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Grain Yield Stability of Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) in Scarce Rainfall Region of Andhra Pradesh under Rainfed Situation

P Shanthi, B Sahadeva Reddy and M Subba Rao
Agricultural Research Station (Dray Land Agriculture), Ananthapuram – 515 001

ABSTRACT

Genotype x environment interaction in pearl millet (*Pennisetum glaucum* (L.) R. Br.) was studied for grain yield by growing a total of ten genotypes including both public and private bred cultivars (six released hybrids and four released open pollinated cultivars). Studies were conducted during rainy season in three years *viz.,* 2011, 2012 and 2013 at AICRP on Pearl Millet, Agricultural Research Station, ANGRAU, Ananthapuram center. The analysis of variance indicated that significance of environments suggesting the presence of considerable influence of differential environments on grain yield. Environment (linear) was significant and larger in magnitude, suggesting its importance in expression of grain yield performance in pearl millet and indicating the prediction of performance across the environments is possible. The significant pooled deviation (non-linear component) mean sum of squares for grain yield indicated that the genotypes differed considerably with respect to their stability for this character. Considering the environmental indices, the environment 1 (*kharif* 2011) is observed to be more favourable environment for grain yield in pearl millet. Based on performance of ten genotypes studied, over the three years of study, the genotypes *viz.,* ICMH 356, ICMV 221 and ICTP 8203 were found stable for grain yield, since these genotypes showed regression coefficient 'bi' nearer to one and values for deviation from regression is as small as possible, mean is higher than the general mean (1370.189 kg/ha).

Key words : Grain yield, Pearl Millet, G x E interaction, Pennisetum glaucum (L.), Stability, Scarce rainfall region of A.P.

Pearl Millet (*Pennisetum glaucum* (L.) R. Br.) is the most important component of Dryland system. The varietal adaptability to environmental fluctuations is important for stabilization of crop production, both over location and seasons. Thus, stability reflects the suitability of a variety or hybrid for general cultivation over wide range of environments. In the evolutionary terms, the breeders' objective is to produce or identify populations / varieties / hybrids that are better adapted to given environment (Simmonds, 1962). Therefore, efforts are required to increase production and productivity of pearl millet crop across the diverse environments by providing seed of suitable population / variety / hybrid.

Several approaches have been made to extract parameters of genotypic stability from genotype-environmental interactions. Many authors have used several approaches to determine the stability of genotypes over wide range of environments. Eberhart and Russell (1966) considered a stable genotype to have a slope equal to unity and deviation from regression equal to zero. They reported that the deviation from regression, second stability parameters appears very important, as the genotype x environment interaction (linear) sum of squares was a small portion of the genotype x environment interaction. This approach has been extensively used by several plant breeders (Reich and Atkins, 1970; Kofoid *et al.,* 1978; Virk *et al.,* 1985; Gupta and Ndoye 1991; Suryavanshi *et al.,* 1991; Yadav *et al.,* 2000, 2001 & 2006 and Patil *et al.,* 2014) emphasizing that linear regression should be regarded as a measure of the response of a particular genotype, where as deviation from regression should be considered as a measure of stability of genotype with the lowest deviation being the most stable.

Stability is practicable performance of genotypes under changing environmental conditions. In agricultural sense, it means whether species display the same production efficiency as predicted. Stability indicates the constant mean efficiency in different environments (Kam *et al.,* 2010). The present investigation was undertaken to identify stable pearl millet varieties and hybrids among the six released hybrids and four varieties of pearl millet for scane rainfall region of A P under rainfedtion.

MATERIAL AND METHODS

In this study the data of the Released Hybrid and Varietal Trial (RHVT of Zone B) conducted at Agricultural Research Station, ANGRAU, Ananthapuram, Andhra Pradesh, was taken. The experimental data collected from three years of experimentation *viz.,* 2011, 2012 & 2013 rainy seasons, considering them as three environments. The three environments and details of latitude, total rainfall received during crop period in the season and environmental mean of grain yield are presented in Table 1.

The number of genotypes tested in RHVT varied from 11 to 13 in different years and data analysis was only carried out on ten common genotypes. These ten genotypes include six released hybrids (*viz.,* GHB 558, 86 M 64, ICMH 356, B 2301, Saburi & Shradha) and four released open-pollinated cultivars (*viz.,* ICMV 221, ICTP 8203, ICMV 155 & Raj 171) of pearl millet.

In each environment the trial was planted immediately after first good rain (*i.e.,* 20 mm and more than 20 mm) in a randomized block design. In each trial there were three replications and the plot size was six rows of 5m long and 50 cm apart. The plant to plant spacing was 15 cm. The same dose of fertilizer (30Kg N, 30 Kg P_2O_5 and 20 Kg K_2O) was applied as a basal dose in each environment. The sowing was done on 29-7-2011, 18-7-2012 and 09-7-2013 in first, second and third years respectively. Thinning of the crop by keeping one plant per hill at a spacing of 15 cm apart from plant to plant was done at the age of 20 days after sowing. The plot areas were weeded with bullock drawn implements and supplemented by hand weeding. Thirty kilos of nitrogen in the form of urea was top dressed at 30-35 days after sowing depending on the receipt of rain. The trials grown in three years / environments were rainfed. At maturity the crop was harvested leaving the boarder plants present on both side of the row in each plot separately, threshed and weighed to estimate grain yield. Harvesting of the crop was done on 21-10-2011, 17-10-2012 and 23-10-2013 in first, second and third years / environments respectively.

Location of the experiment:

The experiment was carried out at AICRP on Pearl Millet, Agricultural Research Station, ANGRAU, Ananthapuram center, (Lat: 14^0 41^1 N, Long: 77^0 40^1 E and 350m above mean sea level) located in the Ananthapuram district and in the scarce rainfall zone of Andhra Pradesh, India. Ananthapuram region is highly prone to scanty and unevenly distributed rainfall and hence it is always drought – prone. High wind speed, low soil depth and low nutrient status in the soils further exaggerates the deleterious effects of drought at this place. The frequency of prolonged dry spells during the season also very high in this region. Therefore the varieties or hybrids identified at this location were suitable to grow in scarce rainfall regions after testing them in multi location testing.

Statistical Procedure:

The data from individual environments were analyzed as a randomized block design. Stability parameters were estimated for grain yield using the model described by Eberhart and Russell (1966). This method utilizes the deviations from the grand mean of the grain yield over the environments as production indexes of the environments. It provides regression response indexes (bi values) and mean squares for deviations from regression minus pooled error (S^2d) as indexes of production response and stability respectively. Pooled error was obtained by averaging the error mean squares from analysis of variance of individual environments and dividing by the number of replications. The significance of mean squares was tested against pooled error. For testing significance of mean values, Least Significance Difference (LSD) was computed by using the pooled error. The t-test based on the standard error of regression value was used to test significant deviation from 1.0. To determine whether deviations from regression were significantly different from zero, the F-test was employed (*i.e.,* comparing the mean squares due to deviations from regression with pooled error).

RESULTS AND DISCUSSION:

The environments used in this study represented a scarce rainfall zone area which receives 553 mm rainfall per annum and around 300 mm to 400 mm rainfall during the rainy season. In this study rainy season *i.e., kharif* season of

Table 1. Different Environments, Years, Total Rainfall received during crop growth period, means for grain yield data.

Environment	Season and Year	Location	Total rain fall received during the crop growth period (mm)	Crop Period (Sowing to Harvesting) is between the standard weeks of	Mean Grain yield (Kg)
Environment 1	*Kharif* 2011	ARS, ANGRAU, Ananthapuram	213.6	31st – 42nd = 12 Standard week	2076.100
Environment 2	*Kharif* 2012	Lat: 14⁰ 41¹ N, Long: 77⁰ 40¹ E	286.6	29th – 42nd = 14 Standard week	1198.100
Environment 3	*Kharif* 2013	and 350m above mean sea level	359.0	28th – 43rd = 16 Standard week	836.367

Table 2. Standard week-wise rainfall at ARS, ANGRAU, Ananthapuram from 22nd to 44th standard week of 2011, 2012 & 2013 Years.

Standard Week No	Duration of Standard week	Rainfall (mm) 2011 *Kharif*	Rainfall (mm) 2012 *Kharif*	Rainfall (mm) 2013 *Kharif*	Rainy days (nos.) 2011 *Kharif*	Rainy days (nos.) 2012 *Kharif*	Rainy days (nos.) 2013 *Kharif*
22	28May-3June	047.2	0.0	040.6	2	0.0	3
23	04-10June	000.6	1.0	016.0	0	1.0	1
24	11-17	000.0	1.6	000.0	0	1.0	0
25	18-24	001.0	1.2	000.0	0	1.0	0
26	25June-1Jul.	001.0	27.8	000.0	0	2.0	0
27	02-08	017.2	1.4	038.4	2	1.0	1
28	09-15	005.0	6.8	003.4	1	2.0	0
29	16-22	007.0	100.2	003.2	1	5.0	0
30	23-29	040.2	2.6	003.8	2	1.0	1
31	30Jul.-5Aug.	006.6	1.4	000.0	2	1.0	0
32	06-12	000.0	0.0	002.4	0	0.0	0
33	13-19	010.4	0.0	006.2	2	0.0	1
34	20-26	053.2	62.2	001.6	3	3.0	0
35	27Aug.-2Sep.	008.6	3.0	001.0	1	2.0	0
36	03-09	000.0	22.4	153.8	0	4.0	4
37	10-16	27.0	0.0	101.4	1	0.0	3
38	17-23	000.0	0.0	015.0	0	0.0	1
39	24-30Sep.	000.0	59.0	000.0	0	4.0	0
40	01-07Oct.	005.6	32.4	003.6	1	3.0	0
41	08-14	62.0	5.4	000.0	1	1.0	0
42	15-21	000.0	1.0	000.0	0	2.0	0
43	22-28	032.6	5.0	025.2	2	2.0	4
44	29Oct.-4Nov.	012.4	31.2	001.6	1	4.0	0
Total Rainfall / Rainy days received during the season		337.6	365.6	417.2	22	40	19
Total Rainfall / Rainy days received during the crop period		213.6	286.6	359.0	13	26	15
Sowing date		29-7-2011	18-7-2012	09-7-2013			
Harvesting date		21-10-2011	17-10-2012	23-10-2013			

Table 3. Growth stages of pearl millet crop.

Growth stage in pearl millet	Represented as	Description
Growth Stage 1	GS1	Sowing / seedling stage to panicle differentiation / initiation of the main stem.
Growth Stage 2	GS2	Panicle initiation to flowering of the main stem.
Growth Stage 3	GS3	Flowering to grain maturity / physiological maturity period of crop.

Table 4. ANOVA for stability analysis for grain yield in pearl millet.

Source	Degrees of Freedom	Mean Sum of Squares
Genotypes	9	1368833.654
Environment	2	4064457.114***
G x E	18	94972.668
Environment + (G x E)	20	491921.113**
Environment (Linear)	1	8128914.229***
G x E (Linear)	9	79872.785
Pooled Deviation	10	99065.296***
Pooled Error	54	20085.952

Table 5. Environmental Means, Environmental Indices, General Mean (X), S^2di and bi values for grain yield in pearl millet.

S.No.	Name of the / variety	Mean Grain Yield (Kg / ha)			General Mean	S^2di	bi
		Environment 1 (*Kharif* 2011)	Environment 2 (*Kharif* 2012)	Environment 3 (*Kharif* 2013)			
1	GHB 558	1812.333	1117.667	388.000	1106.000	42645.240	1.082
2	86 M 64	1655.667	1168.333	769.000	1197.667	-7059.043	0.685
3	ICMH 356	2161.000	1183.667	836.333	1393.667	-18553.809	1.077
4	B 2301	1900.667	1709.667	769.667	1460.000	214984.195	0.783
5	Saburi	2920.333	1175.000	872.667	1656.000	35376.935	1.714
6	Shradha	1773.667	1465.667	926.667	1388.667	34163.594	0.621
7	ICMV 221	2115.333	1311.333	754.000	1393.556	-3363.271	1.064
8	ICTP 8203	2343.667	1578.000	1077.333	1666.333	-8677.537	0.994
9	ICMV 155	2372.000	833.000	1081.000	1428.667	226421.706	1.174
10	Raj 171	1706.333	438.667	889.000	1011.333	279506.320	0.805
Environmental Index		705.911	-172.089	-533.822			
Grand Mean		2076.100	1198.100	836.367	1370.189		
C.V. (%)		15.936	16.932	2.763			
SEDM at 5%		270.141	165.637	141.788			
CD at 5%		567.545	347.990	297.886			

2011, 2012 and 2013 were treated as Environment-1, Environment-2 and Environment-3 respectively and here after three seasons are represented with respective environments.

In the Environment-1, crop period received a total of 213.6 mm rainfall with 13 rainy days *i.e.,* from 31st to 42nd standard weeks (Table 2). It is characterized with less crop growing period *i.e.,* total crop period was completed within 12 standard weeks. In this environment the crop experienced one dry spell (more than 15 days dry period is considered as dry spell) *i.e.,* in 38th and 39th standard weeks and in this period crop was in GS 3 (grain hardening stage) growth stage. (Table 3)

In the Environment-2, crop period received a total of 286.6 mm rainfall with 26 rainy days *i.e.,* from 29th to 42nd standard weeks (Table 2). It is characterized with little higher rainfall than environment-1 with two weeks extended crop growing period *i.e.,* crop period completed within 14 standard weeks. In this environment the crop experienced two dry spells. One was in 32nd and 33rd standard weeks which was during GS 1 (vegetative stage) growth stage of crop and the second one was in 37th and 38th standard weeks, in which period the crop was in GS 2 (grain filling stage) growth stage.

In the Environment-3, crop period received a total of 359.0 mm rainfall with 15 rainy days *i.e.,* from 27th to 43rd standard weeks (Table 2). In this environment higher rainfall was received than the other two environments and the crop growing period extended by 4 weeks than the environment 1 and three weeks than the environment 2. Total crop period was 16 standard weeks. In this environment crop experienced moisture stress in all three growth stages viz., GS1, GS 2 and GS3. During the crop growth period there are two long dry spells / drought periods occurred. One is 57 days duration dry spell from 28th to 35th standard week *i.e.,* in GS1 and GS2 growth stages (vegetative and grain filling stages) and second one is with four standard weeks duration *i.e.,* from 39th to 42nd standard week and it effected GS3 growth stage (grain hardening stage) of the crop.

Even though there is higher rainfall received during the crop period in environment 3 compared to other two environments, the grain yield in pearl millet is mostly affected in environment 3. It is due to the occurrence of drought or prolonged dry spell with more number of dry spells compared to other two environments and that to crop experienced moisture stress in GS2 and GS3 in environment 3. These two growth stages in pearl millet *viz.,* GS2 and GS3 are very sensitive for moisture stress, which will affect the grain yields in pearl millet. Hence, in the present study, the grain yields of all the genotypes in environment 3 were low when compared to environment 1 and 2. These results are in accordance with the studies of Mahalakshmi and Bidinger (1985 and 1987); Mahalakshmi *et al.,* 1988; Yadav and Weltzien (2000).

The analysis of variance (Table 4) indicated that significance of environments suggesting the presence of considerable influence of differential environments on grain yield. The genotype x environment interaction was found non significant. The differences between the mean squares due to environments + (G x E) was highly significant for grin yield. The G x E interaction was partitioned in to linear and non-linear components. On partitioning of G x E interaction, Environment (linear) was significant and larger in magnitude, suggesting its importance in expression of grain yield performance in pearl millet and indicating the prediction of performance across the environments is possible. This is also confirmed from overall ANOVA, where linear component is more than non-linear component. In prediction of performance, non linear component may have its role and it is also significant. The significant pooled deviation (non-linear component) mean sum of squares for grain yield indicated that the genotypes differed considerably with respect to their stability for this character. Considering the environmental indices (Table 5) the environment-1 (*Kharif* 2011) was observed to be more favourable for grain yield in pearl millet with highly positive value (705.911) compared to other two environments (*Kharif* 2012 and 2013). Thus the present findings are in consonance with those of Singh and Gupta (1978), Pethani and Kapoor (1985), Baviskar (1990), Suryavanshi *et al.,* (1991), Anarase *et al.,* (2000 and 2002), Hanif Munawwar *et al*., (2007) and Patil *et al*., (2014).

The assessment of stability parameters, mean (X), regression coefficient (S^2di) and deviation from regression (bi) helped to categorize the genotypes in to different groups (Table 5) *viz.,* those suitable for favourable environmental conditions; characterized by Xi > 0……., bi > 1, S^2di = 0 and those suitable for poor environments had Xi > 0……., bi < 1, S^2di = 0 and genotypes showing general adaptability to all environmental conditions characterized by Xi > 0……., bi = 1, S^2di = 0 and genotypes showing general adoptability to all environmental conditions characterized by Xi > 0, bi = 1 and S^2di = 0. Accordingly among ten genotypes studied, three genotypes *viz.,* ICMH 356, ICMV 221 and ICTP 8203 have shown average stability over the environments for grain yield, since these three genotypes showed regression coefficient 'bi' nearer to one and values for deviation from regression (S^2di) is as small as possible, mean is higher than the general mean (General mean of grain yield over the three environments is 1370.189 kg/ha). Suryavanshi *et al.,* (1991), Anarase *et al.,* (2000 and 2002), Yadav *et al.,* (2001), Yahaya *et al.,* (2006); and Patil *et al*., (2014) also reported similar type of results in pearl millet. The genotype Saburi and ICMV 155 have shown regression coefficient values (bi) more than one, coefficient of determination (r^2) nearer to unity even though there is higher value for deviation from regression (S^2di) and higher mean grain yield than that of the general mean (1370.189 kg/ha) indicating their suitability for favourable conditions. The hybrid 86 M 64 has shown less than one regression coefficient (bi), with higher mean grain yield than the general mean (1370.189 kg/ha) and the values for deviation from regression (S^2di) is as small as possible, indicating its suitability for poor environmental conditions where as the hybrids B 2301 and Shradha were also can be considered as suitable for unfavorable conditions since these two hybrids expressed less than one regression coefficient (bi) and higher mean grain yield than the general mean (1370.189 kg/ha) even though there is higher values for deviation from regression (S^2di). Due to this typical character Shradha is the most popular and stable hybrid of pearl millet in Maharastra state [Patil *et al*., (2014)].

Thus, based on above discussion, it is concluded that the environments studied have shown sufficient variability. On partitioning of G x E interaction, both linear and non linear components, have expressed their important role in expression of grain yield in pearl millet crop. The genotypes Saburi and ICMV 155 were found suitable for favourable environmental conditions and genotypes 86 M 64, B 2301 and Shradha were identified as suitable for unfavourable environmental conditions for grain yield where as the genotypes ICMH 356, ICMV 221 and ICTP 8203 have expressed general adoptability to all environmental conditions. Among the three environments studied the environment 1 is considered as most suitable and favourable environment for grain yield in pearl millet as it received well distributed rainfall during GS1 and GS 2 growth stages of the crop period and environment 3 is considered as unfavourable.

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