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CORRELATIONS AMONG DIFFERENT STABILITY PARAMETERS FOR GRAIN YIELD IN CHICKPEA

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ABSTRACT

The presence of Genotype x Environment (G × E) interaction in plant breeding experiments led to the development of several stability parameters in the past few decades. The interrelationships among different stability parameters available in the literature showed highly significant correlation between S_i^2 and b_i, and among θ_i, $\theta_{(i)}$, σ_i^2, W_i^2, S_{di}^2, r_i^2, S_i1, and S_i4. None of the parameters except CV_i was consistently correlated with mean yield. Ranking of genotypes based on these stability parameters was different over different subsets of environments within each trial indicating their poor repeatability.

Key words : Genotype x environment interaction, phenotypic stability, chickpea

Interaction of genotypes with environments has a strong confounding effect on different genetic parameters like heritability and genetic correlation, thereby restricting steady progress in yield and stability. Moreover, the success of a variety depends not only on its high performance but also on its ability to perform consistently well in ever-changing environments. Therefore, phenotypic stability of varieties over a wide range of environments has received considerable attention from plant breeders. Becker [1] distinguished two basic concepts of stability known as biological and agronomic concepts. The former is a static concept, where a stable genotype is one with constant performance irrespective of the quality of environments i.e. minimum variance across environments. The latter concept, also known as dynamic concept, permits a predictable response to environments i.e. a stable genotype has minimum genotype x environmental (G × E) interaction. There are various stability parameters that quantify these concepts. Among them, the regression coefficient (b_i) and deviation

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from regression (S^2_{di}) proposed by Eberhart and Russell [2] have extensively been used in plant breeding trials despite theoretical objections on their validity [3]. Other parameters viz., coefficient of variation (CV_i), environmental variance (S_i^2) and those proposed by Plaisted and Peterson [4], Plaisted [5], Wricke [6], Tai [7], Shukla [8], Pinthus [9] and Nassar and Huhn [10] have rarely been used as stability measures in spite of being theoretically sound and their potential ability to detect G × E interaction. Some of these parameters have been compared statistically [1, 11, 12] elucidating useful theoretical interrelationships among them. Besides theoretical relationships, empirical correlation is also useful to quantify interdependence of different stability parameters particularly between those whose mathematical models are inexplicit in showing their mutual relations. Another important aspect of stability parameter is repeatability of its results over different subsets of environments. Earlier studies showed poor repeatability for estimates of stability parameters (14-16). In the presence of several alternative parameters for measuring stability of genotypes, it becomes imperative to know consequences of using different stability parameters on the making of genotypes. In this study, the extent of interrelationships among different stability parameters and their repeatability was explored using data from the extensive yield trials of chickpea.

MATERIALS AND METHODS

The data used in the present study were extracted from ICRISAT's International Chickpea Adaptation Trials (ICAT) and Advanced Chickpea Yield Trials (AYT). In ICAT trials, a set of 16 cultivars comprising of seven desi and nine kabuli-types from different regions of the world were evaluated at 17 locations in 12 countries in 1981/82, 31 locations in 16 countries in 1982/83, and 22 locations in eight countries in 1983/84. Each trial was laid out in a randomized complete-block design with four replications. In AYT trials, 25 advanced lines developed at ICRISAT were tested in four environments for two seasons in 1988/89 and 1989/90. The trials were arranged in a 5 × 5 balanced lattice square design with three replications. Various stability parameters along with mean yield were estimated for the ICAT and AYT trials separately for each year and combined over years as per the formulas given by Lin et al. [11] and Becker and Leon [3]. Spearman's rank-correlation coefficients were calculated between all possible pairs of stability parameters and mean yield to demonstrate interrelationships among them. In order to test the repeatability, rank-correlation coefficient was calculated between two estimates of each stability parameter from two random and stratified subsets of environments within a trial.

RESULTS AND DISCUSSION

The joint regression analyses for different trials showed that genotypes, environments and G × E interaction were highly significant. The components of G × E interaction attributable to heterogeneity among linear regressions and deviation from regressions were also consistently significant. Rank-correlation coefficients between different stability parameters are given in Table 1. Depending on the

Table 1. Rank-correlation coefficients between different stability parameters for seed yield in chickpea.

	I C A T (df 14)				A Y T (df 23)		
Stability parameter	1981	1982	1983	Combined	1988	1989	Combined
$S_i^2-CV_i$	0.74^{**}	–0.25	-0.55^{*}	–0.42	0.85^{**}	0.87^{**}	0.91^{**}
$S_i^2-b_i$	0.91^{**}	0.84^{**}	0.95^{**}	0.92^{**}	0.98^{**}	0.94^{**}	0.94^{**}
$S_i^2-\sigma_i^2$	0.22	0.14	0.09	0.02	0.37	0.12	0.38
$S_i^2-S_{di}^2$	0.39	0.01	–0.02	–0.05	0.52^{**}	0.29	0.47^{*}
$S_i^2-r_i^2$	–0.35	–0.19	-0.55^{*}	–0.42	0.34	–0.15	–0.03
$S_i^2-S_{i1}$	0.36	0.14	0.14	0.07	0.08	–0.04	0.33
$S_i^2-S_i4$	0.39	0.14	0.12	0.10	0.17	0.03	0.30
$S_i^2-x_i$	0.29	0.69^{**}	0.90^{**}	0.89^{**}	0.09	–0.23	0.00
CV_i-b_i	0.59^{*}	–0.33	-0.65^{**}	–0.40	0.83^{**}	0.77^{**}	0.83^{**}
$Cv_i-\sigma_i^2$	0.37	0.21	0.33	0.43	0.35	0.21	0.42^{*}
$CV_i-S_{di}^2$	0.49	0.20	0.37	0.49	0.41^{*}	0.41^{*}	0.49^{*}
$CV_i-r_i^2$	–0.08	0.43	0.58^{*}	0.60^{*}	0.23	0.03	0.04
CV_i-S_i1	0.42	0.26	0.11	0.39	0.07	0.12	0.46^{*}
CV_i-S_i4	0.47	0.26	0.13	0.38	0.15	0.18	0.42^{*}
CV_i-x_i	–0.31	-0.81^{**}	-0.76^{**}	-0.74^{**}	-0.40^{*}	-0.62^{**}	–0.37
$b_i-\sigma_i^2$	0.00	–0.34	–0.10	–0.18	0.28	–0.09	0.15
$b_i-S_{di}^2$	0.15	–0.46	–0.22	–0.31	0.41^{*}	0.08	0.24
$b_i-r_i^2$	-0.60^{*}	-0.63^{**}	-0.73^{**}	-0.64^{**}	0.22	–0.34	–0.27
b_i-S_i1	0.17	–0.22	–0.04	–0.17	0.04	–0.26	0.12
b_i-S_i4	0.17	–0.22	–0.06	–0.14	0.13	–0.18	0.07
b_i-x_i	0.50^{*}	0.64^{**}	0.94^{**}	0.81^{**}	0.11	–0.15	0.07
$\sigma_i^2-S_{di}^2$	0.94^{**}	0.95^{**}	0.90^{**}	0.98^{**}	0.85^{**}	0.85^{**}	0.97^{**}

(Table cont. to next page)

Stability parameter	I C A T (df 14)				A Y T (df 23)		
	1981	1982	1983	Combined	1988	1989	Combined
σ_i^2-r_i^2	0.74^{**}	0.92^{**}	0.67^{**}	0.83^{**}	0.86^{**}	0.86^{**}	0.85^{**}
σ_i^2-S_i1	0.67^{**}	0.86^{**}	0.91^{**}	0.91^{**}	0.80^{**}	0.83^{**}	0.62^{**}
σ_i^2-S_i4	0.69^{**}	0.86^{**}	0.89^{**}	0.91^{**}	0.87^{**}	0.85^{**}	0.68^{**}
σ_i^2-x_i	-0.28	0.03	-0.06	-0.06	-0.16	-0.27	-0.20
S_{di}^2-r_i^2	0.62^{**}	0.95^{**}	0.76^{**}	0.91^{**}	0.97^{**}	0.87^{**}	0.83^{**}
S_{di}^2-S_i1	0.78^{**}	0.82^{**}	0.87^{**}	0.87^{**}	0.54^{**}	0.72^{**}	0.68^{**}
S_{di}^2-S_i4	0.80^{**}	0.82^{**}	0.88^{**}	0.87^{**}	0.62^{**}	0.74^{**}	0.73^{**}
S_{di}^2-x_i	-0.15	-0.09	-0.17	-0.18	-0.01	-0.24	-0.16
r_i^2-S_i1	0.38	0.77^{**}	0.64^{**}	0.74^{**}	0.59^{**}	0.83^{**}	0.63^{**}
r_i^2-S_i4	0.40	0.77^{**}	0.66^{**}	0.73^{**}	0.66^{**}	0.82^{**}	0.71^{**}
r_i^2-x_i	-0.53^{*}	-0.39	-0.62^{**}	-0.52^{*}	0.03	-0.17	-0.23
S_i1-S_i4	0.99^{**}	1.00^{**}	0.99^{**}	1.00^{**}	0.97^{**}	0.98^{**}	0.98^{**}
S_i1-x_i	-0.01	-0.03	0.08	-0.03	-0.17	-0.28	-0.38
S_i4-x_i	-0.05	-0.03	0.06	-0.01	-0.13	-0.31	-0.38

magnitude of correlation coefficients, the stability parameters of Table 1 were divided into two groups. The first group consists of S_i^2, CV_i and b_i, and the second group is composed of σ_i^2 (θ_i, $\theta_{(i)}$, W_i^2), S_{di}^2, r_i^2, S_i1 and S_i4. Parameters belonging to the same group were nearly perfectly rank correlated, whereas all correlations between parameters belonging to different groups were small and inconsistent. None of the stability parameters except CV_i was consistently associated with mean yield.

A very strong positive correlation ($r > 0.84^{**}$) was observed between b_i and S_i^2 in all the trials. This is in agreement with the earlier reports [1, 13, 14]. Both the parameters depend mainly on the deviation from the average genotype effect across environments. Consequently, b_i nd S_i^2 are expected to be highly correlated. Since CV_i is a function of S_i^2 and mean yield, correlation is expected to be positive between S_i^2 and CV_i and negative between CV_i and mean yield. In this study, a high positive rank correlation between S_i^2 and CV_i was observed with a few exceptions. Pham and Kang [14] also reported this type of exceptions without any explanation for it.

One possible explanation for this anamoly could be interdependence of S_i^2 and mean yield. To confirm the above explanation, rank-correlation coefficients were calculated among CV_i, S_i^2 and mean yield in 30 subsets of environments. It was found that S_i^2 and CV_i were either independent or negatively correlated in those subsets where S_i^2 and mean yield were significantly positively correlated. The same holds true for the association between b_i and CV_i because of nearly perfect association of b_i with S_i^2. The b_i is often considered to be associated with mean. In this study also, b_i and S_i^2 had high rank correlation with mean yield in ICAT rails but were independent in AYT trials indicating the influence of the range of environmental conditions on the association of b_i and S_i^2 with mean yield. The S_i^2 and CV_i measure stability according to the static concept, whereas b_i can be static ($b = 0$) or dynamic ($b = 1$) depending on its value [3]. The CV_i is not very suitable as a stability measure of a genotype because of its expected negative association with mean yield. Since S_i^2 is free from statistical assumptions, its use as stability measure may be preferred to b_i, which is based on the linear model with stastical assumptions. If data fit the linear model, the b_i should be preferred because it provides the shape of the response as well as its variation.

The perfect correlation ($r = 1$) was observed between all possible pairs among θ_i, $\theta_{(i)}$, W_i^2 and σ_i^2. Therefore, only stability variance (σ_i^2) proposed by Shukla [8] is represented in the table. The θ_i, $\theta_{(i)}$, and σ_i^2 are linear combination of the ecovalence (W_i^2) and therefore, all are equivalent for ranking purposes [3]. With careful interpretation, anyone of the parameters would be used to measure stability. However, Shukla's σ_i^2 [8] may be preferred over others as it provides a test for the homogeneity of the estimates [11]. All these parameters were found independent with mean yield.

The most commonly used parameter S_{di}^2 had nearly perfect rank correlation with θ_i, $\theta_{(i)}$, W_i^2, σ_i^2 and r_i^2 in all the trials. A high rank correlation among them is expected when non-linear component of G × E interaction is predominant i.e. the data do not fit the linear model, or the data fit the linear model but all b_i's are equal [14]. In our study, the data did not fit the linear model and consequently, the rank correlation of S_{di}^2 was very high with θ_i, $\theta_{(i)}$, W_i^2, σ_i^2 and r_i^2.

Other stability parameters available in the literature are S_i1 and S_i4, which are based on rank orders of genotypes and therefore nonparametric in nature. Both were perfectly correlated ($r > 0.96^{**}$) in all the trials. Theoretical relationship between them had been elucidated by Becker and Leon [3]. These nonparametric statistics (S_i1 and

S_i4) had significant positive correlation with the parameters of dynamic concept (σ_i^2, S_{di}^2, and r_i^2) but were independent with the parameters of static concept (b_i and S_i^2) in all the trials. This suggests that the nonparametric statistics measure stability according to the dynamic concept. Although their biometrical relationships with the parameteric statistics have not so far been elaborated, a positive correlation of the nonparametric statistics with the parameters of dynamic concept might be attributed to the predominant effect of nonlinear G x E interaction on the ranking of genotypes. However, it has to be confirmed whether this relationship holds true when data fits the linear model. Since S_i1 and S_i4 are distribution-free and insensitive to errors of measurements, their use as stability parameter may be preferred in the situations where the assumptions of parametric statistics are not fulfilled.

Any stability parameter to be of practical value must show consistent result over different subsets of environments of a trial. Correlation between two estimates of each stability parameters was nonsignificant for random as well as stratified subsets (Table 2) revealing their poor repeatability. This suggests that the information derived from stability parameters and their interpretation are valid only for that specific set of environments.

Table 2. Rank-correlation coefficients between estimates of the stability parameters and mean yield for various subsets of environments.

Environmental subsets	Trial	Stability parameters								Mean yield
		S_i^2	CV_i	W_i^2	b_i	r_i^2	Sd_i^2	S_i1	S_i4	
Random	ICAT81	0.19	0.38	–0.02	0.30	0.21	0.11	–0.09	0.04	0.39
	ICAT82	0.51*	0.25	0.22	0.65**	0.36	0.17	0.32	0.39	0.33
	ICAT83	0.28	0.09	0.21	0.42	0.60*	0.30	0.22	0.27	0.79**
	AYT88-89	0.07	0.16	0.01	0.06	0.05	0.06	–0.17	–0.14	0.01
Stratified	ICAT81	0.32	0.47	–0.06	0.23	–0.24	–0.00	–0.27	–0.32	0.38
	ICAT82	0.11	0.59*	0.60*	0.37	0.46	0.46	0.51*	0.51*	0.72**
	ICAT83	0.33	0.05	0.12	0.29	0.34	–0.22	0.16	0.20	0.84**
	AYT88-89	0.08	0.02	0.16	0.03	–0.23	0.08	–0.06	0.04	0.06

*, ** Significant at 5% and 1% levels.

In the presence of several stability parameters to characterise G × E interaction, the merits and demerits of each parameter lie in the nature of materials to be tested, traits under consideration, and types of environments. The correlations between stability parameters lead to the conclusions that (i) the S_i^2 and b_i may be used interchangeably as a stability measure according to the static concept. However, S_i^2 may be preferred when data do not follow the linear model as is the case with most of the yield trials. (ii) All parameters of the dynamic concept are equivalent for ranking of genotypes and with careful interpretation, any one of the parameters may be sufficient to provide stability measure of a genotype in relation with the genotypes included in the trial. The b_i and S_{di}^2 characterise G × E interaction comprehensively only if data fits the linear model. Otherwise S_i^2 along with σ_i^2 or W_i^2 may be preferred which are more directly related with the stability concepts.

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