Automated Imaging for Phenotyping Plant Pathogen Resistance

Developing new grape varieties that exhibit high resistance to disease while retaining the taste and yield of traditional European varieties is the mission of the VitisGen2 research collaboration. Powdery mildew has been identified as the most damaging and economically costly disease to vineyards. The LRC has teamed with Cornell University and the USDA to develop a robotic high-resolution imaging system to accelerate the process of evaluating thousands of crossbred grape leaf samples in the search for resistance to powdery mildew.

Camera and Lighting System

A 46-megapixel camera was attached to a high precision, 3-axis, motorized positioning system (Figure 1). Four directional white LEDs move with the camera to provide dynamic, high contrast sample illumination. A custom autofocusing routine moves the camera along the z-axis to account for different sample heights. To increase the depth of focus, multiple images are captured over a range of focal distances and stitched together to create one well-focused image for the entire 1-cm diameter sample (Figure 2). This allows *hyphae*, the translucent, fibrous growth of the powdery mildew fungus, to become visible. Hyphae have a diameter of approximately 5 µm, thus high resolution and precise focus over the whole convoluted leaf surface is essential for accurate analysis.

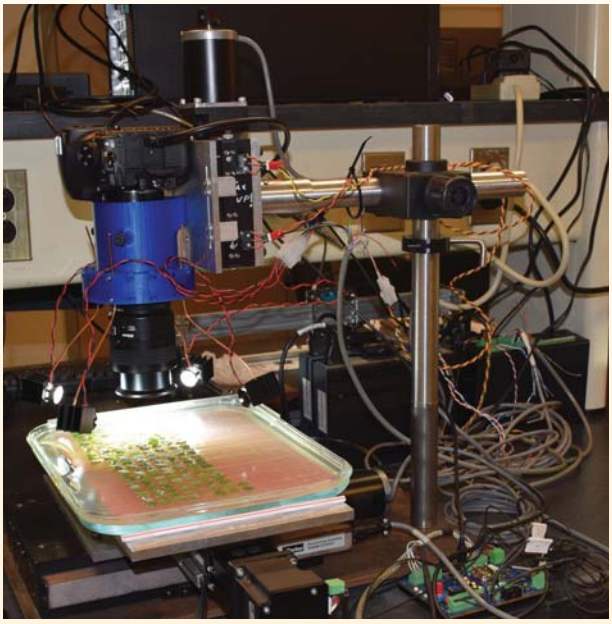

Figure 1. Automated system for imaging grape leaf samples.

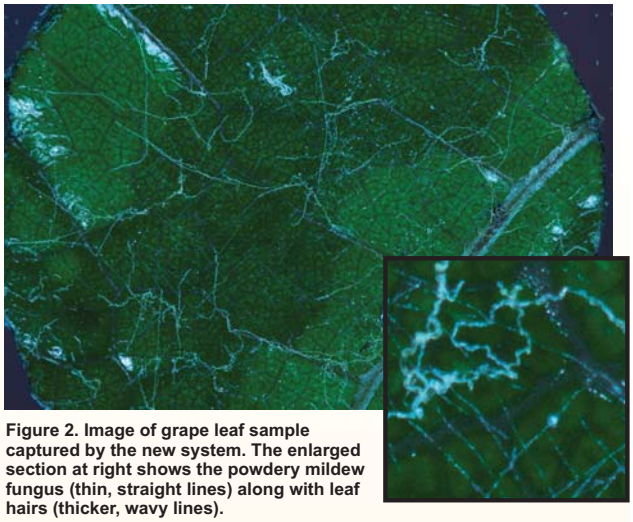

Figure 2. Image of grape leaf sample captured by the new system. The enlarged section at right shows the powdery mildew fungus (thin, straight lines) along with leaf hairs (thicker, wavy lines).

The lighting system was arranged to maximize the light scattered and refracted into the camera lens by the hyphal structures while minimizing the light reflected off the leaf surface. A cool white LED source was chosen to provide a full-color image while providing ample short-wavelength light for high contrast images of the hyphal structures against the green leaf.

Results

Nearly an entire leaf disk can be captured in a single image with a resolution of a few microns. The entire imaging process, including positioning, focusing, image acquisition and processing takes approximately 20 seconds. The system is capable of capturing 1600 well-focused images of leaf disk samples within an 8-hour period without human intervention. The images are saved for analysis by either human observers or fed into a machine-vision algorithm utilizing a deep-learning convolutional neural network.

Sponsor

United States Department of Agriculture (USDA)

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