Leaf Anatomy of Soybean [*Glycine max.* (L.) Merr.] in Relation to Dry Matter Productivity

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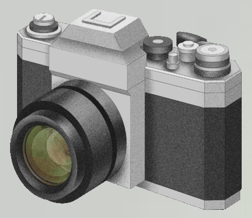
Soybean [*Glycine max.* (L.) Merr.] is an important oil and protein crop but little is known about the physiological basis of variability of dry matter production. US soybean varieties exhibited greater seed yield than Japanese varieties on average (**Table 1**). The greater stomatal conductance in US varieties (**Figure 2**) seemed to contribute, at least partly, to the greater dry matter accumulation (**Figure 1**). The potential of stomatal conductance (g_p) defined by the leaf epidermal structure was also greater in US varieties compared with Japanese varieties (**Figure 3**). The large transgressive segregation of stomatal density in a recombinant population (**Figure 4**) suggested the polygenic inheritance of stomatal traits, and hence the possibility of the indirect selection and optimization of leaf gas exchange capacity in future breeding of soybean.

Experiment 1



Getting the digital image of plant canopy coverage based on Purcell (2000)*

* Purcell (2000) Crop Sci. 40:834-837.

Image analysis using ImageJ (NIH Image) to calculate the fraction of the radiation intercepted.

The US and Japanese varieties were grown under optimal field condition at experimental farm, Kyoto University, Osaka, Japan in 2009. The plant spacing was 0.15×0.7m. N, P_2O_5 and K_2O was applied as the fertilizer for 3, 10 and 10 g m^{-2}, respectively. Stomatal conductance (gs) was measured by SC-1 Leaf porometer (DECAGON) for representative 7 varieties at the seed filling stage. The total dry weight, seed yield were determined at maturity and analyzed in terms of light interception.

Table 1. The phenology and the seed yield of tested varieties

(Emergence: 6/21)		R1	R5	R8	Seed Yield (t ha^{-1})
Japanese varieties	Suzukari	7/18	8/11	10/8	3.64
	Suzuyutaka	7/22	8/16	10/9	4.03
	Enrei	7/19	8/11	10/8	3.93
	Tachinagaha	7/18	8/11	10/22	3.10
	Sachiyutaka	7/30	8/28	10/27	4.16
	Tamahomare	7/25	8/20	10/28	3.44
	PI416937	7/30	8/29	10/29	3.65
US varieties	Athow	7/16	8/11	10/4	5.07
	Omaha	7/17	8/13	10/10	5.91
	Stressland	7/19	8/15	10/15	5.12
	LD003309	7/18	8/13	10/18	5.06
	Manokin	7/25	8/23	10/18	5.23
	5002T	7/27	8/23	10/19	4.69
	UA-4805	8/1	8/22	10/20	5.15
	Osage	8/3	8/29	10/24	5.19
	Graham	8/2	8/22	10/26	4.92
	5601T	7/27	8/23	10/27	5.50
	Ozark	7/30	8/27	10/27	5.19
	Hutcheson	8/3	8/27	10/29	5.03

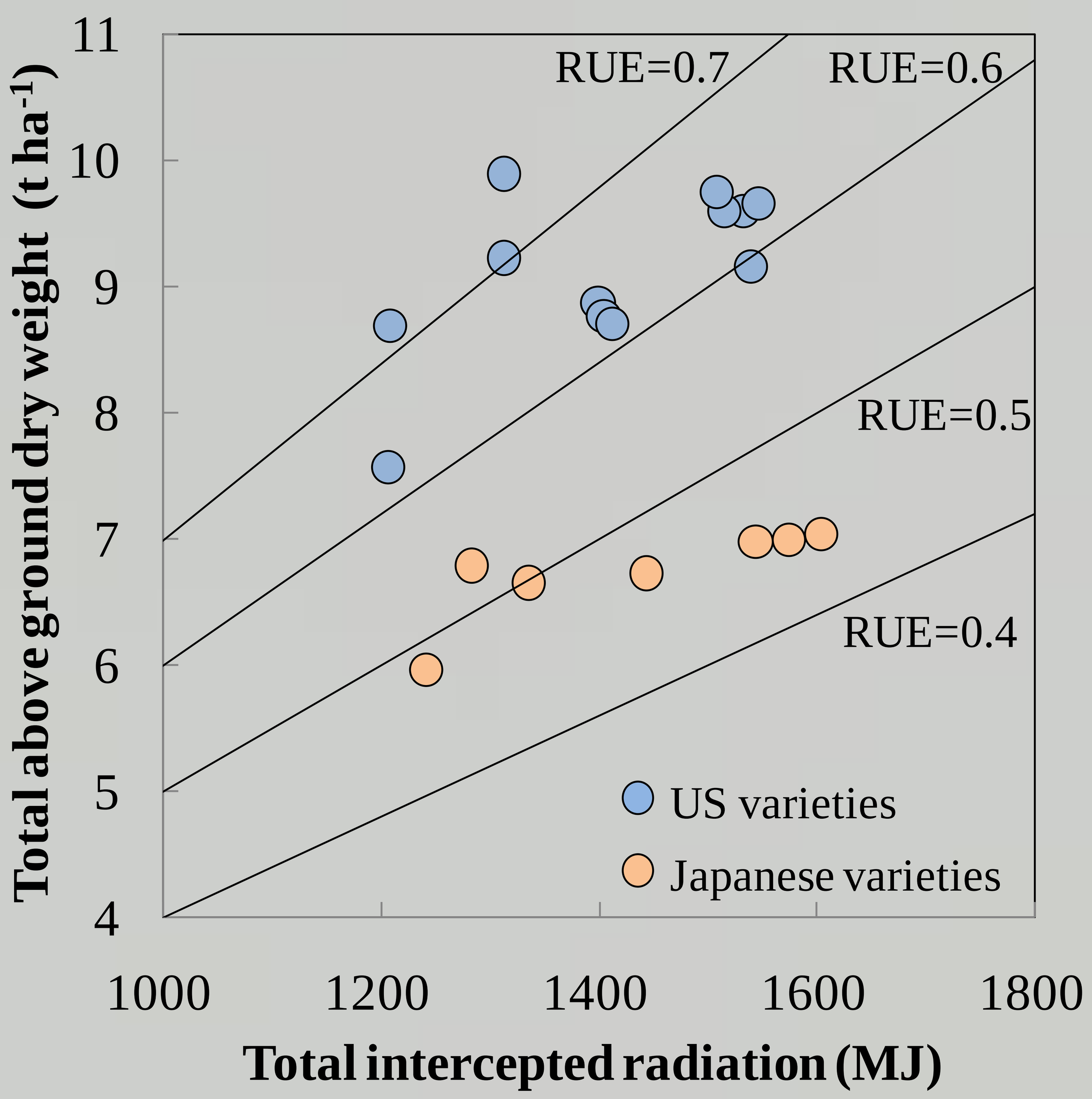


Figure 1. The relationship between total radiation intercepted through all the growth season and total above ground weight at maturity.

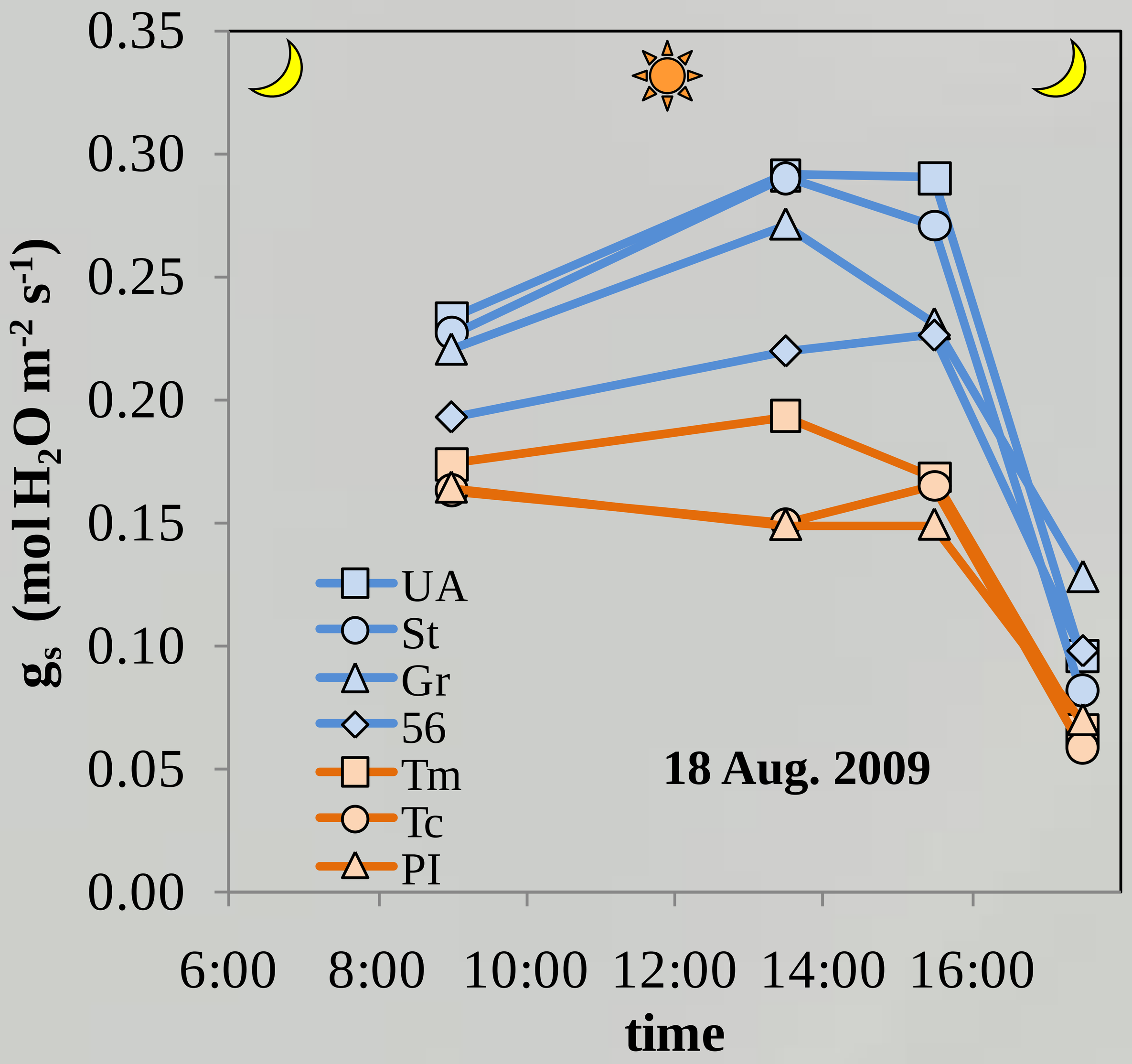
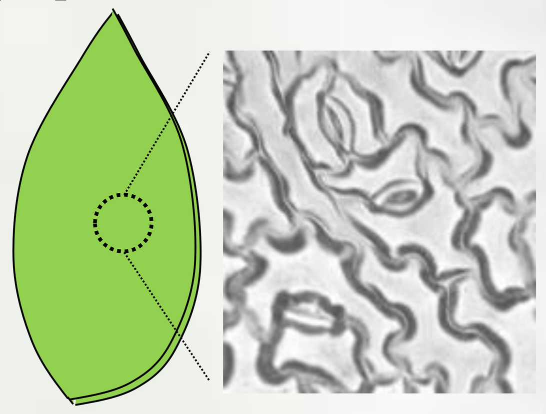


Figure 2. Diurnal change of stomatal conductance (g_s) on a clear sunny day at the seed filling stage.

Experiment 2

(i) Over 70 varieties including US and Japanese varieties (Table 2, Figure 3)
(ii) the recombinant population derived from a cross between Stressland and Tachinagaha (Figure 4) were used for the research of the leaf anatomy.

N_s : stomatal density
N_e : epidermal cell density
L_g : guard cell length
LA: area of single leaflet
g_p : potential stomatal conductance



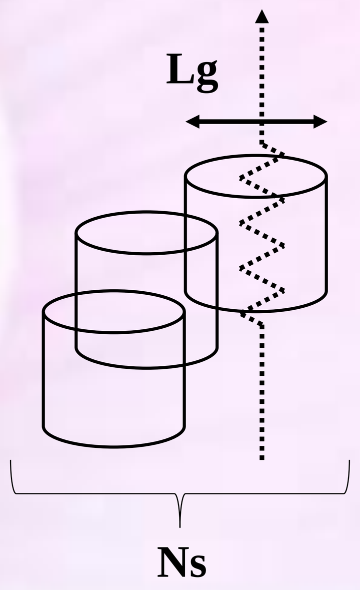
The central leaflet of the uppermost fully expanded leaf on the main stem was sampled at the seed filling stage of each variety.

Leaf anatomy was observed by optical microscopy after creating the template of leaf epidermis by SUMP method.

SUMP: Suzuki's Universal Method of Printing

The gas exchange through stomata is physically approximated by the model of Franks *et al.* (2009)**

$$g_p = \frac{d \alpha N_s \times L_g}{v(0.5 + 0.627\sqrt{\alpha})}$$



α: fraction of stomatal aperture to stomatal size
d: diffusivity of water in air
v: molar volume of air

**Franks *et al.* Plant Cell and Environ. (2009) 32:1737-1748.

Table 2. Correlation coefficients between leaf anatomical traits among various soybean varieties.

	N_s	N_e	L_g	LA
N_s				
N_e	0.89 **			
L_g	-0.31 **	-0.44 **		
LA	-0.43 **	-0.51 **	0.32 **	
g_p	0.93 **	0.77 **	0.05 ns	-0.33 **

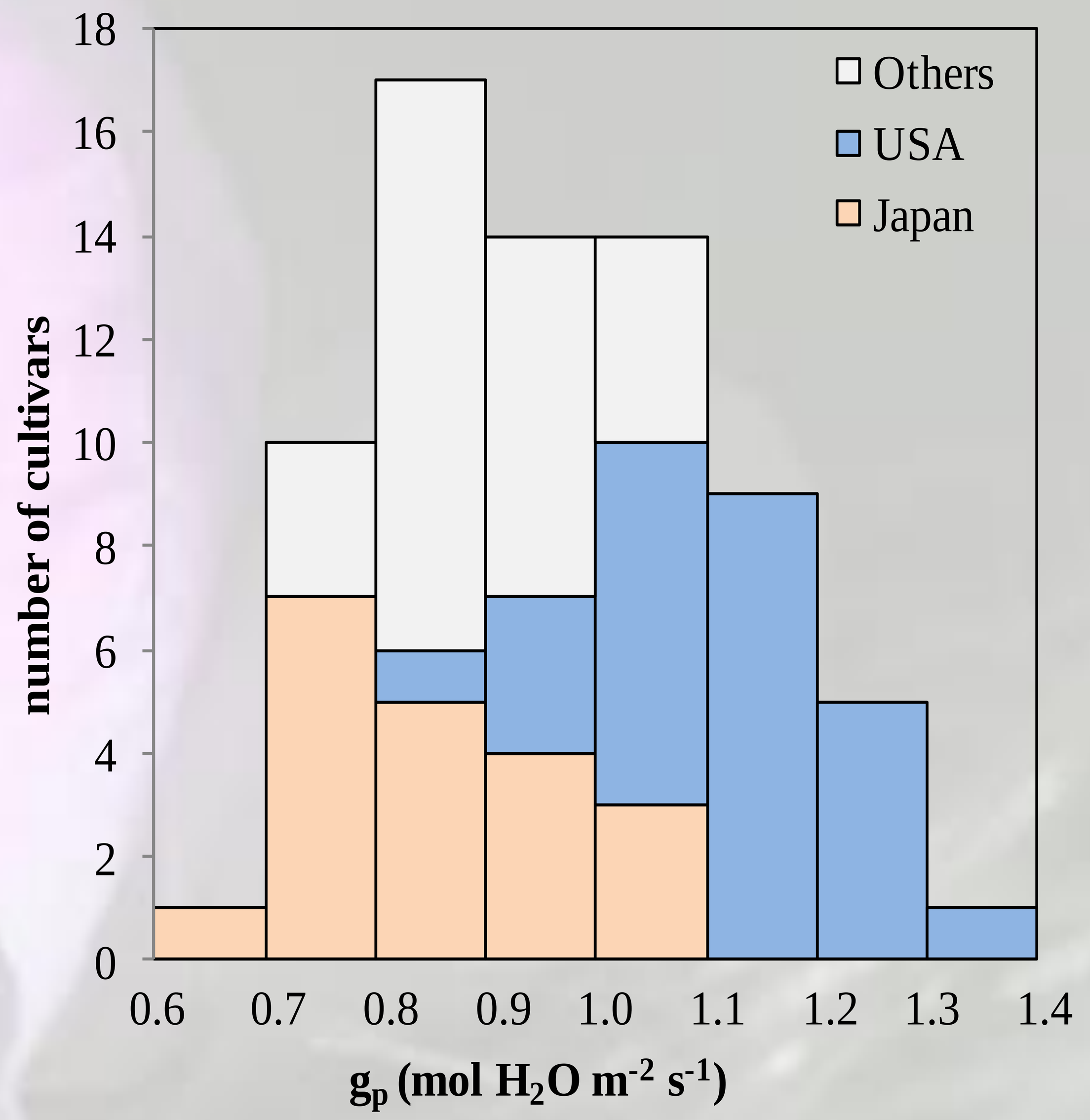


Figure 3. Frequency distribution of the potential stomatal conductance (g_p) among various soybean varieties including the US and Japanese varieties.

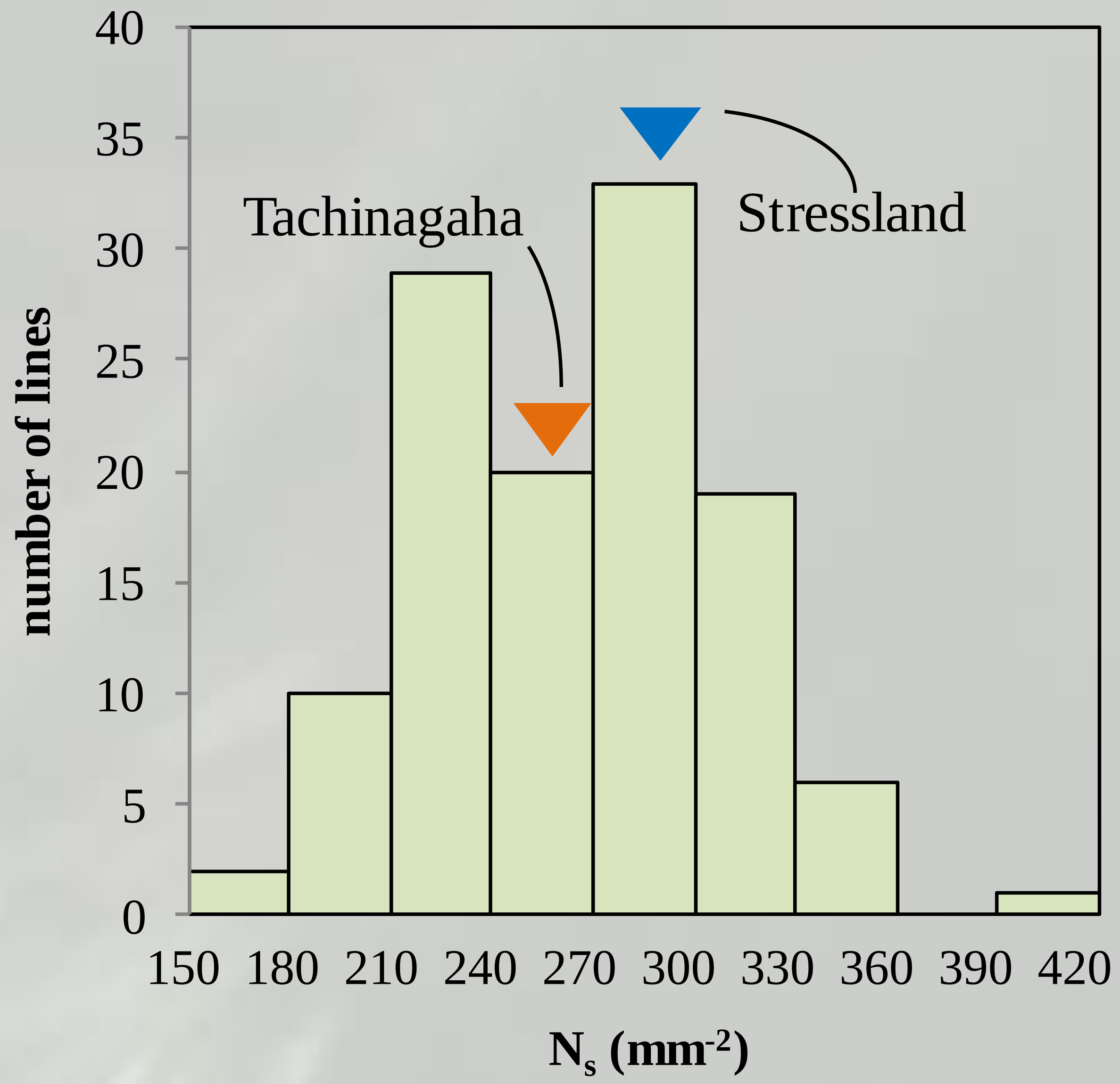


Figure 4. Frequency distribution of stomatal density (N_s) among the recombinant population derived from a cross between Stressland and Tachinagaha.

Acknowledgement We gratefully appreciate Dr. Larry C. Purcell (University of Arkansas) and Dr. Randall Nelson (University of Illinois) for their insightful suggestions and providing the plant materials.

The picture on background: blooming of cultivar 'Tachinagaha'