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Optical measurement instrument for detection of powdery mildew and grey mould in protected crops

Grégory Bouquet[1,*], *Kristin* Kaspersen[1], *Karl Henrik* Haugholt[1]

[1]SINTEF AS, Forskningsveien 1, 0314, Oslo, Norway

Abstract. This study presents an initiative aimed at developing a real-time optical measurement system for non-contact measurement of fungal spores in protected crops such as strawberries, tomatoes and cucumbers. The system is based on a customized microscope. It has been tested in the field under real conditions and image processing algorithms have been developed to identify fungal spores in high resolution microscope images.

1 Background and Objectives

Ensuring an adequate food supply for the escalating human population is a great challenge. Crop losses and value degradation caused by plant diseases are major constraints to food security globally. Fungicides are important tools in management of plant diseases caused by fungal and oomycete pathogens. At present, major crop losses are inevitable without the use of fungicides. However, reliance on fungicides is not sustainable since the fungal pathogens that cause powdery mildews and grey mould are high-risk pathogens capable of developing fungicide resistance [1, 2]. European legislation also restricts pesticide use due to public health concerns and costs associated with pesticide removal from water [3]. This reduces the number of available pesticides in the market, which will accelerate the development of pathogen resistance to the remaining pesticides [4]. Integration and use of new, non-chemical strategies is therefore crucial for continued production of high-quality food in a sustainable manner with minimal environmental impact. Successful management of fungal diseases critically depends on timely treatment. This requires precise identification of pathogen type and inoculum concentration present in crop production system. Various spore trapping devices are available, but all require time-consuming laboratory work for identification of spores/conidia of pathogenic fungi. There have been some attempts at developing semi-automated spore detection systems [5-8], but these systems are still immature and not suitable for agricultural field applications. The systems currently described in literature are based on an off-the-shelf microscopes for indoor use, without considerations for online use or under field conditions [7]. There is thus a need for robust system adapted for in field, real time and automated detection of spores. The two major challenges for automated spore detection are 1) developing the right combination of illumination, optics and sensors to achieve sufficient image quality without losing the required area coverage, depth focus and acquisition speed and 2) training a classifier that can handle different types of spores together with pollen, dust and water droplets at different concentration levels. In a project funded by the Norwegian Research Council, END-IT, we have developed a real-time optical measurement system for detection of spores. The system is based on a modified microscope combined with an automatic system for spore trapping and air sampling. The system has been used in field trial and work is ongoing to develop machine vision algorithm for detecting and classifying fungal spores in the presence of pollen, dust and other aerosols.

2 Optical imaging of spores

The measurement system is a customized microscope equipped with an automatic system for air sampling and trapping of fungal spores, see Figure 1 and Figure 2. It consists in a 10 x microscope objective, focusing light on a colour CMOS camera (BFS-U3-200S6C-C, Sony IMX183, 20 Megapixels, pixel size 2.4 µm). The microscope is focused on a 1 mm^2 area of the tape aiming at trapping the spores. The microscope is mounted on a motorized linear translation stage for automatic focusing

* Corresponding author: gregory.bouquet@sintef.no

on the spores. A 3D-printed house holds a LED illumination system and a guiding support for the tape. The illumination system is designed to provide images of the spores in transmission (dark imaging) and in scattering (bright imaging), see Figure 2. These two imaging schemes are combined to provide better discrimination of the spores. The spore collections system consists of the tape, an automatic system for moving the tape and an air sampling system.

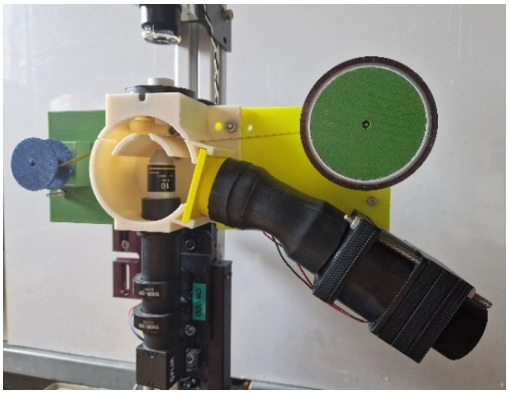

Fig. 1. Picture of measurement system.

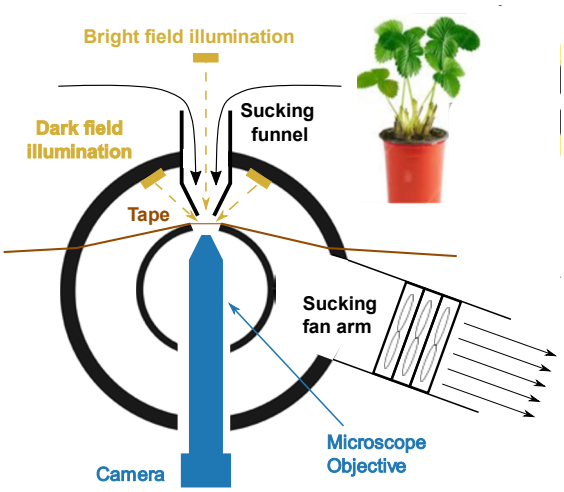

Fig.2. Scheme of the measurement system: A typical collection sequence consists in: 1) moving the tape to present a fresh portion to the microscope 2) sampling air and spores. 3) taking a sequence of images in bright and dark imaging modes.

3 Results

Figure 3 shows an example of images of grey mould acquired in bright and dark modes (zoomed in to show only a small part of the image). The resolution of the imaging system is high enough to enable detection and identification of the spores based on their shape and size. Combining the bright and dark images as shown in Figure 4 provides better discrimination against the background. It also highlights the living spores since the spherical shape and high water content of live spores make them function like a tiny lens. Dead spores tend to dry out and therefore do not light up in the same way as live spores.

The algorithm development is still ongoing, but preliminary results indicate that it is possible to detect the relevant spores and separate them from dust and other objects in the images, see Figure 5 for examples of classification results on images with spores of grey mould and strawberry powdery mildew.

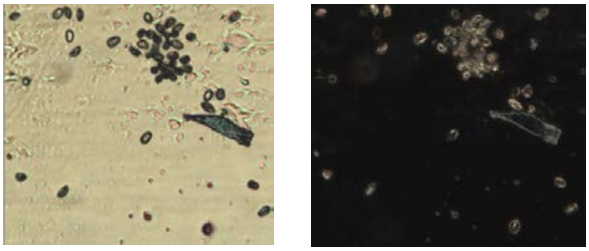

Fig. 3. Example of bright and dark images of grey mould

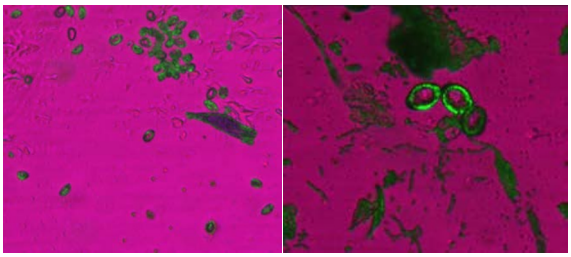

Fig. 4. Illustration of how the combination of dark field and bright field illumination makes more information available for the future development of segmentation and classification algorithms. Grey mould in image to the left, strawberry powdery mildew to the right.

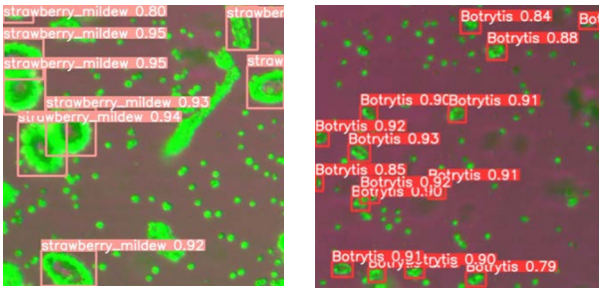

Fig. 5. Example of classification results from YOLO-based object classification network that was trained on images with spores of grey mould and strawberry powdery mildew, together with water droplets, dust and other airborne particles

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