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Integration of root phenes revealed by intensive phenotyping of root system architecture and anatomy

PENNSTATE 1855

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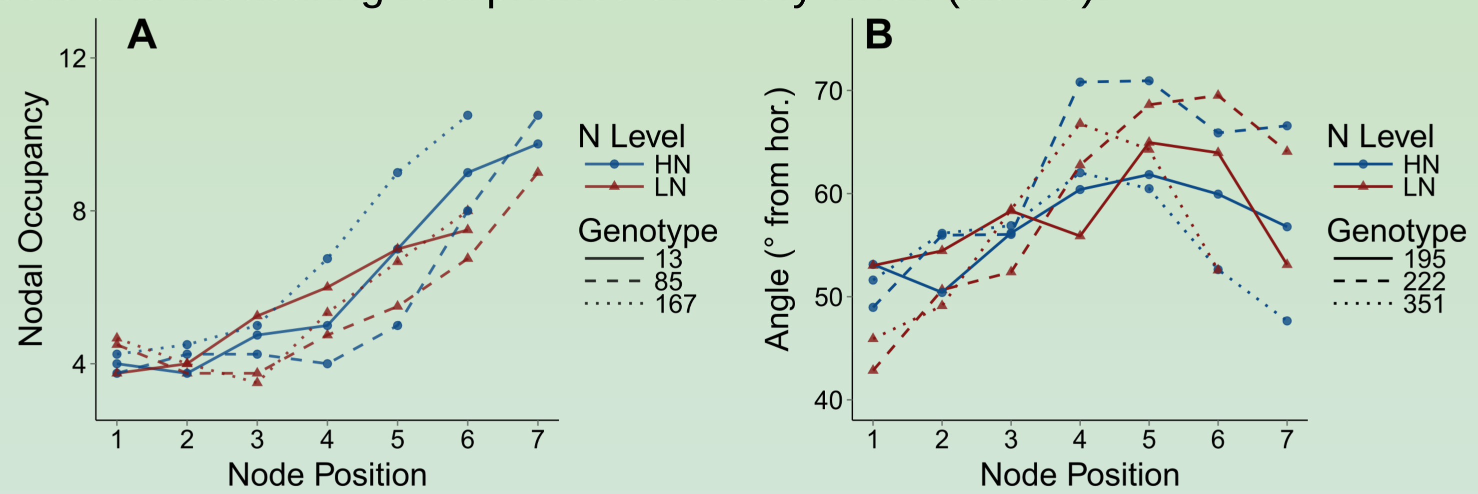
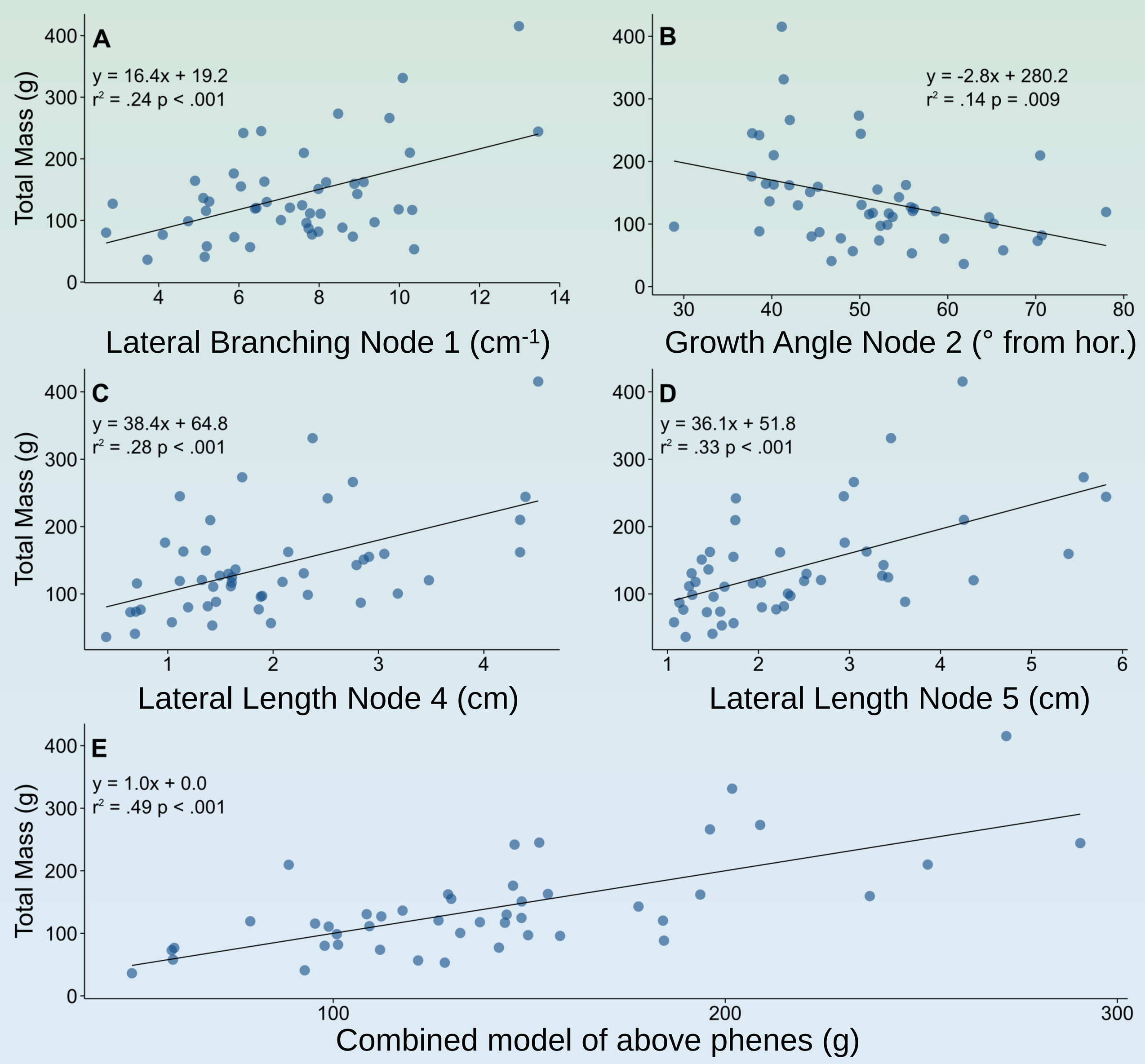
Integration among whorls affects maize growth in the field

Intensive phenotyping of maize root crowns involves removing whorls of roots and measuring root phenes on every whorl (above).

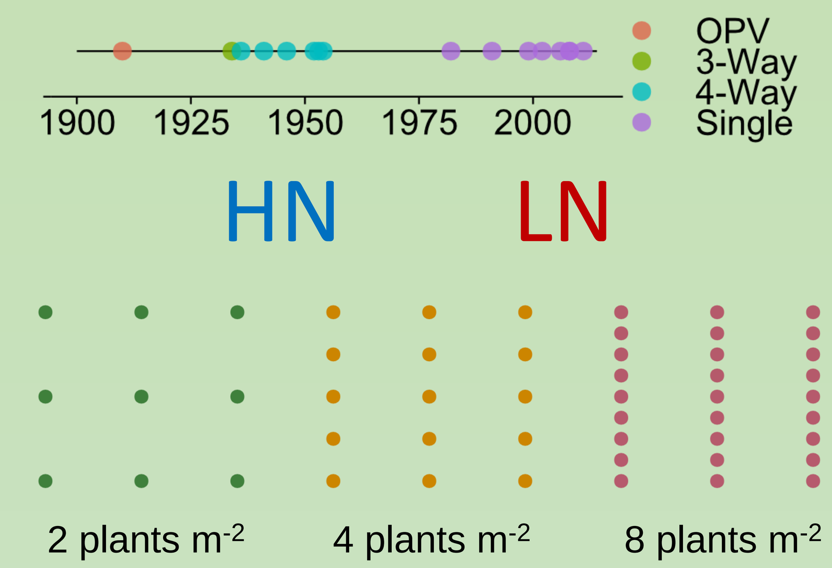


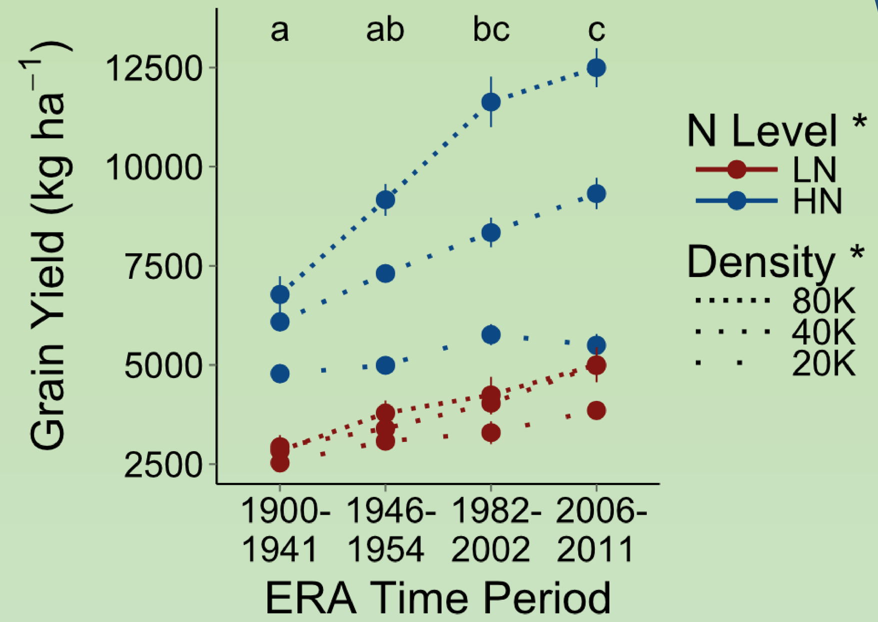
Phene states vary within maize root crowns, among genotypes, and exhibit plasticity to soil nitrogen levels, whether high or low (above).



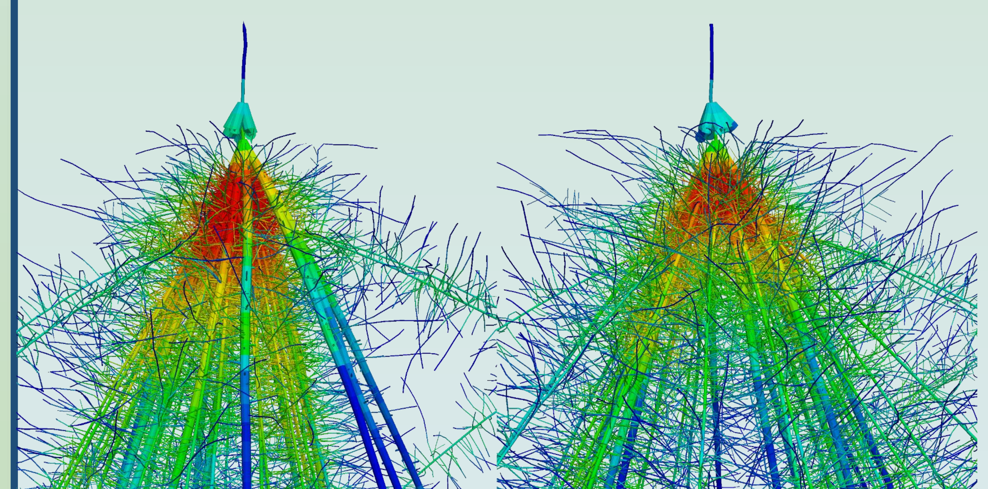
The relation of individual phenes to plant growth in the field are informative (A-D), but their integration (E) provides the most explanatory power (above).

Architectural and anatomical integration affected maize root system evolution





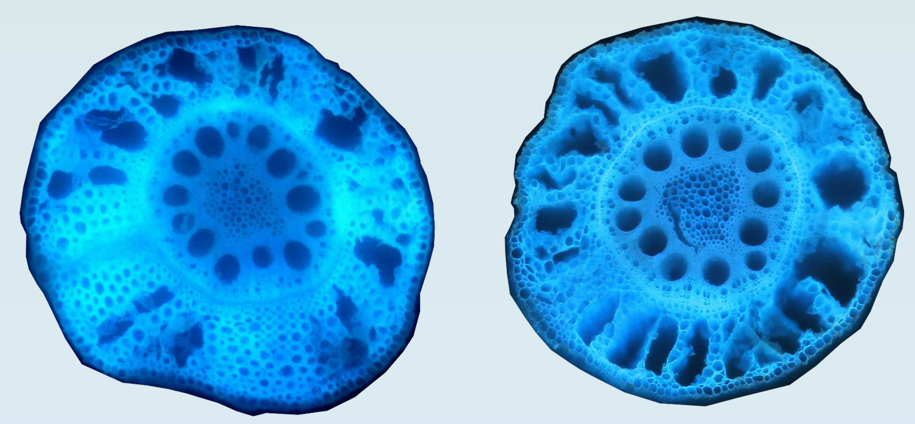
Sixteen hybrids from the past 100 years in the USA were grown at two nitrogen levels and three densities that represent historic and current agronomic conditions (above, left). Current material performed better in all conditions (above, right). Architectural and anatomical **root phenes evolved towards nitrogen acquisition efficiency** (see below).



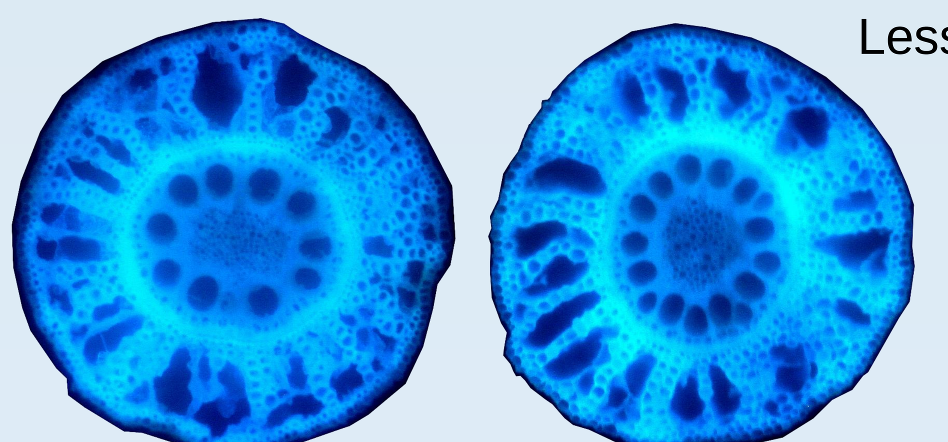
Historic　　Current

Modern material had fewer nodal roots, longer laterals, greater distance from the shoot to lateral emergence, and more shallow nodal root angles (left).

Aerenchyma, air filled spaces in cortex, increased in low nitrogen soil and at greater population densities (right).



Less Aerenchyma　　More Aerenchyma

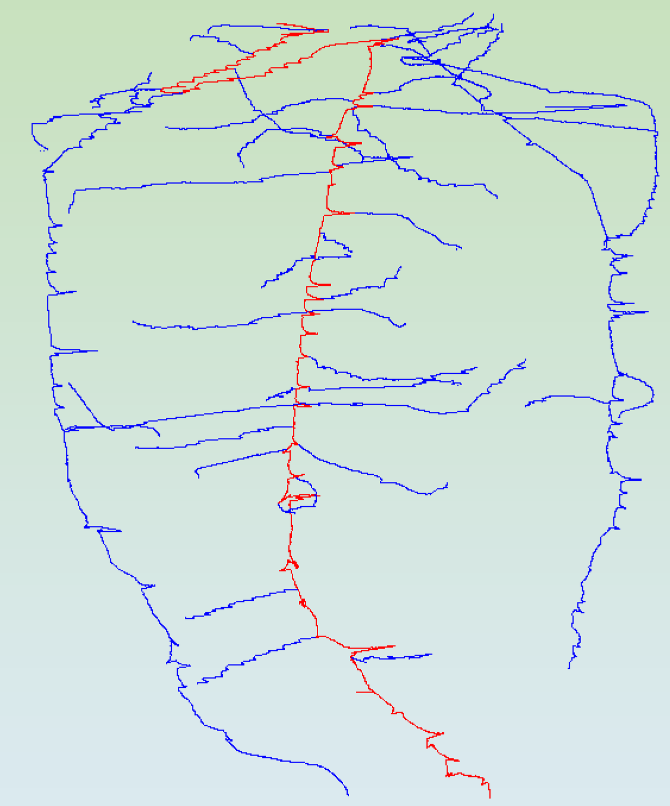


Few, large xylem　　Many, small xylem

The number of xylem vessels, tubes for transporting water in center of the root, increased while the area of each vessel decreased in modern material compared to old (left).

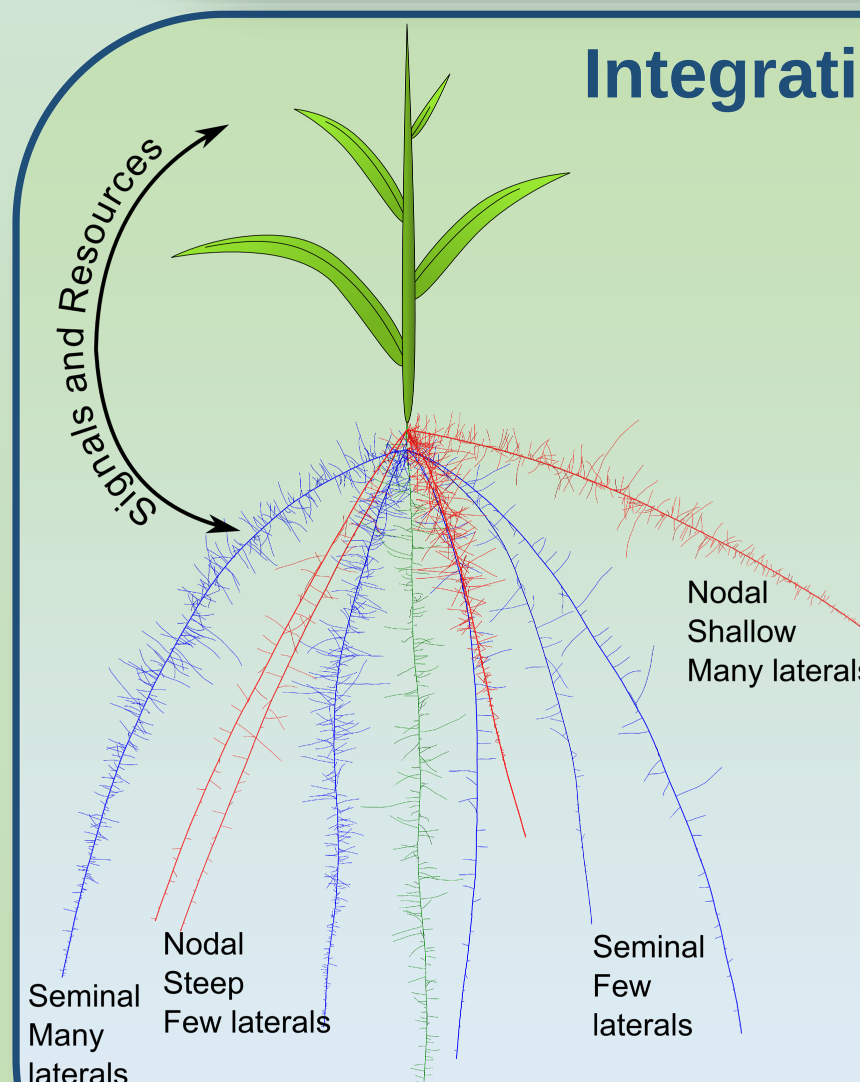
X-ray computed tomography

X-ray computed tomography (left) allows the non-destructive imaging of 3D root systems in soil.



Skeletonization of 3D root systems (above) will allow measurements of global properties like volume of the convex hull, and of local properties like lengths and angles of the different root classes.

Integration



Root system phenotype is built from elemental phenes such as numbers, angles, and diameters of all root classes.

Root phenes integrate through their effects on soil foraging and carbon economy.

Ultimately, whole plant integration will be determined by signalling between the shoot and roots as well as the relative carbon source and sink strengths.

Acknowledgements:

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James Johnson provided the 3D skeletonization

References:

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