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Detection of Verticillium wilt of olive trees and downy mildew of opium poppy using hyperspectral and thermal UAV imagery

Rocío Calderón Madrid, Juan Antonio Navas Cortés, Miguel Montes Borrego, Blanca Beatriz Landa del Castillo, Carlos Lucena León, and Pablo Jesús Zarco Tejada

Institute for Sustainable Agriculture (IAS), Spanish National Research Council (CSIC), Córdoba, Spain

The present study explored the use of high-resolution thermal, multispectral and hyperspectral imagery as indicators of the infections caused by Verticillium wilt (VW) in olive trees and downy mildew (DM) in opium poppy fields. VW, caused by the soil-borne fungus Verticillium dahliae, and DM, caused by the biotrophic obligate oomycete Peronospora arborescens, are the most economically limiting diseases of olive trees and opium poppy, respectively, worldwide. V. dahliae infects the plant by the roots and colonizes its vascular system, blocking water flow and eventually inducing water stress. P. arborescens colonizes the mesophyll, appearing the first symptoms as small chlorotic leaf lesions, which can evolve to curled and thickened tissues and systemic infections that become deformed and necrotic as the disease develops. The work conducted to detect VW and DM infection consisted on the acquisition of time series of airborne thermal, multispectral and hyperspectral imagery using 2-m and 5-m wingspan electric Unmanned Aerial Vehicles (UAVs) in spring and summer of three consecutive years (2009 to 2011) for VW detection and on three dates in spring of 2009 for DM detection. Two 7-ha commercial olive orchards naturally infected with V. dahliae and two opium poppy field plots artificially infected by P. arborescens were flown. Concurrently to the airborne campaigns, olive orchards and opium poppy fields were assessed "in situ" to assess actual VW severity and DM incidence. Furthermore, field measurements were conducted at leaf and crown level. The field results related to VW detection showed a significant increase in crown temperature (Tc) minus air temperature (Ta) and a decrease in leaf stomatal conductance (G) as VW severity increased. This reduction in G was associated with a significant increase in the Photochemical Reflectance Index (PRI570) and a decrease in chlorophyll fluorescence. DM asymptomatic leaves showed significantly higher NDVI and lower green/red index (R550/R670) values than DM symptomatic leaves. The airborne flights enabled the early detection of VW by using canopy-level image-derived airborne Tc-Ta, Crop Water Stress Index (CWSI) calculated from the thermal imagery, blue / green / red ratios (B/BG/BR indices) and chlorophyll fluorescence. The detection of DM infection was achieved by using image-derived Tc-Ta and R550/R670 as a function of aggregated NDVI clusters to compare asymptomatic and symptomatic plants normalized by similar growth levels. These results revealed the potential of high-resolution thermal, multispectral and hyperspectral imagery acquired from UAVs to detect olive trees infected with V. dahliae at early stages of disease development and occurrence of P. arborescens infection in opium poppy fields.