

Intra- and interpopulation variation in finger millet (*Eleusine coracana* (L.) Gaertn) landraces grown in Kachorwa, Bara, Nepal

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Abstract

Finger millet [*Eleusine coracana* (L.) Gaertn) is an important food crop for poor and hilly people of Nepal. The many ecogeographical niches of the country have resulted in large diversity in finger millet landraces. This study was carried out from June to December 2003 at the *in situ* site of Kachorwa VDC, Bara, Nepal to assess the inter- and intrapopulation variability and relationship between different traits in finger millet landrace populations. Five landraces from mid-hill (Begnasa, Kaski), and two landraces from central Terai (Kachorwa, Bara) of Nepal were collected, with one improved Nepalese cultivar *Okhale-1*. Thirty plants from each population were studied. All the 18 studied quantitative traits showed large intrapopulation variability in all populations. Eight quantitative traits were more variable in the *Seto Dalle* population, indicating the operation of natural forces of evolution on its population. The shortest duration of flowering and maturity with high variability was observed in *Jhalari*. A total of 28 morphological classes for 11 qualitative characters were identified in finger millet populations with higher polymorphism in ear shape (5 classes) followed by grain colour (4 classes). Spikelet shattering was found only in *Jhalari* and *Muna*. The *Kalo Jhyape* population showed non-synchronous ear maturity with possibility of its fixation. Quantitative traits except tiller number ($\beta_1=1.5$), finger length ($\beta_1=1.277$), finger width ($\beta_1=-0.061$), and grain yield/plant ($\beta_1=1.277$) were normally distributed without significant skewness. Grain yield/plant was negatively correlated with days to flowering ($r=-0.397$), and days to maturity ($r=-0.351$). However it was positively correlated with tillers/plant ($r=0.526$), leaf number ($r=0.514$), blade length of flag leaf ($r=0.330$), blade breadth of flag leaf ($r=0.401$), finger width ($r=0.565$), grain/spikelet ($r=0.591$), and finger number ($r=0.482$). Terai and hilly landraces were grouped in two different groups. The inter- and intrapopulation variation found in these landraces could be useful for finger millet improvement. The landraces of central Terai could serve as the genepool for earliness and yield purposes for Terai condition.

Key words: Correlation, *Eleusine coracana*, fixation, polymorphism, population structure

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is an important crop in the hills of Nepal. It is grown in dry and extremely marginal areas in the plains, relayed with maize in the majority of mid-hill areas, and grown as a monocrop or in a mixed cropping system with cereals and/or legumes in the high hills and in some western hills of Nepal (Baniya *et al.* 2003a). In Terai, it is a summer as well as a rainy season crop.

However, finger millet is the livelihood of hill farmers of Nepal. Nepalese hill farmers use it as their main diet, as tiffin, for making *Jand* (local fermented and non-distilled alcoholic drink), *Rakshi* and *Tumba* (local fermented and distilled alcoholic drink), and sometimes for animal feed. Finger millet straw is also good animal forage in the mid-hills.

In central Terai it is used as tiffin, for making *haluwa*, *roti* and *chokha*. It is also assumed to be a good diet for pregnant women and for treatment of animal diarrhea (Rana *et al.* 2000). People in the Janakpur – Jaleshwar region use it during fasting on *Jeetiya* (a festival of women). Thus it has strong social and cultural ties in the Nepalese farm community.

Finger millet has high nutritional value especially for calcium, iron, methionine and manganese (ICRISAT 2004). Its slow digestion indicates low blood sugar levels after a finger millet diet thereby it is a safer food for diabetics (LMA 2004). In Nepal, there are many

opportunities for its promotion as income-generating enterprise or as a raw material for agrobased industries (Sthapit *et al.* 1993). Except for promotion of it for some bakery products in Pokhara valley (Bhandari *et al.* 2005), finger millet only occupies the traditional consumption pattern and market channel.

It is an allotetraploid with 36 chromosomes and a haploid genome size of about 2700 Mb (Bennett and Leitch 1995). It is productive in a wide range of environments and growing conditions, from southern Karnataka state in India to the foothills of the Himalayas in Nepal, and throughout the middle-elevation areas of Eastern and Southern Africa (ICRISAT 2004). Thus, finger millet diversity in Nepal is rich at both varietal and population levels (Baniya *et al.* 1992), and this diversity could be used for variety improvement. However, meager work has been conducted to characterize and utilize this diversity. Thus, this study was conducted to assess inter- and intrapopulation variability and relation between different traits of finger millet landraces in central *Terai* conditions, Nepal.

Material and methods

The upland field with sandy loam soil at 85 masl of Kachorwa VDC, Bara (26°53'N, 85°10'07"E) was selected. Five landraces (*Syankhole*, *Arbali Kodo*, *Seto Dalle*, *Kalo Jhyape*) and *Kukurkane* from Begnas, Kaski, two landraces (*Muna* and *Jhalari*) from Kachorwa, Bara, and one improved cultivar (*Okhale-1*) were used for this study. Landraces were selected on the basis of their popularity and distribution within ecosites. Around 150 seeds of each landrace were collected from farm households and sown at the end of June 2003. The 25-day-old seedlings were transplanted to 0.9 m² plots with spacing of 15 × 10 cm. Farmers' cultural practices were used. Thirty individual plants from each entry were tagged and their agronomic and morphological characters studied according to descriptors for finger millet (IBPGR 1985). Intra- and interpopulation diversity was calculated for quantitative and qualitative traits. All populations were pooled for correlation study. The summary of the weather report of the evaluation site can be found in Joshi *et al.* (see p. 73). Data were analyzed using the statistical program Minitab and SPSS.

Results and discussion

Intrapopulation structure

Quantitative traits

The higher mean and range for tiller number, blade width of flag leaf, and finger number is found in *Muna*, for grains/spikelet in *Jhalari*, and for plant height in *Kalo Jhyape* (Table 1). Mean plant height was shorter in *Jhalari* and *Muna*, which were also reported by Tiwari *et al.* (2003) using the same varieties in Nepalese hill conditions. Thus, these populations can serve as the best genepool for increment of the respective characters.

Higher mean with higher coefficient of variation (CV) was found in *Okhale-1* for finger length. Higher CV with high standard error was also found in *Muna* for ear exertion and finger width, in *Jhalari* for blade length of flag leaf and for finger number, in *Seto Dalle* for plant height, total leaf number, leaf sheath length, leaf sheath width, leaf blade width, blade width of flag leaf, grains/spikelet and grain yield/plant, in *Kalo Jhyape* for leaf blade length, and in *Kukurkane* for tiller number (Table 1). Since landraces showing high variability were useful in breeding programmes (Baniya *et al.* 2003b), these landrace populations are the best genepool for respective characters. Similarly, shorter duration for flowering and maturity with higher variability for these characters was found in *Jhalari* followed by *Muna* which could be used as the source genepool for developing a short-duration variety.

Table 1. Mean, coefficient of variation and range of different traits influencing outcrossing among rice landraces, Kachorwa, Bara, Nepal.

Character	Muna	Jhalari	Syank-hole	Arbali Kodo	Seto Dalle	Kalo Jhyape	KukurKane	Okhale-1
Plant height, cm	Mean±SE	66.50±1.45	86.85±1.78	90.63±2.76	94.73±3.16	103.63±3.02	87.37±1.78	101.73±2.52
	CV %	11.51	10.50	16.68	17.06	15.97	11.21	13.62
	Range	48.00–84.00	48.00–85.00	71.00–105.00	48.00–114.00	65.00–119.00	53.00–129.00	62.00–103.00
Tiller no.	Mean±SE	1.70±.12	1.63±.13	1.10±.07	1.33±.11	1.20±.1	1.47±.13	1.10±.05
	CV %	41.31	42.20	37.09	46.51	45.91	49.79	27.74
	Range	1.00–3.00	1.00–3.00	1.00–3.00	1.00–3.00	1.00–3.00	1.00–3.00	1.00–3.00
Culm thickness, mm	Mean±SE	3.64±.18	2.75±.20	3.45±.06	3.73±.15	3.44±.15	3.68±.13	3.98±.10
	CV %	23.32	33.12	10.14	21.96	23.11	19.66	13.94
	Range	1.90–4.80	1.50–4.60	2.80–4.20	2.20–5.40	2.20–4.90	2.30–5.00	2.20–5.50
Leaf, no.	Mean±SE	13.70±.33	11.40±.35	12.31±.52	11.45±.52	10.02±.54	13.79±.61	11.59±.35
	CV %	13.57	17.02	21.65	24.77	27.96	23.92	15.65
	Range	10.00–17.00	7.00–15.00	5.00–17.00	4.00–18.00	5.00–17.00	8.00–20.00	8.00–17.00
Leaf sheath length, cm	Mean±SE	9.53±.21	9.69±.31	11.41±.25	9.22±.32	9.57±.48	11.38±.5	9.73±.36
	CV %	12.32	17.89	11.66	19.14	25.81	23.74	20.58
	Range	7.00–11.50	6.00–12.50	8.50–13.50	5.50–14.00	0.40–13.00	6.50–16.00	5.50–14.50
Leaf sheath width, cm	Mean±SE	0.52±.01	0.50±.01	0.47±.01	0.48±.01	0.47±.02	0.48±.01	0.50±.01
	CV %	17.78	15.20	17.51	17.96	26.80	20.01	23.50
	Range	0.30–0.70	0.30–0.60	0.30–0.70	0.30–0.70	0.30–0.80	0.30–0.70	0.30–0.70
Leaf blade length, cm	Mean±SE	34.20±1.21	38.05±1.33	28.20±1.03	31.88±.75	32.65±.96	34.03±1.34	32.93±.84
	CV %	19.47	19.18	19.16	12.73	15.14	21.22	15.52
	Range	20.00–45.50	22.00–46.50	16.00–37.50	24.00–40.50	22.00–44.00	14.00–50.00	21.00–38.00
Leaf blade width, cm	Mean±SE	1.02±.01	1.02±.02	0.93±.02	0.91±.02	0.91±.04	0.91±.02	0.91±.02
	CV %	6.66	14.22	12.25	12.82	24.30	14.78	12.94
	Range	0.90–1.20	0.70–1.30	0.50–1.00	0.60–1.10	0.70–1.80	0.60–1.30	0.70–1.20
Flag leaf blade length, cm	Mean±SE	22.71±1.03	25.77±1.41	20.52±.81	26.22±1.04	22.94±1.27	24.41±1.2	22.52±1.08
	CV %	24.85	30.10	20.69	21.48	28.36	26.65	28.76
	Range	9.00–32.50	8.50–39.30	10.50–29.00	15.00–36.00	14–34.50	9.50–39.00	7.50–32.50
Flag leaf blade width, cm	Mean±SE	0.81±.02	0.77±.02	0.68±.022	0.69±.02	0.74±.02	0.68±.02	0.72±.02
	CV %	15.86	17.77	16.80	16.33	20.65	16.87	16.93
	Range	0.50–1.00	0.50–1.00	0.40–0.90	0.50–1.00	0.50–1.00	0.50–0.90	0.50–1.00

Table 1. (cont'd.)

Character	Muna	Jhalari	Syank-hole	Arbali Kodo	Seto Dalle	Kalo Jhyape	Kukurkane	Okhale-1
Ear exertion, cm	Mean±SE	10.16±.71	8.19±.45	12.89±.72	14.41±.53	12.58±.6	12.02±.55	9.22±.77
	CV %	38.42	29.70	29.79	19.32	26.21	25.21	45.98
	Range	0.50–13.00	1.00–12.00	0.00–17.50	9.50–20.50	1.00–17.50	4.50–17.00	0.00–14.00
Finger length, cm	Mean±SE	5.80±.22	5.66±.13	5.16±.14	4.92±.18	8.45±.29	7.23±.20	9.72±.51
	CV %	21.24	12.96	15.16	19.71	18.81	15.77	28.78
	Range	3.50–7.00	4.00–7.00	3.50–6.50	3.00–7.00	5.00–11.00	5.00–10.50	4.50–15.00
Finger width, cm	Mean±SE	0.84±.03	0.95±.01	0.80±.02	0.65±.02	0.76±.02	0.80±.02	0.74±.02
	CV %	20.89	10.08	18.70	20.17	16.67	19.97	18.56
	Range	0.50–1.00	0.70–1.00	0.60–1.00	0.50–1.00	0.50–1.00	0.50–1.00	0.50–1.00
Finger no.	Mean±SE	5.72±.27	4.00±.17	4.60±.28	5.00±.24	5.17±.23	5.57±.23	4.20±.17
	CV %	25.53	22.57	24.37	25.30	24.27	22.96	22.89
	Range	3.00–8.00	2.00–5.00	3.00–7.00	3.00–7.00	3.00–8.00	3.00–9.00	1.00–6.00
Grains/spikelet, no.	Mean±SE	270.31±12.44	235.71±10.99	210.00±19.62	143.00±11.85	193.28±11.57	172.43±9.53	198.46±11.91
	CV %	24.79	24.67	36.20	42.29	32.24	30.30	31.76
	Range	145.00–380.00	111.00–370.00	71.00–300.00	39.00–246.00	66.00–358.00	87.00–299.00	100.00–320.00
Grain yield/plant, g	Mean±SE	3.55±.32	3.96±.36	2.04±.24	1.32±.22	2.70±.31	3.15±.44	2.43±.23
	CV %	48.90	58.27	46.26	85.33	62.14	76.99	50.26
	Range	0.36–7.89	0.96–8.42	0.72–3.99	0.21–5.01	0.21–6.95	0.67–10.84	0.38–4.62
Days to flowering	Mean±SE	71.90±1.52	113.70±.47	119.31±1.16	126.67±.98	114.86±.56	115.70±.39	110.17±.69
	CV %	11.63	2.19	5.25	4.05	2.63	1.89	3.39
	Range	67.00–113.00	110.00–119.00	110.00–145.00	116.00–41.00	111.00–123.00	113.00–121.00	101.00–122.00
Days to maturity	Mean±SE	92.83±.78	152.82±.62	153.67±1.08	158.04±.52	156.21±.36	153.83±.34	143.38±.71
	CV %	4.57	2.17	2.74	1.62	1.27	1.22	2.68
	Range	85.00–102.00	142.00–159.00	144.00–157.00	151.00–62.00	151.00–159.00	149.00–157.00	140.00–151.00

High variability for eight studied quantitative characters was found in the *Seto Dalle* population (Table 1), showing greater possibility to improve this population. Greater mutation, migration and recombination may lead this population towards higher variation. However, low variability was observed in most of these populations in Begnas conditions (see Tiwari *et al.*, p. 96). *Seto Dalle* is a landrace of the Begnas area, which may get stress conditions in *Terai*, causing the expression of many genes.

Qualitative traits

Variation in population of different qualitative traits was observed in finger millet landraces; spikelet shattering was found in central *Terai* landraces *Muna* (0.333) and *Jhalari* (0.345) only. Tiwari *et al.* (p. 96) reported that these landraces did not show spikelet shattering in Begnas conditions; however, *Okhale-1*, *Kalo Jyape* and *Kukurkane* expressed this character. *Kalo Jhyape* population has non-synchronous ear maturity. Discontinuity of spikelets on finger was observed on *Muna* (0.70), *Jhalari* (0.30), *Arbali Kodo* (0.067), *Seto dalle* (0.462), *Kalo Jhyape* (0.931) and *Okhale-1* (0.862) (Table 2). This showed the possibility of fixation of this gene on *Kalo Jhyape* and *Okhale-1*. However, the population of *Arbali Kodo* shows fixation against this gene. This trait was found absent in Begnas conditions for all varieties. This may be a researchable question: why were the local landraces observed with spikelet shattering? Possibly there is some form of natural adaptation, which is influenced by favourable environmental conditions. The absence of discontinuity of spikelet in Begnas showed that this gene is environmentally influenced and favoured by central *Terai* conditions. Very low proportion of white grain colour (0.036) was also observed in *Okahle-1*, which may be due to the geneflow in recent generations because it was a modern cultivar by origin. The white grain colour was favoured by the farmers of Begnas hill (Rana *et al.* 2000).

Interpopulation structure

Quantitative traits

Maximum interpopulation variation was observed in grain yield/plot (39.27%) followed by finger length (27.30%), ear exertion (25.38%), days to flowering (19.50%), days to maturity (19.24%), grains/spikelet (19.18%), finger number (17.25%), tiller number (16.63%), and plant height (16.12%). Minimum interpopulation variation was observed in leaf sheath width (3.78%) followed by leaf blade width (5.35%), blade width of flag leaf (6.11%), leaf sheath length (8.48%), leaf blade length (9.69%), blade length of flag leaf (6.11%), culm thickness (10.29%), leaf number (10.95%), and finger width (11.18%). Similar results for finger length were found by Tiwari *et al.* (2003). High variation on days to flowering and days to maturity, in contrast with the report of Tiwari *et al.* (2003), may be due to the environmental variation of growing sites.

Plant height, ear exertion, finger number/ear and grains/spikelet were normally distributed with little skewness in finger millet population (Figure 1). Similarly, culm thickness, total leaf number, leaf sheath length, leaf sheath breadth, leaf blade length, leaf blade breadth, blade length of flag leaf, blade width of flag leaf, and lodging susceptibility were also normally distributed with little or no skewness.

Tiller number was skewed towards the left ($\beta_1=1.5$). This is due to the high frequency of plants with only one tiller. Finger length was also skewed left ($\beta_1=1.322$), but finger width skewed right ($\beta_1=-0.061$). This shows no good relation between finger length and breadth, and correlation between these two was also non-significant (Table 3). Skewness towards the left ($\beta_1=1.277$) was found in grain yield/plant showing fewer plants with extraordinary yielding capacity (Figure 1).

Table 2. Proportion of the different characters of finger millet landrace populations in Kachorwa, Bara.

Traits	Class	Muna	Jhalari	Syan-khole	Arbali kodo	Seto Dalle	Kalo Jhyape	Kukur-kane	Okhale-1
Growth habit	Erect	1	1	1	1	1	1	1	1
Lodging susceptibility	Low	1	1	1	1	0.962	0.897	1	0.966
	Intermediate					0.038	0.103		0.034
Ear shape	Droopy						0.367	0.033	0.207
	Open		0.167	0.071			0.633	0.467	0.138
	Semi-compact	1	0.733	0.571	0.429	0.269		0.500	0.586
	Compact		0.1	0.286	0.536	0.615			0.069
	Fist-like			0.071	0.036	0.115			
Ear size	Small	0.300	0.333	0.321	0.586	0.615	0.167	0.233	0.138
	Intermediate	0.700	0.633	0.643	0.414	0.385	0.567	0.600	0.586
	Large		0.033	0.036			0.267	0.167	0.276
Finger branching	Absent	0.600	0.700	1	1	1	1	1	0.967
	Present	0.400	0.300						0.033
Discontinuity of spikelets on finger	Absent	0.300	0.700	1	0.933	0.538	0.069	1	0.138
	Present	0.700	0.300		0.067	0.462	0.931		0.862
Spikelet shattering	Absent	0.667	0.655	1	1	1	1	1	1
	Present	0.333	0.345						
Grain covering	Exposed				0.333	0.5	1	0.067	0.033
	Intermediate	1	1	1	0.667	0.5		0.933	0.967
Grain colour	White			1					0.036
	Light brown	0.037	0.862		0.800			0.067	0.214
	Copper-brown	0.889	0.138		0.200	0.846	1	0.933	0.750
	Purple-brown	0.074				0.154			
Synchrony of ear maturity	Not synchronous	0.880	0.655	0.607	0.867	0.958	1	0.933	0.207
	Synchronous	0.120	0.345	0.393	0.133	0.042		0.067	0.793
Grain surface	Smooth	1	1	1		0.885	1	0.933	0.828
	Wrinkled				1	0.115		0.067	0.172

For days to flowering (DTF), and days to maturity (DTM), the distribution becomes somewhat platykurtic ($\beta_{1DTF}=-0.876$, $\beta_{2DTF}=-0.698$; $\beta_{1DTM}=-1.012$, $\beta_{2DTM}=-0.785$) with two distinct groups for days to flowering and days to maturity. Since *Muna* and *Jhalari* are *Terai* landraces with significant short duration of cropping and with no photosensitivity and others have long-duration cropping, these two groups are possible. Cluster analysis using all studied traits also showed *Muna* and *Jhalari* as distinct from others. Among hill genotypes, *Kalo Jhyape* was found distinct from the others (Figure 2). The same result was observed by Tiwari *et al.* while using the same varieties and same characters for study in Begnas hill conditions of Nepal.

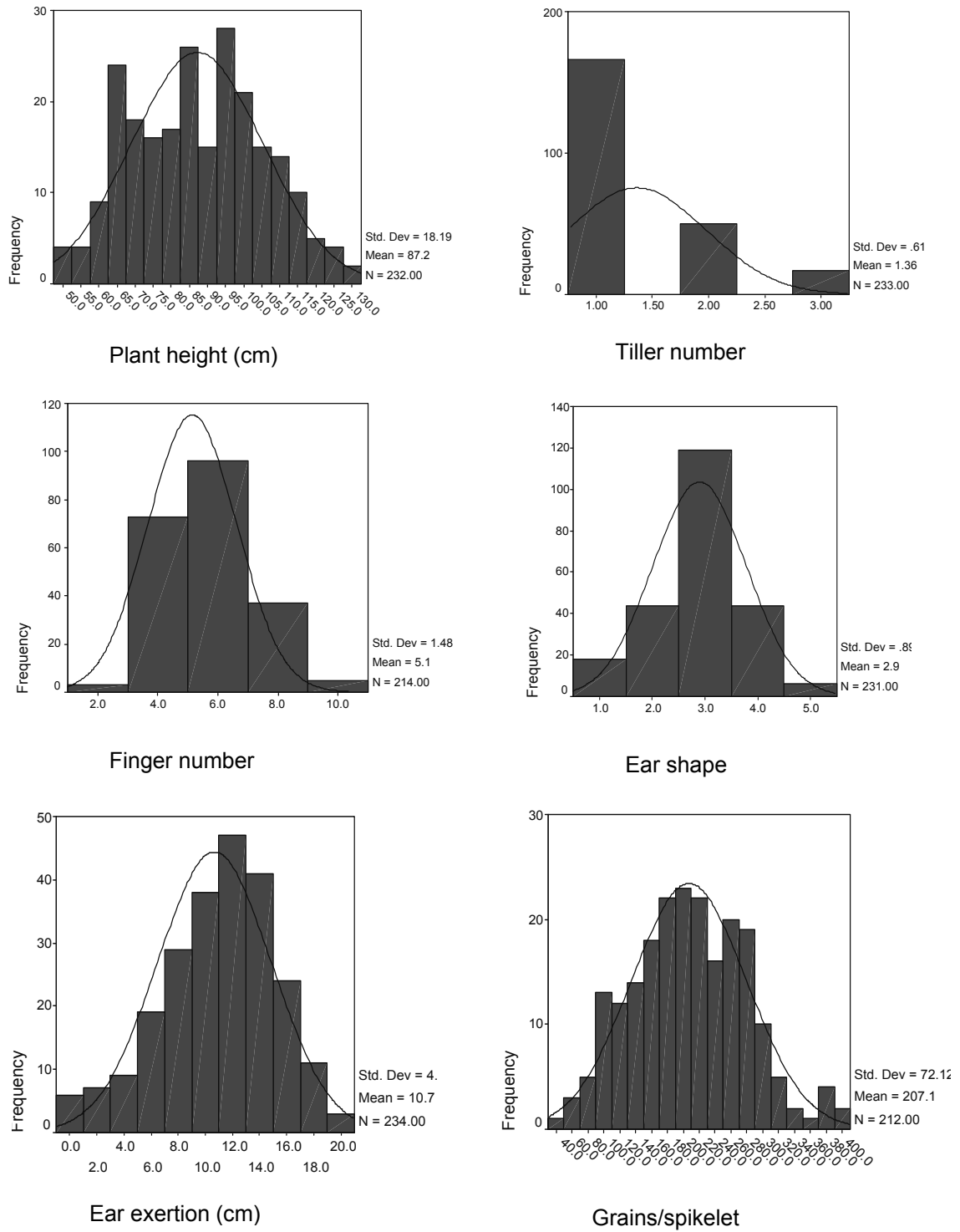


Figure 1. Distribution of different traits of finger millet landraces population.

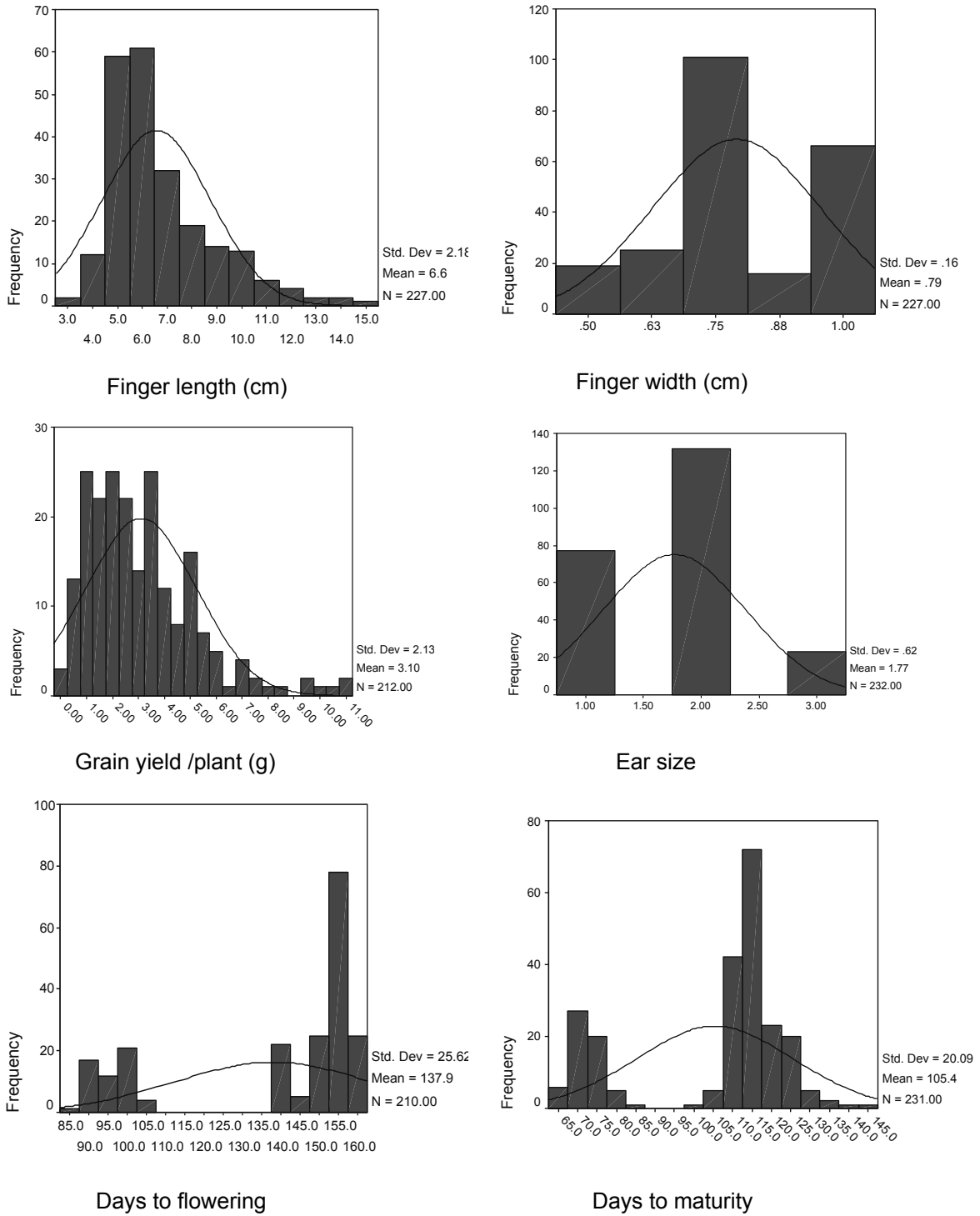


Figure 1 (cont.). Distribution of different traits of finger millet landraces population.

Table 3. Correlation between different traits observed on finger millet landraces.

	Tiller number	Days to flowering	Leaf number	Blade length of flag leaf	Blade width of flag leaf	Finger length	Finger width	Finger / spikelet	Finger number	Grain yield/plot	Ear exertion	Days to maturity
Plant height	-0.108	0.596**	0.277**	0.197**	0.001	0.515**	0.136*	0.020	-0.086	-0.016	0.447**	0.629**
Tiller number		-0.164**	0.063	0.048)	0.066	-0.092	0.167**	0.075	0.184**	0.526**	-0.048	-0.148*
Days to flowering			-0.130*	-0.152	-0.291**	0.150*	-0.137*	-0.422**	-0.371**	-0.397**	0.4**	0.968**
Leaf number				0.150*	0.368**	0.325**	0.325**	0.361**	0.432**	0.514**	-0.122	-0.031
Blade length of flag leaf					0.491**	0.082	0.249**	0.425**	0.249**	0.330**	0.222**	-0.163*
Blade width of flag leaf						0.06	0.157*	0.324**	0.479**	0.401**	0.002	-0.247**
Finger length							-0.015	0.089	-0.005	0.065	-0.006	0.216**
Finger width								0.608*	0.031	0.565**	0.095	-0.108
Grains/spikelet									0.210**	0.591**	0.008	-0.404**
Finger number										0.482**	0.003	-0.387**
Grain yield/plot											-0.114	-0.351**
Ear exertion												0.325**

Note: *0.05<p<0.01, **p<0.01, n = 210

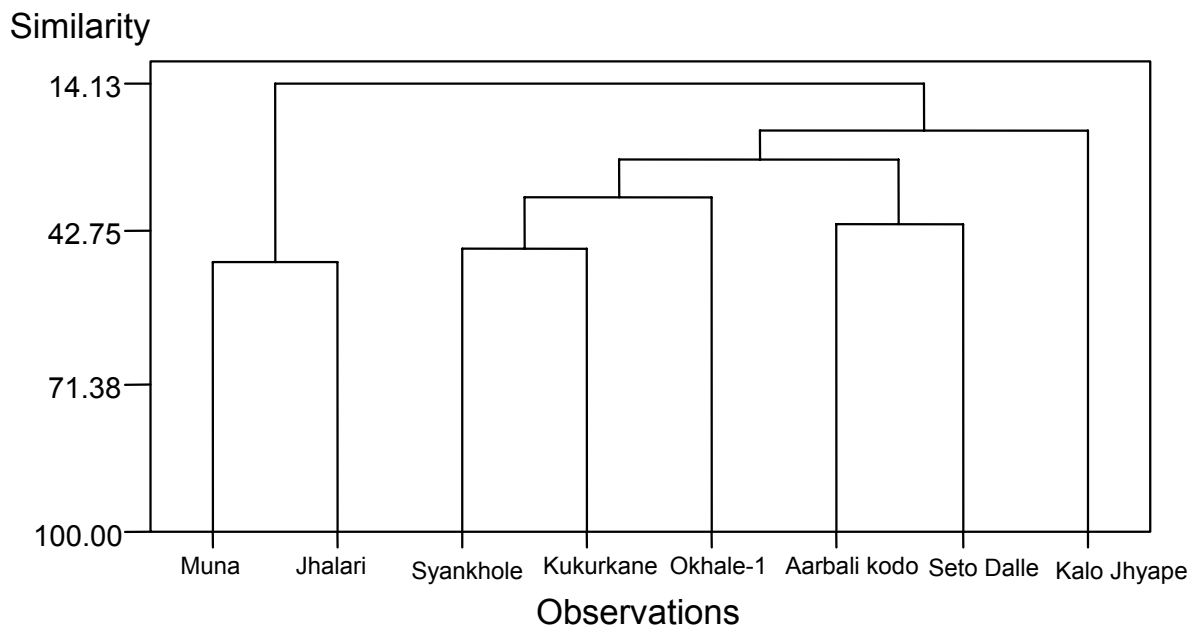


Figure 2. Clustering patterns of 8 finger millet varieties grown at Kachorwa, Bara, Nepal.

Qualitative traits

We identified 28 morphological classes for 11 qualitative characters on finger millet populations. Among them, 18, 20, 17, 18, 20, 16, 19, and 24 classes were identified from *Muna*, *Jhalari*, *Syankhole*, *Arbali kodo*, *Seto Dalle*, *Kalo Jhyape*, *Kukurkane* and *Okhale-1* populations, respectively (Table 2). Higher polymorphism could be seen in ear shape (5 classes) followed by grain colour (4 classes). However, all populations were erect for growth habit. Ear size was also little skewed towards the left ($\beta_1=0.187$) showing lower frequencies of the large size ear on finger millet population (Figure 1).

Correlation among different traits

Correlation between 13 qualitative traits showed different degrees of relationship (Table 3). Tiller number, total leaf number, blade length of flag leaf, blade width of flag leaf, finger width, grain/spikelet, finger number/ear was positively correlated ($P<0.00$) with the grain yield/plant. Negative correlation was found for days to flowering (-0.397 , $P<0.00$) and days to maturity (-0.351 , $P<0.00$) with grain yield/plant. This may be due to sterility problem and non-adaptability of the hill genotypes having longer days to flowering and days to maturity in central *Terai* condition. Negative correlation of plant height (-0.016 , $P<0.819$) and ear exertion (-0.114 , $P<0.097$) with grain yield/plant was also observed.

Farmers use traits like big ear size, well-matured ear, big grain size, free from finger millet blast and insect pest, and non-lodging plants as selection criteria and want new high-yielding varieties with the features of *Dalle* and *Jhyape* local varieties (Baniya *et al.* 2003a). Moreover, as optimum expression of the characters having positive association with yield is important for a breeding programme (Rasmusson and Gengenbach 1980), the relationships observed in our study could be used to develop the varieties asked for by farmers.

Conclusion

Since intrapopulation variation was observed in different finger millet landraces at central Terai conditions, this variation could be effectively used for the improvement of particular populations in the desired direction. The *Seto Dalle* population, which showed maximum variation in many characters, should be best utilized for the population genetic study, and germplasm conservation and utilization programmes. The local landraces, which showed their best performances in local conditions, could be further improved by better selection procedures from its diverse population. Earliness from local landrace populations could be used in the national finger millet breeding programme.

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