Analysis and evaluation of nitrogen cycles in different winter oil seed rape cropping systems of NW Germany

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Abstract

High nitrogen balances can be a serious problem in winter oilseed rape cropping systems in NW Germany. Therefore we analysed two long term field trials with winter oilseed rape in the rotation on the experimental station "Hohenschulen" (Christian-Albrechts-University of Kiel, Germany). Field experiment 1: "Comparison of different crop rotations" and field experiment 2 with the emphasis on the effect of the "interaction of liquid manure and mineral fertilizer on winter oil seed rape, winter wheat and winter barley". These experiments were evaluated using the indicator "extended nitrogen balance" calculated with the indicator system REPRO and the potential nitrate concentration in the leachate with consideration of the specific geomorphologies of the plots as well as heterogeneous climatic conditions in the experimental years 1986 - 2003. For the estimation of the leaching water, three methods (REPRO, ABIMO and BOWAM) were applied.

The nitrogen balances showed a great variation between the years and were also affected by the husbandry treatments. Lowest balances were observed with reduced nitrogen fertilization. Given similar amounts of nitrogen, a mineral fertilization produced lower balances compared with organic fertilizer treatments. A two-year rotation with only winter oilseed rape followed by winter wheat produced a higher nitrogen balance compared with a tree-year rotation of winter oilseed rape – winter wheat and winter barley.

Key words: Oilseed rape, *Brassica napus*, nitrogen balance, crop rotation, nitrogen fertilization, pesticide application

Introduction

Given the current economic situation winter oilseed rape is one of the most profitable food and non-food crop in Germany. For that reason the acreage of winter oilseed rape cropping has increased considerably during the last years. In some parts of Germany winter oilseed rape is grown every third year in the crop rotations. Such a large proportion in the acreage potentially causes a number of environmental effects. Most discussed due to the water regulation of the European Union is the effect of cropping systems on nitrogen balances and subsequent nitrate leaching to the ground water. The second important factor apart from the crop rotation is the type of nitrogen fertilization.

Materials and Methods

Experimental site

The experimental site "Hohenschulen" is located in the German state "Schleswig-Holstein" near the city of Kiel in close vicinity to the Baltic Sea. The climate is temperate with an average temperature of c. 7.9 º and c. 775 mm of precipitation. The soil type is a sandy loam with 21 percent clay, 35 percent silt, 44 percent sand and between 1,4 and 14 percent organic matter.

Field experiment : 1

The field experiment # 1 was conducted in the experimental years 1986 to 2001 in the crop rotation winter oilseed rape – winter wheat – winter barley. The treatments consisted of different mineral and organic fertilizer treatments and different fungicide treatments in order establish a wide range of nitrogen balances.

Field experiment : 2

In the second field experiment included in this analysis we have focussed on the effect of the interaction of slurry and mineral nitrogen fertilization on winter oilseed rape – winter wheat and winter barley in the experimental years 1995 to 2004. Out of a total of 27 different fertilizer treatments we concentrate on 8 treatments starting with 40 kg N/ha (treatment A) to 240 kg N/ ha (treatment H).

Data analysis and modelling

The tolerable nitrogen balances were determined as follows:

Displaceable nitrogen balance

AF = exchange factor (for AF>1 true AF=1)

tolerable nitrogen losses:

$$\Delta N_{tolerable} = \Delta N_{displaceable} + N_{denitrification} + N_{NH_3} - \text{losses}$$

The most important question: Which nitrogen balance is tolerably, so that 50 mg nitrate per litre leach ate are not exceeded? The amount of leaching water was calculated with the three different methods: REPRO, ABIMO and BOWAM (Glugla & Furtig, 1997; Dunger, 2002). Nitrogen balances were calculated with the REPRO software. REPRO is an assessment tool to estimate environmental and economic effects of different agricultural management strategies on the field and on the farm level. It is currently used in the evaluation of field trails, farms and on catchment scale (Christen & Hülsbergen, 2003; Heyer et al., 2003; Deike et al., 2005).

Results

The effect of the three crops winter oilseed rape (WOSR), winter wheat (WW) and winter barley (WB) and different husbandry treatments are shown in figure 1. In all experimental years the lowest nitrogen balance was observed in the treatment with a reduced nitrogen fertilization and average amount of fungicides (N-, F+). The two other treatments always produced higher nitrogen balances. Averaged over all experimental years the nitrogen balances in the N+, F- treatments were 122 kgN/ha, in the N+, F+ 120 kgN/ha and only 86 kgN/ha in the treatment with the reduced nitrogen fertilization.

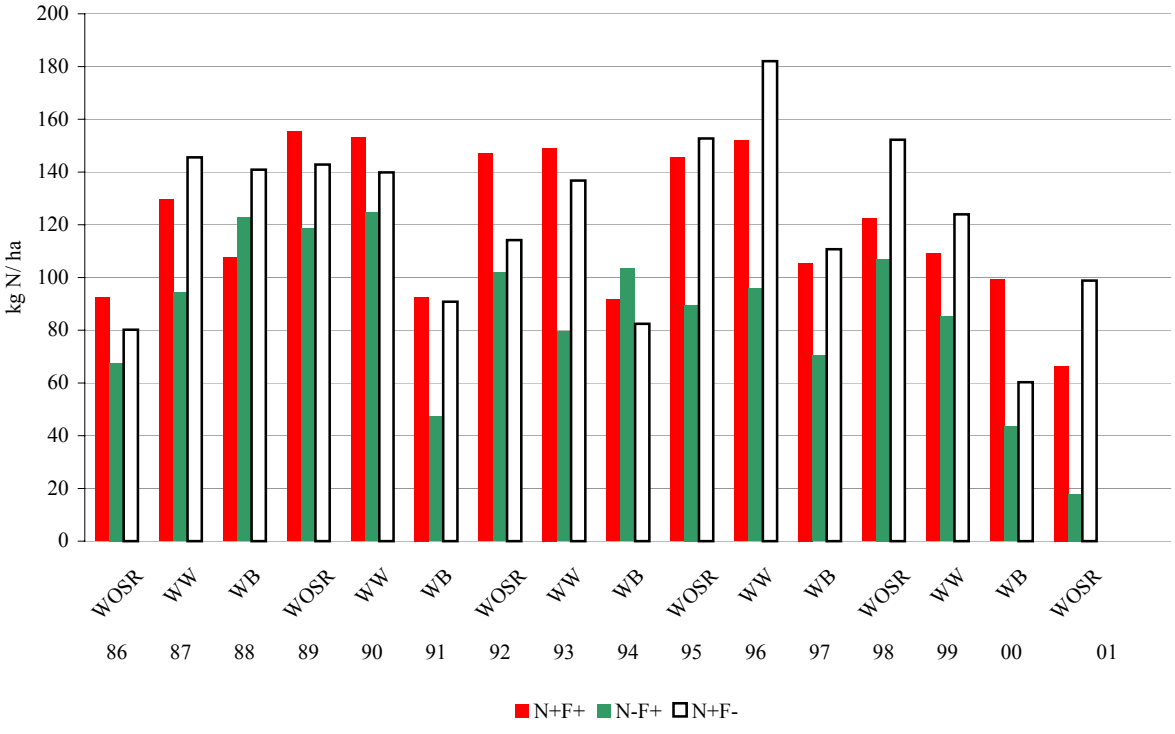

Fig.1: Effect of crop husbandry (nitrogen fertilization and fungicide application) on nitrogen balances [kgN/ha] in the crop rotation winter oilseed rape (WOSR), winter wheat (WW) and winter barley (WB). Experimental station "Hohenschulen", Germany, harvest years 1986 to 2001.

A shorter rotation with only winter oilseed rape and winter wheat produced considerable larger nitrogen balances (Fig. 2) In all experimental years the lowest nitrogen balance was again observed in the treatment with a reduced nitrogen fertilization and average amount of fungicides (N-, F+). Averaged over the experimental years the nitrogen balances was 99 kgN/ha. The two other treatments always produced nitrogen balances of 130 kgN/ha (N+, F+) and 144 kgN/ha (N+, F-), respectively.

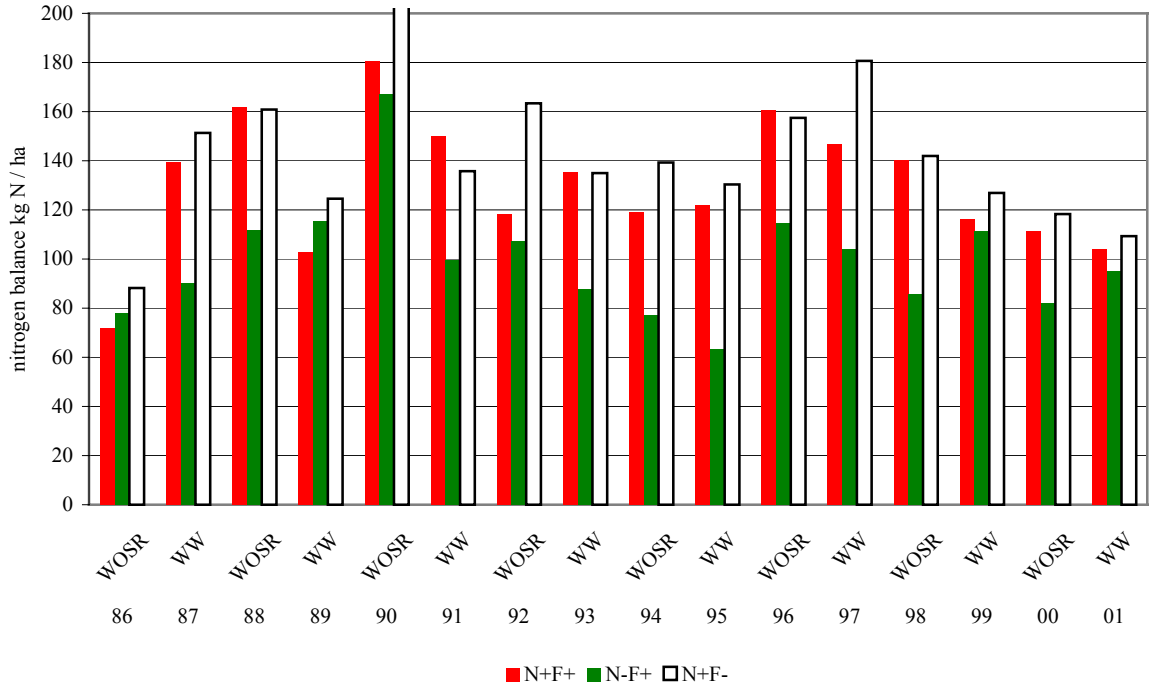

Fig.2: Effect of crop husbandry (nitrogen fertilization and fungicide application) on nitrogen balances [kgN/ha] in the crop rotation winter oilseed rape (WOSR) and winter wheat (WW). Experimental station "Hohenschulen", Germany, harvest years 1986 to 2001.

The environmental effect of those balances, however, is strongly modified by the quantity of leached water. In our experiment we have compared the three models REPRO, ABIMO and BOWAN to calculate the leachate. The results are presented in figure 3. In general the differences between REPRO and ABIMO were limited, whereas the calculations with the BOWAN approach in some years produced larger figures.

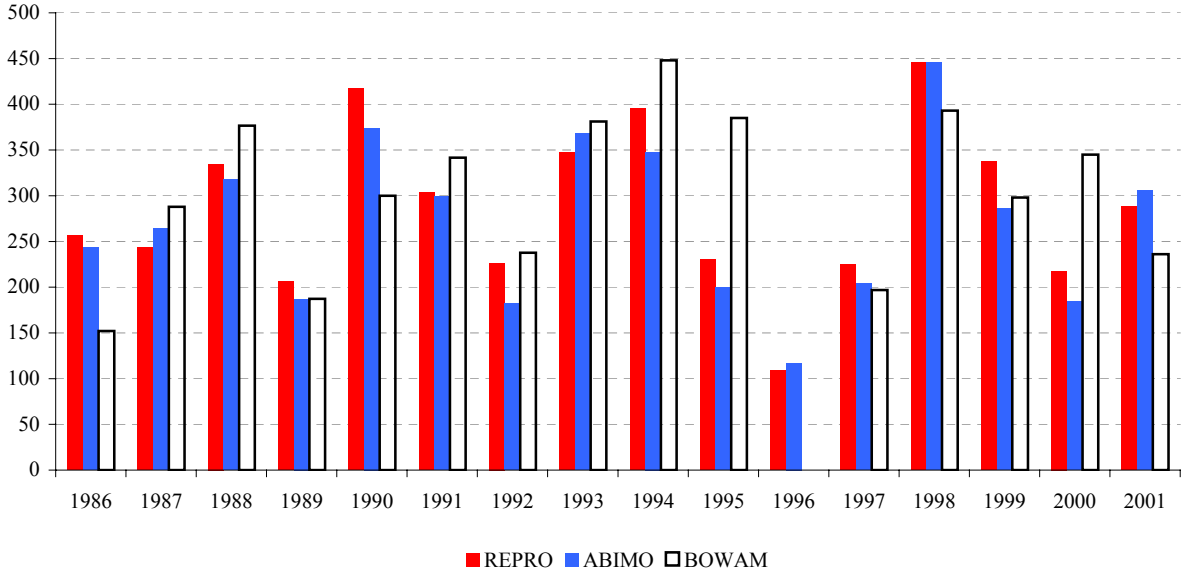

Fig.3: Effect of calculation methods on leachate [mm] with the three methods REPRO, ABIMO and BOWAN. Experimental station "Hohenschulen", Germany, harvest years 1986 to 2001.

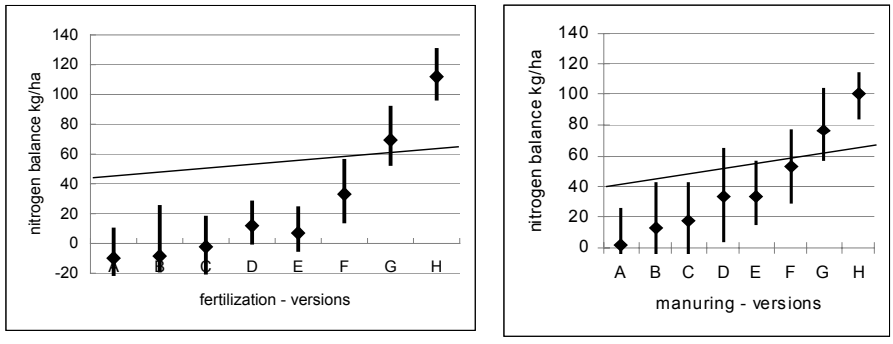

Fig.4: Effect of mineral a) and organic b) fertilization on nitrogen balances. Averaged over a crop rotation winter oilseed rape, winter wheat and winter barley. Experimental station "Hohenschulen", Germany, harvest years 1986 to 2001.

A comparison of the effect of mineral and organic fertilization on nitrogen balances with similar amounts of nitrogen is given in figure 4. The results demonstrate that under the environmental conditions of northern Germany a mineral fertilization of up to 200 kgN/ha produced nitrogen balances well under the threshold for 50 ppm Nitrate in the drinking water, which is represented by the line in the figure. In contrast, the use of organic manure (slurry) with similar amounts of nitrogen causes nitrogen balances above the threshold for drinking water in the EU already with a amount of 160 kgN/ha.

Discussion and conclusion

Nitrogen balances are an important indicator to assess the environmental effects of cropping systems. Strong effects are due the type of fertilization (mineral vs. organic). This concurs with results by Sieling & Kage (2006) and Sieling et al. (2006), who have reported similar findings for a great number of different fertilizer treatments in a rotation of winter oilseed rape – winter wheat – and winter barley. The effect of various fungicide treatments was smaller, however, all effects on yield, either with fungicides or herbicides has consequences for the nitrogen balance (Deike et al. 2005). The second important factor for nitrogen balances in rotations with winter oilseed rape is the length of the rotation itself. Our results clearly indicate that lower nitrogen balances might be achieved by longer rotations. We suggest to include those considerations on crop rotations and on pesticide treatments in nitrate reduction programs and not solely to focus on a reduction of nitrogen fertilization to minimize nitrogen balances.

Aknowledgement

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