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Thermography as non invasive functional imaging for monitoring seedling growth

É. Belin [a,b], D. Rousseau [c,*], J. Rojas-Varela [b], D. Demilly [d], M.-H. Wagner [d], M.-H. Cathala [a], C. Dürr [a]

[a] INRA, UMR 1191, Unité Physiologie Moléculaire des Semences (PMS), IFR Quasav, 16 boulevard Lavoisier, 49045 Angers, France
[b] Laboratoire d'Ingénierie des Systèmes Automatisés (LISA), Université d'Angers, 62 avenue Notre-Dame du Lac, 49000 Angers, France
[c] Université de Lyon, CREATIS, CNRS UMR5220, Inserm U1044, INSA-Lyon, Université Lyon 1, France
[d] GEVES, Station Nationale d'Essais de Semences (SNES), rue George Morel BP 90024, 49071 Beaucouzé Cedex, France

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ABSTRACT

We demonstrate the value of thermal imaging for monitoring growth of seedling organs. An automated procedure is introduced to perform the segmentation of the organs of the seedlings from the thermal contrasts in the images. Results of the automated procedure were assessed visually by expert operators in a separate procedure. This constitutes a new application of thermal imaging as a non invasive imaging providing functional information on the physiology of the seedlings.

1. Introduction

Computer vision systems are powerful tools for plant phenotyping since they allow non contact measurements at high-throughput. When associated with non-conventional optical imaging systems, computer vision systems can outperform the capability of human eye and provide access to functional imaging (Chaerle and Straeten, 2001). The identification and development of new methodological applications of non-conventional optical imaging coupled with computer vision algorithms is therefore an important research goal to widen the set of tools available for automated plant phenotyping. In this report, we focus on thermal imaging. We demonstrate a new application of thermal imaging to monitor seedling growth.

Introduced in the 1960s, thermal imaging uses the Planck law which expresses the luminance of a black body in thermal equilibrium at a given wavelength, to measure temperature. Thermal imaging has received considerable attention in plant science (see Chaerle and Straeten (2001) for a review) and new developments continue to appear. It has, for instance, recently been shown to provide information on stomatal aperture (Leinonen et al., 2006), thermal changes linked to photosynthetic activity (Kana and Vass, 2008), plant water content (Wang et al., 2010a,b), plant freezing (Wisniewski et al., 2008), and the development of pathogens (Chaerle et al., 2007). These applications have been developed at different scales of observation including the canopy (Wang et al., 2010a,b), the individual plant (Wisniewski et al., 2008; Chaerle et al., 2007), and the leaf (Leinonen et al., 2006; Kana and Vass, 2008).

The seed scale, although easier to observe with high-throughput approaches (see Dell'Aquila (2009) for a recent review), has only recently been used with thermal imaging (Baranowski et al., 2003; Kranner et al., 2010). Thermography was used to evaluate the germination capacity of legume seeds (Baranowski et al., 2003). Considerable differences were observed in the average temperature of seeds during the initial stage of the imbibition process depending on the storage time and germination speed. Thermal imaging was also used to predict whether a quiescent seed will germinate or die upon water uptake as thermal imaging can detect biophysical and biochemical changes during imbibition and germination (Kranner et al., 2010).

In the present study, we demonstrate the potential for a new application of thermal imaging at the seedling scale, distinct from those on seed imbibition and germination. We consider the seedling growth after germination. During this stage, the two parts of the seedling elongate allowing the radicle to explore deeper soil layers for water and mineral uptake, and the shoot to grow toward the soil surface. The rates of elongation depend on environmental conditions, but also on species and genotype. Phenotyping the genetic diversity of these plant parameters could help breeding for improved plant tolerance to environmental stresses. In addition, differences in early radicle growth rates may be predictive of differences in adult plant root growth, which are much more difficult to measure. These plant parameters have also been used in plant growth models that predict emergence and crop growth. Finally

* Corresponding author.
E-mail address: david.rousseau@univ-lyon1.fr (D. Rousseau).
URL: http://www.istia.univ-angers.fr/LISA/PHENOTIC (D. Rousseau)

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