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Genotype x environment interaction and stability analysis in sweet corn (*Zea mays* L. Ssp. *saccharata*) hybrids for various quantitative and qualitative traits

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Abstract
The present study was carried out to estimate genotype x environment interaction and stability for qualitative and quantitative traits in sweet corn hybrids (*Zea mays* L. Ssp. *saccharata*). Forty five hybrids using line x tester mating design were developed, which along with their eighteen parents and three checks (Priya, Madhuri and Sugar-75) were evaluated at three different locations during *kharif* 2019 (E1 and E2) and *rabi* 2019-20 (E3), in randomized block design. Stability analysis was done using Eberhart and Russell (1966) model were done on pooled basis for twenty different characters. The results of analysis of variance over the three environments for phenotypic stability revealed that variance due to genotypes and environment (linear) were significant for all the characters included under the study. Further stability analysis revealed that all the genotypes possessed non significant deviations from regression (S^2d_i) reflecting their predictable behavior for the trait green cob yield. Only the hybrid L_{12} x T_1 showed stable performance for protein content over the three environments. Study of data for green cob weight plant^{-1} revealed that two sweet corn hybrids L_7 x T_2 and L_7 x T_3 possessed non significant deviations from regression (S^2d_i) along with regression coefficient value nearly equivalent to unity (b_i=1) and mean greater than the population mean. The performances of these two hybrids thus could be predictable as well as stable for cultivation in various environments. Analysis for quality characters showed that for TSS content of green grain, sweet corn hybrids L_1 x T_1 and L_{11} x T_1 showed non significant deviations from regression (S^2d_i) and regression coefficient equivalent to unity (b_i=1) with greater mean than the population mean, thus signifying their predictable performances and stability for different environments for sweetness.

Keywords: Sweet corn, green cob yield, regression, stability, TSS

Introduction
Sweet corn is a field corn in an arrested state of development (Erwin, 1951) [3]. With high nutritional values, delicate texture and sweet taste within pericarp and endosperm, it is treated as vegetable (Kwiatkowski and Clemente, 2007) [6]. The most useful mutations resulting in its sweetness is due to genes *sh2*, *bt1*, *su1* and *se*, which function either by accumulating sugar at the expense of starch or by changing types and proportions of different polysaccharides stored in endosperm (Boyer and Shannon 1984) [2]. Due to the sweetness and tenderness of its kernels and its appetizing taste, which has in turn resulted in its increased cultivation in the country and ensuring good return to the farmers, popularity of sweet corn is increasing in the national and international market. Further, the left over plant after the harvest of cobs can be used as fresh or dry fodder for the animals. Recombining the same inbreds repeatedly without infusion of new heterotic combinations may lead to the depletion of heterosis (Revilla *et al*., 2000) [10]. The evaluation of genotype environmental interactions gives an idea about the stable performance of the genotype under varying environmental conditions, which in turn helps in assessing the genetic potential of the genotype and its nature. Lower magnitude of genotype environmental interactions indicates consistent performance of a genotype over a wide range of environments. Study of the magnitudes of genotype x environmental interactions for yield and yield related characters and quality parameters is must for any breeding programme aiming to develop stable hybrids.

Material and Methods
Eighteen diverse sweet corn inbred lines, collected from different parts of the country were used as parents (fifteen females and three testers) (Table 1). The crosses were made in line x tester matting design at Instructional Farm, RCA, Udaipur during *kharif* 2018.

Total 66 genotypes comprising of 45 sweet corn hybrids, 18 parental lines and 3 standard checks (Priya, Madhuri and Sugar-75) were evaluated in RBD in three different environments (E_1 at Instructional Farm, RCA, Udaipur during Kharif-2019, E_2 at ARS, Banswara during Kharif-2019 and E_3 at Instructional Farm, RCA, Udaipur during Rabi-2019-20) in RBD with three replications.

Recommended agronomic practices were used to raise a healthy crop. Observations were recorded for 20 yield attributing quantitative and qualitative characters like days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, number of leaves/ plant, length of leaf, breadth of leaf, days to green cob harvest, number of ear/ plant, ear length, ear girth, number of grain rows/ ear, number of grains/ row, 100 fresh seed weight, green cob weight/ plant, moisture per cent of green grain, green cob yield, green fodder yield, TSS content of green grain and protein content.Ten plants were taken from each row for recording observations from each replication. TSS content was recorded using hand refrectrometer.

Estimation was done over the three environments on pooled basis. The procedure proposed by Eberhart and Russell (1966) was used to estimate the stability and study of different characters of genotypes.

Table 1: List of genotypes used

S. No	Symbol	Pedigree	S. No	Symbol	Pedigree
1.	L_1	SC-7-2-1-2-6-1	10.	L_{10}	BAJ-SC-17-2
2.	L_2	SC-18728	11.	L_{11}	BAJ-SC-17-1
3.	L_3	BAJ-SC-17-6	12.	L_{12}	DMSC-28
4.	L_4	BAJ-SC-17-10	13.	L_{13}	Mas Madu (sh2 sh2)
5.	L_5	BAJ-SC-17-12	14.	L_{14}	MRCSC-12
6.	L_6	BAJ-SC-17-9	15.	L_{15}	SC-33
7.	L_7	BAJ-SC-17-11	16.	T_1	SC-35
8.	L_8	BAJ-SC-17-8	17.	T_2	SC-32
9.	L_9	BAJ-SC-17-4	18.	T_3	DMRSC-1

Result and Discussion

In present study, genotype x environment interaction was shared by both predictable (linear) and unpredictable (deviation) components for different traits. Eberhart and Russell model (1966) considered both linear (b_i) and non linear (S^2d_i) components of genotypes x environment interaction for predicting performance of a genotype. According to this model, any genotype possessing a unit regression coefficient (b_i=1) and non significantly deviation from regression (S^2d_i=0) along with higher mean performance than the population mean is regarded as stable or ideal genotype. Further, non significant deviation from regression (S^2d_i) indicates towards predictable and stable performance of any genotype in given set of environments.

The variance due to genotypes and environment (linear) were found significant for all the characters included under the study. The variance due to E + (G x E) interactions were found significant for most of the characters, except for number of leaves/ plant, breadth of leaf, ear length, ear girth and TSS content of green grain. The mean sum of squares due to G x E (linear) interactions were reported significant for all the characters, except for number of leaves plant^{-1}, breadth of leaf, ear length, ear girth, 100 fresh seed weight and TSS content of green grain. Further analysis revealed that the characters days to 50 per cent silking, number of leaves plant^{-1}, length of leaf, breadth of leaf, ear length, ear girth, number of grains row^{-1}, 100 fresh seed weight, green fodder yield and TSS content of green grain had significant mean sums of squares due to pooled deviations, suggesting that prediction for these characters would be difficult as the genotypes differed considerably with respect to their stability.

Analysis for yield characters revealed that for green cob weight plant^{-1} two sweet corn hybrids L_7 x T_2 and L_7 x T_3 possessed non significant deviations from regression (S^2d_i) along with regression coefficient value nearly equivalent to unity (b_i=1) and mean greater than the population mean (Table 2). The performances of these two hybrids thus could be predictable as well as stable for cultivation in various environments. Study for stability parameters for green cob yield revealed that all the genotypes possessed non significant deviations from regression (S^2d_i) reflecting their predictable behavior (Table 3). Only one sweet corn hybrid L_6 x T_1 possessed non significant deviation from regression (S^2d_i) along with regression coefficient nearly equivalent to unity (b_i=1) and mean higher than the population mean, thus making it stable performer and suitable for all the environments for number of grains row^{-1}. One sweet corn hybrid L_{13} x T_1 exhibited non significant deviation from regression (S^2d_i) along with regression coefficient value nearly equivalent to unity (b_i=1) and mean more than the population mean indicating it's predictable nature and stable performance in various environments for 100 fresh seed weight. None of the sweet corn hybrids possessed regression coefficient nearly equal to unity (b_i=1) for number of ears plant^{-1}, ear girth, number of grain rows ear^{-1} and green fodder yield.

Analysis for quality characters (Table 4) showed that for TSS content of green grain, sweet corn hybrids L_1 x T_1 and L_{11} x T_1 showed non significant deviations from regression (S^2d_i) and regression coefficient equivalent to unity (b_i=1) with greater mean than the population mean, thus signifying their predictable performances and stability for different environments for sweetness. While for protein content, the sweet corn hybrids L_2 x T_1, L_6 x T_1, L_8 x T_1, L_{10} x T_1, L_{12} x T_1, L_2 x T_2, L_4 x T_2, L_5 x T_2, L_8 x T_2, L_9 x T_2, L_{10} x T_2, L_{11} x T_2, L_{14} x T_2, L_{15} x T_2, L_1 x T_3, L_2 x T_3, L_4 x T_3, L_5 x T_3 and L_{10} x T_3 showed non significant deviations from regression (S^2d_i) and regression coefficient equivalent to unity (b_i=1) with mean at par from the population mean, thus signifying their predictable performances and stability in various environments. Only the hybrid L_{12} x T_1 showed stable performance for protein content over the three environments.

Similar results for identification of stable genotypes under different environments were reported by Sowmya *et al.* (2018) [11], Raj *et al.* (2019), Machado *et al.* (2019) [7], Pinto *et al.* (2019) [8], Kumar *et al.* (2019) [5] and Boreddy *et al.* (2020) [1].

Among all the sweet corn hybrids, L_{12} x T_1 was identified as stable performer in various environments (b_i=1) with higher mean than the population mean for green cob yield. For unfavorable environments (b_i<1), the sweet corn hybrids L_7 x T_1 and L_9 x T_1 revealed stable performance with high mean value for green cob yield. Within favorable environments (b_i>1), hybrids L_7 x T_3 and L_{10} x T_1 showed stable performances along with higher mean for green cob yield. All these sweet corn hybrids also exhibited positively significant standard heterosis over the best check Sugar-75 on pooled basis. These parents and sweet corn hybrids can be used in future breeding programmes and further multi location testing programmes, respectively.

The quality parameters are relatively more important especially because of direct consumption of sweet corn as vegetable and the preference of the consumers. The overall results indicated that emphasis on green cob yield, green fodder yield and kernel sweetness may be considered in the objective of sweet corn hybrid development.

Table 2: Best sweet corn hybrids for green cob weight plant^{-1} on the basis of stability parameters with corresponding value of economic heterosis and combining ability effects.

S. No	Hybrids	Mean	Suitability for environment	Economic Heterosis (%)	SCA effects
1	L_7x T_2	0.26	All environments (b_i=1)	36.84**	-0.02**
2	L_7x T_3	0.26	All environments (b_i=1)	36.84**	-0.01*
3	L_7 x T_1	0.33	Unfavourable environments (bi<1)	73.68**	0.03**
4	L_3 x T_1	0.27	Unfavourable environments (bi<1)	42.11**	0.01**
5	L_{12} x T_1	0.26	Favourable environments (bi>1)	36.84**	0.01**
6	L_{10} x T_1	0.25	Favourable environments (bi>1)	31.58**	0.06**

**Significant at 1% level of significance

Table 3: Five best sweet corn hybrids for green cob yield on the basis of stability parameters with corresponding value of economic heterosis and combining ability effects.

S. No	Hybrids	Mean	Suitability for environment	Economic Heterosis (%)	SCA effects
1	L_{12}x T_1	15061.11	All environments (b_i=1)	33.72**	832.57**
2	L_7 x T_1	19305.56	Unfavourable environments (bi<1)	71.44**	1550.72**
3	L_9x T_3	15646.67	Unfavourable environments (bi<1)	38.92**	1999.6**
4	L_7 x T_3	15314.44	Favourable environments (bi>1)	35.97**	-281.51
5	L_{10} x T_1	14695.56	Favourable environments (bi>1)	30.47**	3551.09**
**Significant at 1% level of significance					

Table 4: Best sweet corn hybrids for TSS content of green grain on the basis of stability parameters with corresponding value of economic heterosis and combining ability effects.

S. No	Hybrids	Mean	Suitability for environment	Economic Heterosis (%)	SCA effects
1	L_1x T_1	15..93	All environments (b_i=1)	10.47*	-0.07
2	L_{11} x T_1	17.00	All environments (b_i=1)	17.89**	0.33
3	L_2 x T_3	16.03	Favourable environments (bi>1)	11.17**	1.34**
4	L_5 x T_2	15.85	Favourable environments (bi>1)	9.92**	0.92**
5	L_{10} x T_3	16.40	Unfavourable environments (bi<1)	13.73**	-0.23
6	L_1 x T_3	16.34	Unfavourable environments (bi<1)	13.31**	1.22**
**Significant at 1% level of significance					

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Authors' contribution
Conceptualization of research (Divya Chouhan); Designing of the experiments (Dr. R. B. Dubey); Contribution of experimental materials (Dr. Dilip Singh); Execution of field/lab experiments and data collection (Divya Chouhan and Piyush Choudhary); Analysis of data and interpretation (Divya Chouhan); Preparation of the manuscript (Divya Chouhan and Dr. R. B. Dubey).

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