Evaluation of wheat yield and drought resistance indices across water regimes

Ahmadi A[1], Mohammadi V[1], Siosemardeh A[2], Poustini K[1]

[1]Department of Agronomy and Plant Breeding, College of Agriculture, The University of Tehran, Karaj, 3158777871, Iran. [2] College of Agriculture, Kurdistan University, Sanandaj, Iran.

Corresponding author Email: ahmadia@ut.ac.ir

ABSTRACT

The objectives of this study were to evaluate: 1) The relationship among yield and yield components, and 2) the effectiveness of several drought resistance indices under various water regimes. Grain yield under irrigated conditions was adversely correlated with yield under non-irrigated conditions. The grain yield of wheat was associated with the larger number of grains per unit area under both conditions. The results suggested that the larger number of grains/spike under irrigated condition and the higher grain weight and larger number of spikes per unit area under non-irrigated condition should be selected to increase grain yield. Among the indices, MP, GMP and STI were more effective in identifying high yielding cultivars in both drought-stressed and irrigated conditions (group A cultivars). Under severe stress, none of the indices used were able to identify group A cultivars, although regression coefficient (b) and SSI were found to be more useful in discriminating resistant cultivars. It is concluded that the effectiveness of selection indices in differentiating resistant cultivars varies with the stress severity.

INTRODUCTION

Grain yield in wheat can be analyzed in terms of three yield components, number of spikes per unit area, number of kernels per spike and kernel weight. Ehadaie et al. (1988) found that the number of spikes per plant was affected least by drought stress and the number of grains per spike was affected most. Under different drought treatments, Guinta et al. (1993) and Zhong-hu and Rajaram (1994) suggested that kernels per spike and spikes per square meter were the yield components most sensitive to drought while kernel weight remains relatively stable. Several studies have indicated that variation in grain yield between moisture regimes was predominantly associated with variation in spikes per square meter and kernels per spike (Simanae et al., 1993; Garcia del Moral et al., 1991, 2003).

The relative yield performance of genotypes in drought stressed and more favorable environments seems to be a common starting point in the selection of genotypes for use in breeding for dry environments (Clarke et al., 1992). Some researchers believe in selection under favorable condition (e.g. Bertan et al., 2003). Selection in the target stress condition has been highly recommended too (e.g. Rathjen, 1994). Some researchers have chosen a mid-way and believe in selection under both favorable and stress conditions (Byrne et al., 1995; Rajaram and van Ginkel, 2001). To differentiate drought resistance genotypes several selection indices (TOL,MP, SSI,GMP, STI, YSI, YI, p value and b) have been employed under various conditions. The present study was conducted to evaluate the relationship among yield and yield components, and to test the effectiveness of drought resistance indices in eleven wheat cultivars under various stress conditions over three years.

MATERIALS AND METHODS

Six field trials were conducted during 2001, 2002 and 2003 at two dry land research stations, Gerizeh and Ghamloo, in Kurdistan Province (northwest of Iran). Gerizeh (1373m above sea level, 35º16´ N, 47º1´ E) has 440 mm annual rainfall. Ghamloo (1850m above sea level, 35º23´ N, 47º14´ E) has an annual rainfall of 350mm. Both experimental sites have Mediterranean climate with cold winter (specially in Gamloo) and hot dry summers.

Eleven bread wheat cultivars were chosen for study based on their reputed differences in yield performance under irrigated and non-irrigated conditions. A complete randomized block design with four replications was used in the Ghamloo trials. The experimental design for Gerizeh trials was a split plot arrangement of treatments within a randomized complete block with four replications. Water regimes, irrigated and non irrigated (rainfed), were allocated to the main plots and wheat cultivars to the subplots. The irrigated plots were watered at planting, tillering, jointing, flowering and grain filling stages. Non-irrigated plots in both experimental sites received no water other than rainfall. Each plot consisted of six rows with six meter in length, spaced 20 cm apart with seed density of 300 seed/m^2.

Grain yield and its components and harvest index were measured by harvesting 4.2 m^2 of the central part of each plot at crop maturity. Ten plants were also randomly chosen from each plot to measure the number of grains/spike, and the number of grains/spikelet.

Nine selection indices including stress susceptibility index (SSI, Fischer and Maurer,1978), stress tolerance index (STI, Fernandez,1992), tolerance (TOL, Hossain et al., 1990), regression coefficient of cultivar yield on environmental index (b, Bansal and Sinha, 1991), yield index (YI, Gavuzzi *et al.*.,1997), yield stability index (YSI, Bouslama and Schapaugh, 1984), mean productivity (MP, Hossain et al., 1990), geometric mean productivity (GMP, Fernandez,1992) and superiority measure (P, Clarke, et al., 1992; Lin et al., 1986) were calculated based on grain yield under drought-stressed and irrigated conditions.

RESULTS AND DISCUSSION

Grain yield under irrigated condition was adversely correlated with non-irrigated condition suggesting that a high potential yield under optimum condition does not necessarily result in improved yield under stress condition. Under irrigated conditions the number of grains/m^2 was highly correlated with grain yield while grain weight was adversely correlated with grain yield. The results demonstrated that genotypes with larger spikes should be selected under irrigated condition to increase grain yield. Guohua et al. (2000) and Okuyama (2004) suggested the same strategy for increasing grain yield. Under water stress condition, 1000 grain weight, grains/m^2 and the number of spikes/m^2 were directly correlated with grain yield. It was concluded that the increased yield under stress conditions can possibly be achieved by selection firstly for heavier grains and secondly for larger number of spikes/m^2.

The greater the TOL value, the larger the yield reduction under stress conditions and the higher the drought sensitivity. MP was not correlated with yield under stress (Table 1). SSI showed a negative correlation with yield under stress (Table 1). No significant correlation was found between yield under stress and SSI in moderate stress conditions (Table 2), There was no significant correlation between either STI or GMP and yield under stress. However under less severe stress conditions GMP and STI were significantly correlated with both stress and non-stress yields (Table 2). Cultivars with the lowest yield under irrigated conditions exhibited the highest P value (Table 1). On the other hand, there was no association between P and yield under stress. YI was significantly correlated with stress yield. This index ranks cultivars only on the basis of their yield under stress. Cultivars with the highest YSI exhibited the least yield under non-stress conditions and the highest yield under stress conditions.

The findings of this study showed that the breeders should choose the indices on the basis of stress severity in the target environment; The linear regression coefficient (b) and SSI are suggested as useful indicators for wheat breeding, where the stress is severe (northwest of Iran in the present study) while MP, GMP and STI are suggested if the stress is less severe.

Table 1. Simple correlation coefficients between resistance indices and grain yield, grain weight, grains/spike, and harvest index(HI) of 11 wheat cultivars (averaged over years and locations) in irrigated (IR) and non-irrigated (NIR) conditions.

	b	YSI	YI	P	STI	GMP	SSI	MP	TOL
IR-yield	0.96**	-0.91**	-0.61*	-0.85**	0.61*	0.45	0.91**	0.94**	0.97**
NIR-yield	-0.80**	0.87**	0.99**	0.25	0.27	0.41	-0.85**	-0.32	-0.78**
HI(IR)	0.92**	-0.91**	-0.72*	-0.63*	0.36	0.23	0.91**	0.79**	0.93**
HI(NIR)	-0.51	0.59	0.59	0.41	0.11	0.16	-0.61**	-0.26	-0.51
1000-grain eight(IR)	-0.67*	0.69*	0.54	0.38	-0.35	-0.18	-0.68*	-0.56	-0.67*
1000-grain weight(NIR)	-0.81**	0.81**	0.65*	0.57	-0.40	-0.22	-0.79*	-0.68*	-0.80**
Grain/spike (IR)	0.70*	-0.62*	-0.34	-0.83**	0.59	0.54	0.61*	0.80**	0.71*
Grain/spike (NIR)	0.39	-0.48	-0.37	-0.18	0.15	0.04	0.49	0.29	0.42

*p < 0.05.
**p < 0.01.

Table 2 Simple correlations coefficients of stress indices with grain yield of 11 wheat cultivars at Gerizeh and Ghamloo stations in 2001 through 2003.

		YSI	YI	STI	GMP	SSI	MP	TOL
	Grizeh-IR	-0.74**	-0.39	0.29	0.30	0.74**	0.92**	0.94**
2001	Grizeh-NIR	0.90**	1.0**	0.76**	0.75**	-0.90**	0.01	-0.65*
	Ghamloo-NIR	0.91**	1.0**	0.79**	0.78**	-0.91**	0.01	-0.65*
	Grizeh-IR	-0.80**	0.27	0.87**	0.88**	0.80**	0.95**	0.93**
2002	Grizeh-NIR	0.33	1.00**	0.70*	0.69*	-0.33	0.61*	-0.10
	Ghamloo-NIR	0.91**	1.0**	0.70*	0.71*	-0.91**	-0.1	-0.79**
	Grizeh-IR	-0.67*	-0.18	0.44	0.44	0.67*	0.79**	0.86**
2003	Grizeh-NIR	0.85**	1.00**	0.80**	0.80**	-0.85**	0.45	-0.66**
	Ghamloo-NIR	0.89**	1.0**	0.81**	0.83**	-0.89**	0.41	-0.76**

*p<0.05
**p<0.01

REFERENCES

Bansal, K.C., Sinha, S.K., 1991. Assessment of drought resistance in 20 accessions of *Triticum aestivum* and related species. I. Total dry matter and grain yield stability. Euphytica. 56, 7-14.

Betran, F.J., Beck, D., Banziger, M., Edmeades, G.O. 2003. Genetic analysis of inbred and hybrid grain yield under stress and nonstress environments in tropical maize. Crop Sci. 43, 807-817.

Bouslama, M., Schapaugh, W.T., 1984. Stress tolerance in soybean. 1- Evaluation of three screening techniques for heat and drought tolerance. Crop Sci. 24, 933-937.

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

Byrne, P.F., Bolanos J., Edmeades, G.O., Eaton, D.L., 1995. Gains from selection under drought versus multilocation testing in related tropical maize populations. Crop Sci. 35, 63–69.

Clarke, J.M., De Pauw, R.M., Townley-Smith, T.M., 1992. Evaluation of methods for quantification of drought tolerance in wheat. Crop Sci. 32, 732-728.

Ehdaie, B., Waines, J.W., Hall, A.E., 1988. Differential response of landrace and improved spring wheat genotypes to stress environments. Crop Sci. 28, 838-842.

Fernandez, G.C.J., 1992. Effective selection criteria for assessing stress tolerance. In: C. G. Kuo (Ed.). Proceedings of the international Symposium on ″adaptation of vegetables and other food crops in temperature and water stress″. Publication, Tainan, Taiwan.

Fischer, R.A., Maurer, R., 1978. Drought resistance in spring wheat cultivars. 1. Grain yield response. Aust. J. of Agric. Res. 29, 897-912.

Gavuzzi. P., Rizza, F., Palumbo, M., Campaline, R.G, Ricciardi G.L., Borghi, B., 1997. Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Can. J. Plant Sci. 77, 523-531.

Guinata, F.R., Motzo, R., Deidda, M. 1993. Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranian environment. Field Crop Res 33, 399-409.

Guohua. M., Tang, L., Zhang, F., Zhang, J., 2000. Is nitrogen uptake after anthesis in wheat regulated by sink size. Field Crops Research. 68: 183-190.

Hossain, A.B.S., Sears, A.G., Cox, T.S., Paulsen, G.M., 1990. Desiccation tolerance and its relationship to assimilate partitioning in winter wheat. Crop Sci. 30, 622-627.

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

Okuyama, L.A., Federizzi, L.C., Neto, J.F.B., 2004. Correlation and path analysis of yield and its components and plant traits in wheat. Ciecia Rural 34, 1701-1708.

Rajaram, S., Van Ginkle, M., 2001. Mexico, 50 years of international wheat breeding. In The world Wheat Book; A History of Wheat Breeding, A.P., Bonjean and W.J. Angus (Eds.). Paris, France. Lavoisier Publishing, pp. 579-604.

Rathjen, A.J., 1994. The biological basis of genotype × environment interaction: Its definition and management. In: *Proceedings of the Seventh Assembly of the Wheat Breeding Society of Australia*. Adelaide. Australia.

Simane B., 1993. Ontogenetic analysis of yield components and yield stability of durum wheat in water limited environments. Euphytica 71, 211-219.

Zhong-hu, H., Rajaram, S., 1994. Differential responses of bread wheat characters to high temperature. Euphytica 72, 197-203.