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RESEARCH ARTICLE

ASSOCIATION BETWEEN RESPONSE INDICES, STABILITY PARAMETERS AND THEIR COMPARISONS FOR STABILITY OF SUGARCANE GENOTYPES

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Abstract

In a field experiment, 15 sugarcane clones of different maturity groups were grown under eight different environments, viz. autumn and spring seasons for two consecutive years in plant and ratoon crops and association between response indices, stability parameters and their comparisons for stability of sugarcane genotype were analyzed. Significant differences were observed for seven out of 13 traits under study. The stability models, viz. linear regression of Eberhart and Russell, joint regression of Perkins and Jinks, combined regression of Freeman and Perkins, ecovalence of Wricke and stability factor of Lewis were used to estimate the response indices and stability parameters for the seven traits. The varieties with average yield, namely BO 110, BO 109, and BO 130 showed non-significant stability parameters indicating their better stability over environments with all the three regression approaches. As per ecovalence, the varieties BO 109, Co 92032 and BO 110 showed average yields and stability across all the eight environments. Stability Factor (S.F.) nearer to one, along with high yield, was recorded for BO 110, BO 109, BO 128 and BO 130. The varieties BO 110 and BO 109 were stable with respect to yield by all the stability models under study. Simple and rank correlation between regression coefficients (i.e. b_i^E, $b_i^{P\&J}$ and $b_i^{F\&P}$) estimated as per different models, different deviations from regression (i.e. $S^2d_i^E$ and $S^2 d_i^{F\&P}$) and different mean values (i.e. X and $X^{F\&P}$) were significant and positive for all traits which indicated that all approaches gave same stability level. Strong correlation was also exhibited between ecovalence (W_i) and deviation from regression (S^2d_i), W_i and S.F., regression coefficients (b_i) and S.F., and S^2d_i and S.F. It indicated that all these stability parameters provided similar information regarding stability of sugarcane genotypes. Therefore, the stability models based on regression approach will be useful to estimate response indices and stability parameters for further development of stable sugarcane clones with high yielding and sucrose percentage in juice.

Key words : Sugarcane, genotype x environment interaction, stability models

Introduction

Sugarcane is an important agro-industrial sugar crop of India contributing about 17% world sugar production. In India, the total area under this crop was 5.31 Mha with a production of 366.80 Mt and productivity of 69.10 t/ha. Of this, the share of Bihar was an area of 0.30 Mha, production of 14.90 Mt and productivity of 50.00 t/ha (Anonymous 2017). Low productivity of sugarcane has been recorded in Bihar for the last five decades which can be enhanced by increasing the area under stable high yielding varieties. Clones of different maturity groups play an important role in boosting cane productivity. Genotype-environment (G x E) interaction encountered in yield trials is a major challenge to plant breeder. The G x E interaction reduces progress of selection (Comstock and Moll 1963). Yield data and stability performance of genotypes across contrasting environments are essential to enable a breeder to select high yielding and consistently performing genotypes. Linear regression technique had been extensively used by

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sugarcane breeders (Galvez 1979; Tai et al. 1982; Hooda et al. 1987; Tripathi et al. 1989; Tiwari et al. 2011; Khan et al. 2013; Koli et al. 2015) to judge the response to environments and to predict the stability of performance. Several workers criticized the regression technique as inadequate (Freeman and Perkins 1971; Shukla 1972). Byth et al. (1976) reported that the technique could be misleading when the proportion of G x E interaction due to linear regression in environment indices was very small. Powel et al. (1986) observed that the linear regression technique did not adequately explain the G x E interaction and, therefore, suggested the use of genotypes phenotypic variance across environments to measure stability when incorporated in analysis of variance over all environments. Freeman and Perkins (1971) questioned the stability model proposed by Eberhart and Russell (1966) and Perkins and Jink (1968a) regarding the relationship between two stability parameters. According to these models, performance of a genotype in a given environment is regressed over the environmental index. Obviously, the estimation of these two parameters is not independent. Freeman and Perkins (1971) proposed independent estimate of environmental index as they divided the replications into two groups so that one group may be used for measuring the average performance of genotype in various environments and the other group for estimating the environmental index. Here one or more varieties were used as check to assess the environmental index on the basis of their performance. They further questioned the earlier two models regarding portioning of degrees of freedom. Though the sum of squares due to environment (linear) of Eberhart and Russell's model was same as the sum of squares due to environment (joint regression) of Perkins and Jink's model, yet the degree of freedom is one in the former case and 'e-1' (where 'e' indicates number of environments) in the latter case. Ramagosa and Fox (1993) suggested that 50% of G-E interaction should be explained for regression to be practically useful. Kang and Miller (1984) suggested that the methods which provide a stability variance parameter assignable to each genotype should be useful to the breeder. The evaluation of genotypes under different climatic conditions provides information about the different stability parameters and the relative performance of the individual genotype. However, cane yield and quality in sugarcane are dependent on several quantitative traits which are also influenced by environment. Breeders have long been aware of the problem of genotype-environment interactions for yield potential of sugarcane varieties. However, for juice quality and other productive traits information is very scarce. Therefore, the present investigation was carried out to determine the association between response indices, stability parameters and their comparisons for the productive traits of sugarcane.

Materials and Methods

An experiment was conducted by planting 15 diverse sugarcane clones of different maturity groups in randomized block design with three replications in Pusa Farm, Rajendra Agricultural University, Bihar, from 1999-2000 to 2002-2003. There were eight environments, namely two autumn and two spring plant crops with their respective ratoons. Observations of productive traits, viz. germination percent at 45 days after planting (DAP), number of shoots at 120 DAP, number of millable canes (per plot), plant height (cm), cane diameter (cm), single cane weight (kg), sucrose content in juice (pol) at 10th month stage, total soluble solids (Brix) at 10th month stage, purity percent of juice at 10th month stage, sucrose content at 12th month stage, total soluble solids (Brix) at 12th month stage, purity percent at 12th month stage and cane yield (t/ha) were recorded. The data analyzed for ANOVA for seven traits, namely germination percent, number of shoots at 120 DAP, Brix % at 12th month, purity percent at 10th month, purity percent at 12th month, number of millable canes (per plot) and cane yield (t/ha) showed significant differences among the genotypes. Since seven out of 13 traits showed significant G x E interaction (Table 1), these seven traits were considered for estimating the stability parameters (regression coefficients and standard deviations) through different stability models (Tables 2 to 4), namely Eberhart and Russell (1966), Perkins and Jinks (1968a & b) and Freeman and Perkins (1971). Ecovalence (W_i) of the genotype (g_i) under eight environments (n=8) to assess the stability of performance was estimated by Wricke's (1962) ecovalence which is the contribution of each genotype to the interaction sum of squares and expressed as its percentage i.e. $W_i = \sum_j\{Y_{ij} - Y_i - Y_j + Y..\} = \sum_j e^2_{ij}$; where Y_{ij}= the performance of the ith genotype in the jth environment, Y_i= the performance of the ith genotype over the environments and Y_j= the mean of the jth environment. Stability Factor (S.F.), a measure of phenotypic stability, was estimated as suggested by Lewis (1954). S.F. of the genotypes was calculated as X_{HE} (the mean value of a genotype in high yielding environment) divided by X_{LE} (the mean value of a genotype in low yielding environment). All the response indices and stability parameters calculated by using different stability models in the present investigation are presented in Table 5. Simple and rank correlations were calculated among response indices, between response indices and stability parameters, and among stability parameters for the productive traits of sugarcane. The data of general mean value (X), mean value used in Freeman and Perkins ($X^{F\&P}$), stability factor (S.F.), ecovalance (W_i), regression coefficients of Eberhart and Russell (b_i^E), regression coefficients of Perkins and Jinks ($b_i^{P\&J}$), regression coefficients of Freeman and Perkins ($b_i^{F\&P}$), standard deviations of Eberhart and Russell ($S^2d_i^E$) and standard deviations of Freeman and Perkins ($S^2d_i^{F\&P}$) for cane yield traits (Table 5) were used to estimate simple and rank correlation between the response indices and the stability parameters (Table 6).

Results and Discussion

Significant differences for source of genotypic variance and environment were observed at 1% for all the traits except purity percent while significant difference between the genotypes and environment were observed at 1% for germination percent at 45 DAP, number of shoots at 120 DAP, number of millable canes, Brix at 10th month, purity percent of juice at 10th month, Brix at 12th month, purity percent at 12th month and cane yield (Table 1). The significant differences among the genotypes and environments for most of the traits were also reported by Ghosh and Singh (1998), Tyagi et al. (2001) and Khan et al. (2013). The linear, joint and combined environments also showed significant differences at 1% for all the seven traits (Tables 2 to 4). This indicated that specifically adapted genotype in specific environment could be identified, which justified a detailed study of adaptability and stability of genotypes by the different stability parameters (Table 5). Goswami and Borah (1995) also found the significant non-

Table 1. Analysis of variance across the eight environments of 15 sugarcane genotypes for 13 traits

Source of variance	df	Mean square												
		Percent germination at 45 DAP	No. of shoots at 120 DAP	At 10 months [@]			At 12 months			No. of millable canes	Plant height (cm)	Cane diameter (cm)	Single cane Weight (kg)	Cane yield (t/ha)
				Pol	Brix	Purity	Pol	Brix	Purity					
Environment	7	155.81**	86756.00**	0.19**	0.23**	2.37*	0.25**	0.35**	0.83	5631.00**	471.23**	0.03**	0.003**	392.16**
Genotype	14	166.03**	33563.00**	1.39**	1.72**	1.01	1.77**	2.01**	0.62	2177.00**	2738.25**	0.49**	0.08**	355.56**
Genotype x environment	98	9.15**	1702.98**	0.02	0.03	0.56**	0.01	0.05**	0.99**	133.79**	15.46	0.002	0.0002	8.03**
Pooled error	224	0.95	259.36	0.03	0.03	0.02	0.03	0.03	0.01	42.15	26.15	0.003	0.0003	1.51

*$P<0.05$,** $P<0.01$

[@] Pol, Brix and purity indicate sucrose content in juice, total soluble solid in juice and purity percent of juice, respectively

Table 2. ANOVA for G x E interaction across the eight environments of 15 sugarcane genotypes for seven traits (Eberhart and Russel 1966)

S. No.	Source of variation	df	Mean square						
			Germination at 45 DAP (%)	**No. of shoots at 120 DAP**	**Purity at 10 months (%)**	**Brix at 12 months**	**Purity at 12 months (%)**	**No. of millable canes**	**Cane yield (t/ha)**
	Gynotypes	14	166.03**	33563.00**	1.01*	2.01**	0.62	2177.00**	535.56**
	Environment	7	155.81**	86756.00**	2.37**	0.35**	0.83	5631.00**	392.16**
	Envt. (Genotype x Envt.)	105	18.92	7373.0	0.68	0.74	0.98	500.27	33.64
	Envt. (linear)	1	1090.66**	607291.6**	16.57**	2.47**	5.75**	39416.75**	27451.00**
	Gnotype x E.(linear)	14	28.22**	9015.36**	0.57	0.04	1.71**	338.07**	27.49**
	Pooled deviation	90	5.57**	451.96**	0.55**	0.05**	0.81**	93.10**	4.47**
1	CoB 94161	6	2.189*	126.33	0.139**	0.032	0.364**	448.17**	12.286**
2	CoSe 95422	6	0.683	333.22	0.051**	0.047	0.746**	74.506	8.185**
3	BO 130	6	1.234	405.74	0.072**	0.021	0.392**	23.886	0.921
4	CoB 94162	6	7.089**	1308.49**	0.139**	0.083*	1.036**	51.900	1.375
5	BO 91	6	8.182**	643.63*	1.121**	0.061	0.553**	63.317	2.209*
6	BO 120	6	18.579**	433.73	1.087**	0.038	0.493**	128.739**	7.595**
7	Co 92032	6	3.260**	203.36	1.258**	0.010	0.450**	119.278*	6.501**
8	BO 137	6	12.492**	139.92	1.005**	0.089*	0.602**	96.391*	9.284**
9	CoP 9501	6	16.449**	150.94	0.853**	0.024	0.848**	29.110	2.102
10	CoP 9103	6	0.549	618.40*	0.250**	0.082*	1.411**	40.286	1.178
11	Co 92030	6	0.523	270.99	0.074**	0.079*	1.197**	40.939	1.59
12	CoSe 95421	6	1.001	45.89	0.816**	0.053	1.243**	77.576	2.24*
13	BO 110	6	3.031**	165.19	0.578**	0.048	0.710**	12.589	0.91
14	BO 128	6	5.429**	157.25	0.077**	0.068*	1.014**	154.806**	9.06**
15	BO 109	6	2.215**	1776.37**	0.393**	0.065*	1.069**	32.054	1.55
	Pooled error	224	0.948	259.36	0.015	0.031	0.014	42.144	1.508

*$P<0.05$,** $P<0.01$

Table 3. ANOVA for G x E interaction across the eight environments of 15 sugarcane genotypes for seven traits (Perkins and Jinks 1968 a & b)

Sources of variation	**df**	**Mean square**						
		Germi-nation at 45 DAP	**No. of shoots at 120 DAP**	**Purity at 10 months (%)**	**Brix at 12 months stage**	**Purity at 12 months (%)**	**No. of milllabe canes**	**Cane yield (t/ha)**
Lines (difference between genotypes)	14	166.02**	33563.23**	1.06*	2.01	0.653**	2022.65**	535.56**
Environment (joint regression)	7	1090.66**	607291.6**	16.57**	2.47**	5.75**	34916.95**	274510**
Genotype x Environment	98	9.15**	1702.98**	0.56**	0.05*	0.99**	133.8**	8.03**
Heterogeneity between regressions	14	28.22**	9015.36**	0.57/$^{(**)}$	0.04	1.71*/$^{(**)}$	338.07**	27.49**
Remainder	84	5.58**	484.25**	0.56**	0.06*	0.876**	99.75**	4.77**
Error	224	0.948	259.36	0.015	0.03	0.014	42.14	1.50

*P<0.05,** P<0.01

$^{(**)}$ indicates if heterogeneity between regression tested against error

Table 4. Analysis of variance for G x E interaction across the eight environments of 15 sugarcane genotypes for seven traits (Freeman and Perkins, 1971)

Sources of variation	**df**	**Mean square**						
		Germination at 45 DAP	**No. of shoots at 120 DAP**	**Purity at 10 months (%)**	**Brix at 12 months**	**Purity at 12 months (%)**	**No. of milllabe canes**	**Cane yield (t/ha)**
Genotype (G)	14	328.16**	65133.43**	2.02	3.57**	1.37	4242.29**	1106.71**
Environment (E)	7	308.15**	171879.10**	4.63**	0.78**	1.77	12103.14**	765.20**
Combined regression	1	2141.38**	1197665.00**	31.08**	4.54**	11.04**	82038.43**	5250.25**
Residual (1)	6	2.61*	935.90	0.22**	0.15	0.22**	427.26**	17.69*
Interaction G x E	98	20.29**	3497.23**	1.14**	0.13	2.04**	334.88**	18.07**
Heterogeneity of regression	14	53.83**	17324.16**	1.16	0.08	3.51*	800.28**	56.99**
Residual (2)	84	14.70**	1192.74**	1.14**	0.14*	1.80**	245.64**	11.59**
Error between residual	224	3.75	822.93	0.05	0.1	0.05	172.70	6.69

*$P<0.05$,** $P<0.01$

Table 5. **Mean performance (X and $X^{F\&P}$), response indices (b_i^E, $b_i^{P\&J}$ and $b_i^{F\&P}$) and estimates of stability parameters ($S^2d_i^E$, $S^2d_i^{P\&J}$, $S^2d_i^{F\&P}$, W_i and S.F.) for cane yield (t/ha) of sugarcane genotypes**

S. No.	Genotype	X	b_i^E	$S^2d_i^E$	$b_i^{P\&J}$	$X^{F\&P}$	$b_i^{F\&P}$	$S^2d_i^{F\&P}$	W_i	S.F.
1	CoB 94161	41.86	0.757	10.777*	-0.243	41.86	0.686	7.013	123.916	1.379
2	CoSe 95422	54.28	1.281	6.676**	0.281	55.32	1.288	0.064	63.586	1.441
3	BO 130	60.14	1.996*	-0.588	0.996*	60.44	1.992*	-1.109	106.980	1.505
4	CoB 94162	49.26	0.988	-0.133	-0.012	49.56	0.855	-1.380	8.282	1.268
5	BO 91	44.03	1.111	0.701	0.111	44.29	1.056	-4.936	15.488	1.140
6	BO 120	56.08	1.159	6.086**	0.159	56.60	1.030	-0.056	55.792	1.356
7	Co 92032	57.91	0.988	4.992**	-0.012	57.80	0.835	5.172	39.010	1.292
8	BO 137	61.79	0.630	7.775**	-0.370	62.14	0.601	3.331	71.522	1.253
9	CoP 9501	50.49	0.513*	0.593	-0.0487*	50.77	0.492**	-4.309	56.042	1.161
10	CoP 9103	48.78	0.552*	-0.330	-0.448*	48.78	0.487*	-5.216	43.690	1.184
11	Co 92030	43.53	0.840	8.401**	-0.160	43.96	0.892	-3.776	105.036	1.232
12	CoSe 95421	51.54	0.635*	0.731	-0.365*	51.70	0.567*	-4.903	41.641	1.999
13	BO 110	53.57	0.966	-0.596	-0.034	56.26	1.026	-3.443	5.693	1.238
14	BO 128	73.75	1.415*	7.551**	0.415	74.64	1.305	7.825*	147.100	1.296
15	BO 109	56.68	1.169	3.971	0.169	56.69	1.182	-4.325	14.535	1.335

$^*P<0.05$, $^{**}P<0.01$

X & $X^{F\&P}$ indicate mean values used in Eberhart and Russell Model and Freeman and Perkins Model, respectively

b_i^E, $b_i^{P\&J}$ and $b_i^{F\&P}$ indicate regression coefficients of Eberhart and Russell Model, Perkins and Jinks Model and Freeman and Perkins Model, respectively

$S^2d_i^E$ and $S^2d_i^{F\&P}$ indicate deviation from regression coefficients of Eberhart and Russel Model and Freeman and Perkins Model, respectively

W_i and S.F. indicate ecovalance and stability factor, respectively linear genotype–environment interaction for cane yield. Tyagi et al. (2001) reported G x E interactions were highly significant, G x E linear and pooled deviation were also significant and as a result some genotypes showing higher cane yield and lowest regression were most promising and suitable for both favorable and unfavorable environments. Fasahat et al. (2015) reviewed the use of stability parameters in plant breeding and concluded that the priorities and limitations of different parametric stability statistics and also their correlations might help agronomists and plant breeders to choose the proper method of analysis. Breese (1969) agreed that the phenotypic expression of particular genotype in a given environment is dependent on mean performance, a linear response to environment and stability of performance.

Various stability parameters to regression approach have been suggested by different workers: Eberhart and Russell (1966) proposed two stability parameters, i.e. regression (b_i^E) and deviation form regression $S^2d_i^E$. According to Langer et al. (1972), the regression coefficient (b) is a measure of response to varying environments and the mean square for deviation from regression is a true measure of stability. In Eberhart and Russell's (1966) method, regression coefficient significantly different from one ($b_i^E =1$) and/or significant deviation from regression ($S^2d_i \neq 0$) occur because of G x E interaction. Genotype with b_i^E more than one would be adopted for more favorable growing conditions, less than one would be adopted for less favorable growing conditions (Breese 1969; Gama and Hallauer 1980). According to Kang and Miller (1984), the method(s) for partitioning G x E interaction, which provides a means of assigning a variance component to each genotype and a test of significance of the variance components, should be useful in determining the stability of genotypes. Mendes de Panda et al. (2014) worked out the relationships between methods of varietal adaptability and stability in sugarcane and found Eberhart and Russell model being relatively simple with accuracy. Perkins and Jinks had extended the regression approach and suggested that stability parameters such as response indices for both models ($S^2d_i^E$) are similar but regression values are different (i.e. $b_i^E\text{-}1=b_i^{P\&J}$). The approach of Perkins and Jinks (1968a) involves the specification of genotype - environment interaction in terms of components of genotype in the form of a model including additive, dominance and epistatic gene effects, so that the magnitude of genotype-environment action is always in terms of contribution of different types of gene action like that of any other characters. The G x E interactions are parameterized as components of additive and dominance gene effects to determine their genetic control. The sum of squares due to environment (linear) is the same as the sum of square due to joint regression with one df or environment sum of square with n-1 df. The regression indicates the differences among linear regression coefficients of individual lines. Both heterogeneity between regression "mean squares" and remainder mean square are compared with pooled error. The significance of the former reflects that some b_i are significant positive and others are significant negative since $\sum_i b_i=0$. Genotype-environment interactions are indicated if either or both of these two components are statistically significant. If heterogeneity alone is significant, the G x E interaction of each line can be predicted for any given environment. If remainder mean square alone is significant, whole of genotype-environment interaction is unpredictable. If both of these components are significant, the practical usefulness of prediction will depend on the relative magnitude of the two components. If the remainder mean square is significant, it can be further partitioned by grouping of varieties into homogenous groups on the basis of significance of deviation from the linear regression (Perkins and Jinks 1968b). Nagarajan and Ethirajan (1987) observed sizable non-linear genotype x environment interaction for stalk and quality while stalk yield showed predominantly linear interaction. Nahar and Khaleque (2001) studied the joint regression analysis and inferred that genotype–environment interaction accounted for both linear and non-linear function. In fact, a significantly greater portion was accounted for by linear function and they got stable genotypes in poor environment for the traits NMC and TSS. In the previous two models, the mean performance of a variety in a given environment is regressed over the environmental index. Environmental index can be defined as an estimate of the total of all the varieties of the location divided by number of varieties less grand total by total number of observations. Obviously, the estimation of their two variables is not independent and this is an unacceptable point.

Freeman and Perkins (1971) proposed environment (linear) and G x E, if environment residual (1) SS had significant effect. If b_i is not significantly different from unity, then independent environment values adequately estimate additive environment component, and, hence, Freeman and Perkins model (combined regression approach) has relative advantage over the Perkins and Jinks model. Lower W_i value, i.e. higher the ecovalence of a genotype, indicates that the fluctuations from the experimental mean are smaller under different environments and thus it displays a smaller share to the total interaction sum of squares. Accordingly, the variety with higher ecovalence, i.e. lower W_i, was considered most stable. In another approach, Stability factor (S.F.) was equal to one which indicated maximum phenotypic stability because yield of a variety remains same in high yielding and low yielding environments. The greater the deviation of S.F. from unity, less stable is the genotype. But this parameter was highly sensitive to the response of genotype to extreme environment and relies more on consistency in performance with no consideration of absolute yield potential. Singh and Khan (1997) agree with the stability parameters such as deviation from linear regression, relative mean yield and significant square deviation from regression. Rosse et al. (2002) found that measures of environmental quality were numerically different but agreed in general terms for ranking of location. On the other hand, when genotypes were classified based on the yield and response pattern, the non-linear model can be recommended for estimating stability. Nahar and Khaleque (2001) also obtained stable genotypes in poor environment.

The average to low yielding varieties, namely BO 110, BO 109, BO 130 and BO 91 were having non-significant stability parameters indicating their better stability over environments by all the three regression approaches (linear, joint and combined). As per ecovalence, the varieties namely, BO 110, BO 109, CoB 94162 and BO 91 were average to low yielders and stable across the eight environments. Lower values of stability factor along with high to low mean were also recorded for BO 110, BO 109, BO 128, BO 137, CoP 9501, CoP 9301, Co 92030 and BO 91.

Therefore, it can be concluded that BO 110 and BO 109 were stable by the stability parameters along with average yield by different models of stability in the present investigation. Presently, BO 110 is a predominant variety grown in Bihar which has covered more than 20% sugarcane cultivated area of the state (2015) due to its stable nature.

Correlation studies indicated that S.F. had significant and positive association with b_i and $S^2d_i^E$ (Table 6). Similar findings were also made by Prasad and Singh (1980) while working on maize. Stability parameters and response indices estimated by three regression approaches (linear, joint and combined) and their b_i values were highly significant and positively correlated to each other, and also ranked unity and approximate unity for most of the traits. The values of S^2di^E estimated from different models also exhibited significant and positive association among them. Similar ranking pattern was observed under all the three models described.

In the present investigation, the simple correlation exhibited between mean value (X) and response indices (b_i) was positive and significant for cane yield. Similar results were reported by Eberhart and Russell (1966), Perkins and Jinks (1968a), Wright (1971) and Verma et al. (1978). The association between both the mean values (X and $X^{F\&P}$) was found to be significant and positive.

The association between the b_i values of different models was found to be significantly positive and similar result was also found by Luthera et al. (1974). Significant and positive total correlation between b_i^E and S.F. showed that both parameters were similar for all the traits, which is in accordance with the finding of Prasad and Singh (1980) in maize. The S^2di was negatively associated with $X^{F\&P}$ for number of millable canes which means that the mean value for this trait was not efficient to predict the stability and this is in agreement with the results of Fejer (1973). $S^2d_i^E$ was highly significant and positively correlated with $S^2d_i^{F\&P}$ because both the stability parameters were showing similar pattern of stability which is in accordance with the finding of Luthera et al. (1974). $S^2d_i^E$ also showed positive and significant correlation with W_i because both the parameters provide similar information which is in accordance with the finding of Becker (1981), Jha and Khehra (1989). $S^2d_i^E$ also exhibited positive association with S.F. which means stability factors and $S^2d_i^E$ were similar in nature and provide similar information for the trait of total soluble solid at 12 months. Similar results were also obtained by Prasad and Singh (1980). The inter-relationship between W_i and S.F. was also significant and positive. It means both the parameters were showing similar information. $X^{F\&P}$ exhibited significant and negative correlation with W_i for number of millable canes and same findings were obtained by Fejer (1973) in raspberry. There was no correlation between $S^2d_i^E$ and b_i and this finding is in accordance with Qualset (1968).

The results clearly indicated that the different stability models, viz. Eberhart and Russell (1966), Perkins and Jinks (1968a), Freeman and Perkins (1971), Wricke's (1962) W_i and Lewis' (1954) S.F., which were used to estimate the stability parameters i.e. regression coefficients, deviations from regression, mean values, ecovalence (W_i) and stability factor (S.F.), were efficient in the identification of high to average yielders and stable clones over eight environments. The simple and rank correlations between different regression coefficients (b_i^E, $b_i^{P\&J}$ and $b_i^{F\&P}$), different deviations

Table 6. Rank and simple correlations between different stability parameters for three traits of sugarcane genotypes

Rank Correlation	Brix at 12 months		No. of millable canes		Cane yield (t/ha)	
	Rank correlation	Simple correlation	Rank correlation	Simple correlation	Rank correlation	Simple correlation
X and b_i^E	-0.037	0.008	0.214	0.188	0.484*	0.484*
X and $b^{P\&J}$	-0.148	-0.185	0.214	0.634*	0.492*	0.996**
X and $X^{P\&J}$	0.977**	0.994**	0.616**	0.240	0.996**	0.429*
X and $b_i^{P\&J}$	-0.181	-0.098	0.343	0.432*	0.429*	0.471*
X and $S^2d_i^{F\&P}$	0.520*	0.424	-0.164	1.00*	0.471*	0.361
X and S.F	0.279	0.943**	0.048	0.253	0.361	1.00**
b_i^E and $b^{P\&J}$	1.000**	0.065	1.000**	0.970**	1.00**	0.463*
b_i^E and $X^{F\&P}$	-0.046	0.814**	0.206	0.789**	0.463*	0.960**
b_i^E and $b_i^{F\&P}$	0.864**	0.533*	0.928**	-0.665*	0.960**	0.459*
b_i^E and S.F.	0.297	0.306	0.774**	0.880**	0.459*	0.564*
$S^2d_i^E$ and $S^2d_i^{F\&P}$	0.536*	0.778**	0.746**	0.828**	0.564*	0.596*
$S^2d_i^E$ and W_i	0.882**	0.759**	0.386	0.314	0.596*	0.207
$S^2d_i^E$ and S.F.	0.666*	0.695**	0.032	0.253	0.207	0.470*
$b_i^{P\&J}$ and $X^{F\&P}$	-0.114	-0.159	0.0206	0.970**	0.470*	0.921**
$b_i^{P\&J}$ and $b_i^{F\&P}$	0.907**	0.842**	0.928*	0.789*	0.921**	0.452*
$b_i^{P\&J}$ and S.F.	0.299	0.533**	0.774**	0.280	0.452*	0.414
$X^{F\&P}$ and $b_i^{F\&P}$	-0.128	-0.046	0.274	-0.628*	0.414	0.457*
$X^{F\&P}$ and $S^2di^{F\&P}$	0.457	0.468*	0.402	-0.713**	0.457*	0.121
$X^{F\&P}$ and W_i	0.257	0.046	0.477*	0.736**	0.121	0.443*
$b_i^{F\&P}$ and S.F.	0.374	0.466**	0.680*	0.688*	0.443*	0.537*
$S^2d_i^{F\&P}$ and W_i	0.421*	0.408	0.186	0.369	0.537*	0.403
$S^2d_i^{F\&P}$ and S.F.	0.211	0.492*	0.245	0.235	0.403	0.282
W_i and S.F	0.539*	0.456	-0.013	0.188	0.282	0.484*

*$P<0.05$,** $P<0.01$

X and $X^{F\&P}$ indicate mean value used in Eberhart and Russell Model and Freeman and Perkins Model, respectively

b_i^E, $b_i^{P\&J}$ $b_i^{F\&P}$ indicate regression coefficient of Eberhart and Russell Model, Perkins and Jinks Model and Freeman and Perkins Model, respectively

S^2d_i and $S^2d_i^{F\&P}$ indicate deviation from regression coefficient of Eberhart and Russell Model and Freeman and Perkins Model, respectively

W_i and S.F. indicate ecovalance and stability factor, respectively from regression ($S^2 d_i^E$ and $S^2 d_i^{F\&P}$) and different mean values (X and $X^{F\&P}$) were significant and positive for all traits which showed that all the regression approaches resulted in similar stability level. Positive correlation was also recorded between ecovalence (W_i) and deviation from regression (S^2d_i), between W_i and stability factor (S.F.), between regression coefficients (b_i) and S.F., and between S^2d_i and S.F. Therefore, all these response indices provided similar information regarding stability. Stability parameters also provided similar information regarding stability of sugarcane genotypes. Through W_i some common genotypes showed stable ones while S.F with value nearer to unity exhibited stable ones. Hence, it could be inferred that it would be advantageous to select superior genotypes using stability analysis instead of average performance. The studies showed that stability analyses according to various principles can result in better identification of stable genotypes even when there were no interactions among the parameters.

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