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EFFECT OF WATER STRESS ON PLANT WATER STATUS OF FRENCH BEAN (*PHASEOLUS VULGARIS* L.)

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SUMMARY

An experiment was conducted in poly-tunnel at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh during the winter season of 2006-07 to analyze the water status of French bean grown under water stress conditions. Seven tolerance genotypes (BB24, BB43, BB45, BB41, BB36, BARI bushbean-2 and BB04) of french bean were evaluated under continuous water stress and control conditions. The mid-day value of RWC at 13:00 hours decreased remarkably and this trend was more conspicuous in BB04 and BARI bushbean-2 than that of BB24 and BB43. Under stress midday drop of RWC was maximum in the BB04 and BARI bushbean-2 while it was minimum in the genotypes BB24 and BB43. Xylem exudation rate and cuticular transpiration of the genotypes varied significantly. The relationship between exudation rate and cuticular transpiration, midday drop of RWC and seed yield correlated significantly. However, there were negative correlation between midday drop of RWC with pods number and seed yield of all the French bean genotypes.

Key words: **Cuticular transpiration, drought, RWC, *Phaseolus vulgaris,* xylem exudation**

INTRODUCTION

French bean is an important food crop grown under rainfed condition where drought is a major limiting factor for crop production. *Phaseolus vulgaris* is the most cultivated bean species in Central and South America and contribute to 90 % of the total bean production and as much as 60 % of bean production in developing world occurs under conditions of significant drought stress (Graham and Ranalli 1997). It has been introduced in Bangladesh and is grown in Sylhet and Chittagong region only for seed purpose under rainfed condition.

There is a general consensus that water economy is very critical to plant growth and development. Various studies have shown that *Phaseolus vulgaris* is relatively sensitive to drought stress as compared to other grain legumes (Haterlein 1983). The drought stress mainly causes low pod setting ratio, early pod abscission and consequently low productivity (Shen and Webster 1986, Suzuki *et al*. 2001, Tsukaguchi *et al*. 2003). Among the several methods used to characterize internal plant water status under drought conditions, RWC is an integrative indicator (Parsons and Howe 1984). It was used to identify drought resistant barley cultivars (Matin *et al.* 1989). French bean has substantial genetic variability in the high water content of leaves at the midday with decreasing water potential (Omae *et al*. 2004). Slow development of water deficit may induce osmotic adjustment resulting in the maintenance of appropriate water content of leaf during the period of water deficiency. As a result, plants can survive longer under

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a water deficit. Cultivars showing a smaller midday drop in leaf water content set more pods than the cultivars showing a large midday drop in leaf water content (Omae *et al.* 2004, 2005). Water stressed plants showed a marked reduction in xylem exudation rate as compared to control (Islam 2003, Faruquei 2002). The cuticular transpiration was less than stomatal transpiration. The superior drought resistance of a species is frequently ascribed to a lower cuticular transpiration. The information on this aspect of drought resistance under Bangladesh conditions is scanty. An attempt was made to study the effect of water stress on RWC, midday drop of relative water content, xylem exudation rate and cuticular transpiration of French bean.

MATERIALS AND METHODS

The pot experiment was conducted inside a tunnel made of polythene sheet with seven genotypes under two soil moistures regimes at the Banngabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh during the winter period (November, 2006 to February, 2007). The soil was sandy loam with 27 % moisture at field capacity (FC). Five relatively water stress tolerant (BB24, BB43, BB45, BB41 and BB36) and two susceptible (BB04 and BARI bushbean-2) genotypes were used in this experiment. Pre-soaked five seeds were sown on November 20, 2006 in each pot (30 cm x 24 cm) containing 10.7 kg oven-dried soil. After seedling establishment two uniform and healthy plants per pot were retained. Two watering treatments of the plants viz. water stress (50 % of the FC) and control (80 % of the FC) were applied at 12 days after emergence. Levels of soil moisture were maintained throughout the growing season. The pots weighed during one day intervals to compensate the water loss by evapotranspiration. Normal management practices were applied for all treatments. The experiment was designed as a completely randomized (factorial) with four replications (2 plants per pot considered as one replication).

Relative water content (RWC) of leaves was measured just at flowering of each genotype at 8:00 am and 1:00 pm. Fully developed youngest leaf (3rd from the top) was taken. Eight leaf discs were cut with a sharp leaf puncher avoiding the mid-rib and major veins from the leaves in each pot. Then fresh weight (FW) of the leaf discs were measured and water-saturated weight (SW) was determined after floating the discs on distilled water for 4 h in the dark. The leaf discs were then dried in an oven at 65 ^{0}C for 8 h to record dry weight (DW). Relative water content was calculated with the help of the following equation (Kumar and Elston 1992).

$$\text{RWC (\%)} = \frac{\text{FW} - \text{DW}}{\text{SW} - \text{DW}} \times 100$$

The ratio of RWC at midday (1:00 pm) to that in the morning (8:00 am) was calculated for midday drop of RWC. Xylem exudation rate (XER) under two stages- at flowering and pod development was measured at 5 cm above from stem base. Dry cotton was weighed. A slanting cut on stem was made with a sharp knife. Then the weighed cotton was placed on the cut surface. The exuded sap from the stem was collected for 1 h at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was calculated by deducting cotton weight from the sap containing cotton weight and expressed per hour basis as follows-

$$\text{Xylem exudation rate} = \frac{\text{(weight of cotton + sap)} - \text{(weight of cotton)}}{\text{Time (h)}}$$

The cuticular transpiration rate at pod development stage was measured (Itani 1992) as soon as a leaf blade was sampled in the dark at predawn, the fresh weight and the leaf area were measured. The leaf blade was kept into a power drier at 40 ^{0}C and 50 % relative humidity and 10 minutes later, the fresh weight was calculated based on the difference between the values of fresh weight.

All mature pods of two plants in each pot were harvested and the number of pods, seeds per pod, 100-seed weight and seed yield per plant was recorded.

The data were analyzed by MSTATC statistical package. When the ANOVA was significant at $p \leq 0.05$, Duncan Multiple Range Test (DMRT) was used for

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comparison of means. Student's t-test was applied between moisture regimes within the genotype. Functional relationships among different parameters as affected by water stress were established through regression analysis.

RESULTS AND DISCUSSION

Relative water content

Water stress significantly reduced RWC in the morning (8:00 am) and at 1:00 pm (Table 1). The effect of genotype and water stress interaction was not significant at 8:00 am and 1:00 pm. Plants grown under water deficit conditions showed a lower RWC than the plants grown under control conditions. Relative water content was higher in the non-stressed plants of BB43 (90.39 %) and BB24 (89.76 %) at 8:00am. Under water stress condition, BB24 and BB43 had significantly higher RWC than those of BB04 and BARI bushbean-2. This might be due to osmotic adjustment that enabled the plants to maintain a higher RWC during water deficit (Kumar *et al.* 1984, Morgan *et al.* 1986, Kumar and Singh, 1998). This allows plant organs to survive longer than sensitive types.

The water stress reasonably affected the midday drop of RWC (Table 1). Irrespective, of the genotypes, the higher value was recorded in the plants under drought stress. The midday drop of RWC varied from 4.59 to 8.62 % in non-stressed plants and from 8.31 to 17.76 % in water-stressed plants. In non-stressed plants, the midday drop of RWC was minimum at 4.59 % in BB24. In stressed plants too, it was lowest (8.31 %) in the same genotype. The midday drop of RWC in non-stressed and water-stressed plants was the greatest in BB36 (8.62 %) and BB04 (17.76 %), respectively. The relationship between midday drop of RWC with yield and pods number was analyzed using the data from both non-stressed and water-stressed plants (Fig. 1). The midday drop of RWC was negatively correlated with yield and pods number per plant. Similar results were obtained by Omae *et al.* (2005). These results showed that the genotypes with a smaller midday drop of RWC produced higher pods per plant and seed yield per plant as compared to the genotype with a larger midday drop of RWC.

Xylem exudation and cuticular transpiration

Water-stressed plants showed a marked reduction in xylem exudation rate as compared to non-stressed plants (Table 2). In both the stages, the relative exudation rates were higher in BB24 and BB43 compared to the rest of genotypes. Exudation rate is directly associated with the flow of transpiration stream. Higher exudation

Table 1. Relative water content (RWC) and midday drop of RWC in French bean genotypes under non stress and water stress conditions at flowering stage

Genotypes	RWC (%)						Midday drop of RWC (%)	
	8:00 am			1:00 pm				
	Non stress	Water stress	Difference	Non stress	Water stress	Difference	Non stress	Water stress
BB43	90.39	83.87	*	85.12ab	76.47e	*	5.83	8.82
BB24	89.76	84.26	NS	85.64a	77.28de	*	4.59	8.31
BB45	87.54	80.44	*	81.04a-e	71.84f	*	7.42	10.69
BB41	87.21	79.71	*	80.34b-e	71.31f	*	7.88	10.54
BB36	86.96	80.16	*	79.46cde	70.32fg	*	8.62	12.28
BARI bushbean-2	88.03	78.83	*	82.27a-d	66.03gh	*	6.26	16.24
BB04	88.82	79.37	**	84.1abc	65.27h	*	5.36	17.76

*, ** and NS, significant at 5 %, 1 % levels of probability, and not significant, respectively.

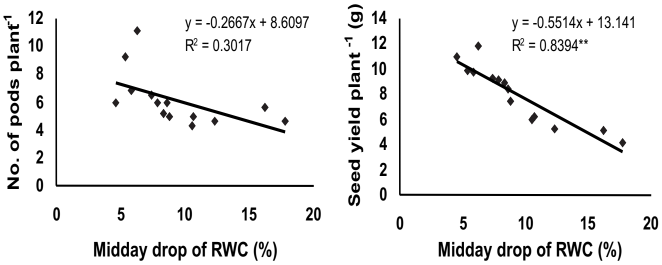

Fig. 1. Correlation of midday drops of relative water content with the number of pods plant^{-1} and seed yield plant^{-1}. ** indicate significance at 1 % level. Data from both non stress and water stress plants of flowering stage were used for establishing the relationships.

rate means a plant absorbs more water from the soil solution than a plant with lower exudation rate. Reduction in water uptake by plants due to water stress was also observed by Islam (2008) in mungbean or due to salt stress by many investigators (O'Leary 1974, Papadopoulos *et al.* 1985, Aziz 2003).

The cuticular transpiration rate was significantly affected by the water stress (Table 2). The cuticular transpiration rate under non stress condition varied from 0.096 to 0.141 g H_2O m^{-2} h^{-1} while, under stressed conditions it varied from 0.034 to 0.088 g H_2O m^{-2} h^{-1}. In both, the watered and stressed plants, the cuticular transpiration rate was lower in BB43 and BB24 while, it was the highest in BB04 and BARI bushbean-2. The lower cuticular transpiration rate of the water stressed leaf suggested that the water stressed leaf was more heavily cutinized (Itani *et al.*1992). The cause of decrease in the cuticular transpiration from a specific leaf can also be due to the increase in the surface lipids. There was positive correlation between cuticular transpiration and xylem exudation rate (Fig. 2).

Yield and yield components at harvest

Yield and yield contributing factors varied significantly in response to moisture stress (Table 3). Irrespective of genotypes, seeds pod^{-1}, pods plant^{-1}, 100-seed weight and seed yield plant^{-1} were lower in the water stress in comparisons with the non stress plants. The yield components affected most by the water stress was pods plant^{-1} with a reduction of 13.3 to 50.0 %, as compared to 2.9 to 14.7 % and 0.36 to 12.86 % observe for seeds pod^{-1} and weight of seeds, respectively. The decrease in yield of grain legumes grown under drought conditions is largely due to the reduction in the number of pods plant^{-1} (Muchow 1985, Pilbeam *et al.* 1992, Barrios *et al.* 2005). However, number of seeds pod^{-1} and 100-seed weight may play an important role in diminishing the final yield. The seed yield of seven genotypes was reduced by 18.9 to 57.9 % under water stress conditions. Reduction in the seed yield by water stress was also reported for green gram and black gram (Tripurari and Yadav 1990), soybean (Liu *et al.* 2003) and *Phaseolus vulgaris* (Lopes *et al.* 1988, Omae *et*

Table 2. Xylem exudation rate and cuticular transpiration rate in French bean genotypes under non stress and water stress conditions

Genotypes	Xylem exudation rate (mg h^{-1}) at flowering stage		Xylem exudation rate (mg h^{-1}) at pod dev. stage		Cuticular transpiration rate (g H_2O m^{-2} h^{-1})	
	Nonstress	Water stress	Nonstress	Water stress	Non stress	Water stress
BB43	178.5eA	8.3fB	139.2dA	4.5fB	0.1016dA	0.343kB
BB24	184.6eA	8.4fB	123.1eA	4.2fB	0.0961eA	0.392jB
BB45	240.3dA	10.4fB	169.2cA	5.6fB	0.1143cA	0.593hB
BB41	285.2cA	12.2fB	177.4cA	5.3fB	0.1042dA	0.451iB
BB36	174.7eA	7.1fB	119.8eA	3.6fB	0.1161cA	0.637gB
BARI bushbean-2	368.1bA	13..4fB	256.1bA	7.3fB	0.1231bA	0.655gB
BB04	418.2aA	16.2fB	301.2aA	8.4fB	0.1391aA	0.884fB

[1] Lower case letters indicate differences among treatment combinations by DMRT ($P \leq 0.01$).
[2] Upper case letters indicate differences between water regimes by student's t-test ($P \leq 0.01$).

Table 3. Seed yield and yield components of French bean genotypes under non stress and water stress conditions

Genotypes	Seeds pod^{-1}		Pods plant^{-1}		100-seed wt.(g)		Seed yield plant^{-1} (g)	
	Non stress	Water stress	Non stress	Water stress	Non stress	Water stress	Non stress	Water stress
BB43	4.3aA	4.1a[1]A[2]	6.8cA	5.0efgB	34.86hA	34.15iB	9.74bcA	7.38efB
BB24	3.4aA	3.3aA	6.0cdeA	5.2efgB	55.35aA	55.15aA	10.92abA	8.86cdB
BB45	3.8aA	3.4aA	6.5cdA	4.9efgB	38.84fA	37.56fA	9.26cdA	6.18fgB
BB41	3.9aA	3.5aA	5.9cdeA	4.3gB	42.25cA	40.46eB	9.12cdA	5.92gB
BB36	3.4aA	2.9aB	6.0cdeA	4.6fgB	43.61bA	41.6dB	8.36deA	5.28ghB
BARI bushbean-2	4.7aA	4.5aA	11.1aA	5.6defB	23.16jA	20.18kB	11.80aA	5.10ghB
BB04	4.8aA	4.4aA	9.2bA	4.6fgB	22.92jA	20.76kB	9.88bcA	4.16hB

[1] Lower case letters indicate differences among treatment combinations by DMRT.
[2] Upper case letters indicate differences (P d" 0.05) between treatments.

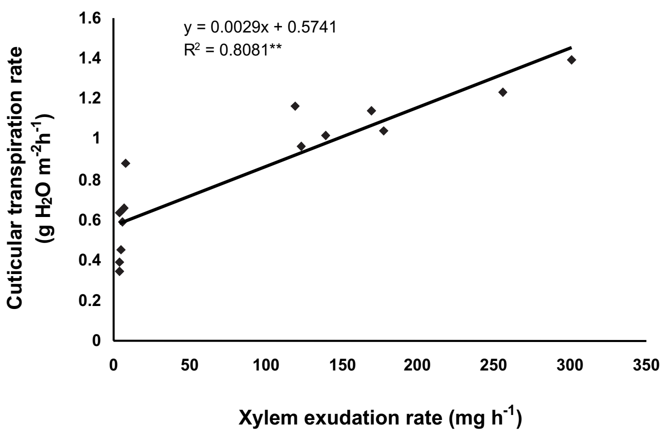

Fig. 2. Correlation of exudation rate with cuticular transpiration in French bean genotypes grown under non stress and water stress conditions. ** indicates significance level at 1 %. Data from both non stress and water stress plants of pod development stage were used for establishing relationship.

al. 2005, Islam *et al.* 2004). In the present study, the seed yield under non-stressed condition was the highest in genotype BARI bushbean-2 followed by BB24, BB04, BB43, BB45, BB41 and BB36, and that under water stress was the highest in BB24 followed by BB43, BB45, BB41, BB36, BARI bushbean-2 and BB04.

Soil moisture had significant effect on RWC, xylem exudation rate, cuticular transpiration and the yield potential of French bean genotypes. The low rate of cuticular transpiration, high RWC enabled the plants to maintain a high water content in leaf cells under water stress conditions. As a result, leaf dehydration is delayed for a longer period of the drought in relatively tolerant genotypes (like BB24 and BB43) compared with a relatively susceptible genotype like BB04 under drought condition.

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