On-Farm Variation and Household Diversity of Pigeon Pea Landraces in Kachorwa, Nepal

Bal K. Joshi[1*], Pitamber Shrestha[2], Madhusudan P. Upadhyay[1], Bedananda Chaudhary[3], Ashok Mudwari[1], Bimal K. Baniya[1] and Hari B. KC[1]

[1] Nepal Agricultural Research Council, Khumaltar, PO Box 1135 Kathmandu, Nepal
[2] LIBIRD, PO Box 324 Pokhara, Nepal
[3] NRRP, NARC, Hardinath, Janakpur, Nepal

* Corresponding author: joshibalak@rediffmail.com

ABSTRACT

Farmers value the diversity because of diverse environments both in production and consumption. On-farm morphological variation on pigeon peas (2n = 2x= 22 or 4x, 6x?) was studied at Kachorwa, Bara, Nepal to assess the household categories that have maintained diversity. Household diversity Index (HDI) of 10 different farmer categories was estimated based on Shanon-Weaver method. Eighteen quantitative and qualitative (quant-qualitative) traits were used for on-farm variation and HDI studies. On farm ANOVA was generated on eight quantitative traits. Highest diversity (HDI, 0.265) was maintained by farmer of medium wealth category who grows pigeon pea in upland bund. Pigeon pea grown in *khet* (low land) bund with Pajawa landrace expressed least diversity (HDI, 0.079). Pigeon pea growing in monoculture was more diverse (HDI, 0.224) for 18 traits than in other production environments. Maximum variation was observed in growth habit followed by seed color pattern. The highest grain yield among the Chanki growers was produced by the farmer of medium wealth category growing pigeon pea in upland bund. Significance variation among farmers in quantitative traits indicates the intra varietal diversity in pigeon pea. Diversity varied with respect to wealth category and production environments. Farmer who has maximum diversity on pigeon pea could able to receive the higher grain yield. Result related to where and who maintain the diversity may be useful for development of on-farm conservation strategy. Possibility of developing good varieties exits using Pajawa and Chanki landraces.

Key words: Household diversity index, on-farm variation, pigeon pea, quant-qualitative traits

INTRODUCTION

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is an important summer crop of farmers living in Tarai and Inner Tarai (< 600 m) of Nepal. It is a multipurpose crop grown as sole crop or an intercrop in many farming systems. It is also grown by small farmers on marginal lands where other crops are not suitable. Many landraces of pigeon pea exist in Nepal (Neupane 1995), which are suitable to diverse environments. Area coverage under pigeon pea is 25460 ha with productivity of 0.78 t/ha in Nepal (NARC 1998). Dehulled seeds of pigeon pea are used as dhal, seed husk are fed to animals, dry stems are used for firewood and to make huts and baskets. Root nodules of this crop fix N_2 thus increasing the soil fertility and the deep roots of pigeon pea take up phosphorus, which is thus available to other crops (Johansen 1990).

Kachorwa is one of selected ecosites to study on-farm agrobiodiversity in Nepal. This site lies in Tarai belt possessing low to moderate level of diversity with high degree of intervention (Upadhyay and Subedi 2000). Pigeon pea is one of the grain legumes growing in larger area in Bara (Sherchand et al 1998). Nepal Agricultural Research Council has released two pigeon pea varieties suitable for low altitude. Even though these improved varieties are not found in this site. Participatory rural appraisal and diversity fair indicated the existence of high landrace richness of pigeon pea in Kachorwa (Khatiwada et al 2000). Among these landraces Chanki is most common. Farmers cultivate pigeon pea under low external input without farmyard manure,

chemicals and agro chemicals (Rana et al 2000). Pigeon pea grains in the market fetches highest price amongst the pulses (Rana et al 2000). Pigeon pea is often self-pollinated and biannual crop. Knowledge on population structure and breeding system could be useful for the maintenance of diversity on-farm. Farmers also use small area to plant pigeon pea. Population genetic structure in such a small population if there is diversity could help in policy formulation for on-farm management of agricultural biodiversity.

On-farm variation is important to farmers, breeders and *in situ* conservationists. Variation in production environments and food value or farmers' need create diversity and help to maintain different forms of crop plants. For genetic resources conservation *in situ* method is treated as complement of *ex situ* conservation. Information on amount and distribution of genetic diversity maintained by farmer and farmers who maintain diversity on-farm is prerequisite for effective implementation of *in situ* conservation activities. Therefore this study was designed to have information about amount and distribution of pigeon pea diversity over household. Additionally population structure of pigeon pea landraces and on-farm characterization and evaluation of these landraces were studied.

MATERIALS AND METHODS

We reviewed baseline report 1998-99 of Kachorwa ecosite to identify/select landraces and farmers. There are 12 different landraces in Bara (Sherchand et al 1998) and 5 landraces in Kachorwa site (Rana et al 2000). But only two landraces are being cultivated now in Kachorwa. Two landraces Chanki and Pajawa were selected in 2003 growing season. Ten farmers were selected based on pigeon pea landraces, cultivation environments and wealth category. Farmers' name and their category are given in Table 1.

Table 1. Farmers' name and their category

SN	Farmer		Category
	Full name	Short form	
1	Shiva Sah	S Sah	Rich growing pigeon pea in upland bund
2	Janga Bahadur Raya Yadav	JBR Rana	Rich growing pigeon pea in lowland bund
3	Rup Narayan P Yadav	RNP Yadav	Medium growing pigeon pea in upland bund
4	Mahanarayan P Raya Yadav	MPR Yadav	Pajawa grower
5	Ram Lal Sah	RL Sah	Medium growing pigeon pea in monoculture
6	Madandas Tatma	M Tatma	Poor growing pigeon pea in lowland bund
7	Shovi Raya Yadav	SR Yadav	Medium growing pigeon pea in lowland bund
8	Narayan Mahato Kahar	NM Kahar	Poor growing pigeon pea in monoculture
9	Rajendra Raya Yadav	RR Yadav	Rich growing pigeon pea in monoculture
10	Mahendra Mahato Kahar	MM Kahar	Poor growing pigeon pea in upland bund

After discussing with farmers, they were categorized rich, medium and poor based on the wealth status, Three types of production environments are common in Kachorwa. These are upland bund, lowland bund and monoculture. MPR Yadav cultivates Pajawa and all others cultivate Chanki landrace.

From each category of farmer, 10 plants were randomly selected from different pigeon pea growing areas of similar production environment of respective farmer. Number of parcels ranged from 1 to 3. We tried to include plant from all parcels in diversity study. Variation within and between parcels of each farmer was captured.

A total of 18 quant-qualitative characters were measured based on descriptors for pigeon pea (IBPGR and ICRISAT 1993). These traits were recorded on individual plant of each farmer's category. For household diversity index (HDI), 14 traits (Table 2) were used. Four quantitative traits, plant height, branch number, raceme number and yield were converted in qualitative traits. Individual plant was defined as tall (> 200 cm) and dwarf (≤ 200 cm) based on plant height. Classes based on total number of branches were high (> 30), medium (16-30) and low (< 16). Similarly classes were high (> 150), medium (51-150) and low (< 50) based on raceme number per plant and high (> 20g), medium (11-20 g) and low (< 11g) based on grain yield per plant. HDI was estimated using the formula of Shanon-Weaver index. This index was used previously for studies of variability in crop plants by Tolbert et al (1979) in barley, Holcomb et al (1977) in rice, and Cruz et al (1997) and Pandey et al (2003) in sponge gourd. The index is calculated as

$$HDI = -\sum_{i=1}^{n} pi \log_2 pi$$

where pi is the proportion of entries in the i^{th} class and n is the number of phenotypic classes for a trait. Mean and standard error (SE) were also estimated for HDI. A hierarchical analysis of variance for testing the significance among farmers and between traits within farmers in HDI was applied.

On farm variation between farmers was tested in quantitative traits. Least significance difference at 5% level was estimated for each trait. Student's t was used to test the yield of two landraces. Population structure of two landraces was studied. Mean, range and standard deviation (SD) were estimated in nine traits for Chanki and Pajawa landraces. Correlation coefficients were estimated among these characters. Characters relation would help in selection process of pigeon pea on-farm. Minitab and Excel computer software were used for analysis.

RESULTS AND DISCUSSION

Phenotypic proportion of classes of each trait with respect to farmers is given in Table 2. Distribution of phenotypic classes was observed in growth habit, plant height, branches, raceme number, seed color pattern, seed eye width, seed shape and grain yield. Distribution pattern of these classes was similar among the farmers. Probably this is due to the low number of observations taken per farmer and these farmers were taken from the same community. Most of the plant showed semi spreading type of growth habit. Trailing growth habit was rare, only observed in Pajawa landrace. Erect and compact was not also common. Such type of plant is important for inter crop planting. Pigeon pea is bund-adopted crop, therefore farmers try to minimize the shading effect of this crop to neighbor crops. All plants have green stem with lanceolate leaflet and smooth leaf surface. Mix pod color with flat shape was common to all populations of these landraces. Two types of seed color pattern were observed. Most of seed were oval and elongate shape was rare. There was variation on plant height, branching type, grain color, seed color and fruiting, which are used by farmers to distinguish landraces (Paudel et al 1999). This means that selection based on farmer's traits could be resulted in positive direction on these traits.

Household diversity index was zero for all farmers for leaf hairiness, leaflet shape, pod color, pod form, pod hairiness and stem color (Table 3). But variation was reported for these characters by Bajracharya et al (1999). This may be due to the inclusion of more landraces in her study. Though low diversity index was not necessarily associated with small sample size (Tolbert et al 1979). The highest HDI (1.00) was observed in grain yield of S Sah, JBR Yadav and R Sah. The lowest HDI (0.095) was recorded on seed shape of RR Yadav. Variation in number of landraces was not found at household (HH) level (Rana et al 2000), but variation exists within population grown by HH. HDI was the highest in pigeon pea grown in monoculture (0.224) followed by upland bund (0.219). Pigeon pea grown in lowland bund expressed the lowest HDI (0.166). Averaging HDI over traits, RNP Yadav expressed highest the HDI and MPR Yadav who grow Pajawa, the lowest. RNP Yadav is a medium wealth status farmer growing pigeon pea in upland bund. Among landraces Chanki gave the highest HDI (0.217). Within landraces medium wealth category farmer has the highest diversity but Rana et al (2000) reported that poor has the highest landrace diversity. Medium wealth category also grows pigeon pea in larger area (Rana et al 2000). Most of the farmers' HDI fall within from 0.18 to 0.26. HDI indicates the farmers that have maintained diversity on-farm. Highly significant difference was found for diversity indices between farmers and between traits within farmer (Table 4).

Table 2. Phenotypic proportions based on percentage of plant numbers (N = 10) for each farmer categoy of pigeon pea for 14 characters

SN	Trait	Classes	S Sah	JBR Yadav	RNP Yadav	MPR Yadav	RL Sah	M Tatma	SR Yadav	NM Kahar	RR Yadav	MM Kahar
1	Growth habit	Erect and compact	0	0	0	0	20	20	0	0	0	0
		Semi spreading	100	100	60	0	80	80	100	90	100	100
		Spreading	0	0	30	100	0	0	0	10	0	0
		Trailing	0	0	10	0	0	0	0	0	0	0
2	Plant height	Tall	20	80	10	0	80	90	90	70	90	100
		Dwarf	80	20	90	100	20	10	10	30	10	0
3	Branches	High	80	70	80	100	90	80	30	60	0	40
		Medium	20	30	20	0	10	20	60	30	80	50
		Low	0	0	0	0	0	0	10	10	20	10
4	Stem color	Green	100	100	100	100	100	100	100	100	100	100
		Sun red	0	0	0	0	0	0	0	0	0	0
		Purple	0	0	0	0	0	0	0	0	0	0
		Dark purple	0	0	0	0	0	0	0	0	0	0
5	Leaflet shape	Lanceolate	100	100	100	100	100	100	100	100	100	100
		Narrow elliptic	0	0	0	0	0	0	0	0	0	0
		Broad elliptic	0	0	0	0	0	0	0	0	0	0
		Obcordate	0	0	0	0	0	0	0	0	0	0

SN	Trait	Classes	S Sah	JBR Yadav	RNP Yadav	MPR Yadav	RL Sah	M Tatma	SR Yadav	NM Kahar	RR Yadav	MM Kahar
6	Leaf hairiness	Glabrous	100	100	100	100	100	100	100	100	100	100
		Pubescent	0	0	0	0	0	0	0	0	0	0
7	Raceme number	High	40	20	60	100	60	60	20	40	0	0
		Medium	60	70	40	0	40	40	50	20	70	80
		Low	0	10	0	0	0	0	30	40	30	20
8	Pod color	Green	0	0	0	0	0	0	0	0	0	0
		Purple	0	0	0	0	0	0	0	0	0	0
		Mixed (green + purple)	100	100	100	100	100	100	100	100	100	100
		Dark purple	0	0	0	0	0	0	0	0	0	0
9	Pod form	Flat	100	100	100	100	100	100	100	100	100	100
		Cylindrical	0	0	0	0	0	0	0	0	0	0
10	Pod hairiness	Glabrous	0	0	0	0	0	0	0	0	0	0
		Pubescent	100	100	100	100	100	100	100	100	100	100
11	Seed color pattern	Plain	100	40	60	20	100	100	100	90	100	100
		Mottled	0	60	40	80	0	0	0	10	0	0
		Speckled	0	0	0	0	0	0	0	0	0	0
		Mottled and speckeled	0	0	0	0	0	0	0	0	0	0
		Ringed	0	0	0	0	0	0	0	0	0	0
12	Seed eye width	Narrow	0	0	0	0	0	0	0	0	40	0
		Medium	100	100	100	100	100	100	100	100	60	100
		Wide	0	0	0	0	0	0	0	0	0	0
13	Seed shape	Oval	80	100	100	100	70	100	90	100	90	80
		Globular	0	0	0	0	0	0	0	0	0	0
		Square (angular)	0	0	0	0	0	0	0	0	1	0
		Elongate	20	0	0	0	30	0	10	0	0	20
14	Grain yield	High	50	20	80	70	30	80	10	50	0	60
		Medium	30	30	10	0	20	20	50	10	60	30
		Low	20	50	10	30	50	0	40	40	40	10

Table 3. Household diversity indices (HDI) for farmers and characters and mean diversity and its standard error

SN	Trait	S Sah	JBR Yadav	RNP Yadav	MPR Yadav	RL Sah	M Tatma	SR Yadav	NM Kahar	RR Yadav	MM Kahar	Mean	SE
1	Branches	0.500	0.611	0.500	0.000	0.325	0.500	0.668	0.668	0.179	0.713	0.466	0.073
2	Grain yield	1.000	1.000	0.639	0.611	1.000	0.500	0.943	0.943	0.673	0.898	0.830	0.064
3	Growth habit	0.000	0.000	0.898	0.000	0.500	0.500	0.000	0.325	0.000	0.000	0.222	0.101
4	Leaf hairiness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
5	Leaflet shape	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Plant height	0.500	0.500	0.325	0.000	0.500	0.325	0.325	0.611	0.325	0.000	0.341	0.065
7	Pod color	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Pod form	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
9	Pod hairiness	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Raceme number	0.673	0.572	0.673	0.000	0.673	0.673	0.668	0.688	0.250	0.179	0.505	0.081
11	Seed color pattern	0.000	0.673	0.673	0.500	0.000	0.000	0.000	0.325	0.000	0.000	0.217	0.093
12	Seed eye width	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.673	0.000	0.067	0.067
13	Seed shape	0.500	0.000	0.000	0.000	0.611	0.000	0.325	0.000	0.095	0.500	0.203	0.08
14	Stem color	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0
	Mean	0.229	0.242	0.265	0.079	0.260	0.179	0.209	0.254	0.157	0.164		
	SE	0.092	0.095	0.091	0.054	0.092	0.069	0.087	0.090	0.065	0.082		

On-farm variation on eight different quantitative traits exists among these farmers. Variation was observed between and within landraces. Significance yield variation (P = 0.006) was found between Chanki and Pajawa landraces. Pajawa produced grain yield three times more than Chanki. Due to the unwanted traits of Pajawa, farmers prefer Chanki even it produces less grains. Intra landraces diversity was also reported by Bajracharya et al (1999) and Khatiwada et al (2000). Plant height, stem thickness and seed characters were mentioned as important traits for measuring variability in pigeon pea (Bajracharya et al 1999). Our study also supports the finding of Bajracharya et al (1999).

Table 4. Analysis of variance for diversity indices between and within farmers for 14 characters

Source	df	MS	%	P
Between farmers	9	0.04898	3.4	< 0.01
Between traits within farmer	130	0.09598	92	< 0.01

Significance variation was found in seven traits among farmers (Table 5). MPR Yadav has pigeon pea with the highest tertiary branches, raceme number per plant and the highest grain yield. The tallest plant was found in SR Yadav's field. Pod was the longest in pigeon pea of S Sah but the highest seed number per pod was in MM

Kahar. Among the Chanki growers NM Kahar produced highest yield. He is a poor farmer growing pigeon pea in monoculture. Rich farmer growing pigeon pea in low land received the lowest grain among Chanki growers. Much variation in the yield level of pigeon pea was already reported at Kachorwa, which ranged from 0.1 to 1.26 t/ha (Rana et al 2000). Medium wealth category had produced the highest yield than rich and poor (Rana et al 2000).

Two populations of Pajawa and Chanki were different for 10 studied traits (Table 6). Chanki landrace showed relatively more variation than Pajawa in plant height, branches, pod number, seed number and 100-seed weight. More variation was observed in Pajawa than Chanki for raceme number, pod length and grain yield. Number of sample for each landrace was different which might have some effect on capturing variability. Due to the variation within and between populations, these landraces are able to cope different biotic and abiotic stresses.

Table 5. Response of different traits with respect to farmers

SN	Farmer	Plant height, cm	Branches, n			Raceme /plant, n	Pod/ raceme, n	Seed/ pod, n	Pod length, cm	Grain yield/plant, g
			Primary	Secondary	Tertiary					
1	S Sah	186.70	1.300	18.100	28.50	130.90	2.6800	2.930	4.5900	23.50
2	JBR Yadav	215.90	1.400	21.000	21.00	115.50	3.2700	3.120	4.0800	11.70
3	RNP Yadav	188.80	1.100	14.800	42.80	186.80	3.0500	3.510	4.5500	41.30
4	MPR Yadav	183.40	1.200	17.700	63.40	365.60	3.0000	2.970	4.1900	57.50
5	RL Sah	220.20	1.300	19.000	31.90	149.70	3.0100	2.980	4.3700	15.30
6	M Tatma	231.40	2.800	13.200	34.70	206.00	2.7900	3.000	4.0200	30.50
7	SR Yadav	235.40	1.600	13.300	14.00	105.10	2.6800	2.960	4.0500	14.30
8	NM Kahar	219.90	2.800	33.800	16.70	141.90	3.0800	3.020	4.4100	33.20
9	RR Yadav	224.70	1.100	15.900	5.30	69.20	2.8600	3.030	4.1400	12.50
10	MM Kahar	272.60	1.200	16.100	10.60	79.80	2.9500	3.190	4.5000	28.90
	P	0.00	0.000	0.001	0.000	0.000	0.315	0.001	0.002	0.000
	LSD (5%)	21.12	0.937	8.72	15.51	70.12	0.001	0.262	0.343	19.66

Table 6. Population structure of Chanki and Pajawa pigeon pea landraces in Kachorwa

Variable	N		Mean		SD		Minimum		Maximum	
	Chanki	Pajawa	Chanki	Pajawa	Chanki	Pajawa	Chanki	Pajawa	Chanki	Pajawa
Plant height, cm	90	10	221.7	183.4	33.95	10.08	145	166	316	200
Primary branches, n	90	10	1.622	1.2	1.241	0.422	1	1	8	2
Secondary branches, n	90	10	18.36	17.7	11.4	6.53	2	9	76	29
Tertiary branches, n	90	10	22.83	63.4	20.23	19.62	0	36	74	100
Raceme/plant, n	90	10	131.7	365.6	85.75	91.6	22	240	438	476
Pod/raceme, n	90	10	2.93	3	0.553	0.508	1.4	2.3	4.3	3.7
Seed/pod, n	90	10	3.082	2.97	0.336	0.221	2	2.7	4	3.3
Pod length, cm	90	10	4.301	4.19	0.418	0.489	3.5	3.3	5.7	4.7
100 seed weight, g	87	8	6.126	8.375	1.054	0.744	4	7	8	9
Grain yield/plant, g	90	10	23.47	57.5	19.2	47.8	1	1	95	133

SD, Standard deviation.

Table 7. Correlation coefficients among nine characters based on 10 farmers' field observations

	Plant height	2	3	4	5	6	7	8
2. Primary branches	0.075							
3. Secondary branches	0.018	0.508**						
4. Tertiary branches	-0.268**	0.056	-0.075					
5. Raceme/plant	-0.186	0.277**	0.183	0.846**				
6. Pod/raceme	0.083	0.114	0.162	0.328**	0.259**			
7. Seed/pod	0.160	0.028	0.136	0.159	0.163	0.378**		
8. Pod length	0.108	-0.008	0.313**	-0.020	-0.016	-0.014	0.341**	
9. Grain yield	-0.110	0.212*	0.260**	0.500**	0.647**	0.212*	0.247*	0.115

**, **, Significantly different from zero at 5 and 1 % level.*

Traits relationship was given in Table 7. There is highly significance correlation between secondary branches and yield, tertiary branches and yield, and raceme number and yield. Coefficients indicate that for yield increment, branches (secondary and tertiary) and raceme number should be given priority during selection. Second important traits are pod number, pod length and seed number for yield improvement. Farmers commonly consider branches and raceme number during selection of pigeon pea plants.

Existence of on-farm variation for these traits indicates the possibility of improvement of these landraces. Branches and raceme number are the primary traits, which would response positively to selection. Rana et al (2000) documented the preferred and unpreferred traits of Chanki and Pajawa landraces. Chanki has more preferred traits but Pajawa produced more grains yield. Major traits considered by farmers are branching, yield and quality. Stem and branches are important for fencing and cooking purpose in Tarai areas. There was diversity at population level among these landraces. Improving Chanki landrace on branching and yield using Pajawa might be a better strategy to conserve landraces and meet the farmers' need. Medium wealth category growing pigeon pea in upland has the greatest diversity. Farmer having the highest diversity could able to produce the highest grain yield. Because of on-farm variation especially in farmer's traits, selection response is expected in both Chanki and Pajawa landraces.

ACKNOWLEDGEMENTS

Farmers of Kachorwa ecosite, FK Chaudhary, SS BK, L Karna and K Shrestha are acknowledged for implementing this research and IPGRI for financial support.

REFERENCES

Bajracharya J, DK Rijal, SP Khatiwada, CL Poudel, MP Upadhyay, YR Pandey, PR Tiwari, RB Yadav and P Chaudhary. 1999. Farmer selection of germplasm using agro morphological and isozyme characteristics. **In:** *A scientific basis of in situ conservation of agrobiodiversity on-farm: Nepal's contribution to the global project* (B Sthapit, M Upadhyay and A Subedi, eds). NP Working Paper No 1/99. Pp. 49-66.

Cruz VMV, MIS Tolentino, NC Altoveros, MLH Villaricercio, LB Siopongeo, AC Dela Vina and RP Laude. 1997. Correlations among accessions of Southeast Asian Luffa genetic resources and variability estimated by morphological and biochemical methods. *Philipp J Crop Sci* 22:131-140.

Holcomb J, DM Tolbert and SK Jain. 1977. A diversity analysis of genetic resources in rice. *Euphytica* 26:441-450.

IBPGR and ICRISAT. 1993. *Descriptors for pigeon pea (Cajanus cajan* (L.) Millsp). International Board for Plant Genetic Resources, Rome, International Crops Research Institute for the Semi-Arid Tropics, India.

Johansen C. 1990. Pigeon pea: Mineral nutrition. **In:** *The pigeon pea* (YL Nene, SD Hall and VK Sheil, eds), CAB International, ICRISAT. Pp. 209-231.

Khatiwada SP, BK Baniya, DK Rijal, CL Panday, RB Rana, P Chaudhary, PR Tiwari, MP Upadhyay, YR Panday and A Mudwari. 2000. Nepal. **In:** *Conserving agricultural biodiversity in situ: A scientific basis for sustainable agriculture* (D Jarvis, B Sthapit and L Sears, eds). IPGRI, Rome. Pp. 134-138.

NARC. 1998. *NARC Annual Report 1996/97 (FY 2053/54)*. Nepal Agricultural Research Council, Khumaltar Kathamndu.

Neupane RK. 1995. Status of grain legumes genetic resources in Nepal. **In:** *Plant genetic resources: Nepalese perspective* (MP Upadhyay, HK Saiju, BK Baniya and MS Bista, eds). Proceedings of National Workshop 28 Nov - 1 Dec 1994. NARI, IPGRI, Kathmandu. Pp. 83-87.

Pandey YR, D Rijal, MP Upadhyay, B Sthapit and BK Joshi. 2003. In-situ characterization of sponge gourd at Begnas, Kaski, Nepal. **In:** *On farm management of agricultural biodiversity in Nepal* (BR Sthapit, MP Upadhyay, BK Baniya, A Subedi, BK Joshi, eds). Proceedings of the National Workshop, 24-26 April 2001, Lumle Nepal. NARC, LIBIRD and IPGRI, Kathmandu. Pp. 63-70.

Paudel CL, P Chaudhary, DK Rijal, SN Vaidya, PR Tiwari, RB Rana, D Gauchan, SP Khatiwada, SR Gupta and BR Sthapit. 1999. Agro ecosystem factors for in situ conservation of agrobiodiversity in different eco-zones of Nepal. In: A scientific basis of in situ conservation of agrobiodiversity on-farm: Nepal's contribution to the global project (B Sthapit, M Upadhyay and A Subedi, eds). NP Working Paper No 1/99. NARC, Nepal. Pp. 9-23.

Rana RB, P Chaudhary, D Gauchan, SP Khatiwada, BR Sthapit, A Subedi, MP Upadhyay and DI Jarvis. 2000. *In situ crop conservation: Findings of agro-ecological, crop diversity and socio-economic baseline survey of Kachorwa ecosite Bara, Nepal*. NP Working Paper No. 1/2000. NARC/LIBIRD/IPGRI.

Sherchand KK, NP Adhakari, SP Khatiwada, AC Shrivastav, J Bajracharya, KD Joshi, KB Kadayat, M Chaudhary, P Vhaudhary, SS Vishwakarma and S Yadav. 1998. *Strengthening the scientific basis for in situ conservation of agrobiodiversity: Findings of site selection in Bara, Nepal*. NP working Paper No 2/98. NARC/LIBIRD/IPGRI.

Tolbert DM, CD Qualset, SK Jain and JC Craddock. 1979. A diversity analysis of a world collection of barley. *Crop Sci.* 19: 789-794.

Upadhyay MP and A Subedi. 2000. Nepal. **In:** *Conserving agricultural biodiversity in situ: A scientific basis for sustainable agriculture* (D Jarvis, B Sthapit and L Sears, eds). IPGRI, Rome. Pp. 15-18.