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Studies on grain mold tolerance in *kharif* sorghum (*Sorghum bocolor* L.)

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Abstract

The present study was conducted to find out the traits conferring grain mould tolerance in *kharif* sorghum (*Sorghum bicolor* (L.) Moench) and to study the genetic variability and character association related to grain mold tolerance. Experimental material comprising eighty four *kharif* sorghum genotypes (Table 3.1) along with 3 checks (296B (SC), B58586 (RC) and PVK 801) were sown following randamised block design with two replications. The characters grain color, FGMR, TGMR, glume color and grain hardness expressed high estimate of heritability accompanied with moderate to high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement. The significant and positive correlation of field grain mold rating had recorded with panicle compactness at both genotypic and phenotypic level. Whereas association was significant in negative and desirable direction with glume coverage, glume color, grain color, grain density, seed hardness and germination percentage. It may be concluded from the present study that the traits like glume coverage, glume color, grain color, grain hardness are important for improving grain mold tolerance. Hence, due consideration should be given to these characters, while planning a breeding strategy for increased grain yield and grain mold tolerance in *kharif* sorghum.

Keywords: Sorghum, Grain mold tolerance, variability and Correlation

1. Introduction

Grain mold, caused by a complex of pathogenic and saprophytic fungi, is a highly destructive disease of sorghum [*Sorghum bicolor* (L.) Moench] and is widely distributed in the semi-arid tropics of Africa and India. Annual global losses due to grain mold have been estimated at US$ 130 million (ICRISAT 1992). Improved cultivars, particularly hybrids bred for early to medium maturity to escape terminal drought stress in India are normally more vulnerable to the disease than late maturing cultivars (Bandyopadhyay *et al*., 1988) [3].

Resistance to grain mold is a complex phenonomenon and several morphological traits have been shown to be associated with resistance (Audilakshmi *et al*., 1999) [2]. Thus, there is a need to identify morphologically diverse sources of genetic resistance with desirable agronomic traits for utilization in breeding to develop hybrids and varieties for diverse use as food, feed and other industrial products.

Several grain, panicle and glume characters contribute to resistance in varying levels. Grain characters include hardness, structure of endosperm, pericarp thickness and color, presence of testa, and wax layer. Hardness of the grain is a significant mechanism of mold resistance (Jambunathan *et al*. 1992; Audilakshmi *et al*. 1999) [12, 2]. Kernel hardness and pericarp color differentially contribute to grain mold resistance in white, red, and brown pericarp sorghum accessions (Menkir *et al*. 1996) [14].

Genetic variability for a traits is the key component of breeding programs for broadening the gene pool and would require reliable estimates of heritability in order to plan an efficient breeding program. Breeding strategies to increase grain mold tolerance would be most effective, if the components involved are highly heritable and genetically independent or correlated with grain yield. However, it is very difficult to judge whether observed variability is highly heritable or not. Moreover, knowledge of heritability is essential for selection based improvement as it indicates the extent of transmissibility of a character into future generations (Sabesan *et al*., 2009).

Further, the information on the nature of association between grain mold tolerance and its components helps in simultaneous selection for many characters associated with its improvement. The utilization of heritability and genetic advance of grain mold and its attributing traits and inferences from significant genotypic correlation between dependent and independent components should permit selection of predictable genotypes for *kharif* sorghum improvement.

Keeping in view the afore said problems and advantages of selection the present study was conducted to study the traits conferring grain mould tolerance in *kharif* sorghum (*Sorghum bicolor* (L.) Moench).

Materials and Methods

The field investigation was undertaken at Sorghum Research Station V.N.M.K.V. Parbhani during *kharif* 2017. Experimental material comprising eighty four *kharif* sorghum genotypes (Table 3.1) along with 3 checks (296B (SC), B 58586 (RC) and PVK 801), were sown following randomised block design with two replications.

Table 1: List of genotypes of *kharif* sorghum used for the study

Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes	Sr. No	Genotypes
1	GM 1	23	GM 23	45	GM 45	67	GM 67
2	GM 2	24	GM 24	46	GM 46	68	GM 68
3	GM 3	25	GM 25	47	GM 47	69	GM 69
4	GM 4	26	GM 26	48	GM 48	70	GM 70
5	GM 5	27	GM 27	59	GM 49	71	GM 71
6	GM 6	28	GM 28	50	GM 50	72	GM 72
7	GM 7	29	GM 29	51	GM 51	73	GM 73
8	GM 8	30	GM 30	52	GM 52	74	GM 74
9	GM 9	31	GM 31	53	GM 53	75	GM 75
10	GM 10	32	GM 32	54	GM 54	76	GM 76
11	GM 11	33	GM 33	55	GM 55	77	GM 77
12	GM 12	34	GM 34	56	GM 56	78	GM 78
13	GM 13	35	GM 35	57	GM 57	79	GM 79
14	GM 14	36	GM 36	58	GM 58	80	GM 80
15	GM 15	37	GM 37	59	GM 59	81	GM 81
16	GM 16	38	GM 38	60	GM 60	82	GM 82
17	GM 17	39	GM 39	61	GM 61	83	GM 83
18	GM 18	40	GM 40	62	GM 62	84	GM 84
19	GM 19	41	GM 41	63	GM 63	85	PVK 801 (Ch)
20	GM 20	42	GM 42	64	GM 64	86	296B (SC)
21	GM 21	43	GM 43	65	GM 65	87	B 58586 (RC)
22	GM 22	44	GM 44	66	GM 66		

Observations

Observations were recorded on five randomly selected plants in each genotype from each replication while, the variation in qualitative morphological traits, such as panicle type, glumes color and grain color were assigned numerical ratings following the DUS (Distinctiveness, Uniformity and Stability) ratings developed by National Research Centre for Sorghum (NRCS), Hyderabad, India (Reddy *et al*., 2006) [18] to facilitate statistical analysis.
Observations were recorded for the following nine characters.

Field grain mould rating (%)

Five panicles from each replication of each test entry were scored visually, for mould-severity on the panicle surface at harvest, using a 1 to 9 scale, where 1 = no mold visible on the panicle, 2 = Resistant, 1-5 per cent grains moulded on panicle, 3 = Resistant, 6-10 per cent grains molded on panicle, 4= Moderately resistant, 11-20 per cent grains molded on panicle, 5 = Moderately resistant, 21-30 per cent grains molded on panicle, 6 = Susceptible, 31-40 per cent grains molded on panicle, 7 = Susceptible, 41-50 per cent grains molded on panicle, 8 = Highly susceptible, 51-75 per cent grains molded on panicle, 9 = Highly susceptible, more than 75 per cent grains molded on panicle (Garud *et al*.1994) [8]

Threshed grain mould rating (%)

Five panicles from each replication of each test entry were harvested 15 days after maturity and threshed. A sample of 35 gm of threshed grain from each panicle was spread in a 9 cm diameter petri plate and scored visually, for mould-severity on the seed surface. Like FGS, TGS was recorded using a 1 to 9 scale, where 1 = no mold and 9 = Highly susceptible, extensive mold growth with more than 75 per cent of the seed surface molded (Garud *et al*.1994) [8].

Germination percentage (%)

The Ragdoll's (rolled paper towel) method (ISTA, 1966) was used for germination studies.

Grain colour

Visual scores given to seed colour were 1 = white, 2 = Grayed white, **3** = Yellow white, 4 = Yellow orange and 5 = Grayed orange.

Grain hardness (kg/cm^2)

Grains of same moisture content were used for observations. Fifty kernels of each genotype were tested for their strength to break and mean was calculated and hardness is expressed in kg/cm^2.

Glume coverage (%)

Observations on kernel covering i.e. amount of kernel covered by the glume were recorded on the basis of following classifications suggested by House (1982) [10].
Grain fully covered – 100% glume coverage, 3/4 grain covered – 75% glume coverage, 1/2 grain covered – 50% glume coverage, 1/4 grain covered – 25%,glume coverage, Grain uncovered – 0% glume coverage.

Panicle type

A visual score of the compactness of a panicle was based on a 1-9 scale, where 1 = Very loose, 3 = Loose, 5 = Semi loose, 7 = Semi compact, and 9 = Compact.

Glume colour

Visual scores of 1 to 6 were given to different glume colours, where 1 = Green white, 2 = yellow white, 3 = grayed yellow, 4 = grayed orange 5 = grayed red ; and 6 = Grayed purple.

Grain density (Kg/ml)

Grain density of sorghum grains was determined by liquid displacement method. Five grams of sample of each genotype (dried and stored under similar conditions) were drawn and added in 50 ml fractionally graduated measuring cylinder containing 25 ml of water and grain density was calculated.

Weight of sorghum grain (g)

$$\text{Grain density (g/ml)} = \frac{\text{Weight of sorghum grain (g)}}{\text{Increase in volume of liquid (ml)}}$$

Results and Discussion

Genotypic and phenotypic coefficient of variation

Genotypic coefficient of variation estimates were lower than phenotypic coefficient of variation for all the characters and differences between them were of lower magnitude.

According to Deshmukh *et al.* (1986) [6], phenotypic coefficient of variance (PCV) and Genotypic Coefficient of Variation (GCV) can be categorized as low (<10%), moderate (10-20%) and high (>20%). In the present study, high estimates of genotypic and phenotypic coefficient of variation were recorded for panicle type, glume coverage, grain color, field grain mold rating, threshed grain mold rating, glume color, germination percentage, grain hardness, however, grain density was categorized as low.

The PCV was relatively greater than GCV for the traits; however, the magnitude of the difference was low for all the traits except panicle type and grain hardness. This suggested that the influence of environmental factors for the phenotype expression of genotypes was low and the higher chance of improvement of these traits through selection based on the phenotype performance.

The high values of GCV and PCV for panicle type, field grain mold rating and threshed grain mold rating suggested that there was a possibility of improvement of these traits through direct selection.

Heritability and Genetic Advance

According to Singh (2001), heritability of a trait is considered as very high or high when the values is 80% or more and moderate when it ranged from 40-80% and when it is less than 40%, it is low. In the present investigation, heritability ranged from 92.3 to 39.6 per cent. High estimates of heritability in broad sense were obtained for grain color, FGMR, TGMR, glume color and grain hardness. High degree of heritability estimates suggested that the characters were under genotypic control and selection could be fairly easy and improvement is possible using selection breeding for improvement of these traits.

Genetic advance as percent mean ranged from 92.71 for glume color to 4.97 for grain density. Deshmukh *et al.*, (1986) [6] classified genetic advance as percent of mean as low (<10%), moderate (10-20%) and high (>20%). Based on this classification, all of the characters except grain density had high genetic advance as percent of mean in the current study.

Johnson *et al.*, (1955) [13] suggested that the importance of considering both the genetic advance and heritability of traits rather than considering separately in determining how much can progress be made through selection. The heritability estimates along with expected genetic advance are more useful for predicting yield under phenotypic selection than heritability estimates alone. High heritability accompanied with high genetic advance indicates preponderance of additive gene effect, in such case selection may be effective.

The characters grain color, FGMR, TGMR, glume color and grain hardness expressed high estimate of heritability accompanied with moderate to high genetic advance indicating additive gene action and thus selection for these characters in genetically diverse material would be more effective for desired genetic improvement.

The characters grain hardness, glume color, grain color, field grain mold rating and panicle type had high heritability with low genetic advance suggesting the variability for these characters is governed by non-additive gene action indicating the limited scope for improving these characters through phenotypic selection.

Correlation

In the present investigation, significant and positive correlation of field grain mold rating had recorded with panicle compactness at both genotypic and phenotypic level. Whereas association was significant in negative and desirable direction with glume coverage, glume color, grain color, grain density, seed hardness and germination percentage.

Panicle compactness, grain hardness, glume, coverage and colour were important components of grain mold resistance. Genotypes with hard grains, loose panicles, medium to long glume coverage and red and black colored glumes had low incidence of grain mold (Patted *et al.*, 2011) [16]. Further it was concluded that progenies with hard seeds showed resistance to grain mold at both field and threshed grain these results are in accordance with Jambunathan *et al.* (1992) [12]. Hard seeds are less amenable for imbibition by continuous rains there shall be less scope for saprophytes to grown on seeds. Glume length and area of coverage over the grain are related to grain mold escape as the grains are protected from exposure to rain. A highly significant negative correlation between grain mold severity and germination was reported by Singh and Bandyopadhyay (2000) [3] indicating that germination rate was adversely affected when the sorghum lines were inoculated with a mixture of *Fusarium thapsinum* and *Curvularia lunata*.

In the present study few genotypes viz. GM 42, 43, 54, 55, 69, 74, 75, 76, 77, showed considerable grain mold tolerance despite having white to grayed white pericarp color (1-3 scale). Jambunathan *et al.* (1992) [12] and Mukuru (1992) also reported grain mold resistance in sorghum cultivars with white pericarp which was mostly due to kernel hardness. Physical kernel attributes may become more important factors in resistance to grain mold after physiological maturity (Castor and Fredriksen, 1980) [5]. In general, darker kernel color was associated with increased resistance to grain mold in our study. This could result from the presence of higher levels of free phenolic compounds that occurred in kernels with darker pericarp than in kernels with a white pericarp (Doherty *et al*. 1987) [7]. Audilakshmi *et al*. (1999) [2] reported similar findings for glume color, grain color and threshed grain mold rating.

It is important to note that the characters which are significant and positively/negatively correlated with grain mold could be considered as important traits for improving mold tolerance in *kharif* sorghum.

Path analysis

The present results revealed that panicle type, glume coverage and seed hardness recorded positive direct effect on field grain mold rating at both level. Similar findings were reported by Aml *et al.* (2012) [1] for panicle type. Whereas, glume color, grain density, germination percentage and threshed grain mold rating recorded positive direct effect on field grain mold at genotypic level only. Similar findings were reported by Bohra *et al.* (1986) [4] and Jain and Patel (2014) [11] for grain density, Potadukhe *et al.* (1992) [17] for glume color, Hemlata Sharma *et al.* (2006) [9] and Veerabadhiran and Kennedy (2001) [19] for germination percentage. The value of residual factors is moderate, it indicates that besides the character studied there are some other attributes which contribute for grain mold tolerance.

Thus considering the estimates of genetic parameters like GCV, PCV, heritability and genetic advance together, it is evident that the characters viz. grain color, FGMR, glume color, and grain hardness which show high values for GCV, PCV, heritability and genetic advance were considered most important and selection of these characters could be more effective for improving grain mold in *kharif* sorghum.

It may be concluded from the present study that the traits like glume coverage, glume color, grain color, grain hardness are important for improving grain mold tolerance. Hence, due consideration should be given to these characters, while planning a breeding strategy for increased grain yield and grain mold tolerance in *kharif* sorghum.

Table 2: Analysis of variance for seventeen characters of *kharif* sorghum

Sources of variation	d.f	Field grain mold rating (1-9 scale)	Threshed grain mold rating (1-9 scale)	Germination percentage (%)	Panicle type (1-9 Scale)	Grain color (1-5 Scale)	Grain hardness (kg/cm^2)	Glume coverage (%)	Glume color (1-7 Scale)	Grain density (kg/ml)
Replication	1	0.44	0.44	8.29	6.25	0.04	0.08	11.12	0.36	0.01
Treatments	86	6.16**	5.34**	374.93**	9.15**	2.52**	2.09**	642.30**	5.07**	0.01**
Error	86	0.53	0.31	44.29	2.37	0.12	0.14	93.95	0.29	0.00

****** Significant at 1 per cent level.

Table 3: Genetic variability parameters for seventeen characters studied in *kharif* sorghum

Sr. No.	Characters	Range		MEAN	σ^2 (g) (Genotypic variance)	σ^2 (p) (Phenotypic variance)	GCV (%)	PCV (%)	h^2 b.s.(%)	GA	GA as% of mean
		Minimum	maximum								
1	Panicle type (1-9 Scale)	1.00	9	3.91	3.43	5.67	47.11	60.61	60.4	2.96	75.43
2	Glume coverage (%)	25	95	67.12	274.17	368.12	24.66	28.58	74.5	29.43	43.85
3	Grain color (1-5 Scale)	1.00	5.00	2.31	2.39	2.68	40.02	42.45	88.9	3.00	77.75
4	Field grain mold rating (1-9 scale)	1.00	60	3.93	2.81	3.34	41.93	45.70	84.2	3.17	79.24
5	Threshed grain mold rating (1-9 scale)	1.00	8.00	3.74	2.51	2.82	42.39	44.93	89.0	3.08	82.38
6	Glume color (1-7 Scale)	1.00	6.50	3.86	1.20	1.32	47.29	49.69	90.6	2.14	92.71
7	100-seed weight (g)	1.20	3.50	2.00	0.15	0.21	19.53	23.28	70.3	0.67	33.74
8	Grain density (kg/ml)	1.02	1.24	1.15	0.002	0.005	3.84	6.12	39.4	0.05	4.97
9	Germination percentage (%)	40	94	64.13	165.32	209.61	20.04	22.57	78.9	23.52	36.67
10	Grain hardness (kg/cm2)	1.20	5.26	4.15	0.97	1.12	35.43	37.92	87.3	1.90	68.18

Table 4: Genotypic and phenotypic correlation coefficient for field grain mold rating characters studied in *kharif* sorghum

Characters		Panicle type (1-9 scale)	Glume coverage (%)	Glume Color (1-7 scale)	Grain Color (1-5 scale)	100 seed weight (g)	Grain density (kg\cm^2)	Germination %	Seed hardness (kg/cm^2)	Threshed grain mold rating (1-9 scale)
Panicle type (1-9 Scale)	G	1.000	-0.340**	-0.077	0.173	0.032	-0.425**	-0.217*	0.098	0.281**
	P	1.000	-0.277**	-0.063	0.130	0.006	-0.238**	-0.183*	0.107	0.251*
Glume coverage (%)	G		1.000	0.250**	-0.162	0.056	0.765**	0.538**	0.0157	-0.491**
	P		1.000	0.205**	-0.115	0.042	0.265**	0.437**	-0.011	-0.395**
Glume color (1-7 Scale)	G			1.000	0.029	0.038	0.229**	0.154*	0.046	-0.208*
	P			1.000	0.012	0.023	0.119	0.124	0.041	-0.185*
Grain color (1-5 Scale)	G				1.000	-0.205**	-0.375**	-0.414**	0.380**	-0.367**
	P				1.000	-0.153*	-0.176*	-0.350**	0.357**	-0.311**
Grain density (kg/ml)	G					1.000	-0.087	-0.177*	0.008	0.035
	P					1.000	-0.072	-0.101	0.034	0.040
100-seed weight (g)	G						1.000	1.244**	-0.138	-1.157**
	P						1.000	0.646**	-0.447**	-0.650**
Germination percentage (%)	G							1.000	-0.222*	-1.019**
	P							1.00	-0.140	-0.808**
Seed hardness (kg/cm2)	G								1.000	-0.171*
	P								1.000	-0.153*
Threshed grain mold rating (%)	G									1.000
	P									1.000

Table 5: Direct and indirect effects (genotypic and phenotypic level) of grain mold related traits on field grain mold rating

Characters		Panicle type (1-9 Scale)	Glume coverage (%)	Glume color (1-7 Scale)	Grain color (1-5 Scale)	Grain density (kg/ml)	100 seed weight (g)	Germination percentage (%)	Seed hardness (kg/cm2)	Threshed grain mold rating (1-9 scale)	Field grain mold rating (1-9 scale)
Panicle type (1-9 Scale)	G	0.096	-0.033	-0.007	0.016	-0.041	0.003	-0.021	0.009	0.321	0.281
	P	0.086	-0.024	-0.005	0.011	0.000	-0.020	-0.015	0.009	-0.018	0.251
Glume coverage (%)	G	-0.061	0.179	0.044	-0.029	0.137	0.010	0.096	0.002	-0.480	-0.491
	P	0.010	-0.037	-0.007	0.004	-0.001	-0.009	-0.016	0.000	-0.004	-0.395
Glume color (1-7 Scale)	G	0.007	-0.022	-0.091	-0.002	-0.021	-0.003	-0.014	-0.004	-0.203	-0.208
	P	0.006	-0.019	-0.093	-0.001	-0.002	-0.011	-0.011	-0.003	-0.005	-0.185
Grain color (1-5 Scale)	G	0.004	-0.004	0.001	0.024	-0.009	0.005	-0.010	0.016	1.066	0.367
	P	0.006	-0.005	0.000	0.046	0.007	-0.008	-0.016	0.025	-0.004	0.311
Grain density (kg/ml)	G	0.090	-0.162	-0.048	0.079	-0.212	0.018	-0.264	0.029	-1.124	-1.157
	P	-0.001	-0.001	-0.001	-0.006	-0.043	0.003	0.004	-0.001	0.001	0.040
100-seed weight (g)	G	-0.004	-0.008	-0.005	-0.030	0.013	-0.150	0.026	-0.001	0.100	0.035
	P	0.051	-0.057	-0.025	0.038	0.015	-0.216	-0.139	0.009	0.098	-0.650
Germination percentage (%)	G	0.178	-0.443	-0.126	0.340	-1.023	0.146	-0.822	0.182	-0.990	-1.019
	P	0.107	-0.257	-0.073	0.206	0.059	-0.380	-0.588	0.082	-0.019	-0.805
Seed hardness (kg/cm2)	G	-0.008	-0.001	-0.004	-0.059	0.012	-0.001	0.019	-0.086	0.021	0.171
	P	0.001	0.000	0.000	0.001	0.000	-0.000	-0.000	0.002	0.000	0.143
Threshed grain mold rating (%)	G	-0.389	0.600	0.254	-0.232	1.404	-0.125	1.238	-0.026	1.000	1.066
	P	-0.007	0.012	0.005	-0.004	-0.002	0.022	0.027	-0.000	-0.032	-0.020

Residual effect 0.538

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