Soybean Nitrogen Fixation at Different Reproductive Stages and Water Regimes

Adriano T. Mastrodomênico*, Larry C. Purcell and C. Andy King

Crop, Soil and Environmental Sciences Department, University of Arkansas, Fayetteville

Introduction

In soybean (*Glycine max* [L.] Merr.), N_2 fixation is a primary source of N nutrition during seed development. N_2 fixation is recognized as a drought sensitive mechanism; however, N_2 fixation response to drought at different reproductive stages is not well documented. We tested the hypothesis that drought during late reproductive stages will cause irreparable damage to N_2 fixation due to the breakdown of essential leaf proteins [1] and the inability of N_2 fixation to recover.

Material and Methods

- Growth chamber experiment repeated in two trials using Hendricks cultivar (MG 0).
- Moderate drought stress at flowering (R2), early seed-fill (R5), late seed-fill (R6) and a well-watered control treatment.
- Well-watered plants watered to 85% of pot capacity.
- Stressed plants watered daily for 5d to maintain transpiration at 40% of controls [2].
- After the drought period, plants were rewatered and kept well-watered until maturity.
- Nitrogenase activity was measured weekly throughout the entire plant cycle using the acetylene reduction assay (Fig. 1).
- Data were analyzed using analysis of variance, and means separated using $LSD_{\alpha=0.05}$.

Figure 1. Soybean nitrogenase activity was measured with a non-destructive, flow-through system (A). Ethylene was quantified by gas chromatography (B).

Results and Discussion

- Control plants peaked N_2 fixation at R3-R4 (40 d), maintained high activity during R5 and decreased after R6 (60 d) (Figure 2).
- Drought stress reduced N_2 fixation to about 40% of the control plants regardless the developmental stage.
- After rewatering, N_2 fixation recovered from drought at R2 and R5 stage and had higher activity than control plants during mid seed-fill (55 d) (Figure 2).
- Drought stress at R5, prolonged high N_2 fixation activity during late seed-fill (66 d) (Figure 2).
- After drought stress at R6 stage, N_2 fixation did not recover and decreased activity compared with control plants (Figure 2).
- Drought stress at R6 stage decreased yield by reducing individual seed mass (Table 1).
- Drought stress at R5 decreased seed number, but compensated seed yield loss by increasing individual seed mass (Table 1).
- Drought stress at R2 decreased plant biomass, but increased harvest index (Table 1) and nitrogen harvest index (Figure 3).

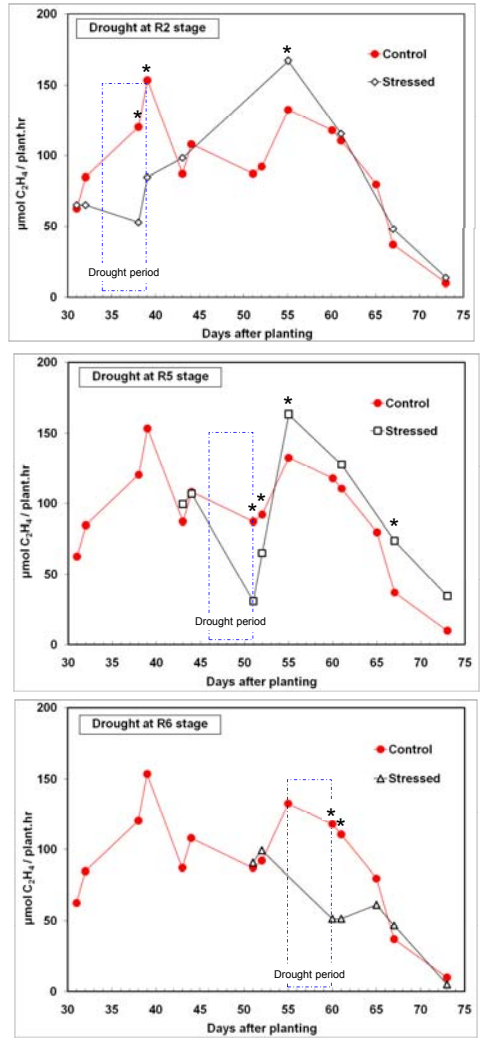

Figure 2. N_2 fixation response to drought at different reproductive stages and N_2 fixation recovering from drought after rewatering. Dates marked with * indicate significant treatment difference (P ≤ 0.05)

Treatment	Seed yield	HI	Biomass	Seed Number	Individual seed mass
	g. plant^{-1}	-	g.plant^{-1}	Number seed.plant-1	mg. seed^{-1}
Control	7.6 A	0.51 B	14.9 A	57 AB	133 B
R2	6.7 B	0.57 A	11.8 B	49 BC	132 BC
R5	7.2 AB	0.56 A	12.9 A	46 C	163 A
R6	6.8 B	0.52 B	13.1 A	60 A	116 C

Table 1. Seed yield, harvest index, plant biomass, seed number and individual seed mass of plants grown under different water regimes. Numbers followed with different letters are significantly different (P ≤ 0.05).

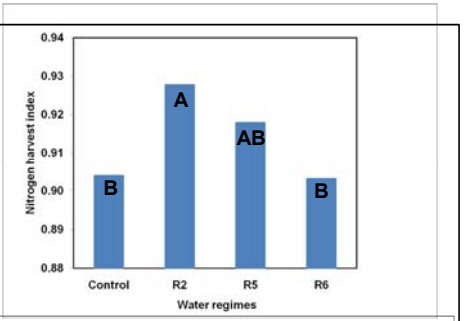

Figure 3. Nitrogen harvest index response to drought at different reproductive stages. Bars containing different letters are significantly different (P ≤ 0.05).

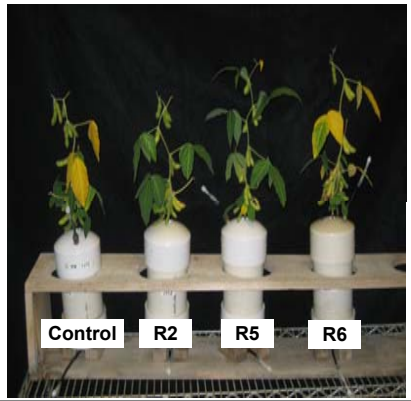

Figure 4. Visual differences in soybean at 66 d after emergence when exposed to drought stress at different developmental stages.

Conclusions

- Soybean plants drought stressed during R2 and R5 were able to recover N_2 fixation activity after rewatering.
- Although N_2 fixation recovered from drought at R2, plant biomass did not recover and had increased NHI.
- After drought stress at R5, N_2 fixation recovered and had prolonged activity through late seed-fill.
- Plants drought stressed at R6 were incapable of recovering N_2 fixation after rewatering, which resulted in early senescence compared with plants stressed at R2 and R5 (Figure 4), supporting our hypothesis.

References

[1] Sinclair, T. R., and C. T., de Wit. 1976. Analysis of the carbon and nitrogen limitations to soybean yield. Agronomy J. 68:319-324.
[2] Ray, J.D. and T.R., Sinclair 1997. Stomatal closure of maize hybrids in response to drying soil. Crop Sci. 37:803-807.

The United Soybean Board is gratefully acknowledged for their support.

For additional information please contact Adriano Mastrodomenico (amastrod@uark.edu) or Larry Purcell (lpurcell@uark.edu).