Soybean Root Development Relative to Vegetative and Reproductive Phenology

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ABSTRACT
Knowledge of soybean [Glycine max (L.) Merr.] primary, secondary, and tertiary root tip locations in the soil vs. seasonal time would enhance modeling of soybean development. The seasonal progression of root tip development and shoot phenology was evaluated in situ using an imaging device inserted into minirhizotron tubes installed in the soil at an in-row 30° angle. Primary root tip extension was linear (i.e., 1.5 and 1.2 cm d⁻¹ each year) until the full-seed stage. Emergent 5-mm secondary roots were routinely detected about 10-cm above the primary root tip, and thus present in a soil layer 11 d after the primary root tip had passed through that layer. Secondary roots followed a similar temporal pattern. Primary root tip location in the soil paralleled a 17°C soil temperature isoline. The 3.7-d phyllochron of main-stem node accrual between first node and seed fill may be a calibratable proxy for inferring correspondent root tip depths.

The soybean root system is characterized as diffuse, but has three distinct morphologically defined components: the primary root, commonly called the taproot that originates as the radicle from a germinating seed, the lateral roots, often referred to as secondary roots that emerge from the taproot, and the tertiary roots that originate from lateral roots (Lersten and Carlson, 2004). The primary root is strongly geotropic and typically has a large diameter (Mitchell and Russell, 1971). The maximum rooting depth attained by a soybean root system, which almost invariably is the depth of the primary root tip, and the composite root length density of all three root types at any given soil depth, are affected by soil texture, moisture, and temperature (Glinski and Lipiec, 1990), plus tillage and planting date (Turman et al., 1995)

Detailed quantification of the phenology of root development requires temporally repetitive measurements of root systems during the course of a growing season. Such measurements are difficult to conduct, and the lack of root phenology data is why roots are often referred to as the significant “hidden” but critically important fraction of a plant (Waisel et al., 2002). However, the importance of understanding the synchrony that may exist between soybean root phenology and soybean vegetative (Vn) and reproductive (Rn) phenology should not be overlooked. A calibration of the root phenology with some aspect of shoot phenology might be useful, if the latter can serve as a proxy for estimating the likely crop rooting depth on any given growing season day. This predictive capability would substantively improve the reliability of crop simulation models such as SoySim (Setiyono et al., 2010), and irrigation management decision tools such as SoyWater (Specht et al., 2010).

Soybean rooting depth research dates back to the 1970s. Mayaki et al. (1976) evaluated soybean rooting depth over time using a soil core method on irrigated and rainfed fields in Kansas for a maturity group (MG) 3.0 soybean cultivar. Seemingly identical sigmoid growth patterns were observed under both water regimes, with both having logistic model inflection points (i.e., maximum rate) between the beginning bloom (R1) and the full seed (R6) stages. These authors made note of an earlier published report that examined the temporal pattern of primary root depth of a soybean cultivar planted in Iowa using a monolith root observation method (Mitchell and Russell, 1971). These latter authors evaluated composite root lengths in the soil on four seasonal sampling dates of 31, 67, 80, and 102 days after planting (DAP), and stated that these sampling dates demarked the start and end of root growth phases that corresponded to: (i) the vegetative growth phase, (ii) the R1 to beginning pod (R3) early reproductive growth phase, and (iii) the beginning seed (R5) to beginning maturity (R7) late reproductive growth phase. They reported a gradual rate of primary root tip extension during Phase 1 of vegetative growth, a rapid rate of primary root tip extension during Phase 2 of early reproductive growth, and a decreased rate of primary root tip extension, coupled with a downward secondary root proliferation, during Phase 3 of late reproductive development. Kaspar et al. (1978) reported similar

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Abbreviations: CRD, completely randomized design; DAE, days after emergence; DAP, days after planting; MG, cultivar maturity group; RCB, randomized complete block; RMSE, root mean square error; R1, beginning bloom; R2, full bloom; R3, beginning pod; R4, full pod; R5, beginning seed; R6, full seed; R7, physiological maturity; R8, 95% pod maturity; SoySim, soybean simulation model; SoyWater, a web-based decision tool for soybean irrigation scheduling; V1, first-node; Vn, vegetative node (where n corresponds to the ordinal number of the given main stem node).