한작지(Korean J. Crop Sci.), 52(4): 469~473(2007)

Stability Analysis of Some Agronomical Characters and Yield Components of Barley in Response to Irrigation Period

M. Anisuzzaman*, Iftekhar Alam, A. H. M. Mahbubur Rahman*, A. K. M. R. Islam*, and Nagib Ahsan**†**

**Department of Botany, Rajshahi University, Rajshahi-6205, Bangladesh*
***Division of Applied Life Sciences (BK21), Gyeongsang National University, Jinju 660-701, Korea*

ABSTRACT With the aim to analyze stability performance of six promising barley genotypes, eleven yield related characters were evaluated employing varied irrigation treatments under the tropical climate of Northern part in Bangladesh. Analysis of variance (ANOVA), phenotypic index, regression co-efficient (*bi*) and deviation from regression (s_d^2) of the individual genotypes were estimated to evaluate the stable performance of the genotypes. A significant interaction was observed between the genotypes and irrigation period (G×T). Among all the genotypes, BSH-2 showed stable performance for plant height under different irrigation period, where P>$\overline{X}$, *bi*~1 and s_d^2~0. High phenotypic index, lower *bi* value and low deviations from regression were observed in case of spikelet number per spike and grain number per spike for genotype BSH-2 and plant height, spike length and harvest index per plant for BB-2 which suggest that those parameters were not usually affected by irrigation. On the other hand the genotype BSH-2 for tiller number and BB-1 for the fertile tiller number were not suitable for favorable moisture content, where P<$\overline{X}$, *bi*>1.0 and low s_d^2. Thus we suggest that genotype BSH-2 might have transmit high mean and increased phenotypic stability to the next progenies, which may consider as an ideal genotype for developing improved barely cultivars.

Keywords : barley, stability, water stress, genotype environment interaction

Barley is the fourth important cereal crop worldwide after wheat, rice and maize (Tiidema and Truve, 2004). Changes in relative ranking appear to be an inevitable consequence of growing a set of genotypes in even a few locations or growing seasons. This phenomenon is highly considered in tropical regions where environmental fluctuations are not only a major cause for yield reduction, lack of crop protections also conferred by purchased inputs (Worku *et al.*, 2001). Phenotype (P) is the product of the genetics (G) of the individual, the environment (E), and the interaction between the genotype and the environment (G×E). Large G×E interaction tends to be viewed as problematic in breeding because the lack of a predictable response hinders progress from selection (Dudley and Moll, 1969; Smithson and Grisley, 1992). This idealized predictable response across multiple environments is generally referred to as stability (Cannon, 1932). High yield stability usually refers to a genotype's ability to perform consistently, whether at high or low yield levels, across a wide range of environments (Annicchiarico, 2002). Genotypes are selected primarily on the basis of the mean performance across environments for that crop year, although those selected may not be the most stable (Yau and Hamblin, 1994). Thus stability concepts are applied to select genotype (s) for increased grain yield that perform consistently across a wide range of stress conditions with high yield potential to take advantage of more favorable environments and with a mean performance that is above average in all environments (Costa and Bollero, 2001; Lee *et al.*, 2003). Yield stability targets for breeding programs can be defined from yields of trials through estimation of variance components for the target environments. One of the major stability measures is the static stability concept (Lin *et al.*, 1986; Becker and Léon, 1988). This can be estimated by measuring (i) The environmental variance i.e. the variance of genotype yields recorded across test or selection environments, and (ii) The regression coefficient of genotype yield in individual environment as a function of the environment mean yield, adopting Finlay and Wilkinson's (1963) *bi* coefficient. When

†Corresponding author: (Phone) +82-10-2892-3438 (E-mail) nagib_ahsan@yahoo.com
<Received November 30, 2007>

genotype-environment interaction is significant, stability parameters are estimated for selecting superior genotypes across a range of environment. Static stability may be more useful than dynamic in a wide range of situations, especially in developing countries (Simmonds, 1991).

In Bangladesh, barley is a secondary crop, commonly grown in marginal land during the winter season with minimum inputs by conventional tillage. Studies for policy changes on production and diversification of secondary crops (coarse grain, pulses, roots and tubers) emphasize diversifying crop agriculture through the expansion of these crops including barley (Alam, 2005; Ali *et al.*, 2007). In addition, its value as a feed crop is increasing day by day not only in Bangladesh but also increases in other South East Asian countries (Kim *et al.*, 2005). Therefore, breeding and agronomic research for the generation of improved barley cultivars should receive a high priority. Water shortage is the main limiting factor to increase the yield production of barely. Greater GE interaction can be presumed due to irregular precipitation. As a result it is not only average performance that is important in genotype evaluation programs but also the magnitude of interactions. Stability performance is of special importance in Bangladeshi barley where especially soil moisture content varies considerably. Some regional yield trials has been conducted in Bangladesh. However, the stability parameters of barley cultivars grown in this region under different soil moisture regime is not sufficiently known. The objective of this study was to investigate the stability of agronomic traits of six barley genotypes under different irrigation treatments using analysis of variance and regression analysis.

MATERIALS AND METHODS

Six cultivars of barley viz. BSH-2, IBON/97, BB-1, BB-2, KARAN-19 and KARAN-163 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, and used as experimental materials. The experiment was carried out in the Botanical Research Field of Rajshahi University, Bangladesh during the year 2003-2004.

The experiment was conducted in a split plot design with three replications. Plot size was 5.0 m × 1.5 m and row to row distance was 20 cm. Seeding rate was adjusted to obtain a total population of 1.5 to 1.6 million plants ha-1 based on 85% germination. A basal dose of urea (80 kg/ha), phosphate (40 kg/ha) and potash (40 kg/ha) was applied.

Irrigation treatment was considered as main plot and genotype was as sub plot. To evaluate the irrigation effects on the six cultivars, irrigation was applied in three different developing stages of the plants such as, (i) crown root initiation and heading stage (ii) crown root initiation stage, and (iii) heading stage. No irrigation was used as control. The data were collected on individual plant basis.

In order to investigate the stability, following eleven yield related characters were evaluated viz. plant height (PH), tiller number (TN), fertile tiller number (FTN), extrusion length (EXL), spike length (SPL), spikelet number per spike (SNS), grain number per spike (GNS), thousand grain weight (TGW), total dry matter (TDM), harvest index per plant (HIP) and grain yield per plant (GYP).

Stability analysis was performed following the biometrical techniques of analysis as described by Eberhart and Russell (1966) in maize based on the mathematical models of Fisher *et al.* (1932). Stability was defined as a function of the regression slope and deviations from regression of genotype yield on an environmental index. Average yield of all genotypes was used as the environmental index.

RESULTS AND DISCUSSION

Analysis of variance for various yield related characters are presented in Table 1. Significant variation was detected for irrigation treatments for all of the characters except in extrusion length, spike length and number of grain per spike. It indicated that irrigation (T) highly affected those characters. Variation among the genotypes was found to be highly significant for all the characters except harvest index which indicated that the genotypes were well differentiated. Similarly, interaction (G×T) item was significant for all the characters except in harvest index and grain yield per plant indicating that the tested genotypes responded differently in different soil moisture treatments. Components of variance were estimated to quantify the relative proportions of genotype and environment by many workers (McIntosh, 1983).

Among all the variables in most of the cases, the magnitude of the variance components due to environment (irrigation treatment) was substantially larger than the other effects (Table 1). Grain weight, extrusion length and spike length were affected mainly by its genetic potential lies within. Therefore, most of the variations in the performance of barley genotypes in these trials were due to environmental and not due to genotype by environment interactions. Differential fitness of genotypes to the environments is reported in different trials worldwide (Costa and Bollero, 2001; Arisnabarreta and Miralles, 2006). The small residual variance (main and sub plot error) indicates that almost all of the variation was accounted and precision of the experiments was high.

A genotype considered to have optimal yield stability measured through regression approaches is one that has a high mean yield, is responsive to favorable environmental conditions indicated by a moderate to high regression coefficient (*bi*) value with low deviations (s_d^2) from regression. This definition of stability was used for the U.S. maize and wheat production (Eberhart and Russell, 1966; Peterson *et al*., 1997).

Character wise phenotypic index, regression co-efficient (*bi*) and deviation from regression (s_d^2) of the individual genotypes are shown in Table 2. Our results indicate that most characters of tested genotypes in this study responded well under improving environmental conditions, while some traits were found to be irresponsive. For PH of genotype BSH-2 had higher mean than grand mean ($P>\overline{X}=101.658$), regression co-efficient nearly 1.00 (0.919) and non-significant deviation from zero (s_d^2 value). This is the only character among others, which satisfied the requirements of higher stability i.e. it was adaptable to all the environments (irrigation). Therefore, prediction of this genotype was feasible that this character was not sensitive to changes in the environment. In contrast, genotypes IBON/97 and KARAN-19 for PH, BB-2 for SNS and BB-1 for TGW with higher phenotypic index ($P>\overline{X}$), higher regression co-efficient ($bi>1.00$) and non-significant s_d^2 indicated very sensitive to changes in the environments above average stability. These characters would perform better in the favorable environments only. Therefore, it can be revealed that these genotypes were specially adapted to high-yielding environments. These results are similar with those of Finlay and Wilkinson (1963) and Perkins and Jinks (1968). Most modern genotypes of barley (> 90%), tested from 1993/94 to 1996/97 in USA, had generally high *bi* values (not significantly different from 1.0) (Costa and Bollero, 2001).

The genotype BSH-2 for SNS and GNS and the genotype BB-2 for PH, SPL and HIP with high phenotypic

Table 1. Mean squares (MS) from the analysis of variance of yield and its components of six barley genotypes under different soil moisture.

Source of variation	df	Plant height (cm)	Tiller number/ plant	Fertile tiller no./plant	Extrusion length (cm)	Spike length (cm)	No. of spikelet/ spike	No. of grain/ spike	1000 grain wt. (g)	Total dry matter (g)	Harvest index (%)	Grain yield/ plant	Grain yield (kg/ha)
Replication	2	61.75*	0.92	0.19	1.52	0.34	0.73	2.35	0.26	5.33	65.86	3.05	1952326.2
Treatment (T)	3	3185.93**	11.86**	8.39**	4.17	1.74	53.92**	323.35	14.37*	278.73**	583.86*	28.80**	18433153**
Main plot error (Ea)	6	9.10	0.70	0.34	2.17	0.91	2.74	81.27	1.94	7.90	99.01	1.33	848700.74
Genotype (G)	5	1332.55**	1.15*	0.44*	38.02**	27.58**	14.04**	147.93**	52.88**	28.61**	490.32	5.61**	3588099.6**
G×T	15	80.00**	1.21**	0.83**	2.99**	3.44**	9.53**	63.26**	1.90*	19.39**	335.75	2.31	1476677.5
Sub plot error (Eb)	40	19.26	0.34	0.13	0.74	0.65	2.16	24.57	0.81	7.54	367.44	1.53	978918.58

*, **, *** Significant at 5%, 1%, 0.1%, respectively

Table 2. Phenotypic stability parameters of six genotypes for eleven characters in barley.

Character	Components	BSH-2	IBON/97	BB-1	BB-2	KARAN-19	KARAN-163
Plant height	*bi*	0.919	1.067	0.814	0.856	1.551	0.429
	Phenotypic index	101.658	92.006	92.932	93.491	76.983	63.335
	s_d^2	36.854	25.203	49.543	34.005	42.408	19.739
Tiller number/ plant	*bi*	1.135	0.690	0.822	0.805	0.420	0.353
	Phenotypic index	3.003	2.458	3.010	2.654	4.878	4.294
	s_d^2	0.470	1.125	0.860	1.126	0.250	0.309
Fertile tiller no./plant	*bi*	0.893	0.662	1.075	0.575	0.455	0.324
	Phenotypic index	2.698	2.446	2.395	2.365	3.461	3.628
	s_d^2	0.284	0.400	0.344	0.574	0.259	0.208
Extrusion length	*bi*	0.527	0.504	0.817	0.500	0.655	0.025
	Phenotypic index	8.871	6.749	6.538	6.339	3.501	2.270
	s_d^2	0.438	0.809	0.891	0.313	1.830	2.618
Spike length	*bi*	0.254	0.551	0.153	0.440	0.435	0.217
	Phenotypic index	18.396	20.370	20.745	21.983	19.783	18.573
	s_d^2	0.453	0.246	0.517	0.134	0.262	0.402
No. of spikelet/ spike	*bi*	0.573	0.606	0.599	1.057	0.639	0.561
	Phenotypic index	18.516	17.239	17.640	17.483	18.00	17.665
	s_d^2	2.227	1.659	0.938	2.281	2.110	1.571
No. of grain/ spike	*bi*	0.450	0.473	0.728	-0.747	0.823	0.496
	Phenotypic index	46.978	38.601	37.323	38.385	38.825	40.389
	s_d^2	2.206	9.205	6.148	16.596	7.216	4.689
1000 grain wt.	*bi*	0.496	0.309	1.059	0.897	0.558	0.558
	Phenotypic index	8.775	13.875	14.300	13.338	12.925	11.088
	s_d^2	0.271	0.654	0.026	0.099	0.404	0.073
Total dry matter (g)	*bi*	0.805	0.937	0.369	0.704	0.522	0.242
	Phenotypic index	8.883	9.986	11.296	10.153	13.155	16.328
	s_d^2	5.695	6.517	8.688	8.605	4.177	4.662
Harvest index	*bi*	0.244	0.497	0.257	0.314	.467	.430
	Phenotypic index	26.254	34.660	36.876	43.075	24.585	19.165
	s_d^2	50.252	16.833	45.580	18.352	33.052	41.349
Grain yield/ plant	*bi*	0.640	0.900	0.908	0.474	0.722	0.915
	Phenotypic index	2.326	3.153	3.774	4.030	2.905	2.515
	s_d^2	0.933	0.008	0.380	0.679	0.183	0.062

index, lower *bi* value with low deviations from regression revealed that these were least responsive to changes in environments. Therefore, these genotypes could be described as suitable for low yielding environments (marginal cultural environment) only. These results are in accordance with those of Shindin and Lokteva (2000), while the genotype IBON/97 for TN, BB-2 for FTN, KARAN-163 for EXL and BSH-2 for GYP with lower phenotypic index ($P<\overline{X}$), regression co-efficient below unity ($bi<1.00$) and non significant s_d^2 indicated that these genotypes for these characters were poorly adaptable to low-yielding (unfavorable) environment but they would not be accepted due to their low mean performance.

Genotype BSH-2 for FTN, KARAN-163 for GYP with low mean performance (2.698 and 2.515, respectively), regression co-efficient close to 1.00 (0.893 and 0.915, respectively) and non-significant deviation indicated that these two characters of these two genotypes were poorly adaptable to all environments.

However, the genotypes for TN and BB-1 for FTN with low mean performance ($P>\bar{X}$), high regression co-efficient and non-significant deviation did not satisfy the requirements of a stable character and indicated that they were poorly adaptable in favorable environments only. Therefore, they were described as unstable characters of these genotypes and also they were not suitable for any changes of environments, so they would not be accepted due to their ill performance.

It has evident that stability (both positive and negative) is heritable and controlled by additive gene action (Eberhart and Russell, 1966; 1969). Based on the overall study it can be inferred that the genotype BSH-2 could be used in hybridization program that may be expected to transmit high mean and increase phenotypic stability in their subsequent progenies.

REFERENCES

Alam, J. 2005. Enhancing Sustainable Development of Diverse Agriculture in Bangladesh. Centre for Alleviation of Poverty through Secondary Crops' Development in Asia and the Pacific (UNESCAP-CAPSA), Bogor, Indonesia.

Annicchiarico, P. 2002. Genotype × Environment Interactions - Challenges and Opportunities for Plant Breeding and Cultivar Recommendations. FAO Plant Production and Protection Paper-174. Food and Agriculture Organization of the United Nations, Rome, Italy.

Arisnabarreta, S. and D. J. Miralles. 2006. Yield responsiveness in two- and six-rowed barley grown in contrasting nitrogen environments. J. Agronomy & Crop Sci. 192 : 178-185.

Becker, H. C. and J. Léon. 1988. Stability analysis in plant breeding. Plant Breed. 101: 1-23.

Cannon, W. B. 1932. The wisdom of the body. Norton, New York.

Costa, J. M. and G. A. Bollero. 2001. Stability analysis of grain yield in barley (*Hordeum vulgare*) in the US mid-Atlantic Region. Ann. Appl. Biol. 139 : 137-143.

Dudley, J. W. and R. H. Moll. 1969. Interpretation and use of estimates of heritability and genetic variances in plant breeding. Crop Sci. 9 : 257-262.

Eberhart, S. A. and W. A. Russell. 1966. Stability parameters of comparing varieties. Crop. Sci. 6 : 275-277.

Eberhart, S. A. and W. A. Russell. 1969. Yield and stability for a 10 line diallel of single-cross and double-cross maize hybrids. Crop Sci. 9 : 357-361.

Finlay, K. W. and G. N. Wilkinson. 1963. The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14 : 742-754.

Fisher, R. A., F. R. Immer, and O. Tendin. 1932. The genetical interpretation of statistics of the third degree in the study of quantitative inheritance. Genetics. 17 : 107-124.

Kim, H-S., K-W Park, S-B Beak, J-G Kim, and J-H Num. 2005. Genetic diversity measured by RAPDs in Korean barley germplasm pools. Korean J. Crop Sci. 50 : 131-141.

Lee, E. A., T. K. Doerksen, and L. W. Kannenberg. 2003. Genetic Components of Yield Stability in Maize Breeding Populations. Crop Sci. 43 : 2018-2027.

Lin, C. S., M. R. Binns, and L. P. Lefkovitch. 1986. Stability analysis: where do we stand? Crop Sci., 26 : 894-900.

McIntosh M. S. 1983. Analysis of combined experiments. Agronomy Journal. 75 : 153-155.

Perkins, J. M. and J. L. Jinks. 1968. Environmental and genotype × environmental components of variability III. Multiple inbred lines and crosses. Heredity. 23 : 339-356.

Peterson, C. J., J. M. Moffat, and J. R. Erickson. 1997. Yield stability of hybrid vs pureline hard winter wheats in regional trials. Crop Science 37 : 116-120.

Shindin, I. M. and O. V. Lokteva. 2000. Evaluation of spring wheat varieties at primorskey for ecological plasticity. Ann. Wheat. Newslet. 46 : 105-106.

Simmonds, N. W. 1991. Selection for local adaptation in a plant breeding programme. Theor. Appl. Genet. 82 : 363-367.

Smithson, J. B. and W. Grisley. 1992. First African bean yield and adaptation nursery: Part II. Performance across environments. Network on Bean Research in Africa. Occational Publication Series No. 3B. CIAT, Der es Salaam, Tanzania.

Tiidema, A. and E. Truve. 2004. Efficient regeneration of fertile barley plants from callus cultures of several Nordic cultivars. Hereditas. 140 : 171-176.

Worku, M., H. Zelleke, G. Taye, B. Tolessa, L. Wolde, W. Abera, A. Guta, and H. Tuna. 2001. Yield stability of maize (*Zea mays* L.) genotypes across locations. Seventh Eastern and Southern Regional Maize Conference. 11th-15th February, 2001. pp. 139-142.

Yau, S. K. and J. Hamblin. 1994. Relative yield as a measure of entry performance in variable environments. Crop Sci. 34 : 813-817.