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Tolerance of 42 Bread Wheat Genotypes to Drought Stress after Anthesis

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Abstract: The present research characterized yield and yield components of 42 wheat genotypes after terminal drought stress. The experiment was in twice replicated simple rectangular lattice design, conducted at irrigated and terminal stress conditions during 2006-2007. These study genotypes had significant differences for grain yield at level of 1%. Genotypes 4057, Viking/5/Gds/4.., Sabalan and 5041 respectively with 6.313, 6.159, 5.793 and 5.774 t ha^{-1} had the highest yield and Gascogen has the lowest yield with 2.561 t ha^{-1}. Mean of total grain yield for under study genotypes was 5.628 t ha^{-1} in non-stress and 3.305 t ha^{-1} in drought stress conditions. Drought stress decreased amount of grain yield 2.323 t ha^{-1} that was noticeable. Interaction of Genotype×environmental conditions was significant at probability level of 1% for grain yield. Yield of all genotypes in drought condition was lower than non-stress condition. Genotypes Viking/5/Gds/4/Anza/3/Pi.., Sabalan, 4061, 4057 and 4041 had more yield in non-stress condition and MV17/Zrn, Sabalan, Saysonz and 4032 in stress condition. Stress intensity pay attention to total grain yield was 42%. Genotypes Viking/5/Gds/4/.. and Sabalan had high grain yield and was better than other genotypes and controls (Toos and Crosse Shahi), according to GMP, STI and MSTI. And had the most amount of stress tolerance index as compared with other genotypes confirms this subject. Correlation of yield with other traits was not significant in non-stress condition. In drought condition, correlation of grain yield with 1000 grain weight and total number of tillers per plant was positively significant. ANOVA showed significant differences between osmotic pressures for coleoptile length, between genotypes for mean and maximum coleoptile length and between interactions of genotypes×osmotic pressures for mean and maximum coleoptile length. Mean comparisons showed the highest total, mean and maximum coleoptile length in -7 bar PEG+1 ml L^{-1} potassium humate treatments. Genotypes Sardari and Sabalan had the highest amounts of total, mean and maximum coleoptile length. With due attention to interaction genotype×osmotic pressures, genotypes Sardari, Sabalan and 4057 in -7 bar PEG+1 ml L^{-1} potassium humate had the most amounts of noted characters than others. In conditions of this experiment, potassium humate caused increase in tolerance rate of genotypes against drought stress.

Key words: Coleoptile, PEG 6000, potassium humate, terminal drought

INTRODUCTION

Drought, the result of low precipitation, high temperature, or wind, is a non-uniform phenomenon, influencing the plants differently depending the development stage at it occurred (Vijendra Das, 2000; Lopez *et al.*, 2003). Most wheat-producing regions of the world are subject to water deficits during some part of the growing season and grain filling is maintained by a high contribution from assimilation before and immediately after anthesis and remobilization of vegetative reserves during kernel growth (Bidinger *et al.*, 1977; Moustafa *et al.*, 1996; Royo *et al.*, 1999). Water deficit around anthesis may lead to a loss in yield by reducing spike and spikelet number and the fertility of surviving spikelets and from anthesis to maturity, especially if accompanied by high temperatures, hastens leaf senescence, reduces the duration and rate of grain filling and hence reduces mean kernel weight (Giunta *et al.*, 1993; Royo *et al.*, 2000).

Although wheat yield potential has been increasing at an annual rate of approximately 0.9% over the last 30 years, it is predicted that wheat yield needs to increase by 1.6% per year over next 20 years to meet the needs of an increasing global demand (Reynolds *et al.*, 2000). Thus, there is a need to increase wheat productivity world wide, in particular in developing countries and for further increase wheat yield potential genetically, it is important for us to understand the physiological and genetic basis of yield (Yang *et al.*, 2006).

Partitioning of dry matter among the organs at anthesis determines the subsequent operation and

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orientation of the source-sink system in the period of grain formation and filling (Kumakov *et al*., 2001). In all grain crops the supply of assimilates to the developing grain originates both from current assimilation transferred directly to kernels and from the remobilization of assimilates stored temporarily in vegetative plant parts (Gebbing *et al*., 1999). The reserves deposited in vegetative plant parts before anthesis may buffer grain yield when conditions become adverse to photosynthesis and mineral uptake during grain filling (Austin *et al*., 1977; Tahir and Nakata, 2005). The relative importance of current assimilation and remobilization changes among genotypes and is strongly related to environmental conditions. Under optimal conditions 80-90% of the carbohydrates translocated to the grain of wheat are assimilates from current photosynthesis and 10-20% from the plants reserves (Vijayalakshmi, 2007). In 25 durum wheat varieties grown in Central Italy, Mariotti *et al.* (2003) found that the contribution of pre-anthesis assimilates to kernel weight ranged from 43-54% and Przulj and Momcilovic (2001) found that this contribution varied from 4-24% in 20 two-rowed spring barley cultivars. Van Herwaarden *et al.* (1998) found that the apparent contribution of stored assimilates to grain yield was 37-39% under high rainfall conditions during grain filling, but arised to 75-100% under dry field conditions.

Polyethylene glycols are used extensively for the experimental control of water stress in plants growing in nutrient solutions. It is frequently assumed that plant water relations are similar whether the plants are growing in soil or in a PEG' solution having an equal water potential (Kaufmann and Eckard, 1971).

Blum (2008) expressed, in 1961 a paper published in Science (Lagerwerff *et al*., 1961) indicated that PEG can be used to modify the osmotic potential of nutrient solution culture and thus induce plant water deficit in a relatively controlled manner, appropriate to experimental protocols. It was assumed that PEG of large molecular weight did not penetrate the plant and thus was an ideal osmoticum for use in hydroponics root medium. During the 1970’s and 1980’s PEG of higher molecular weight (4000-8000) was quite commonly used in physiological experiments to induce controlled drought stress in nutrient solution cultures. Several papers also reported theoretical or measured concentration-osmotic potential relations for PEG of different molecular weights. An example for such relationship which can be roughly defined as standard calibration curves was presented by Money (1989).

Humates are widespread carbonic matters being formed in the processes of biological and chemical decomposition of plant and animal residues. Humates present the complex of high molecular polyfunctional nitrogenic organic compounds with cyclic structure and specific physical, chemical and biological characteristics (Lopez-Fernandez *et al*., 1992). Humic acid causes to increase yield in watermelon and cabbage and potatoes (Salman *et al*., 2005). Humic acid is used to remove or decrease the negative effects of chemical fertilizers and some chemicals from the soil. The major effect of humic acid on plant growth has long been reported (Lee and Bartlette, 1976; Linchan, 1978; Pal and Sengupta, 1985; Hartwigson and Evans, 2000).

Potassium humate is an active hormone with natural origin that extracts from plants and animals remains existed in the bottom of marshes. This material are formed from N, P, K and microelements namely Mo, Cu, Zn, B, Co, Mg (Gadimov *et al*., 2007). Potassium humate causes increased accumulation of chlorophyll, sugar, amino acids and improves the efficiency of nitrogen utilization, allowing for reduced fertilizer rates, the plant’s ability to withstand the stresses of heat, drought, cold, disease, insect and other types of environmental or cultural pressures and also increases general plant productivity, in terms of yield, as well as plant stem strength (Anonymous, 2008). Using of potassium humate increased root system, tuber yield, tuber number per plant in potato (Anonymous, 2007) and pea numbers from 14.4- 52.6 and its weight from 12 to 36 g in condition of saline stress with application of 250 mL ha^{-1} potassium humate at 3-6 weeks after planting as spraying and decreased nitrate amounts in leaves and roots of pea (Gadimov *et al*., 2007) and also decreased nitrate accumulation in potato tubers (Hassanpanah *et al*., 2007).

Bread wheat (*Triticum aestivum* L.) production in Ardabil region, Iran is subjected to water deficit after anthesis. Improving the genetic adaptation of wheat to drought stress represents one of the main objectives of regional breeding programs. In order to this we conducted an experiment on 42 advanced genotypes for identify differences within these and to learn whether response of them was associated with the acquisition of stress tolerance after anthesis. On the other hand, evaluation of important characters in early growth stages is necessary for selected wheat genotypes under terminal drought of farm experiment in our area. Furthermore, uses of potassium humate can help ours to know about its effect on decrease of drought intensity in the most important stage of growth. So we tried to study about response of wheat genotypes to this miraculous natural hormone.

MATERIALS AND METHODS

Farm experiment: The experiment was in twice replicated simple rectangular lattice design, conducted at irrigated and terminal stress conditions during 2006-2007.

Location of experiment was Agricultural Research Station of Islamic Azad University, Ardabil branch (north west of Iran). Two irrigation treatments were normally irrigation and induce of water deficit after anthesis. We characterized yield and its component after the exposure of genotypes to terminal drought stress. Yield and yield components were measured separately for stress and non-stress conditions. So Stress intensity, susceptibility and tolerance indices were calculated. Statistical procedures were done for all of them.

Indices used for evaluation of advanced wheat cultivars were Fischer and Maurer stress index (SSI), Fernandez tolerance index (STI), Rosielle and Hamblin tolerance index (TOL), Baron geometric index (GMP) and Modified tolerance index (MSTI) as below (Fischer and Maurer, 1978; Frenandez, 1992; Rosielle and Hamblin, 1981; Naderi *et al*., 1999):

Stress Susceptibility Index (SSI):

$$SSI = (1-(Ysi/Ypi))/SI$$

Where:
Ysi = Yield of cultivar in stress condition,
Ypi = Yield of cultivar in normal condition
SI = 1- (Ys/Yp)
Where:
Ys = Total yield mean in stress condition
Yp = Total yield mean in normal condition

Stress Tolerance Index (STI):

$$STI = (Ypi \times Ysi)/Yp^2$$

Tolerance Index (TOL):

$$TOL = Ypi-Ysi$$

Geomertic Mean Productivity (GMP):

$$GMP = \sqrt{}Ypi \times Ysi$$

Mean Productivity (MP):

$$MP = (Ypi+Ysi)/2$$

Modified Stress Tolerance Index (MSTI):

$$MSTI = K(Ypi \times Ysi/ Yp^2)$$

Where:
$K = Ysi^2/Ys^2$

***In vitro* experiment:** Seven selected genotypes as tolerant to terminal drought stress, pay attention to results of farm experiment and one sensitive genotype evaluated for some of germination characters. This experiment was done by factorial design on the basis of completely randomized block. PEG 6000 applied to create of osmotic pressure and distilled water as control treatment. A factor had three levels of osmotic pressure (-7 bar PEG and 1 ml L^{-1} K-Humate + -7 bar PEG) and B factor was wheat genotypes. Ten numbers seeds were cultured into the each of Petri dishes. Petri dishes and papers were sterilled in an oven at 120 degrees centigrade for 1.5 h. After sterilization, seeds cultured between papers. Temperature of laboratory was about 24 degrees centigrade during of experiment. They maintained in a dark place for 10 days. Characters such as maximum length of coleoptile and primary root; and mean length of coleoptile and primary root measured.

RESULTS AND DISCUSSION

In farm: These study genotypes had significant differences for grain yield at level of 1%. Genotypes 4057, Viking/5/Gds/4.., Sabalan and 5041 respectively with 6.313, 6.159, 5.793 and 5.774 t ha^{-1} had the highest yield and Gascogen has the lowest yield with 2.561 t ha^{-1} (Table 1). Mean of total grain yield for under study genotypes was 5.628 t ha^{-1} in non-stress and 3.305 t ha^{-1} in drought stress conditions (Fig. 1). Drought stress decreased amount of grain yield 2.323 t ha^{-1} that was noticeable. Interaction of Genotype×environmental conditions was significant at probability level of 1% for grain yield. Yield of all genotypes in drought condition was lower than non-stress condition. Genotypes Viking/5/Gds/4/Anza/3/Pi.., Sabalan, 4061, 4057 and 4041 had more yield in non-stress condition and MV17/Zrn, Sabalan, Saysonz and 4032 in

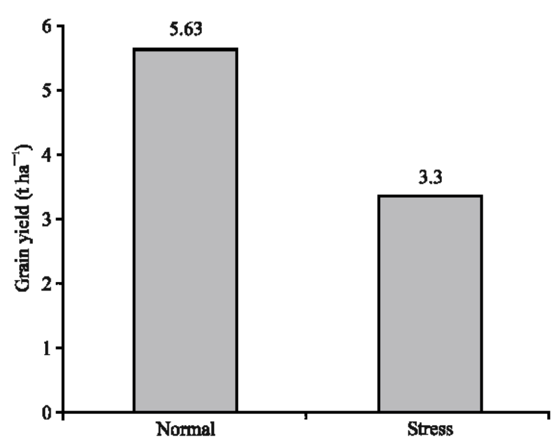

Fig. 1: Grain yield of wheat genotypes in after anthesis drought stress conditions

Table 1: Estimates of water stress indices for wheat genotypes under stress (SI = 0.42)

Genotypes	Mean of yield	Yp	Ys	SSI	GMP	MP	TOL	STI	MSTI
Appolo/90 zhong 87	3.25	3.537	2.967	0.864	2.83	2.90	1.27	0.25	0.099
Mv 17/Zrn	5.38	6.026	4.741	0.513	5.34	5.38	1.28	0.9	1.034
NVd/Gaspard	4.45	4.99	3.913	0.519	4.41	4.45	1.07	0.61	0.480
Shahriar	4.48	6.285	2.672	1.382	4.09	4.47	3.61	0.53	0.660
Viking/5/Gds/4/Anza...	3.43	3.99	2.874	0.672	3.38	3.43	1.11	0.36	0.180
Viking/5/Gds/4/Anza/3/Pi....	6.16	9.037	3.281	1.531	5.44	6.15	5.75	0.93	2.410
Aghbugda/90Zhong87/4/Spn...	3.24	2.983	3.497	0.414	3.22	3.24	0.51	0.32	0.090
Bkt.90-Zhong 87	4.35	6.105	2.590	1.380	3.97	4.34	3.51	0.49	0.580
Bkt/90-Zhong	4.90	6.659	3.149	1.260	4.57	4.90	3.51	0.66	0.920
Alvd/90-Zhong 87	4.31	5.931	2.697	1.310	3.99	4.31	3.23	0.50	0.560
Apollo/Alvd/4/Spn/Mcd//...	5.17	6.972	3.365	1.240	4.84	5.16	3.60	0.74	1.130
Mv 17/Bcn88	5.16	6.99	3.332	1.250	4.82	5.16	3.65	0.73	1.130
SARDARI-HD39/6/SN64//	4.75	6.141	3.366	1.080	4.54	4.75	2.77	0.65	0.770
SARDARI-D39/6/SN64//..	4.17	5.441	2.902	1.120	3.97	4.17	2.53	0.49	0.460
SABALAN/4/VRZ/3/ORF1 ...	4.44	5.859	3.017	1.160	4.20	4.43	2.84	0.55	0.600
ATAY/GALVEZ87	4.53	6.403	2.648	1.410	4.11	4.52	3.75	0.53	0.690
LFN/STDY//LOV24(ES84-....	4.55	6.326	2.771	1.350	4.18	4.54	3.55	0.55	0.690
PYN/BAU/3/AGR1/BJY//VEF	4.86	5.779	3.948	0.762	4.77	4.86	1.83	0.72	0.750
Toos (control)	4.24	5.260	3.225	0.930	4.11	4.24	2.03	0.53	0.460
Cross Shahi (control)	3.81	4.074	3.553	0.300	3.80	3.81	0.52	0.45	0.230
Fenkan	3.58	3.490	3.668	0.120	3.57	3.57	0.17	0.40	0.150
Gasgogen	2.56	2.681	2.441	0.210	2.55	2.56	0.24	0.20	0.040
Bezostaya	4.56	5.618	3.510	0.900	4.44	4.56	2.10	0.62	0.620
Sardari	3.68	4.212	3.157	0.600	3.64	3.68	1.05	0.41	0.230
Sabalan	5.79	7.462	4.126	1.070	5.54	5.79	3.33	0.97	1.700
Azar2	3.69	3.819	3.563	0.160	3.68	3.69	0.25	0.42	0.190
Agosta	3.91	5.083	2.733	1.110	3.72	3.90	2.35	0.43	0.350
Gaspard	3.74	4.288	3.194	0.610	3.70	3.74	1.09	0.43	0.250
Saesonz	4.95	5.356	4.542	1.480	4.93	4.94	0.81	0.49	0.640
MV 17	4.43	6.405	2.456	0.440	3.96	4.43	3.94	0.55	0.370
Zarien	4.21	4.640	3.789	1.140	4.19	4.21	0.85	0.69	0.910
Londa	4.93	6.460	3.392	0.220	4.68	4.92	3.06	0.45	0.220
5204	3.79	3.973	3.601	1.660	3.78	3.78	0.37	0.53	0.910
4061	4.83	7.376	2.283	1.280	4.10	4.83	5.10	1.08	2.550
4057	6.31	8.625	4.000	0.900	5.87	6.31	4.62	0.68	0.750
4025	4.65	5.907	3.396	1.360	4.67	4.80	2.21	0.38	0.340
9203	3.80	5.306	2.296	1.020	3.49	3.80	3.01	0.93	1.750
5041	5.77	7.705	3.844	1.490	5.44	5.77	3.86	0.79	1.650
4041	5.61	8.137	3.084	1.270	5.10	5.61	5.05	0.51	0.550
4033	4.31	5.855	2.760	0.730	4.01	4.30	3.09	0.64	0.590
4063	4.59	5.404	3.773	0.480	4.51	4.58	1.63	0.52	0.230
4032	4.08	3.780	4.388	0.900	4.07	4.08	0.60	0.68	0.750

Ys = Yield of cultivar in stress condition; Yp = Yield of cultivar in normal condition; SSI: Stress Susceptibility Index; STI: Stress Tolerance Index; TOL: Tolerance Index; GMP: Geometric Mean Productivity; MP: Mean Productivity; MSTI: Modifed Stress Tolerance Index

stress condition. We observed that genotype Sabalan produced high yield in both stressed and non-stressed conditions (Table 1).

Analyzing of tolerance and sensitivity evaluation indices to environmental stress conditions showed that efficiency of these indices modify with genotypes yield variation and aims assessment.

Fischer and Maurer index classified genotypes as tolerant or sensitive. This index can recognize genotypes as tolerant or sensitive, be regardless to their yield and have a good efficiency for finding genotypes with resistance genes. TOL has a conditional efficiency, but after classifying genotypes to equal TOL, we can select resistant genotypes with MP. Finding equal TOL in different groups is very hard. With regard to role of TOL and MP, genotype with high MP may not be exists in the least TOL groups and selecting superior genotypes may be difficult. Frenandez index uses stress and non-stress yield and geometric mean. There is a problem and it is geometric equation of coupling data that have natural difference. Environmental changes in all of the Iran provinces are visible. MSTI with calculating KSTI for suitable and unsuitable conditions is useful for selecting superior genotypes for each region. MSTI results are very notable.

Results showed that stress intensity pay attention to total grain yield was 42% (SI = 0.42). GMP, STI and MSTI selected Viking/5/Gds/4/.. and Sabalan; and MP selected Sabalan; TOL and SSI selected Fenkan and Azar2 as better cultivar under drought stress condition. Phenologic investigation of Sabalan in susceptible periods can lead to understanding strategic methods in agronomy and breeding practices (Table 1).

Genotypes Viking/5/Gds/4/.. and Sabalan had high grain yield and better than other genotypes and controls (Toos and Crosse Shahi), according to GMP, STI and

MSTI. And had the most amount of stress tolerance index as compared with other genotypes confirms this subject (Table 1).

Correlation of yield with other traits was not significant in non-stress condition. In drought condition, correlation of grain yield with 1000 grain weight and total number of tillers per plant was positively significant.

***In vitro* evaluation of germination characters:** ANOVA showed significant differences between osmotic pressures for coleoptile length, between genotypes for mean and maximum coleoptile length and between interactions of genotypes×osmotic pressures for mean and maximum coleoptile length. Mean comparisons showed the highest total, mean and maximum coleoptile length in -7 bar PEG + 1 ml L^{-1} potassium humate treatments (Table 2). Genotypes Sardari and Sabalan had the highest amounts of total, mean and maximum coleoptile length (Table 3). With due attention to interaction genotype×osmotic pressures, genotypes Sardari, Sabalan and 4057 in -7 bar PEG + 1 ml L^{-1} potassium humate had the most amounts of measured characters.

Results of this research showed that potassium humate caused to increase in tolerance rate of genotypes against drought stress. These results were in accordance with the findings of similar investigations (Bostan *et al*., 2004). Genotypes that had the highest grain yield in normal and terminal drought stress conditions were grouped in tolerant genotypes by use of drought stress tolerance indices. So they had the most total, mean and maximum coleoptile length. Cultivars emerging rapidly are valuable because rainfall after sowing can result in a soil crust that prevents the wheat coleoptile or first leaf to emerge. Additionally, early emerging crops can maximize the water utilization leading to better stand establishment and grain yield. Although the main variation in the coleoptile length is genetic, the trait was significantly affected by genotype×environment interaction. These are according with findings of Hakizimana *et al.* (2000).

Table 2: Length of coleoptile and primary roots in eight wheat genotypes

Treatments	Mean of coleoptile length	Maximum of coleoptile length (mm)	Maximum length of primary roots	Mean length of primary roots
Control	4.01a	4.51a	17.2a	13.83a
Stress+potassium humate	4.25a	4.85a	17.73a	12.01b
Sterss	3.95ab	4.73a	16.35a	11.21b

Values with different letter(s) are significantly different at $p<0.05$

Table 3: Comparison of germination characters for eight wheat genotypes in different treatments

Cultivars	Mean of coleoptile length	Maximum of coleoptile length (mm)	Maximum length of primary roots	Mean length of primary roots
Mv 17/Zrn	4.28b	5.18a	21.60a	12.91ab
Viking/5/Gds/4/Anza…	4.30ab	5.01a	13.85ab	11.33b
Apollo/Alvd/4/Spn..	2.86c	3.58b	13.92ab	10.48b
Gaskozen	3.11c	3.72b	12.88b	10.89b
Sardari	4.62ab	5.41a	19.25ab	14.79a
Sabalan	4.93a	5.56a	20.13ab	15.33ab
4057	4.76ab	5.23a	16.11ab	12.69b

Values with different letter(s) are significantly different at $p<0.05$

CONCLUSION

Sabalan variety produced high yield in the both of stress and non-stress conditions. And it´s most amount of GMP, STI and MSTI than other genotypes confirm this subject.

Genotypes had different responses to potassium humate treatment. Potassium humate (1 ml L^{-1}) caused to superior tolerance of Sardari, Sabalan and 4057 genotypes than others against drought (-7 bar PEG 6000) in early growth stages.

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