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Original article

Evaluation of bread wheat genotypes under drought stress conditions in seedling stage using drought indices

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Extended abstract

Introduction

The existence of drought stress at the beginning of the growing season is one of the most important threatening factors in wheat production of Iran. The coleoptile length is the most important morphological trait in determining sowing depth, emergence power and seedling establishment. The coleoptile length has been used as an effective indicator for selecting the drought tolerant genotypes in wheat breeding programs. Various indices have been developed to evaluate crop response to various stresses, including tolerance index (TOL), productivity mean (MP), geometric mean productivity (GMP), harmonic mean (HM), stress tolerance index (STI), stress sensitivity index (SSI), yield index (YI), yield stability index (YSI) and relative stress index (RSI). The efficiency of each indices depends on the breeding objectives and the target environment.

Materials and methods

In order to evaluate some of the landrace wheat genotypes under drought stress conditions at the seedling stage, an experiment with 35 pure lines under three moisture conditions (control, drought stress with PEG6000 10% and 15%) was conducted in a completely randomized design (CRD) with three replications at Gorgan university of agricultural sciences and natural resources. The coleoptile length was measured after eight days. The indices of MP, GMP, HM, STI, SSI, YI, TOL, RSI and YSI were calculated based on the coleoptile length values under control (Yp) and stress (Ys) conditions. Data analysis was performed using iPASTIC: an online toolkit to estimate plant abiotic stress indices.

Results

In control and 10%-drought stress conditions, genotypes 11 and 2 had the highest of coleoptile length. While, in 15%-drought stress conditions, genotypes 3 and 6 had the highest of coleoptile length, respectively. Also in control and 15%-drought conditions genotypes 30 and 35 and in 10%-drought stress conditions genotypes 15 and 21 had the lowest of coleoptile length. Based on MP, GMP, HM, STI and YI indices, genotypes 2 and 11 were identified as tolerant genotypes, while genotypes 15, 21

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and 30 were susceptible genotypes, under 10% drought stress conditions. Under 15%-drought stress conditions, MP, GMP, HM, STI and YI indices identified genotypes 21 and 34 as the most susceptible genotypes, whereas genotypes 30 and 35 were the most susceptible genotypes. Under three moisture conditions, the coleoptile length had the highest coefficient of correlation (positive and significant) with MP, GMP, HM and STI indices. Using three-dimensional plots, the genotypes were divided into four groups A, B, C, and D. The most appropriate indices being the ability to distinguish group A, from other groups. Group A selects genotypes that have high yield in both control and stress conditions. The result showed genotypes 3, 6, 11, 16, 19, 20 and 24 were classified as group A in both drought stress conditions. The Iranian commercial cultivars (genotypes 30, 34 and 35) placed in Group D, which indicates insufficient attention to drought stress at the seedling stage, while tolerance to terminal drought stress is one of the most important goals in wheat breeding programs of Iran. Principal component analysis (PCA) showed that the first two PCAs explained 99.78% of the variation in 10%-drought stress and 99.80% in 15%-drought stress conditions. MP, GMP, HM and STI had the sharp angles with together that it indicates high correlation among mentioned indices. Multivariate biplos showed that drought tolerant genotypes were adjacent to vectors related to the best drought tolerance indices.

Conclusions

Correlation coefficients of drought tolerance indices showed that MP, GMP, HM and STI were the most suitable indices for selecting of drought tolerant genotypes. Based on stress tolerance indices and 3D plots, genotypes 3, 6, 11 and 24 (originated from Turkey, Afghanistan, Iran and Afghanistan, respectively) were identified as drought tolerant genotypes at the seedling stage, while genotypes 14, 15, 21, 30 and 35 were identified as the most susceptible genotypes. The landrace genotypes identified in this study could be used in breeding programs of bread wheat under drought stress at the seedling stage.

***Keywords*:** Biplot, Bread Wheat, Coleoptile, Landrace genotypes, Polyethylene Glycol

Table 1. Origin and specifications of the bread wheat genotypes

NO.	Name	Origin	NO.	Name	Origin
1	ATRI 527	India	19	HTRI 5896	Iran
2	ATRI 571	Afghanistan	20	HTRI 6640	Iran
3	ATRI 1495	Turkey	21	ATRI 9687	Mexico
4	ATRI 2441	Nepal	22	ATRI 12922	China
5	ATRI 2603	Afghanistan	23	01C0204938	Czechia
6	ATRI 2675	Afghanistan	24	ICBW 85545	Afghanistan
7	ATRI 2781	Afghanistan	25	ICBW 43075	Turkey
8	ATRI 2818	Afghanistan	26	ICBW 42741	Turkey
9	ATRI 2899	Afghanistan	27	ICBW 42689	Syria
10	ATRI 2956	Afghanistan	28	ICBW 141350	Azerbaijan
11	ATRI 5721	Iran	29	ICBW 138380	Azerbaijan
12	ATRI 5887	Iran	30	Atrak	Iran-Commercial
13	ATRI 5895	Iran	31	SARC 1	unknown
14	ATRI 6112	Iran	32	SARC 4R	unknown
15	ATRI 16073	Iraq	33	SARC 4W	unknown
16	ATRI 16076	Iraq	34	Ehsan	Iran-Commercial
17	ATRI 16079	Iraq	35	Kalateh	Iran-Commercial
18	ATRI 19231	India			

Table 2. Formula calculation of the studied indicators

Indice	Formula	Reference
TOL	$TOL= Y_P - Y_S$	Rosielle and Hamblin (1981)
MP	$MP = \frac{YP + YS}{2}$	Rosielle and Hamblin (1981)
GMP	$GMP = \sqrt{YS * YS}$	Fernandez (1992)
HM	$HM = \frac{2(YP * YS)}{(YS + YP)}$	Bidinger et al (1987)
STI	$STI = \frac{YS * YP}{(\bar{Y}P)^2}$	Fernandez (1992)
SSI	$SSI = \frac{1 - (\frac{YS}{YP})}{1 - (\frac{\bar{Y}S}{\bar{Y}P})}$	Fischer and Maurer (1978)
YI	$YI = \frac{YS}{\bar{Y}S}$	Gavuzzi et al. (1997)
Yield Stability Index (YSI)	$YSI = \frac{YS}{YP}$	Bouslama and Schapaugh (1984)
Relative Stress Index (RSI)	$RSI = \frac{(\frac{YS}{YP})}{(\frac{\bar{Y}S}{\bar{Y}P})}$	Fischer and Wood (1979)

Table 3. The values of drought tolerance indices under 10%-drought stress conditions in wheat genotypes for coleoptile length

Genotype	Yp	Ys	TOL	MP	GMP	HM	SSI	STI	YI	YSI	RSI
G1	7.22	5.52	1.70	6.37	6.31	6.26	2.12	0.93	0.95	0.76	0.86
G2	8.22	7.73	0.49	7.98	7.97	7.97	0.54	1.48	1.33	0.94	1.06
G3	7.61	6.26	1.35	6.94	6.90	6.87	1.59	1.11	1.08	0.82	0.93
G4	6.59	6.38	0.21	6.49	6.48	6.48	0.29	0.98	1.10	0.97	1.09
G5	7.95	6.76	1.19	7.36	7.33	7.31	1.35	1.25	1.16	0.85	0.96
G6	7.67	7.40	0.27	7.54	7.53	7.53	0.32	1.32	1.27	0.96	1.09
G7	7.96	5.76	2.20	6.86	6.77	6.68	2.48	1.07	0.99	0.72	0.81
G8	6.71	6.21	0.50	6.46	6.46	6.45	0.67	0.97	1.07	0.93	1.04
G9	6.75	6.12	0.63	6.44	6.43	6.42	0.84	0.96	1.05	0.91	1.02
G10	6.99	6.63	0.36	6.81	6.81	6.81	0.46	1.08	1.14	0.95	1.07
G11	9.05	8.85	0.20	8.95	8.95	8.95	0.20	1.87	1.52	0.98	1.10
G12	6.32	6.00	0.32	6.16	6.16	6.16	0.46	0.88	1.03	0.95	1.07
G13	6.90	6.00	0.90	6.45	6.43	6.42	1.17	0.97	1.03	0.87	0.98
G14	4.83	4.58	0.25	4.71	4.70	4.70	0.47	0.52	0.79	0.95	1.07
G15	4.68	3.98	0.70	4.33	4.32	4.30	1.34	0.43	0.68	0.85	0.96
G16	7.79	6.65	1.14	7.22	7.20	7.18	1.32	1.21	1.14	0.85	0.96
G17	5.45	5.00	0.45	5.23	5.22	5.22	0.74	0.64	0.86	0.92	1.03
G18	6.93	6.05	0.88	6.49	6.48	6.46	1.14	0.98	1.04	0.87	0.98
G19	7.28	6.32	0.96	6.80	6.78	6.77	1.19	1.07	1.09	0.87	0.98
G20	7.33	6.50	0.83	6.92	6.90	6.89	1.02	1.11	1.12	0.89	1.00
G21	4.86	4.14	0.72	4.50	4.49	4.47	1.33	0.47	0.71	0.85	0.96
G22	7.02	5.28	1.74	6.15	6.09	6.03	2.23	0.86	0.91	0.75	0.85
G23	4.73	4.58	0.15	4.66	4.65	4.65	0.29	0.51	0.79	0.97	1.09
G24	8.27	7.25	1.02	7.76	7.74	7.73	1.11	1.40	1.25	0.88	0.99
G25	6.90	6.85	0.05	6.88	6.87	6.87	0.07	1.10	1.18	0.99	1.12
G26	6.94	5.53	1.41	6.24	6.20	6.16	1.83	0.90	0.95	0.80	0.90
G27	7.45	6.49	0.96	6.97	6.95	6.94	1.16	1.13	1.12	0.87	0.98
G28	5.92	4.70	1.22	5.31	5.27	5.24	1.85	0.65	0.81	0.79	0.89
G29	6.64	6.53	0.11	6.59	6.58	6.58	0.15	1.01	1.12	0.98	1.11
G30	4.62	4.15	0.47	4.39	4.38	4.37	0.91	0.45	0.71	0.90	1.01
G31	5.34	4.46	0.88	4.90	4.88	4.86	1.48	0.56	0.77	0.84	0.94
G32	5.14	4.83	0.31	4.99	4.98	4.98	0.54	0.58	0.83	0.94	1.06
G33	4.97	4.64	0.33	4.81	4.80	4.80	0.60	0.54	0.80	0.93	1.05
G34	5.48	5.03	0.45	5.26	5.25	5.25	0.74	0.64	0.86	0.92	1.03
G35	4.64	4.50	0.14	4.57	4.57	4.57	0.27	0.49	0.77	0.97	1.09

Table 4. The values of drought tolerance indices under 15%-drought stress conditions in wheat genotypes for coleoptile length

Genotype	Yp	Ys	TOL	MP	GMP	HM	SSI	STI	YI	YSI	RSI
G1	7.22	5.13	2.09	6.18	6.09	6.00	2.25	0.88	0.91	0.71	0.82
G2	8.22	5.00	3.22	6.61	6.41	6.22	3.05	0.98	0.89	0.61	0.70
G3	7.61	7.40	0.21	7.51	7.50	7.50	0.21	1.34	1.31	0.97	1.12
G4	6.59	6.32	0.27	6.46	6.45	6.45	0.32	0.99	1.12	0.96	1.10
G5	7.95	5.42	2.53	6.69	6.56	6.45	2.48	1.03	0.96	0.68	0.78
G6	7.67	7.67	0.31	7.83	7.82	7.82	0.30	1.46	1.36	0.96	1.10
G7	7.96	6.04	1.92	7.00	6.93	6.87	1.88	1.15	1.07	0.76	0.87
G8	6.71	6.07	0.64	6.39	6.38	6.37	0.74	0.97	1.08	0.90	1.04
G9	6.12	5.80	0.32	5.96	5.96	5.96	0.41	0.85	1.03	0.95	1.09
G10	6.99	5.40	1.59	6.20	6.14	6.09	1.77	0.90	0.96	0.77	0.89
G11	9.05	6.98	2.07	8.02	7.95	7.88	1.78	1.51	1.24	0.77	0.88
G12	6.32	5.80	0.52	6.06	6.05	6.05	0.64	0.87	1.03	0.92	1.05
G13	6.90	5.49	1.41	6.20	6.15	6.11	1.59	0.90	0.97	0.80	0.91
G14	4.83	4.43	0.40	4.63	4.63	4.62	0.64	0.51	0.79	0.92	1.05
G15	4.68	4.30	0.38	4.49	4.49	4.48	0.63	0.48	0.76	0.92	1.05
G16	7.79	6.98	0.81	7.39	7.37	7.36	0.81	1.30	1.24	0.90	1.03
G17	5.45	5.25	0.20	5.35	5.35	5.35	0.29	0.68	0.93	0.96	1.11
G18	6.93	6.57	0.36	6.75	6.75	6.75	0.40	1.09	1.16	0.95	1.09
G19	7.28	6.18	1.10	6.73	6.71	6.69	1.18	1.07	1.10	0.85	0.97
G20	7.33	6.39	0.94	6.86	6.84	6.83	1.00	1.12	1.13	0.87	1.00
G21	4.86	4.81	0.05	4.84	4.83	4.83	0.08	0.56	0.85	0.99	1.14
G22	7.02	6.47	0.55	6.75	6.74	6.73	0.61	1.08	1.15	0.92	1.06
G23	4.73	4.56	0.17	4.65	4.64	4.64	0.28	0.51	0.81	0.96	1.11
G24	8.27	7.34	0.93	7.81	7.79	7.78	0.88	1.45	1.30	0.89	1.02
G25	6.90	5.70	1.20	6.30	6.27	6.24	1.35	0.94	1.01	0.83	0.95
G26	5.53	5.13	0.40	5.33	5.33	5.32	0.56	0.68	0.91	0.93	1.06
G27	6.49	5.61	0.88	6.05	6.03	6.02	1.06	0.87	0.99	0.86	0.99
G28	5.92	5.30	0.62	5.61	5.60	5.59	0.82	0.75	0.94	0.90	1.03
G29	6.64	5.86	0.78	6.25	6.24	6.23	0.91	0.93	1.04	0.88	1.01
G30	4.62	3.93	0.69	4.28	4.26	4.25	1.16	0.43	0.70	0.85	0.98
G31	5.34	4.75	0.59	5.05	5.04	5.03	0.86	0.61	0.84	0.89	1.02
G32	5.14	4.98	0.16	5.06	5.06	5.06	0.24	0.61	0.88	0.97	1.11
G33	4.97	4.82	0.15	4.90	4.89	4.89	0.23	0.57	0.85	0.97	1.11
G34	5.62	5.48	0.14	5.55	5.55	5.55	0.19	0.73	0.97	0.98	1.12
G35	4.64	4.13	0.51	4.39	4.38	4.37	0.86	0.46	0.73	0.89	1.02

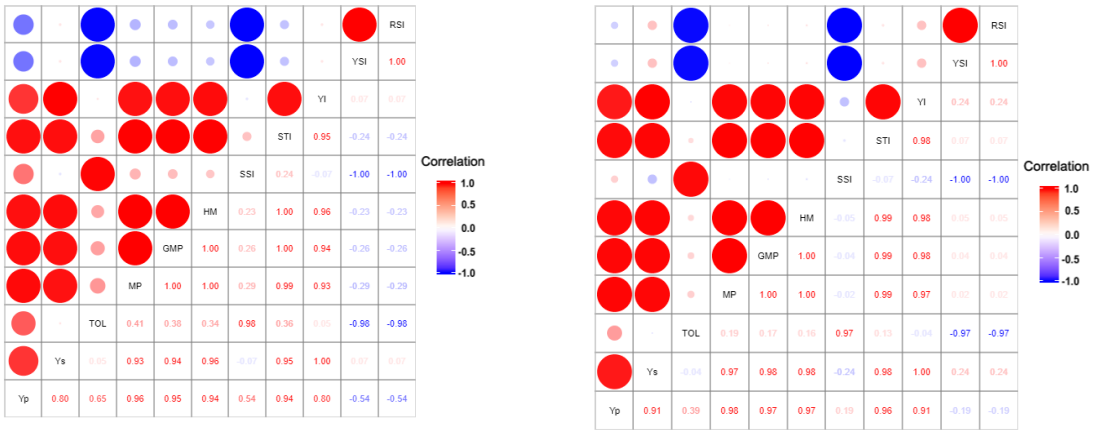

Fig. 1. Correlation coefficients between drought tolerance indices for coleoptile length under 10%-(right) and 15%-(left) drought stress

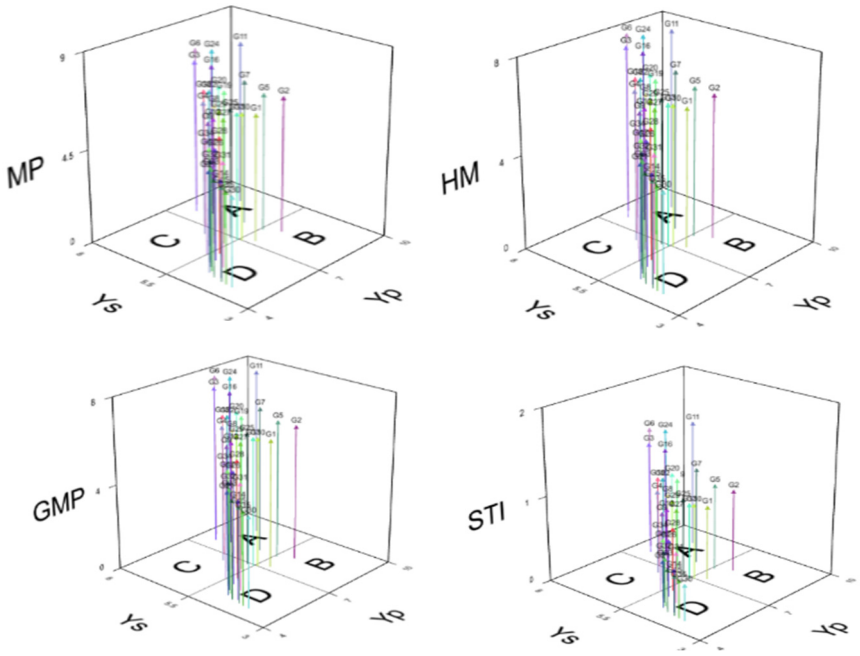

Fig. 2. Three-dimensional plot of coleoptile length traits under 10%-drought stress conditions with STI, HM, GMP and MP indices

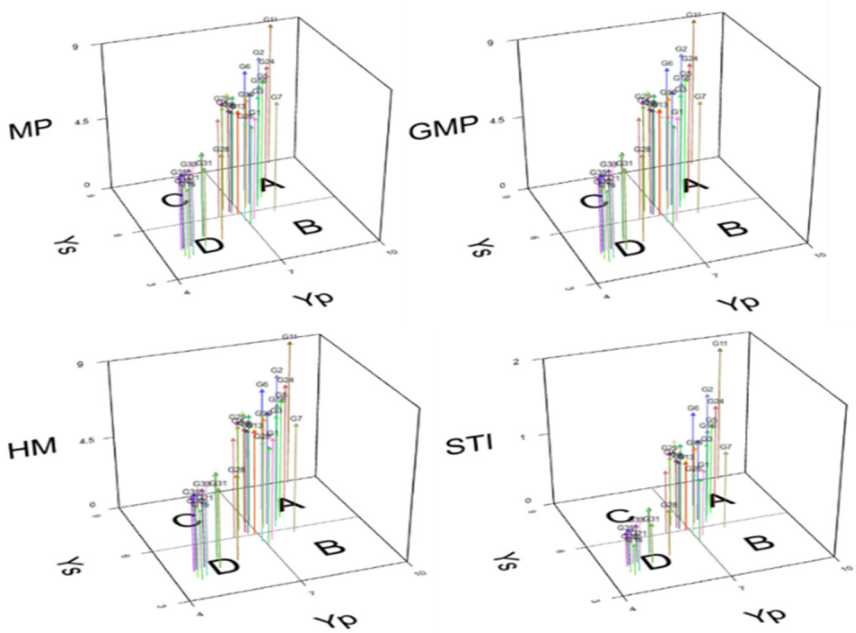

Fig. 3. Three-dimensional plot of coleoptile length traits under 15%-drought stress conditions with STI, HM, GMP and MP indices

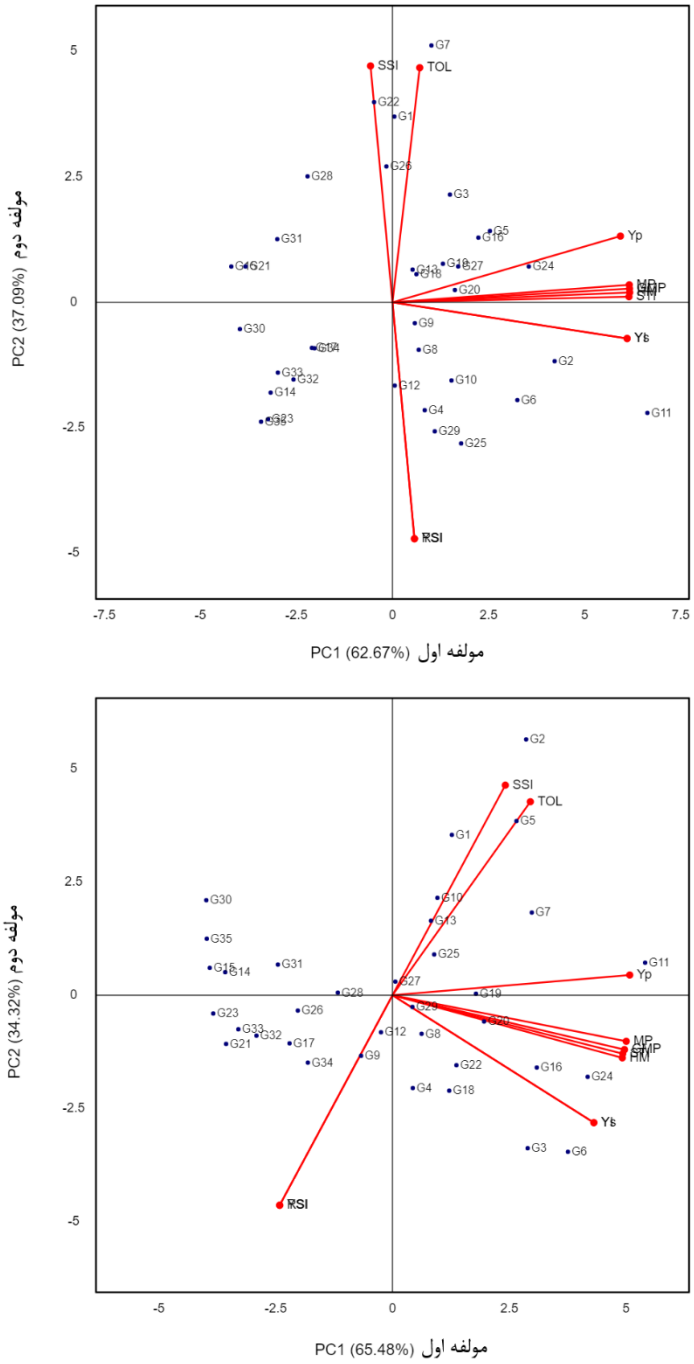

Fig. 4. Biplot plot of the first two principal components for coleoptile length under 10%-(top) and 15%-(bottom) drought stress conditions

Table 5. Mean comparison of grain yield for bread wheat genotypes

No	Yield (kg ha^{-1})	No	Yield (kg ha^{-1})
1	2364	**19**	2951
2	3764	**20**	3617
3	3718	**21**	3500
4	3992	**22**	3102
5	3811	**23**	4136
6	3260	**24**	4370
7	3967	**25**	3064
8	3659	**26**	3969
9	4142	**27**	2675
10	3936	**28**	3939
11	3135	**29**	3832
12	3715	**30**	4630
13	3532	**31**	3804
14	3872	**32**	3114
15	3728	**33**	3931
16	3550	**34**	4988
17	3798	**35**	5668
18	4209		

LSD 1%=129.8; LSD 0.05%=88.6