ABSTRACT

A NITROGEN-RESPONSIVE SMALL PEPTIDE SIGNALING MECHANISM MODULATES PLANT ROOT SYSTEM ARCHITECTURE

By

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The plant root system changes dynamically in response to environmental cues. Plants utilize their root system for uptake of essential mineral nutrients that are heterogeneously distributed in the soil environment. Nutrient-dependent modulation of root system architecture (RSA) traits such as primary root growth, lateral root emergence, and the angles at which these roots grow allows for optimization of nutrient acquisition. Among signaling pathways by which plants may sense the availability of nutrients from the environment, small signaling peptide (SSP) pathways play important roles in optimizing root functions. These SSP pathways may further regulate molecular processes underlying RSA, such as the biosynthesis and transport of the major plant growth hormone, auxin. Characterization of these nutrient-responsive SSP pathways is thus of great importance and critical for understanding plant development in nutrient-poor environments. For my dissertation, I have identified and characterized a nitrogen (N)-responsive SSP pathway modulating root gravitropic response and lateral root development. Co-regulation of these RSA components by this module is proposed to prevent root outgrowth into N-poor regions and drive deeper root growth towards mobile nitrate (NO_3^-) resources stratified deeper in the soil profile. **First**, I show that a signaling pathway involving the CLAVATA3/EMBRYO SURROUNDING REGION-RELATED (CLE) family of peptides and the CLAVATA1 (CLV1) receptor kinase, which is involved in N-dependent repression of lateral root emergence, also enhances root gravitropic

response under N-limited conditions. Transcriptomic profiling of a *clv1* mutant and *CLE3* overexpressing lines identified *Arabidopsis thaliana* CENTRORADIALIS (ATC), a mobile protein previously characterized for its role in flowering regulation, as a downstream target of CLE-CLV1 signaling. Loss of *ATC* function significantly weakens root gravitropic response and has a moderate impact on lateral root emergence under low NO_3^- availability. *ATC* promoter activity and protein localization are also detected throughout the phloem and in the root columella cells, which are major centers for gravity sensing. **Second**, I demonstrate the relevance of ATC function on the molecular processes underlying root gravitropic response. While mutation in *ATC* does not impact gravity sensing via amyloplast sedimentation, it does inhibit the asymmetric transport of auxin needed for gravitropic bending. I determine that this occurs via the significant reduction of the PIN3 auxin efflux transporter in the vasculature and root tip of *atc* mutant lines. **Lastly**, I examine how the known roles of ATC in floral development could be implicated in root developmental processes. ATC binds to phosphatidic acid and phosphatidylserine, which is contrary to the binding capacity of its homolog FLOWERING LOCUS T (FT) to phosphatidylcholine and may contribute to its activity in N-limited environments. I also investigate the interaction of ATC and the transcription factor FD in the transcriptional regulation of *PIN3*. Although FD appears to have an impact on root gravitropic response, FD inhibits the expression of *PIN3,* suggesting potentially complex control of this gene via floral regulatory components. Taken together, the results presented in this dissertation contribute greatly to our understanding of how plant root architecture alters in response to N. These results can be further utilized in plant engineering strategies to regulate root growth in nutrient-limited soils.