基于探地雷达的毛竹笋与竹鞭地下成像实验研究

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摘要：目前对毛竹笋的探测几乎完全依靠人工完成。为提高竹农探寻毛竹笋的效率和准确率，同时降低竹农对毛竹笋探寻的门槛，本文开展了基于探地雷达的毛竹笋与竹鞭地下成像实验，目的是探索一种毛竹笋自动探测方法。用探地雷达设备在浙江省湖州市安吉县灵峰寺林场港口林区开展实验，采用单一变量原则和相关性分析比较单一毛竹笋、单一毛竹鞭以及毛竹笋与竹鞭组合体与测线在不同角度、不同水平面倾斜角度的成像相关性。实验结果显示：（1）单一毛竹笋在水平方向且与测线在不同角度时，图像呈双曲线或双曲线的一半；单一毛竹笋与地平线呈不同角度时，倾斜角度越大图像由双曲线逐渐变为点或只在 A-scan 上有回波反应。（2）单一竹鞭在水平方向且与测线平行时，呈双曲线图像占 70%，呈点图像占 30%；单一竹鞭在水平方向且与测线垂直时，呈双曲线 60%，呈点图像占 40%。（3）毛竹笋与竹鞭组合体在水平方向且与测线平行时，呈双曲线图像占 71%，呈点图像占 29%；毛竹笋与竹鞭组合体在水平方向且与测线垂直时，呈双曲线图像占 90%，呈点图像占 10%。结果表明，当毛竹笋或毛竹鞭在水平方向生长并和测线方向垂直时，探地雷达生成的图像呈双曲线最为显著；毛竹笋与竹鞭组合体相对于地平线的倾斜角度越大，探地雷达越不容易探测到目标形成图像；在探测过程中天线和地面的距离越大，得到的图像效果越差。本研究可为探测毛竹笋与竹鞭提供图像分析理论参考和提高探寻毛竹笋效率。

关键词：探地雷达；毛竹笋；毛竹鞭；测线方向；成像

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Experimental Study on Underground Imaging of Moso Bamboo Shoots and Bamboo Whips Based on Ground Penetrating Radar

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Abstract: At present, the detection of moso bamboo shoots is almost completed manually. In order to improve the efficiency and accuracy of exploring moso bamboo shoots and diminish the experience threshold of bamboo farmers in exploring moso bamboo shoots, underground imaging experiments of moso bamboo shoots and bamboo whips based on ground penetrating radar (GPR) were carried out, with the purpose of developing an automatic detection method of moso bamboo shoots. The experiments were conducted in Lingfeng Temple Forest, Anji, China. Single variable principle and correlation analysis were used to compare the imaging correlation of single moso bamboo shoot, single moso bamboo whip and the combination of moso bamboo shoot and bamboo whip with the detection line at different included angles and different horizontal tilt angles. (1) When a single moso bamboo shoot is in the horizontal direction and at different angles from the detecting line, the image is Hyperbola or half of Hyperbola. When a single moso bamboo shoot is at a different angle from the horizon, the larger the tilt angle, the image gradually changes from Hyperbola to point or only has echo response on A-scan. (2) When a single bamboo whip is horizontal and parallel to the detection line, the Hyperbola image accounts for 70%, and the point image accounts for 30%. When a single bamboo whip is in the horizontal direction and perpendicular to the detection line, it is 60% in Hyperbola and 40% in point image. (3) When the combination of moso bamboo shoot and bamboo whip is horizontal and parallel to the detection line, the Hyperbola image accounts for 71%, and the point image accounts for 29%. When the combination of moso bamboo shoot and bamboo whip is horizontal and perpendicular to the detection line, the Hyperbola image accounts for 90%, and the point image accounts for 10%. The results show that when the bamboo shoots or bamboo whips grow in the horizontal direction and are perpendicular to the detection line, the images generated by GPR show the most significant Hyperbola. The larger the tilt angle of the combination of moso bamboo shoots and bamboo whips relative to the horizon, the less likely it is for GPR to detect targets and form images. In the detection process, the greater the distance between the antenna and the ground, the worse the image effect. This study can provide theoretical reference for image analysis and improve the efficiency of detecting moso bamboo shoots and bamboo whips.

Key words: GPR; moso bamboo shoots; moso bamboo whip; detection line direction; imaging