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Effects of water stress on physiological processes and yield attributes of different mungbean (L.) varieties

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In order to investigate the effect of water stress on Mungbean varieties and its physiological responses to yield, a field experiment was carried out according to split plot design with twenty treatments combination and three replications during 2010 and 2011 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (Uttar Pradesh). The results indicated that drought tolerant varieties maintained highest xylem water potential (XWP), transpiration resistance (TR) and lowest leaf diffusive resistance (LDR) and canopy temperature minus air temperature (Tc – Ta) while drought susceptible varieties maintained lowest XWP,TR and highest LDR and Tc – Ta during the 1300 -1330 h. The rate of net photosynthesis decreased in all the varieties in treatment samples at various stages with the decrease in external CO_2 concentrations. Increase in free proline was observed from vegetative to active pod filling stages in all the varieties. The resistant varieties accumulated higher level of proline under water stress. SML-668 recorded the highest free proline content than all the other varieties. Variety SML-668 produced significantly higher grain yield.

Key words: Mungbean, water stress, yield and yield components.

INTRODUCTION

Among the pulse crops, Mungbean (L.) has a special importance of intensive crop production due to its short growth period (Ahmed et al., 1978). Climatic conditions of western Uttar Pradesh is suitable for Mungbean cultivation throughout the year (Ali and Kumar, 2004). The crop grown under non-irrigated condition, encounters drought stress at different growth stages. The crop is potentially useful for improving cropping pattern as it can be grown as a cash crop due to its rapid growth and early maturing characteristics. In a symbiotic relationship with the soil bacteria, Mungbean roots can fix atmospheric nitrogen and thus improve soil fertility (Nabizade et al., 2011). Further, Mungbean plays an important role in protein supplement in the cereal-based low-protein diet of the people in western Uttar Pradesh, but the acreage and production of Mungbean is steadily declining (Ali and Kumar, 2004).

Plant performance in Mungbean under conditions of drought stress has been extensively studied (Mahmoodian et al. 2012). Water stress affects various physiological processes associated with growth, development, and economic yield of a crop (Allahmoradi et al., 2011). Water deficit disturbs normal turgor pressure, and the loss of

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Abbreviations: Tc, Canopy temperature; **Tc- Ta,** canopy minus air temperature differential; **DAS,** days after sowing; **TR,** transpiration rate; XWP, xylem water potential; **PAR,** photosynthetically active radiation; **LDR,** leaf diffusive resistance; **ROS,** reactive oxygen species.

cell turgidity may stop cell enlargement that causes reduced plant growth (Srivalli et al., 2003). Water stress increases root shoot ratio, thickness of cell walls and amount of cutinization and lignifications (Srivalli et al., 2003). Further, water stress decreases leaf area index in Mungbean (Jordan and Ritichie, 2002). The pre-monsoon period has erratic rainfall leading to water stress in some years and water logging in some years which affects emergence, establishment, growth and productivity of legume crops (Belayet et al., 2010).

Mungbean is reported to be more susceptible to water deficits than many other grain legumes (Pandey et al., 1984). Water stress reduces photosynthesis; the most important physiological processes that regulate development and productivity of plants (Athar and Ashraf, 2005). Reduction in leaf area causes reduction in crop photosynthesis in plants leading to dry matter accumulation (Pandey et al., 1984). Water stress imposed at any growth stage causes reduction in dry matter accumulation depending on the growth stage exposed to stress (Sadasivan et al., 1988). According to Sadasivan et al. (1988), water stress during vegetative phase reduces grain yield through restricted plant size leaf area and root growth which subsequently reduces the dry matter accumulation, number of pods per plant and low harvest index. Water deficits at the flowering and the post-flowering stages have been found to have a greater adverse impact than that at the vegetative stage (Rafiei Shirvan and Asgharipu, 2009). The reproductive stage is the most sensitive growth phase to drought (Brown et al., 1985) resulting to less yield and poor harvest index under drought stress (Uprety and Bhatia, 1989). Identification of genotypic differences in cultivars in tolerance to drought stress is needed for development of Mungbean with reasonably high yield under water deficit. The present study was conducted to identify yield related parameters that are tightly related to grain yield under water stress condition. Mungbean cannot tolerate drought stress (Rafiei Shirvan and Asgharipur, 2009) but there are little reports on negative effects of water stress on yield and physiological characteristics of Mungbean (Asaduzzaman and Hasanuzzaman, 2008). This experiment was carried out to understand the effect of water stress during vegetative and reproductive stages on some physiological traits, yield and yield components of Mungbean.

MATERIALS AND METHODS

The study was carried out at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology in Meerut, Uttar Pradesh, India (28°40′07″N to 29°28′11″N, 77°28′14″E to 77° 44 18″E) in 2010 and in 2011. Experimental design was the split plot design while the moisture regime was the main plot and varieties were the sub-plot with three replications. Each variety was tested for soil moisture regime. The climate of the area is semi-arid. Minimum temperature in the region is 4°C in January and maximum temperature is 41–45°C in June. Relative humidity ranges in between 67–83% throughout the year. The soils are generally sandy loam to loam in texture and low to medium in organic matter content. The treatments were applied as follows: Soil moisture regime as main plot: Irrigation at 0.2 bar soil moisture tension I_1; irrigation at 0.4 bar soil moisture tension I_2; irrigation at 0.6 bar soil moisture tension I_3; irrigation at 0.8 bar soil moisture tension I_4; no post planting irrigation (control) I_5. Varieties as sub plot: Pant mung -1 (V_1); pant mung -2 (V_2); pant mung-3 (V_3); SML-668 (V_4).

Measurement of transpiration rate and leaf diffusive resistance

Transpiration rate and leaf diffusive resistance during 1300-1330 h with the help of a LI 1600 steady state porometer were measured from 30 days after sowing till maturity. Day time measurements of transpiration rate and leaf diffusive resistance were also recorded on the 30th,45th and 60th days after sowing (DAS) from morning (0700-0800h) till evening at an interval of about 2 h. Each value was an average of 3 individual measurements. For measuring transpiration rate and leaf diffusive resistance, well developed, expended leaf was randomly selected in the plot. The resistance to diffusion of water vapour from the sub-stomatal cavities through stomata and the transpiration rate for dorsal leaf surface was measured. This is done by clamping to the leaf (intact with the plant) a small cup containing sensor responsive to change in humidity caused by transpiration.

Measurement of canopy temperature

Canopy temperature and canopy minus air temperature were measured during 1330-1400 h with the help of a Tele temp model AG-42 infrared thermometer from 30 DAS after sufficient canopy was established. Three to four separate measurements were made in each treatment and mean value for each plot was calculated. Measurements were made by directing the instrument towards canopy surface held 50 cm above the crop surface and at an angle of 30°C from the horizontal so as to view the plant parts only. On holding the grip at the above position, the instrument gave canopy temperature (Tc) and on pressing the trigger at the front of the hand grip, it gave canopy minus air temperature differential (Tc- Ta).

Rate of photosynthesis

Rate of photosynthesis was measured by the method of O' Toole et al. (1977). The measurements were made on the leaves from 3rd and 5th node from the top were cut under water at their base and cut ends were inserted in separate funnels of two liters capacity, having water in the bottom. Three trifoliates leaves during vegetative stage and two trifoliates leaves after flowering were used for measurements of photosynthetic rates. The net photosynthetic rates were measured under light intensity of 9000 lux (9 k lux) photosynthetically active radiation (PAR) on the surface of chamber. The light was supplied with three mercury vapor lamps of 400 W capacity. The assimilation chamber was fanned with cool air in order to intercept the excessive heat and regulate the air temperature in the chamber to 30 + 1°C. The relative humidity in the chamber was 90 +2% with the air flow rate of 300 ml/minute during the course of measurements. The time taken to deplete 50 ppm CO_2 in chamber was recorded by an infrared Gas Analyser (Model Type 225 MxII), till CO_2 was depleted from 350 to 100 ppm. The rate of net photosynthesis was computed by the following formula:

Where, V, volume of the chamber (ml); L, leaf area under test (cm^2). The measurements were made during vegetative stages (40 days after sowing), early pod setting and active pod filling stages of the crop growth.

Table 1. Seasonal variation in xylem water potential (XWP,- bar) during 0630-0700 h under I_1,I_2,I_3,I_4 and I_5 condition.

Variety	Transpiration rate (XWP- bar)																			
	Days after sowing (DAS)																			
	30					40					50					60				
	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5
V_1	1.0	1.5	2.0	2.0	2.0	1.5	1.5	2.0	2.5	3.0	1.5	2.0	2.0	3.0	3.5	2.0	3.0	3.5	3.5	4.5
V_2	1.0	1.5	1.5	2.0	2.0	1.0	1.5	2.0	2.0	3.0	1.5	2.0	2.0	3.0	3.5	2.0	3.0	3.0	3.5	4.5
V_3	0.5	1.0	1.5	1.5	2.0	1.0	1.0	1.5	1.5	2.5	1.5	1.5	2.0	2.5	3.0	2.0	2.5	3.0	3.5	4.5
V_4	0.5	1.0	1.0	1.5	1.5	0.5	1.0	1.5	1.5	2.5	1.0	1.5	1.5	2.5	3.0	1.5	2.5	2.5	3.0	4.0

$$\text{Rate of net photosynthesis (mg } CO_2 \text{ dm}^{-2} \text{ hr}^{-1}) = . \quad \frac{50xvx2x3600x100}{10^6 \text{ x L x t}}$$

Determination of free proline

Proline was estimated using the method of Bates et al. (1973). Samples were homogenized in 10 mL 3% (w/v) sulfosalicylic acid, and proline was assayed by the acid ninhydrin method. The absorbance was measured spectrophotometrically at 520 nm. Proline was calculated based on µM. g^{-1}. FW.

RESULTS

Biophysical processes

Seasonal variation in xylem water potential (XWP)

Seasonal changes in XWP during morning (0630-0700 h) were measured from 30 to 60 DAS in various treatments (Table 1). Treatments I_2, I_3 and I_4, follow the trend of XWP during the season but the magnitudes were different. Drought resistant varieties maintained higher XWP than drought sensitive varieties. The highest XWP of varieties (SML-668 and Pant Mung - 3) under I_5 “control” treatment was associated with extensive root system.

Seasonal variation in transpiration rate (TR)

Seasonal changes in TR during post noon (1300-1330 h) is shown in Table 2. Results showed that TR was always higher under I_1 treatment than under I_5 treatment. Under I_1 treatment, TR of V_1 Pant Mung-1, V_2 Pant Mung-2, V_3 Pant Mung-3 and V_4 SML-668 ranged from 24.3 to 26.5, 25.1 to 28.5, 25.5 to 30.2 and 25.3 to 31.5 µg cm^{-2} sec^{-1} during 30 to 60 DAS, respectively. In I_2, I_3, I_4 and I_5, the trend of TR during the season was same but the magnitude was different. In I_1 and I_5, TR ranged from 24.3 to 26.5 and 23.0 to 17.2 in V1; 25.1 to 28.5 and 24.0 to 17.0 in V2; 25.5 to 30.2 and 23.0 to 17.5 in V3 and 25.3 to 31.5 and 23.5 to 19.0 µg cm^{-2} sec^{-1}, respectively, from 30 to 60 DAS. Variety SML-668 was more tolerant to water stress over all other varieties. These were in a sequence of SML-668>Pant Mung-3>Pant Mung-2>Pant Mung-1 in relation to water stress tolerance. Results show that TR increased gradually from 30 to 50 DAS and thereafter decreased. The drought tolerant varieties maintained highest TR and drought susceptible varieties maintained lowest TR during the 1300-1330 h.

Seasonal variation in leaf diffusive resistance (LDR)

Seasonal variations in LDR were recorded during 1300-1330 h as shown in Table 3. LDR was measured from 30 to 60 DAS in various irrigation treatments. In general, LDR of all varieties was low in I_1 than I_5. Treatment I_1, LDR of Pant mung-1, Pant Mung-2, Pant Mung-3 and SML-668 ranged from 0.23 to 0.17 sec cm^{-1}, 0.21 to 0.18 sec cm^{-1}, 0.20 to 0.15 sec cm^{-1} and 0.17 to 0.14 sec cm^{-1} during 30 to 60 DAS. The LDR of Pant mung-1, Pant Mung-2, Pant Mung-3 and SML-668 in I_2,I_3 and I_4 ranged from 0.21 to 0.26, 0.23 to 0.14, 0.21v to 0.23 and 0.19 to 0.21 sec cm^{-1}, respectively, from 30 to 60 DAS. In I_5, the trend of LDR during the season was same but with higher magnitude recorded from 45 and 60 DAS. In I_1, I_5 LDR ranged from 0.23 to 0.17, 0.25 to 0.31 in V_1; 0.21 to 0.18, 0.24 to 0.27 in V_2; 0.20 to 0.15, 0.23 to 0.26 in V_3 and 0.17 to 0.14, 0.20 to 0.24 sec cm^{-1} in V_4, respectively. Variety SML-668 was more tolerant to water stress over all other varieties. The drought tolerant varieties maintained lowest LDR and drought susceptible varieties maintained highest LDR during

Table 2. Seasonal variation in transpiration rate (TR µg cm^{-2} sec^{-1}) during 1300-1330 h under I_1,I_2,I_3,I_4 and I_5 condition.

Variety	Transpiration rate (µg cm^{-2} sec^{-1}) Days after sowing (DAS)																			
	30					40					50					60				
	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5
V_1	24.3	23.4	23.0	23.5	23.0	26.2	24.0	22.5	22.0	21.5	28.0	26.0	23.5	20.2	18.3	26.5	24.5	21.0	17.5	17.2
V_2	25.1	24.3	24.0	24.2	24.0	27.0	24.5	23.6	23.2	22.3	31.0	29.0	24.0	20.5	18.2	28.5	25.5	22.5	18.5	17.0
V_3	25.5	24.6	24.2	23.5	23.0	28.0	25.0	24.0	23.0	22.5	31.5	29.5	24.5	21.0	18.5	30.2	26.5	23.5	19.0	17.5
V_4	25.3	24.5	24.0	24.0	23.5	28.5	26.5	23.5	22.3	21.3	33.5	31.5	25.5	21.5	19.5	31.5	28.5	24.3	20.0	19.0

Table 3. Seasonal variation in leaf diffusive resistance (LDR) (sec cm^{-1}) during 1300-1330 h under I_1,I_2,I_3,I_4 and I_5 condition.

Variety	Leaf diffusive resistance (sec cm^{-1}) Days after sowing (DAS)																			
	30					40					50					60				
	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5	I_1	I_2	I_3	I_4	I_5
V_1	0.23	0.24	0.24	0.25	0.25	0.19	0.21	0.30	0.31	0.33	0.19	0.20	0.28	0.32	0.34	0.17	0.20	0.25	0.30	0.31
V_2	0.21	0.23	0.22	0.23	0.24	0.18	0.19	0.26	0.27	0.29	0.19	0.19	0.24	0.27	0.29	0.18	0.17	0.22	0.26	0.27
V_3	0.20	0.21	0.21	0.22	0.23	0.17	0.19	0.23	0.25	0.26	0.16	0.18	0.21	0.26	0.27	0.15	0.16	0.20	0.23	0.26
V_4	0.17	0.19	0.18	0.19	0.20	0.17	0.18	0.21	0.22	0.24	0.15	0.17	0.20	0.23	0.26	0.14	0.17	0.19	0.21	0.24

the 1300-1330 h.

Seasonal variation in canopy temperature (T_C) and canopy minus air temperature differential (T_C- T_a°C)

Measurements of canopy, canopy minus air temperature differential (T_C), (T_C- T_a°C) during 1300-1400 h from 30, 40, 50 and 60 DAS in various treatments is shown in Table 4. Results showed that T_C, T_C - T_a under I_1 treatment was lower than those under I_5 "control" treatment. Whenever the differences in T_C- T_a among the varieties was equal to or less than the difference among the replicated measurements within the treatments, the varieties were considered similar in character and only average values were reported (Table 4). Treatment I_1 T_C, T_C- T_a of Pant Mung-1,Pant Mung-2, Pant Mung-3 and SML-668 ranged from 31.2 to 36.5, 30.8 to 36.0, 30.6 to 35.5 and 30.2 to 35.0°C, -5.4 to -4.2, -5.6 to -4.7, -6.0 to -5.2 and -6.4 to -5.7°C during 30 to 60 DAS. In I_2, I_3, I_4 and I_5 treatments, the trend of T_C, T_C-T_a during the season was same but the magnitude was different. Among the varieties, SML-668 was superior to all other varieties. These all were in a sequence of Pant Mung-1>Pant Mung-2> Pant Mung-3>SML-668 in relation to drought tolerant.

Physiological processes

Rate of net photosynthesis

The photosynthetic rates varied significantly among the varieties at all three stages, viz., vegetative, early pod setting and active pod filling at all the external CO_2 concentrations (Table 5). The rate of net photosynthesis increased with the advancement of crop stage. Improved moisture supply increased the rate of net photosynthesis over I_5 "control". At all the stages, I_1 and I_2 were found to be superior to other treatment at various levels of external CO_2 concentrations. The rate of net photosynthesis decreased in all the varieties and treatments at various stages with the decrease in external CO_2 concentrations.

The large differences are said to be caused by chlorophyll content, the conductivity of CO_2 particularly the mesophyll resistance and the differential response of varieties to light and the external conditions such as light intensity and its quality, temperature and CO_2 concentrations and finally the utilization or translocation of photosynthesis from leaves. In spite of the several factors influencing the rate of photosynthesis, occasional but

Table 4. Seasonal variation in canopy temperature (T_C) and canopy minus air temperature differential (T_C- T_a°C) during 1300-1330 h under I_1,I_2,I_3,I_4 and I_5 conditions based on infrared thermometry from 30 to 60 DAS.

Variety	Canopy temperature T_C(°C) and canopy minus air temperature differential T_C- T_a(°C)							
	Days after sowing (DAS)							
	30		40		50		60	
	T_C	T_C- T_a	T_C	T_C- T_a	T_C	T_C- T_a	T_C	T_C- T_a
1	2	3	4	5	6	7	8	9
I_1								
V_1	31.2	-5.4	36.0	-0.4	37.0	-3.1	36.5	-4.2
V_2	30.8	-5.6	35.4	-1.2	36.0	-4.1	36.0	-4.7
V_3	30.6	-6.0	35.2	-1.4	35.5	-4.6	35.5	-5.2
V_4	30.2	-6.4	33.5	-3.1	34.5	-5.6	35.0	5.7
I_2								
V_1	32.0	-4.6	36.7	+0.1	37.4	-2.7	37.8	-2.9
V_2	31.5	-5.1	35.7	-0.9	36.7	-3.4	37.2	-3.5
V_3	31.5	-5.1	35.5	-1.1	36.0	-4.1	37.0	-3.7
V_4	30.5	-6.1	33.6	-3.0	35.0	-5.1	36.0	-4.7
I_3								
V_1	32.5	-4.1	36.2	-0.4	37.5	-2.6	37.7	-3.0
V_2	32.0	-4.6	35.0	-1.6	36.8	-3.3	37.0	-3.7
V_3	31.7	-4.9	34.5	-2.1	36.5	-3.6	36.8	-3.9
V_4	31.0	-5.6	33.5	-3.1	36.0	-4.1	36.0	-4.7
I_4								
V_1	32.7	-3.9	37.5	+0.9	38.8	-1.3	39.2	-1.3
V_2	32.2	-4.4	36.5	-0.1	38.2	-1.9	38.5	-2.0
V_3	32.0	-4.6	36.0	-0.6	38.0	-2.1	38.2	-2.5
V_4	31.2	-5.4	35.0	-1.6	37.0	-3.1	37.5	-3.2
I_5								
V_1	32.5	-3.9	37.5	+0.9	39.0	-1.1	39.5	-1.2
V_2	32.0	-4.4	36.7	+0.1	38.5	-1.6	39.0	-1.7
V_3	31.7	-4.7	36.2	-0.4	38.2	-1.9	38.5	-2.2
V_4	31.2	-5.4	35.5	-1.1	37.5	-2.6	38.0	-2.7

positive association of photosynthetic rate with productivity and good heritability of carbon exchange rate was noted.

Free proline content

Increase in free proline was observed from vegetative to active pod filling stages in all varieties (Table 6). This is because of decrease in internal water status of the plant with advancement in crop age, which could be evident from decrease in leaf water potential with crop age. Irrigation significantly decreased free proline at all the stages. In the field, plants are usually subjected to various degree of water deficit even when soil water is considered as adequate. So this might be the reason for some accumulation of free proline in irrigated condition. Improved moisture supply through various treatments decreased the free proline content over I_5 “control” treatment. At all the stages I_5 and I_4 were found to be superior to all the treatments. I_3 was superior to the remaining treatments, respectively. Among varieties, SML-668 had highest free proline content than all other varieties. Varieties having different degree of drought resistance differ in their capacity to accumulate proline under stress. Resistant varieties accumulate higher level of proline under water stress. A similar trend was obtained by Ashraf and Ibram (2005), Ashraf and Foolad (2007) and Tawfik (2008) who found that osmoprotectants such as proline and glycine betaine (GB) were increased under drought stress.

Yield and yield contributing parameters

Improved moisture supply through various irrigation treatments increased the yield attributes and grain yield significantly over I_5 “control” treatment (Table 6). The maximum yield attributes and grain yield were recorded under I_2 and minimum under I_5 treatment. Among varieties, V_4 SML-668 produced significantly higher number of pods per plant, grains per pod, 1000 grain weight and grain yield than all other varieties, respectively.

Table 5. Effect of different treatments on the rate of net photosynthesis (mg CO_2 dm^{-2} hr^{-1}) at different external CO_2 concentrations (ppm) during vegetative,early pod setting and active pod filling stages.

Treatment	Photosynthesis (mg CO_2 dm^{-2} hr^{-1}) at different external CO_2 concentrations (ppm)																			
	Varieties																			
	Pant mung -1					Pant mung -2					Pant mung -3					SML -668				
	350-300	300-250	250-200	200-150	150-100	350-300	300-250	250-200	200-150	150-100	350-300	300-250	250-200	200-150	150-100	350-300	300-250	250-200	200-150	150-100
Vegetative stage																				
I_1	5.74	3.63	3.15	1.57	0.75	4.49	3.63	3.08	1.60	1.28	6.70	5.56	3.74	2.26	1.24	6.38	4.88	3.64	2.26	2.11
I_2	7.31	4.86	4.26	2.87	1.12	9.96	5.90	3.49	2.64	1.75	9.72	7.62	6.20	4.25	2.43	7.75	6.10	4.47	3.67	2.54
I_3	3.32	2.85	2.30	0.90	0.22	4.37	2.40	2.07	1.21	1.13	5.41	3.82	3.30	1.86	0.90	7.12	3.82	3.24	2.23	1.25
I_4	3.20	2.60	1.78	0.80	0.20	4.13	2.63	1.56	1.10	0.75	3.66	3.55	2.51	1.72	0.82	4.43	2.11	1.63	1.18	0.94
I_5	2.16	2.11	1.28	0.38	0.10	2.56	1.44	0.90	0.86	0.55	2.77	2.22	1.36	0.62	0.13	3.87	2.52	2.13	1.15	0.65
Mean	4.34	3.21	2.55	1.30	0.48	5.10	3.20	2.22	1.48	1.09	5.65	4.55	3.42	2.14	1.10	5.91	3.89	3.02	2.10	1.50
Early pod setting stage																				
I_1	7.83	6.41	4.87	3.37	1.44	7.79	6.41	4.63	3.20	1.62	9.13	7.24	6.05	4.68	2.63	9.95	8.22	5.85	5.09	3.08
I_2	9.10	7.51	5.89	4.56	2.09	9.10	7.15	5.83	4.53	2.13	9.66	7.61	6.25	5.09	3.33	10.35	8.95	7.77	6.39	3.91
I_3	5.62	3.90	3.21	2.43	1.23	6.50	5.71	4.25	3.37	1.92	8.75	7.40	6.09	4.58	3.10	8.73	7.14	5.94	4.70	2.66
I_4	5.62	4.33	3.12	2.43	1.14	5.25	4.51	3.17	2.35	1.35	7.26	5.43	4.28	2.96	1.24	7.26	5.46	4.26	2.96	1.30
I_5	3.20	2.40	1.84	1.33	0.59	3.21	2.38	1.91	1.32	0.59	5.64	4.13	3.60	2.50	1.22	5.67	4.16	3.58	2.35	1.25
Mean	6.27	4.91	3.79	2.82	1.30	6.37	5.23	3.96	2.95	1.52	8.09	6.36	5.25	3.96	2.30	8.71	6.79	5.48	4.30	2.44
Active pod filling stage																				
I_1	8.91	7.73	5.87	4.36	2.36	9.32	7.26	6.11	4.46	2.44	9.15	7.20	6.11	4.27	1.94	9.85	8.36	6.41	5.08	2.09
I_2	9.85	8.36	6.41	5.08	2.46	10.23	9.85	8.26	6.46	3.10	11.15	8.16	6.71	5.11	2.64	112.26	9.85	8.23	6.46	3.09
I_3	7.77	6.86	5.44	4.11	2.15	8.94	7.73	5.87	4.39	2.39	9.07	7.40	5.50	4.21	1.87	9.33	7.96	6.10	4.46	2.45
I_4	6.51	5.52	4.61	3.23	1.45	6.65	6.09	4.09	3.09	1.15	8.36	6.66	5.10	4.09	1.66	8.97	7.76	5.87	4.34	2.37
I_5	5.67	4.72	3.38	2.59	1.24	5.93	4.68	3.48	2.41	1.28	5.43	4.45	2.45	1.61	0.90	5.93	4.71	3.48	2.37	1.27
Mean	7.74	6.64	5.14	3.87	1.93	8.21	7.12	5.56	4.16	2.07	8.63	6.78	5.17	3.86	1.80	9.27	7.73	6.02	4.54	2.25

The yield per hectare was primarily improved due to improvement in moisture supply and its beneficial effect on the per plant yield. The grain yield per plant improved with increase moisture supply mainly through improvement in number of pods per plant, number of grains per pod and 1000 grain weight. Thomas et al. (2004) reviewed that Mung bean plants in the rain shelter and rain fed treatments attained maturity earlier than the well-watered treatment.

DISCUSSION

The results indicated that the XWP and LDR decreased with the beginning of transpiration in the morning. The transpiration was maximum during 1300-1330 h (peak radiation load) under I_1 treatment (irrigation at 0.2 bar soil moisture tension) when the LDR and XWP were minimum. As LDR increased, the TR decreased and XWP increased. Decrease in XWP was a result of excess transpiration over water absorption due to rapidly rising radiation load and saturation deficit. As radiation load increased during the day, canopy temperature (T_C) increased from a minimum at sunrise to a maximum during 1300-1330 h and declined gradually thereafter. The canopy minus air temperature differential (Tc-Ta) on the other hand, reduced during 1300-1330 h because of increasing transpiration rate which resulted into cooling of the canopy relative to air temperature. Result indicated

Table 6. Effect of different treatments on free proline content µg/g fresh weight at vegetative stage, early pod setting stage and active pod filling stage.

Treatment	Free proline content (µg/g) fresh weight											
	Vegetative stage				Early pod setting stage				Active pod filling stage			
	Pant Mung-1	Pant Mung-2	Pant Mung-3	SML-668	Pant Mung-1	Pant Mung-2	Pant Mung-3	SML-668	Pant Mung-1	Pant Mung-2	Pant Mung-3	SML-668
I_1	35.2	35.0	32.5	31.6	58.7	56.6	53.5	49.5	68.5	66.3	57.6	50.6
I_2	45.0	44.6	41.5	39.5	66.2	62.5	60.3	56.3	87.2	85.8	70.2	58.5
I_3	55.0	54.5	50.5	48.0	154.8	152.6	145.7	140.8	355.4	350.3	258.6	210.2
I_4	75.5	74.3	68.5	65.6	178.0	175.6	161.2	150.3	415.3	407.0	315.3	295.3
I_5	87.0	86.2	82.5	77.5	215.5	210.3	196.5	184.5	535.5	528.5	420.5	397.7
Mean	59.5	58.9	55.1	52.4	134.6	131.5	123.4	116.3	292.4	287.6	224.4	202.5

Table 7. Yield attributes and grain yield (q/ha) as affected by different treatments.

Treatment	Number of pods plant^{-1}				Number of grains pod^{-1}				1000 grain weight (g)				Grain yield (q/ha)			
	Varieties															
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4
I_1	12.9	14.0	14.2	14.5	7.2	7.1	7.6	7.5	36.2	37.4	37.3	37.9	9.86	10.23	11.25	11.67
I_2	21.7	21.5	22.3	22.7	7.5	7.8	7.9	8.8	36.4	37.6	37.7	38.1	13.87	15.24	18.18	18.58
I_3	10.8	11.0	12.6	12.6	6.6	6.8	6.9	8.0	35.5	36.5	36.7	37.1	6.86	7.08	9.38	9.58
I_4	10.0	10.0	10.3	10.8	5.9	6.1	6.4	6.8	35.2	36.8	36.9	36.6	5.90	5.95	6.58	6.66
I_5	9.0	9.0	8.9	9.3	3.7	4.2	6.1	6.2	34.8	36.0	36.0	36.2	3.37	3.50	3.61	4.15
C D at 5%	0.43	0.45	0.21	0.08	0.18	0.24	0.12	0.15	1.10	1.02	1.01	0.61	3.96	2.18	3.94	5.94

that period between 1300-1400 h was best for canopy temperature measurements as irrigation treatments had little influence on canopy temperature at sunrise and sunset when the solar radiation was low. Genotypic differences were observed in case of XWP and TR in plants. Drought resistant varieties maintained higher XWP than drought sensitive varieties. The higher XWP and TR were recorded in SML-668 and Pant Mung-3 under I_5 “control” treatment. The genotype SML-668 and Pant Mung-3 had lower Tc-Ta both under I_1 and I_5 treatments during 1300-1400h as compared to the other varieties.

Physiological changes occur in response to low water condition in different varieties. The increase of free proline occurs in decrease in water supply. The synthesis of proline in plants extensively protects cell membrane and protein content in plant leaves. The results of this study are in agreement with other investigations (Behnamnia et al., 2009; Zhang et al., 2006). Proline acts as an osmolite beside enzymes and other macromolecules and therefore, protects the plant against low water potential and causes osmotic regulation in plant organs. Also, proline can act as electron receptor preventing photosystems injuries in dealing with reactive oxygen species (ROS) function. Proline accumulation facilitates the permanent synthesis of soluble substances in closing stomata. Stress, especially in the growing stage, reduces the capacity of the source plants for the source and sink is forced to balance the number of flowers and pod production to reduce the stress that can handle grain filling period and also reduced the final yield. Asaduzzaman et al. (2008) also believe that moisture stress reduces grain yield of Mungbean and maximum negative effects of drought obtained with once irrigation during growth season. Pandey et al. (1984), Sadasivan et al. (1988), Reddy et al. (2004) and Rafiei

Shirvan and Asgharipur (2009) also obtained the similar results.

Conclusion

Drought tolerance consists of ability of crop to grow and produce under water deficit conditions. A long term drought stress effects on plant metabolic reactions are associated with plant growth stage, water storage capacity of soil and physiological aspects of plant. Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments. The present results showed that plants in drought stress make changes in some of their physiological and biochemical features. Also, the results of this research showed that drought stress causes low grain yield; and in drought stress conditions cultivars that have more TR, chlorophyll content, XWP, proline content and LDR and canopy minus air temperature (Tc-Ta) are more tolerant to drought stress.

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