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A Survey on Invasive and Non-Invasive Root Imaging Techniques

Abinaya V [1], Chanthini Devi S[2], Divya J[3,] Mrs.R.Maheswari,[4]M.E(Ph.D) ,Mrs.R.Malathy[5]

Final year Students Department of ECE, Agni College of Technology, Chennai, Tamil Nadu, India [1,2,3]

Sr. Asst. Professor, Department of ECE, Agni College of Technology, Chennai, Tamil Nadu, India[4]

Asst. Professor, Department of ECE, Agni College of Technology, Chennai, Tamil Nadu, India [5]

ABSTRACT : In this paper we are going to discuss various root image acquisition and their related processing techniques. Plants get affected by various diseases. The diseases occurring at the aerial part of the plant are visible and can be treated at an earlier stage. Root diseases do not have any visible symptoms associated, or those appear only when it is too late to act. The symptoms occur at latter stages which is difficult to treat and results in reduced crop yield. The root images acquisition helps to identify the disease at the initial stage and result in good quality of crop production.

KEYWORDS: Root image acquisition, image processing techniques.

I.INTRODUCTION

Crop production has to be doubled to keep pace with global population growth by 2050. This target is even more challenging because of the impact of climate change on water availability and the drive to reduce fertilizer used to make agriculture environmentally sustainable[2]. The calculation and analysis of root's characteristic parameter are very important to distinguish the growth condition of plant and to prevent plants from diseases and insects.

The lack of good sensors, instruments, techniques and technologies for field soil measurements is limiting decisive and rapid advances in soil, ecosystem and agronomic science. Currently, only a few techniques are available for visualizing the roots in field conditions, and those that exist are labor intensive and limited in what they can see and measure. Because the root system of plants is involved in the absorption of nutrients and water, understanding their traits, dynamics, and behavior is important to a broad number of disciplines, including soil and plant science, agronomists, hydrologist, earth system modelers and others[1]. The study of root systems has become vital to identify the factors that could contribute to the improvement of crop yields to guarantee the food supply.

II. LITERATURE REVIEW

The disease infects the root of the plant are called root infected disease *(table 1)* and basically, they occur in plants such as chickpeas. The diseases are dry root rot and ascochyta blight which infect the root of the plant, Club root of crucifier, Root rot of pigeon pea.

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Fig:1 Nematodes & root rot

S.no	Crop name	Infected disease
1	Rice	Leaf blast, brown spot
2	Wheat	Leaf rust, leaf blight
3	groundnut	Tikka
4	chickpea	Dry root rot
5	Pigeon pea	Root rot

Table : 1 Different root diseases

A. IMAGE ACQUISITION

Image acquisition is the process of obtaining a digital representation of an object or scene. This representation is known as an image, and its elements are called pixels. The electronic device that is used to capture a scene is known as an imaging sensor. A charge-coupled device (CCD) and complementary metal oxide semiconductor (CMOS) are the most broadly used image sensors. When selecting an imaging sensor (a camera), CCD technology causes less noise and produces higher-quality images, mainly in scenes with low illumination. On the other hand, the CMOS sensors are comparatively faster at processing images. Due to the hardware architecture for pixel extraction, they require low operating electrical power, they allow a region of interest to be processed on the device and they are less expensive than CCDs.

B. MULTI AND HYPER SPECTRAL CAMERAS

Multispectral and hyperspectral cameras have been different fields of science and in industrial applications. The spectral resolution distinguishes multispectral imagery from hyperspectral imagery [1,2,3]. Multispectral cameras are devices able to capture images from a number of discrete spectral bands. The number of bands has increased in the past years as technology has improved. Currently, the main camera manufacturers offer multispectral cameras acquiring between 3 and 25 bands, including visible RGB channels, near infrared (NIR), or a set of custom bands, with a tendency to provide an increasing number of bands.

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C. MONO-RGB VISION SYSTEMS

Mono-RGB vision systems [4] are composed of a set comprising a lens, imaging sensor, specific hardware, and input/output (IO) interface. Depending on if they use a line or matrix of pixels, they are classified as line cameras or matrix cameras. Most phenotyping devices use mono RGB vision systems.

Fig: 2 a) flatbed scanner, b) handheld scanner, c) smartphone scanning application, d) time-lapse camera and rhizotron were placed into insulated boxes to prevent from external temperature variations.

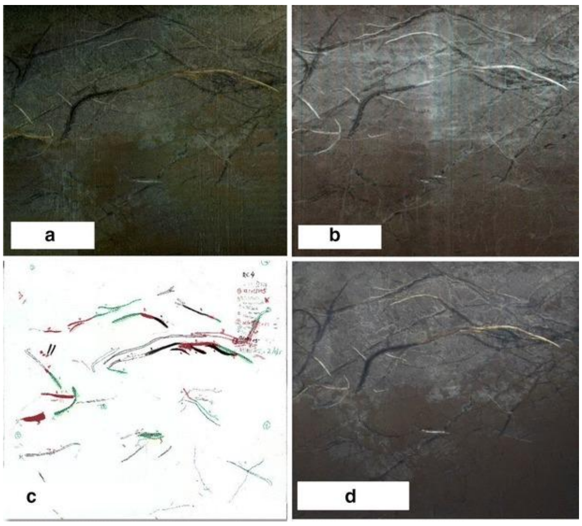

Fig. 3 Root images obtained using a) flatbed scanner, b) handheld scanner, c) smartphone scanning application, d) time-lapse camera

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These systems allow quantification of the plant canopy as well as sufficient computation of vegetation indices. Five methods of root image acquisition are compared using inexpensive technology. Rhizotrons can be used to monitor specific root segments at frequent time intervals without significantly impacting root growth.

D .GROUND PENETRATING RADAR(GPR)

GPR is an existing and rapidly evolving technology [5] that can be used as a high throughput (HT), non-destructive 3-dimensional imaging method for quantifying plant root mass. Most GPR systems workby emitting EM pulses into the ground in which part of the energy is reflected, transmitted or scattered at the boundaries of contrasting materials (i.e. the root soil boundaries). The reflected strength of the return pulse is recorded as a function of travel time.

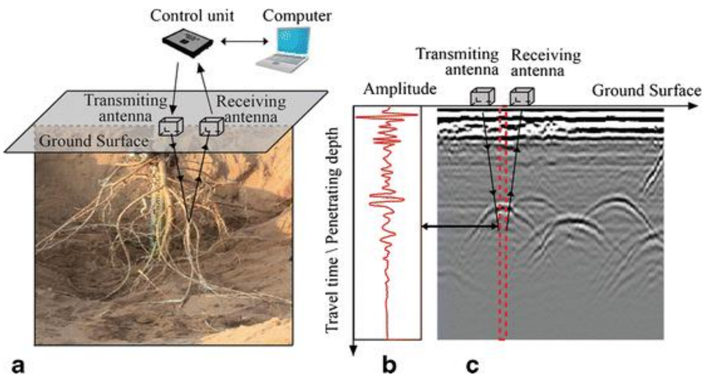

Fig:4 Schematic illustration of GPR detection

a) High frequency electromagnetic pulses emitted from a transmitting antenna reflects the boundary between soils and roots and it is received by a receiving antenna. Time and signal strength are recorded by the control unit; b) A reflected waveform (A-scan) of GPR radargram records the two-way travel time (i.e., the depth of penetration) on the vertical axis and amplitudes of the return signals along the horizontal axis; c) A raw GPR radargram (B-scan) corresponding to (a), with hyperbolic shaped reflections representing root reflectors (*fig. 4)*
Many thousands of measurements are acquired across a planned grid network by moving the antenna along a ground transect at fixed intervals. These returned parameters can be quantified and rendered into a 3-D field allowing for visualization and mapping of underground root biomass. It has the ability to detect fine differences in the soil media GPR has often been utilized as a small cross-section near-surface object detection tool. GPR technology has been utilized to nondestructively image coarse root biomass and architecture previously in various tree and shrub species. In adapting this technology for temporal non-destructive sampling, the tool can be used as a proxy for RBR detection and facilitate genotype characterization at different stages of growth and in responses to cultivation, irrigation, and fertilization practices.

E . OPTICAL PROJECTION TOMOGRAPHY SYSTEM

Figure 5 shows the setup of the optical projection tomography (OPT) system in a plant imaging lab. A maize plant which is germinated and grown inside a glass cylindrical jar filled with transparent gel. During the imaging process [6], this jar is seated inside a rectangle water tank to compensate for refraction induced distortion in optical images. A small rotation stage controls the rotation of the glass jar through magnetic coupling. A DSLR camera captures the images from different angles synchronizing object rotation. A 3D root image [7] can be reconstructed from the captured

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projection images with some specific reconstruction codes like Rootwork or RootReader3D. Traits analysis is conducted in 3D like root system volume, surface area, total root length, number of branches, etc.

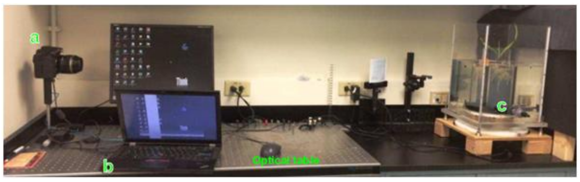

Fig:5 Optical imaging system

III. ADVANCES IN ROOT IMAGE ANALYSIS

As high-throughput image capture of root systems has become more significant and generates larger datasets, there is a requirement for fast and accurate software solutions [8]. Recently software has focused on 2D imaging paradigms, resulting in a large number of tools, exhibiting a mixture of manual (e.g. DART), semi-automatic (e.g. SmartRoot, RootNav) and fully automated (e.g. EZ-Rhizo,GiARoots, DIRT) approaches. This software relied on the assumptions that root images are steady across an experiment and that the root system exhibits high contrast against the background.

A. DART

DART (Data Analysis of Root Tracings) is a tool based on human vision to identify roots, particularly across time-series. Each root is described by a series of ordered links encapsulating specific information and it is connected to other roots.

B. SMART ROOT

A semi-automated image-analysis software to monitor the quantitative analysis of root growth and architecture of complex root systems. The softwarecombines a vectoral representation of root objects with a powerful tracing algorithm that provides a wide range of image sources and quality.

IV. CONCLUSION

In this study, the main focus was on root image acquisition to detect root diseases whereas the detection and analysis of leaf and stem related diseases can be easily obtained. The paper presents a comprehensive view of the various researches done in contemporary domain of root image acquisition. The collection of analysis is done with various invasive and non-invasive techniques using obtained root images.When all methods were compared together, mono RGB vision technique overestimates all other techniques. It is an inexpensive scanning and automated method which provides the correct measurements of root elongation and length. It is capable of detecting the fine roots to a diameter of 0.1mm.

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