

## Development of a Crop Health Sensor (CHS) - Early detection of apple scab in apple leaves

### THE ISAFRUIT PROJECT – TOWARDS SAFER AND BETTER QUALITY OF FRUIT

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#### SUMMARY

In 2006 the project ISAFRUIT ([www.isafruit.org](http://www.isafruit.org)) – “Increasing fruit consumption through a trans disciplinary approach leading to high quality produce from environmentally safe, sustainable methods” – was launched within the 6<sup>th</sup> Framework Program of the EC. Within the project’s work package ECOFRUIT (WP 5.1 – Safe European fruit from a healthy environment) a Crop Adapted Spray Application (CASA) system is developed. This system is developed to ensure efficient and safe spray application in orchards according to actual needs and with respect to the environment. The system consists of three components: 1. Crop Identification System (CIS), 2. Environmentally Dependent Application System (EDAS), and 3. Crop Health Sensor (CHS). A sprayer prototype able to automatically adapt spray and air distribution according to the characteristics of the target, to the level of crop disease and to the environmental conditions is under development. To develop the CHS, spectral analysis has been used, based on the developments in crop sensing techniques for grassland and arable crop production. Crop health status, with as an example the infection of apple scab (*Venturia inaequalis*) on apple leaves, has been evaluated. This paper describes the first results of the spectral measurements done to distinguish typical reflection wavelength from healthy apple leaves and apple scab infected leaves in time after infection.

**Key words:** orchard, apple scab, sensors, spectral analysis, sprayers

#### INTRODUCTION

Pesticide application in orchards are often carried out spraying high volume rates of spray mixtures and adopting large air flow rates, mainly using conventional axial fan air-assisted sprayers that have a limited range of options for their regulation, especially concerning spray profiles and air adjustment (Holownicki *et al.*, 2000; Pergher, 2006). Environmental concerns and rising demands for healthy fruits increasingly lead to the study of sustainable spraying techniques that could optimise pesticide application in orchards by more precise adjustment of spray and air profiles to target characteristics (Gil *et al.*, 2007; Walklate *et al.*, 2007).

The ISAFRUIT project – “Increasing fruit consumption through a trans disciplinary approach leading to high quality produce from environmentally safe, sustainable methods” was launched in 2006 within the 6<sup>th</sup> Framework Programme of the EU. The strategic objective of ISAFRUIT is to increase fruit consumption by a total chain approach to the improvement of fruit quality and safety, and to enhance the health and well-being of Europeans and their environment. Work Package 5.1 of this project aims at the reduction of chemical residue in fruit and minimizing the environmental impact of agrochemical application by precision dosing and crop oriented application of chemicals and thereby contributing to sustainable production of safe and healthy fruit and increased consumption of fruit and fruit products. The tools and methods of agrochemical application in sustainable fruit production have to be strictly oriented on the crop itself and the crop surrounding, taking into account the individual properties of the targets, the actual crop requirements, the environmental circumstances of treatments as well as pest/pathogen development. Due to spatial and transient variability within the crop-environment-pest/pathogen system the precision agriculture methods will be

used for a site specific crop adapted application both in macro and micro scale. This crop adapted application consists in the integration of the following elements and using the extracted information for elaboration of application strategies and chemical dose adjustment according to the actual need and with respect to the environment:

- identification of crop characteristics and its variability across the vegetation season;
- identification of pest/pathogen development on the crop;
- identification of environmental circumstances during the treatment (climatic conditions, crop surrounding, sensitive areas, buffer zones);
- evaluation of effects of crop adapted spray applications.

A prototype of air-assisted sprayer able to automatically adapt the spray application according to the characteristics of the canopy target (size and density), to the level of disease present in the crop and to the environmental conditions at the time of spraying is under development. The system will consist of three components: Crop Identification System – CIS (Balsari *et al.*, 2008), Environmentally Dependent Application System – EDAS (Doruchowski *et al.*, 2007), and a Crop Health Sensor – CHS which are being elaborated respectively by the University of Turin (Italy), the Research Institute of Pomology and Floriculture (Poland), and Wageningen University and Research Centre (the Netherlands).

### **Development of a Crop Health Sensor (CHS)**

To develop the CHS novel technologies will be used to quantify tree health conditions in the orchard, based on the developments in crop sensing techniques for grassland and arable crop production (Schut, 2003), like vision and spectral analysis. By adapting the sensors for fruit production, dose and timing of chemicals will be determined based on crop health situation of the fruit tree. Health status maps of the orchard can be made based on the continuous measuring of plant health during spraying by means of the CHS and using the position of the sprayer (GPS) during the season. Spray volume will be adapted following the relationship between crop health and required protection level using a specific plant protection product; in this case an example is made for apple scab (*Venturia inaequalis*) on apple leaves. This paper describes the first results of the spectral measurements done to distinguish typical reflection wavelength from healthy and apple scab infected apple leaves.

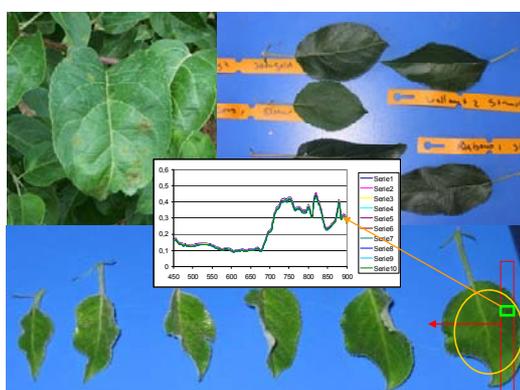
### **Methodology**

A measuring tool developed for characterizing grass-swards has been adapted to measure picked single apple leaves placed on the floor underneath in the laboratory. The device measures with two cameras the reflection in the band-widths 400-900nm and 900-1600nm. Images were taken with a Kappa camera, type DX-2HC. The image size was 1300 x 1030 pixels. The camera was equipped with an Inspector (Specim type V9), with an entrance slot of 80 µm, resulting in a spectral resolution of 5 nm. With the combination camera+V9 images were taken in the wavelength area of 450 to 900 nm. Also, images were taken with an Indigo camera (Alpha NIR). The image size consists of 320 x 256 pixels. The Alpha NIR was equipped with an inspector (Specim N17) and an entrance slot of 80 µm, creating a spectral resolution, depending on wavelength of approximately 10 nm. The combination camera+N17 was used for measuring the spectral reflection in the wavelength area of 900 to 1650 nm. Lenses used were Schneider-Kreuznach, spectral corrected lenses (cinegon series). Light sources used were Xenon flash lamps (line lamp; Broncolor Nano 2) of which the light was focused with a cylindrical lens. With this device spectral analysis measurements were performed on individual apple leaves. In between every image the plate with the leaves was moved 4 mm using a spindle mechanism to sample the next part of the leaves.

In 2006 spectral reflectance measurements were done on the 5 apple varieties (Elstar, Jonagold, Rubens, Wellant, Autento) and 1 pear variety (Conference). For two apple varieties (Elstar and Jonagold) old and young leaves were measured. For those two apple

varieties also measurements were performed on mildew and apple scab infected leaves. Fresh shoots were cut from a tree and put on water. After transport to the laboratory, just before spectral reflectance measurements, leaves were picked from the branches which were directly afterwards measured for spectral reflectance. In order to detect the effect of cover material on the leaf surface half of the leaves were washed before measurement. From each shoot five leaves were picked starting with the youngest leaf at the top of the shoot and descending along the shoot, creating a variation in leaf age in the samples. As the order of the leaves young to old was always the same on the measuring plate an effect of ageing could be determined. Individual leaves were placed on blue coloured plates to create a good spectral contrast between background and leaves.

In 2007 spectral reflectance measurements were carried out on leaves of the 2 apple varieties: Gala and M9-rootstock. For those two apple varieties as well as old as young leaves were measured. On two years old trees branches were identified, on each of which six leaves were marked to be infected at different times with a spore solution (spore density  $10^5$ ) of apple scab conidia (*Venturia inequalis*). From each shoot six leaves were picked starting with the youngest leaf at the top of the shoot and descending along the shoot, creating a variation in leaf age in the samples. Spectral reflectance was measured after 2 hr, 4 hr, 8 hr, 16 hr, 24 hr, 48 hr, 10 days, 17 days and 4 weeks after date of infection, and on healthy leaves and with water treated control leaves. In fact, measurements took place at the same day (1 day measuring for 2 hr, 4 hr, 8 hr, 24 hr, 48 hr and 1 day measuring for 4 hr, 16 hr, 10 days, and 17 days) but inoculations were carried out the appropriate time before measurement time and day. The treated leaves/shoots were covered with a plastic bag for 24 hours to optimise apple scab development and infection. At day of spectral measurement the leaves were picked and placed on a blue coloured plate. As the order of the leaves, young to old, was always the same on the measuring plate an effect of ageing could be determined.



**Fig. 1.** Apple leaves were scanned in lines (1mm x 120mm) for spectral reflection with two cameras (400-900 nm and 900-1600nm wavelength) per  $\text{mm}^2$  to determine areas of difference in reflection between cultivar, healthy leaf and apple scab infected leaves.

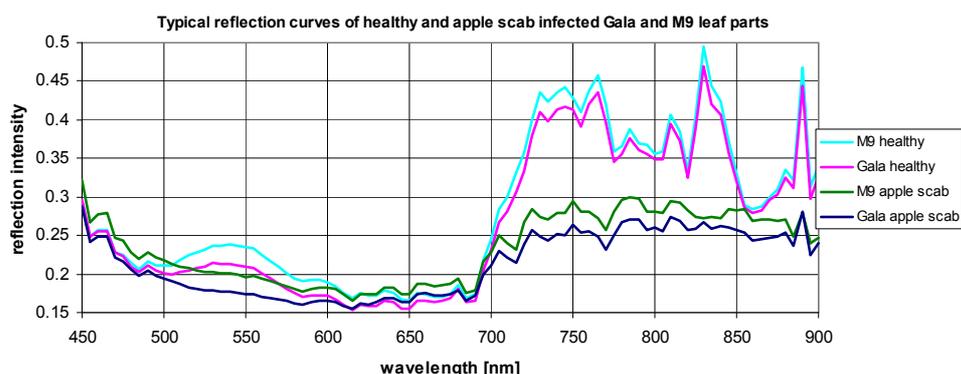
**Rys. 1.** Liście jabłoni skanowano wzdłuż linii (1 mm x 120 mm) przy użyciu dwóch kamer (o zakresie długości fal 400-900 nm oraz 900-1600 nm) z rozdzielczością  $\text{mm}^2$  w celu określenia różnic w intensywności odbicia światła między liśćmi różnych odmian, liśćmi zdrowymi i zainfekowanymi.

## RESULTS

Assessment of leaves of the apple cultivars Elstar, Jonagold, Autento, Wellant and Rubens on the spectral reflectance showed that the apple varieties could be discriminated from each other based on spectral reflectance, expressed as Normalized Differential Vegetation Index (NDVI) for typical wavelengths. Every apple variety has typically its own typical NDVI value. Healthy parts of the leaves can be distinguished from diseased parts of the leaves on the

mm<sup>2</sup> level. Results of the spectral reflectance measurements showed a difference in reflection between infected leaves and healthy leaves in the apple varieties Elstar and Jonagold.

Assessment of the time after infection of leaves with apple scab (apple varieties Gala and M9) showed a difference in reflection between infected leaves and healthy leaves (figure 2). It appears that early detection as 4 hours after infection was possible based on spectral reflectance, whereas visual detection is only possible after 10-12 days when first symptoms become visible.



**Fig. 2.** Spectral reflectance curves of healthy and apple scab infected Gala and M9 apple leaves.

**Rys. 2.** Charakterystyki spektralne zdrowych i zainfekowanych parchem jabłoni liści jabłoni odm. Gala i M9

## CONCLUSIONS AND FURTHER RESEARCH

The early detection of apple scab using spectral reflectance on the leaf opens new ways to develop a Crop Health Sensor (CHS) that can be used for apple scab detection in the orchard and to adapt the crop protection strategy as well. The potential of detecting mildew and apple scab in apple leaves opens the opportunity to develop a detection system for diseases in apple. More research is to be done on the earliest detection moments of the diseases in apple leaf to be able to develop a crop health sensor.

To translate the mm<sup>2</sup> information to an evaluation directly in the orchard at the leaf and tree level is still a big step to be made. Based on the data the development of the crop health sensor will start by identification of discriminant wavelengths for water stress, nutrient stress, cultivar and disease stress. The CHS can then be integrated in the ISAFRUIT crop adapted spray system, working together with the CIS and the EDAS.

## ACKNOWLEDGEMENTS

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### **Crop Health Sensor (CHS) - czujnik zdrowotności roślin – wczesne wykrywanie parcha jabłoni na liściach drzew jabłoni**

#### **PROJEKT ISAFRUIT – KU ZWIĘKSZENIU BEZPIECZEŃSTWA I POPRAWY JAKOŚCI OWOCÓW**

W roku 2006 rozpoczął się projekt ISAFRUIT ([www.isafruit.org](http://www.isafruit.org)) - Zwiększanie spożycia owoców poprzez interdyscyplinarne podejście prowadzące do uzyskania wysokiej jakości produktu za pomocą zrównoważonych i bezpiecznych dla środowiska metod - realizowany w ramach 6. Programu Ramowego UE. Zadaniem pakietu roboczego ECOFRUIT (WP 5.1 - Bezpieczne owoce ze zdrowego środowiska) jest opracowanie inteligentnego opryskiwacza sadowniczego CASA – Crop Adapted Spray Application. Ma on zapewnić skuteczne i bezpieczne opryskiwanie sadów zgodnie z rzeczywistymi potrzebami i z poszanowaniem środowiska. Na opryskiwacz CASA składają się trzy elementy: 1. system identyfikacji upraw (CIS), 2. środowiskowo regulowana technika opryskiwania, 3. czujnik zdrowotności roślin. Prowadzone są prace nad budową prototypu opryskiwacza, który automatycznie dobiera parametry opryskiwania i emisji strumienia powietrza adekwatnie do charakterystyki upraw, zdrowotnego statusu roślin oraz warunków środowiskowych. Czujnik zdrowotności roślin przeprowadza analizę spektralną światła odbitego od roślin, w oparciu o technikę identyfikacji obiektów stosowaną w uprawach polowych. Status zdrowotności roślin określany jest na podstawie oceny infekcji parcha jabłoni (*Venturia inaequalis*) na liściach jabłoni. W artykule opisano wyniki pomiarów spektralnych przeprowadzonych w celu znalezienia specyficznej długości fali świetlnej pozwalającej na odróżnienie liści zdrowych i zainfekowanych.