AFTER-EFFECTS OF MOISTURE STRESS ON STOMATAL RESISTANCE AND TRANSPIRATION OF MUNGBEAN (*Vigna radiata* L.) AT DIFFERENT GROWTH STAGES

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ABSTRACT

The after-effects of moisture stress on stomatal resistance (RS) and transpiration rate (TR) of mungbean were studied using cv. MI-6 at vegetative and flowering stages in the greenhouse of the Department of Botany, Eastern University, Sri Lanka. Moisture stress was imposed for different treatments for a period of 12 days per treatment during the vegetative, flowering and pod-filling stages. Moisture stress was applied by withholding the water completely at once. The control plants were regularly watered at four days interval. There was a complete recovery of RS and TR values of plants after re-watering. The RS was completely recovered on the 5th day and 7th day after re-watering during the vegetative and flowering stages respectively. The TR was completely recovered on the 4th day and 6th day after re-watering during the vegetative and flowering stages respectively. Moisture stress during the flowering stage showed high yield reduction compared to the other growth stages. Moisture stress experienced at the flowering stage caused a severe flower drop. This limitation resulted in low pod set, which reduced the number of pods per plant and the final yield. A delay in the recovery of RS and TR during the flowering stage also would have contributed for the reduction in yield.

Key words: Moisture Stress, Recovery, Stomatal Resistance, Transpiration Rate

INTRODUCTION

Mungbean (*Vigna radiata* L. Wilezek) a major grain legume is cultivated traditionally and predominantly in Sri Lanka under a system of subsistence farming mainly in the dry and intermediate zones (Jayasekera & Ariyaratne, 1988). It is rich in grain protein (ranging from 17% to 27%), carbohydrate (over 60%), vitamins and minerals. It provides not only a cheap source of protein but also ensures an ideal complement with regard to amino acid requirements.

Mungbean suffers from 40% to 60% reduction in grain yield due to moisture stress as compared to irrigated crop (Sadasivam *et al.*, 1988). Yield improvement of mungbean, either through breeding of high yielding cultivars or through improved crop management therefore should be based on the countering effects of water stress (De Costa *et al.*, 1999). Water stress leads to wilting after-effects and the physiological processes fail to return to normal immediately (Mansfield & Davies, 1981). There are numerous reports showing that water deficit limits yield while irrigation increases yield (Mahendran *et al.*, 2000). Further, the recovery after water stress has rarely been investigated in detail (Kirschbaum, 1988). The recovery from water stress is as much important as the water stress itself.

The present study was conducted to assess the response of mungbean var. MI-6 to moisture stress at different growth stages (vegetative, flowering and pod filling) and to determine the extent of recovery of the physiological parameters of mungbean after re-watering.

MATERIALS AND METHODS

Greenhouse experiment

This study was conducted in the greenhouse of the Department of Botany, Faculty of Science, Eastern University, Sri Lanka from May to July 2006. The average temperature and relative humidity inside the green house were 34 ± 1.2 °C and 53 ± 1.8 % respectively during the experimental period.

Agronomic practices

Plants were grown in polyethylene bags and black polyethylene sheets (500 gauge) were used to prepare the bags. Potting mixture was added in the ratio of sand: red soil: cow dung 1:1:1. The mungbean seeds (250g) were treated with Captan ($1 g\ l^{-1}$) before dibbling in the bags. Three seeds were dibbled in each bag. Only the vigorous seedling was allowed to grow and the rest were removed 10 days after the emergence. The plants were arranged 30 cm × 10 cm apart (Anon., 2005). Weeding was done manually at 10 days interval. Watering was done daily in the morning until germination and water was applied to field capacity at 4 days interval for two weeks after sowing.

Fertilizer application

The fertilizer was incorporated with the potting mixture before sowing as the basal dressing at the rate of urea ($35\ kg\ ha^{-1}$), triple super phosphate

(100 kg ha^{-1}) and muriate of potash (75 kg ha^{-1}). Urea (30kg ha^{-1}) was applied as the top dressing 30 days after sowing during the flowering stage (Anon., 2005).

Experimental design

A number of 120 plants were used for the experiment and they were divided into 4 treatments. These treatments were arranged in a completely randomized design and each treatment had 30 replications. The treatments were defined as follows: Treatment-1 (T_1) served as the control. Moisture stress for a period of 12 days was imposed for treatment-2 (T_2) during the vegetative stage. Treatment-3 (T_3), experienced moisture stress for a period of 12 days during the flowering stage. Moisture stress was applied for treatment-4 (T_4), for the same period during the pod-filling stage. Moisture stress was given by withholding water completely at once. The treatment structure was illustrated in the Figure 1.

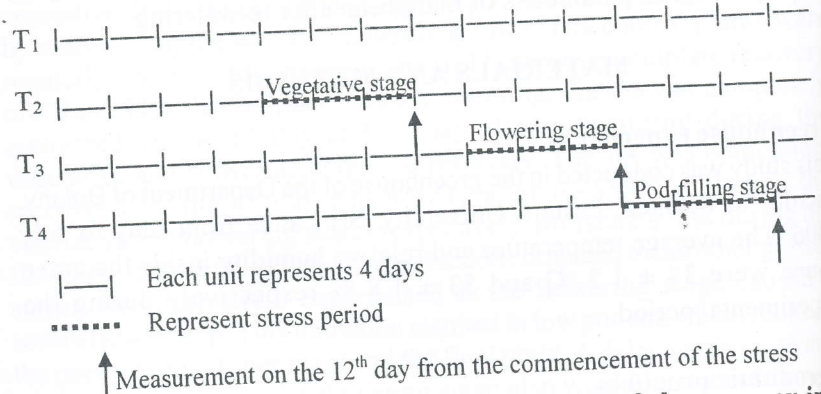

Figure 1: The diagrammatic representation of the manner in which moisture stress was imposed at different growth stages of mungbean

[Note: T_1 = control – regular watering to field capacity at 4 days interval, T_2 = 12 days moisture stress during the vegetative stage at 16 days after sowing, T_3 =12 days moisture stress during the flowering stage at 32 days after sowing, T_4 =12 days moisture stress during the pod-filling stage at 44 days after sowing]

Measurements

The stomatal resistance (RS) and transpiration rate (TR) measurements were made on the 12th day from the commencement of each stress cycle and continued daily after withholding the stress during the vegetative and flowering stages of mungbean. The RS and TR were measured in the control and re-watered plants.

The leaves which were matured most recently, i.e., the 3rd or 4th leaf from the apex was selected for the determination of physiological parameters. The RS and TR were measured by a portable steady state porometer (LI-1600, LICOR Inc, USA) during the vegetative, flowering and pod-filling stages for the stressed, control and re-watered plants. The measurements were made between 10.00 a.m. to noon when the photosynthetic active radiation (PAR) was above the saturation PAR of 1500 μ $Es^{-1}m^{-2}$.

The matured pods were harvested in two pickings. The first picking was done on the 60th day after sowing and the second one was made on the 70th day after sowing. The pods were collected from different treatments and they were pooled together. All the measured data collected from the experimental plants were subjected to statistical analysis.

RESULTS

Stomatal resistance (RS)

During the vegetative (T_2) and flowering stages (T_3) a complete recovery in the RS values was observed on the 5th day and 7th day after withholding the stress (Figs. 2 and 3). RS showed a progressive recovery during the period from 2 to 4 days after re-watering the stressed plants. The RS of the plants during the vegetative stage recovered faster than that, of the flowering stage. This shows that water deficit would have had more impact on the flowering stage than the vegetative stage.

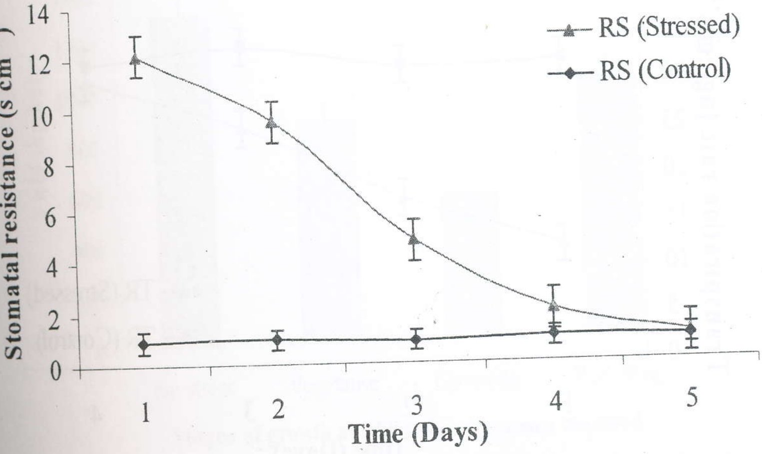

Figure 2: After-effects of moisture stress on the stomatal resistance during the vegetative stage

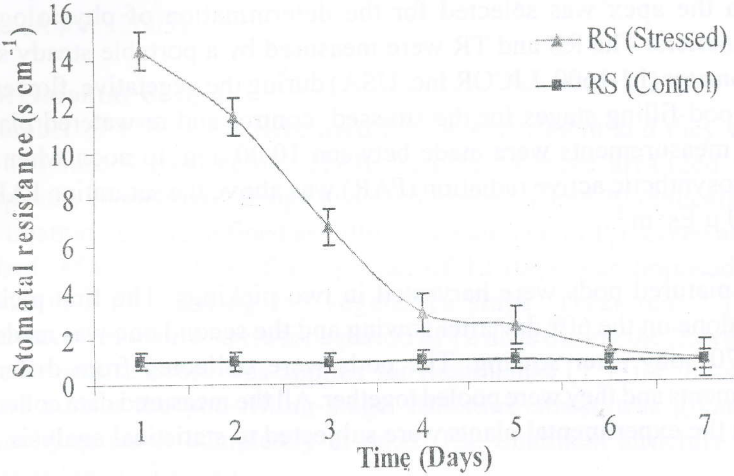

Figure 3: After-effects of moisture stress on the stomatal resistance (RS) during the flowering stage

Transpiration rate (TR)

It was found that there was a complete recovery in the TR values of plants during the vegetative and flowering stages on the 4th day and 6th day after re-watering respectively (Figs. 4 and 5). The plants stressed during the vegetative stage showed quicker recovery in the TR values than those of the flowering stage.

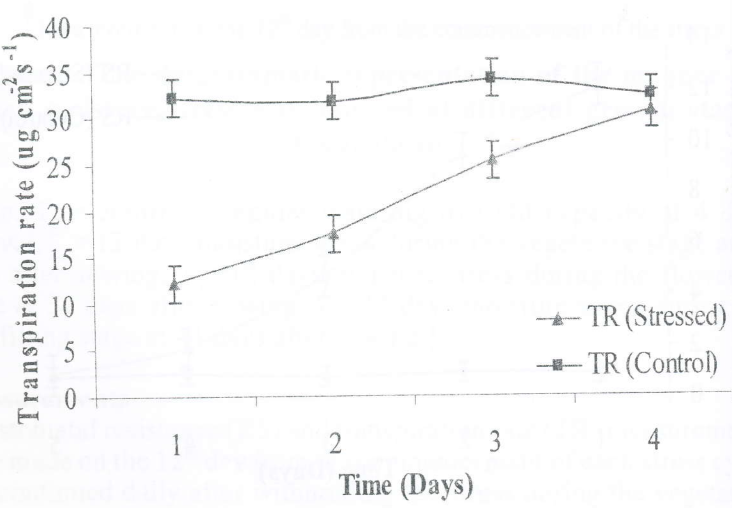

Figure 4: After-effects of moisture stress on the rate of transpiration during the vegetative stage

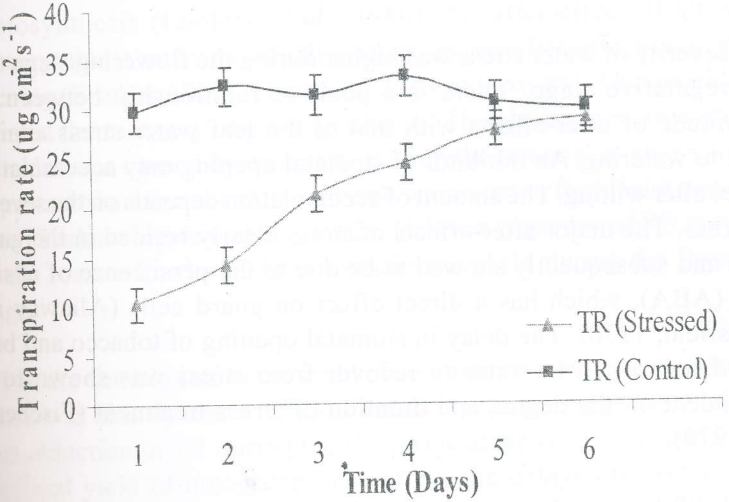

Figure 5: After-effects of moisture stress on the rate of transpiration during the flowering stage

Yield

The highest yield reduction was observed when the stress was imposed during the flowering stage of the plants (Figure 6). The plants stressed during the vegetative stage showed the next highest yield reduction.

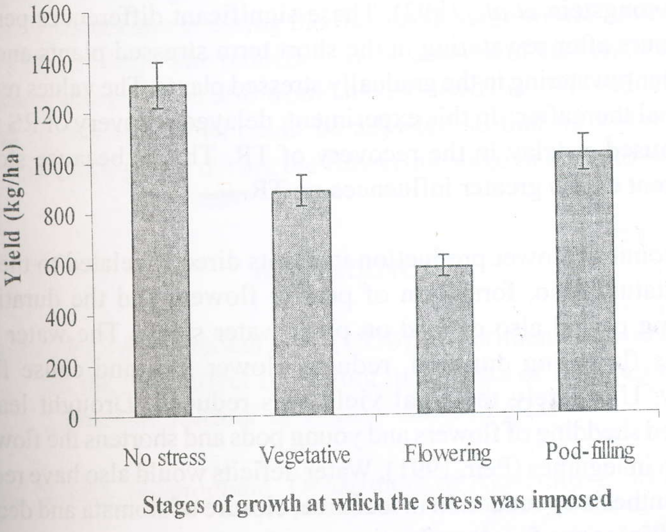

Figure 6: Effect of moisture stress on yield of mungbean var. MI-6 at different growth stages

DISCUSSION

The severity of water stress was higher during the flowering stage than the vegetative stage. There is a positive relationship between the magnitude of after-effects with that of the leaf water stress attained prior to watering. An inhibitor of stomatal opening may accumulate in leaves after wilting. The amount of accumulation depends on the severity of stress. The major after-effects of stress clearly resided in the guard cells and subsequently showed to be due to the persistence of absicic acid (ABA), which has a direct effect on guard cells (Allaway and Mansfield, 1970). The delay in stomatal opening of tobacco and bean leaf discs placed in water to recover from stress was shown to be dependent on the degree and duration of stress treatment (Fischer *et al*., 1970).

A delay from complete recovery of RS during the flowering stage may be due to the higher amount of accumulation of ABA during this stage. The lag in the recovery of RS after rehydration may be due to the persistent effect of ABA produced during water stress period (Torrecillas *et al*., 1995).

Techawongstien *et al*., (1992) observed that in some cultivars of hot pepper, the TR values of the water stressed plants were significantly lower than those of the control throughout the treatment period (Techawongstein *et al*., 1992). These significant differences persisted for 6 hours after rewatering in the short term stressed plants and for 9 days after rewatering in the gradually stressed plants. The values returned to normal thereafter. In this experiment, delayed recovery of RS would have caused a delay in the recovery of TR. This is because stomatal movement exerts greater influences on TR.

The amount of flower production in plants directly related to the plant water status. Also, formation of perfect flowers and the duration of flowering period also depend on plant water status. The water stress shortens flowering duration, reduces flower size and cause flower sterility. Ultimately the final yield was reduced. Drought leads to increased shedding of flowers and young pods and shortens the flowering duration in legumes (Petr, 1991). Water deficits would also have reduced photosynthesis by reduction in leaf area, closure of stomata and decrease in the efficiency of carbon fixation.

Stomatal resistance exerted bigger influence on recovery of photosynthesis (Ludlow *et al*., 1980). An after-effect of stress on photosynthetic rate was actually caused by the after-effect on stomatal opening (Fischer, 1970). Therefore, delayed recovery of RS would have delayed the recovery of photosynthesis. The ability to recover rapidly from damage caused by water stress upon the removal of stress is more important than the ability to survive water stress for a long period of time (Techawongstein *et al*., 1992). Delayed recovery of RS may also be the reason for the highest reduction in yield during the flowering stage.

TR is the function of grain yield. The amount of water transpired by plants was directly related to the dry matter production (Passioura, 1996). The reduction in TR during the flowering stage would have decreased the final yield of mungbean. Therefore, the delayed recovery of TR would also have contributed for the reduction in yield during the flowering stage.

CONCLUSIONS

The above experiment showed the extent of recovery of the physiological parameters after the termination of stress. The flowering stage was found to be the most critical growth stage during stress and this stage brought about the highest yield reduction compared to the other growth stages. Moisture stress during the flowering stage would have caused a severe flower drop. The reduction in the amount of carbon fixation and the rate of transpiration also would have caused the yield reduction. The timing of irrigation thus could be adjusted so that no water stress is experienced by plants during the flowering stage in order to sustain the yield.

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