Ilona Motz and Heinz Dieter Kutzbach, Hohenheim

Nitrous oxide emissions after soil compaction

During 2000/2001 at the University of Hohenheim nitrous oxide emissions from compacted soil were recorded. The areas were compacted through being driven over with tyres of different pressures or different numbers of passes. The results showed that low ground pressure through low tyre pressure led to reduced nitrous oxide emissions. Soil compaction leads to anaerobic soil conditions which can result in increased nitrous oxide emissions.

Dipl.-Ing. sc. agr. Ilona Motz is a member of the scientific staff at the Institute for Agricultural Engineering, University Hohenheim, Specialist Dept. Procedural Technology in Plant Production on the Basis of Agricultural Engineering (director: Prof. Dr.-Ing. Dr. h.c. H.D. Kutzbach), Garbenstraße 9, 70593 Stuttgart; e-mail: *ilomotz@uni-hohenheim.de*

Keywords

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From 50 to 75% of anthropogenic N_2O emissions are from agricultural areas [3]. This led to a field trial at Hohenheim University within the framework of the DFG Research Group „Climate-relevant trace gases“ on the Heidfeldhof trial fields. There, the influences of different soil treatments on nitrous oxide emissions were investigated.

An important factor influencing nitrous oxide emissions is anaerobic conditions in the soil which encourage such emissions. Anaerobic conditions can be caused through tractor-caused compaction [1, 2]. [1] investigated the influence of tractor passes on different physical soil characteristics after conventional pass, reduced soil pressure and without soil pressure. Here it was possible to determine, amongst other things, influences on soil density, air-filled pore volume, soil permeability for air and macro pore distribution. [4] found a relationship between strongly compacted areas (tyre tracks) and increased denitrification rate because in compacted areas after rain anaerobic conditions were more rapidly affected than in non-compacted areas.

This led to trials being conducted in November/December 2000 looking at nitrous oxide emissions from soil with various degrees of compaction. On the same recording area a second trail series was carried out in August 2001 to investigate the long term effects. Presented below are the results of both series.

Heidfeldhof trial field and measurement method

The Heidfeldhof trial field lies around 2 km west of Hohenheim University. Soil is pseudo gleyed parabrown earth over loess. Long term average for precipitation is 685 mm and for temperature 8.7 °C. At the time of the trials a clover/grass sward had been seeded on the area. Hohenheim measurement chambers were used for recording the climate-relevant gases. These worked according to the closed chamber method and have been already described in this publication [5]. Measurement areas were each of 1 m^2 the measurement chambers were automatically controlled via PC, being fitted with automatic samplers. The measurement hoods had each a volume of 127 l. During the chamber-closed time of 1 hour, five gas samples were taken and analysed via gas chromatography.

Trial method

A soil compaction test was carried out from 29. 11. to 17. 12. 2000. Differently compacted areas were achieved through passing over with two different tyre pressures and through two or six passes with wheel loads of 15.7 kN (*table 1*).

The measurement areas comprised two parallel tyre tracks. On the same areas between 24. 8 and 1. 9. 2001 a second measurement campaign was carried out to quantify the long-term effects of compaction on nitrous oxide emissions. The measurement chambers remained on the trial areas from December 2000 to August 2001 to minimise ground disturbance through dismantling and rebuilding activities. On each measurement area 2 l of undiluted liquid manure was distributed on 9. 12. 2000 with 5 l of undiluted cattle liquid manure (dm 4%, Nr. content 2%) brought out on 24. 8. 2001. Soil compaction was measured by penetrometer with 20 insertions per variant and injection cylinder with six repetitions per soil depth and variant.

Weather conditions

Generally during August 2001 it was very warm and dry: soil temperature (-5 cm) 21.3 °C, air temperature (5 cm) 18.8 °C and precipitation 13.5 mm. During the compacting operations in December 2000 the

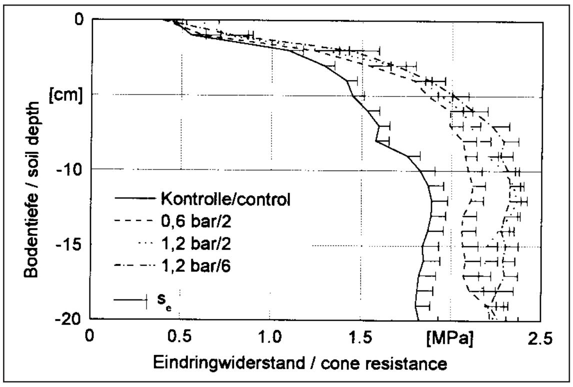

Fig. 1: Cone resistance of differently compacted areas; treatment: tyre pressure/number of passes

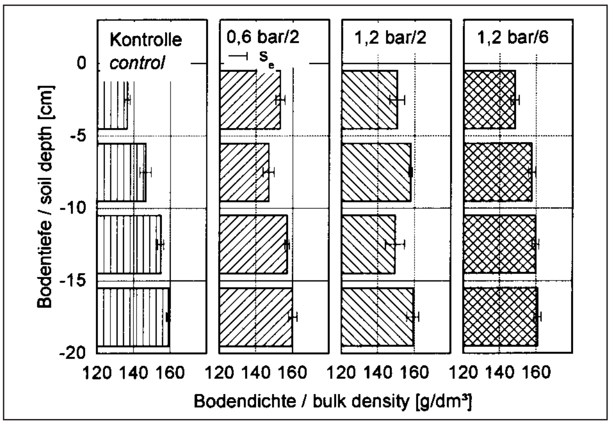

Fig. 2: Soil bulk density of differently compacted areas; treatment: tyre pressure/number of passes

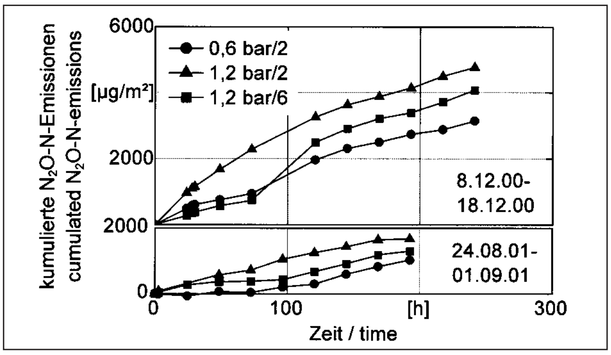

Fig. 3: Cumulated N_2O-N-emissions from compacted soils; treatment: tyre pressure/number of passes

weather was generally very wet and cool causing the soil to be strongly compacted. During the second recording series the underground was still very dry and because of this penetrometer measurements were only carried out to 20 cm and the injection cylinder samples not taken until one month later (soil moisture 17 to 20%).

Soil compaction

It was clear through the penetrometer measurements that in a 10-month period frost working and soil organisms had achieved no significant loosening of compaction (*fig. 1*). The non-compacted control areas showed the lowest penetration resistance with the highest showed by variant 3 (1.2 bar/6).

The October 2001 injection cylinder samplings returned similar results in the case of variant 1 -5 cm as with both other compaction variants. However these showed in the depth between -5 and -10 cm a recognisably lower compaction which was comparable with the non-compacted area (*fig. 2*). In the range from -10 cm depth, hardly any difference between the variants was recognisable. The correlations of penetrometer measurements with soil compaction from the injection cylinder sampling showed that in a comparison of both measurement methods it is still not possible to deduce the soil density from the penetration resistances. With two of the variants (0.6 bar/2 and control) the correlations were very good whilst the other two (1.2 bar/2 and 1.2 bar/6) showed very little agreement.

Nitrous oxide emissions

The cumulated emissions following liquid manure application indicated in both measurement campaigns that the variant 2 (1.2 bar/2) led to highest emissions (*fig. 3*). The variant 3 (1.2 bar/6) and the variant 1 (0.6 bar/2) emitted in December only around 81/78 and in August 66/61 % the nitrous oxide of variant 2.

A reason for the relatively low emissions from the markedly compacted areas could lie in the very marked surface sealing of the areas, leading to substantial reduction of gas diffusion so that the period during which gas was sealed in the soil increased and thus gave opportunity for further conversion activity.

The very low emission values in August 2001 can be traced to the high and effective conversion conditions mainly present at this time of year. With these, only very small areas of nitrous oxide were emitted from the applied manure: 0.002 to 0.0095% of the manure nitrogen. Sometimes even negative emissions were observed (variant 1 after 24 h).

In the correlation of emission values with the results of the injection cylinder sampling (soil compaction) and the penetrometer measurements (penetration resistance) it was clear that the soil compaction correlated very much more badly with the nitrous oxide emissions as with the penetration resistance (*fig. 4*).

The penetrometer measurements showed good correlations in a depth of 0 to -5 and – 10 to – 15 cm.

Table 1: Coefficients of correlation (Pearson) of measurements with penetrometer and injection cylinder samples to a depth of 20 cm

Variant	0	1	2	3
Tyre pressure (in bar)	No	0.6	1.2	1.2
Number of passes	passes	2	2	6
Corr. coefficient r	0.994	0.985	0.240	0.426

Summary

In total the results presented here show that a reduced tyre pressure of 0.6 bar and the lower ground pressure associated with this has a positive effect on nitrous oxide emissions. The results here indicate that a marked compaction brought about by high tyre pressures and unsuitable weather conditions can be negatively evaluated with regard to nitrous oxide emissions. Where the compaction is even more marked the emissions reduce again although this behaviour is not of any use in farm production on yield and soil protection grounds.

Literature

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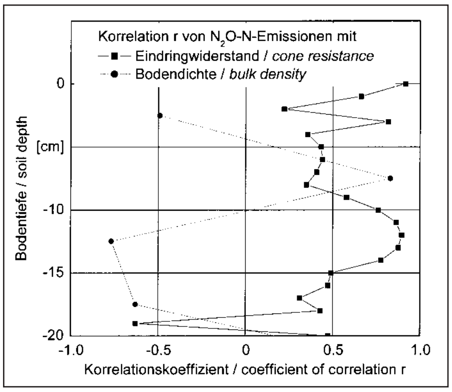

Fig. 4: Correlation (Pearson) of nitrous oxide emissions with cone resistance and bulk density