Relations among Yield Potential, Drought Tolerance and Stability of Yield in Bread Wheat Varieties under Water Deficit Conditions

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Abstract

Twenty four advanced bread wheat varieties were studied in field experiments under water deficits and non deficit conditions both before and after anthesis at Ardabil Agricultural Research Station (A.R.S) of IRAN during 1997-1998. The purpose was to understand the basis of cultivar differences in yield under drought and to identify genotypes with high yield potential and high stress tolerance.

Stress tolerance attributes for the bread wheat varieties estimated from Ys and Yp under water deficit conditions. The three-D plots display among STI, Yp and Ys for classifying the varieties in four groups, group “A” to group “D” were used and two more suitable and stable varieties with high yield potential and high stress tolerance were selected.

Key Words

Wheat, brad, drought, water deficit

Introduction

Interest in crop response to environmental stresses has increased greatly in recent years because severe losses may result from heat, cold, drought and high concentrations of toxic mineral elements (Lewis and Christiansen, 1981; Blum, 1985). Most winter wheat is grown under varied rainfed and water stress conditions in the semiarid cold climate of Iran, year-to-year fluctuations in the amount (annual precipitation ranges between 280-350mm). Frequency and duration of rain are high, and other factors such as low temperature in winter (absolute min. temp. is -32?C) high temperature during the terminal grain filling period (+37?C) and after anthesis water deficit conditions in irrigated wheat, also influence crop growth and yield. The ability of crop cultivars to perform reasonably well in variable rainfall and water stressed environments is an important trait for stability of production under drought stress conditions. Several selection criteria have been proposed for selecting genotypes based on their performance in stress and non-stress environments (2, 4). Rosielle and Hamblin (4) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress environments (Yp) and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurere (2) proposed a stress susceptibility index (SSI), expressed by following relationships SSI=[1-(Ys)/(Yp)]/SI. SI is the stress intensity and is estimated as [1-(Ys)/(Yp)] where Ys and Yp are the mean yield over all genotypes evaluated under stress and non-stress conditions. Fernandez (1) defined a new advanced stress tolerance index, STI= [(Yp) . (Ys)/(Yp)2], which can be used to identify genotypes that produce high yield under both stress and non-stress environments. Detailed measurements of plant water status, plant height, harvest index, yield components, diseases status, anthesis data, cell membrane stability and grain yield made. This paper concentrates upon the grain yield results in stress and non-stress conditions and compares the stress tolerance attributes (TOL, MP, GMP, SSI and STI). The interrelationships between STI and other stress tolerance attributes and the differential yield responses of genotypes under three contrasting environments are illustrated by the multivariate exploratory data analysis, biplot display.

Materials and methods

Three yield trials of 24 different advanced bread wheat (*Triticum aestivum* L.) varieties conducted at field experiments of Ardabil Agricultural Research Station (A.R.S.) (latitude 38?15', longitude 48?20', altitude 1350m) of IRAN during 1997-1998 were used in this study. Drought was created in this rain free environment (total precipitation was 313mm during growing season) by permanently terminating irrigation at various stages before anthesis with stress intensity, SI=[1-(Ys)/(Yp)]=0.331 and after anthesis with SI=0.257. Control treatments (Yp) were well watered throughout the growing period. The total amount of used water in control water deficit after anthesis and before anthesis experiments were 389.5, 274.0 and 255mm respectively. A randomised complete block design with four replications were used for each experiment. The average yield of bread wheat varieties evaluated under non-stress and water deficits before anthesis and after anthesis stresses are presented in table 2 and 3. The data were analysed and stress tolerant estimates were computed using pc-sas (5). The biplot display of principal component analysis (3) was used to identify stress tolerant and high yielding genotypes and to study the interrelationship between the stress tolerance attributes.

Results and discussion

Studied varieties produced significantly less grain yield under water deficit before anthesis than other water management cycles (table 1). The mean grain yield of 24 bread wheat varieties were 6.812, 5.052 and 4.472 t/ha for well watered (Yp), water deficit after anthesis (Ys1) and before anthesis (Ys2) respectively (table 1). The reason for this was the greatly reduced yield per plant from tillers (the spikes/m2 and seeds/spike in control, water deficits after anthesis and before anthesis were 539, 496, 403 and 32, 30, 23 respectively)(table 4). It shows that water deficit before anthesis more reduced grain yield than others. The stress tolerance attributes for the bread wheat varieties estimated from Ys and Yp under water stressed (SI=0.257 and SI=0.331) and non-stressed environments are given in tables 2 and 3, respectively. It shows that TOL favoured varieties with low yield potential such as varieties no 9, 12 and 21 in SI=0.257 (table 2) and varieties no 6 and Sabalan in SI=0.331 (table 3). The correlation coefficients between Yp and Ys under SI=0.257 and SI=0.331 were r = 0.569** and r = 191ns respectively. Thus, the linear regression between “Ys” and “Yp” decreases with increase in SI. The mean GMP was smaller than mean MP in both stress conditions. The correlations between Ys and (MP, GMP, TOL, SSI and STI) in SI=0.257 and SI=0.331 are (r=0.902**, r=0.931**, r=0.537**, r=-0.753**, r=0.932**) and (r=0.765**, r=0.878**, r=-0.695**, r=-0.829**, r=0.867**) respectively. Also the correlations between Yp and (TOL, MP, GMP, SSI and STI) in SI=0.257 and SI=0.331 are (0.348ns, 0.868**, 0.831**, 0.103ns, 0.824**) and (0.570**, 0.736**, 0.620**, 0.377ns, 0.648**) respectively and illustrated by scatterplots. The scatterplots indicated that MP, GMP and STI were better predictors of mean Yp and mean Ys than TOL and SSI under both stress conditions (SI=0.257 and SI=0.331). Overall, STI was a better predictor of mean Ys and Yp under both stress conditions than others. These results corroborate the findings of Fernandez (1). The observed correlation coefficients between YYpMP, YYpTOL, YYsMP, YYsTOL were in close agreement with the theoretical correlation coefficients reported by Rosielle and Hamblin (4).

Three-D-plots among (Ys, Yp and STI) are presented to show the interrelationships among these three variable to separate the group A genotypes from the other groups (groups B, C, D), and to illustrate the advantage of STI as a selection criterion for identifying high-yielding and stress tolerant genotypes. In 3-Dplot the X-Y plane is divided in to four groups and marked as group A to group D. In after anthesis stress (SI=0.257) most of the group A showed high STI (MV17, F13011.1321.Rom/Fdi, 1D13/Mlt.S.Mw 12174.Mex/Tur, Ymh/Tob//Mcd/3/Lira, Mnch//Bez/Grk/Ch89067-Ose...
Jup/4/C11F/3/111.53/Odino//Ci18431/ Waos477, Sbn//Sunnina/Ald“s” and Vratza/Wisc245. Two other genotypes (Au/3/Minn//111k/38Ma/4/Xmh /Era/5/Dhf and Hhkng.SxI-7004/Bow//Ks974681/Sxl/Cit, also expressed moderate STI values (0.773-0.787). However, varieties no 12 and Gaspard were more suitable for stress condition (Group C) and varieties no 14, 15, 17, 22 and 23 were more suitable for non-stress environments (Group B). In water deficit before anthesis stress most of the group A genotypes (MV17, 3, 4, 8, 10, 13, 15, 16, 18 and 23) also had high STI values. However, Group C genotypes (Alamoot and Gaspard) also showed high STI values. Although, MV17 and Vratza/Wisc245 with high yield potential and high stress tolerance were more suitable and stable varieties in both water deficit conditions. Conversely, selection based on SSI (Stress Susceptibility Index) favoured varieties no 9 and 21 in SI=0.257, Sabalan, 21 and Alamoot in SI=0.331 belong group C and D. Furthermore, SSI failed to identify the high yielding and stress tolerant genotypes, such as mentioned varieties above. Although, STI was favouring genotypes with high yielding potential and stress tolerance under both water deficits and non-stress conditions. These findings are accordance with Fernandez (1). Thus the 3-Dplot (Ys-Yp-STI) separated the group A genotypes from other genotypes more effectively and useful in studying the relationship

between the STI and Ys and Yp. In 3-Dplot, only the relationships between any three variables can be studied at once. To investigate the relationships between more than three variables, a multivariate display such as a biplot can be used.

References

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Table 1. The grain yield of bread wheat varieties in well watered (Yp), water deficit after anthesis (Ys1), water deficit before anthesis (Ys2) and date of heading(from January to 50% heading)

Entry	Pedigree	Yp (t/ha)	Ys1 (t/ha)	Ys2 (t/ha)	DHE (day)
1	MV17 (originated from International exp.)	7.151	5.784	5.108	142
2	Alamoot	6.576	4.425	5.065	144
3	F13011.1321.Rom/Fdi	7.334	5.401	4.631	137
4	1D13/M1t.S.Wm12174.Mex/Tur...	7.303	5.667	4.972	141
5	Au/3/Minn//11K/38Ma/4/Xmh/Era/5/Dhf	6.854	5.215	4.007	139
6	Horis	5.765	3.682	5.499	145
7	Gk-Zuyloy	6.108	4.949	4.552	144
8	Ymh/Tob//Mcd/3/Lira	7.407	5.777	4.837	144
9	Ayt94-Tjb788-1089/Aldem/3/Resk//Eno/G11wre86099	5.702	5.190	4.055	142
10	Hkng.Sxl-7044/Bow//Ksa74681/Sxl/Cit	7.021	5.179	4.072	144
11	Mnch//Bez/Grk/Cit89067-Ose...	7.366	5.053	4.499	144

12	Ba/6529.13	6.614	5.763	4.789	143
13	Jup/4/C11f/3/111.53/Odino//Ci18431/Waos477	7.369	5.373	4.960	144
14	Jup/4/C11f/3/Odino.Ci18431/Wa...	6.933	4.868	4.450	144
15	Ow184524-3H-O-Hoh-No/P101//Bb...	7.357	4.463	4.473	144
16	Sbn//Sannina/Ald“S”	6.970	5.538	4.104	139
17	Stepinak/Karvana	7.069	5.752	4.315	139
18	Vratza/Wisc245	7.714	6.159	4.585	141
19	Agri/Nac(Es91-18)Swm6599	5.787	4.186	2.727	149
20	Agri/Nac-Swm65-99-20H-1H-3P-Op-8M-1Mw-Owm	6.740	4.445	2.643	146
21	Gaspard(Originated from French)	6.649	5.743	5.249	146
22	Spn/Mcd//Cama/3/Nzr(Originated from Oregon)	7.254	4.558	4.118	146
23	1-66-76(Sister line of Alamoot)	6.999	4.270	4.994	144
24	Sabalan(Wide adapted for rainfed area)	5.443	3.818	4.617	142
Mean	-	6.312	5.052	4.472	143

Table 2. Estimation of stress tolerance attributes from the potential yield and the stress yield data for bread wheat genotypes evaluated under after anthesis stress SI=0.257 in Ardabil region 1997-98

Genotype	Yp (t/ha)	Ys (t/ha)	TOL	MP	GMP	SSI	STI
1	7.151	5.784	1.367	6.467	6.431	0.744	0.895
2	6.576	4.425	2.151	5.500	5.394	1.273	0.629
3	7.334	5.401	1.933	6.637	6.294	1.025	0.857

4	7.303	5.667	1.666	6.485	6.433	0.874	0.895
5	6.854	5.215	1.639	6.034	5.978	0.930	0.773
6	5.765	3.682	2.083	4.723	4.607	1.406	0.459
7	6.108	4.949	1.159	5.528	5.498	0.738	0.654
8	7.407	5.777	1.630	6.592	6.541	0.856	0.926
9	5.702	5.190	0.512	5.446	5.440	0.349	0.640
10	7.021	5.179	1.842	6.100	6.030	1.021	0.787
11	7.366	5.053	2.313	6.209	6.101	1.222	0.824
12	6.614	5.763	0.851	6.188	6.174	0.501	0.824
13	7.369	5.373	1.996	6.371	6.292	1.054	0.856
14	6.933	4.868	2.965	5.900	5.809	1.159	0.730
15	7.353	4.463	2.890	5.908	5.728	1.529	0.710
16	6.970	5.538	1.432	6.254	6.213	0.660	0.835
17	7.069	5.752	1.317	6.410	6.376	0.725	0.880
18	7.417	6.159	1.258	6.788	6.754	0.660	0.988
19	5.787	4.186	1.601	4.988	4.922	1.067	0.524
20	6.740	4.445	2.295	5.592	5.473	1.325	0.648
21	6.646	5.743	0.903	6.194	6.178	0.529	0.826
22	7.254	4.558	2.696	5.906	5.750	1.446	0.715

23	6.999	4.270	2.729	5.584	5.467	1.517	0.649
24	5.443	3.818	1.625	4.630	4.556	1.162	0.449
Mean	6.812	5.052	1.745	5.920	5.850	0.990	0.749
S	0.608	0.684	0.652	0.574	0.589	0.332	0.140

Yp=Potential Yield, Ys=Yield under Stress, MP= Mean Productivity, GMP= Geometric Mean Productivity, TOL= Tolerance, SSI= Stress Susceptibility Index, STI= Stress Tolerance Index.

Table 3. Estimation of stress tolerance attributes from the potential yield and the stress yield data for bread wheat genotypes evaluated under before anthesis stress SI=0.331 in Ardabil region 1997-98

Genotype	Yp (t/ha)	Ys (t/ha)	TOL	MP	GMP	SSI	STI
1	7.151	5.108	2.043	6.129	6.044	0.863	0.790
2	6.576	5.065	1.511	5.820	5.771	0.694	0.720
3	7.334	4.631	2.703	5.982	5.827	1.113	0.735
4	7.303	4.972	2.361	6.137	6.026	0.964	0.785
5	6.854	4.007	2.847	5.430	5.241	1.255	0.594
6	5.765	5.499	0.266	5.632	5.630	0.139	0.686
7	6.108	4.552	1.556	5.330	5.273	0.770	0.601
8	7.407	4.837	2.570	6.122	5.986	1.048	0.775
9	5.702	4.055	1.647	4.878	4.808	0.873	0.500
10	7.021	4.702	2.319	5.861	5.746	0.998	0.714
11	7.366	4.499	2.867	5.932	5.575	1.176	0.717
12	6.614	4.789	1.825	5.701	5.628	0.834	0.685

13	7.369	4.960	2.409	6.164	6.046	0.988	0.791
14	6.933	4.450	2.483	5.691	5.554	1.082	0.667
15	7.353	4.473	2.616	6.045	5.902	1.750	0.735
16	6.970	5.104	1.866	6.037	5.964	0.809	0.769
17	7.069	4.315	2.758	5.692	5.523	1.177	0.660
18	7.417	4.585	2.832	6.001	5.831	1.153	0.736
19	5.787	2.727	3.060	4.257	3.972	1.597	0.341
20	6.740	2.643	4.097	4.691	4.221	1.836	0.385
21	6.646	5.249	1.397	5.947	5.906	0.636	0.755
22	7.254	4.118	3.136	5.686	5.465	1.306	0.646
23	6.999	4.994	2.005	5.446	5.912	0.865	0.756
24	5.443	4.617	0.826	5.030	5.013	0.458	0.544
Mean	6.812	4.472	2.250	5.639	5.515	1.017	0.670
S	0.608	0.687	0.856	0.558	0.511	0.379	0.122

Yp=Potential Yield, Ys=Yield under Stress, MP= Mean Productivity, GMP= Geometric Mean Productivity, TOL= Tolerance, SSI= Stress Susceptibility Index, STI= Stress Tolerance Index.

Table 4. The mean comparisons of Spikes/m2 and Seeds/spike of bread wheat in well watered (Yp), water deficits after anthesis (Ys1) and before anthesis (Ys2) by Duncan's at alpha 5% in Ardabil region 97-98.

	Spikes/m2			Seeds/spike		
Genotypes	**Yp**	**Ys1**	**Ys2**	**Yp**	**Ys1**	**Ys2**
1	412.5 c	415.8 bc	302.5 bc	44.11 a	35.37 abcd	34.13 a
2	620.8 abc	400.0 bc	385.0 abc	36.77 abc	37.65 ab	25.18 cd

3	591.7 abc	606.7 ab	379.2 abc	35.53 bc	38.64 abcde	35.28 a
4	460.0 bc	538.7 ab	410.8 ab	32.67 bcd	32.62 abcde	24.18 cd
5	502.5 abc	436.7 bc	460.0 a	39.00 ab	33.94 abcde	21.20 cde
6	509.2 abc	512.5 b	425.0 ab	29.08 cde	29.75 bcdef	22.15 cde
7	553.3 abc	477.5 bc	376.7 abc	31.28 bcde	33.55 abcde	32.34 ab
8	677.5 a	516.7 b	425.0 ab	31.34 bcde	32.42 abcde	21.10 cde
9	520.8 abc	452.5 bc	360.0 abc	29.18 cde	26.99 def	22.10 cde
10	546.7 abc	730.8 a	431.7 ab	35.28 bc	32.68 abcde	24.12 cd
11	519.2 abc	450.8 bc	412.5 ab	35.24 bc	29.39 bcdef	21.23 cde
12	464.7 bc	510.8 b	274.2 c	28.81 cde	28.23 cdef	23.98 cd
13	570.0 abc	445.0 bc	407.5 abc	30.58 bcde	29.64 bcdef	25.07 cd
14	664.2 ab	513.3 b	395.8 abc	29.95 bcde	25.84 ef	20.10 cde
15	611.7 abc	508.3 b	381.7 abc	30.74 bcde	27.16 def	22.97 cde
16	548.0 abc	551.7 ab	472.5 a	31.28 bcde	30.69 abcdef	18.95 def
17	553.0 abc	520.0 b	396.7 abc	30.53 bcde	26.51 def	22.26 cde
18	553.3 abc	280.8 c	376.7 abc	32.01 bcde	30.74 abcdef	23.47 cd
19	536.7 abc	565.8 ab	423.3 ab	23.05 e	26.81 def	12.89 f
20	617.5 abc	596.7 ab	480.0 a	30.96 bcde	25.99 ef	12.83 f
21	459.2 bc	503.3 b	408.3 abc	31.00 bcde	31.61 abcdef	26.51 bc

22	510.8 abc	460.8 bc	410.0 ab	34.70 bc	26.20 ef	23.22 cd
23	446.7 c	408.3 bc	424.2 ab	37.19 abc	36.65 abc	27.02 bc
24	504.2 abc	505.8 b	452.5 a	24.39 de	23.52 f	16.15 ef
Mean	539.1 a	496.2 a	403.1 b	32.28 a	30.52 a	23.27 b
LSD 5%	169.7	174.7	112.5	7.725	7.306	5.943