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N_2O Emissions in the Cultivation of Energy Crops

The N_2O-emissions from sites with three nitrogen fertilisation levels have been measured through gas chromatography since 1999. The long-term mean nitrogen conversion factor is 0.7 %. Few sporadic but intensive N_2O emission spots are the reason for a fertilisation dependent conversion factor. Whereas the correlation coefficient between N_2O emissions and annual precipitation is high, there is much lower correlation between soil nitrate and N_2O emissions. N_2O emissions result from nitrogen fertilisation, crops and precipitation.

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Keywords

Nitrous oxide, N_2O emission factor, energy crops, precipitation, soil nitrate

Literature

Literature references can be called up under LT 05515 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

When the cultivation of energy crops is assessed with regard to greenhouse gas abatement, the nitrogen conversion factor (ratio between N_2O-N emissions and N-fertiliser input [1, 2]) plays a significant role. The nitrogen fertiliser-induced emission of N_2O may counterbalance the CO_2 advantage of biofuels (in case of high nitrogen fertiliser application and conversion factor > 2 %), since N_2O as a greenhouse gas contributes to global warming about 300 times more effectively than CO_2 [3]. Farming processes influence N_2O emissions. Tillage can affect microbial populations [4], thus produce enhanced N_2O emissions at the beginning of the crop season. N_2O emissions from croplands have a great variability [5, 6, 7]. There are different emission peaks lasting for hours or weeks, the source of which is not explicitly known [7, 8, 9]. Spatial variability is mainly caused by heterogeneity in soil properties and agricultural management [5, 6, 10, 11]. Numerous authors studied the emission of N_2O dependent on soil type, fertilisation and crop species [e.g. 12, 13, 14, 15,16]. There are still uncertainties regarding the soil specific conversion factor, especially the influence of precipitation, soil moisture, temperature, soil nitrate concentration and other variables. Very high annual emissions of N_2ON between 4.2 and 56.4 $kg\,ha^{-1}y^{-1}$ were found for some fertilised and non-fertilised meadows and fields [13]. The type of soil determined the N_2O soil emissions. On average, using the same crop rotation, 1.5 % of fertiliser-N escaped as N_2O-N from sandy loam, whereas the emissions from loamy silt were only 0.8 % [15]. Since the N_2O emission factor depends on local conditions, the main aim of this study was to determine this factor and its typical variability for the cultivation of energy crops on sandy soils under climatic conditions of Northeast Germany.

Trial Sites and Measuring Technique

The N_2O flux measurements have been performed since 1999 in an experimental field with various energy crops. The field has 40 sites (624 m^2 each). Ten different plant varieties or plant combinations were arranged as columns (four sites each, labelled as A, B, C, and D) with a distance of 6 m between each column. The different types and levels of fertilisation were applied in four rows, perpendicular to the columns. There were sites with different levels of nitrogen input (A:150 kg N $ha^{-1}y^{-1}$; B and C:75 kg N $ha^{-1}y^{-1}$) supplemented by PK-fertiliser (A), wood ashes (B), and straw ashes (C) and sites without fertilisation (D). The gas flux measurements have been performed four times a week by means of gas flux chambers and an automated gas chromatograph (GC) [20]. In one computer-controlled run up to 64 samples could be analysed. For each level of fertilisation, the N2O emission factor was cal-

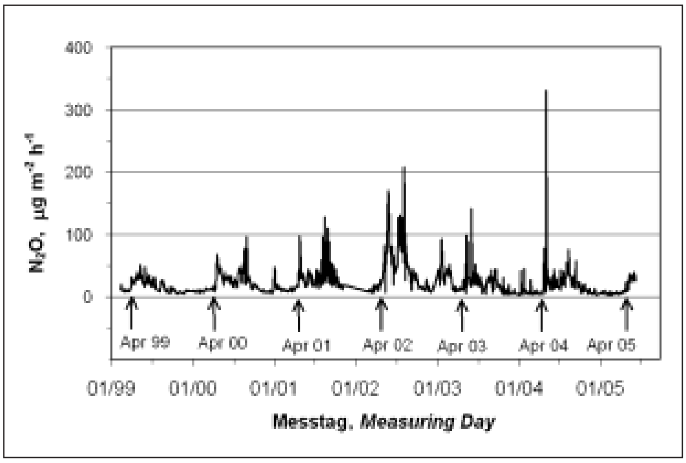

Fig. 1: Time series of N_2O emissions since 1999 (daily means from all measuring spots), Apr JJ: periods of fertilisation (usually April) are indicated by arrows.

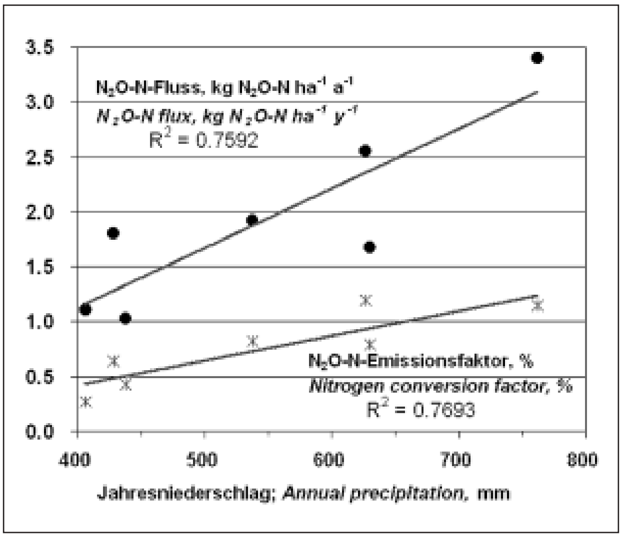

Fig. 2: Mean annual N_2O-N emissions and mean nitrogen conversion factors versus annual precipitation (Sites with 150 kg N ha^{-1} y^{-1})

culated by taking the difference between the mean values of the fertilised sites and the non-fertilised sites. Since 2003 soil samples (0 to 30 cm depth) were drawn from 12 sites with the three fertiliser levels and four crops. The concentration of mineral nitrogen (NH_4^+N and NO_3^--N) was determined by ion chromatography after extracting by distilled water and filtering.

Induced N_2O emissions

The emission of N_2O followed the expected pattern of fertiliser-induced emissions (Fig. 1). The fertiliser induced N_2O emissions had maximum intensities of between 100 and 600 mg N_2O $m^{-2}h^{-1}$ and lasted from four to eight weeks. We also found at fertilised sites temporarily and spatially limited high fluctuations. N_2O emission peaks of up to 1400 mg N_2O m^{-2} h^{-1} were observed from few measuring spots. These findings are in accordance with other studies [e.g. 17 to 27]. The excessive generation of N_2O could result from a sporadic local enhanced mineralisation of soil organic matter or from modified biological activity [e.g. 28 to 34]. Tillage and thus the type of crop could influence the N_2O emission rates too. An obvious difference exists between N_2O emission rates from sites with perennial crops and annual crops. The emissions from sites with annual crops (1.5 kg N_2O-N ha^{-1} y^{-1}) are about 50 % higher than from sites with perennial plants (0.9 kg N_2O-N ha^{-1} y^{-1}). Fallow land generated the highest annual emission rates (annual mean of 5.3 kg N_2O-N ha^{-1} y^{-1}). Considering the conversion factor, it was nearly twice for sites with annual crops, compared to perennial crops (*Tab. 1*).

Table 1: Mean nitrogen conversion for sites with perennial crops and annual crops, A: 150 kg N ha^{-1} a^{-1}; B, C: 75 kg N ha^{-1} a^{-1}

Crops	Nitrogen conversion factor, % Sites		
	A	B, C	A, B, C
Grass	0,40	0,52	0,48
Willow	0,30	0,36	0,34
Poplar	0,64	0,39	0,47
Mean	*0,45*	*0,42*	*0,43*
Rye	1,07	0,74	0,85
Triticale	0,75	1,12	1,00
Hemp	0,33	0,16	0,21
Rape	1,60	0,60	0,94
Mean	*0,94*	*0,65*	*0,75*

Precipitation, soil nitrate, and N_2O emissions

The maximum of the mean annual N_2O emissions and the maximum of the mean nitrogen conversion factor of the differently fertilised rows were observed in 2002, the year with the highest precipitation since 1999. There is a clear correlation between annual precipitation and annual total N_2O emissions (*Fig. 2*). The correlation between soil nitrate and N_2O emissions was much lower. The seasonal change of soil nitrate concentration and N_2O fluxes were similar, but due to the temporal and local fluctuations of N_2O emissions and of nitrate concentrations, the correlation might depend on the locations and time schedule of soil sampling compared to the N_2O flux measurements. The soil samples were taken outside the measuring rings (in order not to disturb the soil surface) in distances of 30 to 50 cm, neither synchronous nor daily, but only weekly. There is nearly no correlation between daily flux measurements and weekly nitrate concentration measurements (R^2 = 0.03), whereas a slight correlation exists for the monthly means (R^2 = 0.20). This is interpreted as a result of high dynamic of N_2O fluxes, which can considerably vary in the course of one week. On the other hand, the monthly means reflect more tendencies. Therefore, the correlation increases, as both quantities show similar seasonal changes.

N_2O emission and CO_2 advantage of energy crops

The mean N_2O-N emission factor was 0.7 % for all A-, B-, and C-sites (0.9 % for A-sites and 0.6 % for B- and C-sites) for the years from 1999 till 2005. Due to the enhanced N_2O emissions from several measuring spots at A-sites, the mean emission factor increased for these sites and annual crops emitted more N_2O than perennial crops (*Tab. 1*). The results measured here are at the lower end of the range of the N_2O emission factor, which is recommended by IPCC [2] for the fertilisation-based N_2O inventories. Thus, it can be stated that the emission of N_2O is comparatively low on the sandy soils of the experimental field. The CO_2 advantage of energy crops will not be reduced by nitrogen fertilising as long as fertilising results in an adequately higher biomass yield [35, 36]. This result is also true for other crops, cultivated on sandy soils as source for renewable vegetable raw materials, if excessive fertilising is avoided.

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