



Genetic Investigations in Pearl Millet for Yield Components, Rust and Blast Diseases

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Abstract: Three A₁ CMS sources (ICMB 94555, ICMB 98222 and ICMB 96666) were crossed with fifteen potential restorer lines in a line × tester fashion to develop 45 hybrids. All the eighteen parents were evaluated for genetic variability parameters for eleven different quantitative traits. Moderate value of GCV and high value of PCV were observed for the trait grain yield. High estimates of heritability coupled with high genetic advance as per cent of mean was detected for the traits like plant height, panicle length, panicle girth and grain yield, revealing that these traits might be governed by additive gene effects and simple selection would lead to faster genetic enhancement of the genotypes under study. All the crosses along with their parents and checks (GHB 558, VPMH 7 and Kaveri super boss) were screened for rust and blast diseases to identify the resistant hybrids and parents, under field conditions in *kharif* 2021. Only one hybrid ICMA 96666 × PRLN 133 showed resistance towards both rust and blast diseases.

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Key words: Pearl millet, A₁ CMS source, GCV, PCV, line × tester analysis.

Pearl millet (*Pennisetum glaucum* (L.) R. BR) is an important cereal crop of India. It shows tremendous phenotypic variability for traits like flowering time, panicle length, grain & stover yield, tolerance to drought, pests & diseases as well as nutritional value (Bhattacharjee *et al.*, 2007). It is one of the most efficient crops for utilizing soil moisture and thus is more tolerant to drought as compared to sorghum and maize. It is a highly cross-pollinated crop with protogynous nature and high photosynthetic efficiency due to C₄ anatomy, which provides an opportunity for high dry matter production capacity (Manning *et al.* 2011). Also, the grain yield and yield attributing characters in pearl millet show polygenic inheritance which make it susceptible to environmental fluctuations. Therefore, choice of parents is very important for developing higher yielding pearl millet hybrids but, the, selection of parents for hybridization has its own complexities (Srivastava *et al.*, 2020).

Variability is the key to success in plant breeding and is hence given a major emphasis in pearl millet breeding programs for developing higher yielding cultivars. Biotic stress management is also important in pearl millet due to increasing

Table 1. Scale for scoring pearl millet blast disease severity

Scale	Description	Category
0	No lesions on leaf	Immune (I)
1	Few scattered pinhead sized lesions on leaf, covering less than 1 per cent area of leaf	Resistant (R)
3	Lesions up to 5 mm in diameter, spindle shaped dark coloured with a lighter centre, covering 1-10 per cent area of leaf	Moderately Resistant (MR)
5	Typical blast lesions scattered throughout the leaf blade, coalescing and covering 11-20 per cent of leaf area	Moderately Susceptible (MS)
7	Typical blast lesions, up to 1 cm in diameter, scattered throughout the leaf blade, coalescing to give blasted appearance to plant and lesions covering 21- 50 per cent of leaf area	Susceptible (S)
9	Typical blast lesions, more than 1 cm in diameter throughout the leaf blade, coalescing to give blasted appearance and lesions more than 50 per cent of leaf area	Highly susceptible (HS)

disease incidences. Blast caused by *Pyricularia grisea* (teleomorph: *Magnaporthe grisea*) and rust by *Puccinia substriata* which affect both forage and grain production, were considered minor diseases in India earlier. However, their incidence has increased alarmingly during the recent years from 10 per cent (2006) to 45 per cent (2016) (Lukose *et al.*, 2007; Nagaraja and Das, 2016). The use of host plant resistance is the most feasible and economical means of managing these diseases. Hence, in present investigation besides assessing the variability parameters in parental lines an attempt was also made to identify potential hybrids for blast and rust disease resistance.

Materials and Methods

The present study was carried out during *kharif* 2021 at Regional Agricultural Research Station, Vijayapura (Karnataka) India, located in the northern dry zone of Karnataka at an altitude of 593 m from mean sea level. Crossing program was carried out in summer 2021 taking three A_1 CMS sources (ICMB 94555, ICMB 98222 and ICMB 96666) and fifteen potential restorer lines (PRLN 102, PRLN 105, PRLN 106, PRLN 109, PRLN 113, PRLN 114, PRLN 115, PRLN 116, PRLN 117, PRLN 120, PRLN 125, PRLN 129, PRLN 131, PRLN 133, PRLN 140) in a line \times tester fashion to develop

forty five hybrids. Evaluation of parents and F_1 's along with checks (GHB558, VPMH 7 and Kaveri super boss) was done in *kharif* 2021 in a Randomized Block Design (RBD) with three replications. Each genotype was accommodated in 2 rows of 3 m length with a row spacing of 45 cm and plant to plant spacing of 15 cm.

Eighteen parents used in developing the hybrids were studied for variability, heritability, genetic advance and genetic advance as per cent of mean for quantitative characters *viz.*, days to 50 per cent flowering, days to maturity, relative chlorophyll content at flowering and maturity stage, plant height (cm), number of productive tillers per plant, panicle length (cm), panicle girth (cm), grain yield (kg ha⁻¹), dry fodder yield (kg ha⁻¹) and thousand seed weight (g). Blast and rust disease severity was recorded in the hybrids at the time of maturity using 0-9 scale as per the method suggested by Mayee and Datar (1986) (Table 1 & 2) by randomly selecting five plants in each genotype. In each entry, severity was recorded by considering lower leaves, middle leaves and top leaves of pearl millet genotypes at maturity stages and based on the disease reaction, genotypes were categorized into immune, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible.

Table 2. Scale for scoring pearl millet rust disease severity

Scale	Description	Category
0	No symptoms on the leaf	Immune (I)
1	Small, dark brown, powdery pustules covering 1 per cent of leaf area	Resistant (R)
3	Typical rust pustules covering 1 to 10 per cent of the leaf area	Moderately Resistant (MR)
5	Typical rust pustules covering 11 to 25 per cent of the leaf area	Moderately Susceptible (MS)
7	Typical rust pustules covering 26 to 50 per cent of the leaf area	Susceptible (S)
9	Rust pustules covering 51 per cent or more of leaf area and withering of leaf	Highly susceptible (HS)

Pearl millet hybrids, parents and checks were later grouped into different categories based on their reaction to blast and rust disease occurrence in field conditions.

Heritability in broad sense was worked out as per Allard (1960) and genetic advance as per cent of mean (GAM) according to Johnson *et al.* (1955). The Analysis of Variance was carried out using data recorded for eleven different morpho-phenological and yield-contributing traits. Statistical analysis of the recorded data was carried out by the Windostat software.

Results and Discussion

Results revealed that the mean sum of squares for genotypes were significant for all the traits (Table 3) except for relative chlorophyll content at flowering which indicated the existence of sufficient variation in the material studied and the mean sum of squares for replication were non-significant for all traits studied, indicating homogeneity between the replications.

The effectiveness of selection depends on the magnitude of genetic variability for a particular character. The trend of the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the characters remained same *i.e.*, the value of PCV was higher than GCV. Moderate value of GCV and high value of PCV was obtained for the character grain yield. Other workers like Sumathi *et al.*, (2010), Kumar *et al.*, (2015), Dadarwal *et al.* (2020), and Narasimhulu *et al.* (2021) have also reported higher values of PCV than GCV for grain yield of pearl millet. Medium values of GCV and PCV were obtained for the characters like plant height, panicle length, panicle girth and 1000 grain weight. The results of the present study on heritability for eleven characters suggested that all the traits except relative chlorophyll content at flowering were highly heritable. Similarly Sumathi *et al.*, (2010), Kumar *et al.*, (2015), Dadarwal *et al.*(2020), Narasimhulu *et al.* (2021) and Athoni *et al.* (2021) also reported high heritability of these characters in pearl millet.

High to moderate heritability coupled with high to moderate values of genetic advance as per cent of mean were obtained for characters like plant height, relative chlorophyll content at maturity, panicle girth and grain yield. This indicated lesser influence of environment in

the expression of these characters and may be governed by additive gene action and traits can be easily fixed. Hence, these traits are likely to respond to direct simple selection. Similar results were reported by other workers in pearl millet (Sumathi *et al.*, 2010; Kumar *et al.*, 2015; Dadarwal *et al.* 2020; Narasimhulu *et al.*, 2021 and Athoni *et al.*, 2022). The results are presented in Table 4.

The screening results for rust disease indicated that, out of 66 genotypes tested which included 18 parental lines, 45 hybrids and three check hybrid varieties screened, none of them were immune. Six genotypes, which included three testers (PRLN 102, PRLN 114 and PRLN 125) and three hybrids (ICMA 98222 × PRLN 140, ICMA 96666 × PRLN 113 and ICMA 96666 × PRLN 133) showed resistant reaction for rust and 25 genotypes (seven testers, one line, 16 hybrids and one check) were found to be moderately resistant. While, 14 genotypes (two testers, 10 hybrids and two checks) showed moderately susceptible reaction. Further, 21 genotypes (three testers, two lines and 16 hybrids) were having susceptible reaction for rust disease. None of the genotypes were found to be highly susceptible for rust disease (Table 5).

The screening results for blast disease indicated that, out of 66 genotypes screened, none of them were immune. Only three hybrids (ICMA 96666 × PRLN 102, ICMA 96666 × PRLN 113 and ICMA 96666 × PRLN 133) expressed resistant reaction to blast while 22 genotypes (one line, four testers, 15 hybrids and two checks) were found to be moderately resistant. 24 genotypes (seven testers and 17 hybrids) displayed moderately susceptible reaction and seventeen genotypes (two lines, four testers, 10 hybrids and one check) showed susceptible reaction for blast infection. None of the genotypes were found to be highly susceptible for blast (Table 6).

The hybrid, ICMA 96666 × PRLN 133 showed resistance for both rust and blast diseases. Whereas hybrids *viz.*, ICMA 96666 × PRLN 113, ICMA 94555 × PRLN 102, ICMA 94555 × PRLN 116, ICMA 94555 × PRLN 133, ICMA 98222 × PRLN 102, ICMA 98222 × PRLN 109, ICMA 96666 × PRLN 125, ICMA 96666 × PRLN 129 and ICMA 96666 × PRLN 131 showed moderately resistant reaction for both rust and

Table 3. Analysis of variance (Mean sum of squares) for eighteen parental lines with respect to morpho-phenological characters in pearl millet

Sources of variation	DF	Days to 50 per cent flowering	Days to maturity	Plant height (cm)	Number of productive tillers per plant	Relative chlorophyll content at flowering	Relative chlorophyll content at maturity	Panicle length (cm)	Panicle girth (cm)	Grain yield (kg ha ⁻¹)	Dry fodder yield (kg ha ⁻¹)	Thousand seed weight (g)
Replication	2	2.07	0.35	779.51	0.03	9.15	3.44	6.97	0.015	479840.01	3821775.14	6.33
Treatments	17	33.31**	28.55**	997.43*	0.19**	11.53	73.83**	21.28**	0.61**	780809.29**	4549121.22**	7.28*
Error	34	0.78	1.27	57.87	0.04	9.23	7.04	2.46	0.02	115559.26	1326618.31	1.21
S. Em.±		0.51	0.6515	4.39	0.12	1.75	1.53	0.91	0.08	196.26	665.04	0.64
CD @5%		1.46	1.87	12.62	0.34	5.04	4.40	2.60	0.22	564.07	1911.33	1.83
CD @1%		1.97	2.51	16.94	0.46	6.77	5.91	3.50	0.29	757.30	2566.06	2.45

Note: *Significance at 5% probability, **significance at 1% probability

Table 4. Estimates of genetic variability in parental lines with respect to morpho-phenological characters in pearl millet

S. No.	Characters	Mean	Range		σ ² p	σ ² g	GCV (%)	PCV (%)	h ² _{bs} (%)	GA	GAM (%)
			Min	Max							
1	Days to 50% flowering	53	44	58	11.62	10.84	6.21	6.43	93.29	6.55	12.36
2	Days to maturity	92	82	97	10.37	9.09	3.29	3.52	87.72	5.82	6.36
3	Plant height (cm)	142	84	183	371.06	313.19	12.51	13.62	84.40	33.49	23.67
4	Number of productive tillers per plant	2.8	2.4	3.6	0.09	0.05	7.74	10.59	53.35	0.33	11.64
5	Relative chlorophyll content at flowering	58.7	51.4	65.8	10.00	0.76	1.49	5.38	7.65	0.50	0.85
6	Relative chlorophyll content at maturity	35.2	25.4	46.0	29.30	22.26	13.38	15.35	75.27	8.47	24.03
7	Panicle length (cm)	23.1	15.6	29.6	8.73	6.27	10.84	12.79	71.80	4.37	18.92
8	Panicle girth (cm)	3.2	2.2	4.2	0.22	0.20	13.78	14.34	92.17	0.88	27.23
9	Grain yield (kg ha ⁻¹)	2479	815	3556	337309.27	221750.01	19.00	23.43	65.74	786.53	31.72
10	Dry fodder yield (kg ha ⁻¹)	10964	6777	15481	2400919.28	1074100.97	9.45	14.13	44.74	1427.98	13.02
11	Thousand seed weight (g)	14.2	10.5	18.8	3.23	2.02	10.01	12.66	62.57	2.32	16.32

σ²p = Phenotypic variance, σ²g = Genotypic variance, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, h²_{bs} = Broad sense heritability, GA = Genetic advance, GAM = Genetic advance as per cent over Mean

Table 5. Reaction of pearl millet hybrids, parents and checks to rust disease (*Puccinia substriata*) in field condition

Scale	Disease reaction	Number of genotypes	Parents/ Inbreds	Hybrids/Checks
0	Immune	-	-	-
1	Resistant	6	PRLN 102, PRLN 114 and PRLN 125	ICMA 98222 × PRLN 140, ICMA 96666 × PRLN 113 and ICMA 96666 × PRLN 133
3	Moderately Resistant	25	ICMB 94555, PRLN 105, PRLN 109, PRLN 116, PRLN 117, PRLN 129, PRLN 133 and PRLN 140	ICMA 94555 × PRLN 102, ICMA 94555 × PRLN 116, ICMA 94555 × PRLN 133, ICMA 98222 × PRLN 102, ICMA 98222 × PRLN 109, ICMA 98222 × PRLN 131, ICMA 96666 × PRLN 102, ICMA 96666 × PRLN 105, ICMA 96666 × PRLN 109, ICMA 96666 × PRLN 114, ICMA 96666 × PRLN 116, ICMA 96666 × PRLN 117, ICMA 96666 × PRLN 120, ICMA 96666 × PRLN 125, ICMA 96666 × PRLN 129, ICMA 96666 × PRLN 131 and VPMH-7(LC)
5	Moderately Susceptible	14	PRLN 106 and PRLN 115	ICMA 94555 × PRLN 106, ICMA 94555 × PRLN 114, ICMA 94555 × PRLN 125, ICMA 94555 × PRLN 129, ICMA 94555 × PRLN 131, ICMA 98222 × PRLN 105, ICMA 98222 × PRLN 115, ICMA 98222 × PRLN 116, ICMA 98222 × PRLN 120, ICMA 96666 × PRLN 106, GHB-558(NC) and K.S.BOSS(PC)
7	Susceptible	21	ICMB 98222, ICMB 96666, PRLN 113, PRLN 120 and PRLN 131	ICMA 94555 × PRLN 105, ICMA 94555 × PRLN 109, ICMA 94555 × PRLN 113, ICMA 94555 × PRLN 115, ICMA 94555 × PRLN 117, ICMA 94555 × PRLN 120, ICMA 94555 × PRLN 140, ICMA 98222 × PRLN 106, ICMA 98222 × PRLN 113, ICMA 98222 × PRLN 114, ICMA 98222 × PRLN 117, ICMA 98222 × PRLN 125, ICMA 98222 × PRLN 129, ICMA 98222 × PRLN 133, ICMA 96666 × PRLN 115 and ICMA 96666 × PRLN 140
9	Highly susceptible	-	-	-

Table 6. Reaction of pearl millet hybrids, parents and checks to blast disease (*Pyricularia grisea*) in field condition

Scale	Disease reaction	Number of genotypes	Parents/ Inbreds	Hybrids/Checks
0	Immune	-	-	-
1	Resistant	3	-	ICMA 96666 × PRLN 102, ICMA 96666 × PRLN 113 and ICMA 96666 × PRLN 133
3	Moderately Resistant	22	ICMB 94555, PRLN 102, PRLN 106, PRLN 114 and PRLN 133	ICMA 94555 × PRLN 102, ICMA 94555 × PRLN 116, ICMA 94555 × PRLN 133, ICMA 98222 × PRLN 102, ICMA 98222 × PRLN 109, ICMA 98222 × PRLN 115, ICMA 98222 × PRLN 131, ICMA 98222 × PRLN 140, ICMA 96666 × PRLN 109, ICMA 96666 × PRLN 114, ICMA 96666 × PRLN 116, ICMA 96666 × PRLN 117, ICMA 96666 × PRLN 125, ICMA 96666 × PRLN 129, ICMA 96666 × PRLN 131, VPMH-7(LC) and K.s. boss (PC)
5	Moderately Susceptible	24	PRLN 105, PRLN 109, PRLN 115, PRLN 116, PRLN 125, PRLN 129 and PRLN 140	ICMA 94555 × PRLN 105, ICMA 94555 × PRLN 106, ICMA 94555 × PRLN 113, ICMA 94555 × PRLN 114, ICMA 94555 × PRLN 117, ICMA 94555 × PRLN 125, ICMA 94555 × PRLN 129, ICMA 94555 × PRLN 131, ICMA 94555 × PRLN 140, ICMA 98222 × PRLN 105, ICMA 98222 × PRLN 114, ICMA 98222 × PRLN 116, ICMA 98222 × PRLN 120, ICMA 96666 × PRLN 105, ICMA 96666 × PRLN 115, ICMA 96666 × PRLN 120 and ICMA 96666 × PRLN 140
7	Susceptible	17	ICMB 98222, ICMB 96666, PRLN 113, PRLN 120, PRLN 131 and PRLN 117	ICMA 94555 × PRLN 109, ICMA 94555 × PRLN 115, ICMA 94555 × PRLN 120, ICMA 98222 × PRLN 106, ICMA 98222 × PRLN 113, ICMA 98222 × PRLN 117, ICMA 98222 × PRLN 125, ICMA 98222 × PRLN 129, ICMA 96666 × PRLN 106, ICMA 98222 × PRLN 133 and GHB-558(NC)
9	Highly susceptible	-	-	-

Table 7. Pearl millet hybrids identified for resistance to rust and blast diseases

Hybrids	Grain Yield (kg ha ⁻¹)	Reaction to blast disease	Reaction to rust disease
ICMA 96666 × PRLN 109	5111	MR	MR
ICMA 98222 × PRLN 109	5074	MR	MR
ICMA 96666 × PRLN 102	5074	R	MR
ICMA 98222 × PRLN 131	5000	MR	MR
ICMA 96666 × PRLN 125	5000	MR	MR
GHB558	3889	S	MS
VPMH 7	4704	MR	MR
Kaveri super boss	4889	MR	MS

blast diseases in comparison to all checks. The crosses viz., ICMA 96666 × PRLN 109, ICMA 98222 × PRLN 109, ICMA 98222 × PRLN 131 and ICMA 96666 × PRLN 125 showed high yield (kg ha⁻¹) along with moderate resistance for rust and blast compared to national check GHB-558 (Table 7).

Various researchers (Panwar *et al.*, 2001; Sharma *et al.*, 2009; Nagaraja, 2013; Lubadde, 2014; Sharma *et al.*, 2020 and Athoni *et al.*, 2021) who have screened pearl millet for blast pathogen in the past have also reported similar variations in the level of resistance.

Conclusion

Genetic variability study among the parents revealed moderate values of GCV and PCV with moderate to high broad sense heritability and genetic advance for plant height, relative chlorophyll content at maturity stage, panicle girth and grain yield indicating that simple selection would be sufficient for these traits to bring genetic improvement in desired direction. Among the parents, one female parent ICMB 94555, three male parents PRLN 102, PRLN 114 and PRLN 133 showed high to moderate resistant reaction to rust and blast diseases suggesting their use for hybrid breeding and parental line improvement. Moreover, one hybrid ICMA 96666 × PRLN 133 showing resistance to both the diseases should be tested for yield performance over location for promotions as a cultivar to enhance the productivity of pearl millet.

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