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MIDDAY DROP OF RELATIVE LEAF WATER CONTENT TO DROUGHT TOLERANCE IN SOYBEAN

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Abstract

An experiment was conducted in a Venylhouse of Bangabandhu Sheikh Mujibur Rahman Agricultural University during September to December 2012 to determine the effect of midday drop of relative water content (RWC) on drought tolerance of soybean genotypes. Four soybean genotypes viz. Shohag, BARI Soybean-6, BD2331 and BGM2026 were used in the study. Plants were grown in pots under stress and control condition. A marked difference in RWC between morning and midday was observed both in stressed and control plants. BARI Soybean-6 showed higher RWC than rest of the genotypes and BGM2026 showed the lowest at all growth stages. The reduced RWC of BARI Soybean-6 under water stress at vegetative, flowering and pod developing stages were 11.35, 13.52 and 15.04% at 1.00 PM as compared to control, respectively. The reduced RWC of BGM2026 at vegetative, flowering and pod developing stages were 18.99, 20.64 and 23.05% at 1.00 PM, respectively. In stressed plants, midday drop of relative water content was minimal in BARI Soybean-6 (8.97%) and maximum in BGM2026 (17.89%) at 1.00 PM. Under water stress condition BARI Soybean-6 gave the highest seed yield (5.23 g plant^{-1}) and BGM2026 the lowest (3.21 g plant^{-1}) which might be attributed to the drastic reduction in 100-seed weight of RWC in the variety BGM2026 due to the significant reduction in RWC in this variety. Considering the midday drop of RWC and seed yield, it may be concluded that BGM2026 is susceptible and BARI Soybean-6 is drought tolerant among the genotypes.

Introduction

Soybean is an important grain legume. It plays an important role in supplying protein and oil needed by humans. Water deficit adversely affects many physiological processes related to water use efficiency in soybean, thus leading to a decrease in plant productivity (Hamayun *et al*., 2010). Water stress has been found to decrease leaf water potential, relative water content and exudation rate and also to influence leaf anatomical characteristics and photosynthetic parameters (Omae *et al*., 2005; Omae *et al*., 2007). So, there is a general consensus that water economy is very critical to plant growth and development. The drought stress mainly causes lowering in some agronomic traits of soybean such as pod setting ratio, early pod abscission and finally leads to lower productivity (Suzuki *et al.*, 2001; Tsukaguchi *et al*., 2003). Among several methods used to characterize internal plant water status under drought conditions, relative water content (RWC) is an integrative indicator (Parsons and Howe, 1984), and was used successfully to identify drought resistance in french bean (Rosales-Serna *et al*., 2004; and mustard (Mondal and Paul, 1992). Cultivars with a smaller midday drop in leaf water content set more pods than the cultivars showing a larger midday drop in leaf water content (Omae *et al.*, 2004; Omae *et al*., 2005). During plant development, drought stress significantly reduced RWC values from 88 to 45% (Siddique *et al*., 1999). Soybean yield enhancement requires selection of tolerant and compatible cultivar in dry climate and low water environment (Maleki *et al*., 2013). Therefore, the present experiment was undertaken to determine the effect of midday drop of relative water content (RWC) on drought tolerance of soybean genotypes.

Materials and methods

A pot experiment was conducted in a Vinyl house at Bangabandhu Sheikh Mujibur Rahman Agricultural University during September to December 2012. Three relatively water stress tolerant (Shohag, BARI Soybean-6 and BD2331) and one susceptible (BGM2026) genotype selected from the previous experiment were used in this study to determine the effect of midday drop of relative water content (RWC) on drought tolerance of soybean genotypes at vegetative, flowering and pod development stages. Seeds of tolerant genotypes and susceptible genotypes were sown in plastic pots, 30 cm in height and 24 cm inner diameter. The soil of the pot was filled with mixture of soil and cowdung at a ratio of 4:1. Pot contained 12.0 kg of soil which was equivalent to 9 kg oven dry soil with 28% moisture at field capacity (FC). Soil used in the pot was sandy loam. The soil of the pot was fertilized uniformly with 24-30-60-15 kg NPKS per hectare, respectively. Six seeds pot^{-1} were sown on 3 September, 2012. After seedling establishment two uniform and healthy plants pot^{-1} were allowed to grow. Drought stress (water stress; 50% water of the FC) and non-stress (control) treatments were applied at 21 days after emergence (DAE) and maintained throughout the growing seasonThe pots were arranged in a completely randomized design (Factorial) with four replications. General management practices were applied for all the treatments equally. Relative water content, midday drop of relative water content, yield contributing characters and yields were recorded. RWC and midday drop of RWC were measured by following methods.

Relative water content (RWC) of leaves was measured at vegetative, flowering and pod development stages of each genotype at 8:00 am and 1:00 pm. Fully developed 3rd leaf from the top was used for RWC measurement. Immediately after cutting, leaves were sealed within plastic bags and kept in ice box and quickly transferred to the laboratory. The fresh weight of leaves from each treatment was recorded just after removal. Turgid weight (TW) was obtained after soaking leaves in distilled water in beakers for 24 hours at room temperature (about 20ºC) and under low light condition of the laboratory. After soaking, leaves were quickly and carefully blotted dried with tissue paper in preparation for determining turgid weight. Dry weight (DW) of the leaf was obtained after oven drying the leaf samples for 72 hour at 70ºC. RWC was calculated using the formula of Schonfeld *et al*. (1988):

RWC (%) = (FW – DW) / (TW – DW) x 100

Where, FW = Fresh weight, DW = Dry weight, TW = Turgid weight

Midday drop of RWC: The difference of RWC at mid-day (1:00 pm) to that in the morning (8:00 am) was calculated for mid-day drop of RWC. The data were analyzed by MSTAT-C statistical package program and treatments means were compared by Least Significant Difference (LSD) test (Gomez and Gomez, 1983). Functional relationships among different parameters as affected by water stress were established through correlation and regression analyses by using Excel program.

Results and discussion

Relative water content

RWC values of four genotypes at three different stages are shown in Figs 1, 2 and 3. Water stress significantly reduced RWC at two sampling times (8:00 AM and 1:00 PM) across the genotypes at different growth stages in all the four soybean genotypes studied. At 8.00 am, RWC of water stressed plants of Shohag decreased by 9.47, 9.99 and 12.26%, BARI Soybean-6 decreased by 8.92, 9.96 and 11.78%, BD2331 decreased by 8.79, 10.32 and 13.16%, and BGM2026 decreased by 13.74, 14.17 and 16.04% from control plants at vegetative, flowering and pod development stages, respectively. At 1.00 PM, RWC of water stressed plants decreased by 11.99, 13.74 and 15.29% in Shohag, 11.35, 13.52 and 15.04% in BARI Soybean-6, 10.8, 14.9 and 16.04 % in BD2331 and 18.99, 20.64 and 23.05 % in BGM2026 at vegetative, flowering and pod development stages, respectively.

Plants grown under water stress conditions showed a lower RWC than those grown under non stress conditions. Relative water content was higher in the morning, while decreased at noon. Several researchers reported that RWC of different crops was the highest in the morning and thereafter gradually decreased (Pual and Aman, 2000; Omae *et al*., 2005. BARI Soybean-6 had higher RWC than the rest of genotypes whereas genotype BGM2026 had the lowest RWC at all the three growth stages under both non-stress and stress condition. The RWC of all the genotypes fell at noon, possibly due to higher evaporation resulting from increased temperature and light intensity.

Midday drop of relative water content

The water stress reasonably affected the mid-day drop of RWC (Fig. 1-3). The difference of RWC between watered and water stressed plants was clear in the midday drop of RWC of the genotypes. In both watered and drought-stressed plant it was minimal in BARI Soybean-6 and the greatest in BGM2026. Irrespective of genotypes, the higher value was recorded in the plants under water stress at all the growth stages.

The midday drops of RWC at non-stressed plants were 4.49, 4.86 and 6.08 % in Shohag, 4.03, 5.06 and 5.47 % in BARI Soybean-6, 4.72, 5.70 and 8.38 % in BD2331 and 5.43, 7.93 and 10.42 % in BGM2026 at vegetative, flowering and pod development stages, respectively. In water stressed plants the midday drops of RWC were 7.10, 8.83 and 9.33 % in Shohag, 6.59, 8.46 and 8.97 % in BARI Soybean-6, 6.82, 8.92 and 11.41 % in BD2331and 11.19, 14.87 and 17.89 % in BGM2026 at vegetative, flowering and pod development stages, respectively.

In well watered plants, the mid-day drop of RWC was minimal in BARI Soybean-6 at vegetative and pod development stage while in Shohag at flowering stage under water-stressed plants, it was minimal in BARI Soybean-6 followed by Shohag and BD2331 irrespective of growth stages. The maximum RWC was recorded in BGM2026 under both the water regimes. Omae *et al*. (2005) reported that tolerant cultivars had the lowest mid-day drop of RWC as compared to susceptible cultivars. They suggested that mid-day drop of RWC might be used as a screening marker for drought tolerance of *Phaseolus vulgaris*.

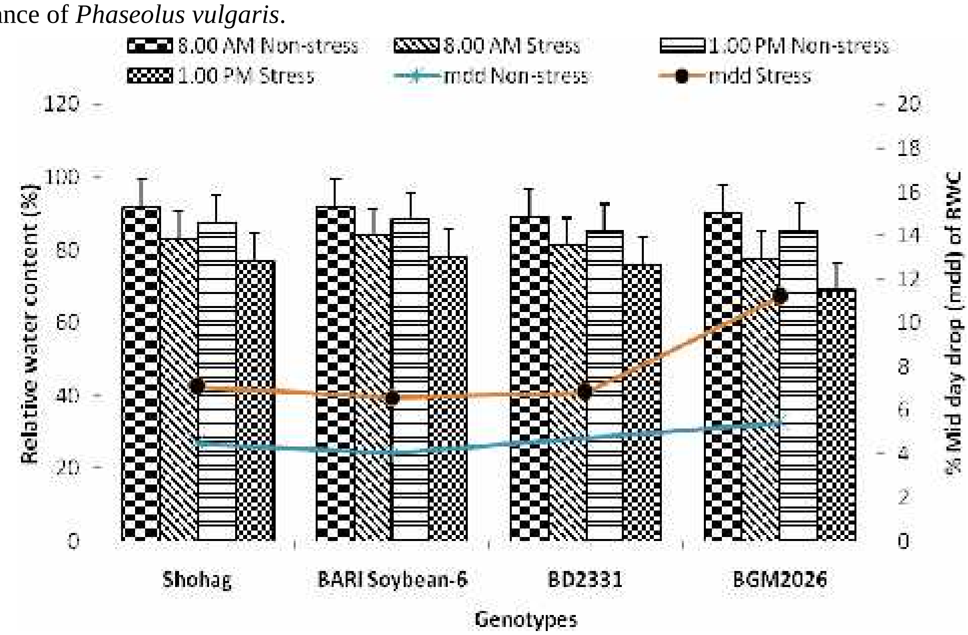

Fig. 1. Relative water content (RWC) and mid-day drop of RWC in soybean genotypes under non-stress and water stress conditions at vegetative stage.
Vertical bar represent LSD value at 5% level of significant.

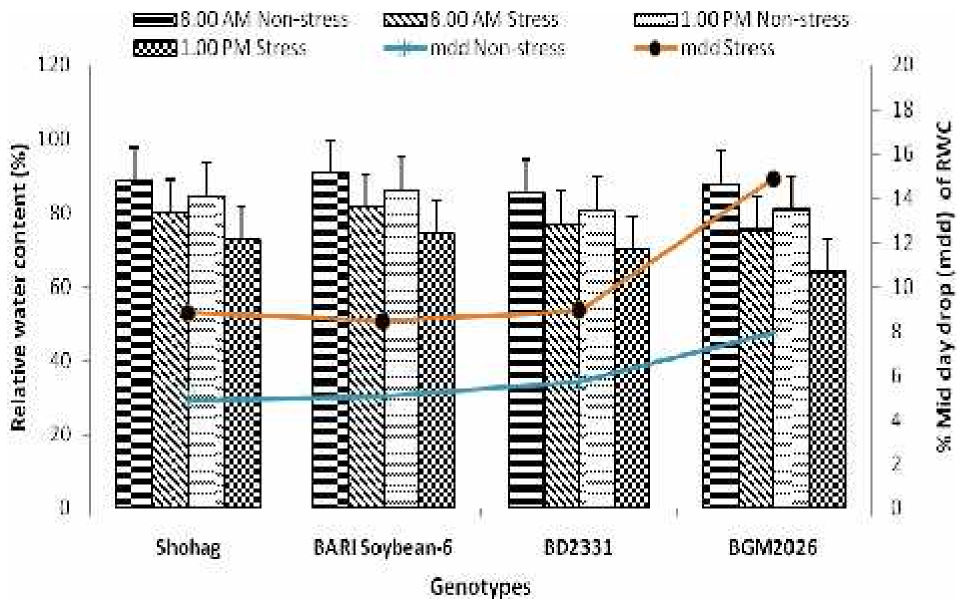

Fig. 2. Relative water content (RWC) and mid-day drop of RWC in soybean genotypes under non-stress and water stress conditions at flowering stage.
Vertical bar represent LSD value at 5% level of significant.

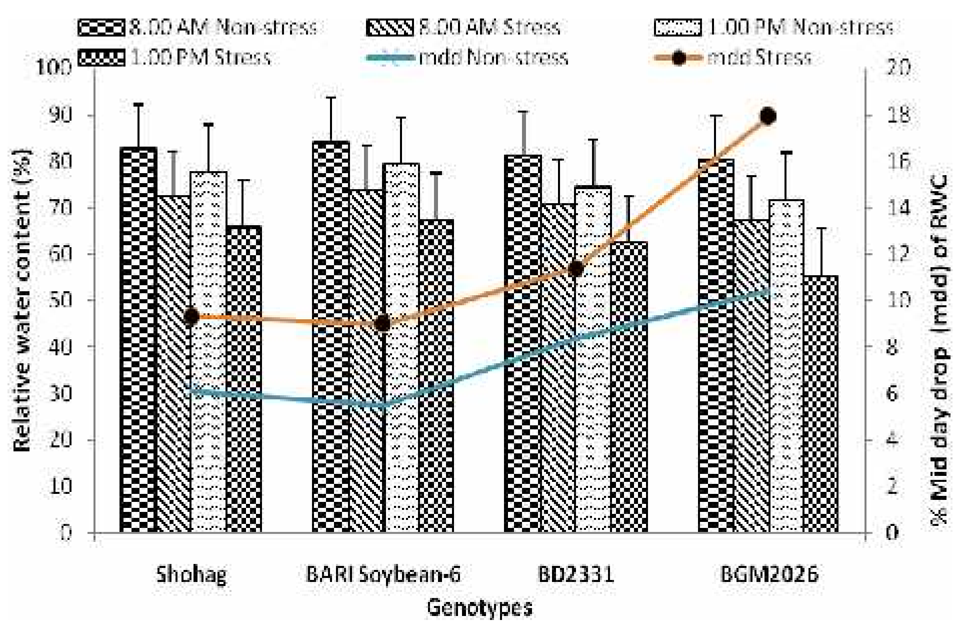

Fig. 3. Relative water content (RWC) and mid-day drop of RWC in soybean genotypes under non-stress and water stress conditions at pod development stage.

Vertical bar represent LSD value at 5% level of significant.

Yield components and seed yield

Moisture levels affected significantly the yield and yield contributing characters of soybean genotypes. Water stress significantly reduced the number of pod plant^{-1} of all the genotypes studied (Table 1). The maximum t pods plant^{-1} was found in BGM2026 (69.18) followed by BARI Soybean-6 (54.41), Shohag (51.85) and the lowest in BD2331 (51.18) under non-stress condition. On the contrary, the number of pods plant^{-1} was the maximum in BARI Soybean-6 (29.37), followed by Shohag (27.92), BD2331 (25.34) and the lowest in BGM2026 (21.34) under water stress situation. The genotype BGM2026 was the most affected genotype by the water stress with 69.51% reduction of pods plant^{-1}; whereas,46% in BARI Soybean-6,. Shohag and BD2331 showed 46.15 and 50.48% , respectively. Cultivars showing a smaller mid-day drop in leaf water content set more pods than the cultivars showing a large mid-day drop in leaf water content (Omae *et al*., 2004). Water stress also significantly reduced seeds number pod^{-1} of all the soybean genotypes studied (Table 1). Genotype BGM2026 produced significantly highest seeds number pod^{-1} under non-stress condition and the lowest under stress condition. Shohag produced the highest number of seeds pod^{-1} under stress condition. This character was reduced by water stress in BGM2026 by 19.45% but in Shohag it was only 5.02%. Hundred seed weight was significantly decreased by the water stress in all the genotypes (Table 2). The highest seed weight was found in BARI Soybean-6 and the lowest in BGM2026 in both the conditions.

Reductions in 100-seed weight ranged from 3.11 to 15.97% under water stress conditions compared to the non-stressed conditions. The reduction of 100-seed weight was the highest in the genotypes BGM2026 (15.97%). The result is in consistent with other studies, which indicated that water stress drastically reduced the number of pods plant^{-1} as compared to 100-seed weight (Lizana *et al*., 2006 and Nun˜ez-Barrios *et al*., 2005).

Crop yield is mainly a function of various components such as number of pods plant^{-1}, number of seeds pod^{-1} and seed size. Thus, the seed yield was reduced drastically as a consequence of reduced pods plant^{-1}, seeds pod^{-1} and 100-seed weight. Seed yield ranged from 8.69 to 10.32 g plant^{-1} and 3.21 to 5.23g plant^{-1} under non-stress and water stress condition (Table 2), respectively. Among the genotypes the highest seed yield was recorded from BARI Soybean-6 and the lowest from BD2331 under non-stress condition. Under water stress condition BARI Soybean-6 gave the highest yield (5.23 g plant^{-1}) and BGM2026 the lowest (3.21 g plant^{-1}). Yield reduction was ranged from 49.32 to 68 46%. The highest reduction (68.46%) in seed yield was observed in BGM2026 and the reduction of Shohag, BARI Soybean-6 and BD2331 showed 50, 49.32 and 50.58%, respectively.

Table. 1. Pod number plant^{-1}and seed number pod^{-1} of soybean genotypes under non- stress and water stress conditions

Genotypes	Pod plant^{-1} (no.)			Seeds pod^{-1} (no.)		
	Non-stress	Water stress	% Reduction	Non-stress	Water stress	% Reduction
Shohag	51. 85	27.92	46.15	2.09	2.08	5.02
BARI Soybean-6	54.41	29.37	46	2.12	1.92	9.43
BD2331	51.18	25.34	50.48	2.1	1.85	11.9
BGM2026	69.18	21.34	69.15	2.21	1.78	19.45
$LSD_{(0.05)}$ S	**			**		
G	4.73			0.05		
S x G	6.69			0.07		
CV (%)	9.24			3.28		

S=Stress, G=Genotypes, **Significant at 1% level

Number of seeds pod^{-1} and weight of 100-seed also played an important role in lowering the seed yield. Reduction in the seed yield by water stress was also reported for soybean (Liu *et al*., 2003) and *Phaseolus vulgaris* (Choudhury 2009; Islam *et al*., 2004; Omae *et al*., 2005; Lizana *et al*., 2006).

Table 2. Hundred seed weight and seed yield plant^{-1} of soybean genotypes under non-stress and water stress conditions

Genotypes		100-seed weight (g)			Seed yield plant^{-1} (g)		
		Non-stress	Water stress	Reduction (%)	Non-stress	Water stress	Reduction (%)
Shohag		13.94	13.06	6.31	9.4	4.7	50
BARI Soybean-6		14.13	13.69	3.11	10.32	5.23	49.32
BD2331		13.61	12.69	6.75	8.69	4.29	50.58
BGM2026		7.01	5.89	15.97	10.18	3.21	68.46
$LSD_{(0.05)}$	S	*			**		
	G	0.97			NS		
	S x G	NS			NS		
CV (%)		6.73			1.92		

S=Stress, G=Genotypes, NS=Not significant, *Significant at 5% level, **Significant at 1% level

The mid-day drop of RWC negatively correlated with seed yield plant^{-1} and number of pods plant^{-1} (Figs. 1 and 2). Simple linear regression between midday drop of RWC and seed yield suggested that the genotype with a smaller mid-day drop of RWC produced a larger number of pods plant^{-1} and consequently had higher yield as compared to others.

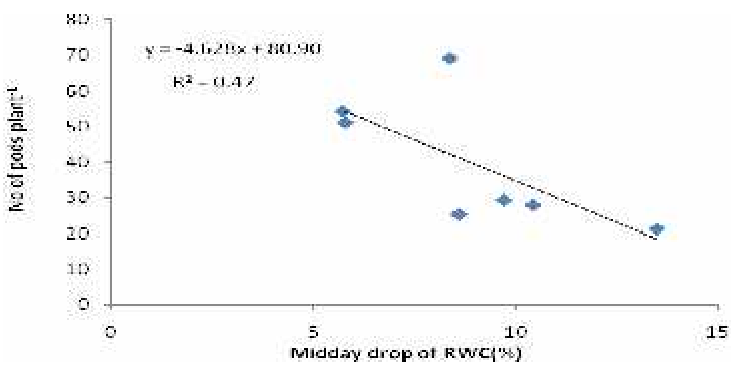

Fig. 1. Functional relationship between mid-day drop of relative water content (RWC) with number of pod plant^{-1}

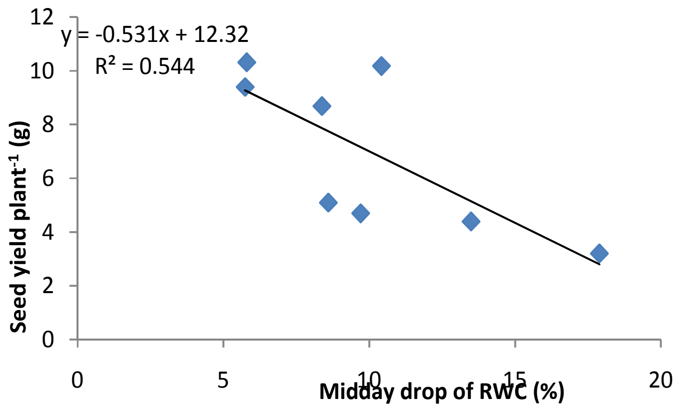

Fig. 2. Functional relationship between mid-day drop of relative water content (RWC) with seed yield plant^{-1}

Conclusion

Considering the midday drop of relative water content, yield contributing characters and seed yield it may be concluded that among the genotypes BARI Soybean-6, Shohag and BD2331 were drought tolerant and BGM26026 was susceptible.

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