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Short Communication

Genetic correlation between test environments and genotype ranking for moisture stress tolerance in sorghum (*Sorghum bicolor* L.)

B. S. Patil and R. L. Ravikumar[1]

Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad 580 005

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Sorghum is cultivated both in rainy (*kharif*) and post rainy (*rabi*) seasons predominantly under rainfed conditions in India. The *rabi* sorghum (*Sorghum bicolor* L.) sown in the months of September/October completes its life cycle with residual soil moisture condition under normal growing season. Due to erratic rainfall the timing and duration of occurrence of moisture stress vary from year to year. If the environmental conditions experienced in the test environment are different from those in normal season, the assessment of plant physiological response to soil water deficits would be incorrect leading to wrong selection [1]. To determine the degree of similarity among the test environments Type-B genetic correlations [2, 3] are used for genotype ranking. Also the model of correlated selection [4] can be used to determine the relative merits of selecting for specific versus broad adaptation. In test environment, the field sowing is postponed by one or two months (rain-out dry season), so that the genotypes are exposed to severe moisture stress condition from seedling to maturity. Based on the superior yield performance in test environment (rain-out dry season) the drought tolerant genotypes are selected and recommended for normal growing season. Although, the test and growing environments are *rabi* season, the change in microenvironment due to late sowing may influence the genotypic performance. The genotypes x microenvironment interaction, is hitherto, not considered. Therefore, in the present study we analyzed the effect of moisture stress treatment *vis-a-vis* test environment on the performance of sorghum genotypes.

Eight post-rainy (E 36-1, Sel 3, SPV 86, GRS-1, RS 29, RSLG 241, AJ 2113 and M 35-1) and two rainy season (DSV 1 and DSV 2) sorghum genotypes were selected for this study. The study was conducted during post rainy and summer season's of the year, 2004-2005. The genotypes were tested under three different dates of sowings *viz*., 18-10-2004 (representing normal growing season = Environment 1), 14-11-2004 (rain-out dry season = Environment 2) and 11-12-04 (summer = Environment 3). Even in normal growing season, the crop depends only on residual moisture and invariably experiences the moisture stress during reproductive and grain filling stage reducing the productivity.

In all the three dates of sowing, the genotypes were tested under two moisture regimes *viz*., no stress and stress in a same experimental block. The non-stress (control) treatment was created by irrigating the crop at regular interval of 8-10 days from sowing, till the physiological maturity. The moisture stress treatment was imposed by withholding the irrigation 15 days after sowing. The genotypes were grown in a factorial randomized block design with two replications each for stress and non-stress treatment in all the dates of sowing. The main treatment was moisture stress, while the sub-plot treatment was genotypes. Each genotype was grown in two rows of 2.5 m per replication. All the production practices were same in all the treatments. The observations on grain yield, test weight, days to 50 % flowering and plant height were recorded on five randomly selected plants per replication per genotype. Drought Susceptibility Index (DSI) for grain yield in all the three environments was calculated as per the method suggested by Fischer and Maurer [5]. The data on ten genotypes was analyzed using different designs - a) Analysis of variance for genotypes separately for

[1]Corresponding author's e-mail: ravikumarrl@yahoo.co.in

each moisture regime, b) the two factorial randomized block design was applied in each date of sowing with moisture regime as main factor and genotypes as sub factors, c) three factorial randomized block design, with environment as main factor, moisture stress as sub factor and genotypes as sub-sub factor. Type-B genetic correlation, correlated response to selection and efficiency of selection environment were estimated between target and test environment. The moisture stress treatment under normal date of sowing was considered as target environment. The remaining other treatments *viz.,* non-stress under normal date of sowing, moisture stress under rain-out dry and summer seasons were considered as test environments.

Type-B genetic correlation was calculated for grain yield and DSI considering different dates of sowing as different genetic traits, and genetic correlation (r_g) among those traits were calculated from variance and co-variances. Correlated response of the traits in environment j (moisture stress in normal date of sowing) from selection in environment k (non-stress under normal date of sowing, moisture stress under rain-out dry season and summer seasons) was estimated. Assuming that the same intensity was applied on both environments ($i_j = i_k$), the efficiency of selection at environment k for planting at environment j ($E_{j.k}$) was estimated as per the method suggested by Falconer [4]. $E_{j.k} = rg_{jk}.(H_j/H_k)$, where, $E_{j.k}$ = Efficiency of selection in environment k for planting at environment j; rg_{jk} = Genotypic correlation between environment j and k; H_j and H_k = Heritability estimates in environment j and k, respectively.

It was observed that the change in date of sowing had significant effect on performance of genotypes in both control and moisture stress treatment. Significant reduction in mean grain yield was noticed in late sown experiments (Table 1). In rain-out dry season, the vegetative growth and crop duration was more as indicated by mean plant height and days to flowering respectively. The change in date of sowing has significant influence on source sink relationship irrespective of moisture regime. The November and December sown experiments, although resulted in increased vegetative growth; the partitioning of photosynthates to reproductive parts was reduced resulting in significant reduction in grain yield. Irrespective of moisture regime, the change in date of sowing altered the hitherto unnoticed environmental variables, consequently low productivity even in the absence of moisture stress.

Table 1. Comparison of yield and its component traits in control and moisture stress condition under differed dates of sowings

Character	Moisture regime	Date of sowing			LSD at 5%
		Normal season	Rain-out dry	Summer season	
Grain yield	C	47.48	25.02	29.37	2.38
	S	23.26	14.95	15.89	1.58
LSD at 5%		0.73	0.38	3.47	
Test weight	C	3.38	3.37	3.45	0.12
	S	2.73	3.14	3.19	0.20
LSD at 5%		0.22	0.14	0.11	
Days to flowering	C	66.30	74.35	69.95	0.26
	S	65.75	72.50	70.40	0.41
LSD at 5%		0.26	0.27	0.48	
Plant height	C	160.17	191.88	152.20	2.55
	S	128.88	152.48	136.65	1.85
LSD at 5%		2.82	2.33	2.69	

C: No-stress or control; S: Moisture stress

The moisture stress had significant effect on grain yield, test weight, plant height and days to flowering in all the three environmental conditions. The effect was highest for grain yield. Drought stress affects yield by depressing both sink and source. The grain yield and its component traits are developmentally correlated with several physiological traits [6]. The results reveal that reduction in grain yield due to moisture stress under normal date of sowing is mainly through reduction in test weight. While, in November and December sowings, test weight was not affected. The reduction in yield under stress could be attributed to inefficient partitioning of photosynthates and imbalance between vegetative and reproductive growth. The dry matter is partitioned differently to plant parts depending on the time of moisture stress.

Drought susceptibility index for grain yield was estimated separately for each environmental condition (Table 2). The genotypic ranking for Drought Susceptibility Index differed considerably with change in date of sowing. The genotypes AJ 2113, SPV 86 and Sel.3 were found to be highly drought tolerant in normal, rain-out dry and summer seasons, respectively. The results indicated that although there is significant effect of moisture stress treatment on genotypic performance in all the three environments, the genotypes differed

Table 2. Drought Susceptibility Index (DSI) for grain yield in sorghum genotypes in three environments

Genotype	Normal date sowing	Rain-out dry season	Summer season
E36-1	1.15	1.26	0.98
SPV 86	1.15	0.02	0.20
Sel. 3	0.96	1.06	1.35
DSV-1	0.96	0.20	0.34
GRS-1	1.02	1.42	1.20
RS-29	0.82	1.64	0.94
RSLG 241	1.19	0.89	0.15
AJ 2113	0.78	1.37	1.00
DSV-2	0.88	0.82	1.46
M35-1	1.08	0.07	1.07

with respect to expression of yield and its component traits with change in environmental conditions. If the relative performance of the genotypes grown in test environment is different, then genotype x environment interaction becomes a major challenging factor in genetic improvement programme [7]. In such cases, it is important to determine test environment that has intrinsic high ability to detect and screen desirable genotypes that would be successful in target environment.

Type-B genetic correlation is one of the criteria, which indicates the degree to which the test environments are similar with respect to ranking of genetic entries [4]. Significant genetic correlation of genotypic performance in moisture stress condition of normal season was observed with no-stress condition in normal season (Table 3). It was negative with rain-out dry season. The results indicated that the genotypes behaves nearly the same way in moisture stress and no-stress conditions of normal season. The correlated response of grain yield in moisture stress condition under normal season from selection in different environments reveals that indirect selection under control condition in normal season is effective when compared to other two seasons. The estimates of efficiency of selection environment indicated that the best environment for improving grain yield under moisture stress condition of normal season would be the no-stress condition of normal season. This observation is consistent with statement by Pfeiffer *et al.* [8] and Richards [9], who found that selection in environment without moisture stress was superior in developing germplasm that combined high genetic potential with tolerance to moisture stress. The estimates of all the three genetic parameters for DSI between normal season and test environments were found to be negative. The genotypic ranking, response to selection and efficiency of test environment for drought tolerance differs significantly with change in environmental conditions. Therefore selection in optimum moisture conditions in target environment found to be more efficient when compared to stress conditions in differed environmental conditions. Thus, we consider that evaluation and selection under no-stress conditions, only in target environment should be conducted to take the advantage of high heritability and correlated response.

Table 3. Type-B genetic correlation, correlated response to selection and selection efficiency of test environment with reference to target environment for grain yield and DSI

Target environment/ moisture regime	Item	Genetic parameter	Test environment		
			No-stress of normal season	Rain-out dry season	Summer season
Moisture stress under normal date of sowing	Grain yield	Type-B correlation	0.661*	–0.034	0.283
		Correlated response	24.78	–1.29	9.21
		Efficiency of selection environment	0.657	–0.035	0.212
	DSI	Type-B correlation	—	–0.266	–0.750*
		Correlated response	—	–7.64	–17.37
		Efficiency of selection environment	-	–0.247	–0.698

* Significant at 5% probability

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