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GENOTYPIC VARIATIONS IN GROWTH, YIELD AND YIELD COMPONENTS OF SOYBEAN GENOTYPES UNDER DROUGHT STRESS CONDITIONS

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Abstract

A pot experiment was carried out in a venylhouse at Bangabandhu Sheikh Mujibur Rahman University during 2012 to investigate the growth, yield and yield contributing characters of ten selected soybean genotypes viz. Shohag, BARI Soybean-6, BARI Soybean-5, BD2331, BD2329, BD2336, BD 2340, BGM2093, G00015 and BGM2026 under drought stress and control conditions. Plant height, number of leaves, leaf area, shoot and root dry weight of all the genotypes were significantly affected by the stress. Among the genotypes Shohag, BARI Soybean-6 and BD2331 were found tolerant in relation to the growth under water stress conditions. The reduction in RGR values was more in the susceptible genotypes at the later stages of growth than in the tolerant genotypes. Seed yield of the genotypes was reduced from 42 to 68% due to drought (water) over non-stress. Susceptible genotypes showed greater reduction in seed yield than the tolerant genotypes.

Introduction

Soybean, a grain legume, is one of the most important oilseed crops of the world. It is the world's leading economic oilseed crop (Manavalan *et al.,* 2009). It is also an important source of plant protein of the people in semi-arid and tropical regions. It has a great value as food, feed and fuel. The production of the crop is often limited by the erratic nature of rainfall. It is reported that water stress affects soybean production worldwide. Among the crops, soybean has the highest sensitivity to drought (Maleki *et al.*, 2013). Drought may reduce yield of soybean by about 40% (Specht *et al*., 1999).

In Bangladesh, soybean is planted during post-monsoon when stored soil moisture rapidly declines and the crop encounters drought at the reproductive stage. Plant growth is affected by moisture stress including leaf expansion which is reduced due to sensitivity of cell growth to water stress. Reduction in leaf area reduces crop growth and thus affects biomass production (Brown *et al*., 1985). Shoot biomass accumulation is considered an important trait to attain high seed

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yield in grain legumes (Saxena *et al*., 1990). Significant differences have been observed for shoot and root biomass accumulation among soybean cultivars grown under severe drought stress. Root have an essential role in tolerating drought as they are the main organs responsible for sourcing valuable water (Eureka *et al*., 2000). Yordanov *et al.*, (1997) claimed that water stress reduces the biomass, seed yield, number of pods in main stem, pod and seed number per plant.

The objective of this study was to assess the morphological growth parameters of ten soybean genotypes subjected to drought stress at different growth stages and to identify the genotype that is most sensitive and most tolerant to water stress.

Materials and Methods

The experiment was conducted in a venylhouse constructed at the Environmental Stress Research Site in Agronomy farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during February to May 2012. Six relatively tolerant soybean genotypes viz., Shohag, BARI Soybean-6, BARI Soybean-5, BD2331, BD2329 and BD2336 and four susceptible viz, BD2340, BGM2093, G00015 and BGM2026 altogether selected from the previous experiment which were grown in plastic pots. The soil of the pot was filled with mixture of soil and cow dung at a ratio of 4:1. Pot contained 12.0 kg of soil which was equivalent to 9 kg oven dry soil and holds about 28% moisture at field capacity (FC). Soil use in the plastic pot was sandy loam and 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 NPK and S hectare^{-1}, respectively. Total amount of all fertilizers were mixed with soil before the sowing of seeds.

Six seeds of each genotype were sown in each pot on 2 February 2012 and later thinned to three healthy seedlings per pot. Most of the seedlings emerged within 7 days after sowing. Plants of each pot received adequate watering regularly to maintain optimal soil moisture until the water stress treatment was imposed. Adequate plant protection measures were taken to keep the plants free from diseases, insects and weeds through the growing season.

Plants of all the genotype were subjected to two levels of water regime viz., S_0 = Non-stress (Control); water was applied as and when it is required and Sw = Drought stress (Water stress) throughout the growing period; pots were irrigated with water at 50% field capacity at appearance of wilting symptom. The experiment was laid out in a Completely Randomized Design with four replications. Three plants pot^{-1} considered as one replication. After 21 days after emergence (DAE), water stress treatments were applied.

Total dry matter of shoot and root was measured at different growth stages (vegetative, flowering and pod filling stages) by oven drying at 70^0C to a constant weight. For each and every sampling of all treatments four times number of replicated pots were maintained. Roots were washed thoroughly in tap water and blotted dry before drying. The leaf area plant^{-1} was measured with an automatic area meter (Model AAM-8, Hayashi denko, Japan) at vegetative, flowering and pod development stages. Yield and yield components were also determine at harvest. Relative growth rate (RGR) was calculated by using the following formula (Gardner *et al*., 1985):

$$RGR = \frac{LnW_2 - Ln\ W_1}{T_2 - T_1} \quad gg^{-1}day^{-1}$$

Where, W_1 = dry weight of plant at time T_1

W_2 = dry weight of plant at time T_2

Ln = natural logarithm

Yield contributing characters viz. number of pods plant-1, seeds pod-1, 100 seed weight and seed yield were measured at harvest. The recorded data were analyzed by 'MSTAT-C' statistical package. The difference between the treatments means were compared by Least Significant Difference (LSD) test (Gomez and Gomez, 1983).

Results and Discussion

Plant height

Drought significantly decreases the plant height of soybean genotypes. Plant height of ten soybean genotypes showed significant differences under both non-stress (NS) and water stress environments at all the growth stages (Table 1.). Under NS environment, BGM2026 produced the maximum plant height (50.42 cm) at vegetative stage which was followed by BARI Soybean-5 and G00015 but under water stress environment, BD 2331 obtained the maximum plant height (41.63 cm) which was identical with BGM2026. The shortest plant was recorded from BGM2093 (32.84 cm) under water stress condition. But from flowering stage to maturity, all the genotypes under non-stress environment produced significantly taller plants than that under water stress environment. The genotype BGM2026 attained the maximum height at non-stress environment but under water stress environment, BARI Soybean-6 produced the tallest plant followed by Shohag. Under water stress environment, BGM2026 was affected severely which produced the shortest plant. It was also observed that irrespective of genotype, plant height changed with the advancement of growth stages in both the environments. Plant height `increased sharply from vegetative to pod development stage and thereafter slowly up to maturity stage. Reduction in plant height was more at maturity stage irrespective of genotypes.

Table 1. Plant height at different growth stages in soybean genotypes under non-stress and water stress conditions.

Genotypes	Plant height (cm)							
	at vegetative stage		at flowering stage		at pod development stage		at maturity stage	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
Shohag	43.76	35.06	63.28	53.2	68.83	55.4	75.97	60.87
BD2329	42.35	33.03	62.1	51.97	70.12	55.31	74.22	57.2
BARI Soybean-5	49.39	35.77	64.56	50.59	69.75	54.17	77.31	59.27
BARI Soybean-6	45.57	40.35	67.6	55.11	74.67	59.22	78.74	64.51
BD2340	41.42	38.8	57.43	47.94	72.95	52.97	75.55	54.8
BD2336	44.74	39.57	58.18	45.44	73.54	52.04	76.68	58.63
BGM2093	39.27	32.84	54.58	46.67	71.85	53.5	78.38	57.32
BD2331	45.85	41.63	68.03	52.1	75.8	55.94	77.33	58.75
G00015	48.21	39.62	68.5	50.2	72.71	56.71	75.72	57.21
BGM2026	50.42	40.7	74.06	44.5	86.67	47.67	92.45	49.8
$LSD_{(0.05)}$ SxG	NS		NS		9.917		6.136	
CV%	9.58		9.86		9.38		5.46	

S=Stress, G=Genotypes, NS=Not significant

At maturity stage extent of plant height reduction under two moisture regimes are presented in Fig. 1. The reduction percent in plant height was found minimum in BARI Soybean-6 (18.07% reduction) and maximum in the genotype BGM2026 (46.13%) due to water stress. The differences in plant height reduction among the genotypes mainly due to genotypic differences. Water stress induced reduction in plant height was also observed by Khan *et al.* (2014) in soybean. The decrease in plant height could be resulted from a reduction in plant photosynthetic efficiency as reported by Hamid *et al*. (1990). It also might be due to decrease in relative turgidity and dehydration of protoplasm which is associated with a loss of turgor and reduced expansion of cell and cell division (Arnon, 1972).

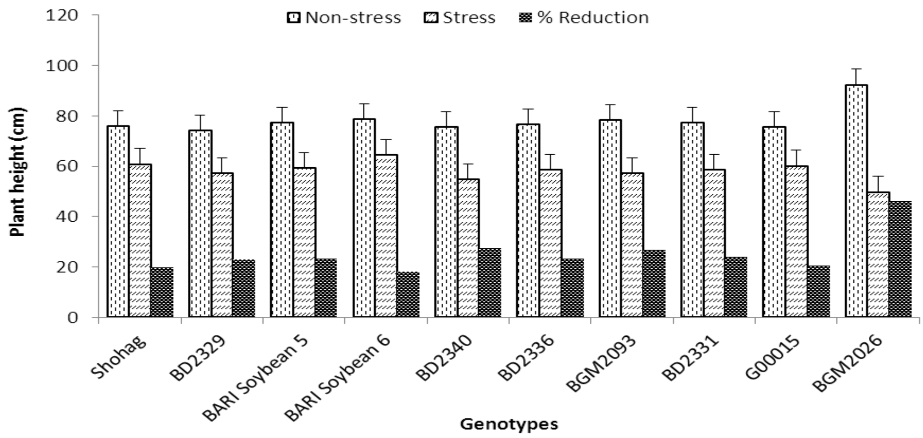

Fig 1. Extent of plant height reduction at maturity under non-stress and water stress environments of 10 selected soybean genotypes. (Vertical bar represent LSD value at 5% level of significant.)

Table 2. Leaf number at flowering and pod development stages in soybean genotypes under non-stress and water stress conditions.

Genotype	Total leaf number					
	Flowering stage			Pod development stage		
	Non-stress	Water stress	% reduction	Non-stress	Water stress	% reduction
Shohag	25	20	20	30	22	26
BD2329	24	18	25	29	20	31
BARI Soybean-5	26	18	30	34	22	35
BARI Soybean-6	26	22	15	28	23	17
BD2340	24	17	29	30	21	30
BD2336	23	14	39	28	16	42
BGM2093	22	14	36	29	17	41
BD2331	24	17	29	28	18	35
G00015	19	13	31	26	17	34
BGM2026	29	14	51	37	15	59
$LSD_{(0.05)}$ S×G	NS			5.513		
CV%	15.23			13.44		

S= Stress, G= Genotype, NS=Not significant

Leaf number plant^{-1}

Decrease in leaf number was observed at two growth stages under water stress environments (Table 2.). Genotypic variations in number of leaves were also found under both non-stress and water stress environment. In all the genotypes decrease in leaf number was higher at pod development stage, than that at flowering stage. Water stress condition reduces the leaf number because drought stress reduces leaf initiation and accelerates leaf senescence. At flowering stage, reduction percent varied from 15 to 51%, whereas it was 17 to 59 % at pod development stage. Razakou *et al*. (2013) observed 5 to 64% reduction in leaf number in cowpea. Under water stress condition, lowest number of leaf was found in BGM2026 genotype but at non-stress condition, it produced the highest number of leaf. Due to water stress the less affected varieties were BARI Soybean-6 and Shohag. Reduction in leaf number occurred may be due to less number of leaf initiation (Thrikawela, and Bandara, 1992)

Leaf area

Reduction in leaf area is convenient morphological parameters for measuring drought stress experienced by the plant (Ku *et al*., 2013). Water stress significantly reduced the total leaf area. Under stress, drought tolerant soybean cultivars exhibited a larger leaf area when compared with less tolerant cultivars (Moreira *et al*., 2010). Leaf area of ten soybean genotypes at different growth stages under non-stress and water stress environments showed significant differences (Table 3.). At vegetative stage, the reduction of leaf area varied from 8.04 to 22.63% and reduction percent does not show any trend among tolerant and susceptible genotypes. But at the later stages of growth these situations were changed. With the advancement of growth the susceptible genotype showed the higher reduction than tolerant genotypes. Under non-stress condition highest leaf area was found in BGM2026 at both flowering and pod development stages but not under stress condition. Under stress condition Shohag produced the highest leaf area. In case of reduction percent BGM2026 showed the highest reduction and BARI Soybean-6 showed the lowest reduction in leaf area at both flowering and pod development stages. Less leaf expansion, leaf growth reduction and leaf senescence acceleration might be responsible for lower leaf area. Khan *et al*. (2014) in soybean and Samson and Helmut (2007) in cowpea reported earlier that water deficit stress reduced significantly the total leaf area. Krishnamoorthy (1993) reported that water stress causes a reduction in the size of leaves as because cell division in the leaf primordial ceases due to water stress. According to Ludlow and Muchow (1990) reduced leaf growth and accelerated leaf senescence is common responses to water deficits and the parameters both reduce leaf area.

Table 3. Leaf area at different growth stages in soybean genotypes under non-stress and water stress conditions

Genotypes	Leaf area (cm^2 $plant^{-1}$)					
	Vegetative stage		Flowering stage		Pod development stage	
	Non-stress	Water stress	Non-stress	Water stress	Non-stress	Water stress
Shohag	728.78	650.54 (10.73)	1043.0	823.97 (21.0)	1204.7	875.69 (27.31)
BD2329	669.21	530.01 (20.8)	936.12	655.67 (29.95)	1164.02	737.66 (36.62)
BARI Soybean-5	674.24	598.91 (11.17)	1027.79	793.96 (22.75)	1212.22	842.37 (30.51)
BARI Soybean-6	616.45	566.86 (8.04)	879.96	747.09 (15.09)	1159.4	862.25 (25.62)
BD2340	638.59	581.11 (9.0)	904.73	653.91 (27.72)	1200.3	733.98 (38.85)
BD2336	665.66	515.02 (22.63)	928.77	606.82 (34.66)	1035.28	630.11 (39.13)
BGM2093	551.96	502.15 (9.02)	902.9	565.58 (37.35)	1179.27	636.64 (46.01)
BD2331	641.32	561.67 (14.18)	895.79	688.06 (23.18)	1081.37	730.79 (32.41)
G00015	582.0	497.09 (14.58)	710.97	527.82 (25.76)	897.4	593.89 (33.82)
BGM2026	735.78	539.61 (26.66)	1066.19	560.57 (52.48)	1311.13	577.98 (55.91)
$LSD_{(0.05)}$ SxG	47.81		64.07		78.78	
CV%	4.74		4.87		5.11	

S=Stress, G= Genotypes

Value in the parentheses represents the percent reduction of the parameters under water stress over non-stress.

Shoot and root dry weight

Due to water stress the reduction in shoot dry weight was not significant at vegetative stage in any genotype. But numerically, reduction was higher in G00015 followed by BGM2026 at vegetative stage (Figs. 2). At this stage BD2336 produced more shoot dry weight under stress condition than non-stress condition (Fig: 2). At flowering or pod development stage the reductions were conspicuous in all the genotypes due to water stress. A large reduction in

shoot dry weight was found in the genotype BGM2026 which was 33.65% at flowering, 48.29% at pod development and 58.98% at maturity stage. On the contrary, the shoot dry weight of tolerant genotypes Shohag, BARI Soybean-6, BARI Soybean-5 and BD2331 were affected the least by the stress. A similar finding was observed by Khan *et al*. (2014) in soybean, Eureka *et al*. (2000) and OO *et al*. (2008) in mungbean. Leaf area has been frequently reported to have a close relationship with crop growth (OO *et al*., 2008; Anyia and Herzog, 2004). The decrease in leaf area (Table 3) by the WS condition was closely related to the shoot dry weight (Figs. 2). This means that tolerant genotypes having a better sustainability in producing more leaf area to keeping a high shoot dry weight under WS condition.

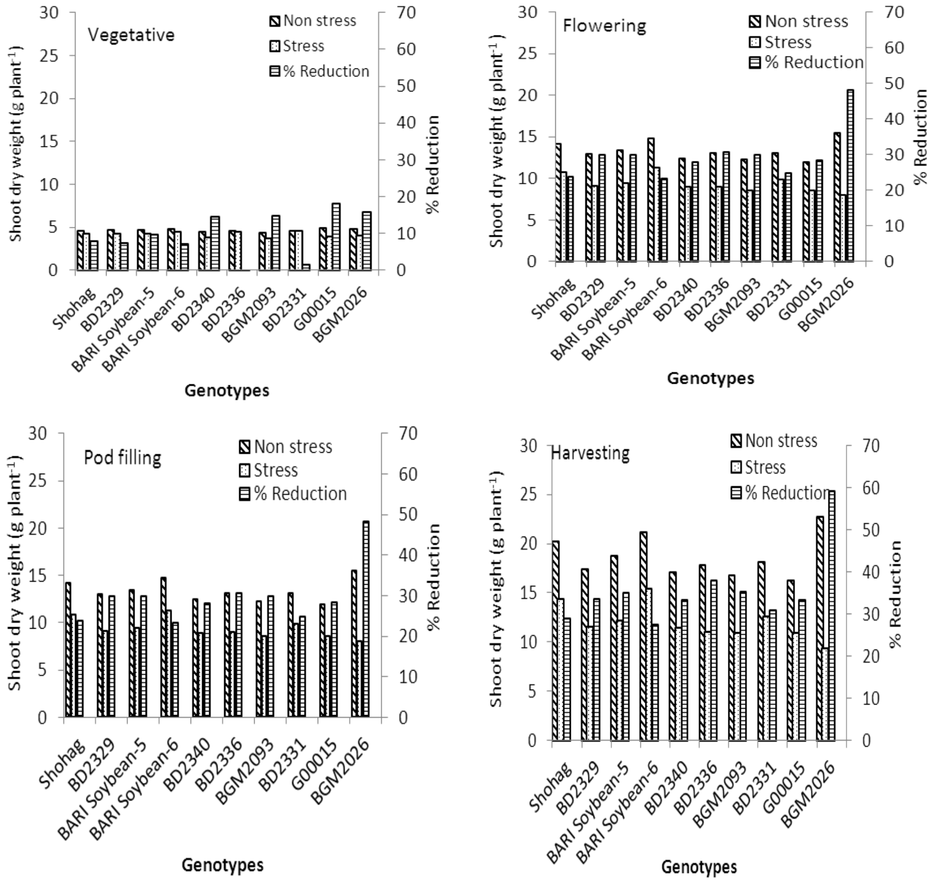

Fig. 2. Dry weight and reduction percent of shoot of 10 selected soybean genotypes at different growth stages under non-stress and water stress conditions.

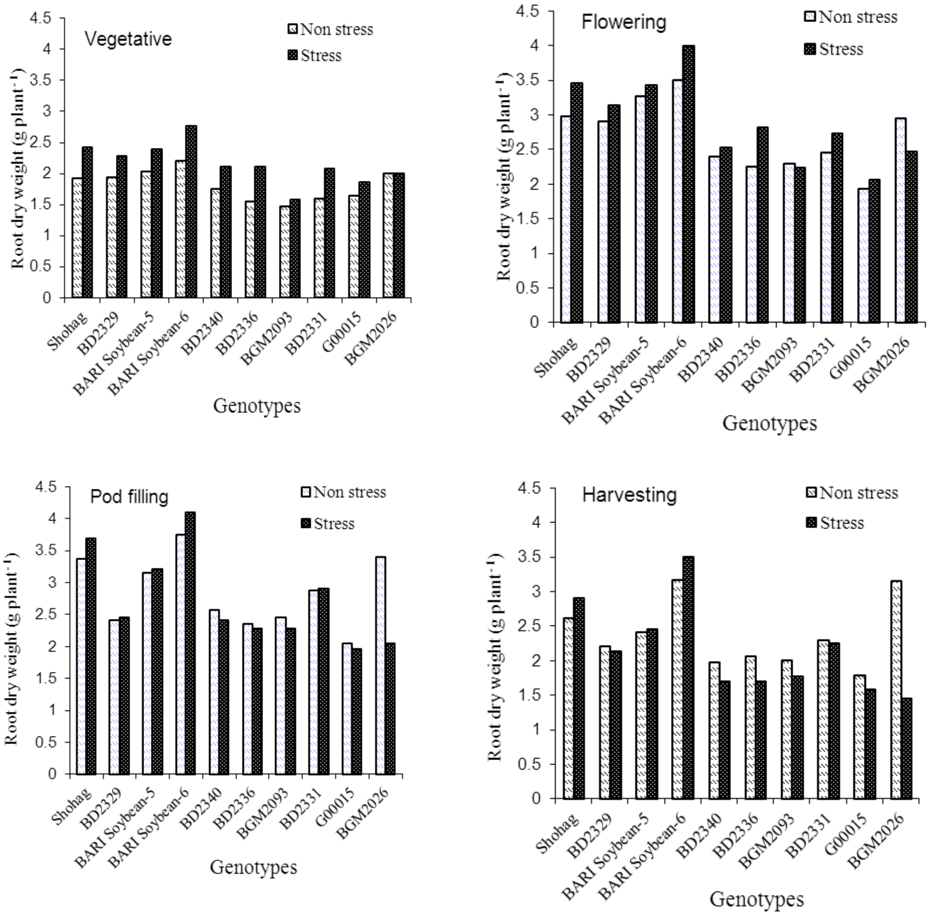

Fig. 3. Root dry weight of 10 selected soybean genotypes at different growth stages under non-stress and water stress conditions

At vegetative stage a remarkable increase in root dry weight was observed in all the genotypes under stress and non-stress conditions (Fig. 3). But root dry weight decreased under WS environment in BGM2026, BD2336, BD2340, BGM2093 and G00015 at pod development stage and onwards. At all the growth stages the genotypes Shohag and BARI Soybean-6 maintained higher root dry weight under water stress environment over non-stress. Islam *et al*. (2004) reported that root dry weight of bushbean measured at harvest remarkably increased with the decrease in the moisture level. Eureka *et al*. (2000) observed that reduction in root dry matter occurred in susceptible genotypes but tolerant genotype were able to maintain their root dry weight under drought at the level of the respective control values. The water uptake was limited by the amount of roots, and the enhancement of root growth could increase drought resistance (Klepper and

Rickman, 1990). Increase in root biomass of water stressed genotypes may be due to ability to divert assimilates to enhance the growth of the roots so as to exploit deeper parts of the soil water (Razakou *et al*., 2013). Maintenance of root growth during water deficit is an obvious benefit to maintain an adequate plant water supply, and is under genetic control (Sponchiado *et al*., 1989). The higher value of root dry weight and less suppressed in shoot dry weight were shown in Shohag and BARI Soybean-6 that might be related to drought resistance (Fig. 3).

Relative growth rate (RGR)

Relative growth rate of all genotypes decreased with the advancement of growth stages at both the moisture regimes (Fig. 4). The RGR recorded in soybean genotypes were always higher in control than under water stress condition. Under water stress condition genotypes BD2336, BGM2093, G00015, BD2340 and BD2329 maintained relatively higher RGR at the early growth stages but at later stage higher RGR was maintained in Shohag, BARI Soybean-5,

BARI Soybean-6 and BD2331. At the later stage of the growth, the value of RGR of BGM2026

was more inhibited compared to other genotypes under water stress environment. The highest value of RGR in Shohag, BARI Soybean-5, BARI Soybean-6 and BD2331 under water stress

was an indication of their drought tolerance, while the lowest value of RGR in the genotype BGM2026 and BD2336 indicated their drought susceptibility. A similar finding was reported by Lizana *et al*. (2006) and Costa-Franca *et al*. (2000) in common bean.

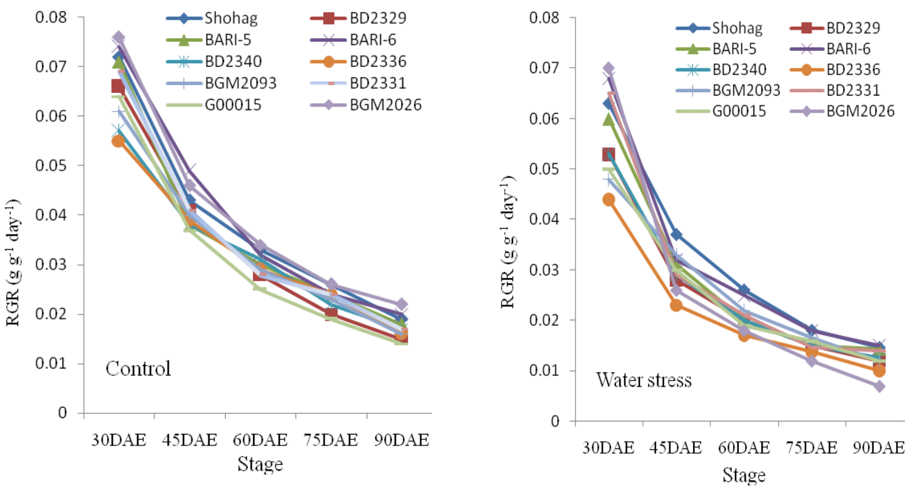

Fig 4. Relative growth rate of ten soybean genotypes at different growth stages under non-stress and water stress conditions

Seed yield and yield contributing characters

Water stress caused significant differences in pods plant^{-1}, seeds pod^{-1} and seed size of soybean genotypes (Table 4 and 5). The highest number of pod plant^{-1} was found in BGM2026 (59.25) which significantly differed from all other genotypes under non-stress environment. Under water stress condition, the maximum number of pod plant^{-1} (30.65) was obtained from BARI Soybean-6, which was statistically identical with Shohag, and BD2331. The rate of reduction was ranges from 31.37 to 55.88% the lowest where was in BARI Soybean-6 followed by BD2331 and Shohag (Table 4). The reduction in pod number plant^{-1} due to WS was reported earlier in french bean (Omae *et al*., 2005), in soybean (Kokubun *et al*., 2001; Liu *et al*., 2004) and in mungbean (Islam, 2008). The highest number of seeds pod^{-1} was observed in the genotype BGM2093 and the lowest from BARI Soybean-5 in both the environment. The genotype BGM2026 also produced the least number of seed pod^{-1} under water stress condition but not in non-stress condition. The rate of reduction varied from 2.65 to 20.43% under water stress over non-stress environment across the genotypes. The maximum reduction of seeds pods^{-1} (Table 4) was obtained from genotype BGM2026 (20.4%) followed by genotypes BD2331 (11.36%). However, the reduction rate was the lowest in BARI Soybean-5 (2.66%). In case of seed size the rate of reduction varied from 14.06 to 26% across the genotypes. The highest 100-seeds weight was found in G00015 at both the environments but its reduction percent was high. Lowest reduction occurred in Shohag followed by BARI Soybean-6 and BD2331. The genotype BGM2093 had the smallest seed size at both the environments.

Water stress-induced yield reduction has been reported in many crop species (Farooq *et al*., 2009). Seed yield plant^{-1} was reduced by water stress in all the soybean genotypes studied (Table 5). The rate of reduction ranged from 42.68 to 68.96% across the genotypes. The seed yield plant^{-1} under non-stress environment was the highest in genotype BARI Soybean-6 followed in decreasing order by BARI Soybean-5, BD2329, BGM2026, Shohag, BD2331, BD2340, G00015, BGM2093, and BD2336 genotypes. Pod number plant^{-1} and 100-seed weight might be responsible for highest seed yield in BARI soybean-6 and lowest in BD2336. Under water stress, the highest seed yield plant^{-1} was also obtained from BARI Soybean-6 followed in decreasing order by Shohag, BD2331, BARI Soybean-5, BD2339, BGM2026, BD2340, G00015, BD2336 and BGM2093. The reduction in seed yield was primarily due to a decrease in pod number plant^{-1}. The decrease in pod number plant^{-1} and seed size under drought stress was possibly due to reduction of photosynthesis, translocation of assimilates and increased rate of reproductive organs abortion (Kukubun *et al*., 2001; Liu *et al*., 2003 and 2004; Tera'n and Singh, 2002). The number of seeds pod^{-1} and seed weight were reported to be more stable and less affected by environmental stress (Tera'n and Sigh 2002).

Table 4. Number of pods plant^{-1} and seeds pod^{-1} in soybean genotypes under non-stress and water stress condition.

Genotypes	Pods plant^{-1} (no.)			Seeds pod^{-1} (no.)		
	Non-stress	Water stress	% Reduction	Non-stress	Water stress	% Reduction
Shohag	44.16	29.57	33.03	2.25	2.15	4.44
BD2329	40.25	22.13	45.01	2.2	2.1	4.54
BARI Soybean-5	42.6	25.95	39.08	1.88	1.83	2.65
BARI Soybean-6	44.66	30.65	31.37	2.2	2.0	9.09
BD2340	41.5	19.14	53.87	2	1.92	4.00
BD2336	44.58	24.96	44.01	2.3	2.2	4.34
BGM2093	49.25	25.11	49.01	2.5	2.3	8.00
BD2331	42.16	28.44	32.54	2.2	1.95	11.36
G00015	25.66	12.08	52.92	2.25	2.04	9.33
BGM2026	59.25	26.14	55.88	2.3	1.83	20.43
$LSD_{(0.05)}$ SxG	9.585			NS		
CV%	16.88			7.14		

S= Stress, G= Genotype, NS=Not significant

Table 5. 1000-seeds weight and seed yield plant^{-1} of soybean genotypes under non-stress and water stress condition.

Genotypes	1000-seeds weight (g)			Seed Yield plant^{-1} (g)		
	Non stress	Water stress	% Reduction	Non stress	Water stress	% Reduction
Shohag	110.2	90.6	14.28	8.62	4.79	44.43
BD2329	110.3	80.8	22.12	9.11	3.38	62.90
BARI Soybean-5	120.1	100.0	17.35	9.18	4.67	49.12
BARI Soybean-6	110.9	100.2	14.28	9.22	5.17	43.92
BD2340	110.3	90.05	19.91	7.99	2.48	68.96
BD2336	60.08	40.86	20.06	5.52	2.18	60.50
BGM2093	50.89	40.53	23.08	5.97	2.18	63.48
BD2331	90.88	80.49	14.06	8.2	4.7	42.68
G00015	130.9	100.4	25.17	6.42	2.22	65.42
BGM2026	70.5	50.55	26	9.1	3.05	66.48
$LSD_{(0.05)}$ SxG	NS			0.5305		
CV%	6.49			5.63		

S= Stress, G= Genotype, NS=Not significant.

Conclusion

The results of the study indicated that the ten genotypes showed marked variations in plant growth characters, yield and yield attributes under water stress condition. Genotypes Shohag, BARI Soybean-6 and BD2331 were relatively water stress tolerant than others in respect of physiological adaptation associated with yield attributes and seed yield under water stress condition.

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