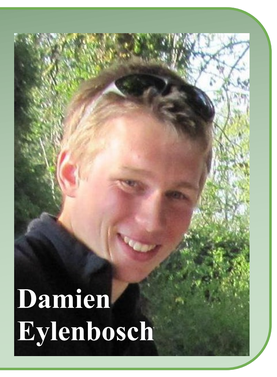
USE OF NIR HYPERSPECTRAL IMAGING TO DETECT AND QUANTIFY NODULES ON ROOT SYSTEM OF ASSOCIATED CROPS

Gembloux Agro-Bio Tech
Université de Liège

D. Eylenbosch[a], J. Pierreux[a], J.A. Fernández Pierna[b], V. Baeten[b], B. Bodson[a]

[a] Gembloux Agro-Bio Tech, University of Liège, Crop Science Unit, Belgium. E-mail: d.eylenbosch@ulg.ac.be
[b] Walloon Agricultural Research Centre, Valorisation of Agricultural Products Department, Food and Feed Quality Unit, Belgium.

cra-w



Context

Winter wheat and peas cultivated in association and harvested when grains are dry show promising results in temperate areas. This association reach a good land equivalent ratio, reduce the nitrogen fertilizer needs and obtain high quality harvest [1, 2]. These results are probably explained by the transfer of nitrogen from peas nodules to wheat roots. To test this hypothesis, **quantification of nodules is required**. Visual counting of nodules is time consuming and discrimination between the two kinds of roots is almost impossible. **A new method** is therefore needed. **Near infrared hyperspectral imaging** (NIR-HIS) was tested as a rapid method to quantify the amount of nodules and roots of each species in soil samples.

Methodology

Field experiment

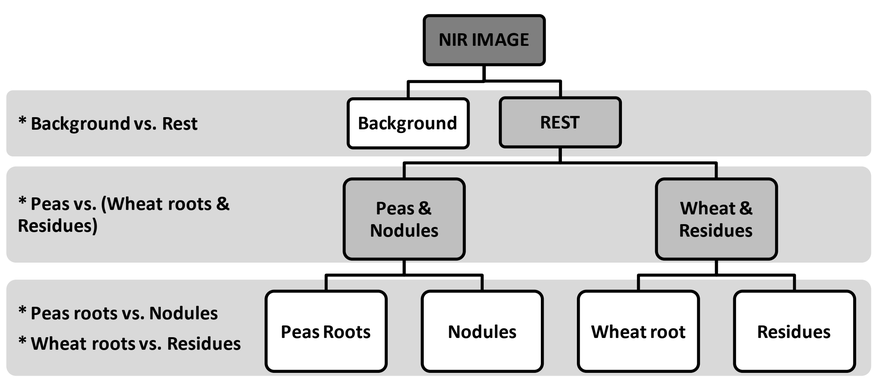
Soil samples were collected from a depth of 30 cm in a field trial comparing different amounts of nitrogen fertilization on an association of winter wheat and peas. Seedling densities of this associated crop were respectively 150 and 50 grains/m² for wheat and peas. Mineral nitrogen was applied in 2 fractions at tillering-redressing (BBCH 29-30) and last leaf (BBCH 39) stage of wheat . These fertilization stages were chosen in order to optimize the growth of both species in the association and to avoid penalizing the nodules development. Five fertilization levels were compared.

NIR hyperspectral images acquisition

Soil samples were washed to eliminate soil particles and extract roots and nodules. Extracted elements were then dried. NIR hyperspectral images were acquired with a NIR hyperspectral line scan (= push-broom) [3, 4]. Samples were laid on a conveyor belt placed under the NIR camera. For each pixel of the NIR image, a complete spectrum including 209 wavelengths (1100-2498 nm) was measured.

Discrimination of NIR spectrum

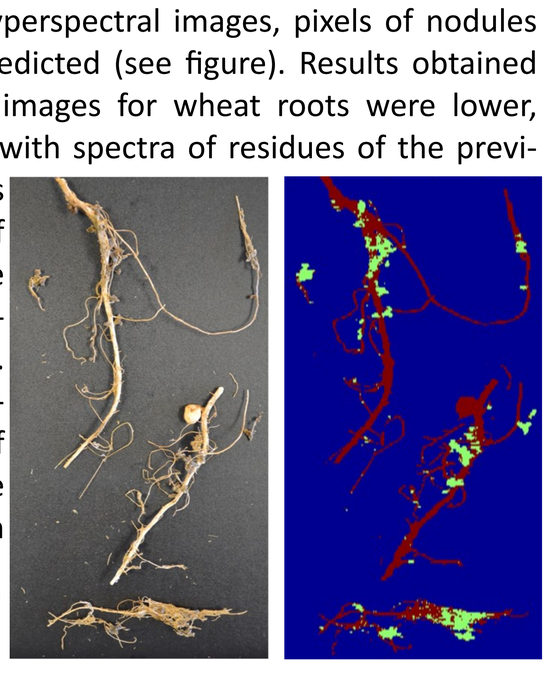
A discriminant classification tree including 4 successive discriminant analysis models was used to separate spectra into 5 distinct classes: background, nodules, roots of peas and wheat and residues of the previous crop. Based on the number of pixels predicted for each class, the amount of nodules and roots of each plant species can be estimated.



Results and discussion

Discrimination of spectra

Models are still in development but first results obtained show a very good discrimination between nodules and roots of both plant species . Testing models on a validation set, 93% of nodules NIR spectra and 92% of wheat root NIR spectra were well classified. Applying models on NIR hyperspectral images, pixels of nodules were also well predicted (see figure). Results obtained on hyperspectral images for wheat roots were lower, due to confusion with spectra of residues of the previous crop and peas roots, but 84% of wheat pixels were however well predicted on average. Due to this confusion, only 62% of peas roots were well predicted on average.

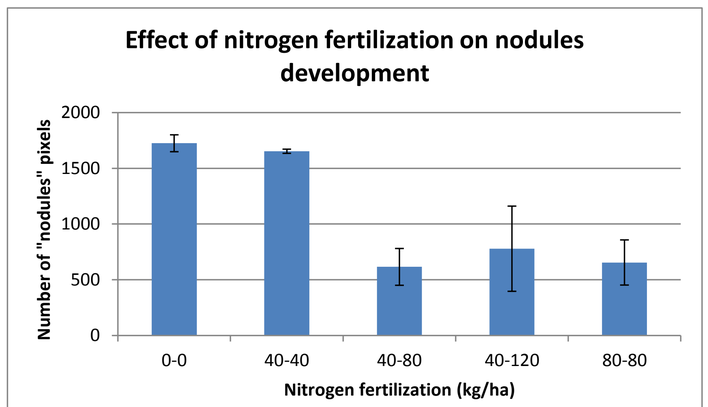


Quantification of nodules, roots of winter wheat and pea in the associated crops

Based on the number of pixels determined as nodules or roots on NIR hyperspectral images, it was possible to study the effect of nitrogen fertilization on root system. Following results were collected on a 30 cm depth.

Effect of fertilization on nodules.
Mineral nitrogen supply higher than 80 kg/ha decreased the number of nodules. Two mineral nitrogen fractions of 40 kg/ha applied at tillering-redressing and last leaf stage had no effect on number of nodules.

Effect of fertilization on roots development.
Without any nitrogen supply, amount of wheat and peas roots were equivalent. Nitrogen supply increased wheat root development but did not seem to have any effect on peas roots. Optimum yield was achieved with 2 supplies of 40 kg N/ha. Fertilization supply of 40 kg N/ha at tillering-redressing stage of wheat followed by 80 kg N /ha at last leaf stage increase wheat harvest quality but doesn't increase crop yield.



These results were obtained on only 2 replicates. Further sampling are needed to confirm these observed trends.

Conclusion

These preliminary results show once again the wide range of uses for NIR hyperspectral imaging combined with chemometric tools. The discrimination and the quantification of nodules under associated crops will be very useful not only to study the importance of nodules in fixation of nitrogen by legumes cultivated in association but also to study the effect of fertilization on the root system of these crops.

References:
[1] J. Pierreux et al.: 2014. Perspectives offertes par la culture en association de froment et de pois protéagineux d'hiver In Livre Blanc Céréales février 2014, (10), pp. 5–11. Eds B. Bodson and J.P. Destain.
[2] J. Pierreux et al.: 2016. L'intérêt de la culture en association de froment et de pois protéagineux d'hiver dans un objectif d'autonomie protéique In Livre Blanc Céréales février 2016, (10), pp. 2–9. Eds B. Bodson and J.P. Destain.
[3] D. Eylenbosch et al.: 2014. Detection of wheat root and straw in soil by use of NIR hyperspectral imaging spectroscopy and Partial Least Square discriminant analysis In Proceedings of the ESA 13th Congress, pp. 237–238. Eds P. Pepó and J. Csajbók.
[4] J. A. Fernández Pierna et al.: 2012. NIR Hyperspectral imaging spectroscopy and chemometrics for the detection on undesirable substances in food and feed. Chemometrics and Intelligent Laboratory Systems, 117:233–239.