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Ecological stability of genetic diversity among landraces of little millet (*Panicum sumatrense*) in south India

V. Arunachalam, R. Rengalakshmi and M.S. Kubera Raj
M.S. Swaminathan Research Foundation, Third Cross Road, Taramani Institutional Area, Chennai 600 113, India

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Abstract

Risk-prone agriculture by resource-poor tribal farmers in Kolli hills, south India is slowly giving way to commercial exploitation for paltry compensation thus eroding genetic diversity of millets. Cultivation and conservation of millets, particularly, little millet (*Panicum sumatrense* Roth ex Roem. et Schult.), called samai in the local language, Tamil are on the wane. Whether irregular and sparse cultivation of little millet by tribals has an impact on the current level of genetic divergence is also not clear. Therefore genetic divergence among 7 landraces and 1 check variety was evaluated based on morphometric traits at two sites over two seasons. The seven landraces formed six distinct groups with high inter-group distances. Days to maturity and flowering time contributed the most to genetic differentiation. Principal component analysis confirmed the results of divergence analysis. But a recent molecular analysis of diversity reported that the landraces were all genetically uniform and any observed diversity could be due environmental variation. An analysis of the contradictory results only emphasized the fact that lack of polymorphism need not imply lack of genetic divergence. The findings co evaluated with relevant published work highlight the value of morphometric analysis and reveal sustained genetic divergence in little millet.

Tribal areas in India are known for their rich genetic diversity in various crops including millets. Kolli hills, situated about 1200 m above mean sea level between 78 °E and 11 °N in the Namakkal district of Tamil Nadu in south India is occupied mostly by one tribe called Malaiyalis. In this fragile hilly ecosystem under drought and unsure rainfall, farmers prefer to grow relatively drought tolerant millets, particularly little millet (*Panicum sumatrense*), called samai in the local language, Tamil.

Landraces of little millet have local names indicating their major diagnostic traits. For example, in the landrace of little millet, Mallia samai, Malli refers to white colour like that of a jasmine flower indicating the white colour of the grains. In the case of Kattavetti samai, Kattai refers to tillers with very thick stems needing big sickles (referred to as 'vetti') for harvest.

A reason why divergent and location-specific landraces of little millet were preferentially cultivated earlier in Kolli hills was that they provided substantially high energy to sustain long hours of farm work compared to rice. However, unsustainably realized yield of around 300 kg/ha usual in farmers' fields is unprofitable. This helped commercial exploitation of millet fields for meagre cash incentives with the result that the area under cultivation of little millet started shrinking rapidly. Yet farmers conserve small quantities of seeds of landraces for use in their religious functions.

The impact of irregular cultivation and farmer conservation of landraces on the extent of genetic

Table 1. Grouping of 7 samai landraces and 1 check based on genetic divergence.

Group	*Expt 1*	*Expt 2*	*Expt 3*
I	ML	ML	ML, BG
II	TL, PN	SN, PN	TL, PN
III	KT	KO, KT	KO, KT
IV	KO	BG	SN
V	VL	VL	VL
VI	SN	TL	–
Range in D^2	161.71–62923.10	17.75–2523.62	17.00–1773.24
pc 1	99.3	94.3	97.8
pc 2	0.6	4.3	1.2

ML: Mallia samai; TL: Thirikula samai; SN: Sadan samai; KO: Kottapatti samai; KT: Kattavetti samai; PN: Perun samai; VL: Vellaperun samai; BG: Birsa Gundli (check); pc 1: % contribution of principal component 1; pc 2: % contribution of principal component 2 TL: Perun samai A, PN: Perun samai B in the Expt 1.

diversity are not clear. Over and above, a recent study at the M.S. Swaminathan Research Foundation has reported that genetic divergence among the landraces of little millet at Kolli hills is very narrow which made it essential to re-assess it. At the same time, we recognized that expression of traits, particularly of landraces, is site-specific, and the traditional, cultural and cropping practices under which plants have acquired their distinctive properties play an important role in maintaining genetic diversity (Worede and Mekbib 1993). In this light, we report in this paper the results on current levels of genetic divergence in little millet based both on an experimental and on a participatory evaluation.

Material and Methods

Experiment 1:

On a tribal community interactive chronicling, seeds of 7 landraces of little millet (details in Table 1) were collected from farmers. While arranging seeds for planting, the seed packet of one landrace, Perun samai was inadvertently labelled as another, Thirikula samai. Perun samai, repeated thus unknowingly, was designated as Perun samai A (replacing Thirikula samai) and Perun samai B (the right one) leaving effectively 6 races. The landraces were multiplied in a randomised block design with 4 replications assigning 4 rows 5 m long to each plot. A distance of 30 cm between rows and 20 cm between plants within rows was maintained. The crop was sown in the month of November with supporting irrigation. Fertilisers at 40 kg N and 20 kg P per ha were applied as basal dressing. The soil was adequately rich in K. The crop received no plant protection measures. This trial is referred to as *Expt 1*.

Since the initiating seed material collected from farmers showed some variation in the field, little millet farmers from Kolli hills selected 'type' plants of each landrace based on their indigenous knowledge. Seeds of the selected plants were used for raising the crop at its native site, Kolli hills next year. A check variety, reported to be highly adapted, was included for comparison.

The 7 landraces and the check (comprising thus of 4 short and 4 long duration landraces) were planted during normal season in Kolli hills in farmers' plots following farmers' cultivation practices. While 5 farmers grew the 4 short duration races independently, one farmer from among them grew also the 4 long duration races.

Experiments 2 and 3:

Data on the 8 landraces grown by the one farmer formed *Expt 2*. The mean values of the 4 short duration landraces grown by 5 farmers along with the values of 4 long duration landraces formed *Expt 3*. Experiment 3 differed from Experiment 2 in accounting for the variation between the plots of short duration races of 5 farmers.

Observations were recorded on plot basis on the characters – flowering time (days to 50% flowering), plot grain yield (g) and days to maturity. The traits, plant height (cm), number of effective tillers, number of internodes and average length of panicle (cm) were based on means of 6 plants selected at random from each plot. Harvest index (%) was computed using plot grain and straw yield.

It may be noted here that there is no known association between flowering time and maturity in the photosensitive samai landraces. They are hence recorded as two different traits.

Variation among landraces was evaluated for various traits by ANOVA. Genetic divergence was measured by the Mahalonobis' distance statistic, D^2. The varieties were grouped based on D^2

Table 2. Values of Inter- and Intra-group divergence in 7 landraces of little millet.

Group	Expt	Group					
		I	II	III	IV	V	VI
I	1	.00	41417.00	62923.10	1887.47	49525.40	529.40
	2	.00	175.08	660.35	218.80	1289.18	248.71
	3	20.35	689.16	1257.46	197.28	1773.24	
II	1		161.71	2629.19	17089.70	608.17	33008.95
	2		17.75	191.56	740.28	560.13	115.75
	3		17.00	98.89	160.07	275.46	
III	1			.00	44220.10	821.35	52230.00
	2			64.85	1604.30	136.26	218.24
	3			26.23	481.09	71.43	
IV	1				.00	3222.20	441.96
	2				.00	2523.62	879.77
	3				.00	813.05	
V	1					.00	40116.50
	2					.00	588.05
	3					.00	
VI	1						.00
	2						.00
	3						–

values using Tocher's method, following Rao (1952). This grouping method uses the simple logic that the average distance within a group (between landraces in the group) should be far less than its average distance from any other group. In other words, intra-group distance should be far less than inter-group distance. Principal component analysis was used to plot the position of the landraces, based on the mean values of the first two principal vectors, in a two-dimensional graph. It was compared with the grouping pattern based on D^2. The importance of traits for genetic divergence was scored on their contribution to D^2 values (Singh 1981; Arunachalam and Bandyopadhyay 1989.

Results

There was significant variation among the landraces for all the eight characters in the Expt 1 and only for flowering time, plant height, panicle length and maturity period in Expts 2 and 3 at Kolli hills. Those observations were reflected in the trait means of various landraces (data not shown).

Substantial inter-landrace divergence (as measured by D^2) was observed in all the experiments. High variation between landraces in Expt 3 for various traits revealed heterogeneity in the experimental management by individual farmers (data not shown). Variation within landraces was also present, possibly due to the seed variability still existing after the single cycle of selection of' 'type' plants by farmers.

The 7 landraces formed six groups in Expts 1 and 2 and five in Expt 3 (Table 1) with high inter-group divergence (Table 2) implying that the landraces are highly divergent and distinct. Mallia samai and Vellaperun samai formed individual groups in all the experiments. Kottapatti samai and Kattavetti samai formed one group in Expts 2 and 3 while each formed a separate group in Expt 1. Only Sadan samai got grouped with Perun samai in Expt 2 and remained a separate group in Expts 1 and 3. The short-duration check variety, Birsa Gundli formed a separate group in Expt 2 and joined Mallia samai in group I in Expt 3. Otherwise, the divergence pattern remained essentially similar in all the three experiments.

Among the traits, days to maturity contributed more than half (57.4%) to genetic divergence followed by flowering time (19.2%) and plant height (12.2%) (Table 3). The principal component analysis further strengthened the results. The first two principal components alone accounted for more than 98% of total variation. Justifiably, the graph

Table 3. Ranking of traits on their contribution (%) to genetic divergence.

Rank	Trait	p	Rank	Trait	p
1	Days to Maturity	57.42	5	Grain Yield	2.83
2	Days to Flowering	19.24	6	Panicle Length	1.93
3	Plant Height	12.17	7	No. of Internodes	1.39
4	Harvest Index	3.73	8	No. of Effective Tillers	1.29

p: Percentage contribution to genetic divergence averaged over Expts 1 to 3.

of mean values of the first two principal vectors confirmed the grouping based on morphometric divergence. Days to maturity and flowering time largely contributed to the first principal vector (primary axis of differentiation), and plant height and days to maturity to the second (secondary axis of differentiation) (*data not shown*).

Discussion

The large range of inter-landrace genetic distances (D^2) (Tables 1 and 2) made it clear that genetic diversity in little millet landraces was substantial. It was stable since the morphometric grouping remained similar across the three experiments, two sites (Kattupakkam, an experimental site of Expt 1 and Kolli hills, a natural habitat of Expts 2 and 3), and two seasons (an off-season, November–March of Expt 1; a regular season, July–January of Expts 2 and 3). Ecological stability of the diversity was high despite the small number of 7 landraces, their less intense and less frequent cultivation. Regardless, it is essential to revive intensive cultivation of little millet not only to conserve site-specific gene sources but also to provide balanced nutrition to the tribal poor.

An analysis of the contribution of component traits to genetic divergence suggests that consistent and unconsciously continued directional selection by tribal farmers for maturity, flowering time along with grain colour, quality and taste could have evolved the short and long duration landraces. Natural selection must have been supporting the preservation of the individual diversity within those short and long maturity groups

It is remarkable that six distinct (five in Expt 3) groups with high inter-group distances (Table 2) could occur in all the experiments. More significant is the result that the two entries of Perun samai in Expt 1 formed one group (Table 1). This illustrates the efficiency of multivariate grouping using D^2 statistic as a measure of genetic divergence.

Landraces, as phenotypes with distinctive characters, were preserved in their native site (Kolli hills) under the cultural and cropping practices of tribals. Expressed traits are known to be a function of not only the genes but also their specific interaction with environment. Genic and hence trait expression in site-specific varieties can be preserved in those sites, as could be inferred from Pardue (1991). It is hence expected that the existing high diversity in little millet would be preserved at Kolli hills as long as the micro- (including traditional cultivation practices) and macro- (like edaphic and climatic factors, soil status and fertility) environments are left largely undisturbed (Doebley et al. 1995).

But a molecular analysis in 11 landraces of little millet (that included the seven of this study) did not reveal genetic divergence in them (2000). Using RAPD markers with 11 primers, it was inferred that it would be “logical to think that the landraces of some of the species of minor millets have a narrow genetic base. The observed variability in the field-grown genotypes could therefore be well attributed to the physical environment of the areas where these landraces have been grown.”

In contrast we state that large differences in maturity, flowering time, yield and harvest index, as found in our study, cannot be accounted for by environment alone. Deviation of marker-based divergence from actual genetic divergence will depend on the degree of association between markers and expressed traits (see for eg., Gupta and Varshney 1999). Therefore absence of polymorphism need not necessarily imply absence of diversity.

Morphometric analysis of diversity, on the other hand, is supported by a study in *Sorghum* (Teshome et al. 1997). Based on 14 phenotypic descriptors, the study finds that five landraces, named by farmers on specific indicator traits, were consistent and indeed represented distinct landraces. The distinctness in our study of groups containing named cultivars agrees with this finding and also with the traditional knowledge of Kolli hills farmers.

Site-specific expression of landraces requires breeding and selection to be preferably executed at the site. In that context, results on genetic diversity based on morphological traits measured at the site would give a definite edge to those programs. Even if the grouping pattern at a site were dynamic, the methodology followed here, when applied, would aptly reveal the diversity pattern and help participatory breeding efforts.

In sum, the study confirmed the sustained availability of distinct divergence in little millet in Kolli hills. Farmer-friendly strategies blending morphometric and molecular methods, where applicable, are the need of the hour to conserve the current genetic diversity in little millet.

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