Optimizing N fertilization of winter oilseed rape

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Introduction

During the last decades the acreage of winter oilseed rape (OSR) has been increased considerably in Europe, mainly because of the increasing market demand for biofuels. According to the EU directive 2009/28/EC, the greenhouse gas (GHG) emission saving from the use of biofuels shall be currently at least 35% and 50% with effect from 1 January 2017. GHG emissions from the rapeseed cropping are mainly related to the energy-consuming production of mineral N fertilizers and to the N_2O emission in the field.

In addition, oilseed rape demands high amounts of N fertilizer often exceeding 200 kg N ha^{-1} to achieve maximum yields, but N offtake by the seeds is comparatively low leading to low nitrogen harvest indices and high N balance surpluses (fertilizer N minus N offtake by the seed) (Shepherd & Sylvester-Bradley 1996; Sieling *et al.* 1999; Sieling & Kage 2006; Rathke *et al.* 2006; Henke *et al.* 2009). Excessive N fertilization rates increase N leaching rates during periods of heavy rainfall, mainly due to large amounts of soil mineral N available after the OSR harvest and the small N uptake of wheat in autumn (Shepherd & Sylvester-Bradley 1996; Beaudoin *et al.* 2005). Otherwise, suboptimal N fertilization leads to yield penalties and in consequence to economical losses for the farmers.

An exact estimation of fertilizer N demand therefore becomes increasingly important, in addition to achieving high seed yields and maximum economic returns. In Germany, N fertilizers are commonly applied according to crop growth stage (Rathke *et al.* 2006) taking soil mineral N content (SMN) at the start of spring growth into account by the Nmin method (Wehrmann *et al.* 1979). In general, high canopy N is considered in the calculation of N fertilization rates by subtracting a fixed value of 20 kg N ha^{-1}. Also the results of both UK and French systems promote a reduced N fertilization of OSR when soil and canopy N are taking into account (MAFF 2000; Reau *et al.* 1994; Makowski *et al.* 2005). However, a detailed investigation of fertilization strategies under different climatic conditions is necessary and extremely important, because different boundary conditions strongly influence N dynamics in the plant-soil system and consequently N fertilization needs.

The aim of this study was to analyze possible functional relationships between the optimum N fertilization rate (Nopt), SMN at the beginning of spring growth and the amount of canopy N at the end of autumn and beginning of spring growth.

Material and Methods

In order to calculate N fertilization rates to oilseed rape more exactly, we initiated experiments in order to test the “French approach” which takes the N amount taken up by the canopy before the spring N application into account. During 2005/06 -2008/09 at several sites (12 in 2009) in Germany, 2 sowing dates and 2 autumn N fertilization levels (0, 40 kg N ha^{-1} in 2005/06 and 2006/07 resp. 80 kg N ha^{-1} in 2007/08 and 2008/09) were used to establish different crop canopies in autumn. Each of these 4 canopies were combined with 5 spring N fertilization levels (0-280 kg N ha^{-1}) in order to estimate the optimal N fertilization rate (Nopt) from the fitted N response curves ($Y = a + bX + cX^2$, where Y is the seed yield (t ha^{-1}), X the N application rate (kg N ha^{-1}), a the intercept, b the linear coefficient and c the quadratic coefficient (Henke *et al.* 2007)) It was assumed that the price for OSR was 400 Euro t^{-1} and for N 1.00 Euro kg^{-1} N. The Nopt values were correlated with the amount of SMN before the first spring N application, the canopy N at the end of autumn growth and that at the start of spring growth to identify possible functional relationships.

Results and Discussion

The level of estimated Nopt between the sites differed remarkably (Fig. 1). A significant linear negative correlation between Nopt and canopy N at the end of autumn growth (Fig. 1) or at the start of spring growth (Fig. 2) was found. No significant interactions between Nopt and the years or the experimental sites occurred. Therefore, all curves showed a similar slope of b=-0.7, indicating that N fertilization of OSR canopies with a high N uptake in autumn can be reduced. In this context, canopy N may be seen as an indicator for the mineralization potential of the site. Additionally, N from lost leaves over winter is likely to be recovered in spring to some extent and as a consequence N fertilization rates can be reduced. Especially after harsh winters this recovery potential is neglected when canopy N in spring is used as an indicator of spring N application. Based on the results of this study we conclude that under conditions of German climate it makes sense to take only autumn canopy N into account when calculating N fertilization rates in spring. From a larger data set we estimate that an 'average' canopy takes up approx. 50 kg N ha^{-1} in autumn and that this N amount is included in current regional site-specific N recommendations. According to our results, if canopy N in autumn is high (>50 kg N ha^{-1}), N fertilization rates could be reduced. On the other hand, poor canopies (<50 kg N ha^{-1}) should get more fertilizers. The extent of correction is calculated as 70% (=slope of the curves) of the difference between the actual autumn N uptake and the 'average' N uptake of 50 kg N ha^{-1}.

In contrast, regression analyses yielded no relationship between Nopt and SMN at the beginning of spring growth, because absolute values and variation in SMN were low.

For farmers, it is normally expensive and time-consuming to determine DM and crop N concentration separately in order to calculate canopy N. In France, an approach has been developed to roughly estimate canopy N from the crop fresh matter which can easily be measured by farmers (H. Hébinger, *pers. communication*). Estimating canopy N by weighing a defined area of crop with several replications is based on the assumption that dry matter content and crop N concentrations vary little during early growth stages in autumn and in late winter before stem elongation starts. Assuming a DM content of 100 g kg^{-1} and a N concentration of 45 mg g^{-1} DM (Reau *et al.* 1994, Colnenne *et al.* 1998), N uptake (kg N ha^{-1}) can be calculated by multiplying the fresh matter (kg m^{-2}) by conversation factor of 45.

In Germany, farmers often apply N fertilizers (20-50 kg N ha^{-1}) in autumn to ensure a sufficient autumn growth of the rapeseed crop, especially at later sowing dates following wheat and/or after minimum tillage without ploughing. Results from the above-mentioned field trials revealed no clear trend. In the first 2 years with high autumn N uptake, no significant yield effects occurred, whereas in the last 2 years with reduced crop growth before winter, autumn N application significantly increased seed yield of oilseed rape. The results indicate that autumn N fertilizers do make no sense in canopies with an uptake of >50 kg N ha^{-1} in autumn.

OSR is indispensable as a favorable preceding crop for cereals, especially wheat. However, the impact of growing oilseed rape on the environment should be as small as possible. Spring N fertilization should be reduced if canopy N in autumn exceeds 50 kg N ha^{-1}. In addition, autumn N fertilization should be an exception, but, first of all, a good practice (preceding crop, soil tillage, sowing date etc.) should ensure a sufficient autumn growth.

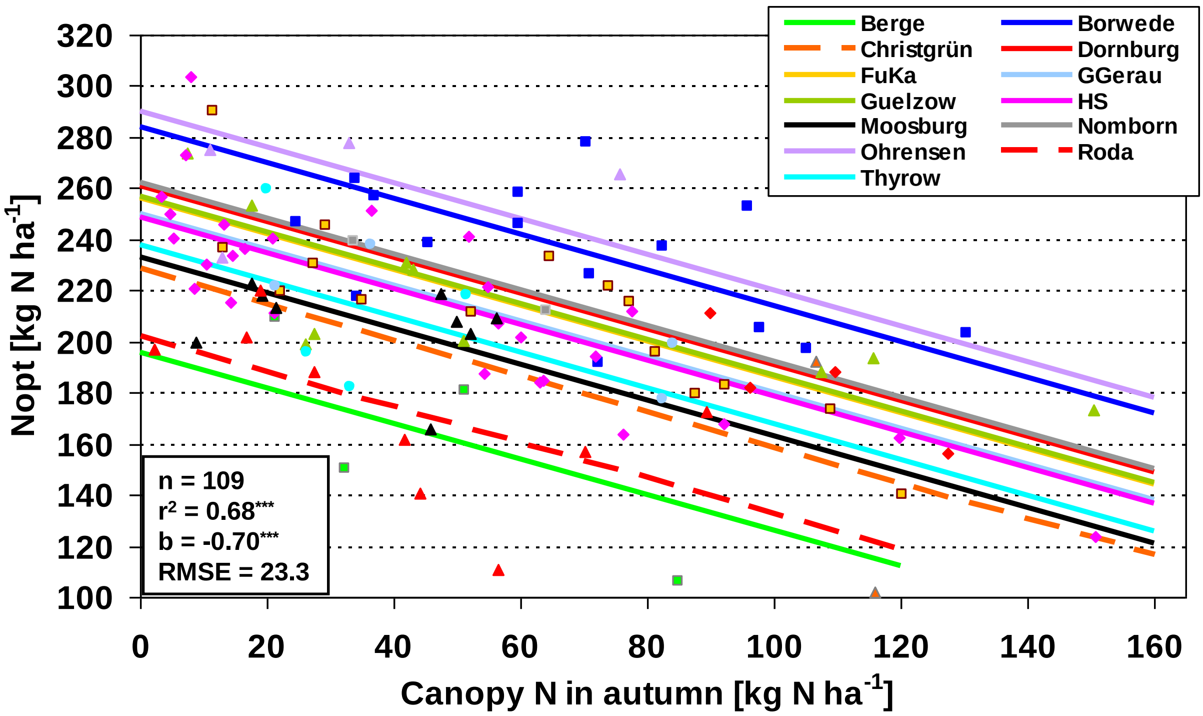

Fig: 1: Regression of Nopt vs. canopy N at the end of autumn growth for different experimental sites in Germany in four years

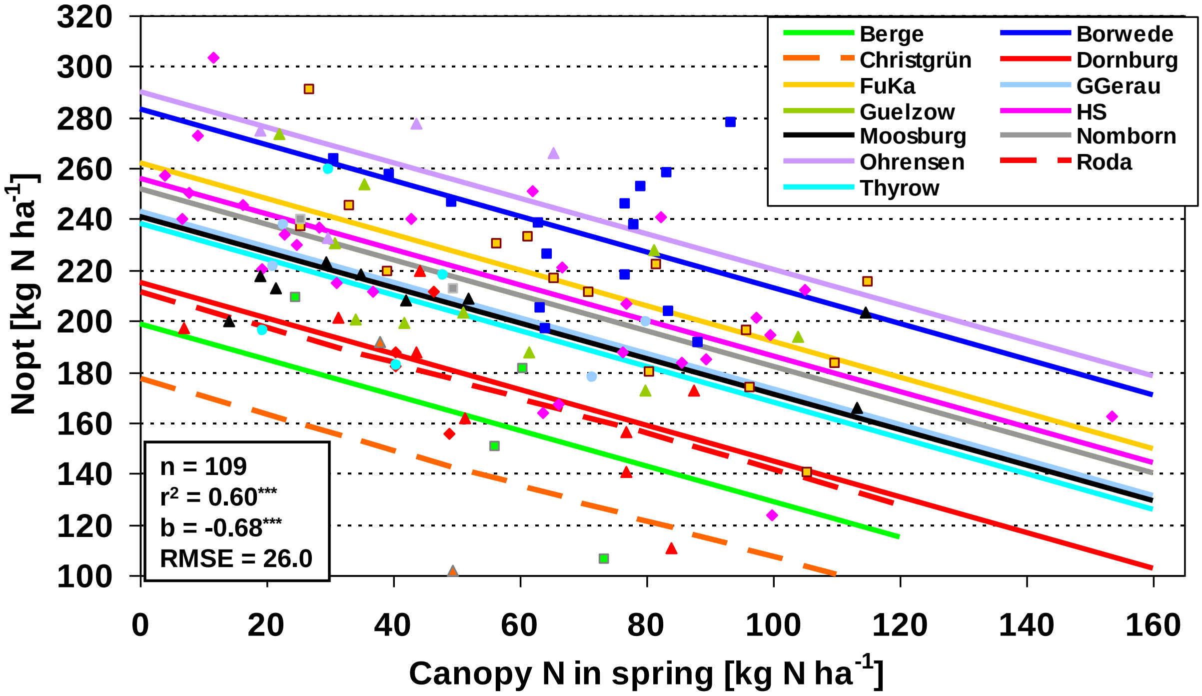

Fig: 2: Regression of Nopt vs. canopy N at the beginning of spring growth for different experimental sites in Germany in four years

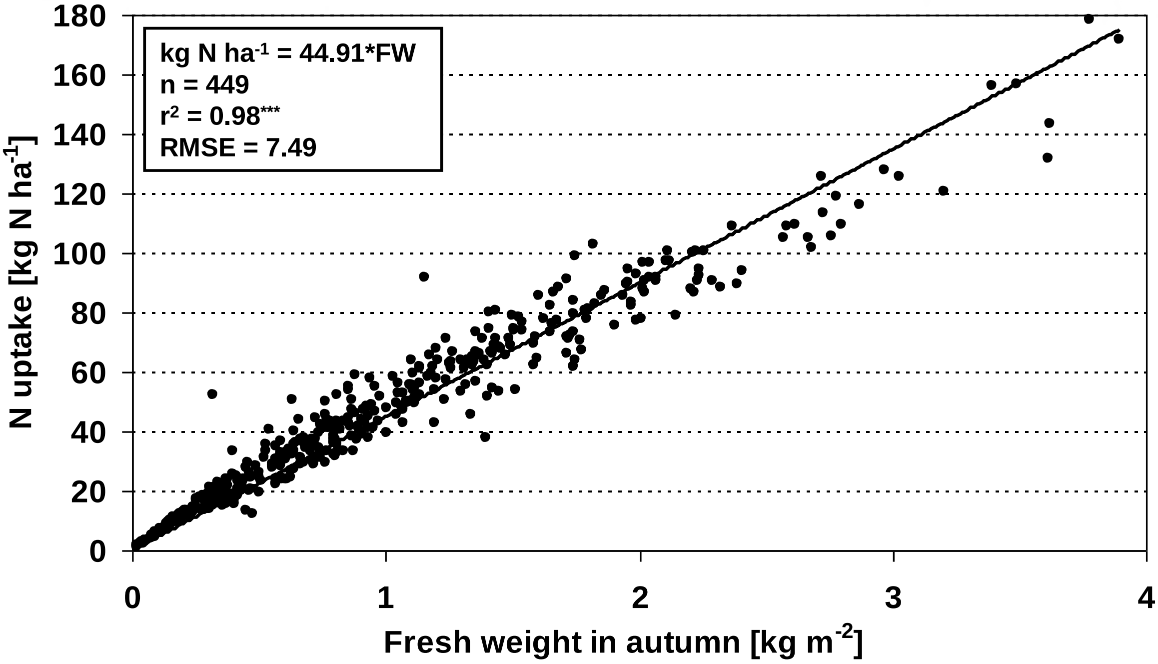

Fig: 3: Regression of N uptake vs. fresh weight (FW) at the end of autumn growth (autumn 2006-2008)

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