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Screening of wheat genotypes for drought tolerance at vegetative stage

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Abstract: Screening of wheat genotypes for drought tolerance was done at the research field of Agronomy Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh during November, 2009 February 2010. Thirty (30) wheat genotypes collected from Wheat Research Centre of BARI, were evaluated against drought at vegetative stage (stress was imposed from CRI stage to before anthesis by withholding irrigation) with control (no drought). Exposure of plants to drought led to noticeable reduction in yield and yield contributing characters such as plant height (1-13 %), number of spikes per plant (10-48 %), TDM (16-45 %), number of seeds per spike (7-43 %), 100- seed weight (49-69%) and seed yield (15-65 %). Under drought stress condition, BCN, BAW- 923(C7), KAN (C9) and BAW- 1138 produced higher seed yield than other genotypes, which gave above 80% seed yield compared to control. These genotypes also showed higher values of all other yield-contributing characters under drought stress. Based on the yield of genotypes under control (YP) and drought stress (YS) conditions, three quantitative drought tolerance indices including relative yield (RY), stress susceptibility index (SSI) and stress tolerance index (STI) used to evaluate drought responses of these genotypes. According to stress tolerance index, Shatabdi, BCN, KAN (C9), BAW- 923/4, BAW- 923/BAW- 824, Garuda and Oasis (RC5 Jo) showed higher values (STI >0.8) though Shatabdi, Oasis (RC5 Jo) and Garuda were discarded from the selection because they produced very lower yield in stress condition and STI was able to identify cultivars producing high yield in both conditions. The genotypes BCN, BAW- 923 (C7), KAN (C9) and BAW -1138 showed higher values in relative yield (RY >80%) and lower values in stress susceptibility index (SSI <0.6). On the basis of STI, SSI and RY, the genotypes BCN, BAW 923- (C7), KAN (C9), BAW -923/4, BAW- 923/BAW- 824 and BAW- 1138 were selected as drought tolerant at vegetative stage.
Key words: Wheat, drought, vegetative stage.

Introduction

Drought is considered the major abiotic stress in many parts of the world (Johansen *et al.* 1994; Malhotra *et al.* 2004) and is responsible for heavy production losses. Among the abiotic stresses, drought leads to a series of morphological, physiological, biochemical and molecular changes that adversely affect plant growth and productivity (Wang *et al.* 2001). Emphasis is given on the problem drought in the recent years. Moreover, it is a constraint for dry land farming or rainfed crop production which retards crop growth and ultimately reduced yield of crops. Physiological means of minimizing drought stress may influence the yield in rainfed environment. Wheat (*Triticum aestivum*) is the second most important cereal crop in Bangladesh in respect of area and production cultivated in winter season. But scanty rainfall and scarcity of available irrigation facilities in the winter season, it suffers from soil moisture stress during the growing period. Villarreal and Kazi (1999) showed that crown root initiation (CRI) and anthesis are the two stages at which yield losses from drought stress can be most critical to wheat. In Bangladesh, up to 60% of the land surface is subject to continuous or frequent stress and drought occurs of about 3.5 million ha of land area causing a great damage to crop production. So, it is important to find out suitable drought tolerant wheat genotype(s) for variety development in rainfed cultivation. Hence, the study was undertaken for screening of wheat genotype(s) for drought tolerance under drought stress condition in the field. Drought resistance is defined by Hall (1993) as the relative yield of a genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum, 1988) while the values are confounded with differential yield potential of genotypes (Ramirez and Kelly, 1998). Drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought-tolerant genotypes (Mitra, 2001). So, in this screening programme, we use some indices like Stress tolerance index (STI), stress susceptibility index (SSI) and relative yield (RY) for selecting drought tolerant genotypes.

Materials and Methods

The experiment was conducted at the farm of Central Research Station of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur during the rabi season of 2009-10. The soil of the research area belongs to the Chiatta Series under AEZ-28. The soil was clay loam and acidic in nature (pH 6.1). Scanty rainfall, low humidity and clear sunny days were the characteristic features of the growing season. Thirty genotypes of wheat were used in this experiment under drought conditions like- i) Control (no drought) ii) drought at vegetative stage (stress was imposed from CRI to before anthesis withholding irrigation). The experiment was done in CRD design with three replications. Each plot consisted of 3 rows of each genotype with 4 meter in length, row to row distance 20 cm apart with continuous sowing. Seeds were sown on 19 November 2009. Pre-sowing irrigation was applied for ensuring seed germination. Fertilizers were applied at the rate of N_{100}, P_{60}, K_{40} and S_{20}, respectively in the form of urea, TSP, MP and gypsum. The 2/3rd N, whole amount of P, K and S were applied as basal and the rest 1/3rd N was top dressed at CRI stage. Other intercultural operations like- thinning, irrigation, weeding and pesticide application were done as and when necessary. At harvest, data on yield and yield contributing characters were recorded. Three selection indices including Relative Yield (RY, %) (Ashraf and Wahed), Stress tolerance Index (STI, Fernandez, 1992) and Stress Susceptibility Index (SSI, Fischer and Maurer, 1978) were calculated by the following formula:

$$1)\ \text{Relative Yield (RY)} = \frac{\text{Yield of drought stressed plant}}{\text{Yield of control plant}} \times 100$$

2) $STI = Yp^{*}\ Ys/\ YP^{2}$

3) SSI = (1-(Ys/Yp))/SI, Stress intensity (SI, %) = 1-(YS/YP)x 100; Here, Yp = Yield of cultivar in normal condition, Ys = Yield of cultivar in Stress condition, YP= Total yield mean in normal condition and YS= Total yield mean in stress condition. Data were analyzed statistically using MSTATC software program.

Results and Discussion

Plant height: In control treatment, plant height varied significantly among the genotypes (Table 1) and Bijoy, KAN (C6), BAW 923 (C7), BAW 1111, BL 1473, BAW 1140 and BAW 1114 gave the higher plant height. The lowest was obtained from BAW 968. The plant height was reduced in all the genotypes when drought was imposed at vegetative stage (Table 1). The relative plant height ranged from 99-87% (reduction from 1-13%) and Prodip, BCN, KAN (C9) and BAW 923/ BAW 824 produced higher relative plant height (Table 1).

Table 1. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	Plant height (cm)			No. of Spikes			Total dry matter (g)		
	Control	Drought	Relative Value	Control	Drought	Relative Value	Control	Drought	Relative Value
Shatabdi	78.00	71.33	91.44	5.33	3.56	66.74	14.31	10.85	75.82
Prodip	77.53	76.26	98.36	4.67	3.67	78.58	12.98	9.98	76.88
BCN	78.00	77.22	99.00	5.33	4.78	89.68	17.41	14.56	83.63
BAW- 923 C6)	74.67	71.45	95.68	5.67	3.56	62.78	13.14	9.92	75.49
BAW- 923 C7)	83.00	78.67	94.78	4.89	4.00	81.79	15.43	12.65	81.98
KAN (C9)	77.33	76.11	98.42	5.22	4.33	81.95	18.29	14.72	80.48
KAN (C6),	86.33	76.56	88.68	5.67	3.56	62.79	14.86	10.53	70.86
OASIS (RC5Jo)	74.00	69.78	94.29	5	2.78	55.60	12.97	9.13	70.39
BL 1473	81.67	79.89	97.82	6.33	3.33	52.60	15.90	10.18	64.02
UP 2338	69.59	66.87	96.09	3.67	2.89	78.74	14.24	8.92	62.64
EMB- 16	69.11	67.56	97.75	4	3.33	83.25	16.54	12.84	77.62
BAW 968	68.33	64.78	94.80	3.11	2.55	81.99	14.73	9.96	67.61
BAW 923/4	78.33	75.11	95.88	5.33	4.11	77.11	13.87	9.60	69.21
BAW 923/BAW824	72.67	71.33	98.15	5	3.66	73.20	15.13	10.03	66.29
Garuda	73.67	71.22	96.67	5.67	3.67	64.72	16.88	12.19	72.21
NL- 922	75.33	66.22	87.90	5.33	3.33	62.47	15.72	9.01	57.31
BAW-1051	74.85	72.67	97.08	3.89	3.11	79.94	17.63	11.09	62.90
BL- 3503	77.00	69.78	90.62	5	2.78	55.60	15.35	9.32	60.71
BAW -1133	73.33	68.44	93.33	4	3.33	83.25	14.20	8.35	58.80
BAW -1135	69.00	66.56	96.46	5.33	4.10	73.92	14.95	9.60	64.21
BAW -1137	73.33	69.33	94.54	4.67	2.89	61.88	13.19	9.07	68.76
BAW -1138	77.67	75.81	97.60	4.44	3.67	82.65	15.96	11.25	70.78
BAW -1140	82.00	73.45	89.57	4.33	3.78	87.29	13.45	9.76	72.78
BAW – 1104	77.67	74.67	96.13	5.78	4.33	74.91	15.12	10.39	68.71
BAW – 1111	84.00	76	90.47	4	3.00	75.00	15.20	9.11	59.93
BAW – 1114,	82.67	72.22	87.35	4.78	3.67	76.77	13.23	9.22	69.64
BAW – 1059	77.33	74.33	96.12	3.89	3.11	79.94	14.59	8.68	59.49
BAW – 1064	79.63	77.48	97.30	4.11	3.33	81.02	14.38	8.93	62.10
Sufi	77.85	74.1	95.18	3.67	2.89	78.74	13.18	7.22	54.77
Bijoy	87.00	78.45	90.17	4	3.21	80.25	12.35	8.52	68.98
SE value	4.91	4.13	-	0.78	0.53	-	1.51	1.74	-

Number of spike per plant: Spike no. per plant was statistically significant among the genotypes under control and drought condition (Table 1). In control condition, BAW- 923 (C6), BL- 1473, BAW- 923/ BAW- 824, KAN (C6), BAW- 1104 and Garuda showed higher no. of spike per plant where as BAW- 968 produced the lowest no. of spike per plant. At vegetative stage, the relative spike no. per plant ranged from 98-52% and BCN, BAW- 923 (C7), KAN (C9), EMB-16, BAW-968, BAW-1133, BAW- 1138 and BAW- 1140 gave higher spike no. per plant than control (Table 1). The minimum reduction in spike no. was noticed in BCN (10 %) at vegetative stage.

Total dry matter: The genotypes were significantly varied in TDM production both under control and drought condition (Table 1.). The genotype KAN (C9) produced the highest TDM and Bijoy produced the lowest under control condition. Under drought stress at vegetative stage, the relative TDM ranged from 84-55% (reduction 16-45%) and BCN, BAW- 923 (C7) and KAN (C9) performed better than other genotypes (Table 1). The BCN showed the minimum reduction (16%) in TDM and Sufi showed maximum reduction (45%).

Seeds per spike: Under control condition, the highest no. of seed per spike was produced by BAW- 1064 and BAW-1059, Shatabdi, KAN (C9), EMB-16, NL- 922 and Bijoy showed better performance in no. of seeds per spike (Table 2). The genotype UP- 2338 produced the lowest no. of seeds per spike. Under drought stress condition, KAN (C9) produced the highest no. of seeds per spike at vegetative stage and the lowest was obtained from Bijoy. The genotypes Shatabdi, BAW- 923 (C7), OASIS (RC5 Jo), EMB- 16, BAW- 923/ 4, Garuda and BAW- 1059 performed better when drought imposed at vegetative stage. The relative no. of seeds per spike ranged from 93-57%. The minimum reduction was observed in genotype KAN (C9) (7%) (Table 2).

100 seed weight: A significant variation in 100 seed weight was observed among the genotypes under control condition (Table 2.). The genotype Prodip gave the highest 100 seed wt. both under control and stress condition. The 100- seed weight per plant was drastically reduced under drought stress at vegetative stage. The relative 100 seed wt. per plant ranged from 51-31% and was higher in BCN, BAW- 923 (C 7), BAW- 1051, BL- 3503, BAW- 1138 and Bijoy at vegetative stage (Table 2).

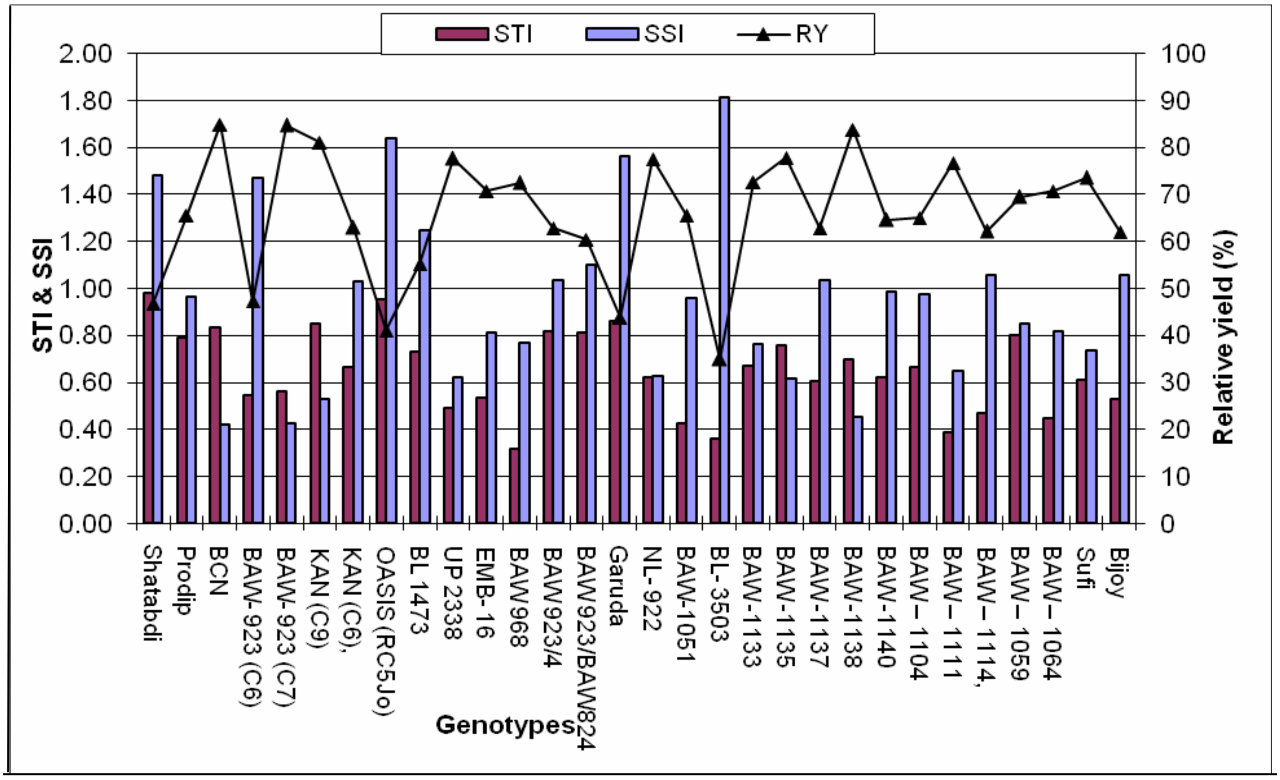

Fig. 1. Stress tolerance index, stress susceptibility index and relative yield under drought stress at vegetative stage of different wheat genotypes

Table 2. Effect of drought stress on yield and yield contributing characters of wheat genotypes

Genotypes	Seeds per spike			100- Seed Weight (g)			Seed yield (g)		
	Control	Drought	Relative value	Control	Drought	Relative value	Control	Drought	Relative value
Shatabdi	56.18	44.67	79.51	3.54	1.63	76.04	11.78	5.51	46.77
Prodip	44.27	36.52	82.49	3.75	1.44	38.40	8.94	5.85	65.43
BCN	43.76	39.12	89.39	3.23	1.63	50.46	8.05	6.83	84.84
BAW- 923 (C6)	46.96	37.26	79.34	3.72	1.52	40.86	8.72	4.11	47.13
BAW- 923 (C7)	45.96	39.59	86.14	3.20	1.54	48.12	6.61	5.60	84.72
KAN (C9)	54.47	50.77	93.20	3.42	1.56	45.61	8.32	6.74	81.00
KAN (C6),	47.51	38.61	81.26	3.44	1.44	41.86	8.35	5.25	62.87
OASIS (RC5Jo)	50.76	43.19	85.08	3.58	1.18	32.96	12.38	5.08	41.03
BL 1473	42.28	35.41	83.75	3.51	1.28	36.46	9.33	5.15	55.19
UP 2338	37.71	33.39	88.54	2.96	1.35	45.60	6.47	5.02	77.58
EMB- 16	53.89	43.63	80.96	3.16	1.46	46.20	7.07	5.00	70.72
BAW 968	46.21	39.40	85.26	3.58	1.51	42.17	5.39	3.90	72.35
BAW 923/4	51.06	42.14	82.53	3.61	1.42	39.33	9.28	5.83	62.82
BAW 923/BAW824	49.95	39.47	79.01	3.58	1.30	36.31	9.43	5.69	60.33
Garuda	51.17	44.09	86.16	3.44	1.56	45.34	11.39	4.98	43.72
NL- 922	54.23	36.33	66.99	3.59	1.40	38.99	7.26	5.63	77.54
BAW-1051	45.39	36.76	80.98	3.08	1.43	46.42	6.55	4.29	65.49
BL- 3503	49.87	35.10	70.38	2.70	1.34	49.62	8.27	2.88	34.82
BAW -1133	46.91	36.86	78.57	3.14	1.40	44.58	7.80	5.66	72.56
BAW -1135	46.04	38.46	83.53	2.91	1.07	36.76	8.01	6.23	77.77
BAW -1137	51.22	38.70	75.55	3.66	1.12	30.60	7.97	5.01	62.86
BAW -1138	42.58	38.50	90.41	3.53	1.65	46.74	7.41	6.21	83.80
BAW -1140	47.27	37.67	79.64	3.24	1.21	37.34	7.97	5.14	64.49
BAW – 1104	43.56	37.59	86.29	3.53	1.22	34.56	8.21	5.34	65.04
BAW – 1111	44.59	34.84	78.13	2.85	1.10	38.59	5.80	4.44	76.55
BAW – 1114,	41.31	33.10	80.12	3.53	1.34	37.96	7.07	4.39	62.09
BAW – 1059	57.94	44.48	76.76	3.47	1.32	38.04	8.72	6.05	69.38
BAW – 1064	58.83	39.15	66.54	3.39	1.32	38.93	6.45	4.55	70.54
Sufi	39.36	26.39	67.04	3.01	1.36	45.18	7.42	5.45	73.45
Bijoy	52.33	24.28	46.39	3.25	1.63	50.15	7.50	4.65	62.00
SE value	5.36	5.17	-	0.28	0.16	-	1.62	0.85	-

Seed yield: Seed yield per plant varied significantly among the genotypes both under control and drought stress condition (Table 2.). Seed yield per plant was the highest in OASIS (RC5 Jo) under control condition and the lowest seed yield per plant was observed in BAW- 968. The reduction in relative seed yield per plant was significant in all the genotypes under drought stress compared to control. The relative seed yield per plant ranged from 85-35% at vegetative stage (Table 2). The minimum reduction was observed in BAW- 1138 (15%) at vegetative stage but genotypes BCN, BAW- 923 (C7) and KAN (C9) also performed better which were produced above 80% relative seed yield per plant.

Stress Intensity (SI), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI)

Under drought stress condition, stress intensity was 36% at vegetative stage. This indicates that seed yield of wheat under drought stress decreased considerably. Yield reduction under the condition of this experiment would be 36%. From the stress tolerance view, Shatabdi, BCN, KAN (C9), BAW- 923/4, BAW- 923/BAW- 824, Garuda and Oasis (RC5 Jo) showed higher values in stress tolerance index (STI >0.8) though Shatabdi, Oasis (RC5 Jo) and Garuda were discarded from the selection because they produced very lower yield in stress condition and STI was able to identify only that cultivars which producing higher yield in both conditions (Talebi *et al.* 2009, Fig 7). In stress susceptibility index (SSI), lower value is the selection criteria for drought tolerant genotypes. In this point of view, BCN, BAW- 923 (C7), KAN (C9) and BAW- 1138 showed lower values in SSI and were similar with relative yield values of those genotypes at vegetative stage (Fig. 1).

From the above results, it may be concluded that under drought stress condition, BCN, BAW- 923(C7), KAN (C9), BAW-923/4, BAW-923/BAW-824 and BAW- 1138 for vegetative stage were selected for drought tolerance on the basis of relative yield (RY), stress susceptibility index (SSI) and stress tolerance index (STI).

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