Novel Manual and Automatic HD Minirhizotron Camera Systems to facilitate MR use in Plant Sciences

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VIENNA SCIENTIFIC INSTRUMENTS

BARTZ Technology

Introduction

Minirhizotron (MR) systems are versatile qualitative & quantitative observation tools to study root and hyphal distribution, growth & longevity *in situ* or in mesocosms. However, the available technology is currently limiting the wide use of MR systems in research, especially due to i) moderate image quality, ii) high purchasing prices, and iii) labor intensive manual imaging campaigns and analyses. Imaging automation seems especially advantageous for large experimental set-ups ('rhizolabs'), featuring hundreds of MR tubes in experiments addressing e.g. root phenotyping or ecological questions; increased image quality (while not compromising on time for image acquisition) is key for adequate imaging of hyphae and root details (e.g. root hair). Thus, a modular set of new MR camera systems was developed by cross-sectoral collaboration between the University of Natural Resources and Life Sciences (BOKU) and the companies Vienna Scientific Instruments (VSI) & Bartz Technology Corp. (BTC). Key features of two developed systems are described and an outlook on future R&D is given.

Key specification of MR cameras

Specification	**Manual MR** (Fig. 1)	**Automatic MR** (Fig. 2)
Nr. of cameras / lighting	One / 2 LED strips (*dimmable*)	Two (*bi-directional*) / 1 LED ring each (*dimmable*)
Rel. position of camera ("dead space" in tubes)	<60mm	<30mm
Image resolution (native)	3280 x 2464 px (*2500 dpi, UHD*)	3280 x 2464 px (*2500 dpi, UHD*)
Image size (native, 7 cm MR tube)	33 mm x 24 mm	ca. 28 mm x 21 mm
Indexing	20 or 30 mm, circular position covering ca. 350° ("*Smucker" handle with turning indexing head*)	Continuously on gear rack, 3 circular positions covering ca. 320° (*accuracy ± 0.05 mm on 1 m*)
Operation unit / comm. with imaging module	RaspberryPi (Touchscreen, Keyboard) / HDMI cable (< 7 m)	Tablet computer / Wireless (*Bluetooth, RFID*)
Remote / automatic imaging	Manual, key stroke or Bluetooth trigger (*<10 m*)	Imaging fully automatic *(after camera module positioning in tube & tube number registering)*
ICAP naming	According to experimental set-up / display on screen	Tube recognition by RFID chip, automatic naming according to position
Energy supply	Wall plug or battery-powered (*via operation unit*)	Battery-powered (*both camera module and tablet*)
Camera modules per operator (in parallel)	One	Up to three (*max. recommended for 150 cm long MR tubes*)
MR tube dimensions (focus factory calibrated) / position	≥54 mm inner diameter (*Bartz-standard*) / vertical to horizontal	≥64 mm inner diameter ('*scanner'-standard*) / horizontal and slightly angled

Devices

Fig. 1 "Classical", manual UHD MR camera

Fig. 2 Automatic UHD MR camera modules for concurrent imaging by one operator in large 'rhizotrons' facilities

Example Images

Fig. 3 *Pisum sativum* roots in a mesocosm experiment at BOKU (native image, A), Magnification (B)

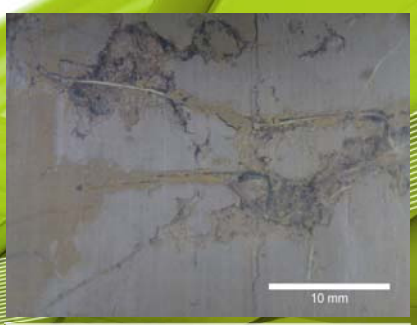

Fig. 4 *Triticum aestivum* roots in the Jülich minirhizotron facility, Germany (native image)

Conclusion & Outlook

Further efforts are needed to make MR imaging system widely available and to increase their versatility. While novel features e.g. Ultra-HD resolution and automatic imaging in horizontal MR tubes could be already implemented in the new systems, consequential next R&D steps include fully automatic, permanent imaging of vertical and angled MR tubes *in situ* and imaging beyond the visible light spectrum to facilitate automatic root recognition.