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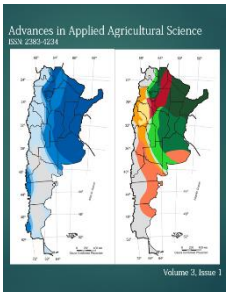

Research Article

Genetic variability and character association in little millet (*Panicum sumatrense*) germplasm collections of (Odisha, India)

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ABSTRACT

Twenty-two genotypes of little millet (*Panicum sumatrense*) were evaluated under 12 environments during Autumn 2008 to Autumn 2009 at the Central Research Station, OUAT, and Bhubaneswar. Analysis of variance on 14 metric traits revealed highly significant differences due to genotypes, environments and genotype x environment interactions. Early maturing genotypes RCM 4 and KCM 594 were the lowest yielders and displayed lower mean performance for most of the component traits. The highest yielder TNAU 98 is a late maturing genotype, having maximum values for plant height, flag leaf length and area, panicle length, panicle exsertion, panicle weight, panicle yield, straw yield, biological yield, and 1000-grain weight resulting in high harvest index. Higher grain yield was also recorded by KCM42, KCM 84, KCM 102D and CO 2 with relatively higher mean performance for all the component characters. Moderate to high estimates of genotypic coefficient of variation, heritability and genetic advance were observed for grain yield, flag leaf area, panicle exsertion, panicle yield, panicle weight, straw yield and biological yield. Grain yield exhibited high positive correlation with all the characters except panicle exsertion and panicle number. Path analysis pooled over environments revealed that biological yield, harvest index and days to heading had maximum contribution towards grain yield.

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Millet is considered as one among the primitive grain yielding crops cultivated ever since the Neolithic period. The oldest historical roots of millets are found in China sometimes in 4500 B.C., where it was adjudged to be a sacred crop. The first record of its cultivation goes back to Chinese civilization during 2800 B.C. Millets represent a collective term referring to a number of small seeded cereals which constitute a part of the classified group of coarse cereals under the family Poaceae. Minor millet is

diverse enough containing 14 cultivated species having their locus-stand under the sub-family Panicoideae and two tribes namely Paniceae and Chlorideae (Rachie, 1975). The genus *Panicum* is one of the largest genera of the grasses constituting more than 400 species distributed primarily in the tropics and sub-tropics and also in the warmer parts of the temperate zones (Roshevits, 1980). Two economically important species within the genus are common millet and little millet. (Cobley, 1976). . Most of the minor millets excepting a few demand South East Asiatic origin covering central Asia and North Africa regions. (Vavilov, 1951; Smith, 1969 and Hutchinson, 1974). Little millet (*Panicum sumatrense Roth ex Roem and Schult* syn *Panicum miliare* Lamk) is an important cultivated species under the tribe Paniceae, sub-family Panicoideae and family Poaceae (Rachie, 1975). It is supposed to have been domesticated in India (Roshevit **,** 1980) and is a source of staple food in its growing region besides providing raw material for industrial products such as starch, malting, brewing, ethanol, jaggery, fast food, cattle feed and fodder. It is invariably grown in Arid and Semi-arid tropics. The spatial distribution of this crop is largely dependent on amount of rainfall. Little millet is usually grown under scarce moisture conditions in areas where no other cereal crop can grow. First systematic germplasm collection of little millet in India was made in 1961 under PL-480 project on 'Storage, maintenance and distribution of millet germplasm'. A germplasm unit was established at Bangalore in 1980 to conserve the millet genetic resources (Seetharam and Rao, 1988; Seetharam, 1997). Genetic variability and Character association between yield and its component characters of little millet was studied extensively using quantitative and qualitative characters (Reddy,1985-; Chaturvedi *et al*., 1990-; Rao,1991-; singh et al.,1995-; Chidambaram & Palanisamy,1996) and reported high genetic variability and high heritability associated with high genetic advance for different characters. However little millet collections of tribal districts of Odisha, India is less studied. Tribal farmers of Odisha, India have been growing localized traditional land races being isolated by forest, mountains, hills and gullies as natural barrier for introgression of genes. These landraces with acceptable phenotypic uniformity are considered to be genetically heterogeneous. These collections, on evaluation, are expected to differentiate between and within the collections resulting in isolation of pure lines with high yielding potential. The broadening of varietal base by including varieties of different maturity periods will definitely impact further production stability. The knowledge of genetic variability in the available germplasm and association of yield with component traits will be quite helpful in evolving genotypes with better yield.

Materials and methods

The investigation was carried out at the Central Research Station OUAT, Bhubaneswar during the period from autumn 2008 to autumn 2009 under 12 different environmental conditions generated through different dates of sowing (Table I). The test genotypes consisting of 17 local germplasms collected from 9 tribal districts of Odisha were evaluated along with 5 released varieties as checks (Table II). The genotypes were sown in RCBD with three replications and observations were recorded for grain yield and 13 component characters *i.e*. days to heading, plant height, flag leaf length, flag leaf area, panicle length, panicle exsertion, panicle number, panicle weight, panicle yield, straw yield, biological yield, harvest index and 1000-grain weight. The coefficient of variability, heritability in broad sense and

Table 1. *Details of 12 environments used for studying the genetic variability and character association of little millet in Odisha, India.*

Environment	Std. week No	Total rainfall (mm)	Total rainy days	Avg R.H	Avg temp (^{0}C)		Avg. sunshine hour	Avg. evaporation (mm)
					Max	Min		
Vegetative Phase								
Env.1	27*-31	294.8	30.0	83.3	31.5	26.0	3.7	3.8
Env.2	29-33	312.8	30.0	82.5	31.6	25.7	4.1	3.3
Env.3	32-36	467.2	27.0	85.2	31.5	25.3	4.0	3.2
Env.4	36-40	432.5	24.0	87.4	31.3	25.1	4.3	3.3
Env.5	40-44	471.8	20.0	86.3	31.0	23.9	5.6	3.4
Env.6	45-49	0.0	0.0	70.3	30.1	16.4	9.2	3.5
Env.7	49-1**	2.5	1.0	67.7	26.7	15.0	7.6	3.3
Env.8	8-12	0.0	0.0	64.5	35.8	20.4	9.3	6.2
Env.9	12-16	2.8	3.0	71.8	37.3	25.1	8.5	7.3
Env.10	21-25	146.1	7.0	69.8	39.3	26.9	7.7	7.4
Env.11	23-27	169.8	12.0	72.3	36.1	26.5	6.1	6.2
Env.12	26-30	256.9	21.0	80.2	34.0	25.8	4.6	4.5
Reproductive Phase								
Env.1	32*-37	481.7	32.0	85.6	31.5	25.3	4.0	3.3
Env.2	34-40	713.4	36.0	87.8	31.2	25.1	3.9	3.3
Env.3	37-42	472.6	26.0	86.8	31.3	24.7	4.9	3.4
Env.4	41-47	259.9	14.0	79.2	30.9	21.0	7.4	3.5
Env.5	45-51	2.5	1.0	69.9	29.3	16.2	8.4	3.5
Env.6	50-4**	10.6	2.0	69.1	27.2	15.0	7.7	3.4
Env.7	2-8	10.6	2.0	68.6	29.6	15.7	8.6	3.5
Env.8	13-18	101.8	9.0	72.4	34.9	24.9	8.3	6.9
Env.9	17-22	142.4	10.0	69.7	37.6	26.1	8.6	7.5
Env.10	26-32	407.8	33.0	82.1	33.0	25.6	3.9	4.2
Env.11	28-34	494.1	38.0	86.0	31.6	25.4	3.2	3.6
Env.12	31-36	340.7	28.0	85.3	31.7	25.6	3.9	3.4

*It is the 27th week of 2008 ** It is the 1st week of 2009

genetic advance were computed following Hanson *et al* (1956) and Johnson *et al* (1955).The genotypic and phenotypic correlations and path coefficients were computed following Al-Jibouri *et al* (1958) and Dewey & Lu (1959).

Results and discussion

The pooled analysis over environments showed that differences due to genotypes, environments and genotype x environment interactions were highly significant for all the characters (Table III).

Performance of the genotypes showed a wide range of variation for all the characters (Table IV). The overall varietal means for grain yield ranged from 10.5 g in KCM 594 and RCM 4 to 16.9 g in TNAU 98. The earliest to flower was RCM 4 (45.2 days) closely followed by KCM 594 (45.9 days), while the late maturing genotype was TNAU 98 (54.4 days) followed by KCM 309 (51.9 days). Plant height varied from 81.5 cm in RCM 4 followed by KCM 594 (82.5cm) to 103.0 cm in TNAU 98. Mean for flag leaf length ranged from 18.7 cm in

Table 2. *Description of the genotypes under study collected from Odisha, India*

Sl. No.	Genotype	IC No.	Parentage	Places of origin in India	Release date
1	KCM 42	273560	Local collection	Nandapur, Koraput, Odisha	
2	KCM 84	298393	Local collection	Raikia, Kandhamal, Odisha	
3	KCM 102D	298411	Local collection	Tumudibandha, Kandhamal, Odisha	
4	KCM 103	298412	Local collection	Tumudibandha, Kandhamal, Odisha	
5	KCM 121	298430	Local collection	Kotagarh, Kandhamal, Odisha	
6	KCM 153	-	Local collection	Rayagada, Rayagada, Odisha	
7	KCM 309	321724	Local collection	Thuamul-Rampur, Kalahandi, Odisha	
8	KCM 404	321819	Local collection	G.Udayagiri, Kandhamal, Odisha	
9	KCM 405	321820	Local collection	G.Udayagiri, Kandhamal, Odisha	
10	KCM 594	-	Local collection	Loisinga, Bolangir, Odisha	
11	RCM 4	-	Local collection	Aska, Ganjam, Odisha	
12	RCM 7	-	Local collection	Kasipur, Rayagada, Odisha	
13	RCM 10	-	Local collection	Rambha, Ganjam, Odisha	
14	RCM 16	-	Local collection	Kandhamal, Odisha	
15	RCM 17	-	Local collection	Paralakhemundi, Gajapati, Odisha	
16	RCM 20	-	Local collection	Boudh, Odisha	
17	RCM 22	-	Local collection	Nuapada, Odisha	
18	Kolab (OLM-36)	1134(E)/15.11.01	Mutant of SS 88-1	RRS, Semiliguda, Odisha	2001
19	Sabar(OLM-20)		Pureline selection	RRS, Semiliguda, Odisha	
20	PRC 3		GPM 97	Coimbatore, Tamilinadu	1985
21	CO 2	13/19.12.78	Pureline selection	Coimbatore, Tamilnadu	1978
22	TNAU 98		CO 2 x TNAU 81	Coimbatore, Tamilinadu	

Table 3. *Analysis of variance for 14 characters of 22 genotypes of little millet pooled over 12 environments*

Character	Mean square				
	Reps/Env. (24)[@]	Genotype (21)	Environment (11)	G X E (231)	Pooled error (504)
Grain yield (GY)	3.0	98.19**	2731.49**	20.51**	2.20
Days to heading (DH)	2.6	128.8**	989.28**	12.08**	0.82
Plant height (PH)	2.8	660.65**	3828.32**	45.47**	4.43
Flag leaf length (FLL)	0.5	29.03**	270.68**	6.51**	0.66
Flag leaf area (FLA)	0.2	19.72**	170.48**	3.52**	0.24
Panicle length (PL)	0.3	62.78**	391.09**	6.75**	0.70
Panicle exsertion (PE)	0.1	8.76**	847.30**	3.11**	0.26
Panicle number (PN)	3.5	410.53**	6835.36**	141.95**	7.48
Panicle weight (PW)	0.002	0.05**	0.92**	0.01**	0.001
Panicle yield (PY)	3.8	153.01**	3765.77**	33.49**	2.92
Straw Yield (SY)	1.4	301.29**	9817.65**	90.28**	4.11
Biological yield (BY)	5.5	757.6**	18834.86**	156.46**	7.56
Harvest index (HI)	8.5	97.18**	4478.94**	36.20**	5.05
1000-grain weight (GW)	0.01	0.44**	2.09**	0.02**	0.0004

@Figures in parentheses indicate the degrees of freedom.

Table 4. *Mean performance of 22 genotypes of little millet for 14 characters pooled over 12 environments.*

Sl No	Genotype	**GY (g)	DH	PH (cm)	FLL (cm)	FLA (cm^2)	PL (cm)	PE (cm)	PN	PW (g)	PY (g)	SY (g)	BY (g)	HI (%)	GW (g)
1	KCM 42	15.4	48.2	90.0	20.5	9.8	24.1	3.3	53.1	0.41	22.0	35.8	57.8	**27.1**	2.12
2	KCM 84	14.6	48.3	89.9	20.5	9.5	24.5	3.3	56.9	0.38	21.8	36.6	58.4	24.8	2.12
3	KCM102D	16.1	49.9	91.4	20.5	9.5	24.7	3.4	54.4	0.43	23.0	35.8	58.8	27.1	2.13
4	KCM 103	12.2	47.2	84.9	20.3	9.2	23.9	3.2	56.7	0.32	17.8	32.7	50.6	24.6	2.10
5	KCM 121	14.1	49.4	90.1	20.5	9.2	24.1	3.3	57.5	0.36	20.9	36.0	56.9	24.0	2.12
6	KCM 153	13.9	48.1	90.6	20.2	9.5	24.6	3.3	54.8	0.38	20.3	36.5	56.7	24.0	2.17
7	KCM 309	12.3	51.9	95.2	20.0	9.6	24.9	**1.7**	**46.1**	0.42	19.1	39.1	58.2	21.0	**1.76**
8	KCM 404	12.7	49.0	88.4	19.5	8.5	23.7	3.3	54.3	0.36	19.0	34.2	53.2	24.4	2.06
9	KCM 405	13.4	48.7	91.3	20.1	9.3	25.0	2.5	54.4	0.37	19.8	35.2	55.0	24.3	2.19
10	KCM 594	**10.5***	45.9	82.5	19.9	8.6	22.4	3.2	51.0	**0.32**	**16.1**	**30.8**	**46.9**	22.0	2.10
11	RCM 4	**10.5**	**45.2**	**81.5**	**18.7**	**8.3**	**21.6**	3.0	49.2	0.33	16.3	33.7	50.0	**20.8**	2.12
12	RCM 7	14.1	48.5	88.1	20.3	9.5	22.9	3.7	51.4	0.40	20.3	34.1	54.4	25.5	2.15
13	RCM 10	11.7	47.3	88.4	20.0	9.0	23.5	3.8	54.5	0.33	17.8	34.3	52.0	23.4	2.12
14	RCM 16	12.3	48.1	90.2	20.3	9.4	24.4	3.7	53.5	0.35	18.9	34.3	53.2	23.6	2.09
15	RCM 17	12.1	49.5	89.9	19.3	9.0	22.6	3.1	47.8	0.39	18.3	34.9	53.2	22.8	1.98
16	RCM 20	12.6	48.0	89.5	20.5	9.5	24.5	3.0	52.6	0.38	20.0	34.7	54.7	23.3	2.10
17	RCM 22	13.1	48.3	86.9	19.4	8.9	22.1	4.0	47.9	0.42	19.7	33.4	53.1	25.6	2.14
18	Kolab	12.5	48.2	90.0	19.8	9.2	23.7	2.9	56.7	0.33	18.7	35.1	53.9	22.7	2.16
19	Sabar	14.1	47.3	91.6	21.4	10.0	24.9	3.4	**58.2**	0.36	21.0	38.0	59.0	23.7	2.08
20	PRC 3	11.9	48.5	92.0	20.1	9.1	24.5	3.1	54.7	0.34	18.2	37.0	55.2	22.1	2.18
21	CO 2	14.7	47.4	92.6	21.0	9.7	24.8	3.5	57.0	0.39	22.4	39.1	61.4	24.2	2.16
22	TNAU 98	**16.9**	**54.4**	**103.0**	**23.3**	**12.1**	**28.0**	**4.0**	51.5	**0.47**	**24.1**	**45.3**	**69.4**	24.9	**2.41**
	Mean	13.3	48.5	89.9	20.3	9.4	24.1	3.3	53.4	0.37	19.8	35.8	55.5	23.9	2.12
	C.D.5%	0.6	0.4	0.8	0.3	0.2	0.3	0.2	1.1	0.01	0.7	0.8	1.1	0.9	0.01
	C.D.1%	0.8	0.5	1.2	0.5	0.3	0.5	0.3	1.5	0.02	0.9	1.1	1.5	1.2	0.01

*The underlined figures indicate the highest(double) and the lowest(single) values
**Abbreviation for characters as in Table 1

RCM 4 to 23.3 cm in TNAU 98 and the same varieties had extreme values for flag leaf area ranging from 8.3 to 12.1 cm^2. The genotype RCM 4 registered the lowest panicle length (21.6 cm) and TNAU 98, the maximum (28 cm). Panicle exsertion among the test entries varied from 1.7 cm in KCM 309 to 4.0 cm in RCM 22 and TNAU 98. The varietal means over environments for panicle number ranged from 46.1 in KCM 309 to 58.2 in Sabar. The panicle weight ranged from 0.32 g in KCM 594 to 0.47 g in TNAU 98 and the same varieties had the extreme values for panicle yield ranging from 16.1 g to 24.1g. Among the test entries KCM -594 recorded the lowest straw yield of 30.8 g whereas TNAU 98 the highest (45.3g). Varietal means for biological yield ranged from 46.9 g in KCM 594 to 69.4 g in TNAU 98. The harvest index varied from 20.8 per cent in RCM 4 to 27.1 per cent in KCM 42. Mean for 1000-grain weight varied from 1.76 g in KCM 309 to 2.41 g in TNAU 98. The earliest flowering genotype RCM 4 was the lowest yielder possessing the minimum height with lowest values for flag leaf length and area, panicle length and harvest index. The second earliest genotype KCM 594 was also the lowest yielder possessing short height and the minimum values for panicle weight, panicle yield, straw yield and biological yield.

The late maturing genotype TNAU 98 was the highest yielder having maximum values for plant height, flag leaf length and area, panicle length, panicle exsertion, panicle weight, panicle yield, straw yield, biological yield, and 1000-grain weight with high harvest index. Besides TNAU 98, high grain yield was recorded by KCM 42, KCM 84, KCM 102D and CO 2 with relatively higher mean performance for all the component characters.

Genotypic and phenotypic coefficients of variation (GCV and PCV) were high for grain yield and panicle exsertion, while it was moderately high for panicle weight and panicle yield, and moderate for flag leaf area, straw yield and biological yield (Table V). The estimates of heritability (h^2) in broad sense were relatively high for all 14 characters ranging from 62.8 to 94.8 per cent. The predicted genetic advance (GA) was high for grain yield, panicle exsertion, panicle weight and panicle yield. It was moderate for biological yield, flag leaf area, straw yield, 1000-grain weight and panicle length. These parameters of variability unbiased by GE interaction have great potential value in selection. The results thus indicate that the evaluation of varietal characters across environments rather than at individual environment leads to precision in predicting probable future performance of the varieties in respect of the characters (Bradley *et al*., 1988). Hereditary variance is constituted of additive and non-additive components, while genetic advance under selection is based on additive effects of genes. In the present study, moderate to high estimates of h^2 along with GA and GCV for grain yield, panicle yield, panicle weight, flag leaf area, panicle exsertion, straw yield and biological yield is indicative of better response to selection due to preponderance of additive gene action. Similar results have been reported in different sets of experimental material by different workers (Yadav & Srivastava, 1976- ; Rao, 1991-; Akhtar & Choudhary, 1998-; Baghel and Maloo, 2002- ; Sasamala *et al.*, 2011- ; Reddy and Reddy 2012).

Positive association of grain yield was significant with all the component characters except panicle exsertion and panicle number in pooled analysis over 12 environments. Besides, the correlation coefficients of grain yield with these characters varied greatly from environment to environment indicating differential response of the genotypes for their character expression

***Table 5**. Estimates of coefficients of variability (GCV and PCV), heritability (h^2) and genetic advance (GA) for 14 characters of 22 genotypes of little millet pooled over 12 environments*

Character	**GCV**	**PCV**	**h^2(bs) (%)**	**GA**	**GA (% of mean)**
Grain yield (GY)	11.1	12.5	79.1	2.7	20.3
Days to heading (DH)	3.7	3.9	90.6	3.5	7.3
Plant height (PH)	4.6	4.8	93.1	8.2	9.1
Flag leaf length (FLL)	3.9	4.4	77.6	1.4	7.1
Flag leaf area (FLA)	7.2	7.9	82.2	1.3	13.4
Panicle length (PL)	5.2	5.5	89.3	2.4	10.1
Panicle exertion (PE)	12.1	15.1	64.5	0.7	20.1
Panicle number (PN)	5.1	6.3	65.4	4.6	8.5
Panicle weight (PW)	9.3	10.3	83.0	0.1	17.5
Panicle yield (PY)	9.2	10.4	78.1	3.3	16.8
Straw Yield (SY)	6.8	8.1	70.0	4.2	11.7
Biological yield (BY)	7.4	8.3	79.3	7.5	13.5
Harvest index (HI)	5.4	6.9	62.8	2.1	8.9
1000-grain weight (GW)	5.1	5.2	94.8	0.2	10.2

(Table VI). High positive correlation of grain yield with days to heading was observed in two, out of twelve environments. Plant height and flag leaf length had positive correlation with grain yield in all the environments with significant correlation recorded in seven and six cases respectively. Both flag leaf area and panicle length exhibited positive correlation with grain yield in eleven environments, six of which were significant. Panicle exsertion did not exhibit any significant correlation with grain yield or in the pooled analysis.

The correlation coefficients estimated between grain yield and panicle number were positive in all twelve environments but statistically significant in nine environments. Therefore non-significance of positive association of grain yield with panicle number in pooled analysis could be ascribed to G x E interaction as revealed in analysis of variance. Grain yield showed significant positive correlation with panicle weight, panicle yield, straw yield, biological yield and harvest index in 9, 12, 4, 11 and 10 environments, respectively. The association between grain yield and 1000-grain weight was of moderate magnitude in positive direction in most of the environments being significant only in two cases. At the genotypic level, the correlation of grain yield with the component characters reflected similar patterns of association as at the phenotypic level. But the genotypic correlation coefficients were higher in magnitude (direction remaining same) as compared to phenotypic values in most of the characters. Thus grain yield is found to be highly correlated with most of the component traits like days to heading, plant height, flag leaf length, flag leaf area, panicle length, panicle weight, panicle yield, straw yield, biological yield, harvest index and 1000-grain weight suggesting that selection based on these characters would be effective in desired direction as has been observed in earlier studies (Reddy, 1985; Sen and Hamid , 1986 ; Chaturvedi *et al.*, 1990 ; Singh *et al.*, 1995; Channappagoudar *et al.*, 2007 ; Salini *et al.*, 2010 and Sasamala *et al.*, 2011).

Table 6. *Phenotypic(r_p) and genotypic(r_g) correlation coefficients of grain yield with 13 other characters of 22 genotypes of little millet in 12 environments and pooled over environments*

Env. (D/S)	Corr.	DH	PH	FLL	FLA	PL	PE	PN	PW	PY	SY	BY	HI	GW
1	r_p	-0.071	0.170	0.230	0.209	0.361	-0.248	0.653**	-0.144	0.978**	0.284	0.428*	0.392	0.268
(5.7.08)	r_g	-0.055	0.186	0.268	0.240	0.388	-0.328	0.698	-0.235	0.990	0.316	0.447	0.349	0.287
2	r_p	-0.352	0.258	0.456*	0.209	0.324	0.228	0.223	0.160	0.587**	-0.120	0.124	0.902**	0.113
(20.7.08)	r_g	-0.371	0.279	0.505	0.217	0.348	0.258	0.219	0.142	0.586	-0.112	0.125	0.901	0.125
3	r_p	-0.021	0.530*	0.372	0.426*	0.576**	-0.048	0.553**	0.394	0.951**	0.384	0.700**	0.864**	0.352
(5.8.08)	r_g	-0.044	0.602	0.376	0.449	0.616	-0.034	0.555	0.363	0.967	0.444	0.741	0.864	0.381
4	r_p	0.553**	0.761**	0.645**	0.661**	0.604**	0.224	0.677**	0.896**	0.991**	0.527*	0.871**	0.870**	0.033
(5.9.08)	r_g	0.581	0.777	0.662	0.683	0.632	0.240	0.705	0.914	0.996	0.538	0.878	0.874	0.034
5	r_p	0.320	0.644**	0.507*	0.444*	0.566**	-0.018	0.581**	0.846**	0.985**	0.370	0.852**	0.695**	0.188
(5.10.08)	r_g	0.336	0.670	0.542	0.461	0.596	-0.017	0.600	0.871	0.994	0.385	0.862	0.678	0.204
6	r_p	0.292	0.542**	0.606**	0.661**	0.516*	0.107	0.339	0.797**	0.983**	0.603**	0.897**	0.863**	0.397
(5.11.08)	r_g	0.309	0.566	0.653	0.695	0.553	0.114	0.355	0.810	0.999	0.661	0.925	0.877	0.413
7	r_p	0.084	0.117	0.035	0.070	-0.018	0.193	0.586**	0.544**	0.882**	-0.043	0.647**	0.853**	0.486*
(5.12.08)	r_g	0.071	0.143	0.004	0.047	-0.060	0.216	0.613	0.512	0.887	-0.113	0.625	0.863	0.511
8	r_p	0.083	0.549**	0.600**	0.625**	0.514*	0.158	0.042	0.764**	0.894**	0.140	0.550**	0.845**	0.578**
(20.2.09)	r_g	0.128	0.589	0.697	0.685	0.552	0.174	0.004	0.792	0.925	0.187	0.586	0.835	0.616
9	r_p	-0.304	0.196	0.044	-0.016	0.076	0.151	0.449*	0.663**	0.778**	0.361	0.509*	0.708**	0.073
(20.3.09)	r_g	-0.339	0.222	0.063	-0.002	0.099	0.174	0.450	0.694	0.808	0.370	0.517	0.669	0.063
10	r_p	0.363	0.341	0.266	0.374	0.317	0.086	0.506*	0.456*	0.965**	0.301	0.588**	0.801**	0.272
(20.5.09)	r_g	0.381	0.364	0.291	0.406	0.338	0.120	0.530	0.422	0.978	0.320	0.597	0.785	0.288
11	r_p	0.493*	0.604**	0.531*	0.616**	0.611**	-0.083	0.667**	0.781**	0.962**	0.762**	0.885**	0.147	0.401
(5.6.09)	r_g	0.519	0.640	0.562	0.632	0.627	-0.077	0.708	0.868	1.011	0.797	0.910	0.043	0.412
12	r_p	0.392	0.494*	0.338	0.368	0.397	0.268	0.433*	0.662**	0.935**	0.495*	0.705**	0.647**	0.323
(25.6.09)	r_g	0.407	0.516	0.353	0.380	0.423	0.279	0.460	0.655	0.943	0.503	0.712	0.641	0.335
Pooled	r_p	0.593**	0.687**	0.741**	0.769**	0.686**	0.379	0.291	0.771**	0.981**	0.667**	0.861**	0.766**	0.450*
	r_g	0.633	0.716	0.793	0.815	0.720	0.426	0.280	0.783	0.989	0.716	0.886	0.777	0.467

*, ** Significant at 5% and 1% level, respectively. (D/S) : Date of sowing

Table 7. *Phenotypic path indicating direct and indirect effects of component traits on grain yield of 22 genotypes of little millet pooled over 12 vironments*

Character	DH	PH	FLL	FLA	PL	PE	PN	PW	PY	SY	BY	HI	GW	Corr. with GY
DH	**0.162**	-0.116	-0.001	0.065	-0.093	0.002	0.027	-0.252	-0.408	-1.398	2.517	0.083	0.005	0.593**
PH	0.142	**-0.133**	-0.002	0.077	-0.117	-0.003	-0.006	-0.225	-0.497	-1.710	3.073	0.075	0.013	0.687**
FLL	0.095	-0.103	**-0.002**	0.085	-0.114	-0.028	-0.037	-0.171	-0.515	-1.464	2.829	0.139	0.027	0.741**
FLA	0.117	-0.113	-0.002	**0.090**	-0.112	-0.022	-0.011	-0.226	-0.531	-1.586	3.005	0.136	0.024	0.769**
PL	0.115	-0.119	-0.002	0.077	**-0.131**	-0.002	-0.037	-0.165	-0.492	-1.557	2.883	0.096	0.019	0.686**
PE	-0.004	-0.005	-0.001	0.026	-0.003	**-0.077**	-0.026	-0.063	-0.227	-0.117	0.634	0.208	0.033	0.379
PN	-0.039	-0.007	-0.001	0.008	-0.043	-0.017	**-0.115**	0.117	-0.200	-0.115	0.573	0.109	0.019	0.291
PW	0.123	-0.090	-0.001	0.061	-0.065	-0.015	0.040	**-0.333**	-0.542	-1.177	2.558	0.204	0.007	0.771**
PY	0.096	-0.096	-0.002	0.069	-0.093	-0.025	-0.033	-0.261	**-0.691**	-1.307	3.036	0.268	0.020	0.981**
SY	0.123	-0.123	-0.002	0.077	-0.110	-0.005	-0.007	-0.212	-0.488	**-1.851**	3.216	0.033	0.015	0.667**
BY	0.120	-0.120	-0.002	0.080	-0.111	-0.015	-0.019	-0.251	-0.618	-1.755	**3.392**	0.141	0.019	0.861**
HI	0.035	-0.026	-0.001	0.032	-0.033	-0.042	-0.033	-0.177	-0.482	-0.159	1.248	**0.383**	0.020	0.766**
GW	0.016	-0.034	-0.001	0.043	-0.049	-0.050	-0.043	-0.045	-0.271	-0.559	1.245	0.148	**0.051**	0.450*

P(R) = 0 .107 R SQR (PC) = 98.855

***Bold and diagonal values indicate the direct effect of component traits on grain yield*.

The correlation of grain yield with its component traits at the phenotypic level was analyzed over environments to assess the cause and effect relationship of yield *per se* versus other characters by partitioning into direct and indirect effects at phenotypic level (Table VII). Among the characters with positive direct effect on grain yield it was found that, biological yield was the maximum (3.392) followed by harvest index (0.383) and days to heading (0.162), while the highest direct negative effect was exhibited by straw yield (-1.851) followed by panicle yield (-0.691) and panicle weight (-0.333). The magnitude of positive indirect effect *via* biological yield was high for all the characters i.e. straw yield (3.216), plant height (3.073), panicle yield (3.026), flag leaf area (3.005), panicle length (2.883), flag leaf length (2.829), panicle weight (2.558), days to heading (2.517), harvest index (1.248), 1000-grain weight (1.245), panicle exsertion (0.634) and panicle number (0.573) in that order. All characters had positive indirect effects via harvest index and 1000-grain weight although of low magnitude. The indirect effects *via* days to heading of all the characters except panicle exsertion and panicle number were positive even though of low magnitude. Indirect effect through straw yield was in negative direction for all the characters, highest being for biological yield (-1.755) followed by plant height (-1.710), flag leaf area (-1.586), panicle length (-1.557), flag leaf length (-1.464), days to heading (-1.398), panicle yield (-1.307) and panicle weight (-1.177). Hence selection based on these characters would be more effective for yield improvement in little millet as reported in past by other workers (Yadav and Srivastava , 1976 ; Saxena *et al* , 1979 ; Reddy *et al*, 1984 ; Sen and Hamid,1986).

Conclusion

Analysis of variance revealed highly significant differences due to genotypes, environments and genotype x environment interactions for all the characters. Moderate to high estimates of heritability along with moderate to high genetic advance and genotypic coefficient of variation were observed for grain yield, panicle yield, panicle weight, flag leaf area, panicle exsertion, straw yield and biological yield in little millet. Grain yield exhibited high positive correction with most of the component traits exception being panicle exsertion and panicle number. It is evident from both direct and indirect effects of the characters at phenotypic level that biological yield followed by harvest index and days to heading would be of high value while selecting for grain yield.

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