DEVELOPING AN ADVISORY SYSTEM FOR N FERTILISATION OF WINTER WHEAT AT WWW.ISIP.DE: I. NON-DESTRUCTIVE MEASUREMENT OF CANOPY PARAMETERS AND SIMULATION MODELLING

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Introduction

Non-destructive measurements of canopy parameters can be useful tools in experimental analysis of crop yield formation but also open new aspects for crop management. During the vegetative growth a close relationship can be observed between aerial dry mass, shoot nitrogen amount (N_{sh}) and leaf area index (LAI) of winter wheat, even under N-limiting conditions, because N shortage reduces leaf growth more than N concentration in the leaves. New non-destructive measurements allow to easily determine LAI and N_{sh} during the vegetation period. N_{sh} values may useful in order to optimise N management in winter wheat and may be advantageous to advisory systems based on measurements of N concentration of leaf tissue (SPAD, N-tester). Simulation modelling, however, may be needed to give growth stage specific reference values for N uptake.

Materials and Methods

The experiment was carried out in 2003 and 2005 to 2007 on the Hohenschulen Experimental Farm of the University of Kiel, located in NW Germany near Kiel and in 2005 to 2007 on 5 experimental sites in Lower Saxony, Germany. Nitrogen (0-240 kg N ha^{-1}) was split-applied at the beginning of spring growth, at the start of stem elongation and at ear emergence. The data collected in 2003, 2005 and 2006 at Hohenschulen were used for calibration of the regression equations. Green area index (GAI) and LAI, the above-ground dry matter (DM) and the N concentrations of the leaf and stem fractions were determined destructively at different stages during the growth periods. At the same sampling dates, GAI and the chlorophyll concentration were estimated using the LAI 2000 (LiCor) and the SPAD Meter (Minolta). Based on these data, N_{sh} during spring growth was estimated with 3 different regression approaches. Approach 1 (A1) correlated directly the measured GAI and the actual N uptake. Approach 2 (A2) includes SPAD values. Approach 3 (A3) estimates N_{sh} from stem and leaf DM and their N concentrations. Leaf DM thereby was estimated by LAI2000 and leaf N concentration by SPAD. Based on allometric relationships stem DM was calculated. Stem N concentration was related to stem DM using a dilution curve approach similar to the approach Justes et al. (1994) used for N_{sh} data. N_{sh} then is calculated by adding N_{stem} and N_{leaf}.

Results

A1 revealed a close linear relationship between N_{sh} and GAI with a highly significant r^2 of 0.76, which is in good agreement with results of Grindlay (1997) and Olesen et al. (2002). The crop N uptake was 39 kg ha^{-1} per unit GAI, lying clearly above the values of Stokes et al. (1998) who estimated a crop N uptake of 30 kg N ha^{-1} per unit GAI. Lemaire et al. (2008) observed 36 kg N ha^{-1} per unit GAI in France and 21 kg N ha^{-1} per unit GAI in Australia under optimal N supply. In A1, an RMSE of 20 kg ha^{-1} was achieved on average of all N treatments as well as for the 240 kg N ha^{-1} treatment.
Using additionally SPAD values (A2) reduced the RMSE to 18 kg ha^{-1} (0-240 kg N ha^{-1}) and 20 kg N ha^{-1} for the highest N fertilization. A3 showed a higher RMSE (37 kg N ha^{-1} for 0-240

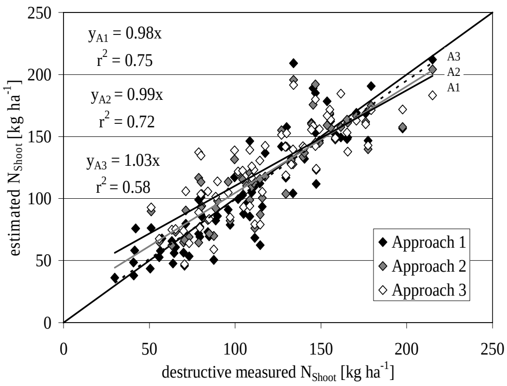

Fig. 1. Quality of Nshoot predictions for approaches A1, A2 and A3 at N application rate 240 kg ha^{-1}

and 24 kg N ha^{-1} for the 240 kg N ha^{-1} treatment). However, due to the underlying allometric relationship it can be used to estimate DM and N uptake for leaf and stem separately, e.g. for calibrating and updating plant growth models. On the other hand, A2 seems to be more suitable to estimate solely N_{sh} of winter wheat. The estimation of N_{sh} of independent validation data (Hohenschulen, 2004, variety Ritmo, N treatment 0-320 kg N ha^{-1}) resulted in somewhat lower but still acceptable levels of accuracy (Fig. 1). A1 achieved on average of all N treatments a RMSE of 31 kg N ha^{-1}, A2 achieved 24 kg N ha^{-1} and A3 showed for the validation data set a lower RMSE than A1 (29 kg N ha^{-1}).

Measured values of leaf chlorophyll concentration using the Yara® N-Tester (SPAD) for different nitrogen fertilisation treatments showed a much lower differentiation than non destructively measured leaf area index values (Fig. 2).

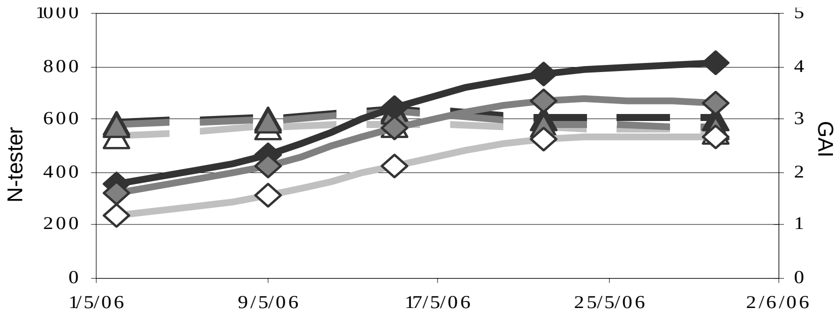

Fig. 2. Measured Leaf area (diamonds) index and N-Tester (SPAD) values (triangles) for treatments 230 kg N/ha (black), 110 kg N/ha (dark grey) and unfertilised (open symbols) winter wheat crops on average of 5 locations during the vegetation period 2006.

Conclusions

N uptake and further parameters of wheat canopies can be successfully determined using non-destructive methods within a monitoring program covering a larger wheat growing area in northern Germany. Leaf area index was closely related to N uptake and differentiated N supply better than measurements of chlorophyll concentration. Crop modelling and empirical approaches are currently used to identify growth stage dependent values of critical N uptake of wheat crops. Further steps in developing an advisory system for site- and management-specific N fertiliser recommendations are to improve predictions of current yield potential as well as to couple this module with modules for soil water contents and net N mineralisation (Heumann et al., 2009, same proceedings).

References

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