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YIELD RESPONSE OF SOYBEAN (*Glycine max* L.) GENOTYPES TO WATER DEFICIT STRESS

Afsana Mimi[1], M. A. Mannan[1*], Q. A. Khaliq[1] and M. A. Baset Mia[2]

[1]Department of Agronomy, [2]Department of Crop Botany
Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.
[*]Corresponding author: mannanbsmrau@yahoo.com

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Abstract

An experiment was carried out at research field of Agronomy, Department of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur from December 2013 to April 2014. Four soybean genotypes viz. i) G 00022 ii) Galarsum iii) BARI Soybean-5 and iv) G 00197 were grown in the field to evaluate the effects of water deficit stress on dry matter accumulation and yield. Plants were subjected to water stress that is irrigation was withdrawn at Blooming stage (R1) and Full Pod (R_4 stages up to maturity. Dry matter accumulation, yield and yield components were reduced by the soil water deficit stress and reduction was higher at R_1 stage than R_4 stage of water stress. Among the genotypes, G 00022 showed the highest tolerance, while G 00197 was highly susceptible in all the water stress conditions. It was found that higher water deficit stress tolerance in G 00022 was associated with higher accumulation of leaf, stem, root and total dry matter under water stress condition.

Introduction

Soybean (*Glycine max* L.) is the world's most important grain legume crop in terms of total production, consumption and international trade. The oil which is 20% of the seed is high in essential fatty acids and devoid of cholesterol and constitutes more than 50% of the world's edible vegetable oil in trade (Ogundipe and Weingartner, 1992). It is an important grain legume because of its high protein (35%), and nitrogen fixing ability (17-127 kg N ha^{-1} $year^{-1}$) (Messina, 1997). Soybean is inherently more stress tolerant (Singh *et al.,* 2003) than other legume crops but it still suffers considerable damage due to drought stresses in different regions where rainfall is scanty or irregular and irrigation facility is unavailable like north western region of Bangladesh. Water stress is an abnormal condition where there is a lack of sufficient water to meet the normal needs of agriculture which causes drought hazards ultimately. Bangladesh is at higher risk from droughts and faces unpredictable water stress due to inadequate and uneven rainfall. So, selection of water deficit stress tolerant crop cultivar among the available genotypes and their introduction to water stressed area or drought prone areas may become a worthy effort to utilize these lands of Bangladesh. Low intake of proteins and fats results in malnutrition, and is therefore, soybean can be considered a functional food crop for the people of developing countries like Bangladesh and might be a worthy effort to utilize drought prone north western regions of Bangladesh to meet up the country's food and nutritional deficits. So, the aim of the present study was to identify relatively water deficit stress tolerant soybean genotypes for drought prone areas of Bangladesh.

Materials and Methods

The experiment was conducted in the Agronomy field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur from December, 2013 to April, 2014. The soil is characterized by silty-clay with pH value of 6.5. Four soybean genotypes G00022, Galarsum, BARI Soybean 5 and G00197 were used in this experiment which was screen out from 50 genotypes at seedling stage water deficit stress condition in previous experiment. The plot was first opened by moldboard plough. Subsequently, it was prepared by deep and cross ploughing and harrowing followed by laddering. The unit plot size was (1.5 m x 2.0 m). The manures and fertilizers were applied as recommended by Mandal *et al.* (2011). Cowdung and all other chemical fertilizer + 1/2 urea were applied as basal. Rest of urea was applied at 25 days after sowing. During sowing, firstly seeds were treated with provex-200 @ 2.0 g kg^{-1} seed for an hour before sowing. The seeds were covered with pulverized soil just after sowing and gently pressed with hand and light watering was done in the line just to supply sufficient moisture need for quick germination. Three different treatments were applied- (i) Control: Irrigation plot, (ii) Water deficit stress 1: Irrigation was withdrawn at R_1 (beginning flowering) stage up to maturity and (iii) Water deficit stress 2: Irrigation was withdrawn at R_4 (full pod) stage up to maturity. The experiment was laid down in split plot design with 3 replications. The crop was protected from the attack of insect pests by spraying of Darsban 20 EC @ 5.0 ml L^{-1} of water and disease was controlled by applying Dithane M-45 @ 2.0 g L^{-1} of water at the base of the plants. At maturity, five plants from each plot were collected and sampled and data on dry weight of leaf, stem, root, total dry weight, as well as yield and yield contributing characters were recorded. Seed yield was adjusted to 12% moisture content. Grain yield was recorded on the basis of total harvested seeds $plot^{-1}$ and was expressed the grain yield in t ha^{-1}. The data recorded on different parameters were statistically analyzed with the help of MSTAT-C program and the difference between the treatments means were compared by LSD test (Gomez and Gomez, 1984).

Results and Discussion

Leaf dry matter

Significant genotypic variation in leaf dry matter accumulation was noticed under water deficit stress conditions (Figure 1). Leaf dry weight was decreased due to water deficit stress in all the genotypes studied and decreasing rate was higher when plants were subjected to water stress at R_1 stage than R_4 stage. But in both stages of R_1 and R_4, G00022 maintained highest relative leaf dry weights which are 77.7 and 81.1%, respectively. At R_4 stage under water deficit stress condition, highest relative leaf dry weight was found in genotype G00022 (81.1%) and it was lowest in G00197 (51.4%). Compare to water stress at R_4 stage, a significant reduction in leaf dry matter in R_1 stage between genotypes was observed (Fig. 1). Compared to control plant a minimum reduction in leaf dry matter was recorded at R_1 stage in G 00022 (22.3%), whereas the maximum reduction was recorded in G00197 (54.1%). Water deficit stimulates leaf abscission as drought stress has been reported to induce production of ethylene in a variety of species (Kacperska and Kubacka-Zebalska, 1989). Though the resulting decrease in leaf area is one of the mechanisms of moderating water loss from the crop canopy and averting excessive drought induced injury to the plant; this may lead to a decrease in leaf dry matter production due to reduction in photosynthetically active leaf area (Vurayai *et al.*, 2011). The genotype G00022 through its capacity of minimum reduction in leaf dry matter actually maintained better photosynthetic tissue under water stress conditions.

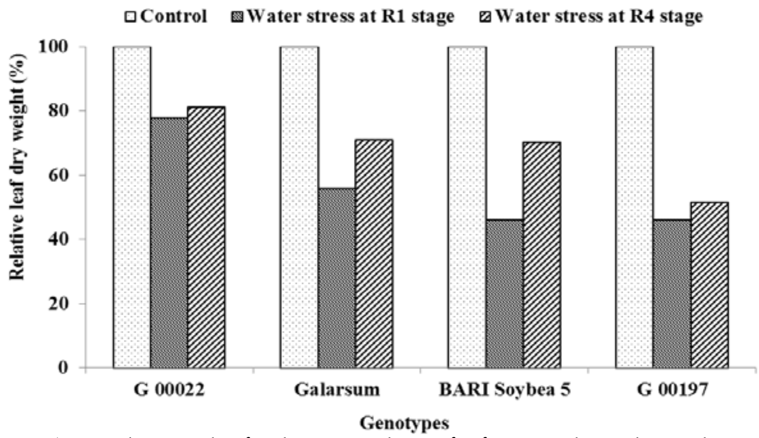

Fig. 1. Relative leaf dry weight of four selected soybean genotypes as affected by water deficit stress

Stem dry matter

Water deficit stress significantly decreased stem dry matter accumulation in all the soybean genotypes at both R_1 and R_4 stages stress (Fig. 2) and the reduction was higher at R_1 stage. The different genotypes showed different relative values (compared to control) of stem dry mass under water deficit stress conditions. At R_1 stage water stress G 00022 produced the highest (57.61%) stem dry mass at maturity, while G00197, BARI soybean 5 and Galarsum produced only 47.20, 38.31 and 35.58% stem dry matter, respectively (Fig. 2). Stem dry mass reduction was the lowest in G00022 among the genotypes. In addition to reduced node m^{-2}, drought stress during the flowering period retards early ovary expansion because of reduced photosynthetic supply (Liu *et al.,* 2004). The period from 10 days before R_1 to 10 days after R_1 is the critical period. On the other hand, Frederick *et al.* (2001) stated that drought stress treatment had no effect on branch number per m^2 measured at flowering but had a large effect on the final number of branches formed. This disagreement may be due to the different environmental conditions and the different soybean cultivars used in the experiments.

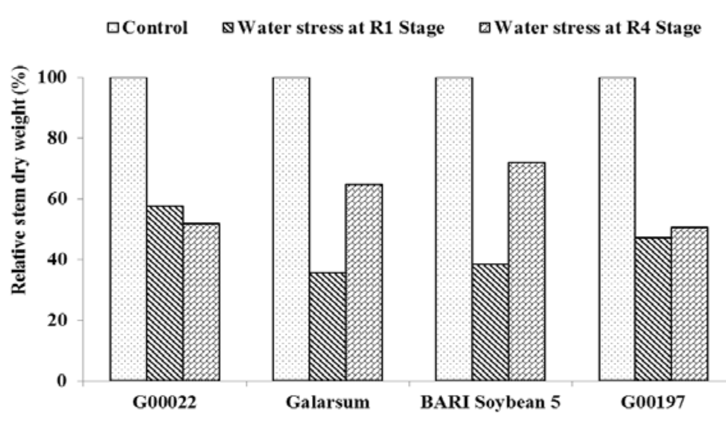

Fig. 2. Relative stem dry weight of four selected soybean genotypes as affected by water deficit stress

Root dry matter

Root dry matter was also significantly reduced by water deficit stress at R_1 and R_4 stages in all soybean genotypes (Fig. 3) and reduction was higher at R_4 stage of water stress compared to R_1 stage of water stress. The highest relative root dry matter (73.56%) was produced by genotype G 00022 and the lowest (40.11%) in G00197 at R_4 stage of water stress. Root growth of other genotypes under water deficit stress conditions was more than 50% at R_1 stage of water stress (Fig. 3). The reduction in root dry matter is probably due to reduction in dry matter of both tap root and adventitious root as a result of a reduction in root length and branching. The better root growth under water deficit condition can be considered as the capacity of the genotype G 00022 to combat the immediate adverse effect of water stress and presumably contributed to higher shoot growth under the stress conditions. Silvius *et al.* (1977) found a decreased dry weight of roots and shoots in response to drought imposed during both vegetative and reproductive stages of soybean.

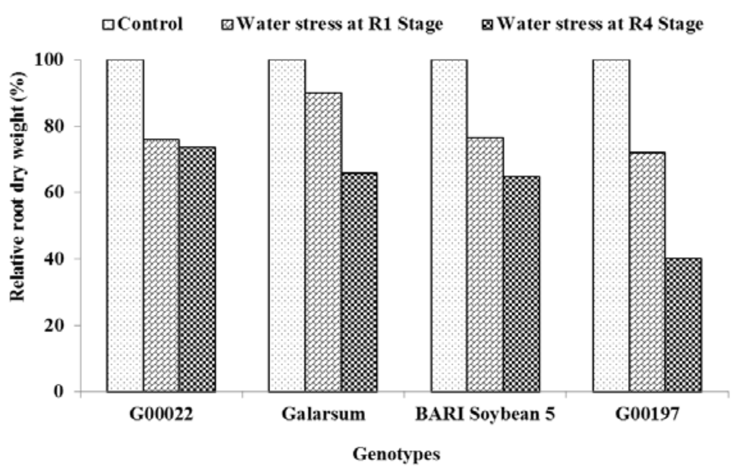

Fig. 3. Relative root dry weight of four selected soybean genotypes as affected by water deficit stress

Total dry matter

Total dry matter production is decreased with increasing soil moisture deficits. Both R_1 and R_4 stages of water deficit affected significantly the total dry matter production in all the soybean genotypes studied. Total dry matter reduction due to water deficit stress was higher at R_1 stage than that at R_4 stage (Fig. 4). De Costa and Shanmugathasan (2002) reported that maximum total biomass increased significantly with the number of stages irrigated, with irrigation during the vegetative stages having the highest positive effect and found that water stress significantly decreased the total dry matter production. Lisar *et al.* (2012) reported that the impacts of water deficit stress in crop plants can reduce productivity by 50% in various parts of the world. Water stress induced differences in total dry matter production among the genotypes were caused by the differences in the reduction of root, leaf and stem dry matter over their control. The dry matter reduction in moderately tolerant and moderately susceptible genotypes was in between this minimum and maximum range. The total dry matter in genotype G 00022 was less affected even at R_1 stage water stress, which could be attributed to more efficient production of leaf, stem, and root dry matter. Water stress generally reduced the growth of plant components resulting in lesser total dry weight (TDW). Abo El-khier *et al.* (1994) found that water stress decreased significantly plant height, number of leaves and branches, total leaf area and dry weight of shoots per plant of soybean cultivars.

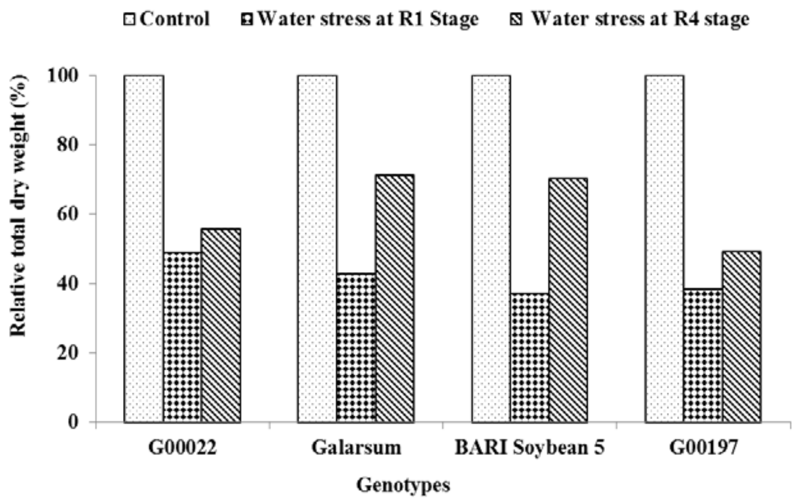

Fig. 4. Relative total dry weight of four selected soybean genotypes as affected by water deficit stress

Number of pod

Water deficit stress significantly reduced the number of pods plant^{-1} compared to that in control in all the four soybean genotypes studied. The reduction was small at R_4 stage of water stress compared to that at R_1 stage. The reduction in pods plant^{-1} at R_4 stage ranged from 15% to 41%. In control treatment, BARI soybean 5 produced the highest pods plant^{-1} (61.20). However, at R_1 stage of water stress treatment BARI soybean 5 produced only 50% pod of the control. The production of pods plant^{-1} at R_1 stage of water stress reduced to a great extent and ranged from 22% in genotype G 00022 and 51% in BARI soybean 5 (Table 1). A similar result was obtained by Ball *et al.* (2000). In a previous study, it was also reported that deficit irrigation at R_2 stage reduced seed yield by 4%, while deficit irrigation at the R_5 stage reduced seed yield by 28%, in comparison to the control (non-stressed) (Karam *et al.,* 2005). The highest relative number of pod in G 00022 might have attributed to a lower reduction in leaf dry matter as well as shoot dry matter of this genotype. Water deficit at flowering stage has more effect on the yield through affecting the pod number decrease. Water stress reduced number of pods plant^{-1} which would reduce the yield sharply.

Number of seed

Water deficit stress also reduced the average number of seed pod^{-1} significantly in all the soybean genotypes studied (Table 1). The number of seeds pod^{-1} was less affected by water deficit at R_4 stage in all the genotypes. The maximum relative seed number pod^{-1} was produced by the genotype G00022 (94%), followed by Galarsum (91%) and BARI soybean 5 (76%) and the lowest by G00197 (74%) at R_1 stage. The highest seed number pod^{-1} in genotype G00022 was probably is due to the lowest reduction in pollen fertility due to drought stress as reported by Omae *et al.* (2005). Withdrawing of irrigation at R_1 (omit irrigation at the onset of flowering stage) had the lowest one.

Table 1. Number of pod plant^{-1} and number of seed pod^{-1} of four selected soybean genotypes genotypes as affected by water deficit stress

Genotypes	Number of pods plant^{-1}			Number of seeds pod^{-1}		
	Treatments			Treatments		
	Control	Water stress at R_1 stage	Water stress at R_4 stage	Control	Water stress at R_1 stage	Water stress at R_4 stage
G00022	23.733	18.600 (78.37%)	20.333 (85.67%)	1.867	1.750 (93.73%)	1.807 (96.79%)
Galarsum	53.267	31.400 (58.95%)	39.667 (74.74%)	1.730	1.583 (91.50%)	1.633 (94.39%)
BARI Soybean-5	61.200	30.333 (49.56%)	36.133 (59.04%)	1.997	1.523 (76.26%)	1.663 (83.27%)
G 00197	37.933	27.533 (72.58%)	29.867 (78.74%)	1.897	1.407 (74.17%)	1.537 (81.02%)
LSD $_{(0.05)}$		15.90			0.23	
CV (%)		27.13			7.93	

Values in the parenthesis per cent of control

100- seed weight

Exercising water deficit stress in grain– filling stage had a high effect on 100– seed weight plant^{-1}, resulting decrease in this yield component. Shortening of grain–filling period due to water stress and decrease of transferring assimilates in to grains due to water stress as two major reasons for reduction of soybean grain weight. Water stress imposed on soybeans throughout the growing stages reduces vegetative growth and affects flowering and yield. Seed weight decreased significantly at R_4 stage water stress, which further decreased at R_1 stage water stress (Table 2). Enormous variation in 100- seed weight was also existed among genotypes. At R_1 stage drought, 100- seed weight ranged from 3.63 g to 10.58 g, whereas at R_4 stage drought that was from 3.93 g to 12.50 g. Relative grain weight was the highest in G00022 (83 %), followed by Galarsum (67%) and BARI soybean 5 (45%), and it was the lowest in genotype G 00197 (43%) at R_1 stage water stress. A remarkable reduction in the size of seeds was observed at R_4 stage water stress in all the genotypes. In genotype G00022, relative seed weight was higher with compared to other genotypes which indicated that this genotype was more capable to partition more dry matter into the seeds than that of other genotypes, especially at water deficit stress. Water deficit stress during reproductive development often decreases the seed size in soybean due to a shortening in the length of the seed filling period, rather than reduced seed growth rate reported by Meckel *et. al.* (1984).

Grain Yield

Grain yield was reduced by water deficit conditions in all the soybean genotypes studied and the decreasing rate was higher in R_1 stage than R_4 stage. Highest yield was found in G00022 (65%) and lowest in G00197 (39%) at R_1 stage. G00022 showed also highest yield at R_4 stage (76%) and lowest in G00197 (58%). Grain yield of different genotypes ranged from 1.65 to 3.09 t ha^{-1} under normal conditions and that from 0.64 to 1.76 and 0.96 to 2.13 t ha^{-1} under R_1 and R_4 stage water stress conditions, respectively (Table 2). The highest relative seed yield was found in genotype G00022 at both the water deficit stress stages and the lowest were in G00197. The highest relative pod number plant^{-1} and individual seed weight in genotype G00022 mostly contributed to the highest relative seed yield of this genotype. Higher yield in tolerant genotype G00022 resulted with increases in the number of pods, higher rate of photosynthesis under water stress (Palta *et al.*, 2010). The higher number pods in tolerant cultivars was probably due to greater availability of the source to the reproductive sinks. Quick recovery of photosynthesis and leaf growth in tolerant genotypes might also have resulted in small reduction of seed yield. There are significant differences in the tolerance of plants to drought stress depending upon intensity and duration of stress, plant species and the stage of development (Sing *et al.*, 2012). Water stress causes a series of physiological, biochemical and morphological responses of crops, which finally results in low yield of green gram (Malik *et al.*, 2006).

Table 2. 100- seed weight and seed yield of four selected soybean genotypes as affected by water deficit stress

Genotypes	100- seed weight (g)			Seed yield (t ha^{-1})		
	Control	Water stress at R_1 stage	Water stress at R_4 stage	Control	Water stress at R_1 stage	Water stress at R_4 stage
G00022	12.633	10.533 (83.38%)	12.400 (98.16%)	2.240	1.460 (65.18%)	1.707 (76.21%)
Galarsum	9.967	6.700 (67.29%)	9.167 (91.97%)	3.097	1.761 (56.86%)	2.056 (66.39%)
BARI Soybean-5	12.233	5.500 (44.96%)	5.867 (47.96%)	3.022	1.764 (58.37%)	2.135 (70.65%)
G 00197	7.867	3.367 (42.80%)	3.933 (49.99%)	1.654	0.648 (39.18%)	0.966 (58.40%)
$LSD_{(0.05)}$		1.62			0.18	
CV (%)		11.13			18.51	

Values in the parenthesis per cent of control

Harvest index

A significant genotypic variation in harvest index was noticed under water deficit stress conditions (Fig. 1). Harvest index was decreased due to water stress in all the genotypes studied and decreasing rate was higher when plants were subjected to water stress at R_1 stage than R_4 stage. At R_1 stage water stress condition, highest relative harvest index was found in genotype G00022 (59%) and it was lowest in G00197 (48%). Compare to water stress at R_4 stage, a significant reduction in harvest index in R_1 stage among genotypes was observed. According to Kobraei *et al.* (2011) the relationship between grain yield and components yield (number of pod, number of grain pod^{-1} and $plant^{-1}$) is positively and significant, therefore, decreasing these components may be reason for reducing grain yield and biological yield. This result is agreement with the results of Daneshian *et al.* (2010) and Kobraei *et al.* (2011) about the soybean responses to drought stress in terms of these traits. Compare to well water condition; water stress caused reduction in harvest index by 12.7% in wheat genotypes as described by Bayoumi *et al.* (2008). Austin (1994) suggested that high harvest index may be due to improved tolerance to drought by making the plants much shorter along with enhancing the supply of nutrients to developing grains.

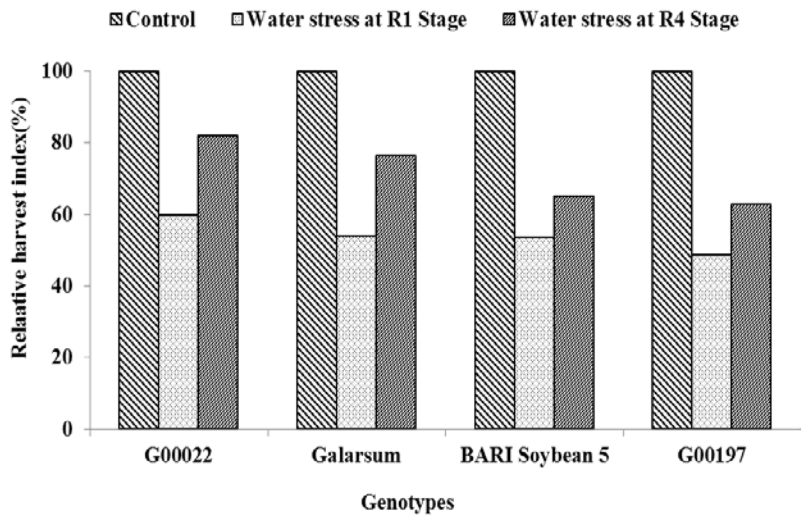

Fig. 5. Relative harvest index of four selected soybean genotypes as affected by water deficit stress

Conclusions

From the above findings it may be concluded that genotypic variability was found in adaptation of soybean plant to water stress. Water stress affects adversely on dry matter accumulation and yield of soybean genotypes and the growth reduction was larger at R1 (blooming) stage drought compared to R4 (pod filling) stage drought. Genotype G 00022 showed a higher water deficit stress tolerance while G 00197 was susceptible genotype in terms of both dry weight and yield performance

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