Evaluation of HLB-Infected Citrus Rootstocks Using Ground Penetrating Radar

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Abstract

Citrus production in Florida continues to decline steadily, since the arrival of Huanglongbing (HLB or citrus greening). HLB does not kill the tree, but HLB-infected trees become less productive. Since now, there is no cure for this disease. However, several strategies have been developed to manage and control HLB-infected citrus trees. We have developed and evaluated a heat thermotherapy system (short-term solution) for sustaining productivity of HLB-affected trees. This system heats the canopy and the roots of the trees for a predetermined time and temperature to kill the bacteria. In order to develop an efficient thermotherapy system for treating the tree roots, we first need to know the location and the structure of the roots. In this study, we utilize a ground penetrating radar (GPR), a noninvasive imaging, to construct the map of the root system of a citrus tree in the field. Additionally, we used this system to evaluate several citrus rootstocks and their ability to be HLB-tolerant. The GPR system can develop a high-resolution map of the internal structure of the tree trunk and the rooting system/mass. We have evaluated two antennas with frequencies: (i) 900 MHz (up to 1 m penetration); (ii) 1.6 GHz (up to 0.5 m penetration; better resolution than the 900 MHz). Several maps of citrus tree rootstocks were created to visualize and evaluate the root morphology of HLB-infected trees.

Keywords: rootstocks, radar, HLB, citrus greening, citrus, root map

Introduction

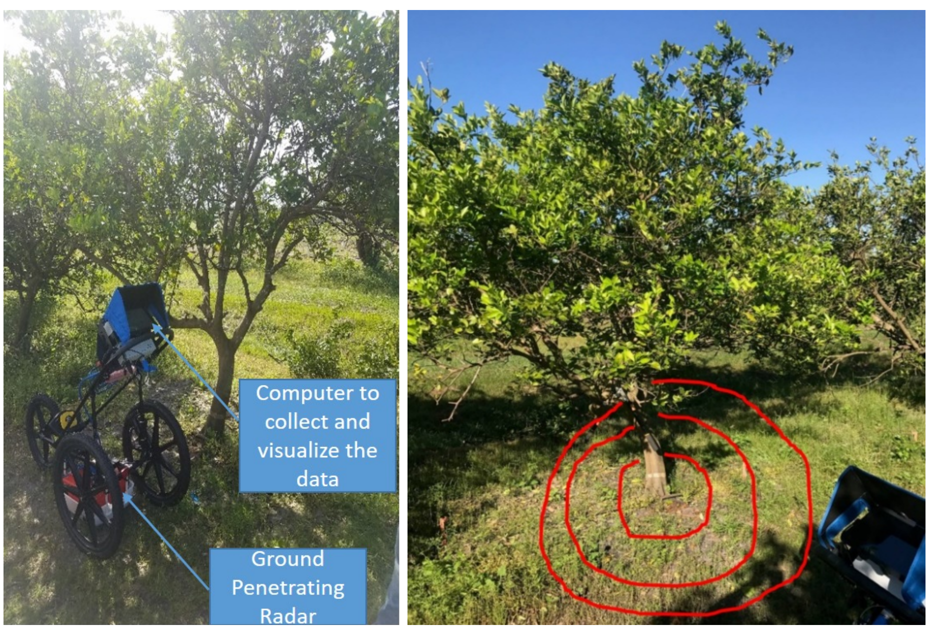
Huanglongbing (HLB or citrus greening disease) is the most detrimental, and rapidly transmittable citrus disease (Alvarez et al 2016). This disease was initially discovered in China in the late nineteenth century (Alvarez et al. 2016). Citrus greening disease is a widespread citrus disease in the state of Florida; and it was identified in the city of Homestead, Florida in late August 2005 on a pummelo tree. Due to the citrus greening disease, the production of citrus has gradually decreased in Florida (Spreen et al. 2014).

Therefore, the state of Florida's citrus industry has suffered substantial financial losses due to HLB (Hodges and Spreen 2015). HLB is an incurable bacterial disease that invades the vascular system of plants. The Asian citrus psyllid (Diaphorina citri Kuwayama) is the most frequent factor of transmitting the disease. Since, a tree's vascular system is being invaded by the bacteria, which impedes the tree from having a proper nutrient flow; it makes confined sections of virulent phloem to be dispersed all over the tree's vascular system (Kanga et al. 2016). When a tree is contaminated with the bacteria, it cannot be treated and it becomes less fruitful.

Various methods are used to control HLB-infected citrus trees (Abdulridha et al. 2018; Ehsani et al. 2013). In this study, we evaluate a ground penetrating radar (GPR), a noninvasive imaging system, to visualize and localize the structure of the tree roots (in order to efficiently treat the tree roots). Additionally, the GPR is utilized to evaluate citrus rootstocks and their capability to be HLB-tolerant. Two antennas with frequencies of 900 MHz (up to 1 m) and 1,600 MHz (up to 0.5 m) were used to conduct this study. Several HLB-infected citrus trees in Hendry County, Florida were selected for this study. Their root structures and densities were assessed and compared.

Materials and Methods

A ground penetrating radar (GPR), mounted to a mobile scanning cart (Fig. 1a), and equipped with: (i) a 1,600 MHz antenna (up to 0.5 m penetration), and (ii) a 900 MHz antenna (up to 1 m penetration) was utilized to generate a 3D map of the rooting systems/mass. At least three complete 360-degree peripheral scans around the tree trunk were completed per tree to cover the entire rooting system (Fig. 1b). A software (TRU Tree Radar) was used to visualize the collected data and generate root morphology and density maps. Top-down 3D images were created to present the root layout (location and depth).



a) b)

Fig. 1. a) A ground penetrating radar (GPR) mounted to a scanning cart; b) 360-degree peripheral scans around the tree trunk to detect tree roots.

Various maps of citrus trees' rootstocks were produced to evaluate the root structures of HLB-infected citrus trees. Also, these assessments were conducted to evaluate (compare) the performance of the 900 MHz and the 1,600 MHz antennas. For the root density evaluation, we divided the root depth in three zones (Fig. 2).

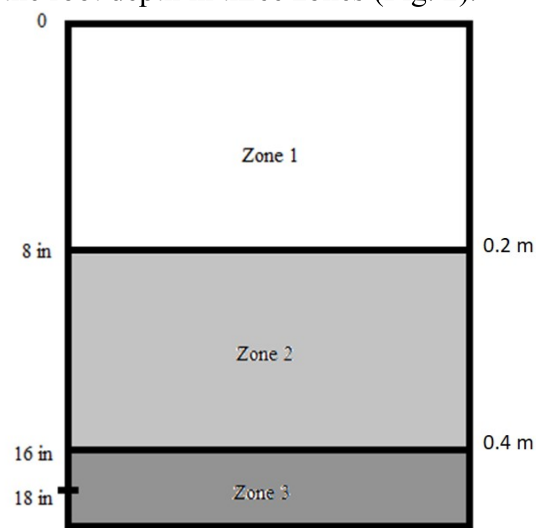


Fig. 2. Three root depth zones to evaluate root density.

Experimental Design

The first experiment evaluates/compares the performance of the (i) 900 MHz GPR and (ii) 1,600 MHz GPR (on the same trees).

The second experiment compares the root system of two citrus trees with similar canopy size, but different rootstocks: (i) US-896 Murcott USDA rootstock; and (ii) Carrizo citrange Murcott USDA rootstock. Preliminary studies were conducted in Hendry County, Florida to evaluate the rootstock structures of various citrus trees. In this paper, we compare the root systems of only two trees (5 year-old): (i) 60 Rep 1-896 with a US-896 Murcott USDA rootstock (Scion tree, Fig. 3); and (ii) 64 Rep 1-Czo with a Carrizo citrange Murcott USDA rootstock (Scion tree, Fig. 4). The citrus trees' names also indicate their location in the farm. Data was collected on Thursday, January 18th, 2018, and on Friday, January 19th, 2018 at the Duda Farm in Felda, Florida. Tree measurements (tree height, canopy size etc.) were also collected during the experiments (Table 1).

Table 1. Characteristics (measurements) of the citrus trees.

Tree	Height of the tree (m)	Height of the tree trunk (m)	Width of the tree canopy (m)
60 Rep 1-896	3.17	0.30	2.29
64 Rep 1-Czo	2.92	0.30	2.16

Fig. 3. Front view of citrus tree 60 Rep 1-896 (US-896 Murcott USDA rootstock) (Scion tree).

Fig. 4. Front view of citrus tree 64 Rep 1-Czo (Carrizo citrange Murcott USDA rootstock) (Scion tree).

Results and Discussion

Experiment 1

The assessments revealed that the 1,600 MHz GPR was able to detect more points (Fig. 5), and hence more roots, than the 900 MHz GPR for the same citrus tree. Substantial density variations were observed in the top-down root density maps of the three combined zones for each citrus tree. This evaluation showed that the 1,600 MHz GPR was capable of detecting a higher degree of root density compared to the 900 MHz GPR. Therefore, the 1,600 MHz ground penetrating radar was used to conduct the second experiment of this study and compare the root system of two citrus trees with different rootstocks.

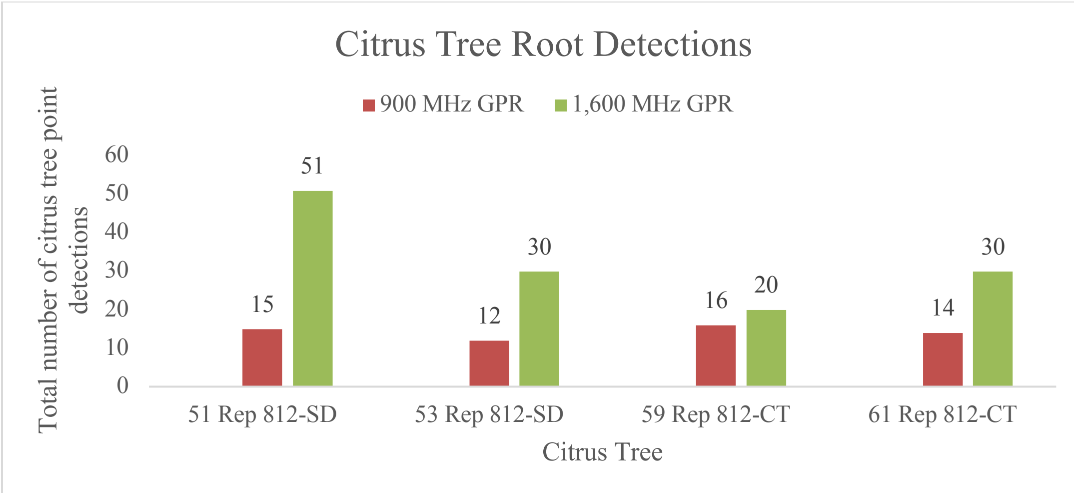


Fig. 5. Citrus tree root points detection by the: (i) 900 MHz GPR, and (ii) 1,600 MHz GPR.

Experiment 2

The rootstock structures (3D morphology) of citrus tree 60 Rep 1-896 are presented in Figs. 6 and 7, and of citrus tree 64 Rep 1-Czo in Figs. 9 and 10. These two trees have different root morphologies (different in appearance). The top-down view images of root detections clearly show the actual roots' positions for each tree in the ground. Table 2 presents the detected root points, for each root depth zone, for each tree. The citrus tree 64 Rep 1-Czo has slightly more than twice the number of detected points (25 points) than citrus tree 60 Rep 1-896 (12 points).

Table 2. Citrus tree root detected points for the three different zones by the 1,600 MHz GPR.

Tree	**Detected points in zone 1**	**Detected points in zone 2**	**Detected points in zone 3**	**Total number of detected points per citrus tree**
60 Rep 1-896	5	2	5	12
64 Rep 1-Czo	7	4	12	25

Top-down root density maps, of the three combined depth zones, are presented in Fig. 8 for the 60 Rep 1-896 tree and in Fig. 11 for the 64 Rep 1-Czo citrus tree. These figures present the density of the rooting system related to the tree trunk.

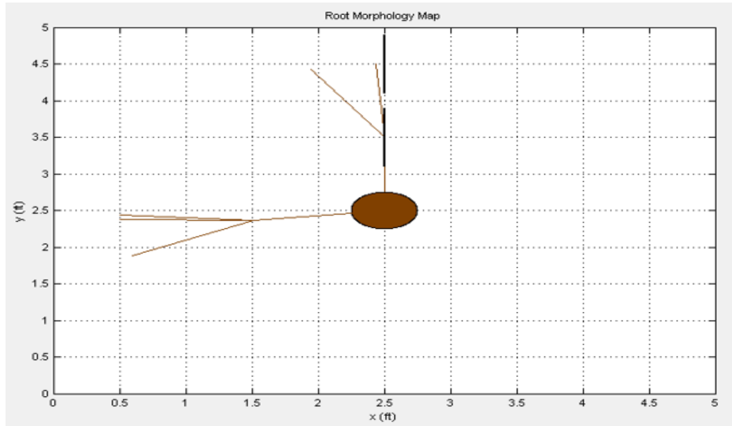


Fig. 6. Top view of the root morphology map for citrus tree 60 Rep 1-896.

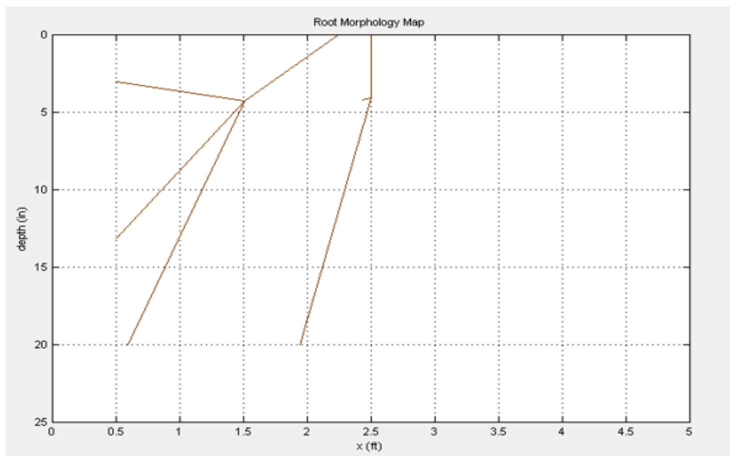


Fig. 7. Front face view of the root morphology map for citrus tree 60 Rep 1-896.

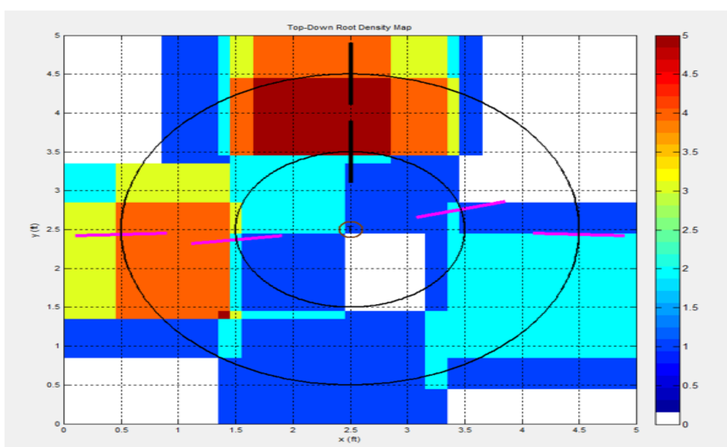


Fig. 8. Top-down root density map of the three combined zones for citrus tree 60 Rep 1-896.

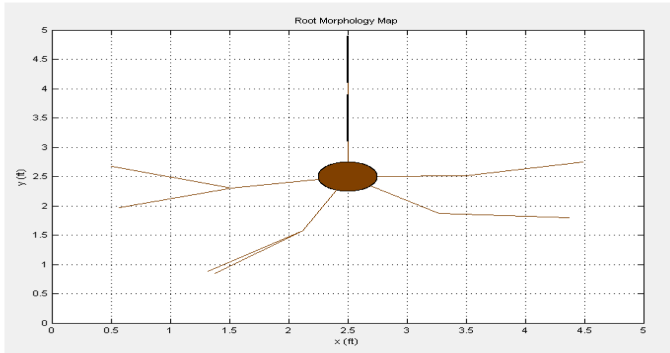


Fig. 9. Top view of the root morphology map for citrus tree 64 Rep 1-Czo.

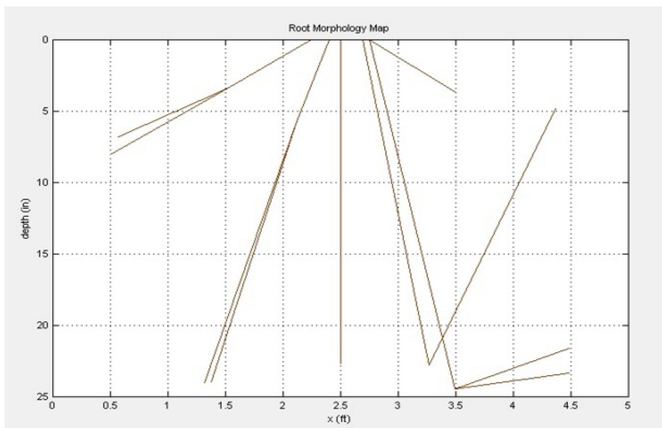


Fig. 10. Front face view of the root morphology map for citrus tree 64 Rep 1-Czo.

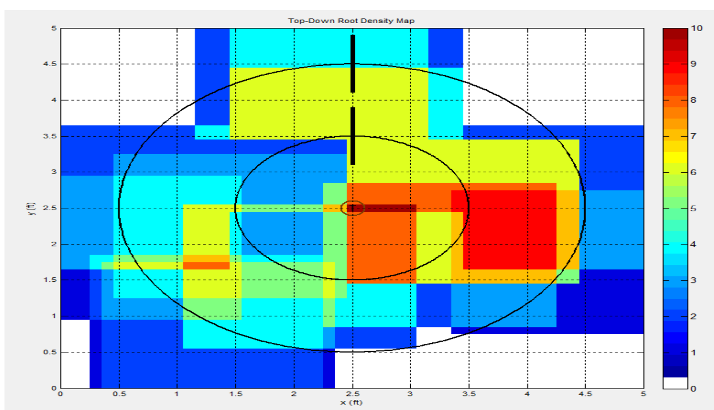


Fig. 11. Top-down root density map of the three combined zones for citrus tree 64 Rep 1-Czo.

Conclusion

In this study, we evaluated the performance of two systems, a 900 MHz GPR and a 1,600 MHz GPR, on detecting citrus tree roots and generating 3D morphology and density maps. Based on the preliminary evaluation, it was revealed that the 1,600 MHz GPR produces higher quality maps (detects more roots) than the 900 MHz GPR. Therefore, the 1,600 MHz ground penetrating radar was used to conduct the second experiment of this study and compare the root system of two citrus trees with similar canopy size, but different rootstocks: (i) US-896 Murcott USDA rootstock; and (ii) Carrizo citrange Murcott USDA rootstock. The rhizome structures of the two trees were distinct. The citrus tree with the most detected points (64 Rep 1-Czo) had roots which went deeper into the ground.

Challenges, Limitations and Future Research

The ground surfaces surrounding the citrus trees needs to be cleaned off (e.g. from weeds and twigs) before each measurement/scanning. Secondly, some of the citrus trees' branches have to be cut off in order for the scientists to perform the scanning. The trunks' heights of the citrus trees are extremely low. Maneuvering around the trees is a difficult task due to the lack of adequate space in the scanning area. In general the scanning procedure is very time-consuming. Often, the ground surfaces are uneven, causing errors in measurements. The duration of the scanning process for a citrus tree varies from 20-40 min per tree. In future research, we plan to automate the procedure by developing an automatic mobile platform to detect tree trunks and collect the data. Furthermore, we will compare the collected data and the developed maps with the actual root systems of citrus trees.

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