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Assessment of Drought Tolerance in Barley Genotypes

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Abstract: In order to evaluate quantitative drought resistance criteria in some wild and cultivated barley, sixteen genotypes were tested under two different irrigation regimes (non-stressed and stressed). Plants were subjected to moisture stress at flowering period till maturity. Six drought tolerance indices, Stress Tolerance Index (STI), stress tolerance (TOL), Stress Susceptibility Index (SSI), Yield reduction ratio (Yr), Mean Productivity (MP) and Geometric Mean Productivity (GMP) were used. The indices were adjusted based on grain yield under stress (Ys) and non-stress (Yp) conditions. There were significant differences for all criteria among the genotypes. The significant and positive correlations of Yp with (MP, GMP and STI) and Ys with (MP, GMP and STI), as well as, significant negative correlation of SSI and TOL under stress environment, revealed that selection could be conducted for high values of MP, GMP and STI under both conditions and low values of SSI and TOL under stress condition. The correlation coefficients indicated that STI, MP and GMP are the best criteria for selection of high yielding genotypes both under stress and non-stress conditions. Results of calculated gain from indirect selection indicated that selection under moisture stress would be efficient in yield improvement compared to non-stress condition. Genotypes were significantly different for their yield under stress and non-stress conditions. Arivat (kavir), Aras, Goharjo and Afzal were the most desirable genotypes for both stress and non-stress environments.

Key words: Barley, water stress, drought tolerance indices, grain yield

INTRODUCTION

Barley is one of the most important cereal crops grown in many developing countries, where it is often subject to extreme drought stress that significantly affects production (Ceccarelli *et al*., 2007). Drought is the main environmental constraint, which occurs in many parts of the world every year, often having devastating effects on crop productivity. Hence, improved tolerance to drought has been a goal in crop improvement programs since, the dawn of agriculture (Ludlow and Muchow, 1990). Drought tolerance is not a simple response, but is mostly conditioned by many component responses, which interact and may different for crops, in relation to types, intensity and duration of water deficit. Moreover, most agronomical characters are expressed differently in normal and stress conditions and are known to be affected by environmental factors. Therefore, selection based on the phenotype would be difficult for such traits (Hittalmani *et al*., 2003).

Drought is an important factor limiting crop production in arid and semi-arid conditions. Breeding for drought tolerance by selecting solely for grain yield is difficult, because the heritability of yield under drought conditions is low, due to small genotypic variance or large genotype-environment interaction variances (Blum, 1988; Ludlow and Muchow, 1990). The genetic structure and phenotypic expression of a quantitative trait are highly influenced by environmental factors, thus, one barrier for understanding the inheritance of a quantitative trait is genotype-environment interactions (Breese, 1969).

Many methods have been employed to identify crop lines that are productive in dry environments (Yadav and Bhatnagar, 2001; Reynolds *et al*., 2007). Some use mathematical models to compare the change in seed yield between stressed and non-stressed environments (Rosielle and Hamblin, 1981). Loss of yield is the main concern of plant breeders and they hence, emphasize on yield performance under moisture-stress conditions. But variation in yield potential could arise from factors related to adaptation rather than to drought tolerance. Thus, drought indices providing a measure of drought based on yield loss under drought-conditions compared to normal conditions are being used in screening drought-tolerant genotypes (Mitra, 2001).

Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield under stress (Ys) and non-stress (Yp) environments and Mean Productivity (MP) as the average of Ys and Yp. Fischer and Maurer (1978) proposed a Stress Susceptibility Index (SSI) of the

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cultivar. Fernandez (1992) defined a new advanced index (STI = stress tolerance index), which can be used to identify genotypes producing high yield under both stress and non-stress conditions. He declared that selection based on STI will be resulted in genotypes with higher stress tolerance and yield potential will be selected. The other yield based estimates of drought resistance are Geometric Mean (GMP), which is often used by breeders interested in relative performance, since, drought stress can vary in severity in field environment over years (Ramirez and Kelly, 1998).

Among the stress tolerance indicators, a larger value of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favoured. Selection based on these two indices favours genotypes with low yield under non-stress conditions and high yield under stress conditions (Golabadi *et al*., 2006). In spring wheat cultivars, Guttieri *et al*. (2001) using SSI criterion suggested that SSI more than 1 indicating above-average susceptibility and SSI less than 1 indicated below-average susceptibility to drought stress. Ramirez and Kelly (1998) reported that selection based on combination of GMP and SSI may be more efficient for improving drought tolerance in common bean. Khalili *et al*. (2004) showed that based on Geometric Mean Productivity (GMP) and STI indices, corn hybrids with high yield in both stress and non-stress environments can be selected.

This study was conducted to assess the selection criteria for identifying drought tolerant genotypes and high-yielding genotypes in drought stress and non-stress conditions.

MATERIALS AND METHODS

The experiment was conducted in a glasshouse at Agricultural College, Shiraz University, Iran, November 2005 to May 2006. Sixteen wild and cultivated barley genotypes (Table 1) were compared at 2 irrigation regimes (irrigation at 50% FC (stress) and keeping pots moisture at FC status (non-stress), on pot weight basis), in a completely randomized design with 4 replications. The experiment was conducted in a glasshouse at Agricultural College, Shiraz University, Iran, during 2005-2006. Seeds were planted in 5 kg pots and subjected to the two mentioned irrigation treatments starting from 50% flowering stage until maturity.

Grain yield was determined under non-stress and stress conditions and indicated as Yp and Ys, respectively.

Stress tolerance indices were calculated using the following relationships:

$$TOL = Yp-Ys \text{ (Rosielle and Hamblin, 1981)} \quad (1)$$

$$MP = \frac{(Yp+Ys)}{2} \text{ (Rosielle and Hamblin, 1981)} \quad (2)$$

$$SSI = \frac{(1-Ys/Yp)}{SI} \text{ and } SI = (1-\bar{Y}s/\bar{Y}p) \text{ (Fischer and Maurer, 1978)} \quad (3)$$

where, SI is stress intensity and $\bar{Y}s$ and $\bar{Y}p$ are mean of all genotype under stress and non-stress conditions, respectively.

$$GMP = \sqrt{(Yp)(Ys)} \text{ (Kristin } et\ al.\text{, 1997; Fernandez, 1992)} \quad (4)$$

$$STI = (Yp/\bar{Y}p)(Ys/\bar{Y}s)(\bar{Y}s/\bar{Y}p) = \frac{(Yp)(Ys)}{(\bar{Y}p)^2} \text{ (Fernandez, 1992)} \quad (5)$$

$$\text{Yield reduction ratio } (Yr) = 1-(Ys/Yp) \text{ (Golestani and Assad, 1998)} \quad (6)$$

Analysis of variances, mean comparisons, correlation analyses, principle component and biplot were done using SPSS 13 software.

RESULTS AND DISCUSSION

Yield potential (Yp), stress yield (Ys) and eight quantitative indices of drought tolerance were calculated (Table 1). Analysis of variance showed highly significant differences for most of the indices of the genotypes (Table 2). To determine the most desirable drought tolerance criteria, the correlation coefficient between Yp, Ys and other quantitative indices of drought tolerance were calculated (Table 3). There were positive significant correlations among Yp and (MP, GMP and STI) and Ys and (MP, GMP and STI). The correlation coefficients for TOL, SSI and Yr vs. grain yield under moisture stress (Ys) were r = -0.295, -0.260, -0.260, respectively. No significant correlations were observed between TOL and GMP ($r = 0.168$, $p<0.01$) and TOL and STI ($r = 0.119$, $p<0.05$).

A positive correlation ($r = 0.28$) was found between grain yield under stressed and non-stressed situations (Table 3).

Biplot analysis (Table 4, Fig. 1) confirmed correlation analysis between studied criteria. Principal Component Analysis (PCA) revealed that the first PCA explained 69.27% of the variation with Yp, Ys, MP, GMP and STI (Table 4) and the second PCA explained 28.59% of the total variability.

Table 1: Yield potential (Yp), stress yield (Ys) and drought tolerance indices for 16 barley genotypes (genotypes No. 1, 2 and 3 are wild and the rest are cultivated)

No.	Genotypes	Yp	Ys	STI	GMP	MP	SSI	Yr	TOL
1	Vineyard-1	0.47e	0.21gh	0.04g	0.31gh	0.34h	0.92abcde	0.53abcde	0.25ef
2	P-21	0.13e	0.10h	0.01g	0.11h	0.12h	0.32f	0.19f	0.02f
3	P-41	0.44e	0.21gh	0.03g	0.30gh	0.33h	0.89bcde	0.51bcde	0.23ef
4	Afzal	2.35ab	1.14abc	1.20ab	1.63ab	1.74abc	0.87bcde	0.51bcde	1.21abc
5	Rihane	1.89c	1.08abc	0.79bc	1.42cd	1.49cde	0.73ef	0.42ef	0.82cd
6	Himalya	2.04bc	0.54ef	0.42de	1.05e	1.29e	1.26abc	0.73abc	1.50a
7	Valfajr	1.29d	0.68de	0.33def	0.94e	0.99f	0.81de	0.47de	0.61de
8	Karoonkavir	2.26abc	0.88cd	0.75bc	1.40cd	1.57bcd	1.04abcde	0.60abcd	1.37a
9	Aljerseres	2.12bc	0.67de	0.53cd	1.18de	1.39de	1.18abcde	0.69abc	1.45a
10	Arivat (kavir)	2.60a	1.20ab	1.18a	1.76a	1.90a	0.92abcde	0.53abcde	1.39a
11	Makooi(star)	1.04d	0.23gh	0.10fg	0.48fg	0.63g	1.35a	0.78a	0.81cd
12	Victoria	0.94d	0.48efg	0.17efg	0.65f	0.71g	0.71ef	0.41ef	0.45def
13	Aras	2.42ab	1.24a	1.14a	1.73ab	1.83a	0.83cde	0.48cde	1.17abc
14	Sina	1.16d	0.29fgh	0.13fg	0.57fg	0.73g	1.29ab	0.75ab	0.87bcd
15	Gohar	2.49ab	1.01abc	0.95ab	1.58abc	1.75abc	1.02abcde	0.59abcde	1.49a
16	Star/lerusa/ Em/rihane-30	2.30abc	0.96bc	0.84b	1.48bc	1.63abcd	1.00abcde	0.58abcde	1.34ab

Means followed by the same letter(s) in each column are not significantly different (p<0.01).Yp: Yield under non-stress condition, Ys: Yield under stress condition, STI: Stress tolerance index, GMP: Geometric mean productivity, MP: Mean productivity, SSI: Stress susceptibility index, Yr: Yield reduction ratio, OL: Tolerance index

Table 2: Analysis of variance for Yp, Ys and drought tolerance indices

Source of variation	df	Mean square Yp	Ys	TOL	MP	GMP	Yr	SSI	STI
Genotype	15	2.749**	0.630**	0.999**	1.440**	1.266**	0.089**	0.264 **	0.723**
Error	48	0.046	0.018	0.054	0.018	0.018	0.014	0.042	0.019
CV		13.23	19.650	24.780	11.650	12.910	21.500	21.630	26.000

**Highly significant (p<0.01). Yp: Yield under non-stress condition, Ys: Yield under stress condition, TOL: Tolerance index, GMP: Geometric mean productivity, Yr: Yield reduction ratio, SSI: Stress susceptibility index, STI: Stress tolerance index

Table 3: Correlation coefficients between Yp, Ys and drought tolerance indices

Variables	Yp	Ys	TOL	MP	GMP	SSI	Yr	STI
Yp	1	0.28**	0.798**	0.86**	0.653**	0.446**	0.446**	0.614**
Ys		1	-0.295**	0.704**	0.854**	-0.260**	-0.260**	0.901**
TOL			1	0.465**	0.168*	0.594**	0.594**	0.119
MP				1	0.917**	0.205**	0.205**	0.866**
GMP					1	-0.046	-0.046	0.915**
SSI						1	1.00**	0.045
Yr							1	0.045
STI								1

*and **Means significant at 5 and 1% levels of probability, respectively. Yp: Yield under non-stress condition, Ys: Yield under stress condition, TOL: Tolerance index, GMP: Geometric mean productivity, SSI: Stress susceptibility index, Yr: Yield reduction ratio, STI: Stress tolerance index

Table 4: Principal component loadings for the measured traits of barley genotypes

Component	Proportion of total variation (%)	Variables Yp	Ys	TOL	MP	GMP	STI	SSI	Yr
PC1	69.27	0.88	0.91	0.44	0.98	0.99	0.98	-0.09	-0.09
PC2	28.59	0.46	-0.39	0.86	0.17	0.04	-0.03	0.98	0.98

Yp: Yield under non-stress condition, Ys: Yield under stress condition, TOL: Tolerance index, MP: Mean productivity, GMP: Geometric mean productivity, STI: Stress tolerance index, SSI: Stress susceptibility index, Yr: Yield reduction ratio

The results indicated that there were positive and significant correlations among Yp and (MP, GMP and STI) and Ys and (MP, GMP and STI) and they hence were better predictors of Yp and Ys than TOL and SSI. The observed relationship between Yp and (MP and STI) and Ys and (MP and STI) are in consistent with those reported by Fernandez (1992) in mung bean and Farshadfar and Sutka (2002) in maize. Ud-Din *et al*. (1992) showed significant and positive correlation between Ys and TOL and Ys and Mp as well as between Yp and MP, while TOL was negatively correlated with Yp and MP. In the present study, the correlation coefficient for stress tolerance (TOL) vs. grain yield under moisture stress (Ys) was r = -0.295. Thus, selection for tolerance should decrease yield in the moisture stress environment and increase grain yield under non-moisture stress (r = 0.798). Thus, selection for tolerance will be worthwhile only when the target environment is non-drought stressed. The

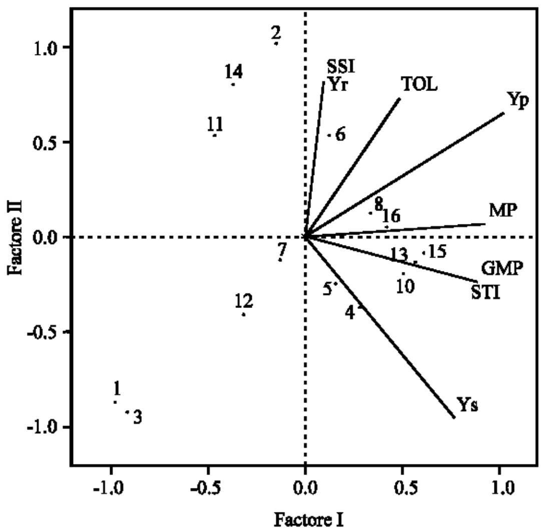

Fig. 1: Biplot for quantitative traits of barely genotypes. Yp: Yield under non stress condition , Ys: Yield under stress condition, TOL: Tolerance index, MP: Mean productivity, SSI: Stress susceptibility index, GMP: Geometric mean productivity, STI: Stress tolerance index, Yr: Yield reduction ratio

correlation coefficient for mean productivity vs. yields in moisture and non-moisture stress environments were 0.704 and 0.86. Thus, selection for MP should give positive responses in both environments. No significant correlations were observed between TOL and GMP ($r = 0.168$, $p<0.01$) and TOL and STI ($r = 0.119$, $p<0.05$). The lack of a correlation between TOL and GMP and between TOL and STI would indicate that the combination of high GMP and STI with a low to moderate TOL is biologically accessible in barley, thereby, combining different traits that associate with each index. Fernandez (1992) proposed STI index which discriminates genotypes with high yield and stress tolerance potentials. Limitations of using the SSI and TOL indices have already been described in wheat (Clark *et al*., 1992) and in common bean (Ramirez and Kelly, 1998). The SSI does not differentiate between potentially drought-tolerant genotypes and those that possessed low overall yield potential. Although, low TOL has been used as a basis for selecting cultivars with resistance to water stress, the likelihood of selecting low yielding cultivars with a small yield differential can be anticipated (Ramirez and Kelly, 1998).

Correlation analysis revealed that Yield potential (Yp) and stress yield (Ys) had highly significant positive correlation coefficients with Stress Tolerance Index (STI), Mean Productivity (MP) and Geometric Mean Productivity (GMP). Moreover, the correlations among STI, MP and GMP exhibited same trend, thus they can be introduced as the most desirable indices for screening drought tolerance genotypes. Stress Tolerance Index (STI) is calculated based on GMP and thus rank correlation between STI and GMP is equal to 1. The higher value of STI means higher tolerance and yield potential for genotype. The stress intensity value is also incorporated in the calculation of STI. Thus, STI is expected to be the most desirable index for drought tolerance. Same result was obtained by Fernandez (1992), Imamjomah (1999) and Farshadfar and Sutka (2003) for STI, MP and GMP.

Under most yield trial condition, the correlation between Ys and Yp is between 0 and 0.5 and genetic variance ratio is <1 (Farshadfar and Sutka, 2003). Present results revealed that the correlation coefficient between Ys and Yp was 0.28 (Table 3). Thus, genotypic selection for yield under a non-stress environment would increase the mean stress yield.

MP is based on the arithmetic means and therefore, it has an upward bias due to a relatively larger difference between Yp and Ys, whereas, the geometric mean is less sensitive to large extreme values.

Higher values of Stress Susceptibility Index (SSI) (Table 1) indicated a higher degree of susceptibility under stress conditions for genotype and vice versa (Bruckner and Frohberg, 1987; Solomon and Labuschagne, 2003).

Mean grain yield under stress conditions was 0.69 g plant^{-1} which showed a reduction of -57% in comparison to the non-stress conditions (control).

Selection based on a combination of indices may provide a useful criterion for improving drought resistance of barley, but study of correlation coefficients are useful in finding out the degree of overall linear association solely between any two considered attributes. Thus, a better approach such as biplot analysis is needed to identify the superior genotypes for both stressed and non-stressed environments. Genotypes subjected to biplot analysis, are compared for assessing relationships between all the attributes at once.

Biplot analysis has been used by many researchers for comparison of different genotypes for different criteria and in different plant species. Thomas *et al*. (1995) distinguished 25 accessions of meadow fescue collected from seven countries using biplot analysis. Kaya *et al*. (2002) were able to reveal that bread wheat genotypes with larger PCA1 and lower PCA2 scores gave high yields (stable genotypes) and genotypes with lower PCA1 and larger PCA2 scores had low yields (unstable genotypes). Yan and Rajcan (2002) showed that applying Genotype-Trait (GT) biplot to the multiple trait data illustrated that, GT biplots graphically displayed the interrelationships among seed yield, oil content, protein content, plant height and days to maturity and facilitated visual cultivar comparisons and selection in soybean.

Present results obtained from biplot analysis (Table 4, Fig. 1) confirmed correlation analysis between studied criteria. Principal Component Analysis (PCA) revealed that the first PCA explained 69.27% of the variation with Yp, Ys, MP, GMP and STI (Table 4). Thus, the first dimension can be named as the yield potential and drought tolerance. The second PCA explained 28.59% of the total variability. Therefore, the second component can be named as stress-tolerant dimension and it separates the stress-tolerant genotypes from non-stress tolerant ones. Thus, selection of genotypes that have high PCA1 and low PCA2 are suitable for both stress and non-stress environments. Therefore, genotypes Arivat, Aras, Gohar and Afzal with higher PC1 and lower PC2, are superior genotypes under both stressed and non-stressed conditions. These genotypes also had the highest amount of Yp, Ys, GMP, MP and STI and therefore, they may be known as desirable genotypes for both stressed and non-stressed environments. Wild genotypes (Vineyard-1 and P-41) had the lowest values for SSI and TOL while their Yp and Ys were the lowest. These two genotypes had low yield potential under stress and non-stress conditions. Low yield is the common character of wild species but their mentioned genetic potential can be used in breeding tolerant genotypes for stressed conditions.

REFERENCES

Blum, A., 1988. Plant Breeding for Stress Environments. CRC Press Inc., Boca Raton, USA., ISBN-10: 0849363888.

Breese, E.D., 1969. The measurement and significant of genotype-environment interaction in grasses. Heredity, 21: 27-47.

Bruckner, P.L. and R.C. Frohberg, 1987. Stress tolerance adaptation in spring wheat. Crop Sci., 27: 31-36.

Ceccarelli, S., S. Grando and M. Baum, 2007. Participatory plant breeding in water-limited environments. Exp. Agric., 43: 1-25.

Clark, J.M., R.M. DePauw and T.F. Townley-Smith, 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci., 32: 723-728.

Farshadfar, E. and J. Sutka, 2002. Screening drought tolerance criteria in maize. Acta Agron. Hungarica, 50: 411-416.

Farshadfar, E. and J. Sutka, 2003. Multivariate analysis of drought tolerance in wheat substitution lines. Cereal Res. Commun., 31: 33-40.

Fernandez, G.C.J., 1992. Effective selection criteria for assessing plant stress tolerance. Proceedings of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Aug. 13-16, Shanhua, Taiwan, pp: 257-270.

Fischer, R.A. and R. Maurer, 1978. Drought resistance in spring wheat cultivars. I. Grain yields responses. Aust. J. Agric. Res., 29: 897-912.

Golabadi, M., A. Arzani and S.A.M. Mirmohammadi Maibody, 2006. Assessment of drought tolerance in segregating populations in durum wheat. Afr. Agric. J. Res., 1: 162-171.

Golestani, S.A. and M.T. Assad, 1998. Evaluation of four screening techniques for drought resistance and their relationship to yield reduction ratio in wheat. Euphytica, 103: 293-299.

Guttieri, M.J., J.C. Stark, K. O'Brien and E. Souza, 2001. Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. Crop Sci., 41: 327-335.

Hittalmani, S., N. Huang, B. Courtois and R. Venuprasad *et al*., 2003. Identification of QTL for growth and grain yield-related traits in rice across nine locations of Asia. Theor. Applied Genet., 107: 679-690.

Imamjomah, A., 1999. Determination of genetic distances by RAPD-PCR, evaluation of drought tolerance criteria and analysis of adaptation in chickpea. M.Sc. Thesis, College of Agriculture, Razi University, Kermanshah, Iran, pp: 4-5.

Kaya, Y., C. Palta and S. Taner, 2002. Additive main effects and multiplicative interactions analysis of yield performance in bread wheat genotypes a cross environments. Turk. J. Agric., 26: 275-279.

Khalili, M., M. Kazemi, A. Moghaddam and M. Shakiba, 2004. Evaluation of drought tolerance indices at different growth stages of late-maturing corn genotypes. Proceedings of the 8th Iranian Congress of Crop Science and Breeding, Aug. 25-27, Rasht, Iran, pp: 298-298.

Kristin, A.S., R.R. Serna, F.I. Perez, B.C. Enriquez and J.A.A. Gallegos *et al*., 1997. Improving common bean performance under drought stress. Crop Sci., 37: 51-60.

Ludlow, M.M. and R.C. Muchow, 1990. A critical evaluation of traits for improving crop yield in water-limited environments. Adv. Agron., 43: 107-153.

Mitra, J., 2001. Genetics and genetic improvement of drought resistance in crop plants. Curr. Sci., 80: 758-762.

Ramirez, V.P. and J.D. Kelly, 1998. Traits related to drought resistance in common bean. Euphytica, 99: 127-136.

Reynolds, M.P., C.S. Pierre, A.S.I. Saad, M. Vargas and A.G. Condon, 2007. Evaluating potential genetic grains in wheat associated with stress-adaptive trait expression in elite genetic resources under drought and heat stress. Crop Sci., 47: 172-189.

Rosielle, A.A. and J. Hamblin, 1981. Theoretical aspects of selection for yield in stress and non-stress environments. Crop Sci., 21: 943-946.

Solomon, K.F. and M.T. Labuschagne, 2003. Expression of drought tolerance in F1 hybrids of a diallel cross of durum wheat (*Triticum turgidum* var. *durum* L.). Cereal Res. Commun., 31: 49-56.

Thomas, H., S.J. Dalton, C. Evans K.H. Chorlton and I.D. Thomas, 1995. Evaluating drought resistance in germplasm of meadow fescue. Euphytica, 92: 401-411.

Ud-Din, N., B.F. Carver and A.C. Clutter, 1992. Genetic analysis and selection for wheat yield in drought-stressed and irrigated environments. Euphytica, 62: 89-96.

Yadav, O.P. and S.K. Bhatnagar, 2001. Evaluation of indices for identification of pearl millet cultivars adapted to stress and non-stress conditions. Field Crops Res., 70: 201-208.

Yan, W. and I. Rajcan, 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. Crop Sci., 42: 11-20.