Yield and Dry Matter Production of Japanese and US Soybean Cultivars under Drought Stress

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Abstract

The difference in soybean yield between Japan and US is enlarging. The authors reported that the higher yields of US cultivars than Japanese cultivars were attributed to greater dry matter production and radiation use efficiency and that the US cultivars tended to have higher leaf stomatal conductance to water vapor (gs). These traits may cause different sensitivity to drought between cultivars. The objective of this study was to examine whether the yield response to drought differed between a Japanese cv. Tachinagaha (Tc) and a US cv. UA-4805 (UA) with low and high leaf gs, respectively. The two cultivars were grown on a drained paddy field in the Exp. Farm of Kyoto Univ. (Takatsuki, Japan) and the treatment with irrigation (Control) and without irrigation (Drought) was started at 20 days after emergence. The volumetric soil water content was on average 6% lower in the Drought than in the control plots. The leaf area development was inhibited only in UA under Drought. The gs was higher in UA than in Tc and it decreased in both cultivars by 34~38%. UA showed a greater mean seed yield and harvest index. Drought reduced mean seed yield and total dry weight of two cultivars. The yield reduction by drought in UA was associated with reduced radiation intercepted, while yield reduction in Tc was associated with reduced radiation use efficiency and harvest index. The significant G×E interaction was detected in harvest index and mean fraction of radiation intercepted. The two cultivars did not differ in yield response to drought, but they differed in the yield components affected by drought.

*Keywords: soybean (*Glycine max *(L.) Merrill), yield, genotype by environment interaction, drought*

Introduction

The difference in soybean yield between Japan and US is enlarging. The authors reported that the higher yields of US cultivars than Japanese cultivars were attributed to greater dry matter production and radiation use efficiency (Kawasaki *et al*. 2010) and that the US cultivars tended to have higher leaf stomatal conductance to water vapor (gs) (Tanaka *et al.* 2010). These traits may cause different sensitivity to drought between cultivars. The objective of this study was to examine whether the yield response to drought differed between a Japanese cv. Tachinagaha (Tc) and a US cv. UA-4805 (UA) with low and high leaf gs, respectively.

Materials and Methods

The two cultivars were grown on a drained paddy field in the Experimental Farm of Kyoto University (Takatsuki, Japan, Eutric Fluvisols) located at 34°51’N and 135°37E’. The date of sowing was 7th of July 2010 and the date of emergence was 12nd of July. Plant spacing was 0.7 by 0.15m. Fertilizers of N, P_2O_5, K_2O were incorporated into the soil before sowing at 3, 10 and 10 gm^{-2}, respectively.

The treatment with irrigation (Control) and without irrigation (Drought) was started at 20 days after emergence. In the Control, irrigation water was evenly applied using the plastic tube

(Sumisansui, Sumika Agrotech Co. Ltd.) extended on the ground in every other interrow. Irrigation was conducted when the soil matric potential declined lower than 50kPa. The volumetric soil water content was measured twice a week using EC-5 (Decagon Devices, Inc.).

The canopy coverage was measured by the digital image analysis using ImageJ (NIH, USA) (Purcell 2000, Shiraiwa *et al.* 2011). The total above-ground plant part was harvested at 35, 47, 61, and 74 days after emergence from a 1.26 m^2 land area and the dry matter weight was determined after drying at 80°C for 72h. The Leaf Area Index (LAI) was estimated by measuring leaf area of representative plants.

Results and Discussion

The volumetric soil water content was on average of 6% lower in the Drought than in the Control plots (Figure 1). The leaf area development was inhibited only in UA under Drought (Figures 2 and 3). The gs was higher in UA than in Tc and it decreased in both cultivars by 34~38% (Figures 4 and 5).

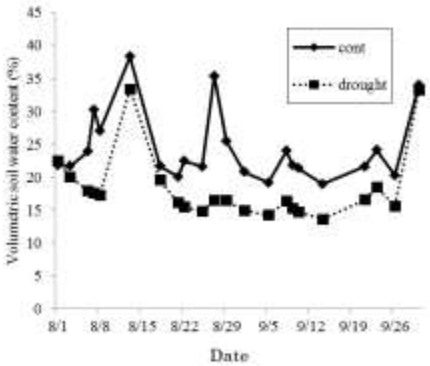

Figure 1. Change in volumetric soil water content measured by EC-5 (Decagon Devices, Inc.).

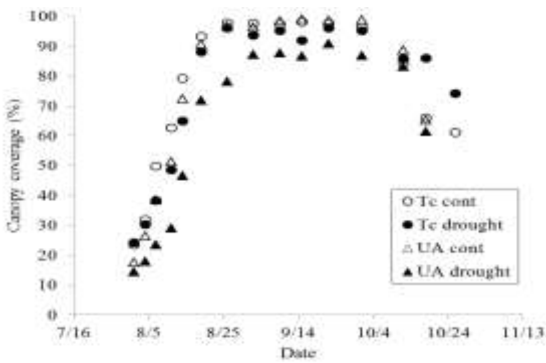

Figure 2. Change in canopy coverage measured by digital image analysis.

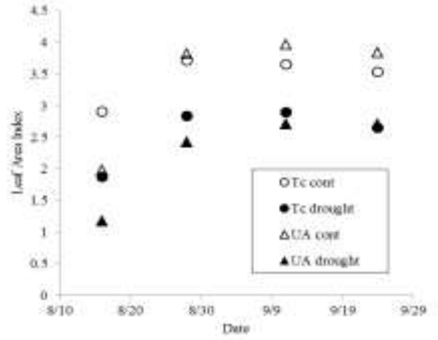

Figure 3. Change in Leaf Area Index.

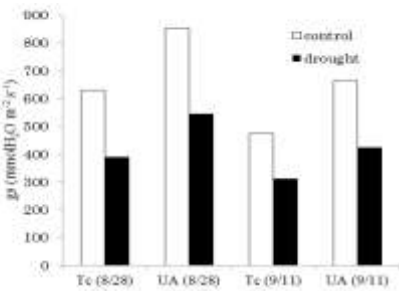

Figure 4. Stomatal conductance of Tachinagaha and UA-4805 under different soil conditions.

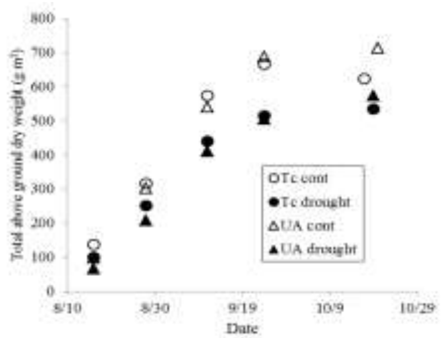

Figure 5. Change in total above ground dry weight.

UA showed a greater mean seed yield and harvest index in both of Control and Drought. Drought reduced mean seed yield and total dry weight of two cultivars. The yield reduction by drought in UA was associated with reduced radiation intercepted, while yield reduction in Tc was associated with reduced radiation use efficiency and harvest index. The significant G×E interaction was detected in harvest index and mean fraction of radiation intercepted (Table 1).

These results indicated that the two cultivars did not differ in yield response to drought, but they differed in the yield components affected by drought.

Table 1. Yield and yield components of drought experiment at Takatsuki in 2010

	Seed yield (t ha^{-1})	Total Dry Weight (t ha^{-1})	HI	Radiation Use Efficiency (g MJ^{-2})	Mean F (%)	Total radiation intercepted (MJ)	Total incident radiation (MJ)
Tachinagaha control	3.77	6.22	0.521	0.504	72.9	1233	1690
Tachinagaha drought	2.17	5.34	0.341	0.455	69.2	1170	1691
UA-4805 control	4.84	7.12	0.585	0.581	71.7	1225	1708
UA-4805 drought	3.65	5.74	0.531	0.572	58.6	1000	1705
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Cultivar	29.75 **	19.65 *	27.49 **	46.75 **	13.87 *	8.84 *	
Treatment	35.49 **	58.79 **	32.50 **	4.16 *	28.33 **	23.13 **	
cultivar x treatment	0.77 NS	2.98 NS	8.14 *	198 NS	8.72 *	7.33 NS	

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