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STABILITY ANALYSIS AND G X E INTERACTIONS FOR GREEN FODDER YIELD IN FORAGE MAIZE (*ZEA MAYS* L.)

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SUMMARY

Genotype x environment interactions and stability parameter analysis are of major importance to sort out high yielding and stable hybrids. Forty-five hybrids and 14 parents were evaluated during **kharif** 2012 (E_1), **rabi** 2012 (E_2) and summer 2013 (E_3) seasons to identify stability for green forage yield per plant in forage maize. G x E (linear) and G x E (non-linear) were found significant for fresh green stem weight per plant and green forage yield per plant. Among the parents, GWC-0401 had above average stability, thereby specifically adapted to poor environment. Among the hybrids, IC-107121 x GWC-0511 and African Tall x GWC-0401 had average stability, which indicated that these hybrids would be well adapted over range of environments, while the hybrids IC-130726 x GWC-0512, GM-6 x IC-130693, GM-6 x GWC-0512, J-1006 x GWC-0319, J-1006 x GWC-0511 and J-1006 x GWC-0512 had below average stability, thereby specifically adapted to favourable environment, whereas the hybrid IC-130726 x GWC-9603 had above average stability, thereby specifically adapted to poor environment.

Key words : Forage maize, stability, G x E interaction, parents, crosses

Maize (*Zea mays* L.) is almost an ideal cereal forage crop because of its fast growing habit, high palatability and nutritious qualities and can be grown in any season. It has a relatively low cell wall content and high content of non-structural carbohydrates, and as a result it has a high digestibility and bio-energy value. Also, it has no toxic compounds and can be fed at any stage of growth. It is true that less number of stable hybrids are released as forage maize. The present study is an attempt to assess the possibilities of commercial exploitation of stable and high yielding hybrids of forage maize, through estimating genotype x environment interactions and stability parameter analysis.

MATERIALS AND METHODS

The hybrids were developed by crossing five lines (IC-107121, IC-130726, GM-6, J-1006 and African Tall) and nine testers (IC-130643, IC-130693, GWC-0319, GWC-0320, GWC-0321, GWC-0401, GWC-0511, GWC-0512 and GWC-9603) in line x tester mating design. The experimental material for the present investigation consisted of 14 parents (5 lines+9 testers) and 45 hybrids. The experiment was conducted at the research farm of Main Forage Research Station, Anand Agricultural University, Anand (Gujarat) during **kharif** 2012 (E_1), **rabi** 2012 (E_2) and summer 2013 (E_3) seasons. Each experimental plot consisted of two rows of 4.5 m length each. The inter-row and intra-row spacings were 30 and 15 cm, respectively. The experiment was evaluated in a randomized block design with three replications. The recommended agronomic practices were followed for raising a normal crop.

For recording observations, five competitive plants were randomly selected from each treatment in each replication and the average value per plant was computed for fodder yield and its contributing traits. The most widely used approach is the regression technique, in which partitioning of G x E interactions component of variability into its linear and non-linear component for assessing the stability of genotypes over a range of environment. This is known as joint regression analysis. In the present study, the same approach as outlined by Eberhart and Russell (1966) has been used.

RESULTS AND DISCUSSION

Pooled analysis of variance over three environments showed that the genotypic variances when tested against G x E were significant for all the traits, which indicated the presence of substantial variation in the material studied. However, when tested against pooled deviations these variances revealed significant differences for all the traits studied except plant height, number of leaves per plant and leaf : stem ratio.

Environmental variances were highly significant for all the characters except fresh green stem weight per plant and leaf : stem ratio, which suggested differences among the imposed environments. The data in Table 1 further indicate the significance of G x E interaction for all the characters except days to 50 per cent tasseling, number of leaves per plant, leaf length, leaf width and stem diameter, which revealed that genotypes interacted differently with environmental variations for all the characters except listed above, and variance due to G x E interaction was further partitioned into components (i) G x E (linear) and (ii) G x E (non-linear) i. e. pooled deviation, for the characters which showed significance of G x E interaction. The values of mean square due to environments + (genotypes x environments) were found to be significant for all the characters except plant height, number of leaves per plant and leaf : stem ratio, which suggested variable response of genotypes to changing environments. Highly significant estimates of mean square due to environments (linear) for all the characters indicated that environments differed considerably among different seasons. In respect of significance of G x E interaction, G x E (linear) and G x E (non-linear) were found significant only for fresh green stem weight per plant and green forage yield per plant and, component of G x E (linear) had greater magnitude than G x E (non-linear) for both these characters so the stability parameters in respect of only these two characters were estimated. Stability parameters viz., deviation from regression (S^2di), second stability parameter, regression coefficient (bi), first stability parameter and mean (m) were estimated here for green forage yield per plant with each genotype. The observed high magnitude of genotypes x environments (linear) component could lead to the identification of genotypes deviating from the regression line of unit slope. Accordingly, three kinds of linear responses (bi) viz., bi=1, bi>1 and bi<1 have been marked. The hypothesis that regression coefficient statistically at par to unity $H_0=b_0=1$ was tested by appropriate 't' test with bi – 0 value. Significance of 't' test suggests that the 'b' value significantly differed from zero, and it's significant deviation from unity was tested with 1-bi value. Significance of 't' test suggests that the 'b' value significantly deviated from unity. However, negative bi values attributed to inadequacy of the scale used for the analysis and/or an inherent capability of the genotypes investigated.

As a stability point of view, higher green forage yield per plant is the most important character. The parental mean was 316.93 g and hybrids mean was 347.40 g (Table 2). Out of 59 genotypes, 23 genotypes had non-significant deviation from linear regression, and 28 genotypes had higher green forage yield per plant

TABLE 1

Analysis of variance (mean squares) for various traits for stability with three environments (Eberhart and Russell, 1966)

Character	Mean sum of squares							
	Genotypes (G)	Environments (E)	G x E	E + (G x E)	Environments (linear)	G x E (linear)	Pooled deviation	Pooled error
d. f.	58	2	116	118	1	58	59	348
Days to 50% tasseling	27.44**++	15308.00**	10.1	269.38++	30616.07++	13.11	6.96	8.56
Plant height	417.61**	3206.09**	215.84@@	266.52	6412.55++	120.94	305.46@@	79.96
No. of leaves/plant	0.88*	21.38**	0.57	0.92	42.74++	0.45	0.67	0.68
Leaf length	46.08**++	1567.29**	22.13	48.32++	3134.06++	19.74	24.12	22.79
Leaf width	0.63**++	18.98**	0.28	0.60++	37.97++	0.33	0.22	0.4
Stem diameter	0.05*+	1.65**	0.031	0.06++	3.29++	0.04	0.03	0.03
Fresh green leaf weight/plant	1319.56*+	48293.73**	872.04@@	1675.79++	96587.19++	983.91	747.28@@	60.38
Fresh green stem weight/plant	7550.26**++	9263.67	4311.00@@	5808.05+	185271.78++	5198.79+	3365.23@@	67.26
Leaf : stem ratio	0.09*	0.16	0.06@@	0.06	0.32+	0.06	0.06@@	0.003
Green forage yield/plant	8553.12**++	269380.10**	4750.40@@	9235.65++	538768.87++	5677.08+	3758.76@@	232.73

*, **Significant at P=0.05 and P=0.01 levels, respectively when tested against G x E.

@, @@Significant at P=0.05 and P=0.01 levels, respectively, when tested against pooled error.

+, ++ Significant at P=0.05 and P=0.01 levels, respectively, when tested against effective pooled deviation.

TABLE 2
Stability parameters (Eberhart and Russell, 1966) for green forage yield per plant (g) in forage maize

S. No.	Parents	Mean	b_i	S^2di	S. No.	Hybrids	Mean	b_i	S^2di
1.	IC-107121	362.56	1.22	13539.49##	16.	IC-130726 x GWC-0511	341.67	-0.30	44.11
2.	IC-130726	330.67	2.09**++	7067.10##	17.	IC-130726 x GWC-0512	507.44	2.41**++	195.34
3.	GM-6	346.33	1.81**++	641.34##	18.	IC-130726 x GWC-9603	394.67	0.32**++	-72.67
4.	J-1006	359.22	1.95**++	2666.83##	19.	GM-6 x IC-130643	322.22	0.02	1584.66##
5.	African Tall	308.22	-0.11	58.75	20.	GM-6 x IC-130693	407.44	1.22**++	-65.00
6.	IC-130643	317.11	1.58*	13640.94##	21.	GM-6 x GWC-0319	330.11	0.83*	842.55##
7.	IC-130693	358.78	0.70	1312.47##	22.	GM-6 x GWC-0320	314.89	1.16**++	-77.30
8.	GWC-0319	244.22	0.90**+	-65.20	23.	GM-6 x GWC-0321	309.22	0.18	6130.82##
9.	GWC-0320	308.00	0.02	-11.85	24.	GM-6 x GWC-0401	357.11	1.06**	1128.18##
10.	GWC-0321	259.67	-0.39	499.34##	25.	GM-6 x GWC-0511	315.89	0.74	5887.98##
11.	GWC-0401	339.22	0.72**++	-77.24	26.	GM-6 x GWC-0512	400.00	2.17**++	174.40
12.	GWC-0511	328.11	-0.17	28.61	27.	GM-6 x GWC-9603	327.33	1.37**++	68.94
13.	GWC-0512	298.56	0.54**++	-53.65	28.	J-1006 x IC-130643	346.44	1.32**+	293.89#
14.	GWC-9603	276.33	0.24	54.50	29.	J-1006 x IC-130693	386.00	2.03**	23328.51##
	Parents mean	316.93	-	-	30.	J-1006 x GWC-0319	411.00	1.43**++	41.77
	Hybrids				31.	J-1006 x GWC-0320	337.33	0.52	2164.59##
1.	IC-107121 x IC-130643	263.00	0.44	1952.62##	32.	J-1006 x GWC-0321	418.00	1.47*	10047.96##
2.	IC-107121 x IC-130693	386.89	-0.21	6278.53##	33.	J-1006 x GWC-0401	454.22	2.22**++	10844.41##
3.	IC-107121 x GWC-0319	265.67	0.63	4349.63##	34.	J-1006 x GWC-0511	406.33	1.53**++	5.96
4.	IC-107121 x GWC-0320	306.67	0.92**+	-70.90	35.	J-1006 x GWC-0512	391.89	1.46**++	-11.57
5.	IC-107121 x GWC-0321	316.67	0.53	2942.62##	36.	J-1006 x GWC-9603	270.33	0.67	1715.60##
6.	IC-107121 x GWC-0401	296.89	1.39*	12628.4##	37.	African Tall x IC-130643	339.78	1.4**	1863.97##
7.	IC-107121 x GWC-0511	354.11	1.05**	13.79	38.	African Tall x IC-130693	360.11	1.61**++	1301.74##
8.	IC-107121 x GWC-0512	306.22	0.64**+	48.87	39.	African Tall x GWC-0319	395.67	2.89**++	7124.03##
9.	IC-107121 x GWC-9603	389.11	0.96	22691.54##	40.	African Tall x GWC-0320	320.78	0.47	2668.28##
10.	IC-130726 x IC-130643	341.56	0.35	2075.89##	41.	African Tall x GWC-0321	383.56	2.7**++	12195.70##
11.	IC-130726 x IC-130693	299.78	1.31	17796.20##	42.	African Tall x GWC-0401	382.67	0.78**	294.29
12.	IC-130726 x GWC-0319	296.89	-0.40	5659.89##	43.	African Tall x GWC-0511	431.44	0.75	1978.82##
13.	IC-130726 x GWC-0320	293.56	0.74	2071.58##	44.	African Tall x GWC-0512	322.44	2.12**++	-0.29
14.	IC-130726 x GWC-0321	311.22	1.99**+	7423.43##	45.	African Tall x GWC-9603	222.22	0.42	95.25
15.	IC-130726 x GWC-0401	296.33	0.63*	231.39#		Hybrids mean	347.40	-	-

[#, ##] Significant at P=0.05 and P=0.01 levels. *, **Significant at P=0.05 and P=0.01 levels when Ho : bi=0. [+, ++] Significant at P=0.05 and P=0.01 levels when Ho : bi=1.

TABLE 3

Classification of parental genotypes and hybrids based on their well adaptation in average, poor and better environments

Character	Classification of environments based on environmental index	Average stability and wide/ general adaptability (Mean>parents or hybrids mean; b_i=0 significant and b_i=1 NS; S^2d_i=0 NS)	Above average stability and adapted to poor environment (Mean> parents or hybrids mean; b_i=0 significant; b_i=1 significant and b_i<1.00; S^2d_i=0 NS)	Below average stability and adapted to better environment (Mean> parents or hybrids mean; b_i=0 significant; b_i=1 significant and b_i>1.00; S^2d_i=0 NS)
Parental genotypes				
Fresh green stem weight per plant	E_1 : Better E_2 : Poor E_3 : Average	-	GWC-9603	-
Green forage yield per plant	E_1 : Average E_2 : Better E_3 : Poor	-	GWC-0401	-
Hybrids				
Fresh green stem weight per plant	E_1 : Better E_2 : Poor E_3 : Average	-	IC-130726 x GWC-0319	GM-6 x GWC-0320
Green forage yield per plant	E_1 : Average E_2 : Better E_3 : Poor	IC-107121 x GWC-0511, African Tall x GWC-0401	IC-130726 x GWC-9603	IC-130726 x GWC-0512, GM-6 x IC-130693, GM-6 x GWC-0512, J-1006 x GWC-0319, J-1006 x GWC-0511, J-1006 x GWC-0512

E_1 : **Kharif** 2012, E_2 : **Rabi** 2012 and E_3 : Summer 2013.

than respective mean of parents or hybrids; out of which, 10 genotypes (bi>1: 7, bi=1: 0 and bi<1: 3) were identified as well adapted to various environments.

Among the parents, GWC-0401 had above average stability (Mean>parents mean; bi=0 significant; bi=1 significant and bi<1.00; S^2di=0 NS), thereby specifically adapted to poor environment (Table 3).

Among the hybrids, IC-107121 x GWC-0511 and African Tall x GWC-0401 had average stability (Mean>hybrids mean; bi=0 significant and bi=1 NS; S^2di=0 NS), which revealed that these hybrids would be well adapted over range of environments, while the hybrids IC-130726 x GWC-0512, GM-6 x IC-130693, GM-6 x GWC-0512, J-1006 x GWC-0319, J-1006 x GWC-0511 and J-1006 x GWC-0512 had below average stability (Mean>hybrids mean; bi=0 significant; bi=1 significant and bi>1.00; S^2di=0 NS), thereby specifically adapted to favourable environment, whereas the hybrid, IC-130726 x GWC-9603 had above average stability (Mean>hybrids mean; bi=0 significant; bi=1 significant and bi<1.00; S^2di=0 NS), thereby specifically adapted to poor environment. Similar findings were also reported by Yadav *et al.* (2010) and Bikash *et al.* (2013) in pearl millet and V"Lchinkov (1992) and Vaghela (2012) in maize.

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