



## An affordable, fully-automated minirhizotron system for observing fine-root dynamics

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For the understanding of the carbon cycle in terrestrial ecosystems as well as of plant stress responses to drought and hypoxia, the study of fine root dynamics plays an important role. However, the number of relevant studies is still limited, which may be due, among other things, to the high costs of commercial minirhizotron systems. Here, we present an affordable (<500 €) and fully automated minirhizotron system, utilizing new developments in low-cost electronics and 3D-printing. The camera system is based on a Raspberry Pi and can be controlled by the user via a Python-based GUI. The open source character of the program also allows it to be adapted to the needs of the user or other requirements. The camera is controlled automatically by a stepper motor, which allows the precise recording of images at defined depths. The highest possible resolution is 3280 x 2464 pixels (8 MP) for an image area of about 2.5 cm x 2.5 cm, thus allowing the imaging of even root hairs and fungal hyphae. The structural components were manufactured using 3D printing. To protect against moisture, the camera and drive system are installed in a waterproof acrylic tube (60 mm diameter), which in turn is inserted into the rhizotron tubes (70 mm diameter) used in the field, making it possible to use the system in humid ecosystems.