SCREENING OF SOYBEAN (*Glycine max* L.) GENOTYPES UNDER WATER STRESS CONDITION

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Abstract

Fifty soybean genotypes were screened for their water stress tolerance in a vinylhouse of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during January to May, 2011. The objective of this study was to screen for drought tolerant soybean genotype(s) for improving yield of soybean under rainfed condition in Bangladesh. Water stress was imposed throughout the growing period by withholding irrigation until appearance of wilting symptom. Water stress caused an overall reduction in seed yield of soybean. However, reduction in seed yield due to water stress varied among the soybean genotypes. Variations were measured by tolerance indices, ranking and cluster analysis. Considering stress tolerance indices, ranking and cluster analysis, the genotypes BARI Soybean 5, BARI Soybean 6, Shohag and BD2331 were found as tolerant to water stress.

Introduction

The yield and quality of soybean are affected by water stress. Water stress is a worldwide problem and one of the major obstacles for crop production in the tropics and subtropics (Kumar *et al*., 2005). Water stress reduces soybean yield by about 40% (Pathan *et al*., 2007). Insufficient water, especially during emergence, flowering and pod-filling stages lower the yield of soybean as reported by Soheil *et al.* (2011) and John (2001). The extent of drought damage depends on cultivars, growth stage, duration and intensity of stress (Mark and Antony. 2005; Araus *et al*., 2002).

Among different abiotic approaches, screening available germplasm of a crop for water stress tolerance is the most important one (Kramer, 1980). Soybean is mainly cultivated during late *rabi* season in Noakhali and Laxipur district of Bangladesh. In these areas rainfall (75%) is concentrated mainly during summer monsoon season (June to September), and there is scanty rain during October to May. Thus, the crop grown during this period faces terminal water stress. Maleki

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et. al. (2013) was reported that water stress is the major yield limiting factor for soybean yield enhancement under dry climate and water stress conditions. Despite the availability of a large number of soybean genotypes in Bangladesh (Khan, 2013), but their tolerance in water stress has not yet been evaluated in a systematic study. Selection of genotypes under water stress conditions is one of the main tasks for developing genetic variations to improve the water stress tolerant cultivar of soybean. Therefore, the present study was undertaken to identify suitable tolerant genotype(s) for improving yield of soybean under water stress condition in Bangladesh.

Materials and Method

Pot experiment was conducted at the Environmental Stress Research Site of the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during January to May, 2011. The experiment consisted of fifty soybean genotypes, which have high yield potential and relatively more tolerant against salinity stress.The genotypes were selected based on the research findings done by Khan *et al.* (2013). The pot was filled with 12 kg air-dried soil including cowdung at a ratio of 4:1 which was equivalent to 9 kg oven dry soil and holds about 28% moisture at field capacity (FC). The soil of the pot was fertilized uniformly with 0.15, 0.18, 0.36 and 0.1 g urea, triple super phosphate, muriate of potash and gypsum corresponding to 24-30-60-15 kg NPKS per hectare, respectively. Six healthy seeds per pot were sown on 16 January, 2011. Most of the seedlings emerged within 6-7 days after sowing. Seedlings were thinned out after two weeks of emergence keeping three healthy seedlings of uniform growth in each pot. Optimum soil moisture conditions were maintained for the seedling growth. Two treatments were imposed such as non-stress and water stress when 50 genotypes were evaluated. The experiment was designed in a completely randomized design (Factorial) with four replications. In water stress treatment, before starting treatment imposition, all pots were equally irrigated. Water stress was induced by withholding water completely from 21 days after emergence. The treatment was continued until symptom of wilting persisted throughout the night. After that they were re-watered to 50% field capacity. During the treatment period, wilting symptom was visually observed every day. In non-stress treatment, water was applied when it was needed. The experiment was designed as a completely randomized design under factorial arrangement with four replications. Admire @ 0.5 ml litre^{-1} of water was sprayed to protect the crop from insect attack. The pots were kept weed free throughout the growing season.

At harvest data were recorded on yield and different drought tolerance and susceptibility indices including relative performance (RP), tolerance (TOL)

and drought susceptibility index (DSI) was calculated based on grain yield under water deficit and control conditions. The tolerance indices were calculated by the following formulae:

$$\text{Relative performance (RP)} = \frac{\text{Value of a plant character under water stress condition}}{\text{Value of that character under non stress condition}}$$

(Asana and Williams, 1965)

Tolérance (TOL) = (Yc - Ys), (Hossain *et al*., 1990)

Drought susceptibility index (DSI) = $(1-\text{Ys/Yc})/(1-\overline{Y}_S/\overline{Y}_C)$, (Fischer and Maurer, 1978)

Where,

Yc = the yield of a given genotype in control condition

Ys = the yield of a given genotype in stress condition

$\overline{Y}_S$ = mean yields of all genotypes under control condition

$\overline{Y}_C$ = mean yields of all genotypes under stress condition

Ranking was done based on yield reduction due to water stress. Cluster analysis was also done to classify the 50 soybean genotypes subjected to water stress. It was carried out using non-hierarchical clustering by using SPSS 11.5.

Results and Discussion

Yield and tolerance indices

Pods plant^{-1}, seeds pod^{-1} and 100 seed weight of soybean genotypes in stress environment was significantly less than that in non stress environment (Table 1). Due to water stress the lowest reduction of pods plant^{-1} was occurred in BARI Soybean 6 (38.00%). But in case of seeds pod^{-1} the lowest reduction was in Shohag (4.58). The lowest reduction percent of 100 seed weight was 9.98% which was found in both BARI Soybean 6 and Shohag. Seed yield of all the 50 soybean genotypes grown in water stress environment was significantly lower than that in non-stress environment (Table 2). The highest (79.97%) reduction in seed yield due to water stress was observed in G00085 and the lowest (42.90%) in BARI Soybean 6. Considering tolerance, lower TOL values were recorded in genotypes BD2336 (3.26) followed by MTD459 (3.28), BD2339 (3.38), PK416 (3.6), G00389 (3.72), BD2331 (3.76), Shohag (3.77), G00056 (3.79), BD2335 (3.81), BD2327 (3.87), G00032 (3.87), G00035 (3.92) and BARI Soybean 6 (3.95). The lower the TOL value, the lower was the reduction in grain yield under stress conditions and consequently indicates lower stress sensitivity. But genotypes BD2336, MTD459, BD2339, PK416, G00389, G00056, BD2335, BD2327, G00032, and G00035 exhibited the lower RP but higher DSI.

Table 1. Seed yield attributes of 50 soybean genotypes under non-stressed and water stressed conditions

Genotypes	Pod no. plant⁻¹		Seed no. pod⁻¹		100-seed weight	
	NS	WS	NS	WS	NS	WS
AGS129	43	17.1	2.2	1.75	10.55	8.66
G00389	41	15	2.1	1.74	10	7.9
MTD459	51	23.06	2.4	1.94	9.5	8.4
G00035	40.67	16.26	2.2	1.91	11.56	9.59
G00382	45	14	2.1	1.68	10.22	9.4
G00103	48	18.4	2.1	1.82	12.2	10.56
BARI Soybean 6	52	32.24	2.2	2.08	12.63	11.37
BD2337	45	20.2	2.4	1.93	8.48	7.12
Bangladesh Soybean 4	43	21	2.1	1.68	8.76	7.18
G00032	45	19.3	2.3	1.93	7.2	5.76
BD2338	45	18.5	2.28	1.82	12.03	10.47
BD2355	44	17.2	2.4	2.01	11.28	9.82
BD2327	41	18.57	2.3	2.01	8.56	7.45
BGM 2026	70	24.4	2.3	1.89	6.96	5.28
G00083	41.67	20	2.2	1.93	12.6	10.06
MTD453	52.67	20	2.5	2.16	8.43	7.72
ASET95	48	14.4	2.2	1.76	7.84	6.75

Genotypes	Pod no. plant⁻¹		Seed no. pod⁻¹		100-seed weight	
	NS	WS	NS	WS	NS	WS
G00015	46	21	2	1.86	12.49	10.56
G00084	48	19	2.1	1.81	11	10.12
BD2336	41	20.6	2.5	2.26	7.58	6.28
G00115	39	14	2.35	1.65	9.77	8.04
BGM2093	44	20	2.3	1.98	7.48	6.82
G00056	49	14.7	2.2	1.65	9.56	9.15
Shohag	51	28.2	2.4	2.29	12.02	10.82
BD2331	50	26.3	2.3	2.14	11.68	9.8
BD2329	50	23	2.1	1.83	11.1	9.33
G00127	44.67	19.2	2.2	1.91	11.1	10
G00168	48	20	1.7	1.46	9.2	8.68
BD2324	54	21.85	2.4	2.01	6.84	6
G00167	53	20.14	2.2	1.65	7.96	6.74
G00003	40.93	18.42	2.33	2.03	10.96	9.92
G00157	53	19	2.4	1.92	7.76	7
G00119	48.5	17	2.2	1.93	10.6	9.98
G00209	50	21	2.6	2.4	8.6	7.92

Table 1. Cont'd

Genotypes	Pod no. plant⁻¹		Seed no. pod⁻¹		100-seed weight		Genotypes	Pod no. plant⁻¹		Seed no. pod⁻¹		100-seed weight	
	NS	WS	NS	WS	NS	WS		NS	WS	NS	WS	NS	WS
AGS275	44.63	18	2.3	1.95	10.08	8.87	G00166	52	17	2.4	2.03	9.04	8.96
BD2339	53	19	2	1.68	13.4	11.8	G00163	46	21	2.3	2.1	10.86	8.5
BD2335	42	18	2.4	1.92	9.12	7.03	G00125	48	18	2.2	1.89	8.76	8.46
G00006	47	18	2.3	1.82	8.45	7.39	G00136	52	20	2.3	2	11.92	10.04
PK416	39.91	18	2.3	1.98	8.4	7.56	G00124	50	15	2.4	2.02	8.6	6.97
BD2340	50	20.5	2.2	1.78	11.6	8.7	BD2325	51	22.44	2.3	2.1	7	6.9
G00342	62	25	2.1	1.85	8.4	6.22	G00044	48	18	2.4	2	8.4	6.84
BARI Soybean 5	49	25	2.4	2.19	11.16	9.82	G00085	42	14	2.5	1.75	11.62	9.1
LSD$_{(0.05)}$	9.144	6.768	0.213	0.211	1.038	2.136	LSD$_{(0.05)}$	9.144	6.768	0.213	0.211	1.038	2.136
CV (%)	11.7	11.29	5.83	6.89	6.58	5.38	CV (%)	11.7	11.29	5.83	6.89	6.58	5.38

NS = Non-stressed, WS = Water-stressed.

Table 2. Seed yield and tolerance indices of 50 soybean genotypes evaluated in non-stressed and water stressed conditions

Genotypes	Seed yield (g plant^{-1})		TOL	RP	DSI	Genotypes	Seed yield (g plant^{-1})		TOL	RP	DSI
	NS	WS					NS	WS			
AGS129	6.15	1.5	4.65	0.24	1.12	G00015	6.42	2.4	4.02	0.37	0.93
G00389	5.17	1.45	3.72	0.28	1.06	G00084	7.25	2.54	4.71	0.35	0.96
MTD459	5.05	1.77	3.28	0.35	0.96	BD2336	5.52	2.26	3.26	0.409	0.87
G00035	5.60	1.68	3.92	0.3	1.10	G00115	5.49	1.26	4.23	0.23	1.13
G00382	5.86	1.41	4.45	0.24	1.12	BGM2093	5.97	2.18	3.79	0.36	0.94
G00103	7.51	2.33	5.18	0.31	1.09	G00056	5.84	1.46	4.38	0.25	1.1
BARI Soybean 6	9.27	5.32	3.95	0.574	0.63	Shohag	8.61	4.84	3.77	0.57	0.64
BD2337	6.40	1.71	4.69	0.26	1.09	BD2331	8.20	4.7	3.76	0.57	0.67
Bangladesh Soybean 4	6.64	1.73	4.91	0.26	1.09	BD2329	9.11	3.65	5.46	0.40	0.88
G00032	5.54	1.67	3.87	0.301	1.06	G00127	6.65	2.33	4.32	0.35	0.96
BD2338	7.90	1.8	6.1	0.23	1.13	G00168	7.02	2.17	4.85	0.309	1.02
BD2355	7.63	2.0	5.63	0.26	1.09	BD2324	7.60	2.28	5.32	0.30	1.03
BD2327	5.96	2.09	3.87	0.35	0.96	G00167	7.58	1.89	5.69	0.24	1.12
BGM 2026	9.23	2.74	6.49	0.29	1.05	G00003	6.57	2.3	4.27	0.35	0.96
G00083	6.60	2.39	4.21	0.36	0.94	G00157	6.84	1.84	5	0.27	1.07
MTD453	7.62	2.67	4.95	0.35	0.96	G00119	6.84	2.06	4.78	0.301	1.03
ASET95	6.47	1.56	4.91	0.24	1.12	G00209	8.05	2.82	5.23	0.35	0.96

Table 2. Cont'd

Genotypes	Seed yield (g plant^{-1})		TOL	RP	DSI	Genotypes	Seed yield (g plant^{-1})		TOL	RP	DSI
	NS	WS					NS	WS			
AGS275	6.61	1.99	4.62	0.301	1.03	G00166	7.50	2.2	5.3	0.29	1.05
BD2339	4.69	1.31	3.38	0.27	1.07	G00163	6.85	2.4	4.45	0.35	0.96
BD2335	5.09	1.28	3.81	0.251	1.10	G00125	7.26	1.9	5.36	0.26	1.09
G00006	6.41	1.47	4.94	0.23	1.13	G00136	7.99	2.3	5.69	0.28	1.07
PK416	5.54	1.94	3.6	0.35	0.96	G00124	5.62	1.41	4.21	0.25	1.10
BD2340	8.61	2.49	6.12	0.28	1.06	BD2325	7.12	2.5	4.62	0.351	0.96
G00342	6.85	2.48	4.37	0.36	0.94	G00044	5.95	1.6	4.35	0.27	1.07
BARI Soybean 5	9.18	4.67	4.39	0.51	0.72	G00085	6.99	1.4	5.59	0.20	1.18
LSD$_{(0.05)}$	1.252	1.302	-	-	-	LSD$_{(0.05)}$	1.252	1.302	-	-	-
CV(%)	11.29	3.5	-	-	-	CV(%)	11.29	3.5	-	-	-

NS = Non-stressed, WS = Water-stressed, RP = Relative performance, TOL = Tolerance in the WS in relation to the NS environment, DSI = Drought susceptibility index.

On the contrary, BARI Soybean 6, BD2331, Shohag and BARI Soybean 5 showed higher RP and DSI. The genotypic variation in drought susceptibility index ranged from 0.63-1.18. The DSI for seed yield was the minimum (0.64) in BARI Soybean 6 (0.63) followed by Shohag (0.64) and BD2331 (0.67). The highest DSI (1.18) for seed yield was found in the genotype G00085. Tera'n and Singh (2002) reported that drought resistant lines had relatively low DSI while the drought susceptible lines had high DSI values and grouping of genotypes based on susceptibility index under stress conditions has been widely used and found to be effective to select tolerant genotypes of different crops, such as french bean (Choudhury *et al*., 2012) and soybean (Mannan *et al*., 2012). Based on tolerance indices values recorded in this experiment, the genotypes BARI Soybean 6, Shohag, BD2331 and BARI Soybean 5 could be considered as relatively water stress tolerant compared to rest of the genotypes.

Table 3. Ranking of 50 soybean genotypes on the basis of their yield reduction under non-stress condition

Rank Order	Yield reduction (%) over control (non-stress)	Genotypes(50)
Tolerant	Less than 50.00	BARI Soybean-6, Shohag, BARI Soybean-5, and BD2331 (4)
Moderately Tolerant	50.01-60.00	BD2336, and BD2329 (2)
Moderately Susceptible	60.01-70.00	G00015, and BGM2093 (2)
Susceptible	Above 70.01	AGS129, G00389, MTD459, G00035, G00382, G00103, BD2337, Bangladesh Soybean-4, G00032, BD2338, BD2355, BD2327, BGM2026, G00083, MTD453, ASET95, AGS275, BD2339, BD2335, G00006, PK416, BD2340, G00342, G00084, G00115, G00056, G00127, G00168, BD2324, G00167, G00003, G00157, G00119, G00209, G00166, G00163, G00125, G00136, G00124, BD2325, G00044, and G00085 (42)

Ranking of genotypes

To determine the most desirable drought tolerant genotype, all soybean genotypes were ranked on the basis of their yield reduction due to water stress over non-stress (Table 3). A hypothetical scale was made to categorize the genotypes in different rank order on the basis of yield reduction. According to the yield reduction, genotypes were ranked into four groups as tolerant (less than 50% yield reduction), moderately tolerant (50.01-60.00% yield reduction), moderately susceptible (60.01-70.00% yield reduction) and susceptible (above 70.01% yield reduction). In consideration to yield reduction, four genotypes were found in tolerant group

because they were relatively more productive both under non-stress and water stress conditions, and exhibited low yield reduction due to water stress. Similarly, two genotypes were found moderately tolerant as they gave lower yield than the tolerant ones, but higher yield than the susceptible genotypes. Two genotypes were grouped as moderately susceptible due to higher yield reduction in water stress condition. The rest of forty-two genotypes were ranked in susceptible group due to their very low yielding ability and very high yield reduction.

Table 4. Distribution of fifty soybean genotypes into different clusters subjected to water stress

Cluster	No. of genotypes	Soybean genotypes
I	1	BARI soybean 6
II	3	Shohag, BD2331, BARI soybean 5
III	2	G00342, BGM2026
IV	7	G00115, G00389, G00124, ASET95, G00056, G00085, G00383
V	37	G00083, G00136, G00015 G00084, G00127, G00103, BD2338, G00003, BD2339, BD2335, G00044, G00006, BD2327, PK416, G00157, BD2355, G00119, G00035, AGS275, G00125, AGS129, G00166, MTD459, BD2329, BD2324, BD2325, BD2340, G00163, G00168, MTD453, G00209, BGM2093, G00167, BD2337, BD2336, Bangladesh Soybean-4, and G00032

Grouping of genotypes

Cluster analysis was used for grouping the genotypes for water stress tolerance. Cluster analysis showed that the genotypes, based on relative value of yield of all genotypes tended to group into five groups with 1, 3, 2, 7 and 37 genotypes (Table 4). The first cluster included only one genotype (BARI Soybean 6) which exhibited the highest relative values in its quantitative characters with very low yield reduction and low DSI value under water stress condition (Table 2). This indicated that the genotype BARI Soybean 6 was tolerant to water deficit stress with good productivity both in non-stress and water deficit stress condition. The second cluster included three genotypes namely Shohag, BD2331 and BARI Soybean 5. These genotypes had the second highest relative values in their quantitative characters with moderately low DSI value under water stress condition. This indicates that they were relatively tolerant to water stress with good productivity in water stress and non-stress condition. The third cluster included two genotypes viz. G00342 and BGM2026. These genotypes showed medium relative values in their quantitative characters with medium DSI under water deficit stress condition indicating moderate susceptibility to water stress and high productivity in optimum soil moisture condition. The fourth cluster included seven genotypes, namely G00115, G00389, G00124, ASET95, G00056,

G00085, and G00383 which had low relative values in their quantitative characters with high DSI value under water stress condition indicating high susceptibility to water stress and high productivity in non-stress condition. The fifth cluster included the rest thirty-seven genotypes which showed very low relative values.

Conclusion

Soybean genotypes exhibited a wide variation in seed yield under water stress conditions. Considering degree of different tolerance as measured by different indices the genotypes BARI Soybean 5, BARI Soybean 6, Shohag and BD2331 were found as tolerance to water stress.

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