Presymptomatic and Early Detection of Tomato Spotted Wilt Virus (TSWV) in Peanut Plants

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Each year, Tomato Spotted Wilt Virus (TSWV) impacts up to 50% of Georgia's peanut fields, causing approximately $12 million in losses and threatening farmers livelihoods. Symptoms in peanuts are first visible around 21 days after seedling emergence, progressing from brown speckles and chlorotic ring-spotting to leaf crinkling, wilting, and eventual plant decline. Our goal is the presymptomatic and early detection of TSWV using volatile organic compounds (VOCs) and imaging techniques. Across two controlled growth-chamber studies in 2025, VOC profiling and imaging were used to distinguish healthy from inoculated plants over time. In Study 1 (spring), hierarchical clustering and Principal Component Analysis (PCA) of VOCs from early post-inoculation collections showed clear separation between control and infected plants, and 8–10 VOCs emerged as putative markers of TSWV presence, while image analysis demonstrated strong potential for early, non-destructive detection of infection. Study 2 (fall) replicated and expanded this work, following a structured inoculation and sampling timeline and using both leaf VOC collections. Despite a relatively small sample size, Partial Least Square-Discriminant Analysis (PLS-DA) models achieved good discrimination between control and TSWV-infected plants at multiple post-inoculation time points (e.g., F1 ≈ 0.88 for several collections), and 14 VOCs consistently associated with post-inoculation states were identified as candidate diagnostic markers, supported by prior literature. Results from these studies include the establishment of a data-reduction and analysis pipeline.

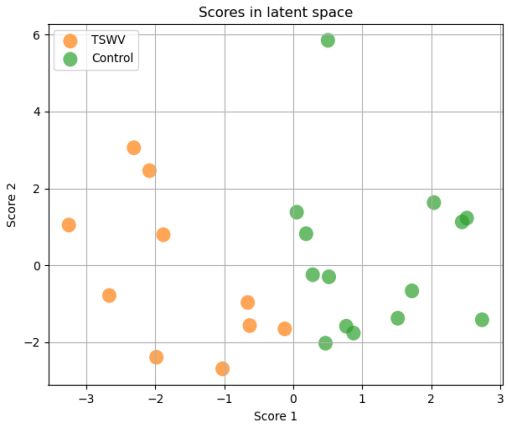

Figure 1. PLS-DA results 3 days post inoculation

Figure 2. Top original image; bottom Mask R-CNN result

We also designed an image capture system to autonomously capture images of the plants using FarmBot. The image data collected during the experiment was analyzed using two different computer vision approaches to explore early detection of TSWV in peanuts. In the first approach, 2D image classification deep learning models were trained to classify the plants as either healthy or infected with TSWV. For the training process, the overhead image of 12 randomly chosen plants, 6 healthy and 6 infected, over its entire growing stage was used as the training data. A Resnet50 model pretrained with the COCO dataset was finetuned on the custom dataset. Various data augmentation techniques, such as resize crop, color jitter, mask R-CNN, Gaussian blur etc., were applied during the training process to generalize the training result. After only 200 epochs of training, the model was able to achieve 93.45% accuracy during training and 86.60% during testing. The second approach used exploratory 3D Gaussian Splatting technique to build realistic 3D representation of the plants to understand the impact of the virus on the structure of the plants.

Future work will focus on feature engineering, exploratory data analysis, and predictive model development to generate robust, high-leverage VOC and image features for early classification of TSWV infection in peanut.

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