Development of deep learning models to detect and quantify symptoms of Barley Yellow Dwarf Virus in barley using RGB images

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Context & objectives

- Barley Yellow Dwarf Virus (BYDV) is a disease transmitted by aphids, causing discoloration and dwarfing of plants, which can lead to significant yield losses.
- The withdrawal of neonicotinoids has increased the need to select BYDV-tolerant barley varieties. That's why, in the context of VSCU (Value for Sustainable Cultivation and Use) studies for registration in the French catalogue, varietal tolerance is assessed by visual ratings in the field ; an effective but subjective method that requires considerable expertise. As part of the European PHENET project (2023-27), the aim of this study is to replace the BYDV visual assessment by reliable artificial intelligence models, based on RGB imaging in order to automate and objectify the phenotyping of varieties.

Methodology for prediction of BYDV symptoms

1. Acquisition protocol

- Site: GEVES
- 4 years 2021-2024
  - 2729 images

Sensors used:

Sony RX0 (4800*3200)
- Resolution : 0,55mm for a height at 1.80m , mounted on a literal stick (Phenoman), in a zenithal position

Plot: 1,30 to 1,60 m²

2. Reference Data

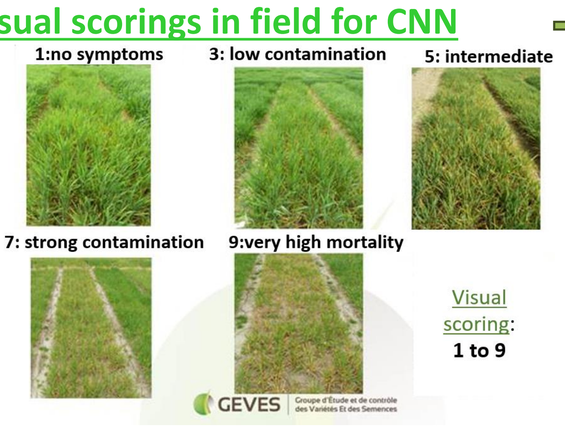
a. Annotation on images for YOLOv11

2 classes: Healthy & BYDV

- 1367 annotated images (350 + 1017 Data Augm.) with a low resolution (0,9Mo)
- 3 methods: Manual, SAM, & development of automatic model

b. Visual scorings in field for CNN

5 balanced classes of severity levels



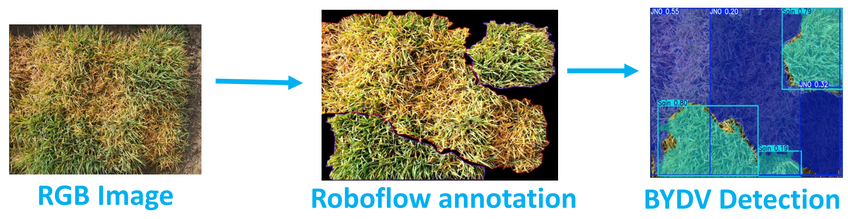
569 images of which 201 in Data Augmentation

3. Two Deep Learning approaches

a YOLOv11

Object detection + precise segmentation

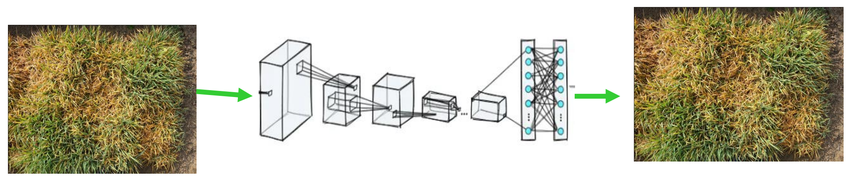
-Train: 1197 images (88 %)
-Valid: 130 images (12 %)
-Test: 53 images (5 %)



b ResNet18 CNN neural network

Classification in 5 classes on 569 images

-Train: 400 images (70 %)
-Valid: 116 images (20 %)
-Test: 53 images (10 %)

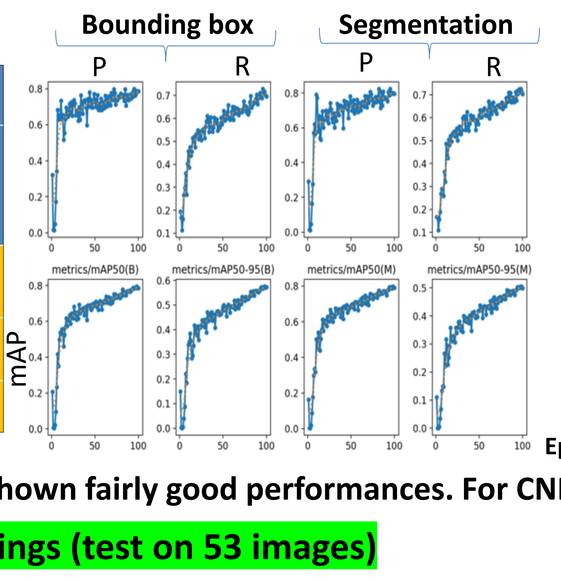


Results of BYDV prediction

Performance of BYDV models (validation)

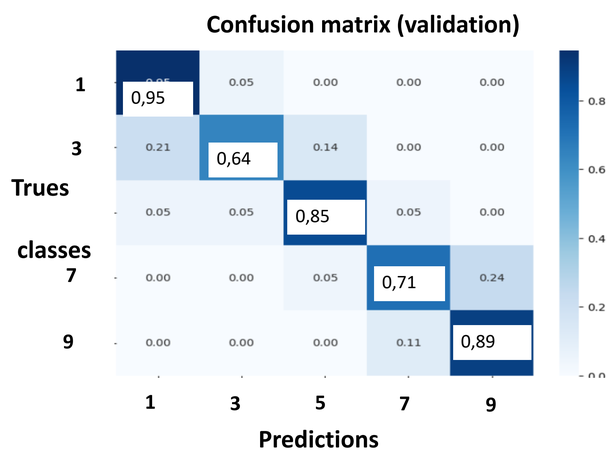
a. YOLOv11

		Bounding box		Segmentation	
	Metric	Healthy value	BYDV value	Healthy value	BYDV value
Cross-Validation (best fold)	Precision (P)	0.74	0.88	0.76	0.84
	Recall (R)	0.71	0.69	0.73	0.66
	mAP	0.79	0.82	0.81	0.80



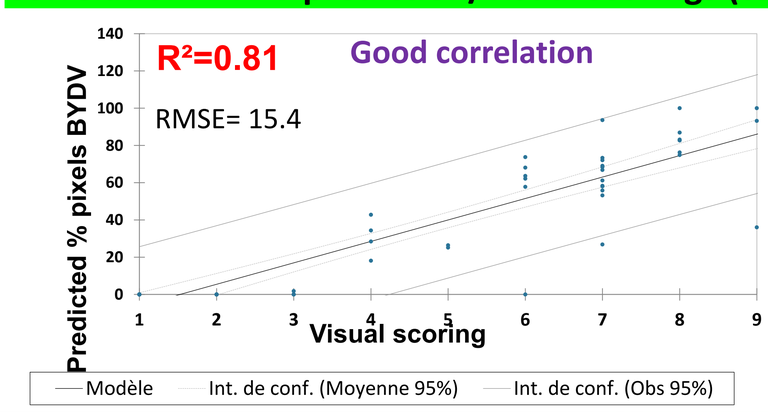
b. ResNet18 CNN

	Validation
Accuracy	0,8
Precision	0,8
Recall	0,81
F1-score	0,8

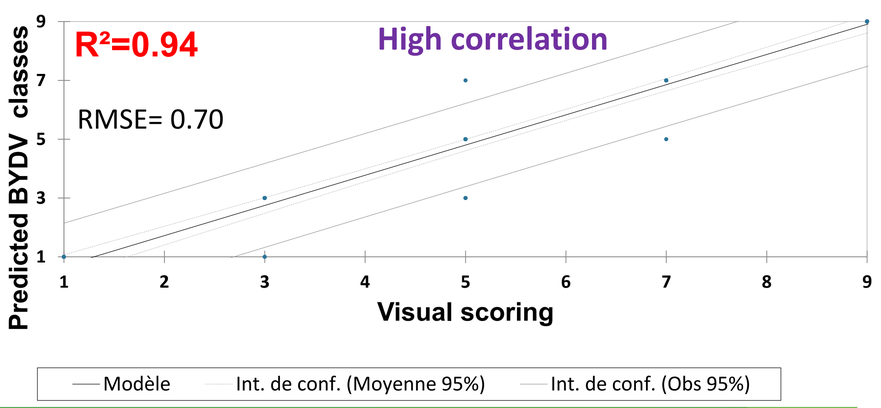


These both processes, YOLOv11 & CNN, have shown fairly good performances. For CNN, this initial model will need improvement for predicting intermediate classes

Correlation: BYDV prediction/visual scorings (test on 53 images)



CNN offers better correlation than Yolov11 with visual scorings, and also a simpler pipeline



Conclusion & outcomes

Both Deep Learning processes (YOLOv11 and CNN ResNet18) showed good BYDV detection performance and strong correlations with visual scorings, but with slightly better performance for CNN: fewer images required, no annotations , faster training.

In the future, it would be interesting to improve these models by testing new hyperparameters and introduce a larger number of images, under various conditions (years, sites, brightness), in interaction with other projects.

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