Locating and managing the mango (*Mangifera indica* L.) genetic resources in Nepal

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Summary

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Mango diversity in Nepal is increasingly threatened by the commercialization of the production systems, changes in land use, habitat loss and population pressure. An ecogeographic survey was conducted to locate, analyse and assess the current status of mango genetic resources, and suggested conservation and sustainable utilization measures. Fruit samples were collected to characterize 19 qualitative and quantitative characteristics to assess genetic variation and establish relationships. A total of 132 different mango cultivars were identified from 11 districts surveyed. A rich diversity of both commercial and local cultivars was found. Local mango cultivars possess unique characteristics, having both economic and cultural value. Important traits identified included ability to grow in marginal and drought areas, adaptation to high altitude, high rate of fruit setting, fruiting in off-season, special aroma, and fibreless pulp. Introduction of Indian commercial mango varieties and a high rate of logging of old mango trees are major threats to maintenance of mango genetic resources. The paper identified Dadeldhura, Parbat, Dhading, Kavre and Sirah districts as major areas of mango diversity and suggests potential methods of community-based conservation action in Nepal.

Key words: Genetic resources, *in situ* conservation, on-farm conservation, mango, Nepal

Résumé

Localisation et gestion de ressources génétiques de manguier (*Mangifera indica* L.) au Népal

Au Népal, la diversité des manguiers est de plus en plus menacée par l'orientation commerciale de production, les changements d'occupation des sols, la disparition d'habitats et la pression démographique. Une étude éco-géographique a été réalisée afin de localiser, analyser et évaluer le statut actuel des ressources génétiques de manguier et de proposer des mesures de conservation et d'utilisation durable. Des échantillons de fruits ont été collectés afin de déterminer 19 caractères qualitatifs et quantitatifs en relation avec la variation génétique. Au total, 132 cultivars différents de manguier de 11 districts ont été identifiés, témoignant d'une riche diversité de cultivars commerciaux ou locaux. Les cultivars locaux de manguier possèdent des caractéristiques uniques et ont une valeur à la fois économique et culturelle. Des caractères importants ont été identifiés, parmi lesquels, la capacité de croître dans des zones marginales et sèches, l'adaptation à une altitude élevée, un taux de nouaison important, la fructification hors saison, un arôme particulier, et une pulpe non fibreuse. L'introduction de variétés commerciales indiennes de manguier et un taux élevé d'abattage des vieux manguiers constituent des menaces importantes. Dans cet article, les districts de Dadeldhura, Parbat, Dhading, Kavre et Sirah sont identifiés comme les principales régions de diversité du manguier et des mesures possibles de conservation s'appuyant sur les communautés sont proposées.

Resumen

Ubicación y ordenamiento de recursos genéticos de mango (*Mangifera indica* L.) en Nepal

La diversidad de mangos en Nepal está amenazada cada vez más por la mercantilización de los sistemas de producción, cambio de uso de los suelos, pérdida de hábitat y presión de la población humana. Se realizó un examen ecogeográfico para analizar y evaluar el estado actual de los recursos genéticos de mango, y se sugirieron medidas de conservación y utilización sustentable. Se recogieron muestras del fruto a fin de examinar 19 características cualitativas y cuantitativas útiles para establecer la variación genética y las interrelaciones. En los 11 distritos examinados se identificaron 132 cultivares diferentes de mango. Hay una rica diversidad de cultivares, tanto comerciales como locales. Los cultivares locales presentan características únicas que tienen valor económico y cultural. Los rasgos de importancia incluyen capacidad de crecimiento en zonas secas y marginales, adaptación a las grandes alturas, elevado porcentaje de rendimiento de frutos, fructificación fuera de estación, aroma especial y pulpa no fibrosa. La introducción de variedades comerciales de mango de la India y un alto índice de madereo de árboles viejos son las mayores amenazas para la conservación de los recursos genéticos de mango. El documento identifica a los distritos de Dadeldhura, Parbat, Dhading, Kavre y Sirah como las principales zonas de diversidad de mangos y sugieren métodos potenciales para la actividad de conservación de base comunitaria en Nepal.

Introduction

The genus *Mangifera* belongs to the order Sapindales in the family Anacardiaceae, with more than 40 species around the world, and 15 species bear edible fruits. Common mango (*Mangifera indica* L.) originated as an alloploid from eastern India, Assam and Burma (Popenoe 1920). Mango has rich intraspecific diversity and there are about 1600 cultivars in the world (Pandey 1998), of which some 350 cultivars are in commercial production and the rest are limited to mixed orchards or home gardens.

Mango is one of the important tropical fruits of Nepal, covering the 9% of total fruit cultivated area, and is ranked second among all fruits cultivated in Nepal (Gautam and Dhakal 1994). The total area under mango cultivation in the country is about 14 000 ha, with annual production exceeding 100 000 t (ASD 2005) mostly in the *tarai*, low-hills, mid-hills and mountains regions. Home gardens, village gardens, commercial orchards, religious or cultural places

and river gorge areas are the major habitats, where both local and commercial cultivars of mango are either cultivated or harvested from escapes from controlled cultivation (Subedi et al. 2005a). Notable local cultivars are *Sindhure, Kali, Supare* and *Lohare* from the lower hills, and *Chinia, Sipiya, Chausa* and *Safeda* from the *tarai* and hills region (NARC 2003).

In recent years the habitats of local mangoes (such as village orchards in communal land or along pilgrim trail) have been affected by various factors, and their existence is threatened by genetic erosion. As part of the 2001–2005 project on *Strengthening the scientific basis of in situ conservation of agricultural biodiversity on-farm*, an ecogeographical survey was funded by IDRC, Canada, to characterize and evaluate mango genetic resources and to understand the extent and distribution of their diversity. This paper presents results of this genetic diversity study and of efforts to locate potential sites for *in situ* conservation of mango genetic resources for future use in research and development (Subedi et al. 2004, 2005a,b).

Materials and methods

Ecogeographical surveys

A literature review, consultation workshops with national crop experts and staff of Horticulture Programme of the Department of Agriculture formed preliminary steps for understanding the mango genetic resources in Nepal, and identification of preliminary sites for field surveys. A multidisciplinary team, consisting of a taxonomist-*cum*-ethnobotanist, social scientists and horticulturalists, carried out surveys in target districts representative of the eastern *tarai* (Saptari, Siraha), central *tarai* (Sarlahi, Dhanusa), central hills (Kavre, Dhading), western hills (Baglung, Parbat), mid-western hills (Surkhet) and far-western hills (Dadeldhura, Doti). According to the literature review, few potential valley bottoms of Panchkhal, Sera, Trishuli, etc., could not be surveyed.

During this period checklists were developed to record the mango samples and establish coordinate values, and short interview were conducted with key informants of the survey sites. 'Farmers' descriptors were documented with the help of the IBPGR Mango Descriptors (IBPGR 1989). Ecogeographical surveys of the target areas (Figure 1) were then undertaken, covering home gardens, village gardens, river gorges, roads and highways, and scattered populations of mango in villages. Mango populations were found to be maintained in sacred groves with cultural and religious importance.

Characterization and evaluation

Fruits from 216 mango cultivars were collected during the surveys, and evaluated for qualitative and quantitative morphological characteristics to assess the genetic variation and relationships (Subedi et al. 2005a). Three fruits of each sample were characterised for 11 quantitative and 8 qualitative

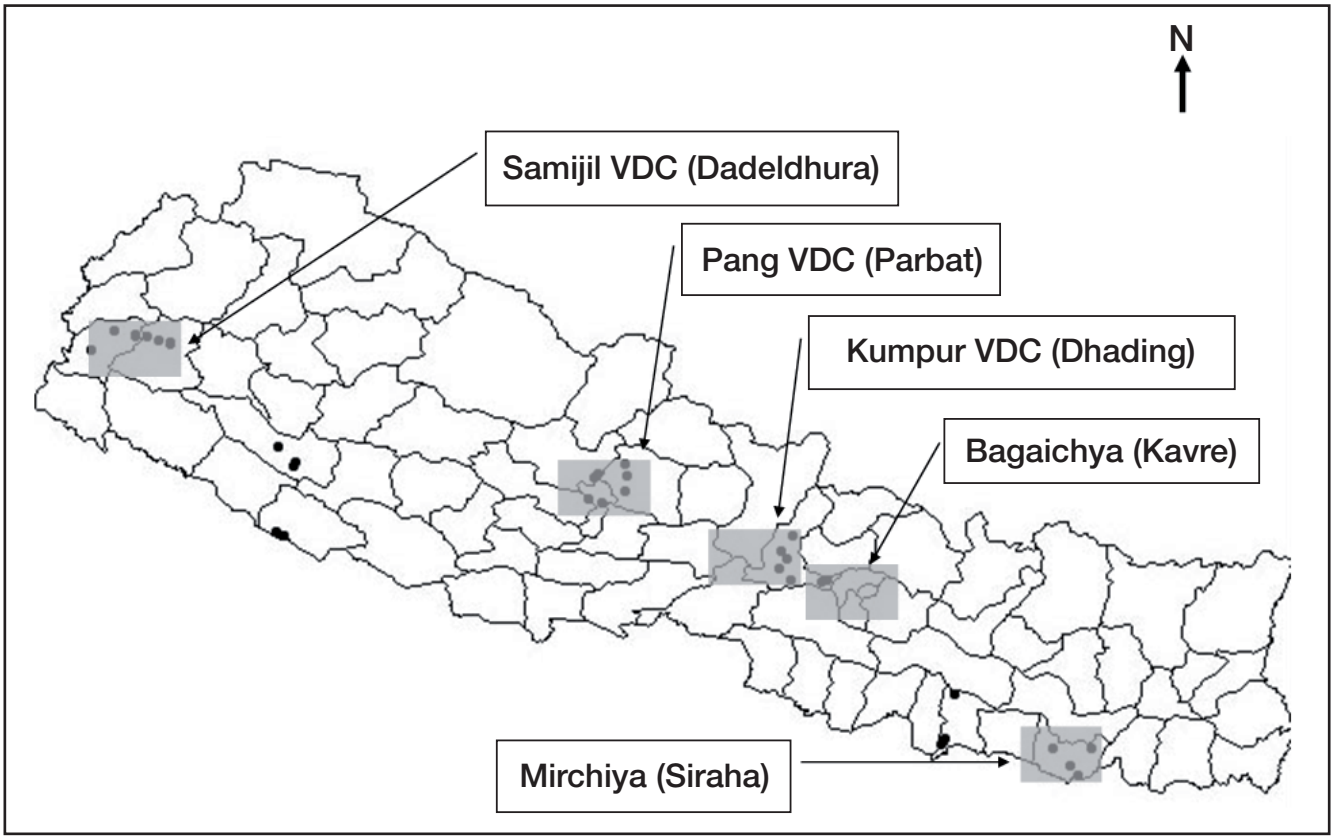

Figure 1. Collecting sites of mango (solid circle) and diversity-rich areas for mango (grey blocks) in Nepal.

traits (selected on the basis of farmer's descriptors used to distinguish cultivars at the community level) following the IBPGR Mango Descriptor list (IBPGR 1989). Descriptive statistics of quantitative traits using two diversity indices (Shannon-Weaver and Simpson) of qualitative traits were estimated across the collection sites (Shannon 1948; Magnussen and Boyle 1995). Analysis of variance and principal component analysis (PCA) using both quantitative and qualitative traits were performed. Significantly different quantitative and qualitative data were standardized for PCA. The importance of traits in determining the genetic variation among the accessions under study was ascertained through their loading values.

Results and discussion

Structure and organization of diversity

The farming communities in Nepal maintain a rich mango genetic diversity resource, both commercial and local cultivars. Local cultivars were often maintained in village orchards and sacred groves, as well as found growing along riverbanks and forest edges. Farmers' varieties were mainly distinguished by fruit morphology (size, shape, colour) and qualitative traits (fruiting time, fibre content in flesh, aroma and taste) (Figure 2). Tree canopy structure and shape and size of leaf were also important characteristics to farmers in distinguishing cultivars. Based on these, farmers have precise names for mango varieties in their own language. A fairly high degree of consistency was noted with respect to the local names given by farmers, whether within or between communities. For example, some cultivars growing in mid-hills and low-hills regions were known as *Supare*, *Lohare* and *Sindhure*, whereas cultivars growing in *tarai* region were named *Supariya*, *Lohariya* and *Sindhuriya*, respectively, which implies the specific cultural influence of *tarai* communities. Nevertheless, the root meaning is the same. A similar case was found with local cultivars *Kali*, *Kathe* and *Dhaule* of central and mid-western hills, known as *Kalya* or *Kathya* in far-western mountains. In contrast, in some cases the same cultivars are known by different names, such as *Bhonth* in eastern *tarai*, *Pharsi* in central hills, *Fajeri* in far-western mountains and *Fajali* in various parts of Nepal: all these apply to the Indian cultivar *Fajli*. In addition, in the mid-western hills, many local cultivar names were found to be very odd and pronounced peculiarly. This highlights the manner in which farmers maintain their cultivars distinct from others. An isozyme study in 2003 also showed genetic variation among cultivars with the same and different names collected from two adjoining districts of Nepal (Subedi et al. 2005b).

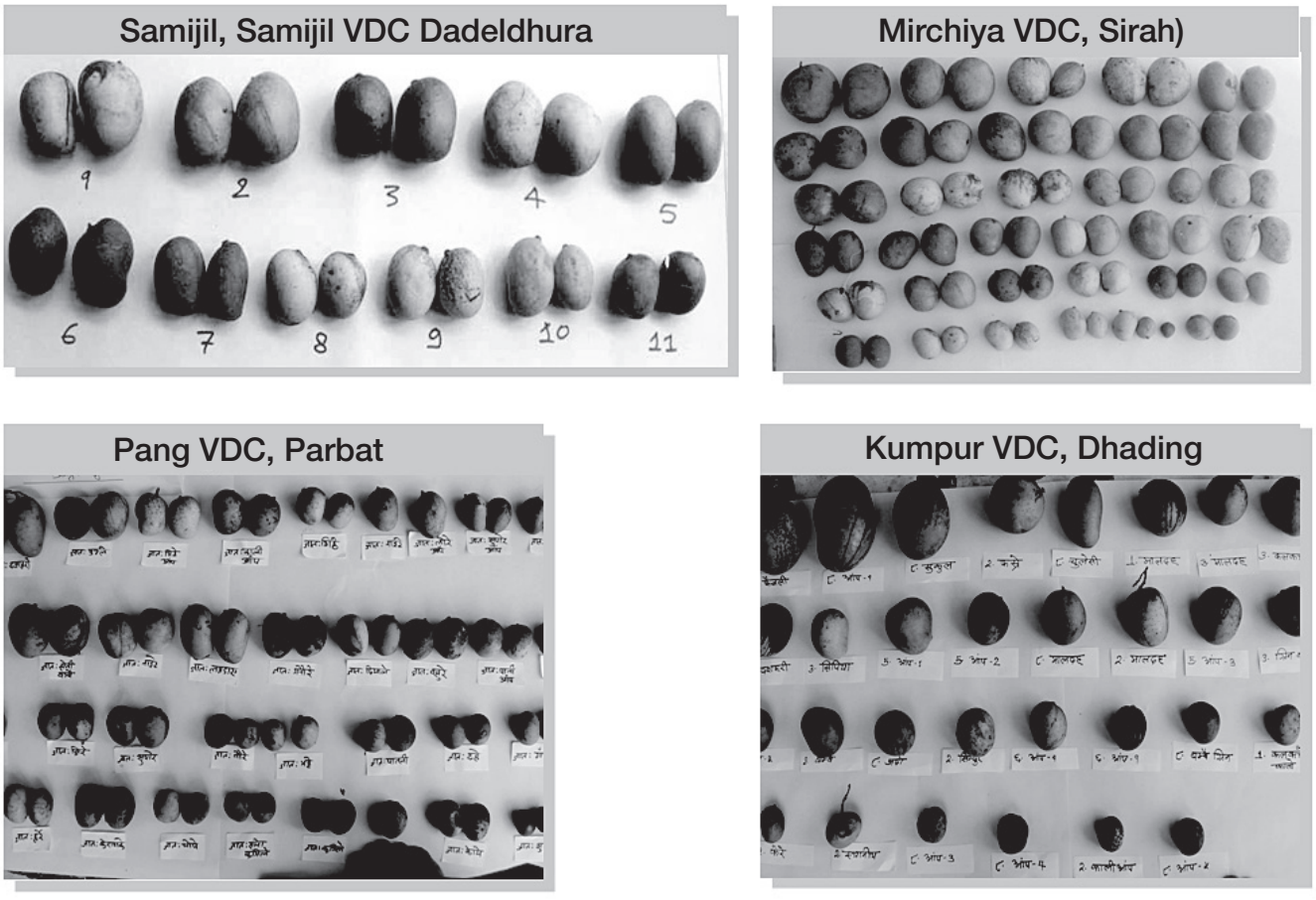

Figure 2. Comparison of mango fruit diversity collected from selected villages in Nepal.

Table 1. An inventory of mango cultivars collected from *tarai*, hills and mountains of Nepal.

Districts	Location(s)‡	Altitude (masl.)	Mango cultivars		
			Local	Indian or commercial	*Bijju* †
Eastern *tarai*					
Saptari	Kanchanpur-6 Kalyanpur-5 Jandole-6 Rajdevi, Rajbiraj-9	90–150	Barbariya, Bathuwa, Bhadaiya, Darmi, Jalmare, Karelwa, Kapuriya, Keruwa, Chiniya, Laduwa, Maldhua, Mishrikand, Rathi, Sindhuriya, Sridhanka, Supariya, Suryapuri	Amarpali, Alponoso, Bhonth (Fajli), Kalkatiya Krishnabhog, Bombay, Malika, Neelam, Sipiya,	Krishnabhog bijju 1,2,3 & 4, Lakhnau Bombay, Nawaras Bombay, Bombay bijju 1 & 2
Siraha	Bishnupur Mirchaiya, Ramnagar-9 Lahan, Lahan-4	100–125	Barbariya, Bathuwa, Bhadaiya, Darmi, Jalmare, Karelwa, Kapuriya, Keruwa, Chiniya, Laduwa, Maldhua, Mishrikand, Rathi, Sindhuriya, Sridhanka, Supariya, Suryapuri	Amarpali, Alphonso, Bhonth (Fajli), Kalkatiya Krishnabhog, Bombay, Malika, Neelam, Sipiya,	Krishnabhog bijju Lakhnau Bombay, Nawaras Bombay, Bombay bijju
Central *terai*					
Dhanusa	Devpuri-rupani-2 Devpuri-rupani-3 Kuwa, Janakpur-12 Ghodghans-1 Ghodghans-2	90	Dudhi-Kerwa, Madhuwa, Gopiya, Kapuriya		Chakariya, Thala, Sarahi, Kunaliya
Mid-western *terai*					
Banke	Bhauniyapur- 5 & 7 Suryapur, Udaipur-5	130–150	Gola, Kapuri, Lakhnaw safeda, Sinduriya		
Central hills					
Kavre	Aanpghari, Baluwa -3 Balakhe, Shikharpur-1 Jadetar, Baluwa-9 Kharkachowr-Baluwa-9 Bagaicha, Kharketar-6	700–900	Banarasi, Bellure, Bhadaure, Chuche kali, Diyale, Dhupi, Dhobi kali, Jhuttre, Kali, Kere, Kari, Kakre, Labate, Lohare, Lokharke, Maldawa, Malta-Bijju, Mishree, Pharse, Saune, Saune malta, Saune maldawa, Sindhure, Sindhure Kali, Supare, Thulo Kali	Bombay, Bombay green	Bijju-1, 2, 3, Kali bijju, Malta-Bijju
Dhading	Baireni, Malang -7 Baharbote, Nalang-6 Muralibhanjyang-3 Majhitar, Kumpur-3 Sayale, Khanikhola-1 Seplaji, Khanikhola-9 Badritar, Jibanpur-8	450–1020	Alini, Aama-bubu, Boke Aanp, Bombay-local, Bombay-old, Budhi Aanp, Chauthe-bali, Chulshi, Farsi, Hade Aanp, Hattijula, Jarda, Jayashree, Jhutte Aanp, Juwane Anp, Kali Bombay, Lohre, Malbhog, Maldawa, Maldhawa-bijju, Mishri-Bombay, Rato-tauke, Saune-aanp, Seti-aanp, Sindure, Sipiya, Sukul, Supare	Bombay-green, Dasahari, Fajli, Kalkatiya, Krishnabhog,	Bombay-bijju, Maldhawa-bijju
Western hills					
Baglung	Baglung Municipality-1 Kalika mindir, Baglung Niraye, Baglung Municipality-11	760–920	Dalle, Gitthe, Kali, Lohare, Mitthe, Naite, Supare	Aamrapali, Bombay	
Parbat	Dimuwa, Tilahar-6 Saharshadhara Pang-1 Pang-2 Patedhunga Mudkuwa-5 Dharmasala Devisthan-9 Rale Devisthan-8 Ekghare Mudkuwa-1	730–850	Bahure, Bhatte, Bhettne, Chope, Dahe, Diyale, Dudule, Dum Gande, Genaurre, Harre, Hade, Jirre, Kamile, Kawale, Kera pake, Koye, Lamadaya, Lamche, Mitthe, Naite, Pani aanp, Patali, Rato kupu, Rato chake, Sano kamile, Supare (28)	Bombay	Seti Bombay

Table 1. An inventory of mango cultivars collected from *tarai*, hills and mountains of Nepal.

Districts	Location(s)‡	Altitude (masl.)	Mango cultivars		
			Local	Indian or commercial	*Bijju* †
Mid-western hills					
Surkhet	Chhinchu-7 Ramghat-6 Birendranagar	490–590	Safeda	Bombay, Chausa, Dasahari, Kalkatiya,	Local Dasahari bijju,
Far-western hills					
Doti	Punnagaun, Silgadi-5 Sungada Dipayal-7 & 8 Talkot Pachnali-6 Bandumrisain Banlekh-4	560–1490	Dhaulya, Kalya, Kokya, Kathi, Maldaha	Bombay, Bombay-green, Dasahari, Dasahari, Dhaulya, Fajri (Fajari), Langda	
Dadeldhura	Samaiji-1 Samaiji-2 Mastamandu-3	1400–1430	Achare, Chaksa, Kathya, Rithya	Bombay, Bombay-green, Dasahari, Fajri, Langda	Dasahari bijju, Langdi-bijju, Local bijju, Local golakar bijju

Notes: † = chance seedling; ‡ number refers to ward number of each village development committee-(VDC) – the smallest political unit of Nepal.

Origin and ecogeographical distribution of mango in the study area

Based on farmer's descriptors, 132 different mango cultivars were characterized from the 11 districts of Nepal, representing *tarai*, low-hills, mid-hills and mountains (Table 1). Characterization of all 216 accessions was not possible as some of the collected germplasm died. Broadly three groups of mango cultivars can be recognised in Nepal, all mono-embryonic in origin: (1) Commercial cultivars of Indian origin; (2) 'Bijju' (chance seedling); and (3) Local cultivars (Kashkush et al. 2001; NARC 2003). In Nepal, most mango diversity is mono-embryonic and therefore needs to be propagated vegetatively from the best tree.

Indian cultivars

Many cultivars are of Indian origin and most of them are the result of open pollination leading to chance seedling and then further maintained asexually. Noteworthy cultivars are *Alphonso, Bombay, Bombay green, Chausa, Chiniya, Dashehari, Langara, Fajli, Kalkatiya, Kishenbhog, Neelum, Sipiya* and *Zardalu*. Two common hybrid cultivars are *Amarapali* and *Mallika.* The cultivars are found in home gardens, commercial nurseries and community gardens throughout the country, within an altitude range of 100 to 800 masl, with a rich diversity of commercial cultivars that are maintained to meet home and commercial demands. Eastern and central *tarai,* namely the districts of Siraha, Sarlahi, Mahotari, Sunsari, and Dhanusa, are known for their high production of commercial mango. Many Indian commercial cultivars, such as *Bombay, Dashehari* and *Langara,* are also cultivated above 1300 masl in far-western mountains.

Bijju (seedling)

These *Bijju* cultivars are chance local seedlings, found mainly in the lower hills and *tarai* plain regions. These are mono-embryonic and need to be propagated vegetatively. Some of these cultivars are the chance seedlings of Indian commercial cultivars. This category includes *Lucknow Bombay, Kali Bombay, Mishri-Bombay, Nawaras Bombay, Saune Bombay, Lucknow-safeda, Dasahari Bijju, Kali Bijju, Krishnabhog Bijju, Local golakar Bijju* and *Malta-Bijju*.

Local cultivars

These seedling cultivars can be found along riverbanks and tropical/sub-tropical forest areas; with time some have been gradually domesticated in village gardens, in diverse ecosystems, including mountains, mid-hills and *tarai*. The most popular local cultivars are *Supare* (a small fruit with a betel-nut shape), *Lahare* (a cluster of chained fruits) found from 200 to 1000 masl across the country. About 60% of all local cultivars were documented from central and mid-western hills (Kavre, Dhading and Parbat districts). In far-western mountains, the local cultivars *Rithya*, *Achare*, *Kathi* and *Local golakar* were found at high altitude (>1400 masl), representing the highest-altitude distribution of mango genetic resources in Nepal.

Extent and distribution of genetic diversity in mango in Nepal

The coefficient of variation (CV%) was found to be high for most fruit characteristics among the accessions studied. The range of variation for fruit weight and length among the accessions within and between surveyed districts was high, along with fruit and kernel (seed) measurements. Fruit shape, flesh colour, pulp taste and seed shape were found to be significant when assessing the level of variation among mango cultivars (Figure 2). Samples from eastern *tarai* and central hills were found to be more diverse, with high coefficients of variation and high diversity indices (Tables 2 and 3), especially for skin colour.

Table 2. Means and coefficient of variation (CV%) of quantitative characters among mango fruit collected from different regions of Nepal.

Character	Statistics	Eastern tarai	Central hills		Western hills		Far-western hills	*F* value
		Siraha (n=62)	Kavre (n=31)	Dhading (n=34)	Baglung (n=10)	Parbat (n=29)	Dadeldura (n=50)	
Fruit weight (g)	Mean	217.5	133.9	206.0	101.2	69.4	160.7	1.10 ns
	CV	0.85	0.58	1.01	0.60	1.50	0.61	
Fruit length (cm)	Mean	8.9	10.1	8.3	7.0	5.8	8.2	1.55**
	CV	0.23	1.89	0.33	0.18	0.29	0.21	
Fruit width (cm)	Mean	6.5	5.6	6.2	5.0	4.3	5.7	1.55**
	CV	0.23	0.18	0.28	0.16	0.27	0.23	
Fruit thickness (cm)	Mean	6.0	5.2	5.8	4.6	3.9	5.4	1.42*
	CV	0.19	0.19	0.26	0.20	0.31	0.23	
Skin thickness, (cm)	Mean	0.21	0.21	0.22	0.25	0.17	0.22	0.78 ns
	CV	0.34	0.17	0.25	0.21	0.30	0.42	
Flesh thickness, (cm)	Mean	1.9	1.6	1.7	1.3	1.2	1.6	2.33***
	CV	0.30	0.23	0.37	0.21	0.17	0.32	
Seed length (cm)	Mean	7.2	6.2	6.9	5.9	4.9	6.8	1.66 **
	CV	0.20	0.26	0.33	0.19	0.30	0.21	
Seed width (cm)	Mean	3.5	3.2	3.6	3.2	2.8	3.3	1.10 ns
	CV	0.18	0.14	0.28	0.14	0.19	0.18	
Seed thickness (cm)	Mean	2.1	1.9	2.0	2.0	1.9	1.9	2.19***
	CV	0.17	0.25	0.17	0.20	0.19	0.17	
Seed weight (g)	Mean	27.0	18.9	28.4	22.1	17.1	22.4	1.27 ns
	CV	0.37	0.58	0.63	0.39	0.42	0.34	
Brix (%)	Mean	16.6	15.6	14.2	13.4	14.8	15.2	0.88 ns
	CV	0.24	0.23	0.24	0.31	0.22	0.29	
Average	CV	0.30	0.43	0.38	0.23	0.36	0.29	

Notes: CV = coefficient of variation (%). Figure in parenthesis is sample size (n). For *F* value: ns = not significant; *p = >0.05; **p = >0.01; ***p = >0.001.

Table 3. Shannon-Weaver and Simpson Indices based on qualitative traits showing diversity of fruit types across the collection sites.

Character	*F* value	Eastern tarai	Central hills		Western hills		Far-western hills
		Siraha (n=62)	Kavre (n=31)	Dhading (n=34)	Parbat (n=29)	Baglung (n=10)	Dadeldhura (n=50)
Fruit shape	2.58*	0.73 (0.39)†	0.24 (0.12)	0.30 (0.16)	0.33 (0.19)	0.00 (0.00)	0.59 (0.31)
Skin colour	1.77 ns	1.07 (0.65)	0.73 (0.46)	1.01 (0.61)	1.03 (0.63)	1.03 (0.62)	1.03 (0.62)
Flesh colour	4.97***	0.83 (0.46)	0.68 (0.49)	0.81 (0.49)	0.55 (0.37)	0.61 (0.42)	0.84 (0.48)
Fibre content	2.67	0.55 (0.61)	0.53 (0.64)	0.61 (0.60)	0.46 (0.53)	0.50 (0.56)	0.37 (0.63)
Fruit aroma	0.03 ns	1.01 (0.37)	1.05 (0.35)	1.00 (0.42)	0.87 (0.29)	0.95 (0.32)	1.05 (0.21)
Pulp taste	0.23 ns	0.88 (0.53)	0.91 (0.55)	0.96 (0.58)	0.80 (0.51)	1.03 (0.62)	1.03 (0.62)
Pulp colour	5.12***	0.86 (0.50)	0.67 (0.48)	0.65 (0.46)	0.68 (0.49)	0.61 (0.42)	0.85 (0.50)
Seed shape	8.23***	0.99 (0.54)	0.14 (0.06)	0.49 (0.26)	0.40 (0.19)	0.00 (0.00)	0.60 (0.09)
Mean		0.87 (0.51)	0.62 (0.39)	0.73 (0.45)	0.64 (0.40)	0.59 (0.37)	0.79 (0.43)

Notes: data figures in parentheses are the Simpson indices. ns = not significant; *p = >0.05; **p = >0.01; ***p = >0.001.

These results show that quantitative characters are the most influential for selection under heterogeneous environments of the eastern *tarai* and central hills regions (Tables 2 and 3). In contrast, it was quality traits that mattered most in the western hills (*Parbat* and *Baglung* districts). This finding supports the earlier studies of fruit tree species where qualitative traits have been found useful in identification and assessment of varieties for fruit production on large scale (Leakey et al. 2000). In addition, earlier studies on diversity of crop species within centres of diversity have demonstrated the importance of quantitative traits outside the centre of diversity, and qualitative traits within the centre of diversity (Tolbert et al. 1979; Witcombe and Gilani 1979). In comparison, the accessions from western hills are less variable than eastern *tarai* or central hills regions. At the same time, the large variation in the eastern *tarai* and central hills are limited by natural selection.

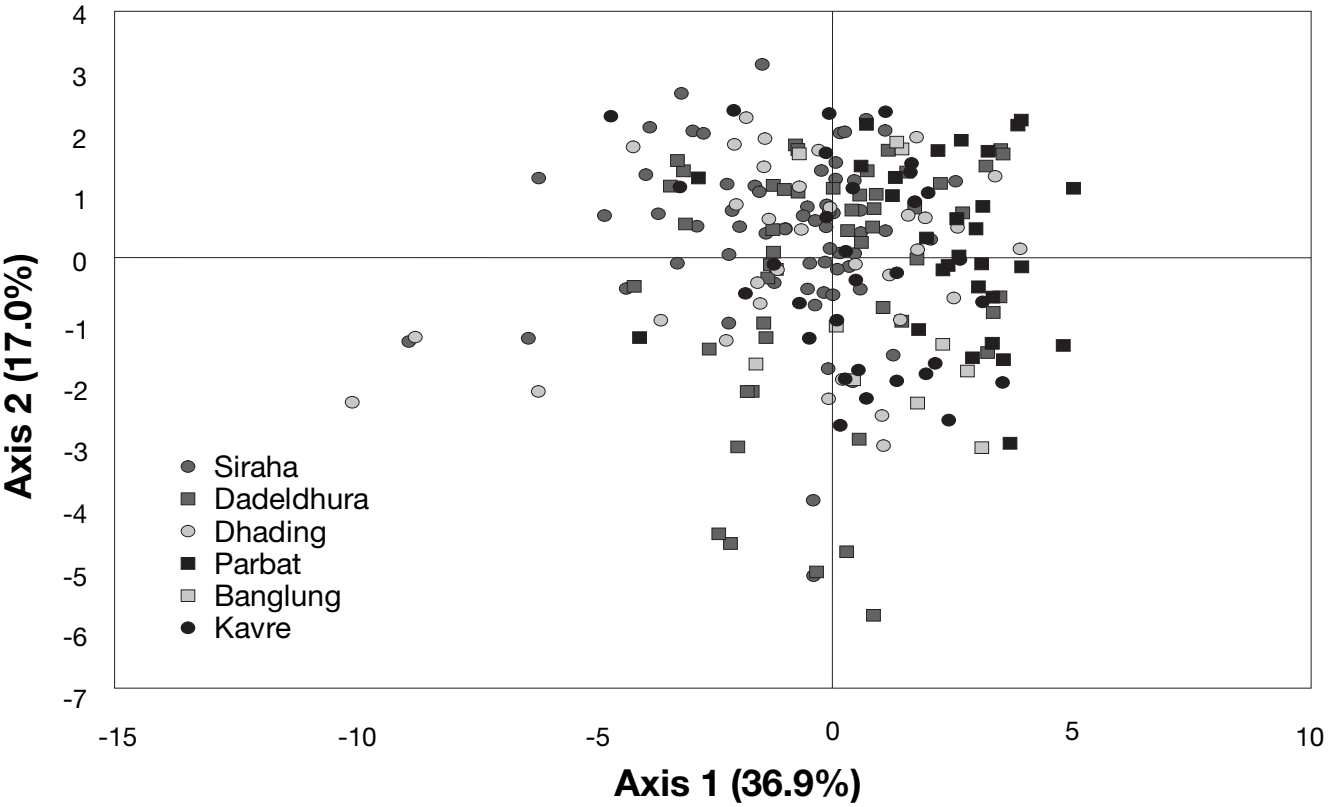

Figure 3. Scatter plot of the accessions of mango based on significantly different quantitative and qualitative characters.

Production areas and maintenance of mango diversity in Nepal

Historically, farmers grew local Nepali cultivars, but abandoned them in favour of more lucrative commercial cultivars. Farmers with access to the research system have been systematically maintaining commercial mango cultivars for fresh consumption and income generation. This influence is clearly seen throughout the *tarai* and lower-hills, where most commercial Indian cultivars were found, originating from research stations. This is because many farmers depend upon informal exchange within the community or across the border with nearby Indian villages, or obtain their seedling from private nurseries or government horticultural farms. Elsewhere, in the areas with limited access to the formal research system and where the environment is less favourable for commercial mango production, such as dry or marginal lands or mountainous areas, local cultivars are grown for fruit, fodder, fuelwood and shade purposes. Generally, old mango cultivars are maintained in either home or village gardens, within the precincts of temples and on public sites such as schools. This system continues due to the mango's religious and cultural importance. According to Hindu mythology, mango leaves are part of auspicious offering in worship as *Panchapalav*. Village gardens (*bagichas*) represent social prestige, and hence old mango orchards have been maintained in these *bagaicha* for hundreds of years. This phenomenon is unique to Nepal, where hundreds of hectares in the hills and *tarai* have been maintained as *bagaicha* under the protection of the elite royal caste, such as *Shah* and *Rana*.

Conservation of mango genetic resources is intimately interlinked with the perspectives of the farmers who grow, use and market them. The formal system emphasizes production countrywide of commercial mango of Indian origin. For example, Nawalpur Horticultural Farm of the Department of Agriculture (DoA) and Tarahara Research Station of Nepal Agricultural Research Council (NARC) promoted commercial mango cultivation. Major commercial production areas of mango are located in the Central and Eastern Development Regions of Nepal (ASD 2005). Comparatively, the *Sarlahi, Siraha, Kavilbastu, Mahotari* and *Dhanusa* districts have a high proportion of commercial mango production, with the main cultivars being *Bombay, Bombay Green, Chausa, Dashehari, Fazli, Kishen Bhog, Langra, Neelum* and *Chausa,* alongside hybrid cultivars such as *Amarapali* and *Malika*.

Appreciating the use-values of mango diversity

Table 5 shows that local mango cultivars possess various positive characteristics, such as ability to grow in dry and marginal areas or at high altitude, absence of fibre in pulp, high fruit setting rate and off-season fruiting. Production of these local cultivars is based upon intended use. For example, local cultivars like *Lahare* are produced on a large scale because of high market demand, while *Jarmale* of *tarai* region is popular for its sweet taste, even at the green stage, and used as as a salad or pickle. Fibrous cultivars are used for pickling or making fresh local juice. Some mango diversity is conserved because of its association with the ethnic food culture of *tarai* and mid-

Table 4. Possible *in situ* conservation sites for mango genetic resources in Nepal.

Site	Eco-geographical characteristics	Total number of cultivars	Unique local cultivars
Samijil, Samijil Village Development Committee VDC, Dadeldhura district (Far-western Nepal)	Middle mountain with valley bottoms (1400–1430 masl)	21	*Achare, Kathe, Kathya* and *Rithya*
Pang, Pang VDC, Parbat district (Mid-western Nepal)	Middle mountain (900 masl)	25	*Bahure, Bhetne, Bhatte, Chope, Dayhe, Diyale, Doom Harre, Kamile, Lamche, Naite, Rato-kupu, Patali* and *Supare*
Majhitar, Kumpur VDC & *Badritar* Jibanpur VDC, Dhading district (Western Nepal)	Middle mountain with river valleys (550–1000 masl)	33	*Alini, Aama-bubu, Boke tauke, Budhi, Hade, Jhutte, Kali, Lohare, Supare, Jwane, Seti* and *Saune*
Bagaichya, Kharketar-6, Kavre District (Central Nepal)	Middle mountain (700–900 masl)	30	*Bellure, Chuche kali, Diyale, Dhupi, Dhobi Kali, Jhuttre, Kere, Kari, Kakre, Labate, Lohare, Lokharke, Supare* and *Thulo Kali*
Mirchiya, Ramnagar -9, Siraha district (Eastern Nepal)	Indo Gangetic plain with river bottom (100 masl)	35	*Barbariya, Bathuwa, Bhonth, Darmi, Jarmale, Karelwa, Keruwa, Laduwa, Sridhanka* and *Supariy*

Table 5. Use value of local mango cultivars in Nepal.

Fruit value	Juice value	Pickle and salad value
Chinia, Chuche kali, Chulesi, Kalame, Kalapahad, Kali, Lamdaya, Lohare, Mithhe, Naite, Safeda, Sindhure, Sipiya, Pharse, Tamburiya, Thulo kali	Harre, Kalya, Kathe, Kerapake, Koke, Pani aanp, Rato tauke, Supare	Achare, Bhatte, Gande, Githhe, Gola, Jarmale, Jhutte, Jhuttre, Rithya, Thulo kamile

hills. Other typical products are *Amchurna,* made of immature mango; *Mada* is made of ripe pulp, cooked, and which may be salted, sun-dried and kept for long-term storage purposes; and *Chutney,* made of peeled, sliced green mangoes, parboiled and combined with sugar, salt and spices.

Implications for conservation of mango genetic resources

Local mango genetic resources have been found to be community assets for fulfilling the nutritional and other local requirement in Nepal, such as fuelwood and shade. Maintenance of local mango orchards is a relatively cost-effective strategy since many of the cultivars are adapted to marginal conditions. In contrast, the original habitats of local mango have been rapidly changing in response to biotic, economic and other pressures in recent years (Subedi et al. 2004).

Results of this present study point towards two important facets that have influenced the genetic erosion of local mango genetic resources as well as the loss of potential local cultivars.

Firstly, there is an alarming increase in the tendency of farming communities to replace the local mango by commercial Indian mangoes. Many historical village gardens—the *Bagaincha*—in *tarai* and mid-hills have been severely threatened due to conversion to modern orchards, and logs from local mango trees are extensively used the furniture industry, and as fuel wood, such as in brick factories. This situation is more severe in the *tarai* region of Nepal due to easy access to improved or commercial cultivars and the economic incentive to sell old mango trees for timber and fuelwood.

Secondly, the national research system has yet to exploit available mango diversity in the country through identification, evaluation, characterization and promotion of good local mango cultivars. Rather, the extension programme focuses on promoting a few commercial mango cultivars under the 'mango pocket programmes' in *tarai,* aiming to increase income generation for farmers, but affecting the existence of various local mango genetic resources. Moreover, there is a profound lack of access to information and technology to harness the large amount of local mango genetic resources in order to meet consumer demands. The existing markets for mango are largely for fresh fruit consumption; farmers do not have access to alternative value addition options, such as further processing or juice preparation.

Ways forward

Ex situ conservation

Previous studies indicate that *ex situ* conservation of mango is difficult because of the recalcitrant nature of mango seed, so that it can not be stored in conventional genebanks (Bompard 1995). At best, mango seeds of can be stored for about 100 days (Chin and Roberts 1980). Therefore, conservation needs to focus on the establishment of field genebanks in *tarai* and hills of Nepal. NARC has initiated work on the collection of different local mango cultivars at Tarahara Horticultural Farm

in eastern *tarai,* where some 80 different mango accessions have been maintained (NARC 2003). A field genebank has both advantages and disadvantages but the system can complement with *in situ* conservation method effectively. High maintenance costs, large land area requirement, the limited amount of genetic variation that can be stored and vulnerability of natural and human disasters are often barriers to this approach (Hodgkin et al. 2003). At the same time, a field genebank is readily accessible and useable for characterization, evaluation and crop improvement. For really long-term storage of genetic resources of species like mango, on-farm and cryopreservation are the only options, and these have yet to be systematically developed.

Field genebanks of mango should focus on core germplasm maintenance, and conduct research and development work such as stock-scion relations, use local cultivars in mango breeding programmes, and produce planting materials of local cultivars. For sustainability, the field genebank should be made self-sustaining by integrating with commercial fruit sapling nurseries, so that income can be generated to meet the cost of its maintenance. An urgent need is to salvage the mango diversity from the old village orchards (*Bagaichya*) and conserve them in field genebanks to maximize the use of diversity on-farm.

In situ *conservation in natural habitat or sacred groves*

In situ conservation is a viable tool for recalcitrant-seeded species. It extends the conservation of a species beyond the level of the individual to the habitat or ecosystem. Protected areas system scattered through out the *tarai*, hills and mountains are those areas where long-term *in situ* conservation of mango genetic resources is possible in Nepal. However, there is inadequate information on the extent, distribution and diversity of mango genetic resources in the protected areas. Table 1 illustrated some of potential low cost options for *in situ* conservation of mango genetic resources in Nepal. These sites are characterized by high intraspecific diversity and representative of different ecogeographical regions. Figure 1 shows suggested sites, including as *Mirchiya,* Ramnagar VDC, Siraha district; *Bagaichya,* Kharketar VDC, Kavre District; Trisuli valley of Nuwakot district; Kumpur and Jibanpur VDC, Dhading district; *Pang,* Pang VDC of Parbat district; and *Samijil,* Samijil VDC of Dadeldhura district. The concept of a Forest Genebank (Umashaanker and Ganeshaiah 1997) is being employed in the Western Terai Landscape Project of Nepal after locating source and sink of mango diversity in protected and natural forest ecosystems.

On-farm conservation

On-farm conservation of existing mango diversity could be promoted by improving access to diverse germplasm and creating incentive mechanisms for use of different types of mangoes in the market. This process will lead to dynamic exchange of materials and selection in a decentralized manner, which will continue to shape the genetic diversity. Home gardens, semi-commercial orchards, old sacred groves and community orchards, such as mango orchards on school premises, are strategic sites where mango diversity has been maintained for generations and needs to be conserved for future use. The potential local mango cultivars *Chinia, Chuche Kali, Chulesi, Kalame, Kalapahad, Kali, Lamdaya, Lohare, Mithhe, Naite, Safeda, Sindhure, Sipiya, Pharse, Tamburiya* and *Thulo Kali* can be immediately promoted for home gardens and commercial mango orchards. An important aspect of on-farm management is to promote and improve the locally available technologies for processing of mango for various mango products, with linkages to the market, which could play important roles in generating incentives for conservation and maintenance of germplasm in the long term.

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