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Nitrogen use efficiency of oilseed rape cultivars evaluated using experimental data and simulation modelling

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Background:

Crop improvement by plant breeding in a target set of environments underlies complex interactions between the environment, the crop management and genetically determined crop traits (Hammer et al. 2019). Additionally, the phenotype of crops is always the result of a mixture of genetic and environmental influences. In order to disentangle genetic from environmental effects and to explore the potential of specific alleles for improving crop performance, crop growth models may be helpful tools.

Objective:

Nitrogen use efficiency (NUE) of oilseed rape (OSR) is a complex trait presumably influenced by a larger number of plant traits interacting with management and environment. The aim of our study was to evaluate the potential contribution of different traits to NUE of OSR by means of simulation modelling using genotype specific estimated parameter values.

Methods:

At the Hohenschulen Experimental Farm, located in a prominent winter oil seed rape (WOSR) growing region in northern Germany, different WOSR-cultivars were thoroughly examined regarding their model parameter values under 5 different nitrogen fertilisation levels. Relevant state variables, like green area index, were frequently phenotyped by UAV-borne sensors. Additional data from older field experiments were added to enlarge the phenotypic variation of the cultivars. The dynamic crop growth model HUME-OSR (Böttcher et al., 2020) was parameterised and evaluated with the experimental data and generalised into estimates of available variation of specific traits. In-silico trials were performed in order to analyse the trait x environment interaction for NUE.

Results:

The analysis revealed component traits with little (e.g. leafiness pre booting, specific leaf area (SLA) pre booting) and large (e.g. specific stem area, SLA post booting) variation. Simulations with the comprehensively phenotyped cultivars matched field observations of biomass and green area index and allowed explorative analyses of trait effects on NUE with the model. The oldest cultivars underperformed with regard to nitrogen use efficiency. Sensitivity analyses within the predefined genotypic parameter range revealed – beside the mostly obvious positive effect of radiation use efficiency – a large positive influence of the parameters “SLA pre booting” and “stem critical nitrogen concentration pre booting”. These positive effects stem from an increased nitrogen uptake prewinter and reduced loss of nitrogen due to leaching in the target environment.

Conclusions:

Genotypic parameterisation based on direct measurements of specific crop traits allowed prediction of genotypic specific differences in seed yield and other higher level crop traits. The genotypic parameterized model allowed identification of relevant crop traits for NUE. In the presented target environment, traits associated with prewinter nitrogen uptake showed to be promising tracks to an improved nitrogen use efficiency.

References:

Hammer, G., Messina, C., Wu, A., & Cooper, M. (2019). Biological reality and parsimony in crop models - why we need both in crop improvement! *in silico Plants*, 1(1)

Böttcher, U., Weymann, W., Pullens, J. W. M., Olesen, J. E. & Kage, H. (2020). Development and evaluation of HUME-OSR: A dynamic crop growth model for winter oilseed rape. *Field Crop Res* 246, 107679