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Plasticity of root hair development in a wheat ancestor and a landrace under nutrient deficiencies

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Introduction

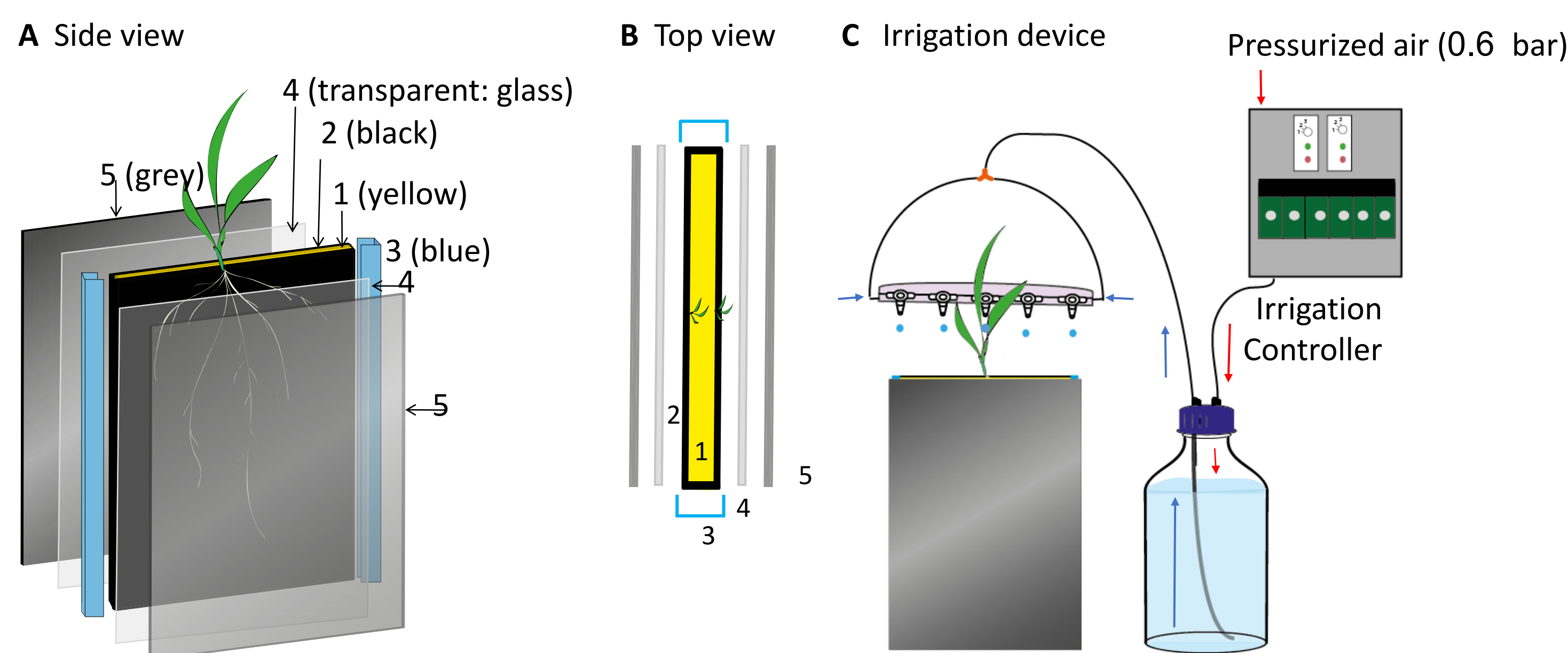
While root hairs strongly contribute to soil foraging for nutrient ion acquisition, no affordable high-throughput methodology for phenotyping the development of this cell type in intact whole root systems was available. We established such a methodology and used it to compare two wheat genotypes, an ancestor and a landrace, by analyzing the contribution of root hairs to the entire root system surface area, and root hair length and density per root class (seminal and lateral roots) under phosphate (Pi) deficiency conditions

Our objectives are :

- To develop a methodology for phenotyping root hair development in entire root systems.
- To investigate the effect of nutrient availability on wheat root hair development.

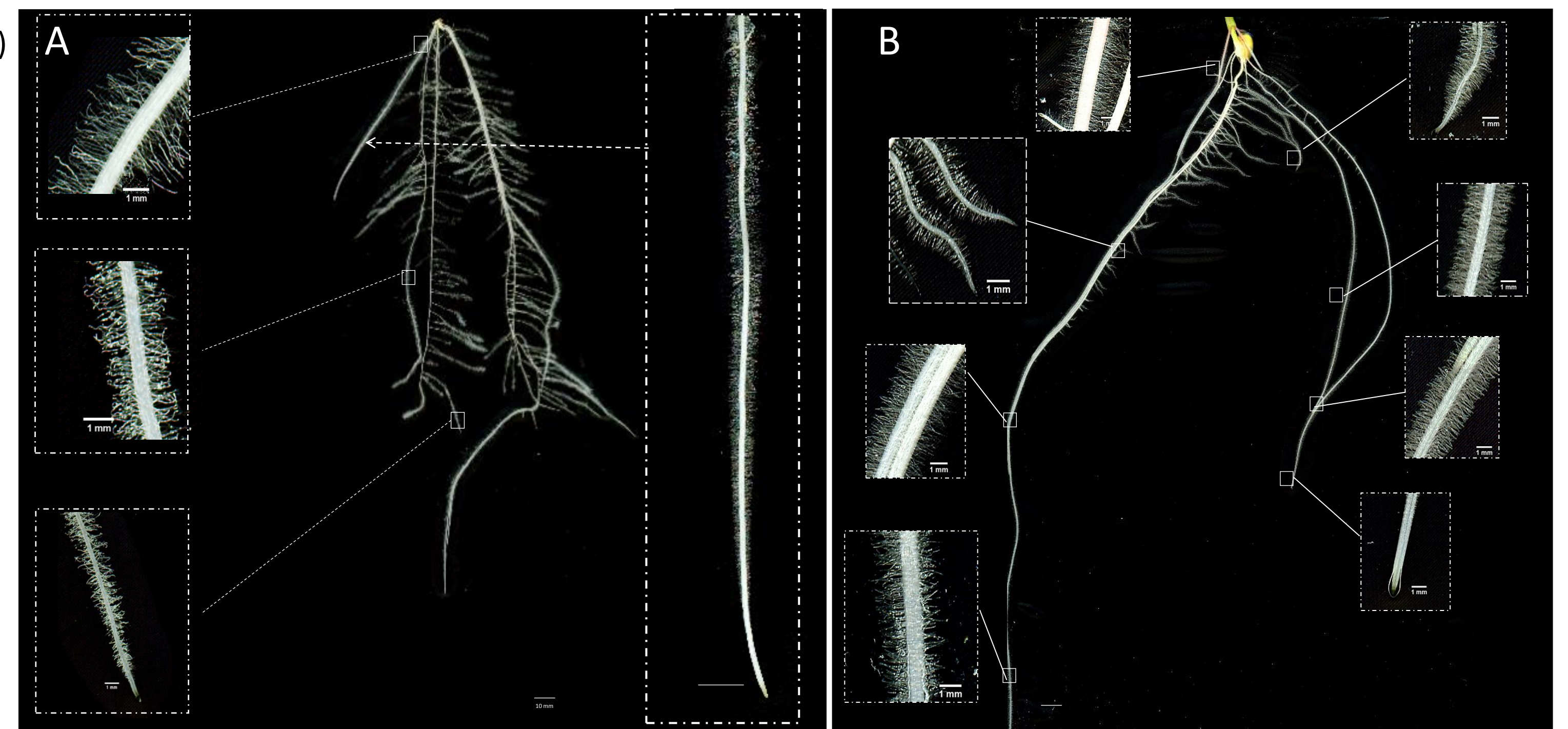
A rhizobox-type device providing high resolution images of root hairs (Rh) on intact root systems

Root hair phenotyping system (Rhizobox-type system)



(1) Solid polyurethane foam board (2) Black polyester fabric (3) U-shape aluminium sliding bar. (4) Glass plate (5) Polystyrene board (C) Watering system. Pressurized air (0.6 bar) moves the nutrient solution from a reservoir bottle via a symmetrical circuit. Roots are scanned through glass plate

Examples of root system images obtained using the Rhizobox-type system



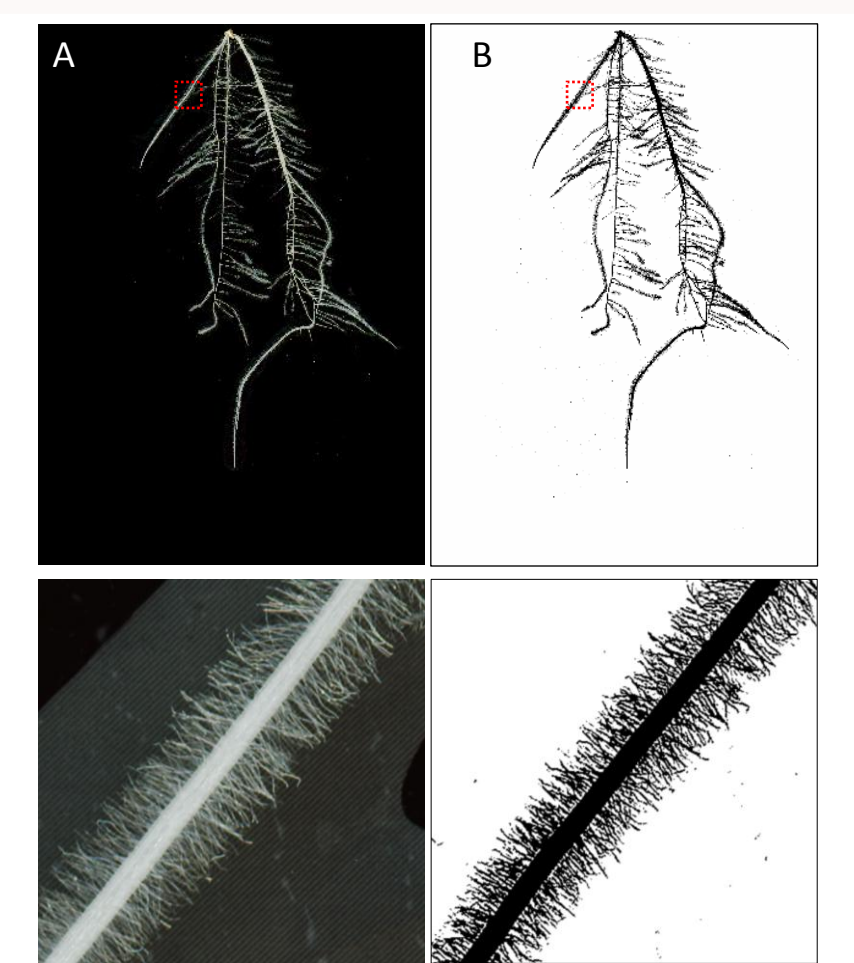
Wheat seedling (A) and Maize (B) grown for 14 days in a rhizobox and watered with complete Hoagland solution (white bars: 1 mm)

Effect of phosphorus availability on wheat root system and root hair developments

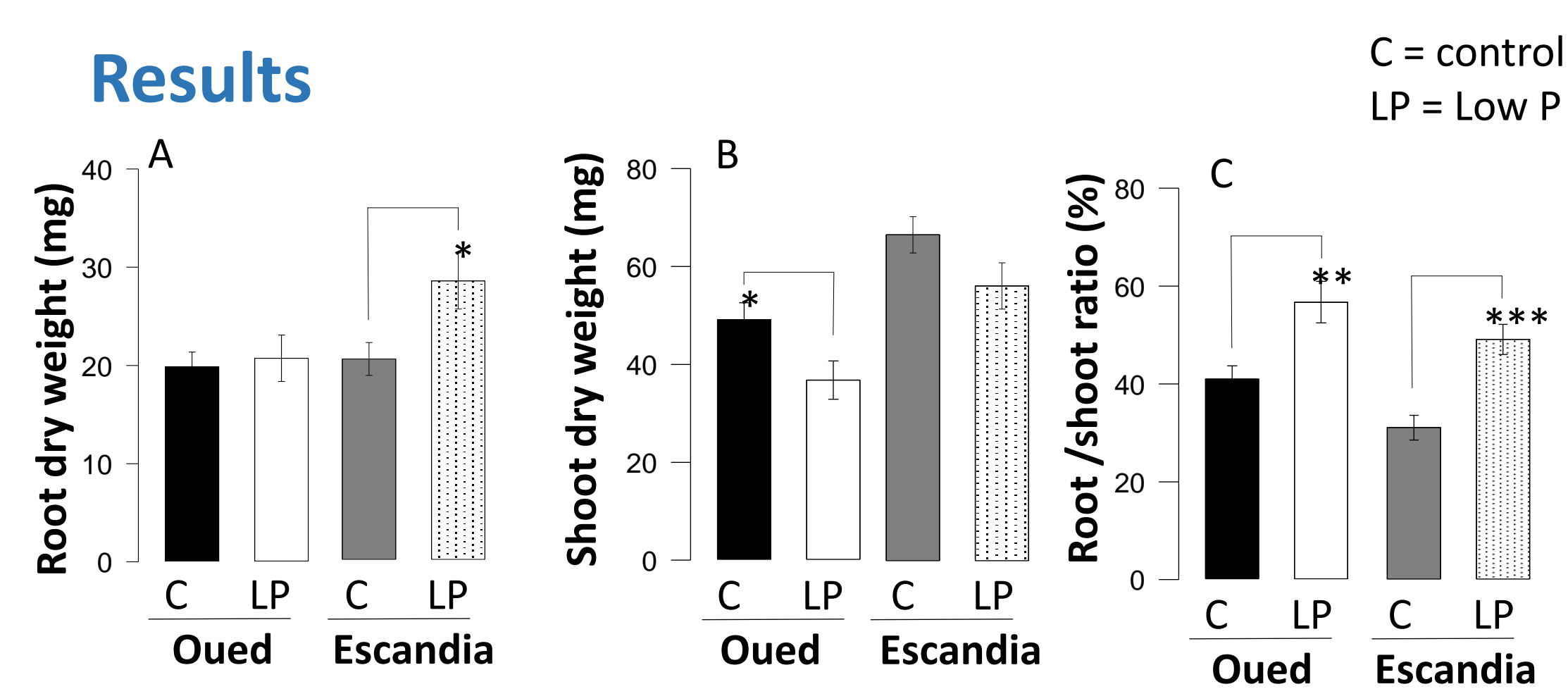
Material and methods

Two wheat varieties : a landrace *Triticum turgidum ssp. durum* cv. Oued Zenati and an ancestral wheat variety *T. t. L. spp. dicoccum* cv. Escandia were grown for 14 days in Rhizobox-like systems and watered with either complete Hoagland (C) or low phosphate (LP) solution (containing 1 mM KH_2PO_4 or 2 μM KH_2PO_4 , respectively).

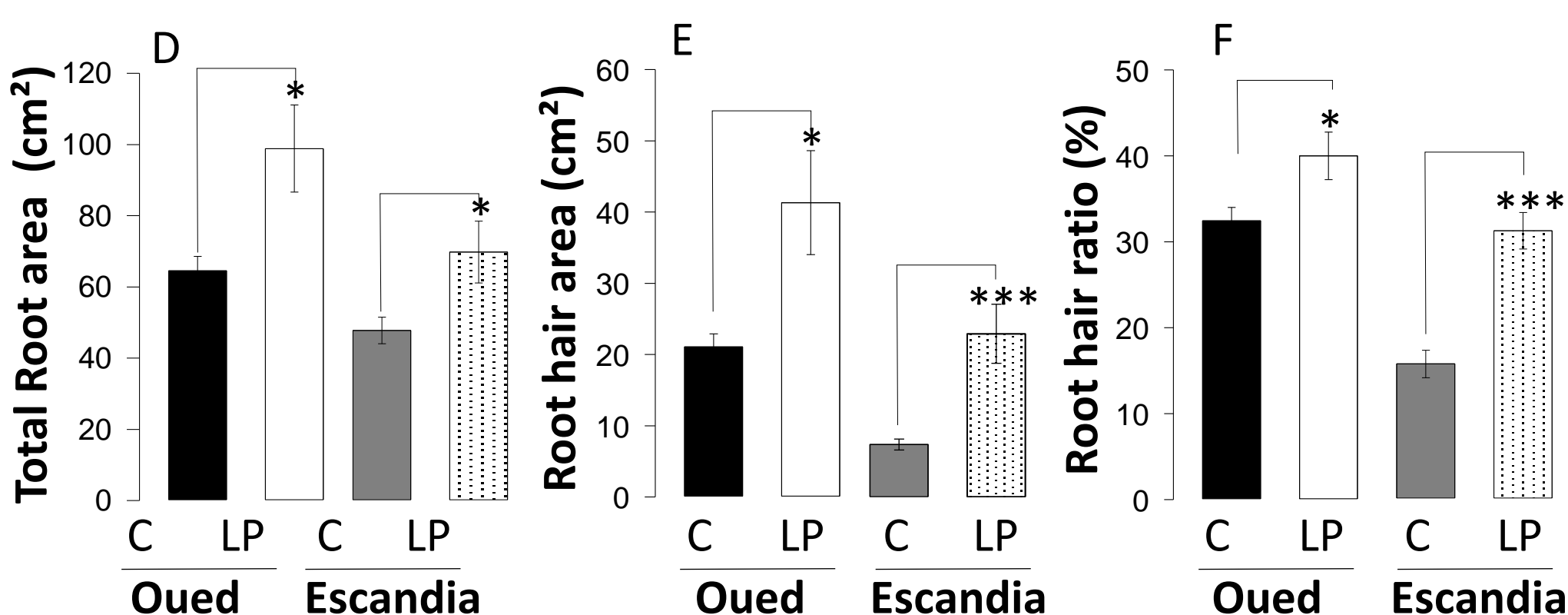
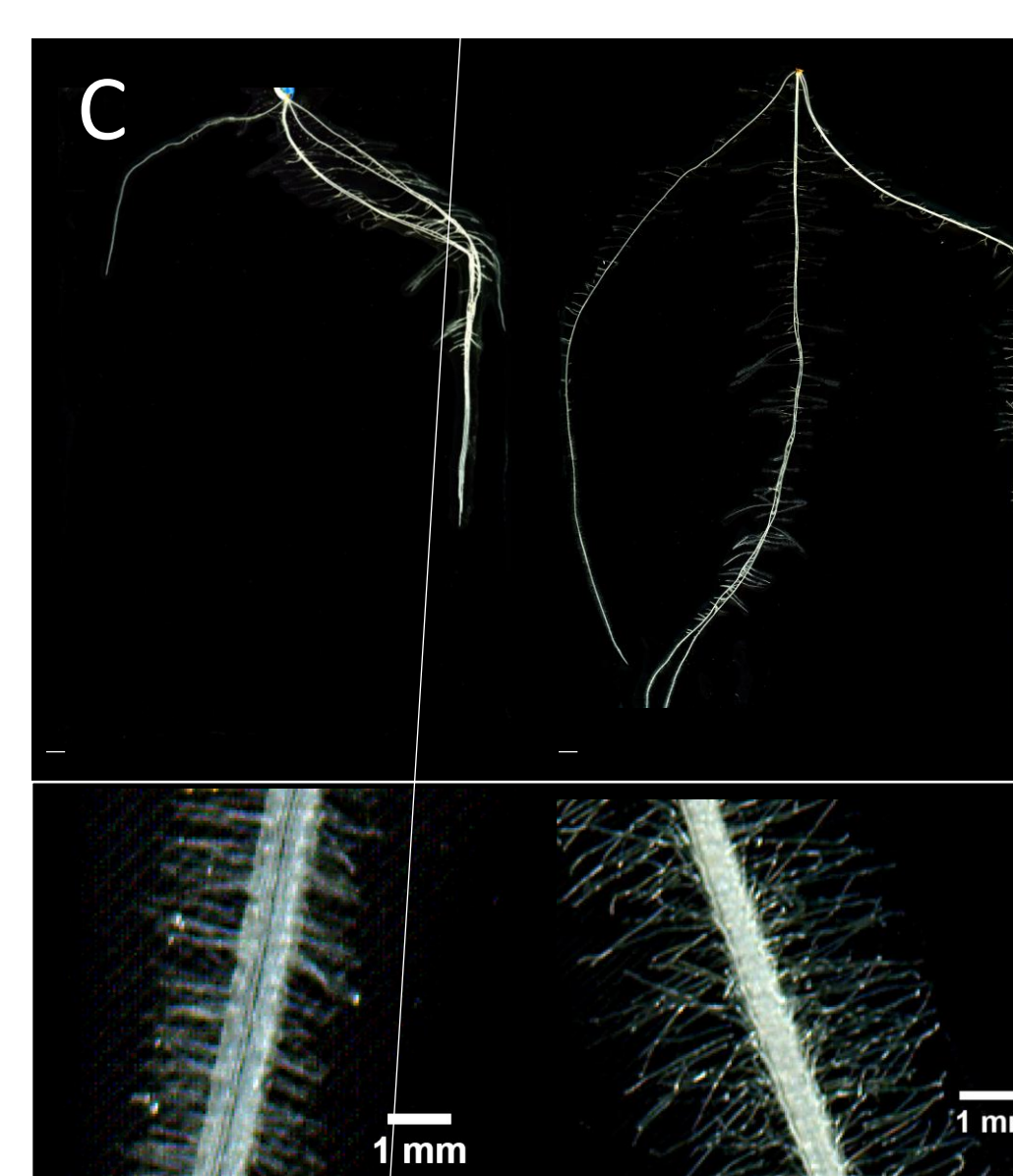
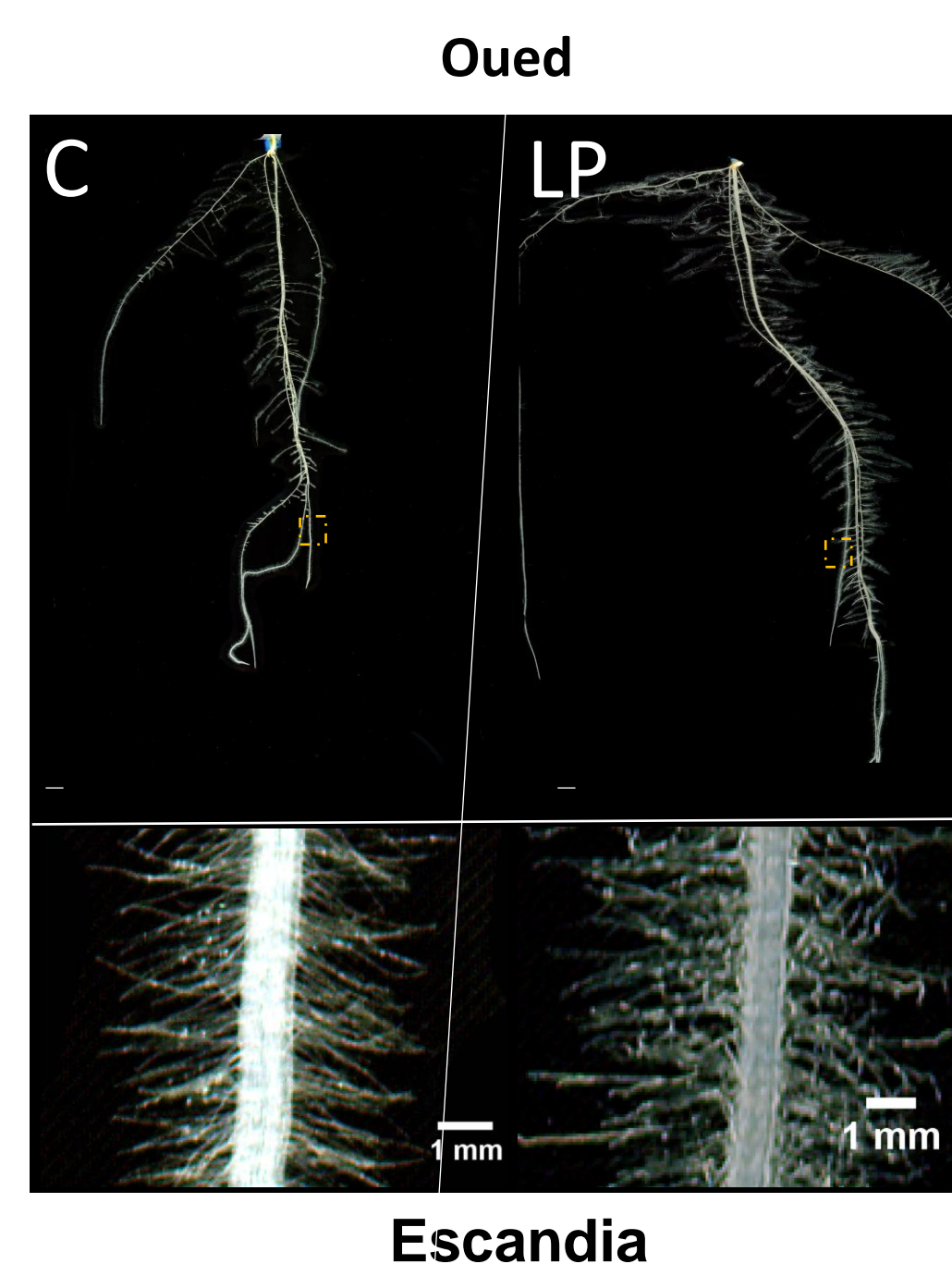
Root images were acquired using a scanner. Image segmentation was performed using the pixel classification procedure of the interactive machine learning for (bio)image analyses software Ilastik (Berg et al., 2019) and then analyzed with Winrhizo™ for root and root hair surface area and with ImageJ for root hair density and root hair sheath width (mm)



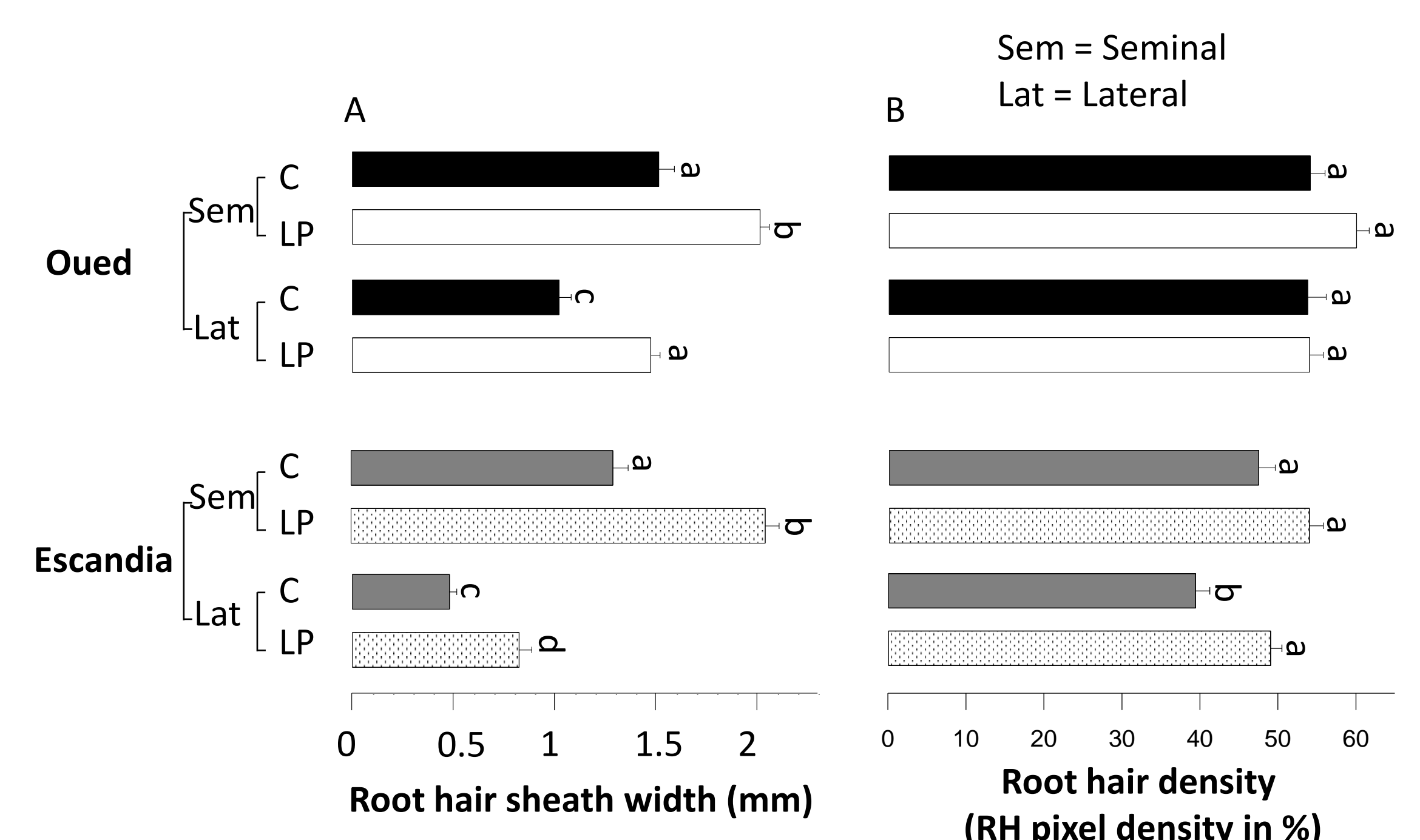
Results



Pi shortage affected plant growth leading to a strong increase in the root to shoot biomass ratio in both accessions



Pi shortage resulted in an increase in total root area (root skeleton +RHs) mainly due to a large increase in RH area.



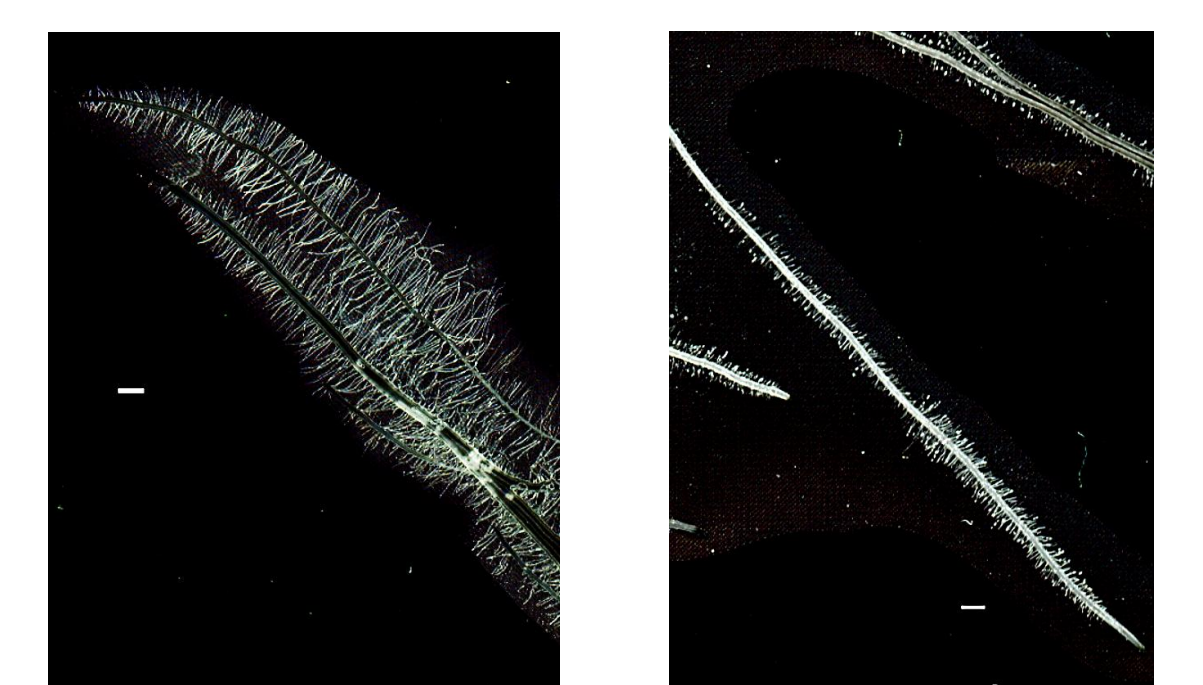
Pi deficiency increased both root hair length and root hair density, the most prominent effect being on root hair length.

In summary

Escandia (wheat ancestor) showed a greater plasticity than Oued Zenati (the landrace) under Pi shortage, particularly in terms of increasing root hair area and ratio of root hair area to total root area.

Conclusions & perspectives

The developed methodology allowed to reveal differences between root architectural traits of the two accessions (and in particular root hair development), and their responses to nutrient starvation. Such methodology paved the way to integrative phenotyping of root hair development in intact root systems allowing to compare different genotypes of a given species (wheat, maize, rice, Arabidopsis etc..). Furthermore, the range of root architectures observed in our phenotyping platform can be simulated using root modelling Softwares, i.e. SimRoot. Also, the root and root hair are physically accessible, which can allow to perform targeted root transcriptome analysis.



references

Berg, S. et al. (2019) 'Ilastik: Interactive Machine Learning for (Bio)Image Analysis', *Nature Methods*. Springer US, 16(12), pp. 1226–1232. doi: 10.1038/s41592-019-0582-9.

