Controlled-environment Assessment of Soybean [*Glycine max* (L.) Merr.] Yield Response to Soil Water Deficits Using 1-m Rooting Columns

Plant Agriculture

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GRAIN FARMERS OF ONTARIO

Introduction

- Soil water deficits significantly limit soybean yield in Ontario, Canada, in most growing seasons with demonstrated losses in field experiments ranging from 8 to 24% [1].
- Such yield-limiting water deficits result in fewer pods per plant, reduced seed size, and hastened crop maturity, which shortens the seed filling period [1,2].
- The most important determinant of soybean yield is pod number, and this yield component is determined by the availability of concurrent photosynthate during the first pod (R3) to first seed (R5) growth stages [2,3].
- Controlled-environment phenotyping of soybean germplasm for traits related to drought tolerance is often carried out in artificial media in small pots, where roots easily explore the entire pot volume [4].
- Identification of physiological traits, especially rooting traits, to improve drought tolerance in soybean would benefit from controlled environment phenotyping methods that permit the use of mineral soils and produce field-like soil water distributions.

Objectives

- Evaluating the effects of different drought stress protocols on soil water extraction, whole plant water use, biomass accumulation, and yield formation.
- Selecting the best drought stress simulation method that makes use of lightly amended mineral soil in 1-m long, 10-cm diameter rooting columns.

Methodology

- The soybean cultivar *OAC Bayfield* was grown in 10-cm diameter, 1-m long polyvinyl chloride tubes, in the Crop Science Building's greenhouse at the University of Guelph in the 2016 summer season.
- The soil mixture was 67% clay loam field soil from the Elora Research Station. The remaining 33% was a mixture of 2/3 granitic sand and 1/3 peat-based potting mix by volume.
- The tubes were filled with the soil mixture to ~1 cm below the top of the tube in a systematic fashion of loading and packing.
- The soil mixture loaded into the top 30 cm of each tube contained a commercial 20-20-20 plus micro nutrients fertilizer at the rate of 1 g per tube dissolved in 100 mL water.
- Randomized complete block design was used with 3 watering treatments, 5 replicates, and 4 border tubes.
- The 3 watering treatments were imposed from R1 through to maturity. Tubes were watered to 100, 75 or 50% soil water holding capacity.
- Volumetric soil water content (VSWC) was monitored at multiple depths in the profile using time domain reflectometry (TDR).
- Other measurements included: total plant dry weight, water used, water use efficiency, root: shoot ratio, seed yield, and yield components.


a


b


c

Figure 1(a-c): Culture system developed for studying rooting traits in soybean using 1-m rooting tubes. Tubes are drilled on the sides for TDR measurements of VSWC. Plastic liners allow for removal of intact root systems, so that root distribution can be accurately determined by depth.

Results & Discussion

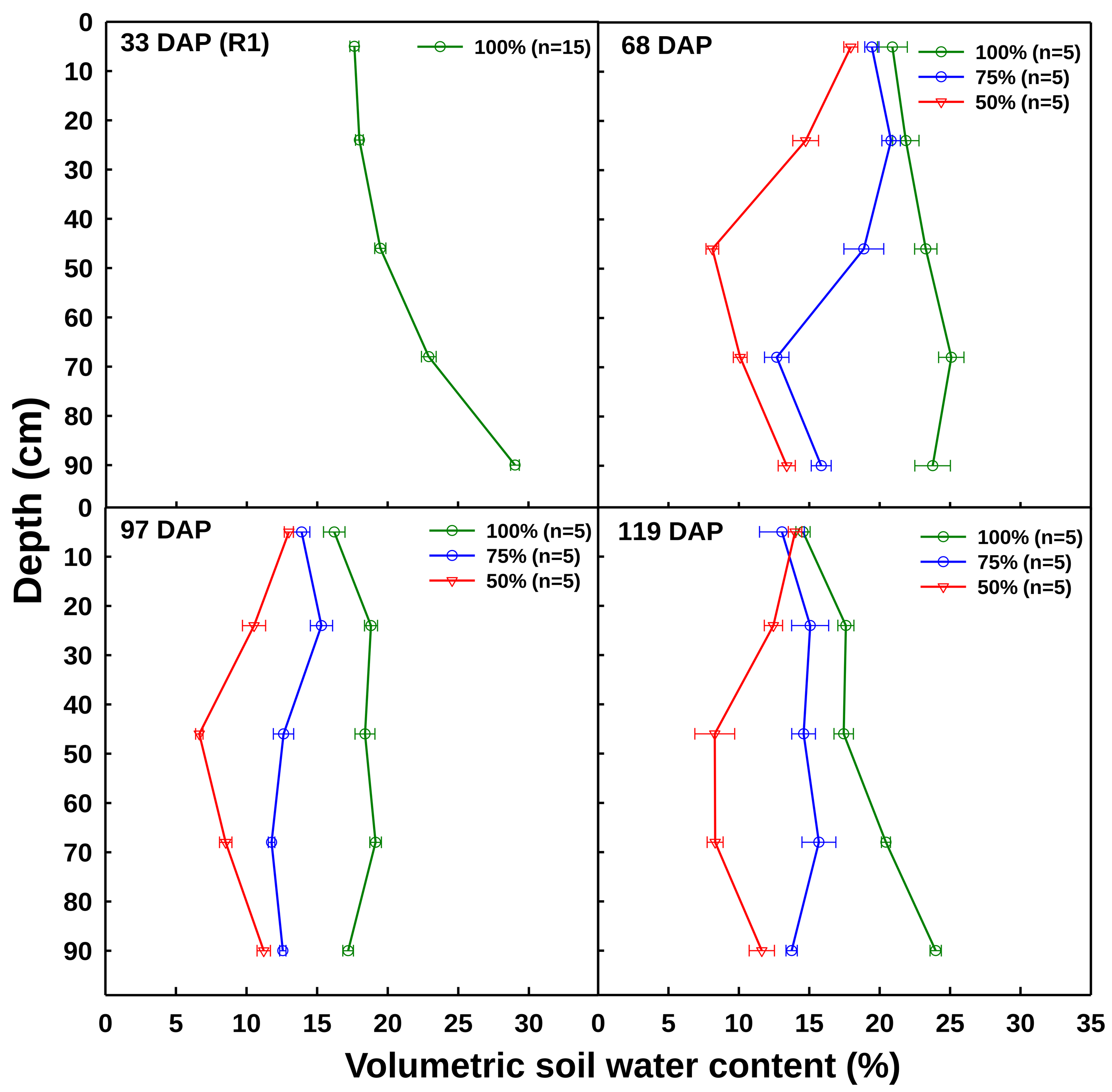

Figure 2: Volumetric soil water content as a function of depth for tubes maintained at 100%, 75% or 50% of the maximum soil water holding capacity, measured at four different days after planting (DAP).

- Watering to 100% of the tube water holding capacity resulted in a field-like soil water profile with depth (**Figure 2**).
- Watering to 50% significantly reduced biomass accumulation, pods per plant, seed yield, and water used by 49, 41, 38, and 52%, respectively (**Table 1**).
- The 75% treatment was intermittent between the other two treatments for these parameters (**Table 1**).
- These results suggested that the 50% watering protocol was the best treatment for subsequent phenotyping studies.

Table 1: Soybean yield response to soil water deficits.

Yield and yield components	Watering treatment		
	100%	75%	50%
Pods plant^{-1}	58.1 a^{Z}	51.1 b	34.2 c
Seeds pod^{-1}	2.33 ab	2.38 a	2.25 b
100-seed wt. (g)	16.3 a	17.3 a	17.3 a
Seed yield (g plant^{-1})	21.3 a	20.9 a	13.2 b
Total plant dry wt. (g plant^{-1})	62.9 a	53.1 b	32.3 c
Water used (L plant^{-1})	39.4 a	31.0 b	19.0 c
Water use efficiency (g L^{-1})	1.60 a	1.71 b	1.71 b
Root: shoot dry wt. ratio	0.101 a	0.084 b	0.091 ab

^{Z} Mean values with the same letter are not significantly different according to a Tukey-Kramer's test (α = 0.05; n=5).

Conclusions & Implications

- A 1-m rooting column provides a reasonable field-like soil water profile by depth.
- Water stress treatments imposed in this culture system affect yield components in a manner similar to what is observed in the field, with pod number being the yield component most strongly affected.
- The system provides an opportunity to investigate final root biomass distribution in the profile, as well as soil water extraction from different profile strata at any growth stage of the plant.
- This study provides novel phenotyping tools to select root traits that could increase soybean yield under soil water deficit conditions.

Acknowledgement

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References

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