Impact of sowing date of maize catch crops on yield and environmental effects – a trade-off ?

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Abstract

Regions in northern Germany that are characterised by high livestock/biogas plant density, light sandy soils and extensive silage maize production are facing major challenges with respect to environmental pollution, in particular nitrate leaching. The objective of the current study was to investigate a management strategy, i.e. an optimisation of maize harvest date and catch crop species, for mitigating the environmental pollution risk, based on a 2-year field study. Rye turned out more effective in N uptake than Italian ryegrass when sown no later than the second decade of September. A trade-off between maize yield, catch-crop N uptake, or N losses need not necessarily occur.

Keywords: *Zea mays*, harvest date, catch crop, leaching, nitrous oxide emission

Introduction

Growing silage maize for high output dairy farming or energy production on light sandy soils with a long manuring history may lead to high residual soil nitrogen (N) in autumn, which can be lost via nitrate leaching or as nitrous oxide (N_2O) emission (Oenema *et al.,* 1998). Catch crops may contribute to a mitigation of environmental pollution when residual N is taken up in autumn and after successful carry-over reduces the N-fertiliser demand of the following maize. However, the remaining growing season in autumn often is limited. The main objective of the present study was to analyse the impact of maize harvest date and catch crop species on maize yield, catch crop N uptake before winter, nitrate leaching and N_2O emission.

Materials and methods

The study is based on a 2-year (April 2012-April 2014) field experiment conducted in three environments in Schleswig-Holstein, northern Germany. The experimental farm 'Ostenfeld' is located in the Eastern Upland with an average annual precipitation of 847 mm, a mean air temperature of 8.9 °C and a silty sand soil. The experimental farm 'Schuby', located in the Geest region (885 mm, 8.6 °C, carbic sand), provided two environments, which differed with respect to irrigation (with/without) and preceding crops. The experimental setup was a 4-factorial randomised block design with three replicates and a plot size of 51 to 72 m^2. Treatments comprised two years, three environments ('Ostenfeld' (OF); 'Schuby' with irrigation (SI); 'Schuby' without irrigation (SnI)), four maize harvest/catch crop sowing dates (10 September (hd1) and 20 September (hd2) after early maize cv. Suleyka; 30 September (hd3) and 15 October (hd4) after mid-early cv. Ronaldinio) and four different winter catch crop treatments (Italian ryegrass cv. Gisel (LM); rye cv. Protektor; bare fallow after shallow soil cultivation (SC); undisturbed bare fallow (BF)). N fertilisation to maize was 180 kg N ha^{-1} taking soil mineral N in spring into consideration, applied shortly after maize sowing as calcium-ammonium-nitrate. Selected maize and catch crop treatments remained unfertilised. Maize was harvested with a plot harvester to determine dry matter yield. The catch crops were sampled manually to ground level at the end of the vegetation period in November to obtain aboveground biomass and N content, determined by near-infrared spectrometry. N_2O fluxes were determined weekly in selected treatments (hd1 and hd3, fertilised rye and unfertilised BF) using the closed-chamber technique by Hutchinson and Mosier (1981). Ceramic suction cup samplers were used to obtain leachate samples for N analysis, with three P80 suction cups installed per plot (70 cm depth).

Treatments comprised the rye and Italian ryegrass catch crops as well as unfertilised bare fallow of the first and third harvest date. Leachate was sampled weekly from catch crop sowing until end of March/ beginning of April. Nitrate load was calculated from the nitrate concentration and the drainage obtained from a climatic water-balance. Analyses of variance were calculated using 'R' software by assuming year, environment, harvest date, catch crop species and interactions as fixed and block as random. Multiple comparisons of means were conducted by linear contrasts. In addition, a regression model was developed to quantify the catch crop N uptake before winter as function of temperature sum.

Results and discussion

Aboveground N uptake (AGN) of the catch crops varied substantially between 0.5 and 52.3 kg N ha^{-1}, and was significantly affected by the interactions of environment × sowing date × catch crop ($P \leq 0.05$) and year × sowing date × catch crop ($P \leq 0.01$). Therefore, the four-way interaction is presented (Figure 1). Earlier maize harvest (hd1 vs hd3) resulted in higher catch crop N uptake, except for rye grown at OF in 2012 and Italian ryegrass grown at SI in 2013. Rye achieved higher N uptake than Italian ryegrass when sown early (hd1), with the exception at OF 2012, where rye performed better than Italian ryegrass at hd3 instead of hd1. Finally, more favourable weather conditions in 2013 resulted in generally higher AGN than in 2012.

The data allowed the derivation of two functions quantifying the aboveground N uptake of rye and Italian ryegrass, respectively, as function of temperature sum. When applying an exponential function, a base temperature of 5 °C gave best model fit (Figure 2). For typical silage maize harvest date, i.e. October 1st (long-term average), a temperature sum of 175 °Cd can be expected until the end of the vegetation period. This corresponds to an AGN of below 10 kg N ha^{-1}, for both species. An N uptake of 20 kg N ha^{-1}, regarded as the minimum for efficient ground water protection, would require a temperature sum of 285 °Cd (rye) or 330 °Cd (Italian ryegrass) and a latest sowing in the second decade (rye) or the first decade of September (Italian ryegrass). Considering a root:shoot ratio of 0.35 (Thorup-Kristensen, 2001) with appropriate additional belowground N uptake, opportunity for delayed sowing is given to reach the target N-uptake. Earlier maize harvest need not necessarily result in yield losses. We found significant year × harvest date ($P \leq 0.001$) and environment × harvest date ($P \leq 0.01$) interactions. Very early harvest (hd1) caused a significant yield reduction of up to 22% in each environment, whereas harvest later than hd2 showed a yield increase only at SI in 2013. Thus, from a yield perspective there was no need to harvest silage maize later than the second decade of September, which would provide potential for N uptake by a rye catch crop. However, forage quality aspects, e.g. rumen by-pass starch, may advocate later harvesting (Zom *et al.,* 2012). Cumulative N_2O emission showed a significant N fertilisation effect

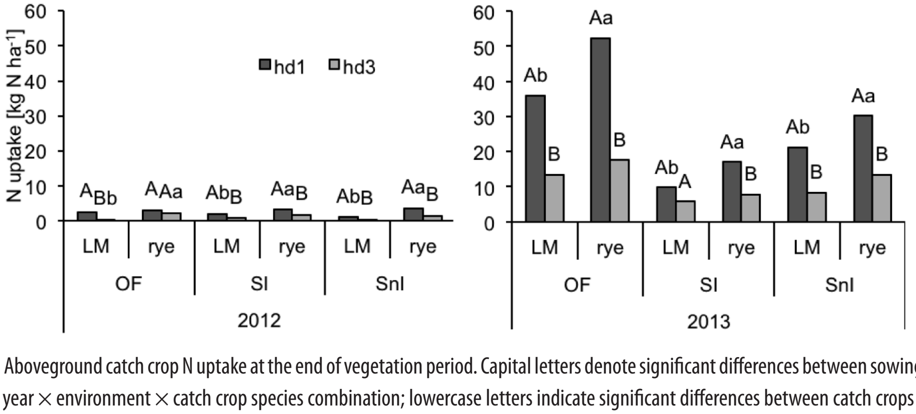

Figure 1. Aboveground catch crop N uptake at the end of vegetation period. Capital letters denote significant differences between sowing dates within a year × environment × catch crop species combination; lowercase letters indicate significant differences between catch crops within a year × environment × sowing date combination.

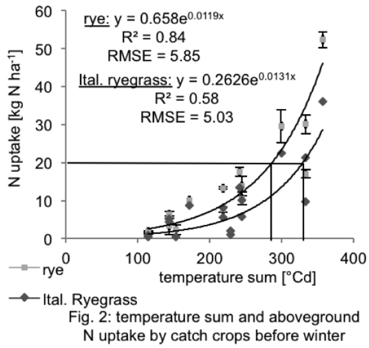

Figure 2. Temperature sum and aboveground N uptake by catch crops before winter.

(P≤0.001) and a significant year × harvest date interaction (P≤0.05). Overall, emissions were at a very low level, ranging between 0.1 and 0.85 kg N_2O-N ha^{-1} (data not shown). As expected, N fertilisation nearly doubled emissions compared to unfertilised control treatment. Catch-crop seedbed preparation in autumn did not cause any considerable N_2O peak fluxes, which mainly occurred during the maize growth period. Our results are in good agreement with van Groenigen *et al.* (2004) who reported low N_2O peaks for sandy soils and showed that N_2O emissions are raised significantly by the use of manure. Thus, the low N_2O emission found in our study can be mainly attributed to the use of mineral N fertiliser and the high draining capacity of the upper soil layers. Nitrate leaching was significantly influenced by year × environment × catch crop species (P≤0.05). Substantial nitrate leaching of up to 82 kg NO_3-N (2013/2014) ha^{-1} was found, with fertilised treatments tending to cause higher losses than unfertilised control. Furthermore, leaching tended to increase with later maize harvest. Significant differences, however, were detected only in the comparably warm winter period of 2013/2014 at SnI between rye and BF (hd1) and between Ital. ryegrass and BF (hd3).

Conclusions

Silage maize harvested in the second decade of September latest, followed by a rye catch crop seems to be a suitable management strategy to reduce environmental pollution while not adversely affecting maize yield. Earlier or later maize harvest/rye establishment will inevitably reduce maize yield or increase nitrate leaching. Future work will focus on residual effects on maize following a catch crop.

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