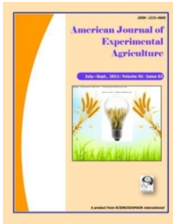

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Assessment of Genotype X Environment Interaction and Stability of Promising Sugarcane Genotypes for Different Agronomic Characters in Peshawar Valley

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Authors' contributions

This work was carried out in collaboration between all authors. Author MT Designed, and laid out the experiment; compiled the study results, followed by statistical analyses; wrote the first draft. Author HR critically reviewed the first draft. Authors AA and SA helped in relevant literature search. Author MK helped a lot during field work and compilation of the data. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Sugarcane germplasm screening and testing for superior attributes is a regular feature of the breeding program at Sugar Crops Research Institute, Mardan, Khyber Pakhtunkhwa, Pakistan. Sixteen genotypes which were in the final stages of selection were evaluated in three different environments for Genotype by Environment (G x E) interaction and stability performance. Combined analysis of variance showed highly significant variances for Environments (E), Genotypes (G), and their interaction (G x E). The effect of environments was very pronounced for all the characters highlighting their importance in the performance of genotypes. None of the genotypes was stable across the three environments for all characters. However, genotypes Mardan 93 and CP 77/400 showed a comparative stability for cane yield (t/ha).

Keywords: Environments; stability; sugarcane.

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1. INTRODUCTION

Sugarcane is an important field crop of the Khyber Pakhtunkhwa Province of Pakistan. It is cultivated on an area of 0.1 million hectare with a production of 4.65 million tones and cane yield amounting 46 tons per hectare [1]. Sugar Crops Research Institute (SCRI), Mardan, is mandated with the development of sugarcane varieties with high yield, disease and frost resistance and accompanied with better quality. Germplasm is procured from within the country and abroad as well. It is tested in various selection stages and advanced to final stages of selection. Varieties are sought which would interact the least with the environment so that they could be selected for a wide range of environments.

Genotype by environment (G x E) interactions considerably complicates selection and testing of plant genotypes, particularly when exposed to diverse set of environments. Measuring G x E is important in order to determine an optimum strategy for selecting genotypes with adaptation to target environments [2,3]. Productivity stability is shown by some cane varieties in both predictable and unpredictable environments. In a predictable environment (i.e. climatic, soil type, day length and controllable variables such as fertilization, sowing dates and harvesting methods), a high level of genotype and environmental interaction was desirable, so as to ensure a maximum yield and financial return; whereas, in an unpredictable environment (inter and intra-season fluctuation, fluctuation in quantity and distribution of rainfall and prevailing temperature), a low level of interaction is desirable so as to ensure maximum uniformity of performance over a number of locations or seasons [4]. However, the performance of genotypes in favorable environments does not indicate their adaptability and stability. Hence, breeders are in search of suitable high yielding genotypes which would interact minimal with the environments and are stable over a series of environments.

The current study was undertaken to assess genotype by environment interaction and stability of 16 sugarcane genotypes for different plant and yield characters.

2. MATERIALS AND METHODS

Three experiments were carried out in three environments: two at Sugar Crops Research Institute during 2005-06 and 2006-07 and one at Harichand Seed Multiplication Farm during 2005-06. The experimental material comprised of 16 advanced lines/varieties mostly of CP (Canal Point, Florida) origin, including two checks (Mardan 93, and CP 77/400), laid out in randomized complete block design. Data were recorded on germination percentage, number of tillers, plant height, cane yield and millable canes.

The data were analyzed using MSTATC version 2.01 [5]. Combined analyses of variance and stability parameters were worked out using PBSTAT online version 1.0 [6]. It calculates regression coefficients (bi) values by regressing individual variety means on the mean yield of all varieties for each environment.

3. RESULTS AND DISCUSSION

3.1 Mean Squares for Individual Environments

The mean squares for individual environments are given in Table 1. The range of coefficient of variation (cv) for all the characters studied over the three environments was less than 20

[7] and hence were forwarded for combined analysis of variance. Mean squares were significant for the characters under study except a non-significant effect for number of tillers only.

3.2 Mean Performance of the Genotypes over Environments

Genotypic means are given in Table 2. Mean performance of the genotypes for germination percentage showed that MS-94-CP-90, MS-92-CP-1100, and MS-91-CP-965 performed better than the rest with a mean range of 51 to 54. For number of tillers, genotypes Mardan 93, MS-94-CP 90, and MS-91-CP 965 outperformed the rest of the genotypes. MS-91-CP-288, Malakand 17, MS-94-CP-90 and MS-92-CP-623 were taller than the rest of the genotypes. Regarding cane yield (t/ha) MS-91-CP-920, MS 92-Cp-623, MS-91-CP-623, and CP 77/400 performed well above average. Higher Millable canes were given by MS-92-CP-623, Mardan 93, and MS-94-CP-90, respectively.

3.3 Genotype x Environment Analysis

G x E analysis in Table 3 revealed highly significant variances for Environments (E), Genotypes (G), as well as their interaction (G x E). The effect of environments was much pronounced for all the characters signifying its importance in the performance of genotypes. Mean square differences were also significant for genotypes showing that the differences among the genotypes were persistent over the environments. These were higher than G x E interaction mean squares, indicating the varied response of the genotypes was a permanent characteristic for locations. Similar results were reported by Tai et al. [8] where in they found significant cultivar differences over interactions. Variance components analyses exhibited that interaction variance was larger for all characters except germination percentage. Higher phenotypic variance revealed the impact of environmental factors on the genotypes. Similar results have also been reported by Singh and Singh [9], where in they found significant mean squares for environments, genotypes and their interaction for various characters studied sugarcane.

3.4 Stability Analysis

A cultivar with ‘b’ value less than 1.0 has above average stability and is anticipated to perform well under unfavorable environments, while a cultivar with ‘b’ value greater than 1.0 has below average stability and is specially adapted to improved environments. On the other hand a cultivar with ‘b’ value equal to 1.0 has average stability and is expected to be well adapted to all environments accompanied with high mean performance [10].

3.5 Germination Percentage

Regression values for germination percentage (Table 4) indicated that genotypes MS-91-CP-623 and MS-94-CP-90 had regression coefficient value close to unity, showed average stability for this character with means higher than grand mean and were therefore, well adapted to all environments. Genotypes MS-91-CP-471, MS-91-CP-965, MS-92-CP1100 and CP 77/400 (Figure 1) showed regression values above unity indicating that they had below average stability and were expected to perform better under favorable environments. The rest of the genotypes exhibited a slope value less than 1 indicating that they were comparatively better performing under unfavorable conditions.

Table 1. Mean squares for the characters over individual environment

Environments	Source of variation	D.F	Germination %	No. of tillers	Plant height	Cane yield	Millable cane
E1	Replications	2	12.771 ns	2541.396 ns	1563.271**	50.333 ns	20.813 ns
	Genotypes	15	221.022 **	8645.106 **	577.654**	312.706**	177.321**
	Error	30	43.726	639.418	138.538	111.556	22.79
	cv		12.1	10.61	8.1	12.62	4.94
E2	Replications	2	134.021*	4497.646*	280.750 ns	180.063 ns	21 ns
	Genotypes	15	120.465**	4456.800**	453.222**	389.343**	941.443**
	Error	30	31.932	1015.646	148.106	91.351	38.822
	cv		11.16	13.08	7.52	16.18	7.03
E3	Replications	2	6.083 ns	446.333 ns	63.521 ns	59.313 ns	95.063**
	Genotypes	15	59.194**	642.706 ns	1626.376**	90.154**	47.699**
	Error	30	2.61	378.156	395.876	20.913	15.507
	cv		4.74	14.25	11.43	8.74	9.17

*ns: non-significant; **: Significant at P=0.01; *: Significant at P=0.05*

Table 2. Genotypic means of the 16 genotypes combined over environments

S.No.	Genotype	Germination %	No. of Tillers	Plant Height	Cane Yield (t/ha)	Millable Cane*
1	Malakand 17	40.22^{de}	159.67^{ef}	177.22^{ab}	53.00^{d}	47.00^{d}
2	MS-92-CP-623	44.11^{bcd}	225.67^{abc}	168.44^{abc}	71.11^{ab}	83.89^{a}
3	MS-92-CP-624	45.78^{bcd}	198.89^{bcdef}	163.11^{abc}	67.67^{abcd}	77.78^{abc}
4	MS-91-CP-611	34.89^{e}	189.22^{cdef}	149.56^{cd}	60.33^{abcd}	73.22^{c}
5	MS-91-CP-572	38.33^{de}	210.67^{bcd}	157.67^{bcd}	65.22^{abcd}	76.33^{abc}
6	MS-91-CP-288	45.00^{bcd}	204.56^{bcd}	183.44^{a}	68.11^{abc}	77.56^{abc}
7	AEC-86-347	47.00^{abcd}	202.00^{bcde}	166.33^{abc}	66.89^{abcd}	76.33^{abc}
8	Mardan 93	42.11^{cde}	258.22^{a}	155.33^{bcd}	69.11^{abc}	82.11^{ab}
9	MS-91-CP-471	50.00^{abc}	211.00^{bcd}	132.33^{d}	63.22^{abcd}	76.78^{abc}
10	MS-91-CP-623	50.56^{abc}	203.33^{bcde}	154.00^{bcd}	70.89^{ab}	77.44^{abc}
11	MS-91-CP-920	39.44^{de}	177.33^{def}	144.44^{cd}	72.22^{a}	79.33^{abc}
12	MS-91-CP-965	51.67^{ab}	234.56^{ab}	160.56^{abc}	57.00^{bcd}	74.00^{bc}
13	MS-92-CP-1100	51.44^{ab}	200.22^{bcdef}	149.22^{cd}	66.00^{abcd}	78.78^{abc}
14	MS-94-CP-90	54.78^{a}	234.67^{ab}	168.56^{abc}	63.67^{abcd}	81.11^{abc}
15	CPF-236	45.22^{bcd}	156.89^{f}	166.44^{abc}	56.00^{cd}	74.67^{bc}
16	CP 77/400	50.22^{abc}	231.33^{abc}	165.33^{abc}	70.00^{abc}	75.33^{abc}

** Means followed by the same letters do not differ significantly.*

Table 3. Mean Squares for environments and genotypes in combined analysis of variance

Source	df	Germination %	Tillering	Plant height	Cane yield	Millable canes
Environments(E)	2	7215.05**	175140.36**	9559.15**	13109.42**	39277.75**
REP*E	6	50.96 ^{ns}	2495.13**	635.85*	96.57 ^{ns}	45.63 ^{ns}
Genotypes (G)	15	282.97**	6726.29**	1443.88**	301.92**	604.07**
G*E	30	58.86**	3509.16**	606.69**	245.14**	281.19**
Error	90	25.97	677.74	226.51	74.61	25.54
cv		11.16	12.63	9.4	13.28	6.67
Variances						
V_P		31.44	747.37	160.43	33.55	67.12
V_G		24.9	357.46	93.02	6.31	35.88
V_{GxL}		10.96	943.81	126.73	56.85	85.22
h^2_{bs}		79.2	47.83	57.98	18.81	53.45

*ns: non-significant; **: Singinficant at P=0.01 *; Significant at P=0.05; V_G= Genotypic Variance V_{GxL}= Interaction Variance V_P= Phenotypic variance h^2_{bs}= Broad Sense Heritability.*

Table 4. Means and regression slope for 16 genotypes

S. No.	Genotype	Germination %		No. of tillers		Plant height		Cane yield		Millable canes	
		Mean	bi*	Mean	Bi	Mean	bi	Mean	bi	Mean	bi
1	Malakand 17	40.22	0.85	159.67	0.2	177.22	2.17	53	1.18	47	0.3
2	MS-92-CP-623	44.11	0.89	225.67	1.19	168.44	1.37	71.11	1.22	83.89	1.23
3	MS-92-CP-624	45.78	0.61	198.89	1.08	163.11	1.04	67.67	1.16	77.78	1.12
4	MS-91-CP-611	34.89	0.63	189.22	1.16	149.56	1.69	60.33	0.77	73.22	1.17
5	MS-91-CP-572	38.33	0.93	210.67	1.09	157.67	0.59	65.22	0.75	76.33	0.88
6	MS-91-CP-288	45	0.95	204.56	0.73	183.44	1.59	68.11	0.75	77.56	1.02
7	AEC-86-347	47	1.08	202	0.95	166.33	2.45	66.89	0.84	76.33	0.99
8	Mardan 93	42.11	0.88	258.22	1.31	155.33	1.53	69.11	0.97	82.11	1.11
9	MS-91-CP-471	50	1.32	211	0.91	132.33	0.41	63.22	1.43	76.78	1.07
10	MS-91-CP-623	50.56	0.99	203.33	1.06	154	0.52	70.89	1.6	77.44	1.1
11	MS-91-CP-920	39.44	0.89	177.33	0.54	144.44	0.86	72.22	1.37	79.33	0.85
12	MS-91-CP-965	51.67	1.58	234.56	1.69	160.56	0.56	57	0.41	74	0.81
13	MS-92-CP-1100	51.44	1.36	200.22	1.12	149.22	0.24	66	1.07	78.78	1.21
14	MS-94-CP-90	54.78	1.02	234.67	1.28	168.56	-0.43	63.67	0.9	81.11	1.08
15	CPF-236	45.22	0.64	156.89	0.3	166.44	1.42	56	0.6	74.67	1
16	CP 77/400	50.22	1.39	231.33	1.4	165.33	0.01	70	0.98	75.33	1.06
	Grand Mean	45.67		206.14		160.12		65.03		75.73	

Regression Slope

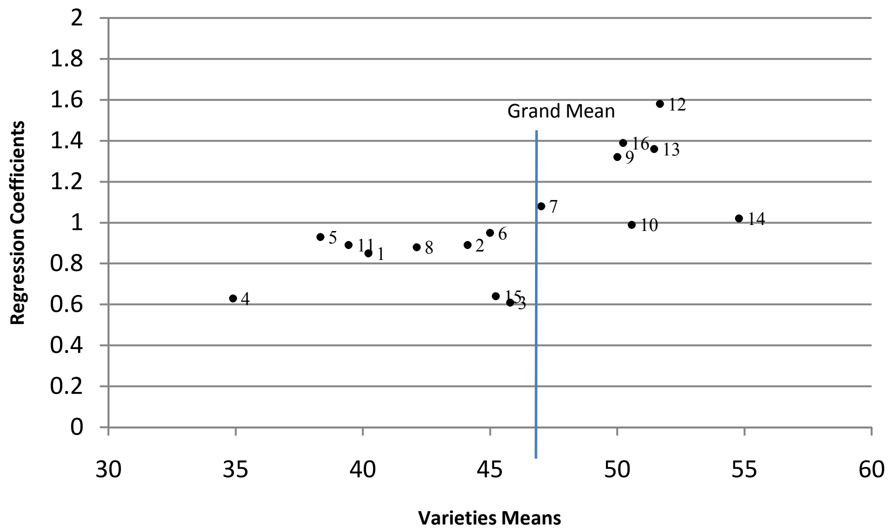

Figure 1. Variety Means Vs Regression Coefficients for Germination Percentage

3.6 Number of Tillers

For number of tillers, genotypes MS-91-CP-572 and MS-91-CP-471 exhibited regression coefficient values closer to unity accompanied with higher mean values. This indicated that these genotypes performed well under all tested environments. Figure 2 shows that genotypes MS-91-CP-288, MS-91-CP471, MS-91-CP-920 and CPF-236 had values regression coefficient values below 1 and hence were expected to perform well under unfavorable environments. The rest of the genotypes had values more than 1 and were supposed to be specifically adapted to favorable environments.

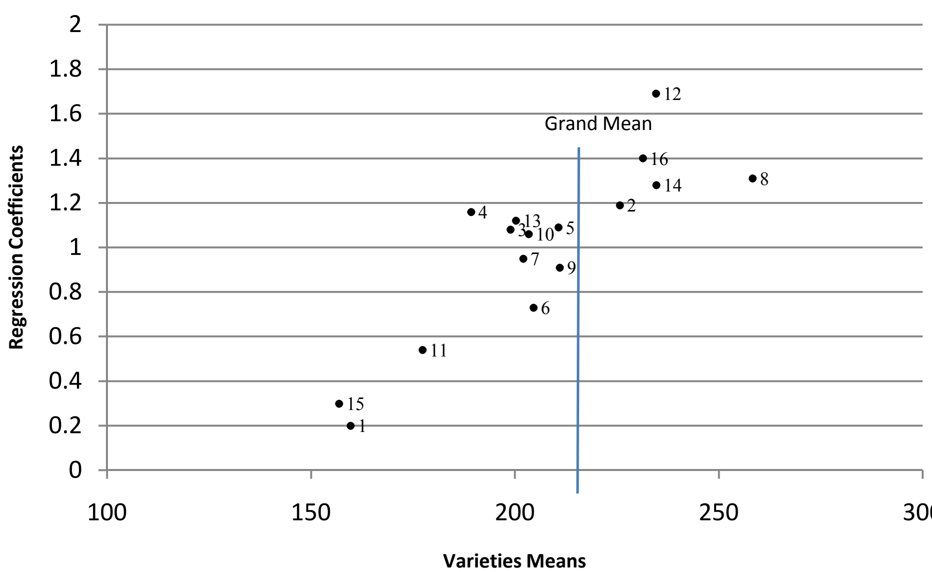

Figure 2. Variety Means Vs Regression Coefficients for No. of Tillers

3.7 Plant Height

For plant height only genotype MS-92-CP-624 had a value close to unity (Figure 3) and higher mean yield (Table 4), 8 genotypes had a value less than 1 while remaining genotypes exhibited slope value more than 1.

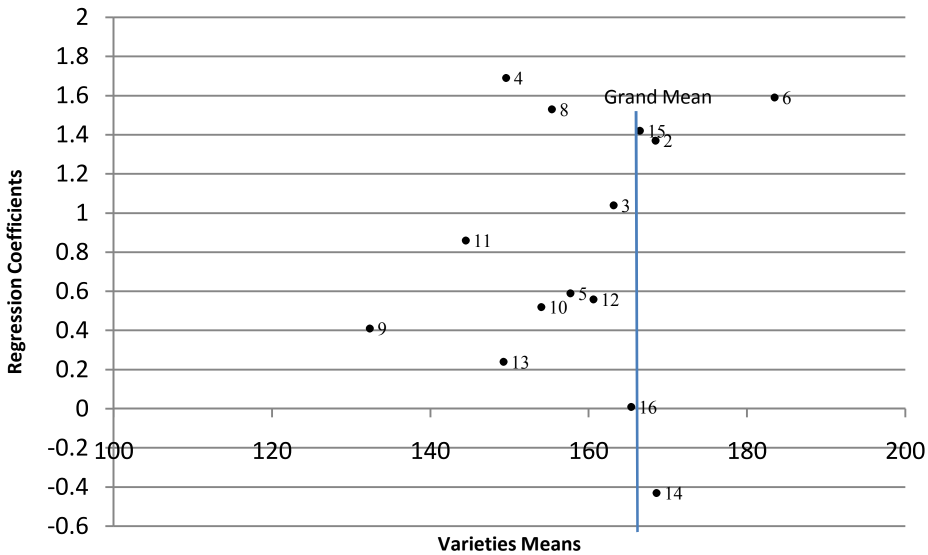

Figure 3. Variety Means Vs Regression Coefficients for Plant Height

3.8 Cane Yield

For this character, genotypes Mardan 93 and CP 77/400 showed values close to unity and had higher mean yields (Figure 4). Seven genotypes showed regression values lesser than 1 while rest of the genotypes were having regression coefficient values above 1.

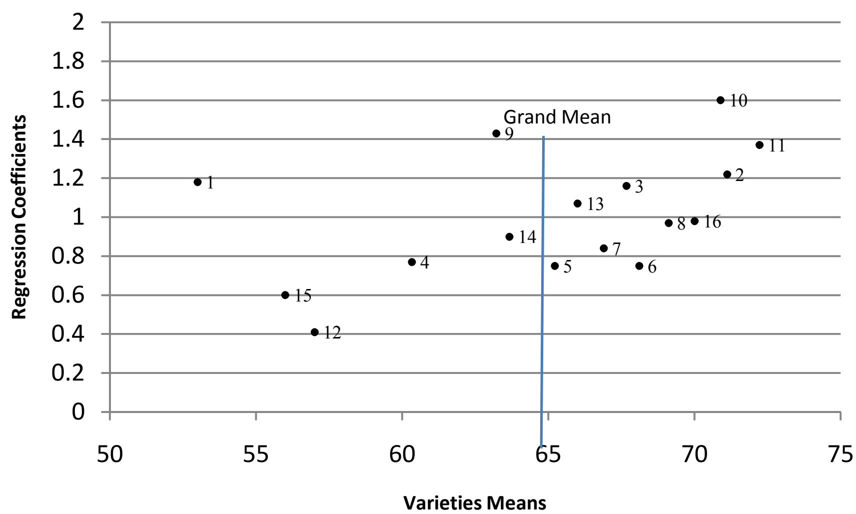

Figure 4. Variety Means Vs Regression Coefficients for Cane Yield

3.8 Millable Canes

For millable canes genotypes MS-91-CP-288 and MS-91-CP-471 showed regression values close to unity and had higher mean yields. Genotype 15 though showed a unit regression, had a lower mean yield than the grand mean. Genotypes MS-91-CP-572, MS-91-CP-920, and MS-91-CP-965 (Figure 5) had regression values less than 1 and hence exhibited above average stability. The rest of the genotypes showed their adaptability to favorable environments.

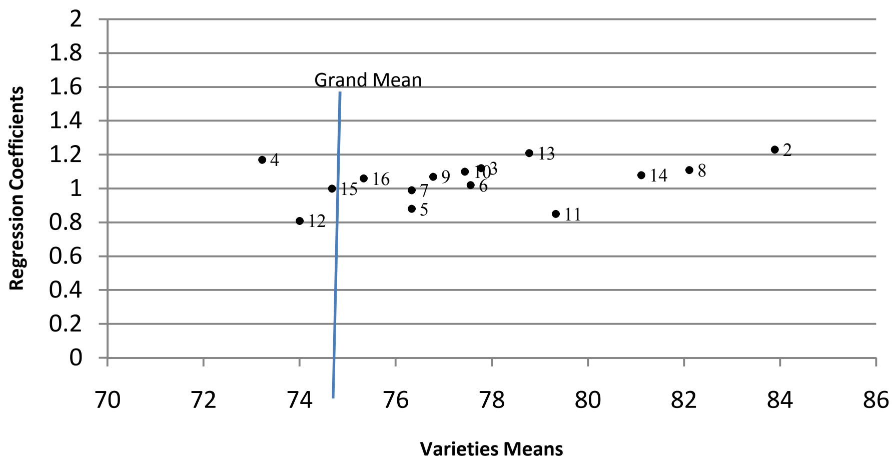

Figure 5. Variety Means Vs Regression Coefficients for Millable Canes

4. CONCLUSION

The present study indicated that none of the genotypes performed well under all environments with respect to all characters. However, genotypes Mardan 93 and CP 77/400 showed average stability with higher mean cane yield (t/ha). It means that they can yield better under all environments. It can be concluded that G x E interaction and stability analysis/testing of advanced breeding material needs to be an integral part of sugarcane breeding program so that sugarcane genotypes with superior cane yield and other desirable attributes could be identified for multiple environments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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