Effect of Soil Moisture Stress on Post Harvest Seed Physiology, Quality, and Chemical Composition of Soybean

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Introduction

- Soybean is the world's leading economic oilseed crop and a major source for human nutrition and livestock feed.
- Soybean seed quality is often determined by proteins, fatty acids, carbohydrates, isoflavones, and minerals thus, maintaining an improved seed quality is imperative to sustain overall human and animal nutritional aspects.
- However, these constituents have been reported to be affected by prevailing abiotic stresses such as soil moisture conditions during seed development.
- Therefore, understanding the soil moisture stress effects on seed yield and seed quality characteristics is much needed to develop suitable management practices to mitigate the impact of moisture stress on nutritional attributes of soybean seed.

Hypothesis and Objective

- We hypothesized that soil moisture stress during reproductive growth stage will reduce the soybean yield components and alter the seed quality and mineral composition.
- The objective of this study was to investigate the effects of soil moisture stress conditions during reproductive stage on seed yield components, seed composition, and seed minerals using two soybean cultivars having two different growth habits.

Materials and Methodology

Seed Material:

- Two soybean cultivars from Maturity Group V, Asgrow AG5332 (indeterminate type) and Progeny P5333RY (determinate type) were used in this study.

Growth Conditions:

- Conducted in the sunlit growth chambers located at the Environmental Plant Physiology Laboratory, Mississippi State University, MS (Fig. 1).

Fig. 1. Pictorial representation of two soybean cultivars grown at 100%, 80%, 60%, 40%, and 20% ET in the Soil-Plant-Atmosphere-Research (SPAR) chambers to study soil moisture stress effects on yield components with the average soil moisture readings.

- Pots were arranged in a completely randomized block design with twelve replicate plants.
- Seeds were sown in PVC pots (6″ diameter by 12″ high) filled with the soil medium consisting of 3:1 sand: top soil classified as sandy loam (87% sand, 2% clay, and 11% silt).
- Initially, all the pots were grown outside the SPAR units and when the plants reached R1 stage [40 days after planting (DAP)], pots were moved into the SPAR units.

Treatments:

- Five levels of soil moisture stress treatments (100, 80, 60, 40, and 20% evapotranspiration, ET of the control) were established based on the ET-based irrigation measurements.

Harvest:

- Plants were harvested 126 days after planting (Fig. 2) and seeds were collected separately for each treatment (Fig. 3).
- About 25 g of seeds collected from each plant were ground using a Laboratory Mill 3600 (Perten, Springfield, IL).

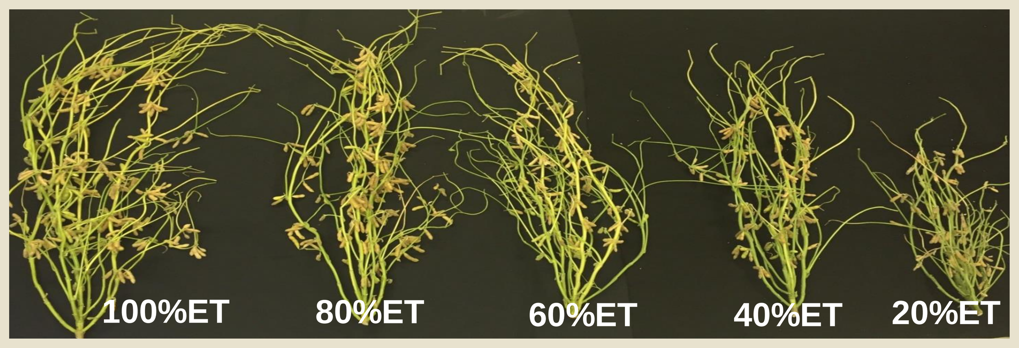

Fig. 2. Pictorial representation of Progeny 5333RY soybean cultivar harvested 126 d after planting from different soil moisture stress treatments.

Measurements

Seed Vigor Traits: Seed yield, seed number, and seed germination
Seed Quality Traits: Protein, oil, fatty acids, sucrose, raffinose, and stachyose
Seed Minerals: N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, and B

Data Analysis:

- Data were analyzed using PROC MIXED procedure of SAS (9.4, SAS Institute) at α = 0.05 level.
- The regression analyses were carried out using Sigma Plot 13 software.

Results

Source	Seeds no.	Seed Yield	Protein	Oil	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Linolenic acid	Sucrose	Raffinose	Stachyose
Drought (TRT)	***	**	***	*	***	NS	***	***	NS	***	NS	***
Cultivars (CUL)	NS	***	***	***	***	NS	NS	***	***	*	*	***
TRT*CUL	NS	*	**	NS	***	NS	NS	***	***	***	NS	***

Table 1. Seed traits as affected by drought (TRT), cultivar (CUL), and CUL×TRT interaction. The significance level ***represents P ≤ 0.001 respectively, according to LSD.

Fig. 3. Seeds collected from different soil moisture stress treatments for Asgrow AG5332 soybean cultivar. Each seed lot from each treatment represents the 1/10 of the total seed number per plant.

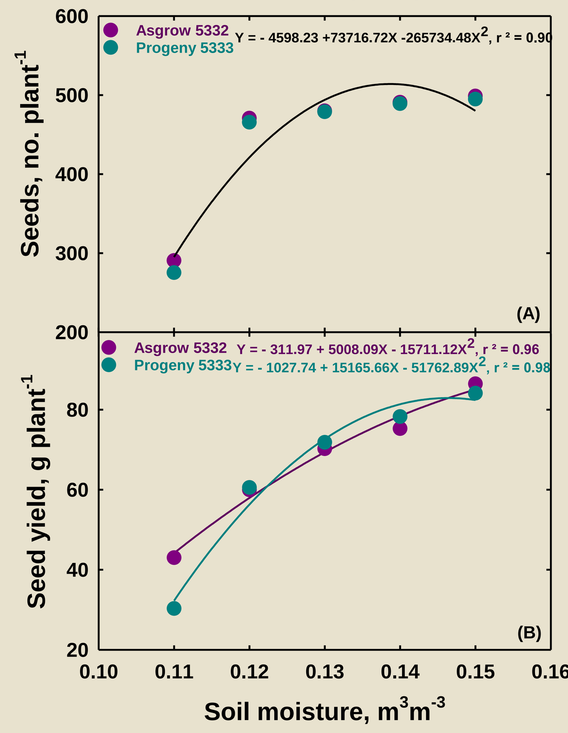

Fig. 4. Soil moisture stress effects on seed number and seed yield of two soybean cultivars.

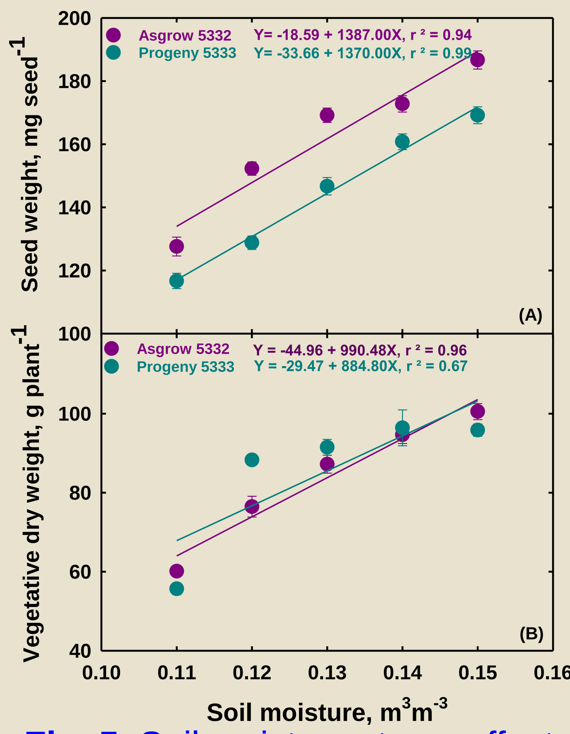

Fig. 5. Soil moisture stress effects on (A) individual seed weight and (B) vegetative biomass for the two soybean cultivars.

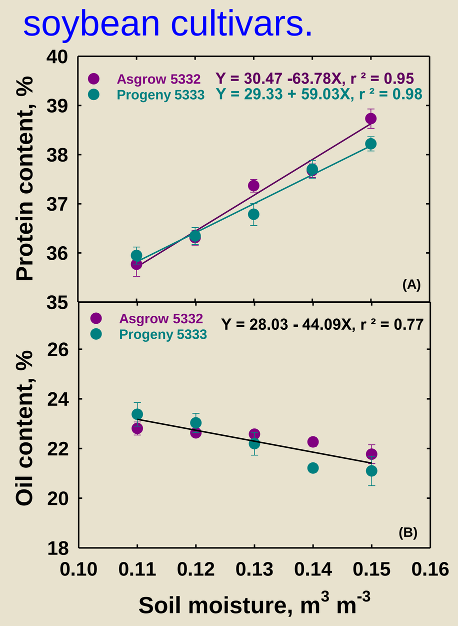

Fig. 6. The relationship between soil moisture and (A) protein and (b) oil content for the two soybean cultivars.

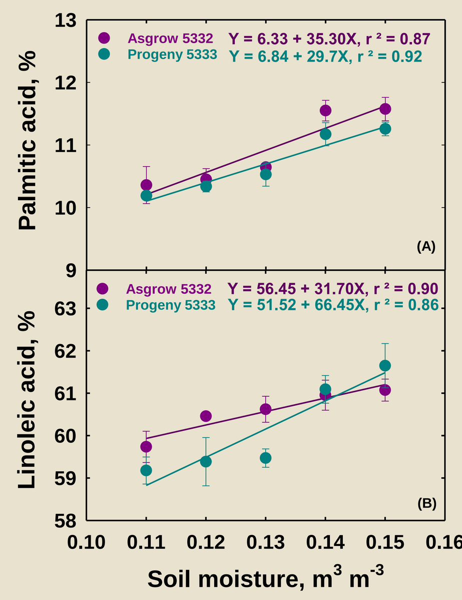

Fig. 7. The relationship between soil moisture and (A) palmitic acid and (B) linoleic acid of the two soybean cultivars.

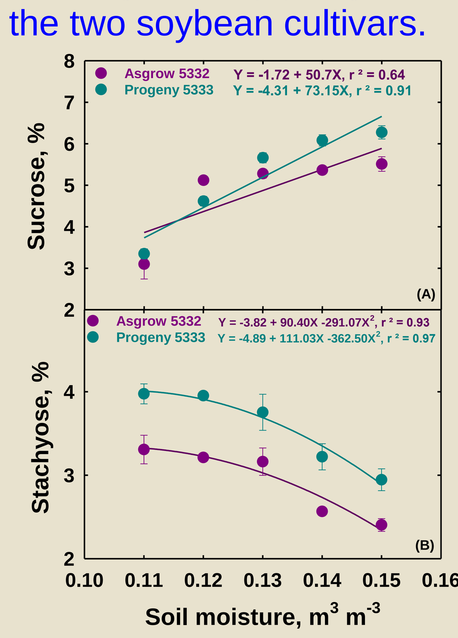

Fig. 8. The relationship between soil moisture and (A) sucrose and (B) stachyose of the two soybean cultivars.

Parameters	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Drought (TRT)	***	***	***	***	**	***	***	***	***	NS
Cultivars (CUL)	***	***	**	*	NS	***	NS	NS	NS	NS
TRT*CUL	*	*	NS	NS	NS	***	NS	NS	NS	NS

Table 2. Seed mineral composition as affected by drought (TRT), cultivar (CUL), and CUL×TRT interaction. The significance level ***, **, * represent P ≤ 0.001, ≤0.01, ≤0.05 respectively, according to LSD.

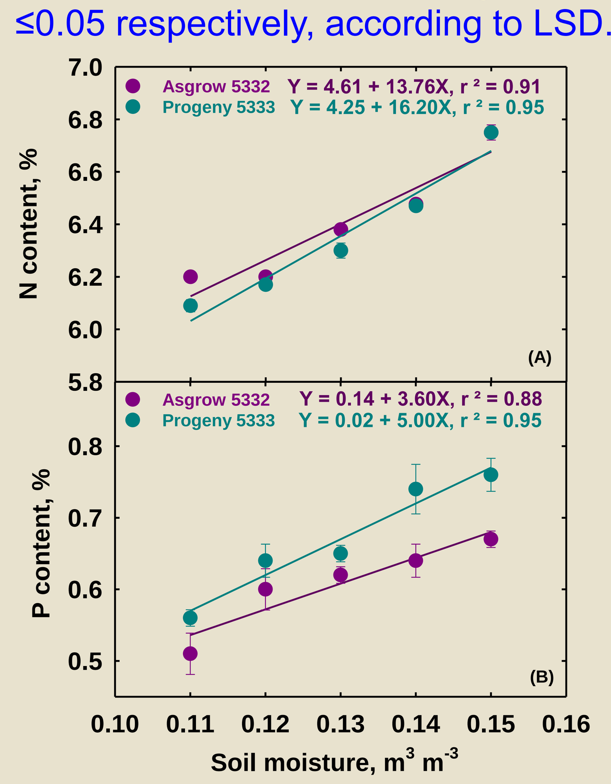

Fig. 9. The relationship between soil moisture and (A) seed N and (B) seed P of the two soybean cultivars.

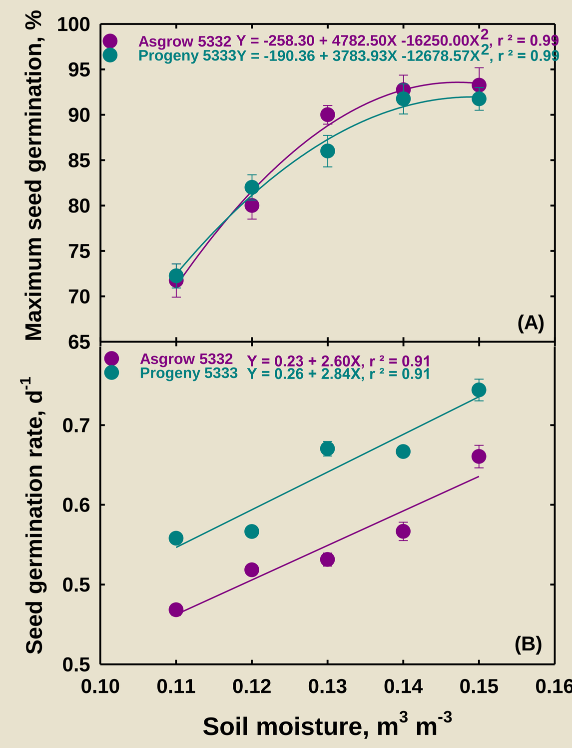

Fig. 10. Soil moisture stress effects on (A) maximum seed germination and (B) seed germination rate.

Discussion

Seed Physiology and Vigor

- The seed number declined quadratically with increasing the soil moisture content (Fig. 4A) and it may be due to the production of fewer flowers per plant (Brevedan and Egli, 2003) and the pod and seed abortion under stressful conditions.
- The seed yield was reduced by 50% (Asgrow 5332) and 64% (Progeny P5333RY) cultivars (Fig. 4B) from optimum to severe soil moisture stress conditions.
- Individual seed weight (ISW) (Fig. 5A) and vegetative dry weight (Fig. 5B) exhibited linear reductions with decreasing soil moisture.
- Seed weight is a result of the distribution of photosynthetic products, hence, the decrease of ISW under stress conditions might be due to the disruption of carboxylation and remobilization of photosynthetic products during reproductive growth stages resulting pod and seed abortion.

Seed Quality

- Significant cultivar differences were observed for protein, oil, palmitic, linoleic acid, sucrose, and stachyose (Table 1).
- Moisture stress during seed developmental stages resulted in a low protein and high oil percentage (Fig. 6) and the relationship was negative between soybean seed protein and oil.
- Both palmitic (Fig. 7A) and linoleic (Fig. 7B) acids decreased linearly with decreasing soil moisture content.
- The concentration of polyunsaturated fatty acids such as linoleic can be reduced by hydrogenation, which leads to heart disease and decrease shelf life of soy products (Bellaloui and Mengistu, 2007).
- Sucrose (Fig. 8A) content decreased linearly and stachyose content (Fig. 8B) increased quadratically with decreasing soil moisture content and Asgrow 5332 had higher sugar content.
- High sucrose is desirable because it improves taste and flavor in tofu like soy based products.
- High stachyose is undesirable because they have detrimental effects on the nutritive value of the meal and are indigestible by human and animals, often causing flatulence and diarrhea in non-ruminants (Reddy et al., 2015).

Seed Mineral Composition

- Soybean seed N, P, K, Ca, and Fe significantly varied among the cultivars under different moisture stress conditions (Table 2).
- Seed N (Fig. 9A) and P (Fig. 9B) contents decreased linearly with decreasing soil moisture and it could be due to changes in nutrient uptake and partitioning in soybean seeds under soil moisture stress.
- Maximum seed germination (Fig. 10A) decreased quadratically and seed germination rate (Fig. 10B) declined linearly with decreasing soil moisture content in both the cultivars.
- Reduced individual seed weight and changes in seed constituents under limited soil moisture conditions affected for loss in seed germination and seed vigor.

Conclusions

- Soil moistures stress decreased the total seed number and individual seed weight contributing to a loss in seed yield with an increased amount of small shriveled seeds in the seed lot.
- The protein, fatty acids, sucrose, N, and P decreased with decreasing soil moisture, where as oil and stachyose contents increased significantly.
- Seed germination and vigor decreased proportionately with the decrease in the individual seed weight and the changes in the constituents of the seeds and this may be due to lower storage reserves in the seed under stressful conditions.
- Low vigor seeds may associate with inferior seedling emergence capability in the field, particularly under limited soil moisture conditions.
- This information suggests that maintaining optimum soil moisture condition during seed-filling stages will be essential to obtain high quality soybean seed that meets the needs of human health, livestock feed, and producer planting.

Literature Cited

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- Brevedan, R., and D.B. Egli. 2003. Short periods of water stress during seed filling, leaf senescence, and yield of soybean. Crop Sci. 43:2083-2088.
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Acknowledgment

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