Automated Detection of European Canker (*Neonectria ditissima*) in Apple Trees via Multispectral Sensors and Computer Vision

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Abstract.

European canker, caused by the fungus Neonectria ditissima, represents one of the major economic challenges for Brazilian pomiculture, severely affecting 'Gala' and 'Fuji' cultivars. The disease manifests primarily in woody tissues, such as trunks and branches, although it can also cause fruit rot during the pre-harvest stage. Infection occurs obligatorily through wounds, whether natural (leaf scars) or resulting from management practices (pruning and harvesting). Effective disease management depends on early detection and the immediate elimination of inoculum sources. However, conventional manual inspection is time-consuming, costly, and limited in identifying incipient lesions or those hidden by foliage. In this context, this study aims to develop faster and more efficient detection methods through an automated system based on image processing. To enable this system, an image database of apple tree branches was established under field conditions, monitoring the stages of disease development associated with pruning wounds. The experimental design consisted of: an Inoculated Group, comprising 50 branches (across ten plants) subjected to pruning cuts and inoculation with a N. ditissima fungal suspension; and a Control Group, with 50 branches subjected only to cutting and treated with distilled water. Image captures were performed at approximately seven-day intervals using three distinct sensors: conventional RGB, multispectral RedEdge (725 nm), and RG-NIR. A sample of 132 images was annotated with segmentation masks and used to train a YOLOv8n-seg model to assess the feasibility in finding European canker on branches. The database obtained from this experiment comprises more than 4,000 images. Preliminary results indicate that physiological changes resulting from infection generate detectable contrasts in the images, especially at wavelengths above 700 nm. This spectral signature highlights the potential of this range for the early identification of diseased branches. The generated database will allow for detailed spectral analysis and the training of convolutional neural networks (CNNs) for the automated recognition of infection patterns. The preliminary training showed promising results, achieving mAP50-95(M) of 0.63, Precision(M) of 0.89, and recall(M) of 0.91, even with a relatively low number of annotated images. Future stages will involve testing different segmentation models, the development of equipment for the detection, quantification, and geospatial localization of diseased branches in the orchard. Such tools are fundamental for the *consolidation of precision fruit farming, enabling localized interventions, rapid diagnostics, and a reduction in operational costs for growers.*

Keywords.
Malus domestica, apple disease, plant pathology, spectroscopy.

Introduction

Apple production in Brazil, heavily concentrated in the Southern region, plays a vital economic role but faces constant phytosanitary challenges that threaten its yield. Among these challenges, European canker, caused by the fungus Neonectria ditissima, stands out as one of the most impactful diseases in the region's orchards (Alves and Czermainski 2019). This pathogen primarily affects the woody tissues of the apple tree, such as trunks, scaffolds, and branches, and can also cause pre-harvest fruit rot during early developmental stages (Xu and Robinson 2010).

Infection by N. ditissima occurs primarily through wounds, which may be of natural origin—such as leaf scars, petal fall, or the shedding of bud scales—or result from cultural practices. Among these pathways, entry points created by pruning, harvesting, and leaf fall constitute the primary infection routes for the fungus (Alves Nunes 2017). Although early and precise identification is vital for effective control and eliminating inoculum sources, conventional manual inspection exhibits severe limitations. The process is highly labor- and time-intensive, making it particularly prone to errors when lesions are small or concealed by the density of the tree canopy (Zhang et al. 2019).

In this context, developing faster and more efficient detection methods is crucial for optimizing disease management. Previous studies have demonstrated measurable differences in reflectance above 700 nm between healthy tissues and those affected by European canker (Alves et al. 2024). This finding indicates that spectral reflectance can serve as a valuable parameter for assessing plant health, providing a foundation for developing automated systems that enable highly precise localization and georeferencing of diseased trees within the orchard.

Materials and Methods

The development of the automated detection system was based on the construction of a standardized image database focusing on the temporal progression of European canker (*Neonectria ditissima*) in apple trees (*Malus domestica*) of the 'Fuji' cultivar. The methodological pipeline comprised four interconnected phases: phytopathological experimental design, multispectral image acquisition protocol, relational metadata structuring, and a multi-level computational annotation strategy.

Experimental Design and Field Trials

The experiment was conducted under field conditions in an experimental apple orchard. The experimental design consisted of two homogeneous groups: (i) Inoculated Group: composed of 50 branches uniformly distributed across 10 trees (5 branches per tree), which were subjected to standard pruning cuts to simulate management wounds and immediately inoculated with a macroconidia suspension of *N. ditissima* calibrated in a Neubauer chamber to a concentration of 1.10^5 conidia/mL; (ii) Control Group: composed of 50 biologically equivalent branches subjected to the same pruning procedure but individually treated with sterile distilled water (SDW).

At approximately 7-day intervals, the branches were monitored for symptom progression. Infection confirmation was based on the development of typical symptoms: cortical tissue depression around the wound, discoloration of the cortex, and the subsequent appearance of fungal reproductive structures. Control group branches exhibiting any atypical symptoms of cross-contamination were summarily discarded from the final database count to ensure class purity.

Image Acquisition and Sensor Specifications

Digital data acquisition began on day zero (the day of inoculation) and extended through a schedule of periodic captures every seven days, capturing the transition between the asymptomatic and symptomatic phases. Three distinct optical sensors were used: a conventional RGB sensor, a RedEdge multispectral sensor (725 nm), and an RG-NIR (Red-Green Near-Infrared) sensor. Images of the pruning wounds were captured at a distance of approximately 500 mm. To mitigate light variability in the field environment, data collection was preferentially performed under diffuse sky conditions.

Metadata Architecture and Structure

To ensure that the database complies with the FAIR (Findable, Accessible, Interoperable, and Reusable) principles, each of the more than 4,000 images was indexed to a standardized metadata dictionary. A relational table was established containing: a unique image identifier to link the sensor, plant, and time in days post-inoculation (string); sensor type (string); host (string); pathogen (text/boolean: inoculated or control); wound type (text); inoculation date (YYYY/MM/DD); and image collection date (YYYY/MM/DD). The difference between the collection date and the inoculation date automatically generates the DPI (Days Post-Inoculation) numerical vector, which is a critical metadata component for the temporal training of neural networks.

Following image collection, a sample of 132 RGB images was annotated with segmentation masks and used to train a YOLOv8n-seg model to assess the feasibility of detecting European canker on branches.

Results

The database obtained from this experiment comprises more than 4,000 images. Over time, images of the branches from the inoculated group revealed the development of typical canker symptoms associated with the pruning wound. These symptoms included the formation of a necrotic tissue ring originating from the cut point, which subsequently expanded in a downward direction (Figure 1). Conversely, branches from the control group were characterized by a slight discoloration of the tissues adjacent to the pruning cut, showing no progression over time (Figure 2).

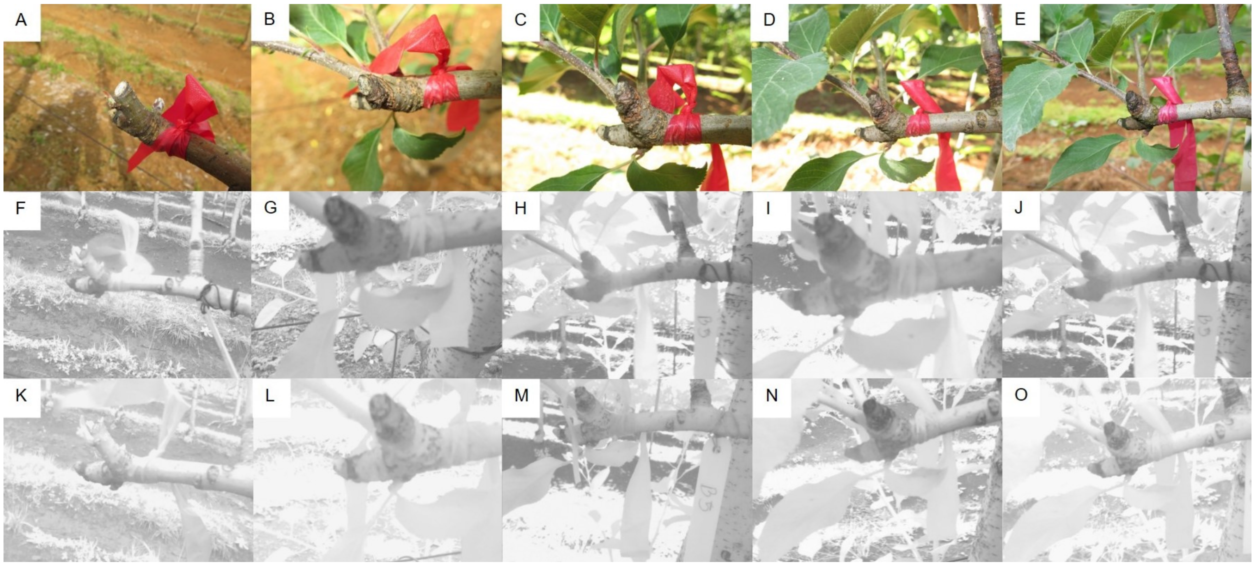

Fig. 1 Images of branches from the group inoculated with *N. ditissima* over time using different equipment. RGB images (A–E), RedEdge images (F–J), and RG-NIR images (K–O). Columns represent chronological evaluation dates: 29 DPI (A, F, K), 99 DPI (B, G, L), 119 DPI (C, H, M), 155 DPI (D, I, N), and 183 DPI (E, J, O)

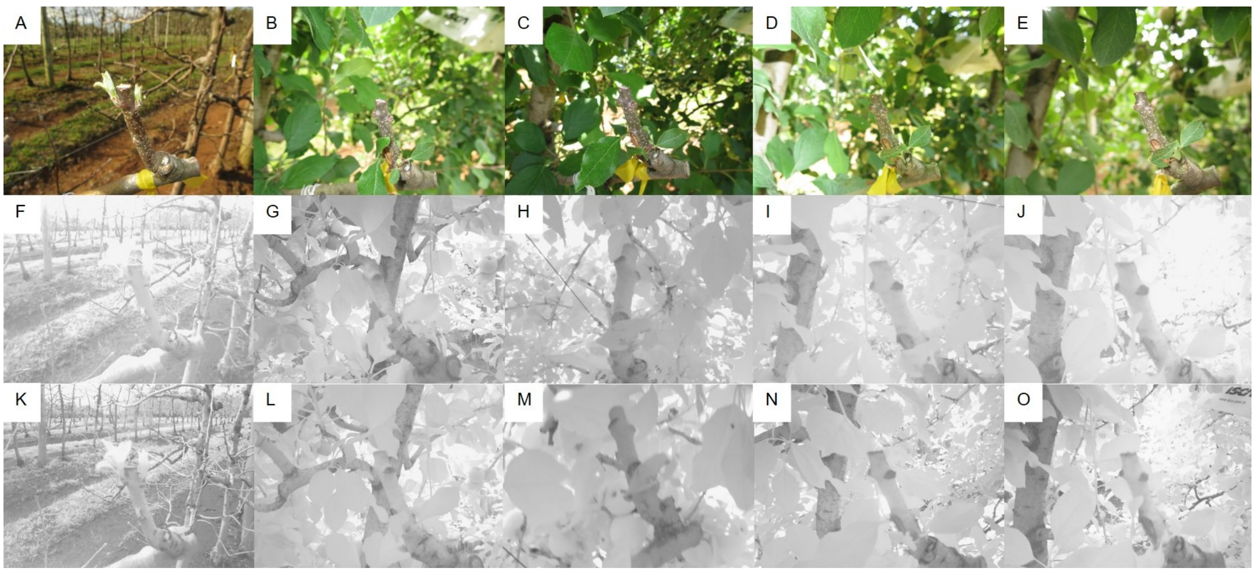

Fig. 2 Images of branches from the control group over time using different equipment. RGB images (A–E), RedEdge images (F–J), and RG-NIR images (K–O). Columns represent chronological evaluation dates: 29 DPI (A, F, K), 99 DPI (B, G, L), 119 DPI (C, H, M), 155 DPI (D, I, N), and 183 DPI (E, J, O)

Image acquisition using the RGB sensor was more straightforward than with the other sensors, yielding sharp, well-focused images that allowed for the observation of visible textures within the standard human visible spectrum. Although achieving optimal focus was more challenging with the other two sensors, they successfully facilitated the identification of altered plant tissue areas (disease symptoms), which exhibited lower reflectance.The generated database will allow for detailed spectral analysis and the training of convolutional neural networks (CNNs) for the automated recognition of infection patterns. The preliminary training showed promising results, achieving mAP50-95 (M) of 0.63, Precision(M) of 0.89, and recall(M) of 0.91, even with a relatively low number of annotated images. Future stages will involve testing different segmentation models, the development of equipment for the detection, quantification, and geospatial localization of diseased branches in the orchard. Such tools are fundamental for the consolidation of precision fruit farming, enabling localized interventions, rapid diagnostics, and a reduction in operational costs for growers.

Conclusions

This study successfully established a robust, multi-sensor temporal image database that adheres to FAIR principles, providing a critical foundation for the automated detection of European canker (*Neonectria ditissima*) in apple orchards. The integration of phytopathology with advanced optical sensing and computer vision yields several key conclusions: Sensor Complementarity: While conventional RGB sensors offer superior sharpness and ease of focus for visual texture analysis, the RedEdge (725 nm) and RG-NIR sensors successfully capture early-stage physiological changes through a distinct drop in spectral reflectance within altered cortical tissues.Model Feasibility: Preliminary deep learning deployment using the YOLOv8n-seg architecture demonstrated high efficacy, achieving a Precision of 0.89 and a Recall of 0.91. These metrics confirm that automated edge-detection models can accurately segment complex disease symptoms on woody branches, even when trained on a relatively small subset of annotated images.Impact on Precision Viticulture/Fruit Farming: The progression from manual, labor-intensive scouting to an automated pipeline represents a significant shift in orchard management. Ultimately, this methodology paves the way for integrating deep learning models into commercial agricultural machinery or unmanned aerial vehicles (UAVs). Future research will focus on expanding the segmentation training across the full database, benchmarking alternative architectures, and embedding these algorithms into field-ready hardware. This will enable real-time, georeferenced, and localized interventions, drastically reducing operational costs and mitigation times for apple growers facing phytosanitary threats.

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