Trends in Plant Science | **Technology of the Month**

Beyond Digging: Noninvasive Root and Rhizosphere Phenotyping

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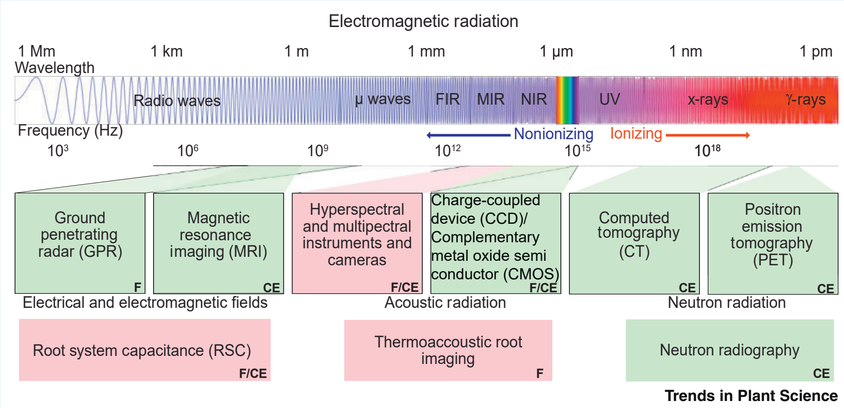
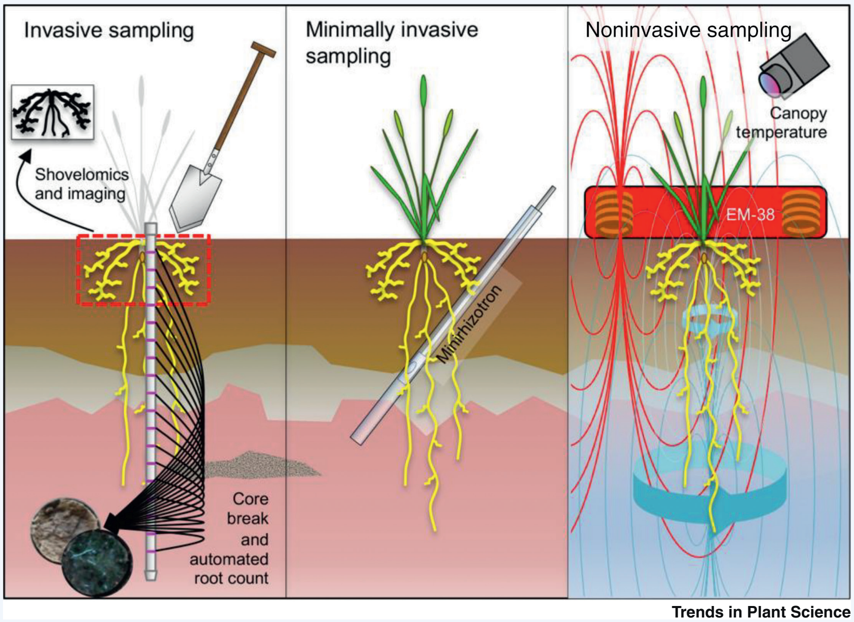


A wide spectrum across physical domains has been tested to directly phenotype roots noninvasively in soils in controlled environments (CE) and fields (F). Some are established (green) in specialized groups, others are developing (pink). Magnetic resonance imaging (MRI), computed tomography (CT), and position emission tomography (PET) localize root structure and functions in containers of soil in CE. Neutron radiography, hyperspectral and multispectral instruments, and RGB (red, green, blue) cameras are applied to detect changes in root and rhizosphere chemistry through windows of rhizoboxes in CE. Field direct, noninvasive measurements are limited to ground penetrating radar (GPR) and to thick tree roots and tubers. Root system capacitance (RSC) shows promise where root thickness and the soil allow; thermoacoustic imaging is being explored.



Today, routine phenotyping of crop roots is invasive or indirect. Sampling is either: (left) invasive and destructive, using coring or shoveling to extract or image root systems at a point in time; (middle) minimally invasive, perturbing root growth by inserting an imaging window and allowing repeated measures; (right) or indirect, inferring root phenotypes by noninvasive measuring of soil water (and water uptake over time) or access to water or nitrogen (via canopy temperature and spectral emission).

ADVANTAGES:

Noninvasive root phenotyping does not disturb root system structures, architecture, and functions within the rhizosphere and bulk soil environments.

The rhizosphere can be monitored as a holistic phenotype, which includes the root, for discovery of new traits, selection in breeding, and interventions with management.

Noninvasive phenotyping provides root and rhizosphere dynamics, to move beyond simple static traits.

Shoot-only phenotyping captures limited variation in root phenotypes.

Noninvasive whole-plant and crop phenotyping has the potential to greatly speed up genetic gain and agronomic improvement.

CHALLENGES:

Field root and rhizosphere development are dominated by a soil environment that can be highly variable across scales from mm to km.

Technologies successful in laboratories for 4D root imaging rely on detectors around pots or placed in the soil or plant.

Fine root structures and function as well as deep roots (regularly penetrating beyond 1.5 m) are difficult to measure, but contribute strongly to productivity under water and nutrient limitations.

Ionizing radiation exposure from CT and PET may affect root development and function.

Robotics and automation of root phenotyping and analysis needs to be developed for high-throughput applications, such as plant breeding and management.

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