Soybean Reproductive Growth, Development, and Yield Responses to Temperature

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Introduction

- The soybean-corn agricultural ecosystem is arguably the largest single ecosystem type in the contiguous United States, occupying over 160 million acres, most of which is located in the Midwest.
- Recent advances in management and cultivars have increased acres and are contributing significantly to agricultural value in the state, region and the world.
- Soybean planting dates have large window, depends the cultivars and maturity groups. Therefore, higher temperatures during flowering and early-pod-filling stages may impact yield potential of soybean crop in US-Midsouth.
- High Temperature during soybean seed development affects soybean yield and seed composition (Wilson, 2004).
- Temperature effects on soybean have been conducted in the field where other factors co-vary or in indoor plant growth chambers with unrealistic light environment.
- Based on these studies, temperature optima for several soybean processes, from 23 to 39°C, depending growth and developmental stages (Egli and Wardlaw,1980; Boote et al., 1997; Salem et al., 2007).
- However, fewer studies have provided the functional relationships between temperature and soybean reproductive growth and development, particularly on most-recently released cultivars, to develop management tools.

Objectives

- The objective of this study were to quantify temperature effects on reproductive growth and development on two contrasting soybean cultivars, and to provide quantitative information that could be used to improve the functionality of soybean models for management applications.
- We hypothesize that cultivars vary in their response to temperature for certain traits.

Experimentation

- This study was conducted using sunlit, controlled environment facility known Soil-Plant-Atmosphere-Research (SPAR) chambers located at the Environmental Plant Physiology Laboratory at the Mississippi State University, MS, during the 2014 growing season (*Fig. 1*).
- Treated seeds were sown in 120 PVC plastic pots (15.2 cm in diameter and 30.5 cm tall), filled with a sandy soil and 500 g of gravel at the bottom of each pot. Initially, 4 seeds were planted in each pot at a depth of ½ inch and thinned to 1 after emergence.
- Plants grown outdoor from seeding were moved into the SPAR units prior to initial flowering (R1).
- Plants were irrigated three times per day through an automated, computer-controlled drip system with full-strength Hoagland's nutrient solution (Hewitt, 1952).
- All SPAR chambers were maintained at 400 ppm CO_2 throughout the experiment.

Fig. 1. Outdoor pot-culture facility and Sunlit, Soil-Plant-Atmosphere-Research (SPAR) chambers used in the study.

Treatments

- Two cultivars, Maturity group V (MG V): AG 5332, with indeterminate growth habit, and PR 5333, with determinate growth habit.
- Five day/ night temperature treatments include: 21/13 °C, 25/17 °C, 29/21 °C, 33/25 °C, and 37/29 °C.

Measurements

- **Physiological measurements:** Gas exchange and fluorescence measurements were taken **65-75 days** after planting, using LI-6400 portable photosynthesis system *(Fig 2)*.
- **Reproductive measurements**
  Reproductive stages R1 and R8.
- Optimum temperature were calculated using quadratic function, $Y = a + bx + cx^2$, and equation Opt. T = b/(2c) (Gajanayake et al, 2011).
- Yield- and yield-component measurements

Fig. 2. LI-6400 portable photosynthesis system

Design of the Experiment & Data Analysis

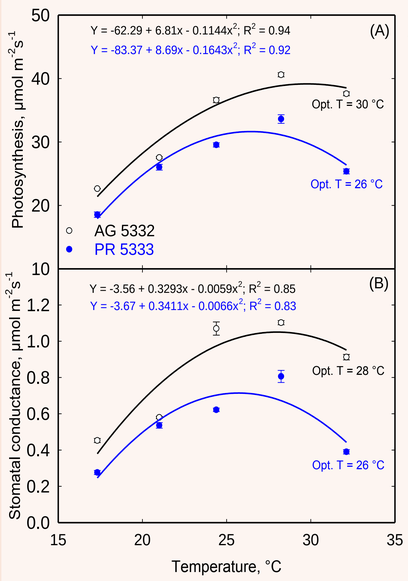
- Pots were arranged in a complete randomized design 4 rows, 3 pots per row, 12 pots of each cultivar, in one SPAR chamber.
- The SAS program " PROC GLM" was used to analyze the data.
- SigmaPlot 13.0 was used to plot the graphs.
- The least significant difference (LSD) test was used to distinguish the differences among treatments for measured parameters.
- The standard errors of each mean were calculated and presented in the graphs as error bars.

Results & Discussions

Table 1. Analysis of variance (ANOVA) of soybean growth and reproductive and physiological parameter.

Sources of variation	Temperature	Cultivar	Temperature x Cultivar
Photosynthesis	***	***	ns
Stomata conductance	***	***	**
Transpiration rate	***	***	ns
Water use efficiency	***	ns	**
Reproductive development, R1 to R8	***	***	***
Total plant dry weight	*	ns	***
Root dry weight	ns	***	***
Stem dry weight	***	***	***
Leaf dry weight	***	***	**
Pod numbers	***	***	***
Seed numbers	***	***	**
Pod dry weight	***	***	**
Seed dry weight	***	***	**
100 seeds weight	*	ns	ns
Seed production efficiency	***	***	**

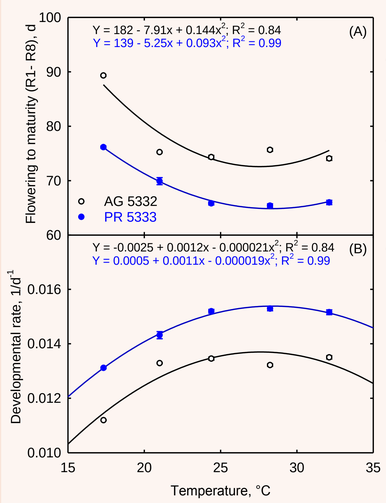
*, **, *** indicates a significance at P = 0.001, 0.01, and 0.1 level respectively.



A - Gas Exchange Parameters

- Temperature impacted gas exchange parameters significantly (*Table 1*).
- Photosynthesis and stomata conductance increased with temperature in both the cultivars (*Fig 3A & B*).
- Temperature optima varied for photosynthesis and stomatal conductance between the cultivars.
- AG 5332 showed higher rates of gas exchange parameters, particularly at the high temperatures.

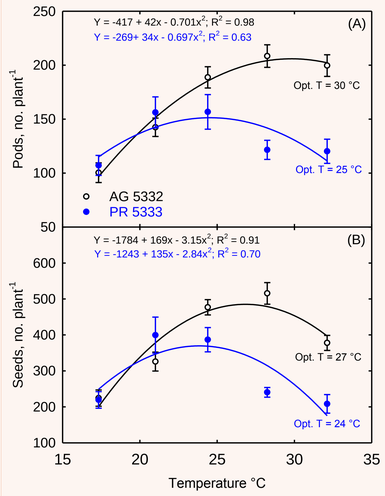
Fig. 3. Temperature & cultivars effects on (A) photosynthesis and (B) stomatal conductance.



B - Reproductive Development

- Time from flowering (R1) to maturity (R8) decreased with in temperature in both the cultivars (*Fig. 4A*).
- The rates (R1 to R8) increased with temperature up to 28 °C, and declined slightly at higher temperatures (*Fig. 4B*).
- AG 5332 took more time from flowering to maturity than PR 5333 across all temperature conditions.

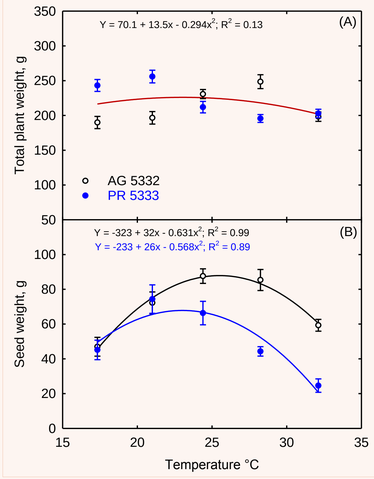
Fig. 4. Temperature effects on soybean pod-filling time; (A) flowering to maturity and (B) rate for development.



C - Seed Components

- Temperature impacted significantly yield- and yield-component parameters *(Table 1)*.
- Pod and seed numbers per plant increased quadratically with temperature in both the cultivars *(Fig. 5A & B)*.
- The optimum temperatures for these yield contributing factors varied among process and cultivars.
- Cultivar AG5332 showed greater high temperature tolerance than cultivar PR 5333.

Fig. 5. Temperature & cultivar effects on soybean (A) pods and (B) seed numbers.



D - Biomass and Yield

- Total plant weight was affected by temperature treatments significantly *(Table 1 & Fig 6A)*.
- Seed weights increased quadratically in both the cultivars *(Fig 6B & 7)*.
- Temperature optima for AG 5332 was 26°C and PR 5333 was 23°C.
- Seed yield decline was much steeper for PR 5333 than AG 5332 from their respective optima temperatures.

Fig. 6. Temperature & cultivar effects soybean (A) total plant and (B) seed weights.

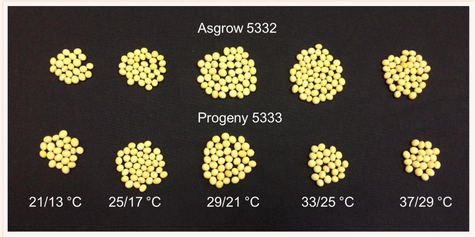
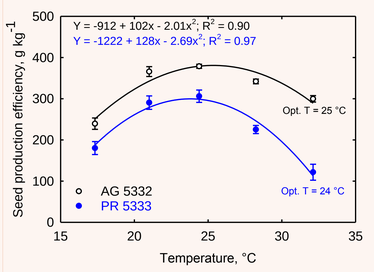


Fig. 7. Temperature & cultivars effects on soybean seed number & size (0.1 plant yield).



E - Seed Production Efficiency

- Temperature impacted biomass partitioning *(Table 1)*.
- Seed production efficiency, defined as g seed weight per kg 4total weight, showed quadratic trends with temperature in both the cultivars *(Fig 8)*.
- Also, temperature optimum was greater for AG compared to Progeny cultivar.

Fig. 8. Temperature & cultivar effects soybean seed production efficiency.

Fig. 9. Some of the experimental activities.

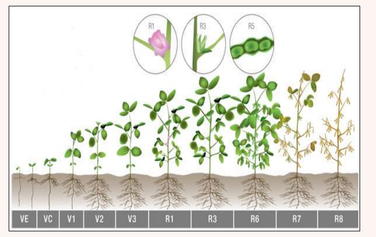


Fig. 10. soybean vegetative and reproductive growth stages.

Source:

http://prairiecalifornian.com/soybean-growth-stages/

Summary & Conclusions

- Temperature affected physiological, growth and developmental processes of soybean cultivars.
- The temperature optima varied among the processes with the cultivar and between the cultivars for many growth and developmental parameters.
- In general, the indeterminate cultivar, AG 5332, showed greater tolerance and high temperature optima for many traits.
- The functional algorithms presented here will be useful to improve the functionality of soybean models for field applications and to help adjust soybean management decisions such as cultivar selection and planting dates depending the niche environment.

Acknowledgments

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