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Repeatability of different stability parameters for grain yield in chickpea

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Abstract

The presence of genotype × environment (GE) interactions in plant breeding experiments has led to the development of several stability parameters in the past few decades. The present study investigated the repeatability of these parameters for 16 chickpea (*Cicer arietinum* L.) genotypes by correlating their estimates obtained from extreme subsets of environments within a year and also over years. Based on the estimates of response and stability parameters within each trial, the ranking of genotypes in the low-yielding subset differed from that in the high-yielding subset. This indicates poor repeatability for response and stability parameters over the extreme environmental subsets. The estimates of mean yield and stability parameters represented by ecovalence, W_i^2, were consistent over years, whereas those of response parameters (b_i and S_i^2) showed poor repeatability. Our results suggest that single-year results for yield and stability can be used effectively for selecting cultivars with stable grain yield if tested in a wider range of environments.

Key words: *Cicer arietinum* — genotype × environment interaction — phenotypic stability — repeatability

Because of the widespread presence of genotype × environment (GE) interaction, yield stability is one of the most important breeding objectives in any crop. Several parameters for measuring yield stability have been proposed (Lin et al. 1986) but few are used as selection criteria in breeding programmes. An important aspect of a stability parameter, which requires breeders' attention before being considered as a selection criterion, is the repeatability of results over different subsets of environments. Earlier studies have shown poor to medium repeatability for stability parameters over different subsets of environments in several crops (Eagles and Frey 1977, Virk et al. 1985, Leon and Becker 1988, Pham and Kang 1988). In this paper, the repeatability of stability parameters over different environmental sets using extensive yield trial data of chickpea is examined.

Materials and Methods

The chickpea (*Cicer arietinum* L) data used in the present study were extracted from ICRISAT's International Chickpea Adaptation Trial (ICAT) and Advanced Chickpea Yield Trial (AYT). In ICAT trials, a set of 16 cultivars comprising seven desi types and nine kabuli types from different regions of the world was 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 the 5 × 5 balanced lattice square design with three replications. Various stability parameters — coefficient of variation (CV_i), environmental variance (S_i^2), Wricke's (1962) ecovalence (W_i^2), Eberhart and Russell's (1966) regression coefficient (b_i) and deviation from regression (S_{di}^2), Shukla's (1972) stability variance (σ_i^2), Pinthus's (1973) coefficient of determination (r_i^2), Nassar and Hühn's (1987) mean rank difference (S_i1) and variance of ranks (S_i4) — along with mean yield were estimated for each trial and various subsets of the environments as per the formulae given by Lin et al. (1986) and Becker and Leon (1988). To test the repeatability of these parameters, the locations in each year were divided into high-yielding and low-yielding subsets following the extreme method (Eagles and Frey 1977). Spearman's rank-correlation coefficient was calculated between two estimates of each parameter obtained from the two extreme subsets of environments. The repeatability of stability parameters over years was measured by rank correlating the results of different years and the results of single-years with multi-year trials.

Results

The joint regression analyses for all the environments in a year and for the two extreme subsets of environments within a year showed that genotypes, environments and GE interaction effects were highly significant ($P < 0.01$). The components of GE interaction attributable to heterogeneity among the linear response of genotypes and deviation from regressions were also consistently significant. Mean, regression coefficient and ecovalence for each genotype are given in Table 1. The genotypes showed large differences for mean values between the two extreme subsets of environments for each year. The high-yielding subset had a greater range for mean yield than the low-yielding subset, reflecting the disproportionate number of the environments that had low productivity in our trials. The arrays of b_i from the two extreme subsets of environments and their overall values were interesting in the sense that the b_i values for some of the genotypes were significant in one or both the subsets, whereas their overall b_i values were not and vice versa. This reflects the change of response of genotypes with the sample of environments.

To be of practical value, any stability parameter must show consistent results over different subsets of environments of a trial. Eagles and Frey (1977) used the term 'repeatability' to describe this characteristic of a stability parameter. Rank-correlation coefficients between the estimates of different parameters from the two extreme subsets within a year and over years are given in Table 2. From the results, the parameters can be subdivided into three groups that showed different degrees of correlation. The estimates of mean yield from the two extreme

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

Environmental subsets	Trial	Mean yield	CV_i	Response parameter S_i^2	Response parameter b_i	Stability parameter W_i^2
Extreme (High vs. low)	ICAT81	0.40	−0.19	−0.17	−0.32	−0.06
	ICAT82	0.86**	0.63**	−0.19	0.28	0.54*
	ICAT83	0.86**	0.00	−0.23	0.05	−0.06
	Mean	0.71**	0.27	−0.20	0.00	0.14
	AYT88–89	0.01	0.12	0.08	0.11	0.09
Year-wise	1981 vs. 82	0.69**	0.56*	0.03	0.29	0.65*
	1981 vs. 83	0.76**	0.47	0.06	0.15	0.41
	1982 vs. 83	0.87**	0.63**	0.77**	0.69**	0.59*
	Mean	0.77**	0.55*	0.29	0.38	0.55*
	1988 vs 89	0.00	0.03	0.27	0.34	0.05
1981 vs. multi-year		0.83**	0.72**	0.29	0.42**	0.84**
1982 vs. multi-year		0.94**	0.92**	0.86**	0.93**	0.85**
1983 vs. multi-year		0.96**	0.78**	0.91**	0.82**	0.73**
1988 vs. multi-year		0.68**	0.40*	0.59**	0.61**	0.35
1989 vs. multi-year		0.68**	0.90*	0.86**	0.88**	0.84**

*, ** Significant at P = 0.05 and P = 0.01, respectively.

subsets were always highly correlated (mean r = 0.71**) for all years. Correlations between the two estimates of response parameters (b_i and S_i^2) were always small and nonsignificant, whereas the correlation of stability parameters represented by W_i^2 showed a large fluctuation (r = −0.06 to 0.54*) for the extreme method of environmental division. For stability parameters, only W_i^2 is given as an example since it was found to be strongly correlated (mean r = 0.90**) with all other parameters (S_{di}^2, r_i^2, σ_i^2, θ_i, $\theta_{(i)}$, S_i1, and S_i4) in our trials. A nonsignificant correlation between two estimates of W_i^2 suggests that the stability of genotypes based on low-yielding environments would not be useful in predicting their stability in high-yielding environments, and vice versa, unless the trial was conducted in a wider range of environments. This also suggests that the information derived from the stability parameters and their interpretations are valid only for that specific set of environments.

Discussion

Single year results for yield and stability can be used effectively for selection only if they are repeatable over various environments in subsequent years. The estimates of mean yield and stability parameter W_i^2, but not of the response parameters S_i^2 and b_i, were consistent over years, as indicated by positively significant correlation coefficients between 1981 and 1982, 1981 and 1983, and 1982 and 1983 (Table 2). This suggests good repeatability for yield and stability parameters over years. In these years, the same set of genotypes was tested in many locations (more than 17) giving a fair representation of environmental conditions. The stability parameters, however, were not repeatable over years when the number of locations was restricted to four in 1988 and 1989. It is suggested that the stability parameters might be consistent over years if a trial is conducted in a large number of locations, thereby substantially reducing the proportion of genotype × year interactions. Further, the results of single-year and multi-year trials (Table 2) were also strongly correlated for mean yield and all the parameters, indicating that the genotype × location interaction was far more important in our trials than the genotype × year interaction. This contradicts the results of Leon and Becker (1988) for climatic conditions in middle Europe, but all the locations in their experiment were located within the same geographical region of Germany. A high genotype × location interaction in our trials may result from the ICAT trials being situated in several countries, representing a wider array of environments (17 in India; four each in USA and Pakistan; two each in Italy, Spain, Syria and Sudan; and one each in Algeria, Bangladesh, Brazil, Bulgaria, Canada, Costa Rica, Egypt, Iran, Iraq, Lebanon, Mexico, Nepal, Saudi Arabia, Turkey and Thailand).

A significant correlation between mean yield values from the two subsets of environments, irrespective of methods of division, indicates that selection based on mean yield from multilocation trials would be highly effective in producing chickpea lines that would be superior at all yield levels. The response parameters (S_i^2 and b_i) appear to be nonrepeatable across environments for mean yield and, therefore, may not be useful in selecting cultivars with stable yield. However, the stability parameters (W_i^2, S_{di}^2, r_i^2, σ_i^2, θ_i, $\theta_{(i)}$, S_i1, and S_i4), which appeared to be repeatable over years for grain yield, could be used to a limited degree for selecting genotypes with stable grain yield.

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