Field assessment of Fusarium Head Blight on wheat using near infrared hyperspectral imaging

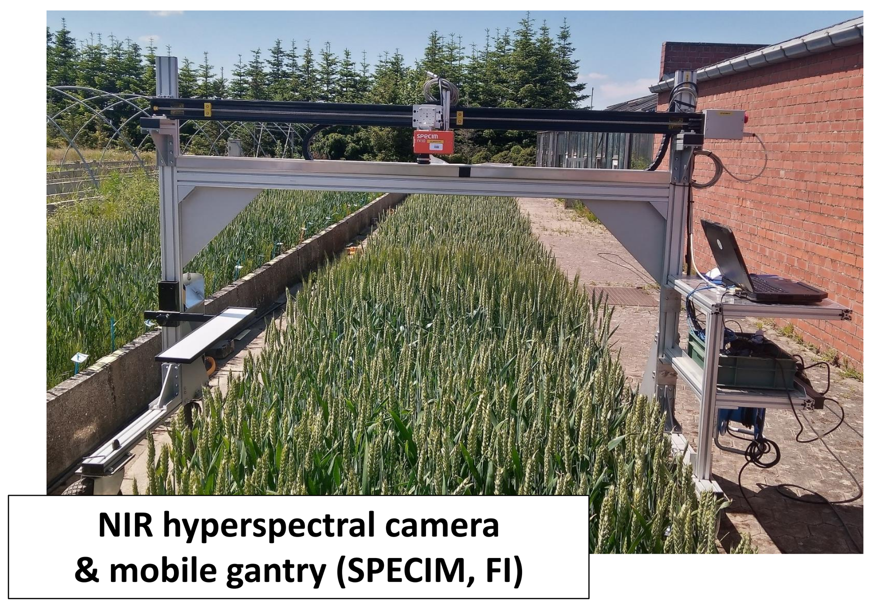
Damien VINCKE [a,d], Damien EYLENBOSCH [b], Anne CHANDELIER [c], Corentin DEMOITIÉ [a], Vincent BAETEN [a], Benoît MERCATORIS [d] and Philippe VERMEULEN [a]

(a) Walloon Agricultural Research Centre (CRA-W), Knowledge and valorisation of agricultural products Department, Gembloux, Belgium
(b) Walloon Agricultural Research Centre (CRA-W), Productions in agriculture Department, Crop Production Unit, Gembloux, Belgium
(c) Walloon Agricultural Research Centre (CRA-W), Life sciences Department, Crops and forest health Unit, Gembloux, Belgium
(d) University of Liège, Gembloux Agro-Bio Tech, TERRA Teaching and Research Centre, Biosystems Dynamics and Exchanges, Gembloux, Belgium

Contact: d.vincke@cra.wallonie.be

Recent reviews pointed out several gaps in current research on **plant stress** detection using hyperspectral imaging (HSI). Among these gaps is the limited number of HSI applications in real **field conditions.** In addition, the current research focuses on discriminating between healthy plants and those affected by the stress of interest, meaning that the models are not tested against other stresses.

This study is a contribution to filling both gaps by applying **near infrared hyperspectral imaging** (NIR-HSI) in the field to detect **Fusarium Head Blight** (FHB) and investigate the ability of this technique to **differentiate** FHB, which is caused by fungal pathogens on the ear, and **take-all** infections**,** caused by a fungal root pathogen affecting the whole plant. The differentiation of both diseases is of great interest as they show similar symptoms on the ear, but their respective pathogen agents are well distinct.



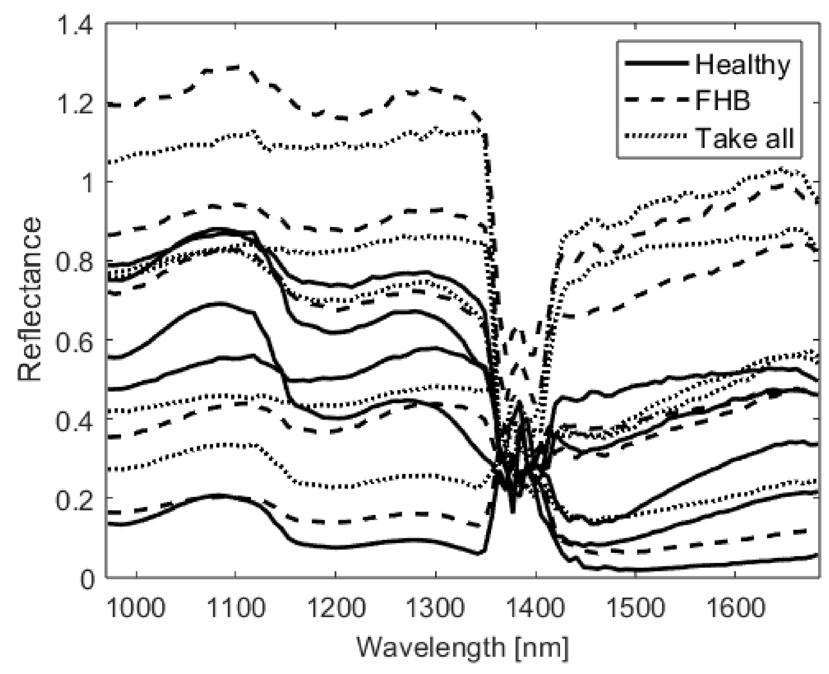
NIR hyperspectral camera & mobile gantry (SPECIM, FI)

Material and method

In 2022 a **field trial** with six winter wheat varieties was sown in a cultivation bed. The trial was **inoculated** at flowering with ***Fusarium graminearum*** (causing FHB) and the plants were **scanned in the field** at seven different dates using a **NIR hyperspectral camera** (FX17 model, SPECIM, Finland) working in the spectral range from **900 to 1700 nm** and mounted on a **mobile gantry**. During the trial's growing period, a **take-all infection (***Gaeumannomyces graminis tritici*) occurred simultaneously with the FHB infection. This co-occurrence of two biotic stresses provided an opportunity to test the method's ability in **classifying both stresses** affecting the ears.

FHB infected ear

Spectra of pixels from healthy and diseased ears



Performances of PLS-DA models calibrated at different dates and applied consecutively on a pixel basis

Date	Classes	Preprocessing	Latent variables	Sensitivity (Val) [%]	Specificity (Val) [%]
June 28th	Leaf vs. Ear	1st Deriv. (order 2, wind. 7 pt)	5	99.9	96.7
	Healthy ear vs. Diseased ear	SNV + 1st Deriv. (order 2, wind. 7 pt)	6	93.8	90.2
	FHB vs. Take-all	SNV + 1st Deriv. (order 2, wind. 7 pt)	5	97.3	46.0
July 4th	Leaf vs. Ear	1st Deriv. (order 2, wind. 7 pt)	5	98.6	93.3
	Healthy ear vs. Diseased ear	SNV + 1st Deriv. (order 2, wind. 7 pt)	6	90.4	91.9
	FHB vs. Take-all	SNV + 1st Deriv. (order 2, wind. 7 pt)	5	57.8	50.1

Classification models

The images acquired were used to build **spectral libraries** of the different objects present in the images. Different images of different wheat varieties at different dates were kept to create independent datasets for **calibration and validation**.

Then, **machine learning classification models** (PLS-DA) were developed and optimized. The models were designed to be **applied in a dichotomic way** on hyperspectral images of wheat trial plots and to **consecutively detect** the **diseases** (FHB or take-all) on a pixel basis.

Results and discussion

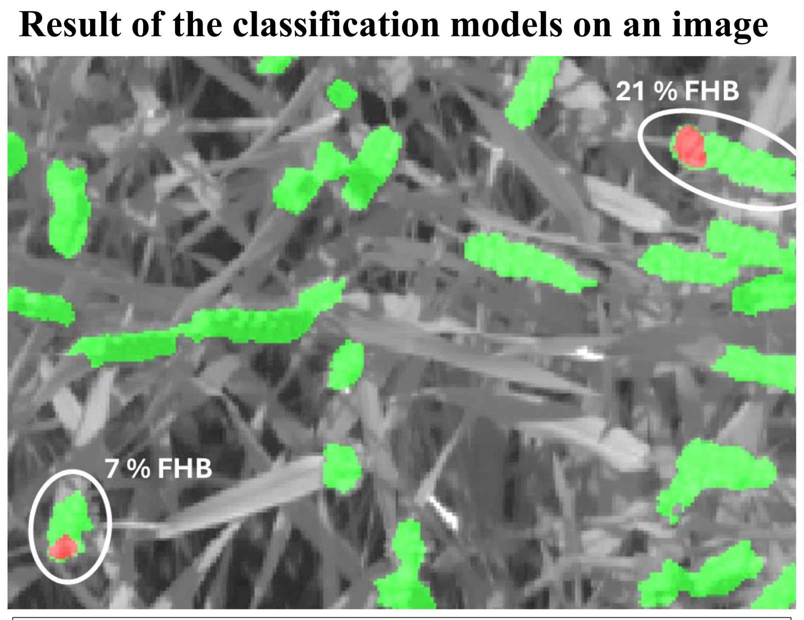
The **best performances** were obtained for the **models** classifying **leaves and ears** with few errors in validation. **Sensitivities and specificities above 90%** were reached for the models classifying **healthy and diseased ears**. However, the models classifying **fusarium head blight and take-all** did not provide satisfactory performances. The **low specificity** of these models is due to the spectral similarity of FHB and take-all infected ears.

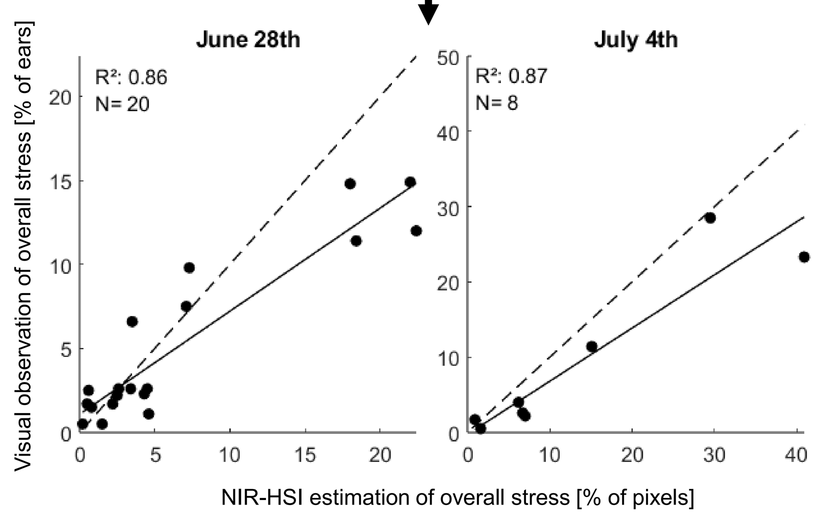
At the plot level, an evaluation of the models was achieved by comparing the **predicted disease severity** (% of coverage on the plot) with the **field-observed disease incidence** (% of infected ears on the plot). The parameter **overall stress** is expressed as a pixel ratio of diseased ears (FHB + take-all) to healthy ears. This parameter is a **good indication** about the general health status of the ears but not sufficient to quantify the severity of individual diseases, **visual observations by experts in the field are still needed**.

Results of the classification models applied at plot level and compared with the visual observations

	FHB		Take-all		Overall stress	
Model date	RMSE	R^2	RMSE	R^2	RMSE	R^2
June 28th	0.7	0.1	4.0	0.40	2.0	0,86
July 4th	0.6	0.26	7.8	0.56	4.2	0.87

Result of the classification models on an image





NIR HSI allowed assessing the general health status of the ears, however, **further developments are needed** to accurately **discriminate individual stress types**. The current method remains a **research tool** and is not yet transferable for varietal evaluation in routine experiments. This work also highlights areas for potential improvements in future studies, such as using a **blackout enclosure** for field image acquisitions. Such an enclosure combined with **artificial lighting** could enhance the quality of the spectral data. Additionally, it would provide more stable lighting, thereby improving the repeatability of the method. Furthermore, this setup could be used under cloudy weather, increasing the frequency of image acquisitions.

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