

# Determination of ground-source trace gas flows in the production of regenerative raw material crops

*The environmental balance of regenerative raw material crops is influenced by emissions of climate relevant and environmentally relevant trace gases. In association with the intensity and type of nitrogen fertilisation, nitrous oxide or ammonia is emitted and degradation of methane in the soil is influenced. FTIR measurements indicate that ammonia flows, in association with fertilisation by calcium-ammonium-nitrate, lie under the identification level. The average value for the fertiliser-induced  $N_2O$ -N emissions lies only at 0.2% of the Nr. fertiliser application. The GC measurements show that the ground-source degradation of atmospheric methane is influenced by ground temperature.*

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## Keywords

Emission rates, ammonia, nitrous oxide, methane, FT-IR spectroscopy, gas chromatography

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Intensive discussion over nitrous oxide emissions and the real requirement for nitrogen applications in regenerative raw material crop production occurred after the publication of the ecological balance for rapeseed oil and rape oil methyl ester [1]. This led to several authors [2 – 5] subsequently having a closer look at this problem. The UBA study arrived at the, in-part controversial, result that rape oil as a diesel substitute offered no distinct advantage over diesel fuel regarding climate influence. The environmental effects of fertiliser-induced  $N_2O$  emissions represents important support for this argument. A newer UBA study on evaluation of the performance of rape oil/RME in comparison with diesel fuel [6] also pinpoints the  $N_2O$  creation as a dominant negative factor in the environmental balance. In the ecological balance [1] the fertiliser induced  $N_2O$ -N emission from 2% to 3% of the annual Nr. applications was accepted as a more likely scenario. In the newer evaluation [6], the calculation factors recommended by the IPCC [7] were used. According to this, the  $N_2O$ -N emissions lay within a reasonable area at 1.25% and should, according to soil and climate conditions, vary between 0.25% and 2.25%. In that the  $N_2O$  emission depends on many factors, substantial differences can take place according to location. Further gases are classified in the environmental balance, especially ammonia ( $NH_3$ ) and methane ( $CH_4$ ). In order to better evaluate the ecological advantages of regenerative raw material cropping, more detailed knowledge on influence of management (fertilising, plant species) on ground-source gas flows

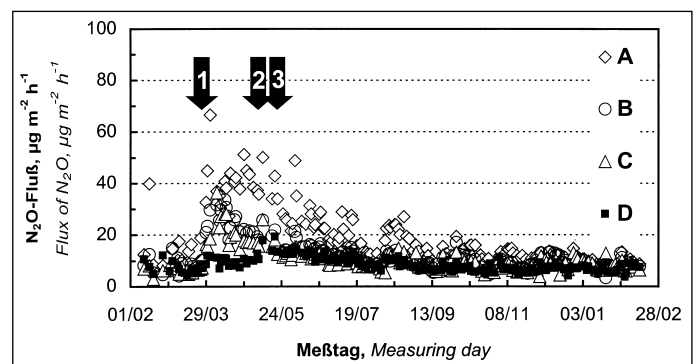
should be gained through the investigation presented here

## Ground-source gas flows

Biological activity in soil leads to a flow of gases between atmosphere and ground. Many organisms consume oxygen. Some, according to soil conditions, can decompose hydrogen ( $H_2$ ), carbon monoxide ( $CO$ ) as well as  $CH_4$ , or can emit  $CH_4$ .  $CH_4$  emissions as the result of anaerobic decomposition of organic substances can be found mainly in hydromorphic ground (moorland) [8]. Carbon dioxide ( $CO_2$ ) and oxidation stages of nitrogen ( $N_2O$ ,  $NO$  and  $NO_2$ ) are emitted as gas-form metabolic products. Although ground emissions of nitrogen monoxide ( $NO$ ) can be substantially higher as  $N_2O$  emissions [9, 10] because of its short atmospheric lifetime  $NO_2$  indicates lesser climatic relevance.  $NO$  and the oxidation product nitrogen dioxide ( $NO_2$ ) must be considered in the environmental balance because they influence the ozone content of the troposphere [11]. In total, the knowledge up until now regarding biogenic  $NO_2$  emissions are not yet sufficient in order to classify  $NO$  ground emissions in the environmental balance of regenerative raw materials. For this reason, biogenic  $NO_2$  emissions are not evaluated in the UBA study [1] and in the study [6]  $NO_x$  field emissions are placed at zero.

Fertilising can influence the biological activity. In that methane production organism activity is limited by nitrate ions [12], nitrogen fertiliser must reduce the production of methane. Methanotroph bacteria oxidise

Fig. 1: Course of  $N_2O$  emission rates from the soil of the poplar plots A, B, C and D during 1999/2000. Fertilising dates are indicated by arrows: 1 – 50 kg N/ha for the plots A, B and C on March 26<sup>th</sup> 1999; 2 – 50 kg N/ha for plot A on May 18<sup>th</sup> 1999



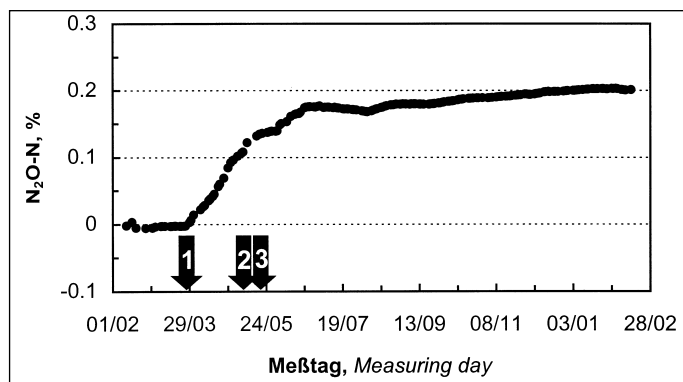


Fig. 2: Accumulated fertiliser induced soil emission of  $N_2O-N$  as ratio to the total annual fertilisation level (Fertiliser related mean values of all plots A, B, and C as difference to the mean value of all plots D). Dates of fertilising are indicated by arrows (see Fig. 1).

methane and reduce, or limit, methane emissions, especially in wet areas where a stronger methane production is present [13, 14]. The oxidation of the atmospheric methane is still not completely explained [15].

Less secure is the data situation with regard to  $NH_3$  ground emissions, i.e., after incorporation or seepage of ammonia content fertiliser and following ammonification of the protein-content organic substances (ground dunging). The good solvency and the high absorption capabilities of  $NH_3$  on the surface, strongly limits  $NH_3$  ground emissions.  $NH_3$  stimulates  $N_2O$  emissions through nitrification and denitrification processes taking place in the soil. This leads to higher  $N_2O$  emissions being observed from ammonia-content nitrate fertiliser compared with pure nitrate fertiliser [11].

#### Trial field and gas measurement technique

Since the beginning of 1997 accompanied gas flow measurements have been carried out on an ATB trial field (40 plots each of  $624 m^2$ ) [17], where the environmentally-acceptable cultivation of regenerative raw material crops is carried out under near-practical conditions. The results from 1997 and 1998 are based on weekly sampling followed by FTIR gas analyses [5]. Since the beginning of 1999 the gas samples have been evaluated four times weekly with an automated GC [18]. The FTIR analyses led, with the chosen measurement adjustments, to a variation coefficient of 7% in the analysis of  $N_2O$  and  $CH_4$  within the area of atmospheric concentrations, and of around 20% regarding  $NH_3$  determination in very small concentrations ( $<0.5 ppm$ ). The standard variation in the determination of the mass-associated flow for all three gases lies in the area of around  $20 \mu g m^{-2} h^{-1}$ . The automated GC measuring technique has a standard variation of  $0.6 \mu g m^{-2} h^{-1}$  for  $CH_4$  and  $0.17 \mu g m^{-2} h^{-1}$  for  $N_2O$  in the investigation of the ground-source flows.

#### Ammonia, nitrogen dioxide and methane

Although, applying calcium ammonia nitrate means using an ammonia-content fertiliser, there was with  $NH_3$ , as opposed to the  $N_2O$  measurements, no fertiliser-induced emissions identifiable with the FTIR measuring technique. The FTIR  $NH_3$  measured value varied stochastically within the measurement accuracy limits. In association with the FTIR  $NH_3$  standard variation of  $20 \mu g m^{-2} h^{-1}$ , this means for the plots with the highest fertiliser rate that fertiliser-induced  $NH_3$  emissions from around  $2 kg NH_3-N ha^{-1} a^{-1}$  must be able to be observed. The  $NH_3$  identification limit of flow amount is above  $5 \mu g m^{-2} h^{-1}$ . Therefore it is probable that these emission are even substantially smaller.

Fertiliser induced  $N_2O$  emissions could already be observed in the years 1997 and 1998. The measurement frequency and the uncertainty of measurement precision hindered a quantitative evaluation. With the change-over to the GC measuring technique and increasing the measuring frequency by a factor of four it was possible to record the emission process more precisely. Significantly increased  $N_2O$  emissions appeared on the day after fertiliser application and were still detectable three months later (fig. 1). The weighted difference of the accumulated average values of unfertilised and fertilised plots gave a first statement as to the  $N_2O$  emission factor. On the loam-sand trial site fertiliser-induced emissions appeared only in amounts of around 0.2% (fig. 2). This value lay at the lower end of the IPCC advised [7] concept for the determination of fertiliser-induced  $N_2O-N$  emissions. Because of this, the nitrogen dioxide emissions at the tri-

al location influence the environmental balance of regenerative raw material only to a limited extent. Measurements over further years are still required to consolidate the findings.

In the measurement period since 1997 nearly all  $CH_4$  ground emissions measured were negative, this means there was degradation of atmospheric  $CH_4$  in the ground. The  $CH_4$  degradation correlated with the ground temperature. Whilst from December to March the degradation rate sank to values around  $5 \mu g CH_4 m^{-2} h^{-1}$ , in the period from June to November the measurement values were mainly in the area of 10 to  $20 \mu g CH_4 m^{-2} h^{-1}$ . As average value over all plots, a  $CH_4$  degradation rate of  $700 g CH_4 ha^{-1} a^{-1}$  was determined for the trial site (table 1).

#### Conclusion

- Ammonia-content mineral fertiliser does not lead to essential  $NH_3$  ground emissions.
- Nitrogen fertilising on loam-sand locations sets free 0.2% of the fertiliser nitrogen as  $N_2O$ . This value lies at the lower end of the IPCC-recommended concept for the determination of fertiliser-induced  $N_2O-N$  emissions. The  $N_2O$  emissions of the trial site influenced the environmental balance of regenerative raw material crops only to a limited extent.
- A decisive, fertiliser-induced limitation to degradation of atmospheric methane in the ground is not identifiable. Rather, the results indicate a fertiliser-stimulated degradation of methane.

Table 1: Soil methane ( $kg \cdot ha^{-1} \cdot a^{-1}$ ) at release of plots with plants plots at different fertilisation levels

Plants	Fertiliser rates			Average
	0 kg N $ha^{-1} a^{-1}$	75 kg N $ha^{-1} a^{-1}$	150 kg N $ha^{-1} a^{-1}$	
Poplars	0,25	0,29	0,50	0,35
Willows	1,00	0,57	0,51	0,69
Rye	0,46	0,63	0,96	0,68
Cocksfoot	0,52	0,75	0,98	0,75
Triticale	0,89	1,02	0,91	0,94
Average	0,62	0,65	0,77	0,68