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Research Note

Analyzing the variability parameters of the landraces and varieties of little millet (*Panicum sumatrense* Roth ex Roem. & Schult.)

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Abstract
Little millet is one of the underutilized crops among the cereals, which is being cultivated by farmers of tribal agriculture. The landraces under cultivation possess excellent variability presenting good opportunities for selection. In view of this, the current study was carried out with 17 little millet landraces for 10 quantitative and nine qualitative traits. The study revealed the preponderance of additive gene action for all the 10 traits and hence effective selection could be done for their improvement. Higher to moderate ranges for PCV and GCV with minimum ECV for genetic variability for all the traits were observed. Among the nine qualitative traits, there were significant variations observed for inflorescence shape and panicle compactness. Hence, these traits could be utilized as major DUS descriptors in differentiating the little millet landraces in future. Further the PCA analysis exhibited three reliable principal components contributing to an overall variation of 74.54%. The traits such as days to 50% flowering, peduncle length and flag leaf length were the major positive contributors for variability across all the eigen vectors. These traits were found to exhibit a higher variability among the population and thus a rewarding selection and hybridization for improving these traits could be effected in future breeding programs. Among all the landraces and varieties *chittan samai*, *perunsamai*, ATL 1, CO 4 (*samai*), *paakulam karunjamai* and *vellai samai* could be further identified as desirable donors for improving the yield parameters in little millet breeding programs in future.

Keywords: Little millet, landraces, GCV, PCV, heritability, genetic advance, PCA

Little millet (*Panicum sumatrense*), also known as “*sama*,” or “*kutki*,” is one of the most significant underutilized, indigenous and drought resistant millet grown extensively in tropics. This is one of the climate resilient crops that could guarantee access to food and meet the nutritional security in near future. It belongs to the *Poaceae* family and the *Panicoideae* subfamily. It is a self-pollinated crop owing to its cleistogamous flowers with a chromosomal number of 2n=4x=36 (Nirmalakumari *et al*., 2010). In India, it is grown over an area of 0.26 million hectares and Madhya Pradesh stands as the largest producer (Pradeep and Guha, 2011). This millet is well reported to have a superior nutritional profile, including higher levels of proteins, micronutrients, carbohydrate, fat, fibre and iron (Dey *et al*., 2022). Also, little millet has comparatively higher folic acid, anthocyanin, phenols and flavonoids which are essential for cell growth and regulation (Arunachalam *et al*., 2005). Besides these facts, it has received a least amount of research attention as compared to other small millets owing to its lower productivity, area of cultivation, shattering and post-harvest yield losses (Madhavilatha *et al*., 2020). Since this crop is mostly preferred and cultivated in the rainfed areas, it productivity is comparatively less than major food crops. Hence, the characterization of landraces assumes importance for identifying novel traits which could be utilised in future breeding programs of little millet.

Recent reports on variability of little millet landraces by principal component analysis depicted a higher variability in the population with the role of all the morphological traits in little millet from days to 50% flowering to single plant yield (Selvi *et al*.2015; Gopikrishnan *et al*.2022; Patel *et al*.2023). Succeeding them, Matere *et al*. (2022) observed the effective selection with additive gene action for seed yield per plant, panicle weight, total number of tillers per plant, productive tillers and iron content with higher PCV, GCV, heritability and genetic advance. Even though little millet is a highly self-pollinated crop, these findings further enable the significance of the presence of variability among little millet landraces and genotypes which needs to be utilized in future. Also, these reports on landraces emphasizes on the importance of characterization for all the traits for utilization in future breeding programs (Gopikrishnan *et al*.2022). In view of these, the present study was conducted to analyse the variability for yield contributing traits in little millet and assess the heritability (h^2) and genetic advance (GA) for all the morphological traits to generate information for future crop improvement.

The experimental material comprising of 17 little millet cultivars collected from the farmers of different geographical regions were evaluated at Karunya Institute of Technology and Sciences, Coimbatore during *Kharif,* 2022 (**Table 1**). The genotypes were raised in a Randomized Block Design (RBD) with three replications adopting a spacing of 20x10 cm. The entire recommended packages of agricultural practises were implemented. Five plants were selected randomly from each genotype in of each the replications and observations were recorded for 10 quantitative traits *viz*., basal tillers (number), days to 50% flowering, peduncle length (cm), flag leaf blade length (cm), flag leaf blade width (cm), panicle length (cm), number of branches per panicle (number), plant height (cm), 1000 grain weight (g) , grain yield per panicle (g) and nine qualitative traits *viz*., plant growth habitat, plant pigmentation at leaf sheath, leaf sheath pubescence, ligule pubescence, leaf blade pubescence, inflorescence shape, culm branching, panicle compactness and seed colour. The data recorded were subjected to variability and PCA analyses for further selection and improvement. The PCA analysis was carried out by using STAR (Statistical Tool for Agricultural Research) version 2.0.1 developed by IRRI (International Rice Research Institute). In addition, variability parameters like PCV, GCV, ECV, h^2, GAM% were analysed using the package 'variability' in R studio version 4.2.2 (Allaire, 2012).

Table 1. List of little millet genotypes used for evaluation

S.No	Genotype	Place of collection
1	*Samai ATL 1*	Athiyanthal
2	*Kolunthana samai*	Jawadhu hills
3	*Chittan samai*	Jawadhu hills
4	*IR 20 samai*	Jawadhu hills
5	*Kottathara samai*	Attapadi, Kerala
6	*CO 4 samai*	TNAU, Coimbatore
7	*Vellai samai*	Jawadhu hills
8	*Periya samai*	Kolli hills
9	*IR 8 samai*	Jawadhu hills
10	*Siru samai*	Jawadhu hills
11	*Kalman samai*	Jawadhu hills
12	*Kothu samai*	Jawadhu hills
13	*Paakulam karunjamai*	Attapadi, Kerala
14	*Jawadhu local samai*	Jawadhu hills
15	*Perungolai samai*	Jawadhu hills
16	*Kochamai*	Jawadhu hills
17	*Perunsamai*	Jawadhu hills

The mean squares of traits furnished in ANOVA revealed that the genotypes utilized in the study had significant variations (**Table 2**), suggesting presence of significant variations among the landraces for all the morphological traits. Among the ten quantitative traits, the days to 50% flowering was observed to exhibit a high PCV and GCV with lower ECV, indicating that there was a lower influence of environment on days to 50% flowering. Similar observations for days to 50% flowering in little millet was also reported by Anuradha *et al*. (2020). Except for days to 50% flowering, rest of the traits recorded a moderate GCV and PCV. This indicates the existence of considerable amount of genetic variation for rest of the traits in the population screened. Based on ECV, among all traits, the number of branches per panicle was observed to be moderately influenced by the environment. Similar high PCV, GCV and lower ECV for these traits were also reported by Suryanarayana and Sekhar (2018). On contrary, the lowest GCV, PCV and ECV were observed for 1000 grain weight. This suggests that there was minimum variability for 1000 grain weight among the little millet genotypes utilized in the study and this was also observed by Anuradha *et al*. (2017). Hence the genotypes with higher 1000 grain weight could be utilised as donors and further evaluated in other breeding trails for their stable performance (**Table 3**). Although the coefficient of variations for phenotype, genotype and environment presented the variability in the population, the effectiveness of selection depends upon the heritability and genetic advance. This defines the presence of additive gene action and suggests the desirable breeding method for improving the traits in the future breeding programs.

Regarding the heritability and genetic advance, the genotypes exhibited a high heritability for all the traits. Among all the traits, days to 50% flowering recorded high heritability cum genetic advance. This indicated the preponderance of additive gene action and selection could be effective for this trait. Similar observations for days to 50% flowering were also reported by Anuradha *et al*. (2017). The traits such as, plant height, flag leaf length, basal tillers, peduncle length, grain yield per panicle and panicle length also exhibited a high heritability cum genetic advance. Hence for improvement of all the traits except for 1000 grain weight, selection would be rewarding due to the presence of additive gene action. Regarding the 1000 grain weight, high heritability with low genetic advance accompanied by low PCV and GCV were observed. This suggested the preponderance of non-additive gene action for the above trait and selection for this trait will not be rewarding. Therefore, heterosis breeding could be adopted by utilizing potential donors for 1000 grain weight in hybridization programs. Matere *et al*. (2022) presented similar observations for variability in 1000 grain weight. On the whole, this population could be effectively used for selection and improving yield attributing traits like days to 50% flowering, plant height, flag leaf length, basal tillers, peduncle length, grain yield per panicle and panicle length.

The variability for all the major traits towards the population were also further computed by using Principal Component Analysis (PCA) **(Table 4**). The PCA exhibited three reliable principal components with eigenvalues greater than one out of the ten principal components. The three PCs in total accounted for 74.54 percent of the total variability. Among all, PC1 contributed to an overall variability of 37.99 per cent, followed by, PC2 with 25.07 per cent and PC3 with 11.48 per cent of the contribution to total variation (**Fig. 1**)**.** From PC1, the traits namely, days to 50% flowering and peduncle length had positive contribution towards the overall variability. These traits positively contributed to the overall variability existing in the population from PC1. The rest of the traits exerted a negative contribution towards the variability from PC1. In

Table 2. ANOVA for 10 quantitative traits of little millet

Character	Mean sum of squares		
	Genotype	Replication	Error
Degrees of freedom	2	16	32
Plant height	356.84***	13.69*	2.77
Basal tillers	4.0228***	0.1713	0.0710
Days to 50% flowering	523.44***	12.39*	3.26
Peduncle length	15.2438***	0.3691	0.2737
Flag leaf length	33.133***	4.666	0.309
Flag leaf width	0.078127***	0.027231	0.007740
Panicle length	25.9964***	0.8704	0.6535
No.of branches per panicle	1.96362***	0.11053	0.24310
1000 grain weight	0.144481***	0.003349	0.001649
Grain yield per panicle	16.2534***	2.3665	0.3292

Table 3. Variability parameters for yield and other component traits in little millet

Characters	Mean	Range		PCV%	GCV%	ECV%	h^2 (%)	GAM%
		Min	Max					
Plant height	92.43	72.00		112.06	11.89	11.75	1.80	97.71
Basal tillers	6.58	4.80	9.73	17.89	17.43	4.04	94.89	34.98
Days to 50% flowering	61.24	44.00	83.00	21.70	21.50	2.94	98.15	43.87
Peduncle length	14.16	11.00	20.57	16.19	15.76	3.69	94.80	31.62
Flag leaf length	22.63	17.20	30.00	14.81	14.61	2.45	97.25	29.68
Flag leaf width	0.98	0.61	1.30	17.88	15.52	8.90	75.32	27.75
Panicle length	22.23	16.50	29.00	13.56	13.07	3.63	92.82	25.94
No.of branches per panicle	4.67	3.00	6.60	19.32	16.19	10.54	70.23	27.96
1000 grain weight	2.54	2.20	2.90	8.70	8.56	1.59	96.75	17.35
Grain yield per panicle	14.68	10.55	22.5	16.16	15.69	3.90	94.16	31.36

Table 4. Eigen values, Percentage of variation and Cumulative percentage for principal components

Principal Components	Eigen values	Percentage of variation	Cumulative percentage
PC1	3.80	37.99	37.99
PC2	2.51	25.07	63.06
PC3	1.15	11.48	74.54
PC4	0.94	9.41	83.96
PC5	0.70	6.99	90.95
PC6	0.42	4.23	95.18
PC7	0.23	2.31	97.49
PC8	0.14	1.39	98.88
PC9	0.07	0.68	99.56
PC10	0.04	0.44	100.00

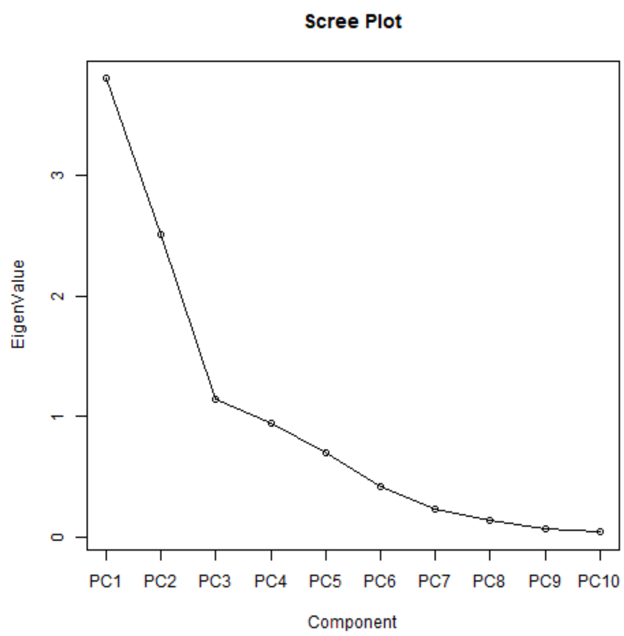

Fig. 1. Scree plot diagram using principal components and their Eigenvalue

PC2, the variability was exerted positively by number of basal tillers, panicle length, 1000 grain weight and grain yield per panicle. Similarly, from PC3 the traits namely, number of basal tillers, flag leaf length, flag leaf width, number of branches per panicle and plant height were observed to be the positive contributors towards the total variability (**Table 5**). The rest of the traits had a negative influence on their principal components towards the overall variability. Hence, these traits namely days to 50% flowering, peduncle length, number of basal tillers, panicle length, 1000 grain weight, grain yield per panicle, flag leaf length, flag leaf width, number of branches per panicle and plant height were found to be varying among the genotypes analysed and thus selection for these traits will be effective for future breeding programs. Similar contribution of these traits towards variability through principal components was also reported by Nirmalakumari *et al*. (2010). Further, the equal loadings of positive and negative in PC's depicted the presence of multivariable differences among the landraces for various traits (Prabu *et al*.2020). Hence, this population could be exploited in future with other little millet germplasm for effective selection and improvement.

Considering the interaction among the traits in the PCA biplot, the traits *viz*., number of basal tillers, 1000 grain weight, panicle length, plant height, flag leaf blade length, flag leaf blade width and number of branches per panicle were found to show a positive correlation towards grain yield per plant. Thus, these traits can be considered as a major selection indices for single plant yield (**Fig. 2**.). From the PCA biplot, the genotypes *viz., chittan samai* and *perunsamai* were found to be desirable for 1000 grain weight and basal tillers. Additionally from biplot the

Table 5. Contribution of first three principal components to variation in little millet landraces/varieties

Parameters	PC1	PC2	PC3
Plant height	-0.1847	-0.4515	0.0395
Basal tillers	-0.3037	**0.2841**	**0.3235**
Days to 50% flowering	0.1090	-0.5081	-0.2986
Peduncle length	**0.1325**	-0.4738	-0.1561
Flag leaf length	-0.3958	-0.2711	0.2533
Flag leaf width	-0.3662	-0.2976	0.1063
Panicle length	-0.3018	0.0856	-0.5902
No.of. branches per panicle	-0.4267	-0.0106	0.0497
1000 grain weight	-0.2167	0.2479	-0.5943
Grain yield per panicle	-0.4830	0.0418	-0.0254

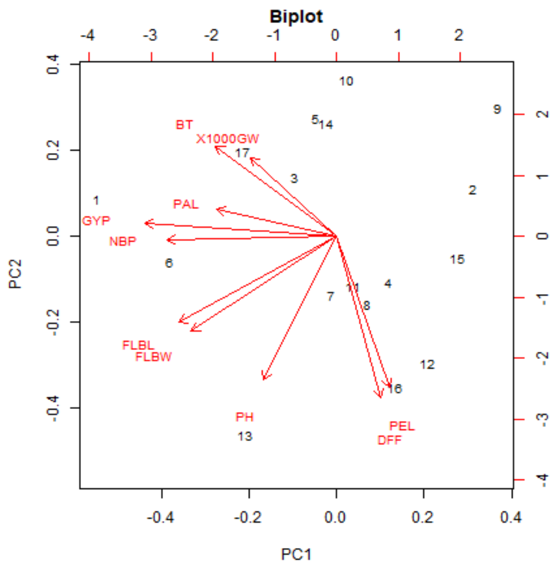

Fig. 2. Biplot diagram of PC1 and PC2

(BT: Basal tillers, 1000GW: 1000 grain weight, PAL: Panicle length, GYP: Grain yield per panicle, NBP: Number of branches per panicle, FLBL: Flag leaf length, FLBW: Flag leaf width, PH: Plant height, PEL: Peduncle length, DFF: Days to 50% flowering) genotypes namely, ATL 1 and CO4 (*samai*) exhibited a better performance for the traits such as grain yield per panicle and number of branches per panicle. Similarly, *paakulam karunjamai* and *vellai samai* were observed to be plotted nearer the plant height axis depicting its higher performance for plant height. Thus, *chittan samai*, *perunsamai*, ATL 1, CO 4 (*samai*), *paakulam karunjamai* and *vellai samai* could be identified as the desirable genotypes which could be used in future hybridization program of little millet. The selection of desirable genotypes from PCA biplot trait axis was also suggested by Selvi *et al*. (2015).

Analysis of the nine qualitative traits revealed a considerable amount of variability among the little millet genotypes. Among all**,** the plant growth habit was observed to be erect in 14 genotypes, while three of the genotypes exhibited a decumbent growth habit. Thus, among the genotypes, erect growth habit was observed to be predominant in nature. Regarding the pigmentation in leaf sheath, except for IR 20, all other genotypes were pigmented. With respect to the pubescence in leaf sheath, leaf blade and ligule, the leaf sheath pubescence was observed in CO 4 and IR 8 *samai*. Similarly, ligule pubescence was exhibited by *siru samai*. However, the leaf blade pubescence was recorded in IR 8 *samai* (**Table 6**). These unique features in the little millet landraces could be used as key traits to identify these landraces from different germplasm collections.

The little millet landraces were found to exhibit a higher variation for inflorescence shape, panicle compactness and seed colour than the rest of the qualitative traits **(Table 6**). Similar observations of variability in qualitative traits were reported by Vetriventhan *et al*. (2021). Among the 17 genotypes, seven were found to exhibit a diffused inflorescence shape and nine comprised of arched shape while *vellai samai* showed a globose-elliptic type of inflorescence. Open panicle was found in seven genotypes, while the panicle was compact in four. Further, six genotypes revealed an intermediate type of panicle. It was also observed that the landraces that recorded a higher yield depicted a diffused shape of inflorescence with an open panicle type (**Table 6 and Table 7**). Hence, these two qualitative traits could be further screened among other genotypes and could be utilised as an indicator of yield in little millet (**Fig. 3)**

Culm branching was observed in all the genotypes except for *siru samai*, *paakulam karunjamai* and *perungolai samai*. Among all the genotypes, a higher variation was observed for seed colour. Out of the 17 genotypes, eight were brown and five were light brown while grey was observed in CO 4 (*samai*) and dark grey was in *paakulam karunjamai*. Further two genotypes depicted a golden yellow colour (**Fig. 4**). Thus, the predominant seed colour types were observed to be brown and light brown among the landraces (**Table 6**).To conclude, the present study exhibited a

Table 6. Qualitative traits recorded in the little millet genotypes

S.No.	Genotype	PGH	PLS	LSP	LP	LBP	IS	CB	PC	GC
1	*Samai ATL 1*	Erect	P	A	A	A	Diffused	P	Open	Light brown
2	*Kolunthana samai*	Erect	P	A	A	A	Diffused	P	Open	Brown
3	*Chittan samai*	Erect	P	A	A	A	Diffused	P	Open	Brown
4	*IR 20 samai*	Erect	A	A	A	A	Arched	P	Intermediate	Light brown
5	*Kottathara samai*	Erect	P	A	A	A	Diffused	P	Open	Brown
6	*CO 4 samai*	Decumbent	P	P	A	A	Arched	P	Intermediate	Grey
7	*Vellai samai*	Erect	P	A	A	A	Globose-elliptic	P	Compact	Brown
8	*Periya samai*	Erect	P	A	A	A	Arched	P	Compact	Golden yellow
9	*IR 8 samai*	Erect	P	P	A	P	Arched	P	Intermediate	Light brown
10	*Siru samai*	Erect	P	A	P	A	Diffused	A	Open	Light brown
11	*Kalman samai*	Erect	P	A	A	A	Arched	P	Intermediate	Brown
12	*Kothu samai*	Erect	P	A	A	A	Arched	P	Intermediate	Brown
13	*Paakulam karunjamai*	Decumbent	P	A	A	A	Arched	A	Compact	Dark grey
14	*Jawadhu local samai*	Erect	P	A	A	A	Diffused	P	Open	Light brown
15	*Perungolai samai*	Erect	P	A	A	A	Arched	A	Intermediate	Brown
16	*Kochamai*	Erect	P	A	A	A	Arched	P	Compact	Golden yellow
17	*Perunsamai*	Decumbent	P	A	A	A	Diffused	P	Open	Brown

(PGH: Plant Growth Habitat, PLS: Pigmentation at Leaf Sheath, LSP: Leaf Sheath Pubescence, LP: Ligule Pubescence, LBP: Leaf Blade Pubescence, IS: Inflorescence Shape, CB: Culm Branching, PC: Panicle Compactness, GC: Grain Colour, P: Present, A: Absent)

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CO 4 samai
IS- Arched
PC- Intermediate

Paakulumkarunsamai
IS- Arched
PC- Compact

Chittansamai
IS- Diffused
PC- Open

Kolunthanasamai
IS- Diffused
PC- Open

Kothusamai
IS- Arched
PC- Intermediate

Kottatharasamai
IS- Diffused
PC- Open

Samai ATL 1
IS- Diffused
PC- Open

Sirusamai
IS- Diffused
PC- Open

Vellaisamai
IS- Globose-elliptic
PC- Compact

Periyasamai
IS- Arched
PC- Compact

Jawadhu local samai
IS- Diffused
PC- Open

Perungolaisamai
IS- Arched
PC- Intermediate

Fig 3. The inflorescence shape and panicle compactness of little millet landraces (IS: Inflorescence shape, PC: Panicle compactness)

Table 7. Mean Performance of the Little Millet Genotypes for Morphological traits

Genotype	DTF	BT	PH	PEL	FLL	FLW	PAL	NBP	1000SW	GYP
Samai ATL 1	45.00	8.42	104.17	11.50	27.26	1.22	24.32	6.10	2.61	21.13
Kolunthana samai	51.17	5.44	91.43	12.17	18.68	0.81	18.11	4.14	2.25	12.22
Chittan samai	52.67	7.30	95.62	14.39	21.32	0.94	22.49	4.84	2.85	16.23
IR 20 samai	55.00	5.49	96.20	14.60	22.76	1.02	22.78	4.14	2.24	13.20
Kottathara samai	51.00	6.63	73.38	11.33	24.36	1.07	23.79	4.15	2.76	14.53
CO4 samai	51.67	7.04	96.06	13.42	29.22	1.24	26.02	5.22	2.52	18.35
Vellai samai	74.00	6.06	95.35	16.13	20.63	1.06	24.04	5.11	2.72	14.22
Periya samai	80.33	5.76	110.19	13.20	21.04	0.87	21.33	4.63	2.66	14.29
IR 8 samai	52.00	6.42	75.57	13.18	17.54	0.70	20.38	3.23	2.42	12.58
Siru samai	52.00	9.52	75.66	13.58	20.41	0.81	20.28	5.22	2.60	13.52
Kalman samai	80.33	5.42	84.22	15.14	22.12	1.05	28.52	4.12	2.56	14.23
Kothu samai	80.00	5.21	98.17	16.30	22.29	0.85	20.34	4.64	2.20	13.63
Paakulam karunjamai	81.67	7.51	106.20	16.46	29.67	1.27	20.24	5.35	2.33	15.11
Jawadhu local samai	50.00	6.74	86.81	13.01	20.81	0.88	24.39	4.53	2.86	15.20
Perungolai samai	60.00	6.11	85.59	14.40	21.71	1.04	17.35	3.54	2.30	11.55
Kochamai	71.00	5.76	102.57	20.27	22.66	1.02	19.25	4.18	2.68	13.57
Perunsamai	53.33	7.09	94.24	11.74	22.34	0.93	24.33	6.25	2.74	16.07

DTF: Days to 50% flowering, BT: Basal Tillers, PH: Plant Height, PEL: Peduncle Length, FLL: Flag Leaf Length, FLW: Flag Leaf Width, PAL: Panicle length, NBP: Number of Branches per Panicle, 1000SW: 1000 Seed weight, GYP: Grain Yield per Panicle

ATL 1 (light brown)

Kolunthana samai (Brown)

Chittan samai (Brown)

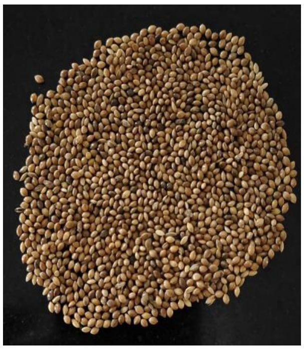
IR 20 samai (light brown)

Kottathara samai (Brown)

CO 4 samai (Grey)

Vellai samai (Brown)

Periya samai (Golden yellow)



IR 8 samai (light brown)

Siru samai (light brown)

Kalman samai (Brown)

Kothu samai (Brown)



Paakulam karunjamai (Dark grey)   Jawadhu local samai (light brown)   Perungolai samai (Brown)


Kochamai (Golden yellow)   Perunsamai (Brown)

Fig. 4. Grain colour of the little millet genotypes

higher variability for days to 50% flowering, basal tillers, flag leaf length, flag leaf width, panicle length, peduncle length, plant height and grain yield per panicle among little millet genotypes. Thus, these population could be utilized for further selection in breeding programs. Since, this involves the landraces and their characterization, the genotypes could be further used in other germplasm collections to broaden the genetic base of the little millet collections. Among all the genotypes, *chittan samai*, *perunsamai*, ATL 1, CO 4 (*samai*), *paakulam karunjamai* and *vellai samai* were identified as desirable genotypes for yield attributing traits and could be implied in little millet breeding programs in future. The DUS descriptors utilized in the study could be used to identify the true to type landraces in future.

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