapulapalle Babi Reddy Naati 2	TBRN2	589.07	13.70	9.08	7.80	81.39	51.89	20.33	77.38	9.75
9	Talapulapalle Babi Reddy Bogam Rangasani	TBRBR	369.32	10.34	7.82	7.10	50.85	52.07	20.32	72.13	4.57
10	Talapulapalle Babi Reddy Chittithotha	TBRC	327.68	11.10	7.84	6.94	46.54	44.53	17.83	72.21	5.87
11	Talapulapalle Sreeramulu Pillai Naati 1	TSPN1	129.76	9.00	5.10	4.32	28.86	19.78	17.96	62.51	5.46
12	Talapulapalle Sreeramulu Pillai Naati -2	TSPN2	396.98	10.52	8.56	7.62	44.25	43.08	16.1	78.00	4.98
13	Kalepalle Rajendra Reddy Naati 2	KRRN2	238.43	8.52	7.00	6.48	42.43	25.07	18.82	71.69	15.1
14	Kalepalle Subramanyam Chetty Najoka	KSCN	195.87	9.34	6.48	5.64	23.83	32.16	18.32	71.41	-
15	Kalepalli P Subramanyam Naati 1	KPSN1	243.17	9.83	7.20	6.13	35.10	29.97	15.9	73.24	-
16	Kalepalli P Govinda Chetty Naati 1	KGCN1	444.86	12.84	8.74	7.68	81.80	55.26	20.16	69.19	4.54
17	Kalepalli Rajendra Reddy Naati 3	KRRN3	715.08	13.80	9.84	8.48	107.25	41.38	19.54	79.22	-
18	P. Reddyvaripalle K Rajasekar Reddy Naati 1	RKRRN1	362.09	10.73	7.98	7.25	61.11	32.27	18.9	74.21	18.51
19	P. Reddyvaripalle K Rajasekara Reddy Naati 2	RKRRN2	114.26	7.53	5.23	4.87	19.07	24.67	16.33	61.72	14.78
20	P. Reddyvaripalli V Ramamoorthy Reddy Naati 3	RVRRN 3	421.37	12.46	8.56	7.32	69.15	38.36	13.64	74.49	26.44
21	P. Reddyvaripalle V Ramamurthy Reddy Naati -2	RVRRN2	245.18	8.24	7.12	6.44	33.99	35.37	21.52	71.71	9.52
22	Gandlapalle K Gurappa Chetty Naati Khader	GGCNK	214.01	8.66	6.44	5.76	33.73	34.07	18.74	68.32	10.71
23	Gandlepalle P Jayachandra Reddy Naati 2	GPJN 2	187.13	8.74	6.32	5.60	23.94	26.05	20.24	73.28	-
24	Gandlapalle Sreeramulu Reddy Naati 3	GSRN3	280.07	9.04	7.24	6.94	54.72	34.16	17.76	68.27	4.89
25	Gandlepalle Sreeramulu Reddy Naati 4	GSRN4	393.25	13.00	7.64	6.98	37.00	27.37	18.58	83.63	-
26	Gandlapalle Sreeramulu Reddy Naati 5	GSRRN5	148.08	10.10	5.74	4.16	23.99	23.1	17.26	68.2	8.15
27	Gandlapalle Sreeramulu Reddy Naati 1	GSRRN1	157.84	7.86	6.44	5.34	45.68	37.48	15.28	47.32	2.73
28	Gandlapalle Sreeramulu Reddy Naati 2	GSRRN2	178.23	10.00	5.83	5.23	26.84	27.18	13.9	69.69	7.5
29	Thumbavaripalle K. Subramanyam Reddy Naati 3	THKSRN 3	128.24	8.42	5.52	4.60	15.24	14.21	21.32	77.04	5.5
30	Thumbavaripalle Munirathnam Reddy Manoranjitham	THMRM	254.92	9.00	7.64	6.38	65.74	40.36	24.04	58.38	29.4
31	Thumbaripalle Munirathnam Reddy Punasa	THMRP	188.69	7.70	6.65	6.20	40.30	21.66	20.68	67.17	11.24
32	Thumbavaripalle K Subramanyam Reddy Naati 1	THKSRN1	490.49	12.00	8.60	7.60	45.67	37.47	19.85	98.32	3.74
33	Thumbavaripalle K Subramanyam Reddy Naati 2	THKSRN2	148.72	8.35	6.00	4.90	38.00	27.06	21.15	56.25	4.44
34	Thumbavaripalle K Subramanyam Reddy Naati 4	THKSRN4	186.86	9.08	6.44	5.98	37.51	25.17	21.54	66.46	39.5
35	Palamakulapalle K Ravindranath Naati 1	PKRN1	414.04	9.93	9.00	7.70	66.39	52.62	12.88	71.26	23.16
36	Palamakulapalle K Ravindranath Naati 2	PKRN2	549.51	14.87	8.40	7.80	117.22	82.19	13.73	63.71	12.93
37	Palamakulapalle K Ravindranath Naati 3	PKRN3	274.19	8.25	7.85	7.00	35.92	43.72	18.05	70.96	8.65
38	Palamakulapalle K Ravindranath Naati 4	PKRN4	168.86	7.55	6.45	5.95	31.45	27.17	18.6	65.29	-
39	Palamakulapalle K Ravindranath Green Baneshan	PKRNGB	464.41	12.97	8.43	7.50	77.57	70.75	8.77	68.06	8.99
40	Baitpalle V Ranga Reddy Naati 1	BVRRN1	530.73	11.63	9.10	7.98	80.57	47.01	14.08	75.96	5.67
41	Baitpalle V Ranga Reddy Naati 2	BVRRN2	324.34	9.55	8.25	6.63	44.81	41.54	16.3	73.38	10.51
42	Baitpalle V Ranga Reddy Gadiyaram	BVRRG	422.51	12.08	7.88	7.20	52.95	56.75	13.93	74.2	-
43	Gudipalle K Surendra Reddy Naati 1	GKSRN1	177.88	9.44	5.88	5.28	23.35	36.54	19.6	66.34	11.63
44	Gudipalle K Surendra Reddy Naati 2	GKSRN2	344.38	10.72	8.18	7.06	65.24	44.7	20.66	68.08	6.3

Table 2. Characteristics of the 8 microsatellite markers with repeat motif, number of alleles, Observed Heterozygosity (Ho), Expected Heterozygosity (He) and Polymorphic Information Content (PIC)

Locus	Primer (5'-3')	Repeat motif	Number of alleles	Allele size range (bp)	He	Ho	PIC
MiIIHR17	F: GCTTGCTTCCAACTGAGACC R: GCAAAATGCTCGGAGAAGAC	$(GT)_{13}$ GAGT$(GA)_{10}$	10	230-269	0.867	0.477	0.841
MiIIHR18	F: TCTGACGTCACCTCCTTTCA R: ATACTCGTGCCTCGTCCTGT	$(GT)_{12}$	11	148-193	0.724	0.023	0.693
MiIIHR23	F: TCTGACCCAACAAAGAACCA R: TCCTCCTCGTCCTCATCATC	$(GA)_{17}$GG$(GA)_{6}$	13	117-156	0.693	0.409	0.667
MiIIHR26	F: GCGAAAGAGGAGAGTGCAAG R: TCTATAAGTGCCCCCTCACG	$(GA)_{14}$GGA$(GAA)_{2}$	19	127-171	0.889	0.523	0.869
MiIIHR30	F: AGCTATCGCCACAGCAAATC R: GTCTTCTTCTGGCTGCCAAC	$(CT)_{13}$	11	190-213	0.857	0.674	0.831
MiIIHR31	F: TTCTGTTAGTGGCGGTGTTG R: CACCTCCTCCTCCTCCTCTT	$(GAC)_{6}$	10	207-260	0.752	0.523	0.718
MiIIHR34	F: CTGAGTTTGGCAAGGGAGAG R: TTGATCCTTCACCACCATCA	$(GGT)_{9}(GAT)_{5}$	09	203-245	0.771	0.364	0.734
MiIIHR36	F: TCTATAAGTGCCCCCTCACG R: ACTGCCACCGTGGAAAGTAG	$(TC)_{17}$	14	210-250	0.834	0.545	0.805

success for any particular goal. Earlier the breeders were content to go not much further for their material than the old landraces and varieties that were then available in their own countries or from neighbouring ones, but in the last 50 years or so, breeders are requiring a much wider range of genetic diversity (Paroda and Arora, 1991). As per Frankel and Soulé (1981), one of the methods of conservation is in the region of cultivation. The indigenous varieties are observed to have large diversity in most of the mango growing regions in India. However, maintaining everything in *ex situ* collection is extremely difficult due to the large area that is needed for maintenance. The diversity studies would help in identifying core collections that can represent the diversity of a particular region. This in turn help in identifying varieties for crossing and development of recombinants with desirable traits.

The study very clearly points out that there is excellent scope for locating useful seedling diversity in mango and the varietal variability in a geographic region is the resultant of the present day commercial varieties in that particular region. The assessment of such diversity in the seedling population would help in locating genotypes with useful traits and also some of them can directly be popularized as a commercial variety. The real benefit sharing by the farmers would happen when these varieties are registered and further propagated. Further these varieties would also be conserved 'on farm' by the farmers *in situ.*

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References

AOAC (1995) Fruits and Fruit Products. *In: Official Methods of Analysis of AOAC InternationaI,* 16th Ed., Vol. 1: Agricultural Chemicals; Contaminants; Drugs. Association of Official Analytical Chemists International, Arlington, Virginia, USA.

Begum H, MT Reddy, S Malathi, BP Reddy, J Narshimulu, Nagaraju, and Siddiqui EA (2013) Morphological and Microsatellite Analysis of Intravarietal Heterogeneity in 'Beneshan' Mango (*Mangifera indica* L). *Int. J. Biotechnol. Res. Practice* **1**: 1-18.

Dillon NL, ISE Bally, CL Wright, L Hucks, DJ Innes and RG Dietzgen (2013) Genetic diversity of the Australian Mango Genebank, *Sci. Hort.* **150:** 213-226.

Duval MF, T Bunel, C Sithon and AM Risterruci (2005) Development of micro-sattelite markers for mango (*Mangifera indica* L.) *Mol. Ecol. Notes* 51824-826.

Frankel OH and ME Soulé (1981) *Conservation and Evolution.* Cambridge University Press. Cambridge.

Honsho C, K Nishiyama, W Eiadthong and K Yonemori (2005) Isolation and characterization of new microsatellite markers in mango (*Mangifera indica*). *Mol. Ecol. Notes* **5:** 152-154.

Kalinowski ST, ML Taper and TC Marshall (2007) Revising how the computer program CERVUS accommodates genotyping error increases success in paternity assignment. *Mol. Ecol*. **16**: 1099-1006.

Karibasappa GS, Nalawadi, GS Sulikeri and NC Hulmani (1999) Characterization of mango germplasm in North Karnataka, India: Cluster Analysis. *Indian J. Plant Genet. Resour.* **12**: 341-347.

Karihaloo. JL, Dwivedi YK, Sunil A and Gaikwad AB (2003) Analysis of genetic diversity of Indian mango cultivars using RAPD markers. *J. Hort. Sci. Biotechnol.* **78**:285–289.

Marcela DM, SG Ingrid, RGE, Manuel and H Jaramillo (2009) Analysis of diversity among six populations of Colombian mango (*Mangifera indica* L. cv. Hilacha) using RAPDs markers. *Electronic J. Biotechnol.* **12**:1-6.

Mukherjee SK (1953) The mango – its botany, cultivation, uses and future improvement, especially as observed in India. *Econ. Bot*. **7**: 130–162.

Nagabhushanam S and PA Mathew (1994) Promising cultivars for Goa. *Indian Hort.* 42–45.

Pandit SS, S Mitra, AP Giri, KH Pujari, BP Patil, ND Jambhale and VS Gupta (2007) Genetic diversity of mango cultivars using inter simple sequence repeat markers. *Curr. Sci*. **93**: 1135–1141.

Paroda RS and RK Arora (1991) Plant Genetic Resources: General Perspective. In Plant Genetic Resources Conservation and Management Concepts and Approaches .*International Board for Plant Genetic Resources*, Regional Office for South and Southeast Asia, New Delhi-110012, India.

Perrier X, A Flori and F Bonnot (2003) *Data analysis methods*. In: Hamon P, Seguin M, Perrier X, Glaszmann JC (ed). Genetic diversity of cultivated tropical plants. Montpellier (France): *Enfield, Science Publishers* 43-76.

Perrier X and JP Jacquemoud-Collet (2006) DARwin software. http://darwin.cirad.fr/.

Rajwana IA, N Tabbasam, AU Malik, S Malik, A Rahman and Y Zafar (2008) Assessment of genetic diversity among mango (*Mangifera indica* L.) genotypes using RAPD markers. *Sci. Hort.* **117**: 297-301.

Ravishankar KV, Mani, BHR, Anand L and Dinesh MR (2011) Development of new microsatellite markers from mango (*Mangifera indica*) and cross-species amplification. *Am. J. Bot*. **98**, e96–e99.

Ravishankar KV, L Anand and MR Dinesh (2000) Assessment of genetic relatedness among a few Indian mango cultivars using RAPD markers. *J. Hort. Sci. Biotechnol.* **75**: 198-201.

Sagar SP, M Sirsha, PG Ashok, HP Keshav, PP Bhimarao, DJ Narayan and SG Vidya (2007) Genetic diversity analysis of mango cultivars using inter simple sequence repeat markers. *Curr. Sci.* **93**: 135–1141.

Schnell RJ, CT Olano, WE Quintanilla and W Meerow (2005) Isolation and characterization of 15 microsatellite mango (*Mangifera indica* L.) and cross-species amplification in closely related taxa. *Mol. Ecol. Notes* **5**: 625–627.

Schnell RJ, CT Olano, WE Quintanilla and W Meerow (2005) Mango genetic diversity analysis and pedigree inferences for Florida cultivars using microsatellite markers. *J. Am. Soc. Hort. Sci.* **131**: 1-11.

Schuelke M (2000) An economic method for the fluorescent labeled of PCR fragment. *Nature Biotechnol.* **18**: 233-234.

Teaotia SS and RP Srivastava (1979) Study of some important commercial varieties of mango of eastern Uttar Pradesh. *Indian J. Hort.* **18**: 65-79.

Vasugi C, MR Dinesh, K Sekar, KS Shivashankara, B Padmakar and KV Ravishankar (2012) Genetic diversity in unique indigenous mango accessions (Appemidi) of the Western Ghats for certain fruit characteristics. *Curr. Sci.***103**:199-207.

Yadav IS and Rajan S (1993) Genetic Resources of Mango. *Adv. Hort.* **1**: 77-93.

Yamanka N, M Hasran, DH Xu, H Tsunematsu, S Idris and T Ban (2006) Genetic relationship and diversity of four *Mangifera* species revealed through AFLP analysis. *Genet. Resour. Crop Evol.* **53:** 949-954.

Valdomiro Aurélio BDS and SDC Paulo (2004) Genetic variability in mango genotypes detected by RAPD markers *Acta Hort.* **645:** 303-310.

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OBITUARY

John Trevor Williams
(1938 – 2015)

MT Jackson and N Murthi Anishetty
Bromsgrove, Worcs., UK and Hyderabad, India

John Trevor Williams, Executive Secretary and Director of the International Board for Plant Genetic Resources (IBPGR) between 1978 and 1990, passed away on 30 March 2015 at the age of 76, after a long illness.

Born in 1938 in Thingwall, Cheshire, he soon developed a life-time passion for natural history – and botany in particular – when, as a young boy, he was evacuated to the Isle of Man during the Second World War. After high school in Cheshire, Williams attended Cambridge University (at Selwyn College), graduating in 1959 with an MA in botany. After Cambridge, he joined eminent plant ecologist and population biologist Professor John Harper at the University of Wales, Bangor to complete a PhD in 1962 on the weed biology of *Chenopodium* L. Williams was a co-author of a paper that is regarded as one of the most significant to be published from the Harper laboratory (Harper *et al*., 1965). From 1964 he spent three years at the Geobotanical Institute at ETH Zurich, and was awarded the Dr sc nat degree in 1968 for his research on the nitrogen relations and ecology of wet fertilized meadows in Switzerland, southern Germany, and France. His research was supervised by geobotanist Heinz Ellenberg.

Between Bangor and Zurich, he lectured at Goldsmiths College, University of London, and after his return to the UK from Switzerland, at Lanchester Polytechnic (now Coventry University). However, in September 1969 came the move that was to make such an impact on his career and the world of genetic conservation. He was recruited by internationally-renowned genetic resources scientist and potato expert Professor Jack Hawkes to join the Department of Botany at the University of Birmingham as Lecturer and Course Tutor for the graduate MSc course on *Conservation and Utilization of Plant Genetic Resources* that saw its first intake of four students that same month. In 1976, Williams was seconded from Birmingham to FAO in Rome for two years as Genetic Resources Officer/ Senior Officer in the Crop Ecology and Genetic Resources Unit that housed the recently-formed (in 1974) IBPGR, an organization funded by the Consultative Group on International Agricultural Research (CGIAR). In June 1978 he was appointed Executive Secretary of IBPGR.

In 1974, there was just a handful of genebanks or *ex situ* collections worldwide where germplasm could be safely stored. Furthermore, few germplasm collecting missions had been made to systematically collect germplasm from farmers' fields before it was lost forever. Under Williams' dynamic leadership, IBPGR helped many countries set up genetic resources programmes where none had previously existed, and promoted the development of an international network of genebanks. In turn, this led to demands for training and research, for technical information, and technical assistance to collect and conserve crop genetic resources. IBPGR sponsored over 800 collecting trips in 100 or more countries, with the result that almost 211,000 germplasm samples were placed in genebanks. Today, deep beneath the Arctic permafrost on the island of Spitsbergen, millions of these seeds are stored for posterity in the Svalbard Global Seed Vault (SGSV). The opening of the SGSV, popularly known as the 'Doomsday Vault', came three decades after IBPGR first proposed setting up a permafrost genebank for these important germplasm collections (IBPGR 1990, p. 10).

The opening of the Birmingham MSc course in 1969 could not have been better timed, and by the mid-1970s, IBPGR stepped in to sponsor many scholars from developing countries. IBPGR also provided financial and staffing support to the university in order to increase its capacity to accommodate such a significant increase in student numbers.

Early on, IBPGR promoted international collaboration between crop experts to form crop advisory committees and working groups to develop collecting and conservation guidelines, and under Williams' leadership published

descriptor lists for 73 crops in its *Genetic Resources of Crops* series for the characterization of conserved germplasm, an essential first step for its successful use in crop improvement. The application of information technology and databases to manage germplasm collections was another important aspect that Williams supported as Director. Another significant development that Williams championed towards the end of the 1980s, was the IBPGR research program focusing on genetic diversity, seed physiology, germplasm health, and *in vitro* or tissue culture conservation for crops that cannot be stored as seeds.

When Williams stepped down as Director of IBPGR in February 1990, there were hundreds of genebanks or *ex situ* collections around the world. And IBPGR's research capability enabled it to evolve – in 1991 – into the International Plant Genetic Resources Institute (IPGRI) independent of FAO, and after 2006 as Bioversity International.

Williams moved to Washington, DC as Director of the IFAR/IBPGR Tropical Tree Crops Program, and thus developed his involvement with bamboo and rattan as Scientific and Policy Adviser to the International Network for Bamboo and Rattan (INBAR), helping it to become an intergovernmental organization in 1997 with its headquarters in Beijing. He also took up the mantle of underutilized crops and was a founder member and Board Chair between 1998 and 2005 of the International Centre for Underutilized Crops, Southampton, UK. For many years he advised the management of and contributed to *Diversity*, a magazine published for the genetic resources community. He was a prolific writer on all aspects of genetic resources conservation and use.

Nicknamed 'The Boxer' by Birmingham students for his stocky stature and prominent eyebrows, Williams was a whirlwind of energy, an inspirational teacher and mentor, and encouraged many students to follow a career in genetic conservation. Many went on to become leaders of their own national genetic resources programmes. His legacy is enormous. He is survived by his elder sister, the Reverend Wendy Williams; he never married.

References

Harper JL, Williams JT, Sagar GR (1965) The behavior of seed in soil. 1. The heterogeneity of soil surfaces and its role in determining the establishment of plants from seed. *J. Ecol.* **53:** 273–286.

IBPGR (1990) Annual Report 1990. Rome, Italy. 66 p.

GUIDELINES TO AUTHORS

GENERAL

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Key Words: The abstract should be followed by not more than five key words indicating the contents of the paper and useful for abstracting purposes.

Main Text: The main text of the paper should start from the second page which should contain the title of the paper followed by the text divided into following main headings which are to be typed in running text and flushed with the margin: Introduction, Materials and Methods, Results, Discussion, Acknowledgements, References. Wherever appropriate, results and discussion can be combined and acknowledgements be omitted.

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Materials and Methods should include relevant details on the nature of material, experimental design, the techniques employed and the statistical method used. For well-known methods, citation of reference will suffice.

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2. Withers LA and F Engelmann (1998) In vitro conservation of plant genetic resources. In: A Altman (ed.) *Agricultural Biotechnology*. Marcell Dekker Inc., New York, pp 57-58.
3. WOI (1985) *The Wealth of India - Raw Materials. A Dictionary of Indian Raw Materials and Industrial Products - Raw Material* Vol 1: A (Revised). Publications and Information Directorate, Council of Scientific and Industrial Research, New Delhi, 513 p.
4. Engels, JMM and V Ramanatha Rao (eds) (1988) *Regeneration of seed crop and their wild relatives*. Proceedings of a Consultation Meeting, 4-7 December 1995. ICRISAT, Hyderabad, India and IPGRI, Rome, Italy, 167 p.

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