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WATER STRESS INDUCED CHANGES IN PHYSIOLOGICAL ATTRIBUTES OF MUNGBEAN

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ABSTRACT

The production of mungbean [*Vigna radiata* (L.)] is adversely affected by drought in the tropics and sub-tropics. This study investigated the physiological responses of six mungbean varieties viz. BUmug 2, BUmug 4, BARI Mung-5, BARI Mung-6, Binamoog-5 and Binamoog-8 to non-stress (80% of field capacity) and water deficit (50% of field capacity) conditions. The experiment was laid out in a completely randomized design having four replications at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. The variety Binamoog-5 showed the highest level of physiological parameters related to drought tolerance, such as proline content (32.57%), xylem exudation (577.00 mg hr^{-1} and 383.70 mg hr^{-1}) and total chlorophyll content (2.65 mg g^{-1} and 2.81 mg g^{-1}) at preflowering and pod development stage, photosynthesis (38.94 µmol m^{-2} s^{-1} CO_2), transpiration (15.00 mg $H_2O/dm^2/h$), and relative water content (66.14%), whereas that showed the lowest level of cell membrane thermostability (63.8%) under water stressed condition, followed by Binamoog-8. The measured physiological characteristics of other varieties were affected noticeably. Therefore, Binamoog-5 may be considered as a resource for drought tolerant genetic material.

Keywords: Proline, water relation, mongbean, photosynthesis

Introduction

Mungbean [*Vigna radiata* L.] is an important pulse crop in the developing countries of Asia, Africa and Latin America (Alderfasi *et al*. 2017). It is a short duration grain legume (Islam *et al.* 2022) that contains digestible dietary protein of around 25% of seed dry weight and fixes substantially environmental N_2 to the soil (Islam *et al.* 2017). It is generally cultivated during the pre-monsoon season (March–May), when the scarcity of water is a common incidence in Bangladesh (Islam *et al.* 2021a). Mungbean is reported to be more susceptible to water deficits than many other grain legumes (Pandey *et al.* 1984). According to Imtiaz *et al.* (2020) drought affects a variety of morphological, physiological, and biochemical processes in crop plants either temporarily or permanently. Physiological traits that are generally affected by drought could be CO_2 assimilation rate, efficiency of photosystem II (PSII), and photochemical activity (Ghotbi-Ravandi *et al.* 2014) and water relation traits, stomatal conductance, root architecture, and osmotic adjustment. Moreover, under drought condition the concentration of soil solution in the soil increases, which reduces the access of the roots to soil moisture, thereby decreasing water absorption by the roots, and consequently declining leaf water potential (Nejadsahebi *et al.* 2010).

Drought tolerance can be evaluated through less disturbed bio-physiological parameters, such as metabolic compatible solutes (e.g., proline, soluble sugar), chlorophyll content, relative water content, leaf area index, antioxidant enzymatic activities, plant water relations and yield components (Islam *et al.* 2022, Swathi *et al.* 2017), though varieties that perform better in terms of yield loss in drought condition could be considered as tolerant ones (Tiwari *et al.* 2018).

Mungbean varieties revealed variation in drought tolerance. However, more systematic studies are required to clarify the physiological reasons for the variation of drought tolerance in mungbean varieties. This study was therefore undertaken to evaluate the effect of drought

stress on changes in physiological attributes of some popular mungbean varieties of Bangladesh.

Materials and Methods

Seeds of mungbean were grown in pots of 30cm in diameter and 24 cm in height inside a vinylhouse in the research field of the Department of Agronomy, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur. The soil used in the pot belongs to Salna series of Shallow Red-Brown Terrace soil type (AEZ 28) with silty clay in surface and silty clay loam in sub-surface region (Brammer 1971). Each pot was filled with 14 kg air-dried soil with mixture of soil mixed with cowdung at a ratio of 4:1. The pot soil was fertilized with 0.20g, 0.80g, 0.40g and 0.20g of Urea, TSP, MoP and Gypsum @) 15.5-25.5-30.5-15.5 kg N-P-K-S ha^{-1}, respectively (FRG, 2012). All the fertilizers except half of urea were applied as basal and rest half of urea was applied at 25 DAE (days after emergence). The experiment was laid out in a RCBD factorial design with four replications where two factor i.e. water stress; T_1=Control (crop was grown at 80% of field capacity moisture), T_2=Water stress (crop was grown at 50% of field capacity moisture) and the other one was variety, viz. V_1=BUmug 2, V_2=BUmug 4, V_3=BARI mung-5, V_4=BARI mung-6, V_5=Binamoog-5 and V_6=Binamoog-8. Pre-soaked six healthy seeds were sown in a pot by hand on February 28, 2012 and covered with soil by hand. After sowing of seeds light irrigation was given to ensure uniform germination of seeds. Water stress treatments were imposed at 18 DAE. One day before treatment imposition, 500 ml of water was applied to each pot to maintain similar soil moisture content of all pots. Water stress condition was induced by withholding water until wilting symptom was observed in plants when water of 50% field capacity was applied. Intercultural operations were done uniformly in each pot to ensure normal growth of the crop.

Proline content: Proline content of leaves of five replicated plants of each treatment at anthesis in all mungbean varieties grown in two water regimes was estimated. Leaves from each replication of each variety were collected and immediately kept in the ice-bag and brought to Laboratory for proline estimation. The 0.5g of fresh weight of leaf was taken for proline estimation and subsequently proline was estimated according to Bates (1973). At first Ninhydrin reagent was prepared. For preparing Ninhydrin reagent, addition of 30 ml glacial acetic acid and 20 ml 6M orthophosphoric acid was mixed with 1.25 g of Ninhydrin. It was subsequently heated and stirred gently to dissolve but the temperature was not allowed to exceed 70^0C. Proline standards were prepared for 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 µg/ ml with distilled water. A fresh sample of 0.5g was crushed in mortar and pestle and homogenized the material in 10 ml 3% sulphosalicylic acid until no large segments of plant material remained. Homogenate was filtered through Whatman No. 2 filter paper. Two ml of the filtrate and each standard proline solutions were then reacted with 2 ml of ninhydrin reagent and 2 ml of glacial acetic acid in a pyrex test tube, boiled for one hour at 100^0C in water bath covering the tube with aluminium foil to prevent excess evaporation. Subsequently, it was cooled in ice bath, and 4 ml of toluene was added to each tube using a dispensor. Each tube was then shaken vigorously for 15 to 20 seconds in an electrical shaker and allowed the layer to separate for 30 minutes. The absorbance of layer was measured through spectrophotometer at 520 nm with pure toluene as a blank. The proline content was determined from a standard curve and calculated on a fresh weight basis as follows:

µmoles proline/g of fresh plant material =
{(µg proline/ml × ml toluene)/15.5 µg/µmoles}/ (g sample/5)

Leaf water potential: Leaf water potential in the fully expanded leaf was measured at anthesis stage using a pressure chamber. The leaf was cut and quickly sealed inside the chamber with the cut end appearing above the rubber seal. Pressure was applied to the leaf from a cylinder of compressed gas until xylem sap appeared at the cut surface in the leaf. The gas flow was immediately stopped and the pressure was noted in the gauge. This balancing pressure was regarded as the tension originally existing in the xylem sap and approximately equal to water potential in the cells. For each stage three randomly selected plants were used and the sampling was done between 6.00 and 9.00 a.m. to avoid evaporation losses. Leaves of five replicated plants were used for the measurement.

Relative water content: Relative water content (RWC) was measured using fully expanded leaf of five replicated plants of each treatment under both control and water deficit condition at noon. Immediately after cutting at the base of lamina, leaves were sealed within plastic bags and kept in ice box and quickly transferred to the laboratory. The fresh weight of flag leaf 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 the low light condition in the laboratory. After soaking, leaves were quickly and carefully blotted dried with tissue paper for determining turgid weight. Dry weight (DW) of leaf was obtained after oven drying the leaf samples for 72 hour at 70ºC. The RWC was calculated in following equation.

Relative water content (RWC) (%) = [(FW-DW)/ (TW-DW)] ×100

Where, FW = Fresh weight (mg), DW = Dry weight (mg) and TW = Turgid weight (mg)

Xylem exudation rate: Exudation rate of five replicated plants of each treatment was measured at anthesis, 5 cm above in base in the stem. At first, 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 exudation of sap was collected for 1 hour at normal temperature. The final weighed in the cotton with sap was taken. The exudation rate was measured by deducting cotton weight in sap containing cotton weight and expressed in mg per hour as follows-

$$Xylemeculation\ rate = \frac{(Weight\ of\ cotton + sap) - (Weight\ of\ cotton)}{Time\ (h.)}$$

Leaf chlorophyll content: Chlorophyll was determined on fresh weight basis extracting with 80% acetone by using double beam spectrophotometer using the following equation.

$$Chlorophyll\ (a + b)\ mg\ g^{-1}\ leaf\ tissue = \frac{[20.2\ (D_{645}) + 8.02\ (D_{663})] \times v}{1000 \times w}$$

Where,

D = Optical density regarding in the chlorophyll extract at wave length of 663 and 645 nm.

V = Final volume (ml) in the 80% acetone with chlorophyll extract.

w = Fresh weight in grams in the tissue extracted.

Five replicated plants for each treatment were considered for chlorophyll measurement.

Membrane thermostability: Procedures used for measuring membrane thermostability to high temperature were the same as those described by Blum and Ebercon (1981). Leaf samples of five replicated plants of each treatment were collected from plants at pod development stage. Samples collected from each pot of non-stressed and water deficit plants consisted of a paired set of 10 leaf discs (10-mm diameter) cut from fully expanded upper leaves. After rinsing, 2 ml of water was added to the vials to prevent desiccation of the tissue during the heat treatment. The heat treatment vials were covered with plastic wrap and incubated at 42^0C for 90 minutes in a water bath, while the control vials were kept at room temperature during the same period. After the heat treatment, 8 ml of de-ionized water was added to both the control and heat stressed vials which were kept at room temperature for 24 hours. The vials were then shaken well to mix the diffused electrolyte. An initial conductance of the vials was determined with an electrical conductivity meter. Thereafter, the vials were placed in water bath at 44ºC for 30 minutes to release the electrolytes and then cooled to 25ºC, the contents were mixed and the final conductance was measured with an Electric Conductivity Meter (HI 8033, HANNA Instruments, Portugal). The level of injury was calculated in following equation:

$$Percent\ injury = [1 - \{(1 - T_1/T_2) / (1 - C_1/C_2)\}] \times 100$$

Where, T_1= first conductivity measurement of desiccation treatment, T_2= second conductivity measurement of desiccation treatment, C_1= first conductivity measurement of control and C_2= second conductivity measurement of desiccation treatment.

Photosynthesis and transpiration : Leaf photosynthesis (CO_2 µ mol m^{-2} $sec^{-1)}$ was measured on young fully expanded leaves of three replicated plants for each treatment in the same position at vegetative stage and subsequently on leaf at anthesis and maturity stage at full sunshine. The measurement were taken using a portable photosynthesis system (Li-COR-LI-6200) assembled with an infra-red gas analyzer (Li-COR-LI-6250) and data logger following the procedure described by Al-Khatib and Paulsen (1990).

The data were analyzed by MSTAT-C statistical package program. The difference between the treatments means were compared by least significant difference (LSD) test (Gomez and Gomez, 1983). Table and graph were made by using Excel program.

Results and Discussion

The accumulation of the amino acid proline is a common physiological response of plants to drought stress (Mafakheri *et al*. 2010). Accumulation of proline under stress in plant has been positively correlated with stress tolerance (Ashraf and Foolad 2007). Different varieties of mungbean exhibited different magnitude of proline accumulation both in control and water deficit conditions. Significant differences in proline content were recorded under water stress condition (Figure 1). The highest accumulation of proline under water stress was observed in variety Binamoog-5 followed by Binamoog-8 while the lowest in variety BUmug 4 followed by BUmug 2. The highest increase in proline content was found in Binamoog-5 (32.57%) followed by Binamoog-8 (28.97%) and BARI mung-6 (23.53%). High levels of proline enable a plant to maintain low water potentials. It is well documented that accumulated proline plays a role as a compatible solute in plants, regulating and reducing water loss in cell under water deficit (Bayoumi *et al.* 2008). The results of proline accumulation in mungbean that obtained in this experiment was also in agreement with the findings of Islam *et al.* (2022) who found accumulation of proline content in the leaf tissues of the BMX-08010-2 genotype was higher under both stress conditions and stated that genotypes having different levels of drought resistance differ in their capacity to accumulate proline under stress.

Water stress caused significant differences in leaf water potential (LWP) in mungbean varieties. In control condition a very little variation was observed in leaf water potential among the varieties but at water deficit condition the difference among varieties was significant.

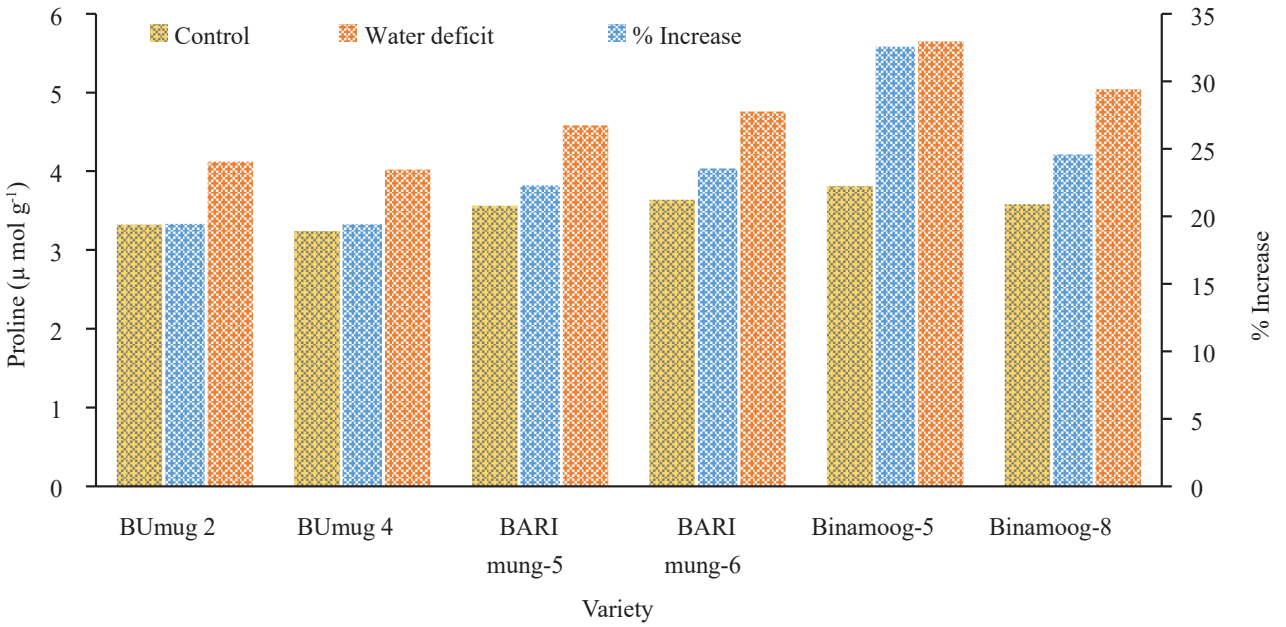


Figure 1. Proline content of mungbean varieties as influenced by water deficit. Bar indicates standard error (±).

At pod development stage, the leaf water potential ranged from -0.36 to -0.43 MPa and from -0.43 to -0.59 MPa in control and water deficit conditions, respectively (Figure 2). However, the highest leaf water potential was recorded in the variety BUmug 4 and BUmug 2 (-0.43 MPa) respectively in control condition. On the other hand, the lowest LWP was recorded in BUmug 4 (-0.59 MPa) followed by the variety BUmug 2 (-0.56 MPa). Large decreased in leaf water potential was found under water deficit condition in variety BUmug 4 (24.12%) compared to control condition. The tolerant varieties are more capable of maintaining plant water status at moisture stress conditions. Reduction of water loss may be due to increased stomatal and cuticular resistance to transpiration and reduced radiation absorbed (Islam 2008). Nazran *et al*. (2019) reported that leaf water potential of mungbean varieties was reduced significantly due to reducing field capacity levels and stress decreased leaf water potential from -0.67 to -0.55 MPa in non- stress to -1.64 to -1.13 MPa in stressed condition. Choudhury (2009) observed significant differences in water potential among bushbean varieties under water stress.

Relative water content (RWC) is the water content of a tissue compared with the water content in the same tissue in fully turgid condition. Relative water content is considered as a measure of plant water status, reflecting the metabolic activity in tissues and used as a most meaningful index for dehydration tolerance (Anjum *et al*. 2011). Water stress induced reduction in relative water content varied with the varieties under both control and water stress conditions (Figure 3). The highest RWC was recorded in variety Binamoog-8 followed by Binamoog-5 in control condition whereas the lowest in variety BUmug 4 followed by BUmug 2. The highest RWC was recorded in variety Binamoog-5 followed by Binamoog-8 under water stress condition and the lowest in variety BUmug 4 followed by BUmug 2. The lowest reduction in RWC was observed in Binamoog-5 (21.20%) followed by Binamoog-8 (24.58%) and BARI mung-6 (26.42%), respectively under water deficit condition at preflowering stage. At pod development stage, the highest RWC was observed in variety Binamoog-8 and Binamoog-5 in control and water stress condition. The highest reduction in RWC compare to control condition was recorded in BUmug 4 (20.87%) followed by BUmug 2 (17.68%) and BARI mung-6 (17.10%). The lowest reduction was observed in Binamoog-5 (14.70%) followed by BARI mung-5 (16.07%) and Binamoog-8 (16.48%). Osmotic adjustment and cell wall elasticity might enable the plant of Binamoog-5 to maintain highest RWC both in preflowering and pod development stages. A decrease in

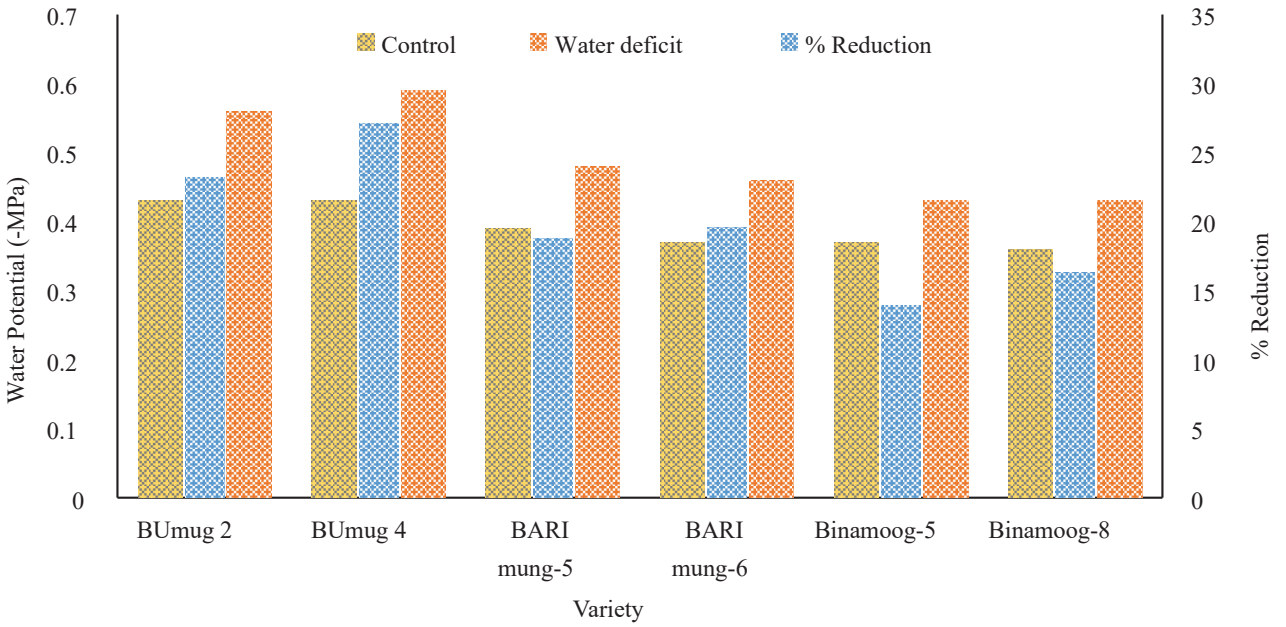


Figure 2. Water Potential of mungbean varieties as influenced by water deficit. Bar indicates standard error (±).

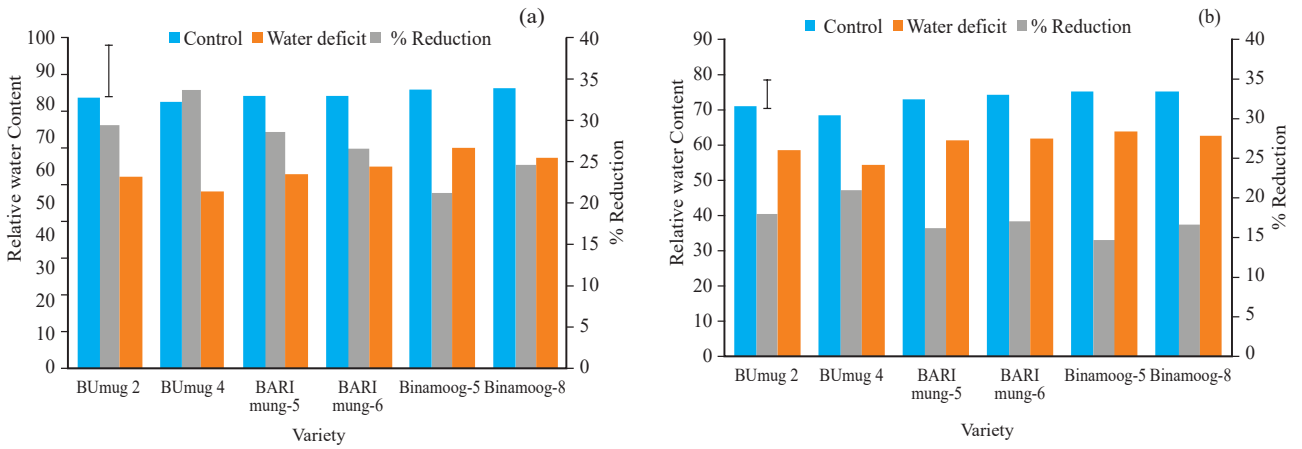


Figure 3. Relative water content at preflowering (a) and pod filling stage (b) of Mungbean varieties as influenced by water stress. Bar indicates standard error (±).

the relative water content (RWC) in response to drought stress has been noted in wide variety of plants as reported by Nayyar and Gupta (2006). Genotypic differences for RWC were also reported by Bharadwaj *et al.* (2018) in cowpea and other pulses.

Xylem exudation rate is known as the flow of sap through the cut end of a stem against the gravitational force. Under normal condition, exudation rate is higher than that under any kind of stress condition. Thus, the exudation rate can be used as an indicator to measure the severity of water deficit (Islam *et al.* 2021b). The exudation rate was found significantly higher in control than under water deficit conditions in both the growth stages (Figure 4a). At preflowering stage, the exudation rate varied from 491.00 to 577.00 mg hr^{-1} and from 298.70 to 386.70 mg hr^{-1} in control and water deficit conditions, respectively. The highest exudation rate was recorded in the variety Binamoog-5 (577.00 mg hr^{-1}) in control condition and the lowest was recorded in variety BUmug 4 (298.70 mg hr^{-1}) in water deficit condition. The highest reduction in exudation rate due to water deficit was recorded in variety BUmug 4 (39.16%) whereas, the lowest reduction was recorded in Binamoog-5 (32.98%) compare to control conditions.

At pod development stage, the exudation rate varied from 282.30 to 383.70 mg h^{-1} and from 122.00 to 200.00 mg hr^{-1} in control and water deficit conditions, respectively (Figure 4b). The highest exudation rate was recorded in the variety Binamoog-5 (383.70 mg hr^{-1}) in control and water deficit condition. The highest reduction in exudation rate due to water deficit was recorded in variety BUmug 4 (56.78%) whereas, the lowest reduction was recorded in Binamoog-5 (47.87%) compare to control conditions. These results indicated that BUmug 4 suffered more from water deficit compared to other varieties of mungbean. The decreased water uptake of a plant due to water stress was also observed in mung bean Islam *et al*. (2021c) and Choudhury (2009) in French bean.

The membrane stability index (MSI) was significantly affected by water stress conditions, and the MSI decreased significantly with increasing stress intensity. Thus, the higher MSI reflects the relative tolerance to drought stress (Bajji *et al*. 2002). Cell membrane thermo- stability as evaluated the relative electrolyte leakage at 44º C temperature differed significant among the mungbean varieties under water stressed conditions (Figure 5). The membrane injury among the varieties varied from 46.00 to 51.90% and from 63.80 to 71.37% in normal and water deficit conditions, respectively. The highest injury was obtained in the variety BUmug 4 in both control (51.90%) and water deficit condition (78.43%), while the lowest in the variety BARI mung-6 (45.10%) in control condition and Binamoog-5 (63.80%) in water deficit condition, respectively. The highest injury percentage was recorded in BUmug 4 (33.82%) and the lowest in Binamoog-5 (27.27%) compare to control condition. The decrease in membrane stability under water deficit stress may be due to

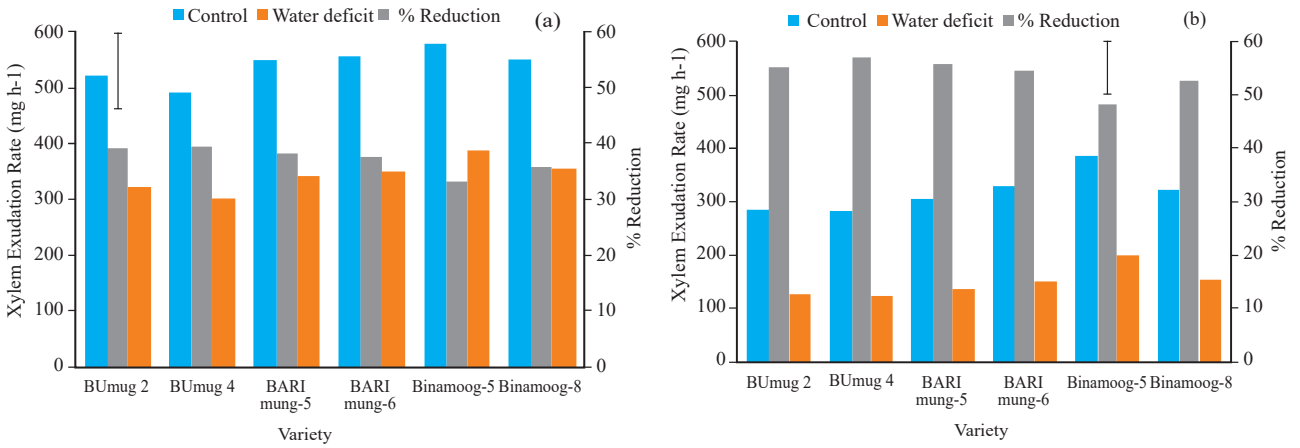


Figure 4. Xylem exudation rate at the preflowering (a) and pod filling stage (b) of Mungbean varieties as affected by water stress. Bar indicates standard error (±).

membrane disorganization because of the overproduction of ROS, which is responsible for the higher leakage of ions from leaves (Ratnasekera and Subhashi 2015). Many researchers opined that the cell membrane stability has been extensively used as selection criterion for drought stresses in mungbean (Islam *et al.* 2021a). Islam *et al.* (2021a) also found that the BMX-08010-2 genotype gave better membrane stability index compared to BARI Mung-1 under stress and reflects the relative tolerance to drought stress.

Chlorophyll contents act as an important role in photosynthesis, which allow plants to absorb energy from light (Carter and Knapp 2001). The results of the present study revealed that all the mungbean genotypes exhibited a substantial variation in the leaf chlorophyll content under

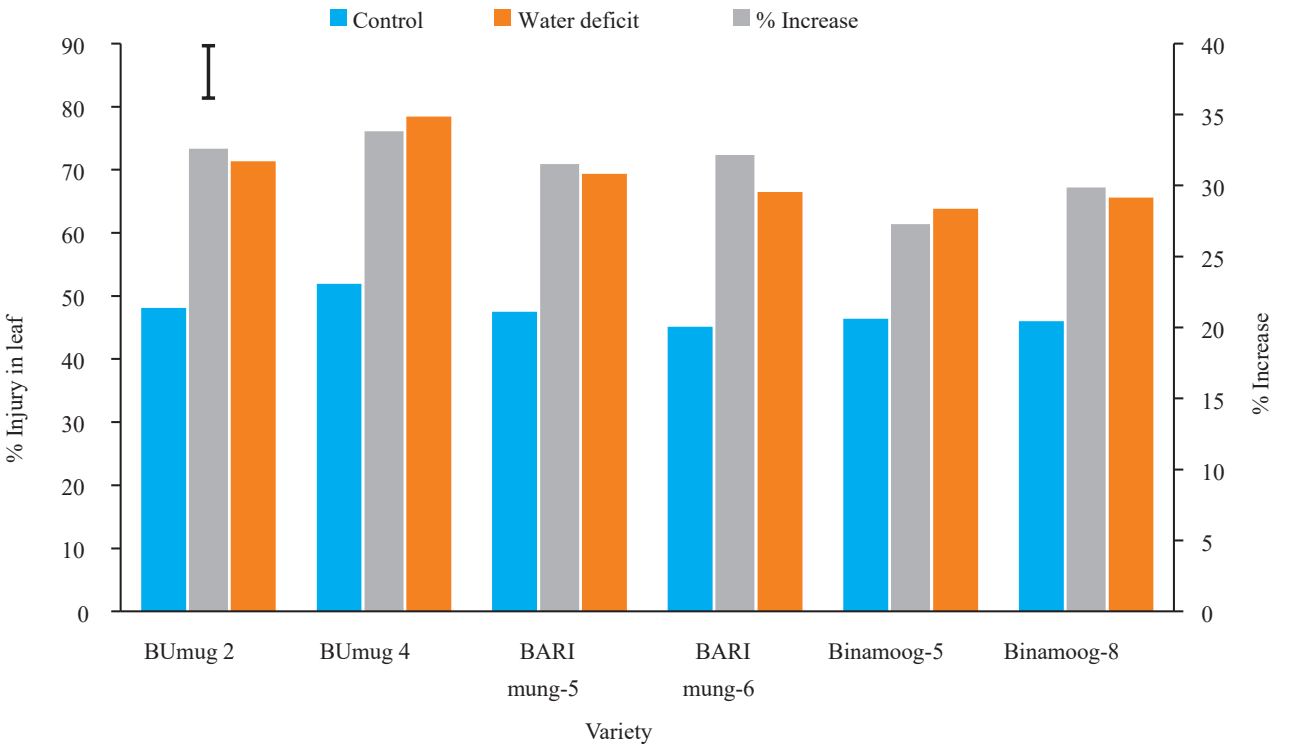


Figure 5. Injury percentage in leaf of mungbean varieties as influenced by water stress. Bar indicates standard error (±).

control and water deficit conditions, respectively in both preflowering and pod development stages (Table 1). At preflowering stage, the total chlorophyll content ranged from 2.4 to 3.3 mg g^{-1} and 1.7 to 2.7 mg g^{-1} in control and water deficit conditions, respectively. The variety Binamoog-5 contained the highest chlorophyll content (3.3 mg g^{-1} and 2.7 mg g^{-1}) whereas BUmug 4 contained the lowest total chlorophyll (2.4 mg g^{-1} and 1.7 mg g^{-1}) in non-stress and water stressed condition respectively. The lowest reduction in total chlorophyll content was recorded in variety Binamoog-5 (19.5%) followed by Binamoog-8 (23.2%) whereas the highest reduction in BUmug 4 (29.5%). At pod development stage, the total chlorophyll content ranged from 2.2 to 3.1 mg g^{-1} and from 1.5 to 2.8 mg g^{-1} in control and water deficit conditions. The variety Binamoog-5 contained the highest amount of total chlorophyll (3.1 mg g^{-1} and 2.8 mg g^{-1}) whereas BUmug 4 contained the lowest total chlorophyll (1.5 mg g^{-1} and 1.5 mg g^{-1}) in control and water deficit condition. The lowest reduction in total chlorophyll content was recorded in variety Binamoog-8 (9.9%) followed by Binamoog-5 (10.2%) and the highest reduction in BUmug 2 (24.7%). Islam *et al.* (2022) concluded from their study that water stress remarkably reduced the leaf chlorophyll contents in mungbean. The results are also in line with that of Allahmoradi *et al.* (2011) who revealed that drought stress significantly decreased the total chlorophyll content in mungbean.

The photosynthetic rates varied significantly among the mungbean varieties at pod development stage (Figure 6). Water stress reduced the rate of net photosynthesis over the control condition. The rate of Pn ranged from 37.13 to 46.70 µmol m^{-2} s^{-1} CO_2 and 27.39 to 38.94 µmol m^{-2} s^{-1} CO_2 in control and water deficit conditions, respectively. The highest net photosynthesis, 46.70 µmol m^{-2} s^{-1} CO_2 and 38.94 µmol m^{-2} s^{-1} CO_2, was recorded in variety Binamoog-5 and the lowest net photosynthesis, 37.13 µmol m^{-2} s^{-1} CO_2 and 27.39 µmol m^{-2} s^{-1} CO_2, was recorded in variety BUmug 4 both in control and water deficit conditions, respectively. The lowest reduction in net photosynthesis was recorded in variety Binamoog-5 (16.61%) followed by Binamoog-8 (17.84%) whereas the highest reduction was in BUmug 4 (26.23%). Under drought stress condition, the reduction in photosynthesis was accompanied by a parallel decrease in stomatal conductance (Xue *et al.* 2002). These results are in agreement with the findings of that the reduction in photosynthesis was mostly due to lower stomatal conductance in soybean.

The whole plant transpiration in all six mungbean varieties decreased under water deficit condition (Figure 7). The rate of transpiration ranged from 13.00 to 18.00 mg $H_2O/dm^2/h$ and from 10.00 to 15.00 mg $H_2O/dm^2/h$ in control and water deficit conditions, respectively. The highest transpiration 18.00 mg $H_2O/dm^2/h$ and 15.00 mg $H_2O/dm^2/h$ were recorded both in variety Binamoog-5 and Binamoog-8 in control and water deficit conditions, respectively and the lowest transpiration 10.00 mg H_2O/

Table 1. Total chlorophyll content at preflowering and pod development stages in six Mungbean varieties in control and water deficit conditions

Variety	Total chlorophyll content (mg g^{-1})			
	Preflowering stage		Pod development stage	
	Control	water stress	control	water stress
BUmug 2	2.9	2.1 (26.8)	2.5	1.9 (24.7)
BUmug 4	2.4	1.7 (29.5)	2.2	1.5 (29.0)
BARI mung-5	2.9	2.1 (27.6)	2.8	2.2 (20.1)
BARI mung-6	3.1	2.3 (26.1)	2.9	2.5 (13.7)
Binamoog-5	3.3	2.7 (19.5)	3.1	2.8 (10.2)
Binamoog-8	3.1	2.4 (23.2)	2.9	2.6 (9.9)
CV (%)	3.4		3.9	
LSD(0.05)	0.05		0.17	

Value in the parenthesis is percent reduction in water stress compare to control.

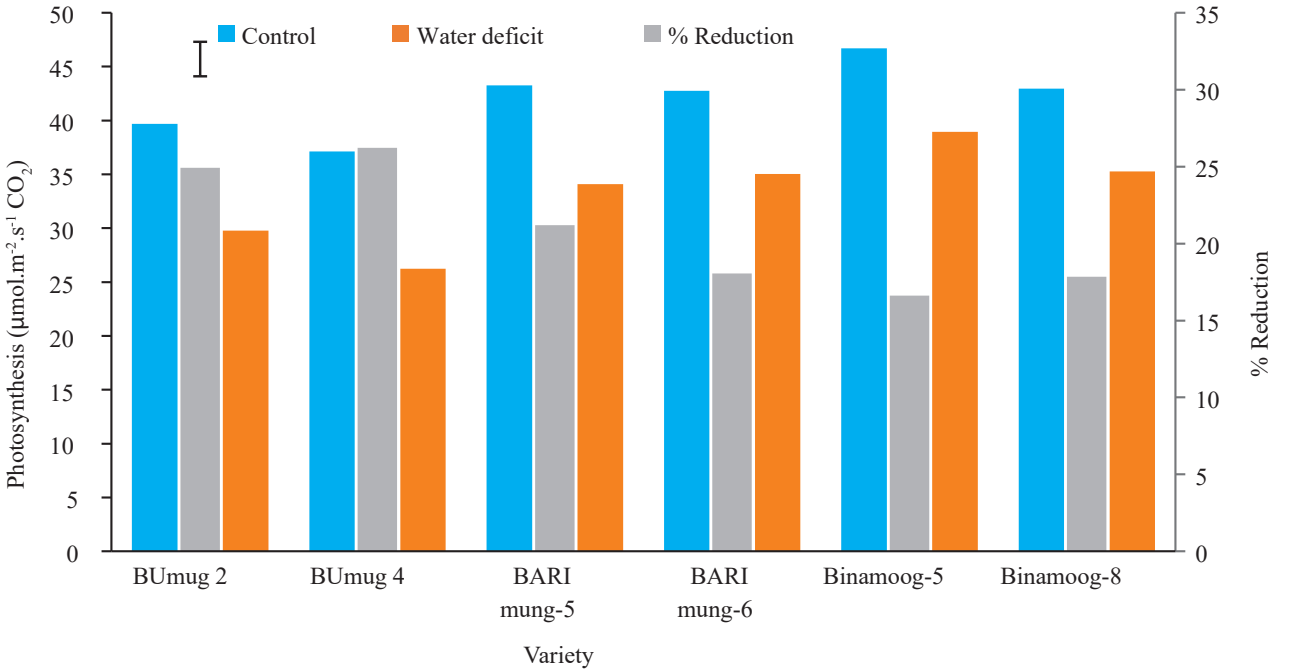


Figure 6. Rate of photosynthesis as influenced by water deficit in mungbean varieties. Bar indicates standard error (±).

dm^2/h and 13.00 mg H_2O/dm^2/h were recorded both in variety BUmug 4 and BUmug 2 in control and water deficit conditions, respectively. The lowest reduction in transpiration was recorded in variety Binamoog-5 (16.67%) and Binamoog-8 (16.67%) whereas the highest reduction in BUmug 4 (23.08%) followed by BUmug 2 (21.43%). Similar result was found by Naresh *et al.* (2013) in mungbean, Chaudhury (2009) in bushbean who stated

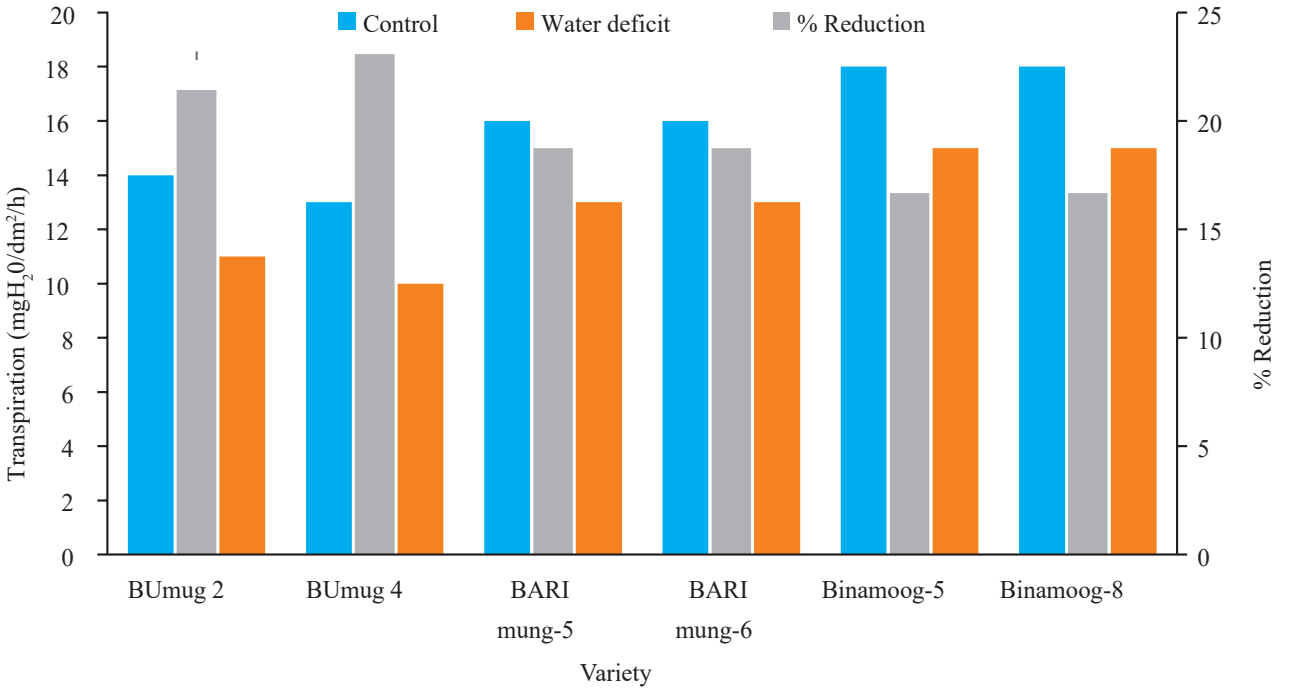


Figure 7. Transpiration rate as influenced by water deficit in mungbean varieties. Bar indicates standard error (±).

that drought tolerant varieties maintained highest xylem water potential transpiration rate and canopy temperature compared to drought susceptible varieties.

Conclusion

Wide variations in physiological responses of mungbean varieties to water stress were observed. The varieties Binamoog-5 and Binamoog-8 were rather tolerant to water stress in relation to its high proline content, leaf water potential, leaf chlorophyll content, photosynthesis and transpiration, xylem exudation rate, relative water content and lower cell membrane thermo-stability.

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