Interreg Baltic Sea Region

Baltic Slurry Acidification

EUROPEAN REGIONAL DEVELOPMENT FUND

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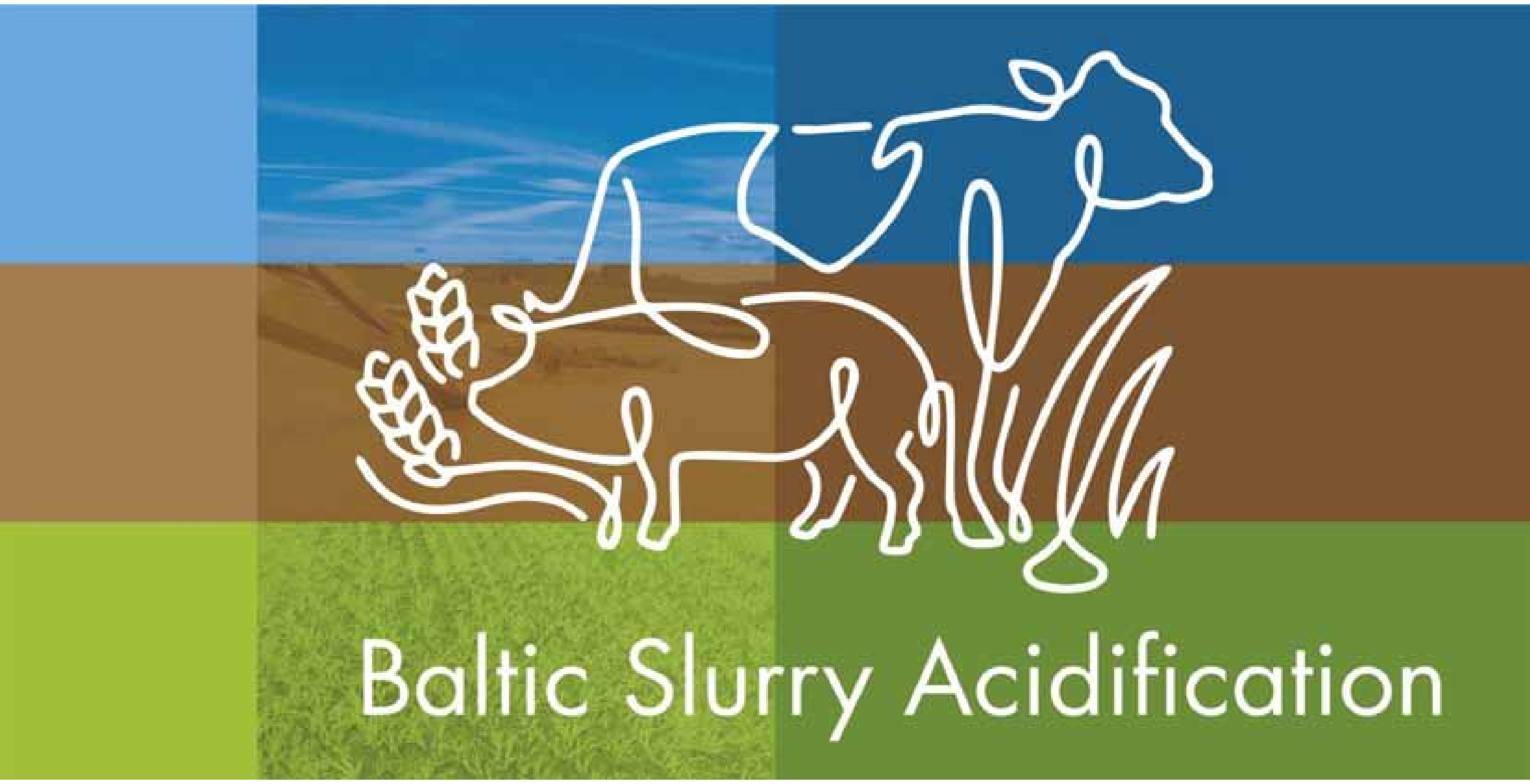

Methodology, results collection and Partners practical experiences 2016-2018

WP4 Field Trials, activities 1-2

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EU STRATEGY FOR THE BALTIC SEA REGION FLAGSHIP

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WP4 Field Trials:Methodology, collection of results and Partners' practical experiences 2016-2018

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Preface

Ammonia emissions is a major problem associated with management of animal slurry, and solutions to overcome this problem are required worldwide by farmers and stakeholders. An obvious way to minimize ammonia emissions from slurry is to decrease slurry pH by addition of acids or other substances. This solution has been used commonly since 2010 in Denmark, and its efficiency with regard to the minimization of NH3 emissions has been documented in many studies. Nevertheless, there is still a need for more studies on impact of such treatment, since the studies performed so far have provided different scenarios.

Baltic Slurry Acidification is an agro-environmental project financed by Interreg Baltic Sea Region under the priority area Natural resources and specific objective Clear Waters. A budget of this project is more than 5 million euros, of which 4 million euros is funded by the EU.

The aim of the project has been set taking into account the fact, that livestock manure is the main source of ammonia-nitrogen emissions in the Baltic Sea Region. So, the aim of the project is to reduce nitrogen losses from livestock production by promoting the use of slurry acidification techniques (SAT) in the Baltic Sea Region and thus mitigating eutrophication of the Baltic Sea.

The project clarifies technological aspects and potential risks of acidification, analyses the environmental and economic implications, conducts market analysis and suggests policy recommendations that could help dissemination of SAT technology. This technology has been widely used in Denmark, and it has given positive results in many ways.

The Baltic Slurry Acidification project started in March 2016 and will continue until February 2019. Seventeen partners from eight Baltic Sea Region countries have cooperated implementing this project. The lead partner is RISE Research Institutes of Sweden. All of the project's activities are divided into six work packages: WP1 – Project management and administration; WP2 – Technical feasibility studies; WP3 – Pilot installations and demonstrations; WP4 – Field Trials; WP5 – Environmental and economic implications; and WP6 – Policy recommendations and analyses of markets and legislation.

Each work package has its own objectives. The partners that were included in the relevant work package had to implement these objectives through different activities.

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Introduction to activities in field trials (WP4)

The aim of WP4 is to reach a broad base of farmers and other end-users in each country, raise their awareness, increase knowledge and help them to build confidence relating to the effects of slurry acidification technologies (SATs). This WP acted as a link between the pilot installations and farmers.

These specific objectives of WP4 were implemented by preparing methodology for SAT testing, partners' activities in field trials (FT), and collecting information from partners about activities of testing acidified slurry.

WP4 organized Information events for farmers and other end-users of such knowledge, advisers, relevant Nongovernmental organizations (NGO) as well as public authorities and policy makers.

Aside from the aims of this WP, the results of field trials were delivered and used in WP5 to verify theoretical estimates of impacts of SATs that were evaluated through environmental and economic analyses.

It can be stated that all activities of partners in WP4 were very intensive and creative. Partners were strongly oriented towards getting new knowledge on using of acidified slurry. Their great interest in this WP was natural and engaging local stakeholders, researchers and policy makers. It is evident from annual reports and visual material of Information events.

It should be noted that the report about WP4.1 and WP4.2 activities was not planned in the first stages of the project. This idea was offered by an expert (external partner Jūratė Aleinikovienė, ASU), who had been asked to evaluate the forthcoming results of field trial activities in 2017. In addition to elaborated excel sheets on every trial circumstances and results, it was suggested to provide a text document to WP4 that could present more concrete views on activities implemented. During the Steering Group's Skype meeting (early spring, 2018), it was decided that such text material with more concrete explanations and photos about partners activities in the field would help other partners and people interested to have a more general view about the activities in WP4. So, before starting field trial season 2018 all partners that had been and would be involved in the activities of field trial were asked to present their activities both in Excel format and in Word.doc format with visualisation of their activities.

In this report, the determination of Methodology for field trials, field trials carried out in diferent countries during implementation of project and finally a short material from Information events are presented.

Summarised results from all field trials (WP4.2) have been used as a basis for the report WP4.3 "Guidelines and recommendations". This report is provided as a separate document of outcomes from WP4.

For comfortable use it is useful to know that e-version of this report contains interactive List of Contents and additional information (raw material – Report forms in Excel from field trials).

Gintarė Kučinskienė,

BSA WP4 Leader

January 2019

Determination of Methodology for field trials

Introduction

The first WP4 task in this project was to determine clear, short and easy to use methodology and possible plan schemes to test SATs. It was a tricky task because from the very first discussions it was seen that almost every country had a special requirements for manure/slurry management and quite diferent posibilities to implement testing plans. After the discussions it was decided to write/prepare the Methodology and the sheets for Result collection.

From the begining, it was clear that the partners will be busy with two types of activities in FTs: scientific and demonstration.

Of course, most of the partners (institutes, research centres) had already had scientific trial exprience and they started their activity with FT quite early – since 2016.

Below the Methodology document under the name ”Basic Recomendations for Field Trials” is presented. This short document iliustartes common understanding of main principles that were followed in field trial activities.

Updated Report forms of every year for result collection can be found in e-version of this report after each partner annual report.

Basic Recommendations for Field Trials

The author: Gunnar Lundin from RISE Research Institutes of Sweden

Background

The main task of field trials is to compare the effects of using untreated and acidified slurry on crop production in every country. Field trials can be carried out at two different levels:

1) Scientific field trials

2) Demonstration field trials.

For the scientific field trials, it would be most beneficial if the same experimental layout and factors examined were the same in every country, however, it is just a recommendation.

For the demonstration trials a greater degree of freedom is possible.

This document is intended to give an overview of criteria that should be considered when deciding on when, where and how to perform scientific and demonstration field trials within the project in each country.

Due to the nature and cost of conducting scientific field trials, they will likely be limited to one location in a particular country. In order to give us an indication of acidification effects across a larger gradient of conditions, we can use the demonstration field trials.

Safety

Sulfuric acid is VERY risky to handle! It is classified as a D1A-Very Toxic Chemical and shall be handled accordingly.

All staff engaged with these activities should be educated in safety techniques and proper handling methods for sulfuric acid.

At manual handling of sulfuric acid the staff should be equipped with protective clothing and respiratory protection in the form of a full face mask

Manual handling of sulfuric acid should never be recommended to be used by farmers.

Scientific field trials

Aim

The aim of the field trials is to examine to which extent acidification of slurry improves the nitrogen uptake at crop cultivation.

Experimental design

Trials should be performed as a randomized complete block design. A minimum of 3 replicates (blocks) however, 4 replicates is better. Block location should be selected so that all treatments within the block have similar conditions. Each treatment must be included once in each block and the treatment locations must be randomly assigned to plots within each block. The purpose of randomizing the location is to avoid biasing the results.

Treatments should be:

- Control (unfertilized)
- Mineral fertilizer
- Untreated Slurry
- Acidified Slurry

For all treatments (except control) the crop should be fully supplied with P, K and S so that N will be the limiting factor. In this way the trial will highlight the nitrogen effects of acidification.

Preferably, there should be a stepwise increasing nitrogen rate of mineral fertilizer from zero and up to an overoptimal economic rate. If only one mineral fertilizer treatment will be included, it should provide a mineral N dose equal to the NH4-N content of the slurry.

Acidified slurry should be essentially exactly the same as untreated slurry except that it was acidified prior to spreading.

Possible additional treatments:

- Untreated and acidified slurry treatments that do not receive pre- application with sulfur. This will illustrate the sulfur effect of using acidified slurry which could be particularly important in areas where farmers typically do not fertilize with sulfur.
- Treatments with digestate.
- Treatment with injected untreated slurry. This will illustrate the comparison of acidification to injection techniques.

Field location

Things to avoid when choosing a test site:

- Fields with high variability in topography, water gradients, soil types or other.
- Soils with high N-delivering capacity (= organogenic soils).
- Fields where the preceding crops are known to have nitrogen effects.
- Fields with a history of frequent or heavy organic plant nutrient supply.
- Fields where manure was spread either earlier the same year or the autumn before.

Select a uniform and representative portion of the field for the test site. If variability cannot be avoided, account for its effects by laying out the blocks oriented across the direction of the variation, so that all treatments within the same block have reasonably similar conditions.

Crop

In general, acidification of slurry offers the greatest relative advantage when spreading in growing crops; normal tillage incorporation is not possible and injection techniques can be both costly and damaging to crops.

Otherwise, the crops chosen for the field trials mainly depend on the slurry type:

- Cattle slurry – grassland;
- Pig slurry –grains (wheat or barley).

Avoid crops with high N-delivering capacity (grassland with high content of legumes etc.)

Plant nutrient rates

Rates of plant nutrient supply should be adapted to prevailing circumstances according to below.

Soil: Class and plant nutrient status.

Crop: Expected dry matter yield and desired quality parameters

Slurry acidification

Slurry should, if possible, be acidified just before spreading to avoid a raise in pH after acidification which is due to the buffering capacity of slurry. Concentrated sulfuric acid (94-98%) is most commonly used in Danish acidification techniques, but it is also possible to work with lower concentrations.

Document the amount of acid used per volume of slurry during acidification. Note that concentrated sulfuric acid has a density of 1.84 g/cm^3.

Add enough sulfuric acid to the slurry according to below.

1) If the acid is added in the same moment as the spreading the pH-value should be lowered to 6.4.
2) For systems with duration times up to 24 hours between adding and spreading the pH-value should be lowered to 6.0.
3) For even longer duration times the pH-value should be lowered to 5.5.

The most convenient and safest way for acidification is to use some SAT installation. If such are not available the acidification has to be done manually according to below.

Acid should be added slowly to untreated slurry during constant mixing. A large amount of foaming is possible so leave adequate space in the mixing tank or bucket so the foam does not spill over. A number of silicon based anti-foaming agents can also be used to control the foaming.

If it is difficult to manage correct monitoring of pH under dosing - mixing, it is possible to add a predetermined amount of acid to the slurry based on earlier lab tests (titration) to determine the amount needed to reach the desired pH-value.

Slurry spreading

Slurry spreading in the field trials should be conducted on normal dates depending on local circumstances.

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Acidification is a technique to decrease ammonia-nitrogen loss from slurry which in turn has positive correlations with sunny, warm and windy conditions. The losses take place during several days after the application. To get representative results in the trials spreading should preferably be conducted during periods with normal weather situations. Consequently, avoid application during low temperatures, when rain is expected or wind still conditions.

During the day for spreading and five days thereafter meteorological data should be documented according to:

- Temperature;
- Wind speed;
- Precipitation.

Slurry analysis

Samples of untreated and acidified slurry respectively taken just prior to spreading should be analyzed for: Dry matter content, Total N, NH4-N, P, K, S and pH-value.

Harvest

At harvest yields are determined and samples should be taken for analysis of: Moisture content and protein content (in oil seed rape oil content).

Demonstration field trials

Aim

The main emphasis on the demonstration trials is on visual impact. However, some basic measurements on yield can be gathered for general comparisons.

Method

The most simple demonstration trial is the strip design and will include treatments:

- Untreated slurry
- Acidified slurry

Both treatments will receive equal doses of slurry, and the only difference will be that the acidified slurry was acidified prior to spreading. Strips should be wide enough to allow yield sampling from the middle of the strip. Yield sampling can be done by either: 1) collecting and weighing the harvest from one cutting width along the center of each strip, 2) one smaller yield sample (0.5-1 m2) is taken from the middle of each strip, or 3) multiple samples (3-10) are taken randomly from each strip and the averages are compared for each strip. Results should be interpreted with discretion since they can show general trends but not statistically significant differences.

Another method that could be used for demonstration trials could allow for a larger paired t-Test analysis. On multiple fields, possibly even on multiple farms, half of the field would receive untreated slurry and the other half would receive acidified slurry. Choosing which half is acidified should be random and could be determined by flipping a coin. This would suit well to be used in conjunction with the in-field acidification SATs, since the acidification could simply be turned on or off half way through the field. Yield would be sampled by taking single or multiple paired samples along the treatment gradient of each field. Alternatively average yield and quality parameters could be collected from the farmers harvest data.

Field location and crops

The same field location and crop recommendations as described for the scientific trials should be followed here.

Slurry rates

Slurry spreading rates should be based on nutrient contents in the untreated slurry and local conditions.

Slurry analysis

Samples of untreated and acidified slurry respectively taken just prior to spreading are recommended to be analyzed for: Dry matter content, Total N, NH4-N, P, K, S and pH-value.

Harvest

At harvest yields are determined/estimated and samples would preferably be taken for the analysis of: Moisture content and protein content (in oil seed rape oil content).

Field Trials Reports

ESTONIA

Estonian Crop Research Institute

General information:

<table>
<tr><th rowspan="2">Project partner</th><th rowspan="2">Contact person</th><th rowspan="2">Type of activity in Field Trial</th><th colspan="2">2017</th><th colspan="2">2018</th><th rowspan="2">Ammonia emission</th></tr>
<tr></tr>
<tr><td rowspan="3">Estonian Crop Research Institute</td><td rowspan="3">Kalvi Tamm kalvi.tamm@etki.ee</td><td rowspan="2">Scientific</td><td>Grassland</td><td>Winter wheat</td><td>Grassland</td><td>Winter wheat</td><td rowspan="3">Ammonia losses were not measured</td></tr>
<tr><td>Cattle slurry</td><td>Pig slurry</td><td>Cattle slurry</td><td>Pig slurry</td></tr>
<tr><td>Demonstration</td><td>-</td><td>-</td><td colspan="2">Grassland
Cattle slurry</td></tr>
</table>

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

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Report of Estonian Crop Research Institute

Summary

The field trials with winter wheat were carried out between April and August in 2017 and in 2018, and with grassland – between April and August in 2017 and between April and September in 2018. The experiment was located in the Üksnurme, Saku (Figure 1). The field trials are characterized as calcaric cambisol with sandy loam. Winter wheat pre-crop was red clover, calculated N impact is 50 kg/ha. The same choice to spread slurry was made every year: cattle slurry on grassland and pig slurry on winter wheat.

Background

Baltic Slurry Acidification is an EU project where the main goal is to study possible applications of slurry acidification techniques in the context of Baltic Sea region. The possible effects behind these techniques are beneficial effects on environment: the reduction of ammonia emission from livestock production and decreased eutrophication of the Baltic Sea. Three slurry acidification methods have been established and successfully employed in Denmark. In Estonia, in-field acidification of livestock slurry during field spreading was applied.

Aim

The aim of this study was to evaluate the effect of acidification on the nitrogen emission of cattle slurry on grassland and of pig slurry on winter wheat (variety `Edvins`); also to evaluate a yield of the crop as well as on soil chemical and microbiological property treated with slurry.

Specification of sulfuric acid and safety issues

Concentrated (96%) sulfuric acid (Sigma-Aldrich) was used for acidification of slurry. The titration of slurry samples with acid was carried out in Estonian Crop Research Institute (ECRI) laboratory before the field trials to determine the amount of acid needed to reach the desired target pH. Subsequent acidification of the slurry used in the field trials was carried out outside near the area of experiment.

Persons handling sulphuric acid were aware of safety issues and equipped with protective clothing. The handling of sulfuric acid was manual and should never be recommended for farmers.

Figure 1. The location of experiment (red) was in the Üksnurme, Saku, Estonia.

2017, grassland

Written by: Kalvi Tamm, Taavi Võsa, Liina Edesi, Elina Akk, Tiina Talve, Raivo Vettik, Kaspar Vulla

Materials and methods

Study site

Permanent grassland with 23 different plant species was determined (of which 6 were grass species, 3 legumes and 14 other species).

Soil samples were taken before fertilization from two layers of soil on 10.04.2017 to determine initial content of chemical elements (Table 1).

Table 1. *Content of chemical elements in soil samples before fertilization (10.04.2017)*

Layer cm	pH_{KCl}	N_{tot}, %	C_{org}, %	P, mg/kg	K, mg/kg	SO4, mg/kg	Ca, mg/kg	Mg, mg/kg	Mn, mg/kg	Cu, mg/kg	B, mg/kg	Zn, mg/kg
0-10	6.6	0.48	5.5	30	169	9.1	4095	212	50	1.4	1.94	2.6
10-20	6.8	0.41	4.6	17	137	7.4	4365	185	58	1.4	1.84	2.1

Field trials were conducted with 4 variants of treatments. Every variant had 4 replications. The treatments were: (1) control (unfertilized), (2) mineral fertilizer (+70 N), (3) untreated cattle slurry and (4) acidified cattle slurry (Table 2, Table 4, Figure 2). Plot sizes were 2.5 X 10 m (25 m2). The placement of variants/replications was randomized.

Table 2. *Variants on grassland trial.*

Variant no	Variant description
1	Control (unfertilized)
2	+70 N with mineral fertilizer
3	untreated cattle slurry
4	acidified cattle slurry

Analysis of slurry component and titration

About 1 m^3 cattle slurry was collected to IBC tank from cattle farm (Kehtna Mõis OÜ, ≈ 700 cattles) on April and transported to the ECRI, Saku, Harjumaa. Components of initial slurry, untreated slurry (before spreading) and acidified slurry (before spreading) were determined in accredited laboratory of Agricultural research centre, Estonia (Table 3).

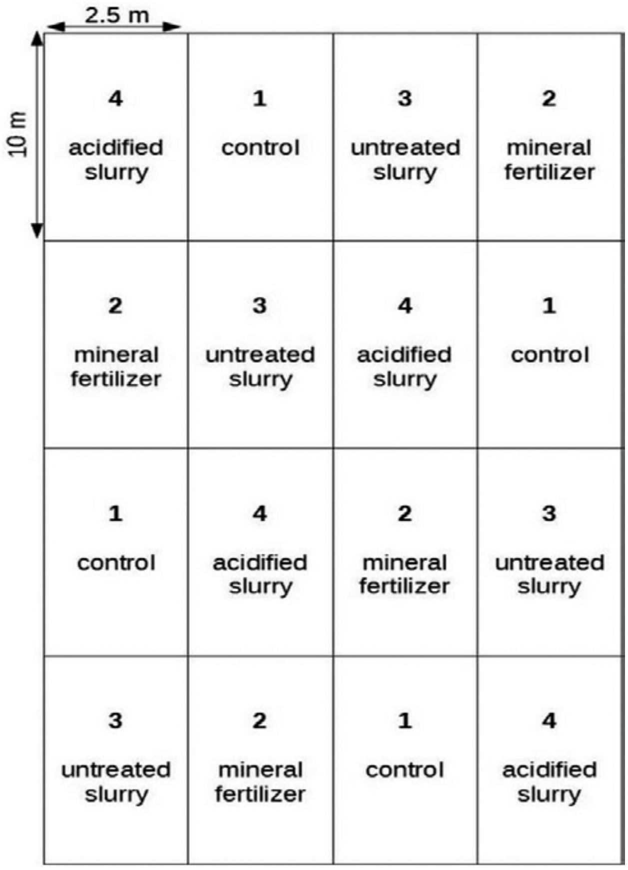

Figure 2. *Scheme of field trials. Every variant had four replications with the size 25 m2 (2.5 x 10 m). The placement of replications is randomized.*

Table 3. *Cattle slurry properties after bringing from farm (initial slurry), and 1 hour before spreading (untreated slurry and acidified slurry)*

Slurry	pH_{KCl}, (labor)	pH H_2O, (field)	Dry matter, %	C_{org}, %	Ca, %	S, %	N_{tot}, kg/m^3	NH_4-N, kg/m^3	P, kg/m^3	K, kg/m^3
Initial analysis	7.9	-	8.0	40.1	0.112	0.029	3.8	2.3	0.59	2.2
Untreated Slurry*	7.6	6.9	7.5	38.1	0.159	0.035	5.5*	2.1	0.9*	3.5*
Acidified slurry	5	5.54	7.7	36.7	0.146	0.257	3.8	2.4	0.6	2.3

*Measured values of N_{tot}, P and K are extraordinary too high.

A titration was performed in ECRI laboratory to assess the amount of sulfuric acid needed to acidify the slurry on the field trial. Three mixed cattle slurry samples were taken (approximately 500 g, average of three samples). Slurry was titrated with sulphuric acid with an interval of 0.2 ml to reach the pH

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value of 5.5. Samples were continuously mixed with magnetic mixer. The pH was measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Titration process took about 10 hours and final pH 5.62 was achieved with 3.2 ml of H_2SO_4 used for 500 g of sample (Figure 3). In addition, the pH of acidified slurry decreased to 5.16 after 24 h.

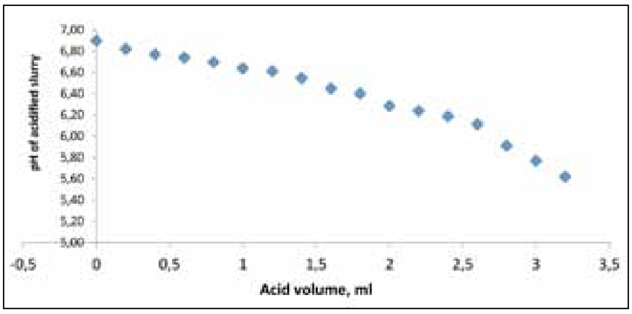

Figure 3. *Titration curve of cattle slurry (≈500 g). Titrant was concentrated (96%) sulphuric acid*

Slurry acidification

In total, 5.14 l/m³ of Sulphuric acid (96%) was added.

Calculation from titration showed that 5.14 l of sulphuric acid (96%) per m³ of cattle slurry was needed to reach the target pH of 6.0. Mixed cattle slurry was divided into two IBC tanks on 16.06.2017. The pH was measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Composition of non-acidified and acidified slurries was measured in lab.

Slurry spreading

Slurry spreading was made on 16.06.2017, from 11 until 13.00. Weather on spreading time: 16° C, partly sunny, wind 2–4 m/s, no precipitations (EMHI, Harku weather station).

Each plot of variants 3 and 4 got 76 l of slurry (30.4 t/ha). Slurry was spread with 10 l plastic watering cans. Slurry was measured to the watering cans in 6 l portions; each portion was spread to 10 m distance. Spreading was made by two persons, who trained with water before slurry spreading. Every plot was spread by both persons. Helping were 5 persons: two filling cans, two carrying cans and one mixing slurry and documenting.

Table 4. *Plant nutrient supply. Mineral fertilizer (Axan 27-4) was applied on 23 May. Cattle slurry was applied on 16 June after the first harvesting*

Treatments	Fertilization rate, t/ha	N, (NH_4-N) kg/ha	N_{tot}, kg/ha	P, kg/ha	K, kg/ha	S, kg/ha
Control	-	-	-	-	-	-
Mineral fertilizer (Axan)	0.26	70	-	-	-	9.62
Untreated cattle slurry	30.4	63.84	167.2*	27.36*	106.4*	10.64
Acidified cattle slurry	30.4	72.96	115.52	18.24	69.92	78.13

*Measured values of Ntot, P and K were extraordinary too high (in lab, Table 4).

Harvesting

The first cut was taken before fertilization on 9 June. Total yield was calculated over the trial area (4 replications). Dry mass (DM) was 1578±457 kg/ha and crude protein was 18.5%. The second cut was harvested on 1 August with bar mover.

Data analysis

Soil samples (0.5 kg) for chemical and microbial analyses from each treatment in four replications from the 0–20 cm soil layers were taken with a 16 mm diameter auger. The first trial area average soil sample was taken before fertilization (10.04.2017). The second soil samples were taken after the harvest (2.08.2017). Third soil samples were taken 5 months after the slurry spreading (30.10.2017) and final samples for after effect in spring 2018 (25.04.2018).

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Soil enzymatic activity is a sensitive indicator to evaluate the influence of different agricultural practices on the soil processes which are carried out by microorganisms (Watts et al., 2010). Dehydrogenase is an enzyme that occurs in all viable microbial cells (Watts et al., 2010) and therefore important bioindicator, relating to soil fertility (Wolinska, Stepniewska, 2012). For soil dehydrogenase activity (DHA) analyses the soil samples were sieved (2 mm) and stored at 4 °C until analysis in laboratory. Measurements of soil DHA based on Tabatabai (1982). Soil samples (5 g) were incubated at 30 °C for 24 h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product (triphenylformazan) was extracted with acetone and measured in a spectrophotometer at 546 nm.

The data was analysed by ANOVA, the Tukey-Kramer Honest Significant Difference (HSD) test was used via the software *JMP 5.0.1.2* (SAS, 2002).

Final yields were calculated at harvest: dry mass (DM) and percentage of crude protein.

Results and discussion

Soil samples

Soil samples from each plot were taken after harvest (2.08.2017) (Table 5), 5 months after the slurry spreading (7.11.2017) (Table 6) and in spring 2018 (25.04.2018) (Table 7).

Table 5. *The first soil analyses after harvesting (2.08.2017). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	NO_3-N, mg/kg	NH_4-N, mg/kg	Ca, mg/kg	P, mg/kg	SO_4, mg/kg
Control**	6.3^a	0.48^a	19.7^a	1.42^a	3955.3^a	21.0^a	6.00^b
Mineral fertilizer	6.2^a	0.44^a	21.2^a	1.48^a	3701.8^a	21.5^a	6.58^b
Untreated slurry	6.4^a	0.46^a	18.4^a	1.39^a	3930.0^a	23.5^a	6.03^b
Acidified slurry	6.5^a	0.47^a	20.5^a	1.38^a	4089.5^a	24.5^a	17.25^a

*** In one of the control variant replication plot data an anomaly occurred. We decided to leave this plot data out as unrepresentative.*

Table 6. *The second soil analyses 5 months after the slurry spreading (7.11.2017). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	NO_3-N, mg/kg	NH_4-N, mg/kg	Ca, mg/kg	P, mg/kg	SO_4, mg/kg
Control**	6.47^a	0.40^a	4.17^{ab}	4.17^a	3807.67^a	18.67^a	7.70^b
Mineral fertilizer	6.38^a	0.41^a	3.28^b	4.80^a	3756.25^a	19.00^a	8.58^{ab}
Untreated slurry	6.58^a	0.42^a	4.88^a	3.60^a	3876.00^a	19.25^a	7.75^b
Acidified slurry	6.60^a	0.41^a	4.15^{ab}	4.35^a	4038.50^a	19.00^a	9.98^a

** In one of the control variant replication plot data an anomaly occurred. We decided to leave this plot data out as unrepresentative.

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Table 7. *Soil analyses next year spring (25.04.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	Ca, mg/kg	P, mg/kg	K, mg/kg	Mg, mg/kg	SO_4, mg/kg
Control**	6.43^{a}	0.40^{a}	3754.00^{a}	18.00^{a}	132.00^{a}	203.33^{a}	7.53^{a}
Mineral fertilizer	6.43^{a}	0.41^{a}	3724.75^{a}	18.50^{a}	129.50^{a}	199.75^{a}	8.10^{a}
Untreated slurry	6.53^{a}	0.40^{a}	3820.25^{a}	17.75^{a}	142.50^{a}	209.75^{a}	7.50^{a}
Acidified slurry	6.58^{a}	0.41^{a}	3902.50^{a}	21.25^{a}	151.75^{a}	210.00^{a}	8.38^{a}

** In one of the control variant replication plot data an anomaly occurred. We decided to leave this plot data out as unrepresentative.

Significant differences between treatments were tested after harvesting, 5 months after the slurry spreading and in next year spring. Results showed no significant differences (p<0.05) of pH, percentage of N_{tot}, NH_4-N, Ca, P and N_{min} regardless of treatment (Table 5, Table 6, Table 7, Figure 4, Figure 5, Figure 6, Figure 7, Figure 8). Nmin is mineralized N in soil (Nmin = NO_3 + NH_4 concentrations) (Figure 8).

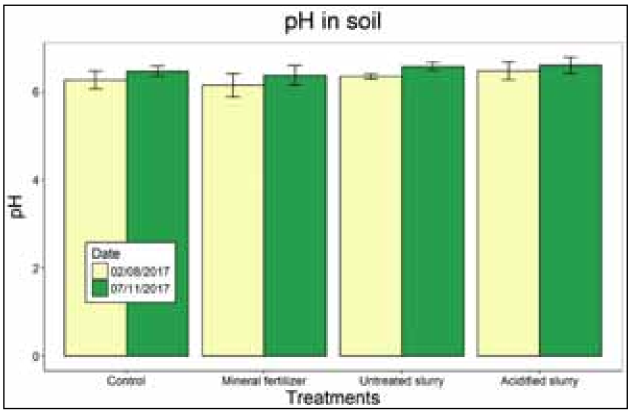

Figure 4. *pH_{KCl} of the soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

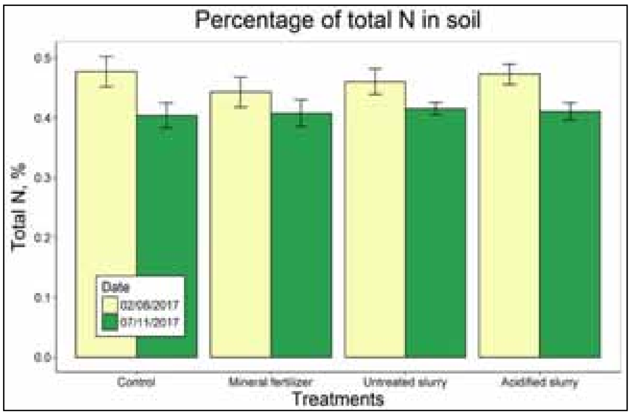

Figure 5. *Percentage of total N during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

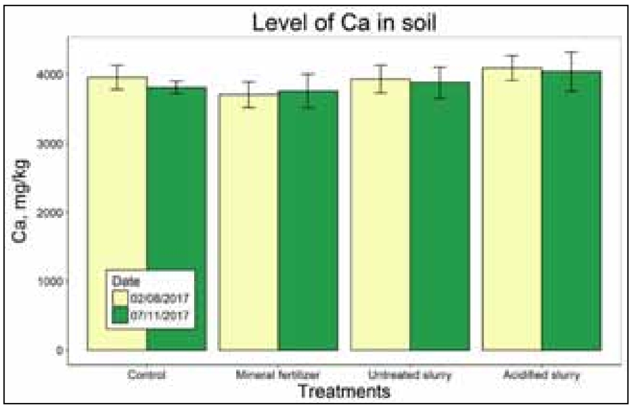

Figure 6. *Amount of Ca in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

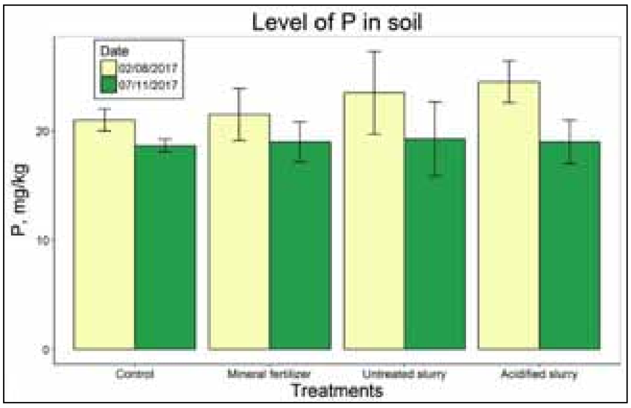

Figure 7. *Amount of P in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

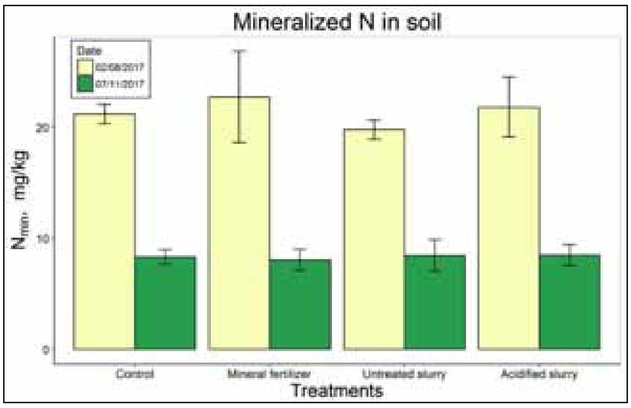

Figure 8. *Amount of mineralized N (Nmin = NO3 + NH4 concentrations) in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

Fertilization of acidified slurry showed significantly higher value of SO_4 after harvesting and 5 months after the slurry spreading (Table 5, Table 6 and Figure 9). After harvest, level of SO_4 in soil was almost three time higher compared to other treatments. However, level of SO_4 decreased 5 months after the slurry spreading but was still significantly different (Table 6, Figure 9). While, in the next year spring the SO_4 content in soil was in all variants similar and no significant differences between treatments did not occurred (Table 7).

No significant differences of NO_3-N were identified in autumn (after harvest) (Table 6). However, significant differences of NO_3-N were identified 5 months after the slurry spreading (7.11.2017) (Table 6, Figure 10). The level of NO_3-N was the lowest in soil with mineral fertilizer and the highest with untreated slurry. Control and plots with acidified slurry were intermediate.

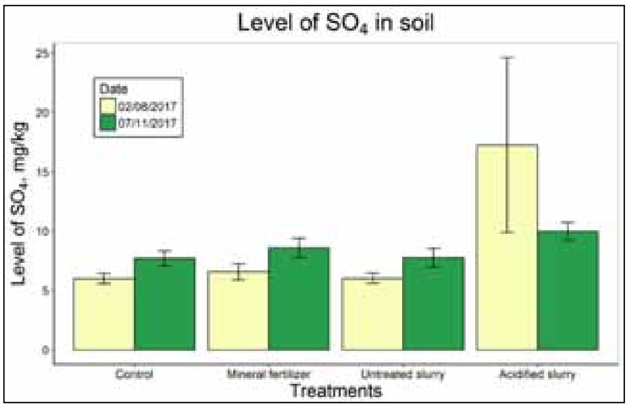

Figure 9. *Amount of SO_4 in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

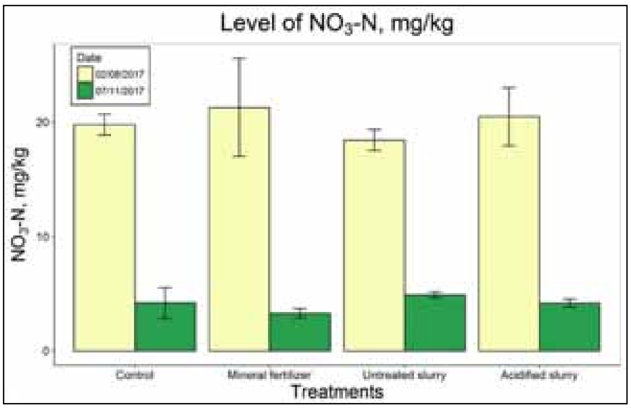

Figure 10. *Amount of NO_3-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

Yield and raw protein after the harvest

The second cut was harvested on 1 August. Significantly higher total yields were observed in plots with mineral fertilizer and the lowest in control and acidified cattle slurry (Table 8, Figure 11). Crude protein percentages were equivalent among all treatments (Table 8, Figure 12).

Table 8. *The yield and crude protein at harvest. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Yield, DM kg/ha	Crude protein, %
Control**	4088.6b	10.77a
Mineral fertilizer	4877.0a	11.68a
Untreated cattle slurry	4350.5ab	10.63a
Acidified cattle slurry	4231.8b	10.95a

** In one of the control variant replication plot data an anomaly occurred. We decided to leave this plot data out as unrepresentative.

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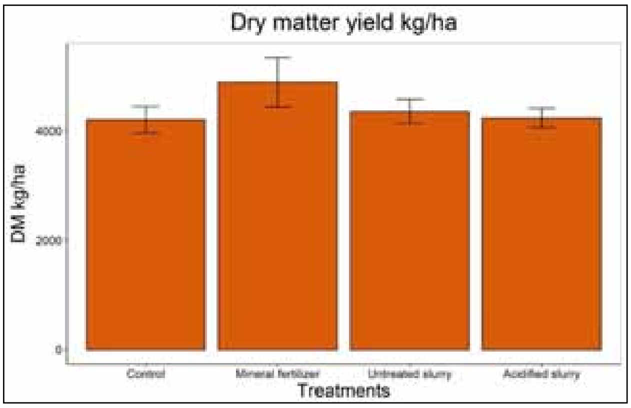

Figure 11. Dry matter yield after harvest. The error bar refers to the standard deviation of the mean (n=4).

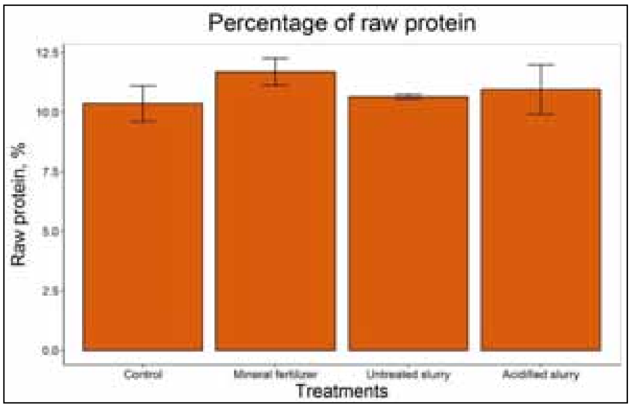

Figure 12. Percentage of raw protein after harvest. The error bar refers to the standard deviation of the mean (n=4).

Soil dehydrogenase activity (DHA)

Results showed high microbial activity in all treatments compared to winter wheat trial, which was probably caused by high soil Corg content (0–20 cm soil layer C_{org} was 5.05). Significantly higher soil DHA was measured in plots with acidified slurry in June and in August after the harvest (Table 9, Figure 13). In the end of experiment (30.10.2017) and in the next year (25.04.2018), no significant differences between treatments were identified. DHA was the lowest in plots with mineral fertilizer.

Table 9. Soil dehydrogenase activity (DHA, TPF µg/g/h). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category

Treatment	26 June	2 August	30 October	25 April 2018
Control**	12.67b	14.85ab	17.27a	16.87a
Mineral fertilizer	13.16b	12.60b	14.81a	14.10a
Untreated slurry	13.18b	16.44ab	17.43a	14.16a
Acidified slurry	18.03a	18.13a	17.21a	16.75a

** In one of the control variant replication plot data an anomaly occurred. We decided to leave this plot data out as unrepresentative.

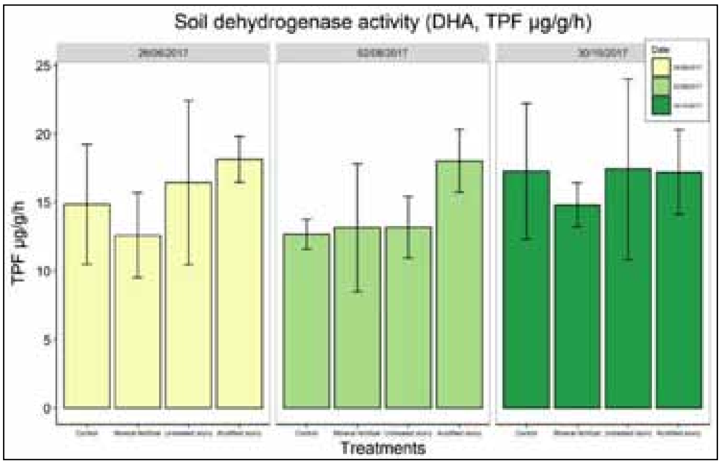

Figure 13. Soil dehydrogenase activity (DHA, TPF µg/g/h). The error bar refers to the standard deviation of the mean (n=4).

Reporting form: 2017, grassland *(please, activate the link below)*
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2017, winter wheat

Written by: Kalvi Tamm, Taavi Võsa, Liina Edesi, Elina Akk, Tiina Talve, Raivo Vettik, Kaspar Vulla

Materials and methods

Study site

Whole trial area was fertilised in autumn 2016 with mineral fertilizer `YaraMila 7-12-25 + S B Mg`, amount 300 kg/ha (Table 1).

Table 1. *Amounts of added chemical elements with mineral fertilizer `YaraMila 7-12-25 + S B Mg`*

	N	P	K	S	B	Mg
Element content in fertiliser, %	7	5.2	20.8	2.6	0.02	1.2
Element amounts, kg/ha	21	15.6	62.4	7.8	0.06	3.6

Samples were taken before fertilization from two layers of soil on 10.04.2017 to determine initial content of chemical elements (Table 2).

Table 2. *Content of chemical elements in soil samples before fertilization (10.04.2017)*

Layer cm	pH_{KCl}	N_{tot}, %	C_{org}, %	SO_4, mg/kg	P, mg/kg	K, mg/kg	Ca, mg/kg	Mg, mg/kg	Cu, mg/kg	Mn, mg/kg	B, mg/kg	Zn, mg/kg
0-10	7.1	0.24	2.7	6.6	98	237	4361	76	2	285	1.85	4.4
10-20	7.1	0.24	2.6	3.4	101	235	4300	77	2	295	1.86	4.4

Field trials were conducted with 7 variants of treatments. Every variant had 4 replications. The treatments were: (1) control (unfertilized), (2) mineral fertilizer (+70 N), (3) mineral fertilizer (+96 N), (4) mineral fertilizer (+130 N), (5) mineral fertilizer (+160 N), (6) untreated pig slurry and (7) acidified pig slurry (Table 3; Figure 1). Plot sizes were 2.5 X 10 m (25 m^2) and the space between plots was 0.5 m. The placement of variants/replications was randomized.

Table 3. *Variants on winter wheat trial*

Variant no	Treatment
1	Control (unfertilized)
2	+ 70 N with mineral fertilizer
3	+ 96 N with mineral fertilizer
4	+ 130 N with mineral fertilizer
5	+ 160 N with mineral fertilizer
6	untreated pig slurry
7	acidified pig slurry

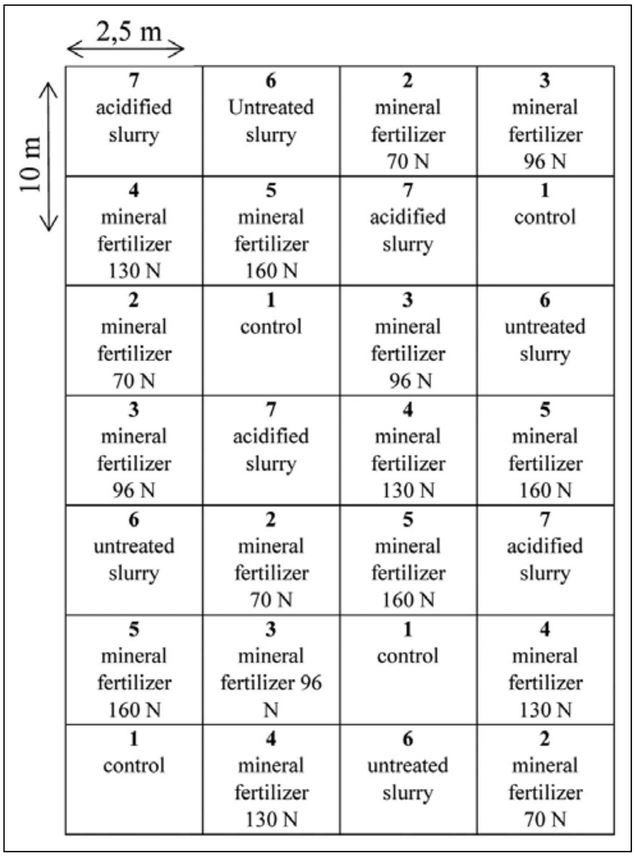

Figure 1. *Scheme of field trials. Every variant had four replications with the size 25 m² (2.5 x 10 m) and the space between plots was 0.5 m. The placement of replications was randomized.*

Analysis of slurry component and titration

About 1 m^3 pig slurry was collected to IBC tank from pig farm (Valdereks OÜ, 6800 places for fatteners plus piglets and 800 places for sows)

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on 07.04.2017 and transported to the ECRI, Saku, Harjumaa. Components of initial slurry, untreated slurry (before spreading) and acidified slurry (before spreading) were determined in accredited laboratory of Agricultural research centre, Estonia (Table 4).

Table 4. *Pig slurry properties after bringing from farm (Initial slurry), and 1 hour before spreading (Untreated slurry and Acidified slurry)*

	pH_{KCl}, (labor)	pH_{H2O} (field)	DM, %	N_{tot}, %	NH_4-N,	C_{org}, %	S, %	P, kg/m^3	K, kg/m^3	Ca, kg/m^3
Initial slurry	7.6	-	0.87	2	2	26.3	0.013	0.11	1.0	0.025
Untreated slurry	7.7	7.43	0.83	2	1.5	29.6	0.002	0.1	1.1	0.150
Acidified slurry	6.3	5.87	1.2	2	1.7	17	0.11	0.12	1.1	0.160

A titration was performed in ECRI laboratory to assess the amount of sulfuric acid needed to acidify the slurry on the field trial. Three mixed pig slurry samples were taken (approximately 496 g, average of three samples). Slurry was titrated with sulphuric acid with an interval of 0.2 ml to reach the pH value of 5. Samples were continuously mixed with magnetic mixer. The pH was measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Titration process took about 10 hours and final pH 4.89 was achieved with 1.8 ml of H_2SO_4 used for 500 g of sample (Figure 2). In addition, the pH of acidified slurry increased to 5.16 after 24 h.

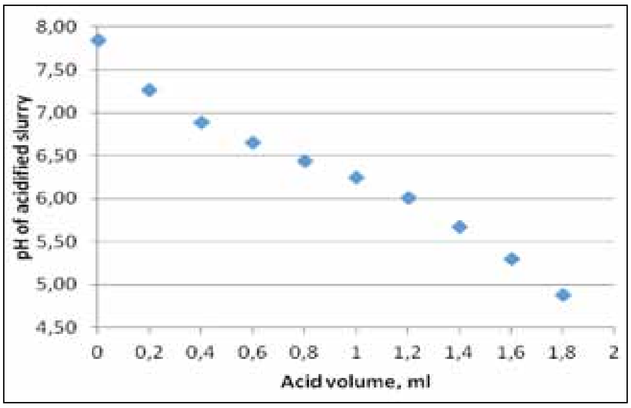

Figure 2. *Titration curve of pig slurry. Titrant was concentrated (96%) sulphuric acid.*

Slurry acidification

Calculation from titration showed that 2.47 l sulphuric acid (96%) per m^3 of pig slurry was needed to reach the target pH of 6.0.

Mixed pig slurry was divided into two IBC tanks on 22.05.2017 (two days before spreading). In one tank the amount of 510 l of slurry was mixed with 1.257 l concentrated H2SO4 on 22.05.2017.

Slurry spreading

Slurry spreading was performed on 24.05.2017 from 11.00 until 14.00. Growth stage of winter wheat was beginning of stem elongation (GS 30). Weather on spreading time: 14° C, partly sunny, wind 3-6 m/s, no precipitations (EMHI, Harku weather station).

Amount of slurry being spread was 48 m^3/ha (Table 6). The pH values were measured before spreading for both untreated slurry and acidified slurry being 7.43 and 6.3 correspondingly. The pH and sample temperatures were measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Slurry subsamples were taken during slurry spreading, mixed, and average samples from both types were sent to the laboratory for component analyses.

Each plot of variants 6 and 7 got 120 l of slurry. Slurry was spread with 10 l plastic watering cans. Slurry was measured to the watering cans in 6 l portions; each portion was spread to 5 m distance. Spreading was made by two persons, who trained with water before slurry spreading. Every plot was spread by both persons. Helping were 5 persons: two filling cans, two carrying cans and one mixing slurry and documenting.

Mineral fertilizer spreading

First mineral fertilizer was spread on 23.05.2017 by hand to the variants 2, 3, 4 and 5 with fertiliser ´NS 27-4´. Growth stage of winter wheat was beginning of stem elongation (GS 30). Additional N was added to the variants of 4 and 5 on 16.06.2017 (Table 5; Table 6). Growth stage of winter wheat was heading (GS 56-58).

Table 5. *Amounts of N with mineral fertilizer to the variants 2, 3, 4 and 5*

Variant No	Applied on 23.05.2017 N kg/ha	Additional N on 16.06.2017 N kg/ha
2	70	-
3	96	-
4	96	+34
5	96	+64

Table 6. *Plant nutrient supply. Mineral fertilizer (Axan 27-4) was applied on 23 May (GS 30 beginning of stem elongation) and the second mineral fertilizer treatment (N 130 and 160) got additional N in 16 June (GS 56-58). Pig slurry was applied on 24 May*

Treatment	Fertilization Rate, t/ha	N, (NH_4-N) kg/ha	P, kg/ha	K, kg/ha	S, kg/ha
Control	-	-	-	-	-
Mineral fertilizer 70 N	0.26	70	-	-	9.6
Mineral fertilizer 96 N	0.356	96	-	-	13.2
Mineral fertilizer 130 N	0.482	130	-	-	17.8
Mineral fertilizer 160 N	0.593	160	-	-	21.9
Untreated pig slurry	48	72	4.8	52.8	1.0
Acidified pig slurry	48	82	5.76	52.8	52.8

Harvesting

The trials were harvested with combine on 24 August.

Data collection and analysis

The first soil samples were taken before fertilization (10.04.2017) from two layers (0–10 cm and 10–20 cm) to determine initial content of chemical elements. The second soil analyses were conducted 2 weeks after slurry spreading (7.06.2017) and before additional fertilizer for 4 and 5 variants (16.06.2017). The third soil samples were taken after the harvest (31.08.2017) and final in next year spring (17.04.2018).

Leaf chlorophyll was measured on the field by SPAD-502 twice. The first measurement was performed on 7.06.2017 during the time of heading and the second measurement on 28.06.2017 at the time of flowering. In addition, raw protein content in leaves was measured on 7.06.2017 during the time of heading.

Final yields were calculated at harvest: volume weight, 1,000-kernel weight, Yield (DM) and total yield (at 14% humidity).

Measurements of soil dehydrogenase activity (DHA) based on Tabatabai (1982). Soil samples (5 g) were incubated at 30°C for 24h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product (triphenylformazan) was extracted with acetone and measured in a spectrophotometer at 546 nm. The data was analysed by ANOVA, the Tukey-Kramer Honest Significant Difference (HSD) test was used via the software *JMP 5.0.1.2* (SAS, 2002).

Disease assessment key used to determine levels of damage on leaves and stem (Lane, 2012). In total, 10 plants in each plot, 40 plants in each treatment were measured. Average diseases occurrence in each treatment was calculated. *Fusarium* fungi occurrence was evaluated on harvested grain (Leslie

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and Summerell, 2006). Hundred kernels from each treatment were placed on *Fusarium* selective broth. The infected kernels were counted and calculated incidence of *Fusarium* after 7 days. Mycotoxin deoxynivalenol (DON) in harvested kernels was measured by gas-cromatography with mass spectrometry (GC-MS, Agilent) according to the method Saastamoinen and Saloniemi, 1997.

Results and discussion

Soil samples

Soil samples were taken two weeks after the slurry spreading and the first fertilization from the plots on 7.06.2017 to determine content of chemical elements. Additional fertilizer to the variants of 130N and 160 N was added after (16.06.2017). Results are in Table 7. Next soil samples were taken and analysed after harvest (31.08.2017) (Table 8) and the final in the next year spring (17.04.2018) (Table 9).

The measurements of pH, Ca and NH4-N showed similar results regardless of treatments (Table 7, Table 8, Table 9 and Figure 4). Level of NO_3-N and Nmin depended on fertilization rate. Two weeks after slurry and mineral fertilizer application in all treatments with mineral fertilizer showed higher rate of NO_3-N and Nmin (Table 7, Figure 3 and Figure 5). Fertilization of acidified slurry showed significantly higher value of SO_4 two weeks after slurry spreading but no differences after harvest and in the next year spring (Table 7, Table 8, Table 9 and Figure 6).

Table 7. *Soil analyses: 2 weeks after slurry spreading (7 June 2016). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	SO_4, mg/kg	Ca, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	7.0^{a}	4.1^{b}	3451.0^{a}	3.3^{d}	0.8^{a}
Mineral fertilizer 70 N	6.9^{a}	5.8^{b}	3345.3^{a}	25.5^{bc}	0.9^{a}
Mineral fertilizer 96 N	6.9^{a}	8.6^{b}	3559.8^{a}	46.9^{a}	0.8^{a}
Mineral fertilizer 130 N	6.9^{a}	7.6^{b}	3340.0^{a}	37.3^{ab}	0.8^{a}
Mineral fertilizer 160 N	7.0^{a}	7.4^{b}	3670.8^{a}	41.9^{ab}	0.7^{a}
Untreated slurry	7.0^{a}	3.0^{b}	3604.5^{a}	13.7^{cd}	0.8^{a}
Acidified slurry	7.0^{a}	36.5^{a}	3772.0^{a}	15.4^{cd}	0.8^{a}

Table 8. *Soil analyses after harvest (31.08.2017). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	SO_4, mg/kg	P, mg/kg	K, mg/kg	Ca, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	7.1^{a}	3.8^{c}	101.3^{a}	273.5^{a}	3710.0^{a}	6.67^{a}	1.25^{a}
Mineral fertilizer 70 N	7.1^{a}	4.4^{c}	101.5^{a}	269.8^{a}	3716.3^{a}	7.48^{a}	1.25^{a}
Mineral fertilizer 96 N	7.1^{a}	5.4^{abc}	100.3^{a}	266.8^{a}	3683.5^{a}	8.36^{a}	1.32^{a}
Mineral fertilizer 130 N	7.0^{a}	6.0^{ab}	97.3^{a}	253.3^{a}	3475.3^{a}	7.92^{a}	1.00^{a}
Mineral fertilizer 160 N	7.1^{a}	7.1^{a}	102.3^{a}	255.0^{a}	3880.3^{a}	7.58^{a}	1.44^{a}
Untreated slurry	7.2^{a}	3.5^{c}	98.3^{a}	289.5^{a}	3926.0^{a}	8.81^{a}	1.33^{a}
Acidified slurry	7.1^{a}	6.8^{a}	97.0^{a}	282.8^{a}	4009.0^{a}	8.01^{a}	1.36^{a}

Table 9. *Soil analyses in next year spring (17.04.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	SO_4, mg/kg	P, mg/kg	K, mg/kg	Ca, mg/kg	Mg, mg/kg	N_{tot}, %
Control	7.03[a]	3.75[a]	96.00[a]	280.25[a]	3548.25[a]	65.25[a]	0.23[a]
Mineral fertilizer 70 N	6.95[a]	3.50[a]	100.50[a]	280.25[a]	3207.00[a]	67.75[a]	0.22[a]
Mineral fertilizer 96 N	7.08[a]	3.68[a]	97.50[a]	281.25[a]	3561.50[a]	64.75[a]	0.23[a]
Mineral fertilizer 130 N	7.03[a]	3.80[a]	99.25[a]	293.50[a]	3424.50[a]	66.50[a]	0.22[a]
Mineral fertilizer 160 N	7.15[a]	3.80[a]	93.00[a]	255.75[a]	3675.25[a]	64.50[a]	0.22[a]
Untreated slurry	7.08[a]	3.73[a]	104.00[a]	296.50[a]	3793.75[a]	67.25[a]	0.23[a]
Acidified slurry	6.95[a]	3.73[a]	107.25[a]	304.50[a]	3211.25[a]	68.50[a]	0.22[a]

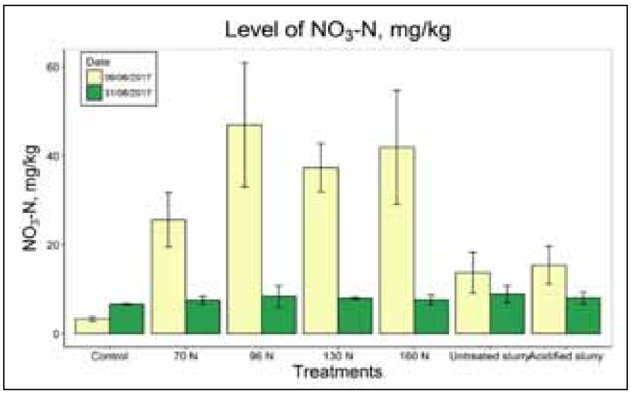

Figure 3. *Amount of NO_3-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

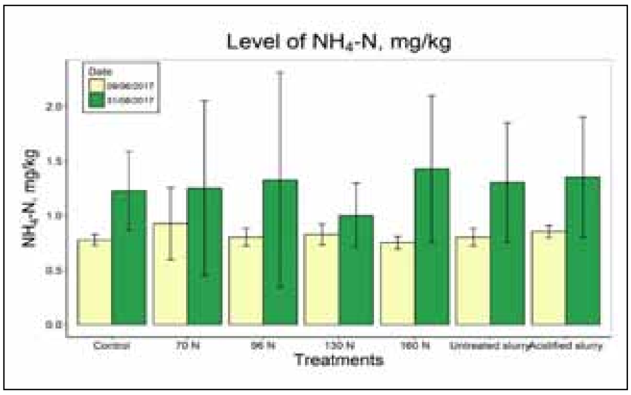

Figure 4. *Amount of NH_4-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

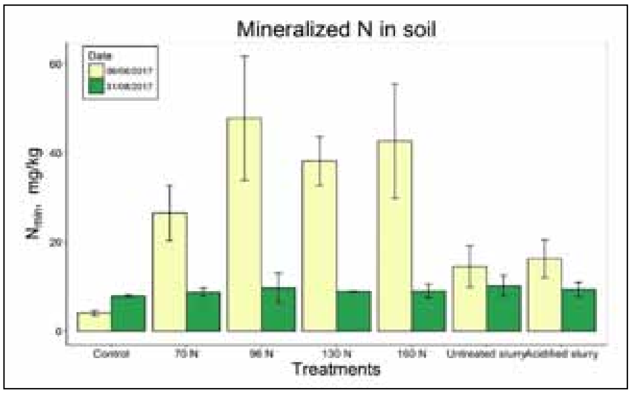

Figure 5. *Amount of mineralized N (Nmin = NO_3 + NH_4 concentrations) in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

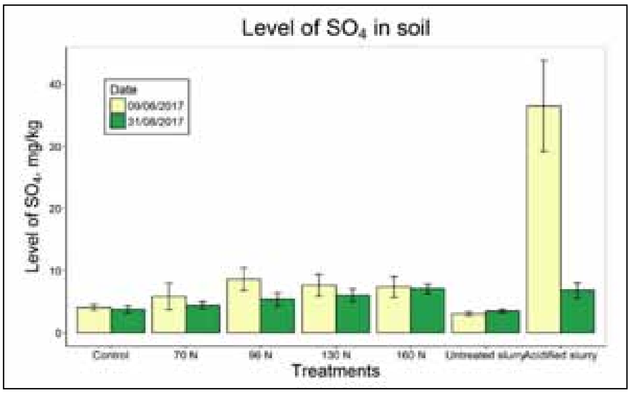

Figure 6. *Amount of SO_4 in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

Leaf chlorophyll and raw protein content

Leaf chlorophyll content in leaves was measured twice: on 7.06.2017 during the time of heading and on 28.06.2017 at the time of flowering (Table 10; Figure 7). Leaf chlorophyll content was the lowest in the control with no fertilization during the experiment (*p<0.05*). Fertilization of untreated and acidified slurry showed the highest value of leaf chlorophyll in the headings but was intermediate at the time of flowering (Table 10). During the time of flowering, the leaf chlorophyll was equally higher in all treatments with mineral fertilizer (variants 2, 3, 4 and 5) (Table 10). Additional fertilizer

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to the variants of 130 N and 160 N was added only 12 days before measurements of leaf chlorophyll (16.06.2017). Results indicate that nitrogen assimilation from slurry was faster compared to mineral fertilizer during the time of heading.

Table 10. *Leaf chlorophyll content by SPAD-502. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	7.06.2017, heading	28.06.2017, flowering
Control	33.8 [d]	32.8 [e]
Mineral fertilizer 70 N	38.4 [bc]	44.6 [bcd]
Mineral fertilizer 96 N	38.7 [b]	45.7 [abc]
Mineral fertilizer 130 N	39.1 [b]	47.0 [ab]
Mineral fertilizer 160 N	37.1 [c]	47.9 [a]
Untreated slurry	41.5 [a]	42.3 [d]
Acidified slurry	42.0 [a]	44.1 [cd]

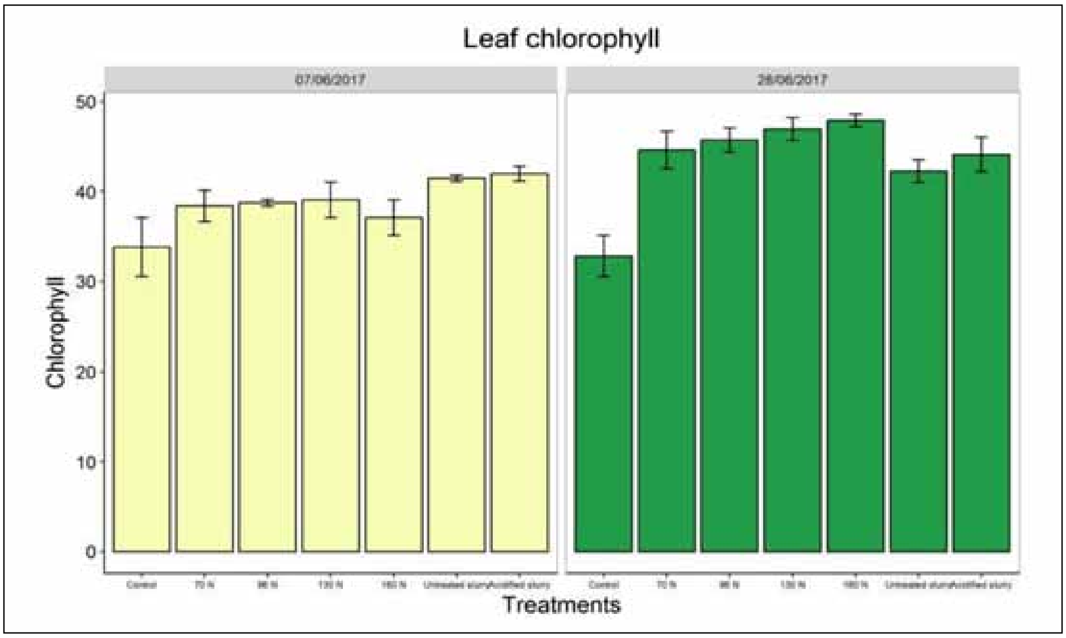

Figure 7. *Leaf chlorophyll content in leaves during the time of heading (7.06.2017) and at the time of flowering (28.06.2017). The error bar refers to the standard deviation of the mean (n=4).*

The raw protein content in leaves was significantly lower in control plots with no fertilization and higher in plots with acidified slurry (Figure 8; Table 11). The variants with mineral fertilizer were intermediate with no differences between treatments (70 N, 96 N, 130 N and 160 N). Additional fertilizer to the variants of 130 N and 160 N was added after the measurements of raw protein (16.06.2017). Results show that fertilization with slurry (untreated and acidified) has positive effect to raw protein content and acidified slurry gives better results compared to untreated pig slurry (Figure 8, Table 11).

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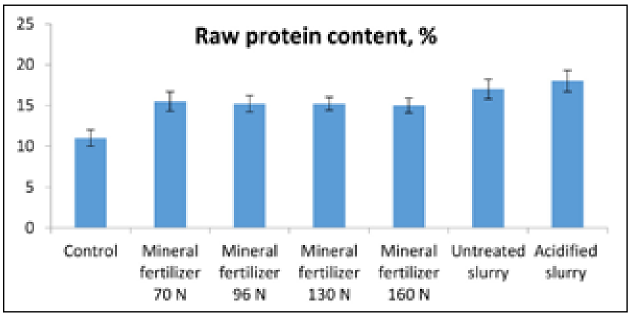

Figure 8. *Raw protein content in leaves (7.06.2017). The error bar refers to the standard deviation of the mean (n=4).*

Table 11. *Raw protein content in leaves. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category. Data of sampling 7.06.2017*

Treatment	Raw protein content in leaves, %
Control	11.0c
Mineral fertilizer 70 N	15.5b
Mineral fertilizer 96 N	15.2b
Mineral fertilizer 130 N	15.2b
Mineral fertilizer 160 N	15.0b
Untreated cattle slurry	17.0ab
Acidified cattle slurry	18.0a

Harvest

In control treatment the wet gluten index, falling number, volume weight and yield was significantly lower than in other treatments (Table 12). Results of 1,000-kernel weight and yield showed no significant differences between the treatments irrespectively of fertilization type (Table 12).

Table 12. *The yield and quality at harvest. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Proteins, % of DM	Wet gluten	Gluten index	Falling number	Volume weight, g/l	1,000-kernel weight, g	Yield, DM kg/ha	Yield, (at 14% humidity) kg/ha
Control	9,98^{d}	21,75^{e}	52,25^{ab}	348,00^{b}	850.3^{c}	50.7^{a}	3967.5^{b}	4522.9^{b}
70 N	10,88^{c}	24,88^{cd}	47,50^{ab}	415,75^{a}	854.7^{abc}	49.2^{a}	5400.5^{a}	6156.6^{a}
96 N	11,51^{b}	26,83^{bc}	43,50^{ab}	419,25^{a}	856.4^{ab}	49.6^{a}	5808.3^{a}	6621.4^{a}
130 N	12,17^{a}	29,18^{ab}	40,50^{b}	424,00^{a}	856.6^{ab}	49.1^{a}	5894.3^{a}	6719.5^{a}
160 N	12,52^{a}	31,18^{a}	43,75^{ab}	424,00^{a}	859.4^{a}	50.7^{a}	5472.6^{a}	6238.8^{a}
Untreated pig slurry	10,69^{c}	24,58^{cd}	55,50^{a}	403,25^{ab}	856.0^{ab}	50.8^{a}	5430.9^{a}	6191.3^{a}
Acidified pig slurry	10,40^{cd}	22,80^{de}	50,00^{ab}	414,00^{ab}	852.5^{bc}	48.9^{a}	5675.3^{a}	6469.8^{a}

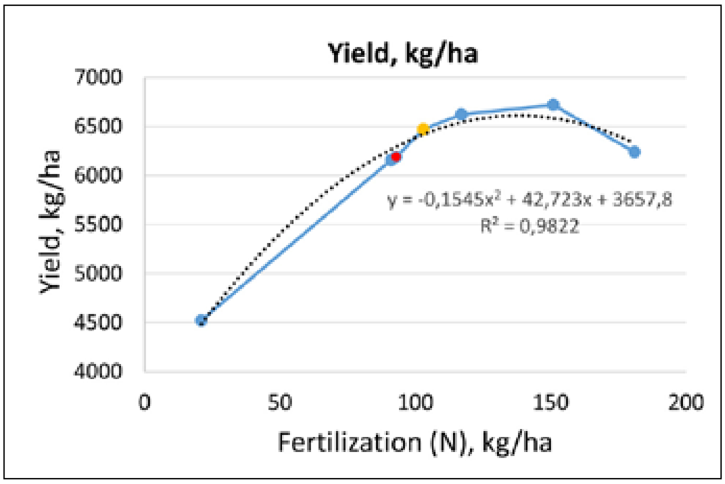

Figure 9. *Regression analyses between yield and fertilization rate. Red dot shows the fertilisation with untreated slurry and yellow dot acidified slurry.*

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Soil dehydrogenase activity (DHA)

In general, soil dehydrogenase activity was expectedly higher in August compared to samples collected in June indicating the higher soil microbial activity (Table 13, Figure 10). The mean value of DHA was the highest in plots with acidified slurry but differences were not significant ($p<0.05$) (Table 13).

Table 13. *Soil dehydrogenase activity (DHA, TPF µg/g/h). DHA of trial area was 7.64 in 10 April before fertilization. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	**7 June**	**31 August**	**17 April 2018**
Control	6.7[a]	7.4[a]	6.23[a]
Mineral fertilizer 70 N	5.6[a]	6.5[a]	7.80[a]
Mineral fertilizer 96 N	6.1[a]	6.5[a]	7.53[a]
Mineral fertilizer 130 N	5.5[a]	7.8[a]	7.31[a]
Mineral fertilizer 160 N	6.2[a]	7.1[a]	7.00[a]
Untreated slurry	6.5[a]	7.2[a]	6.45[a]
Acidified slurry	6.2[a]	8.6[a]	7.67[a]

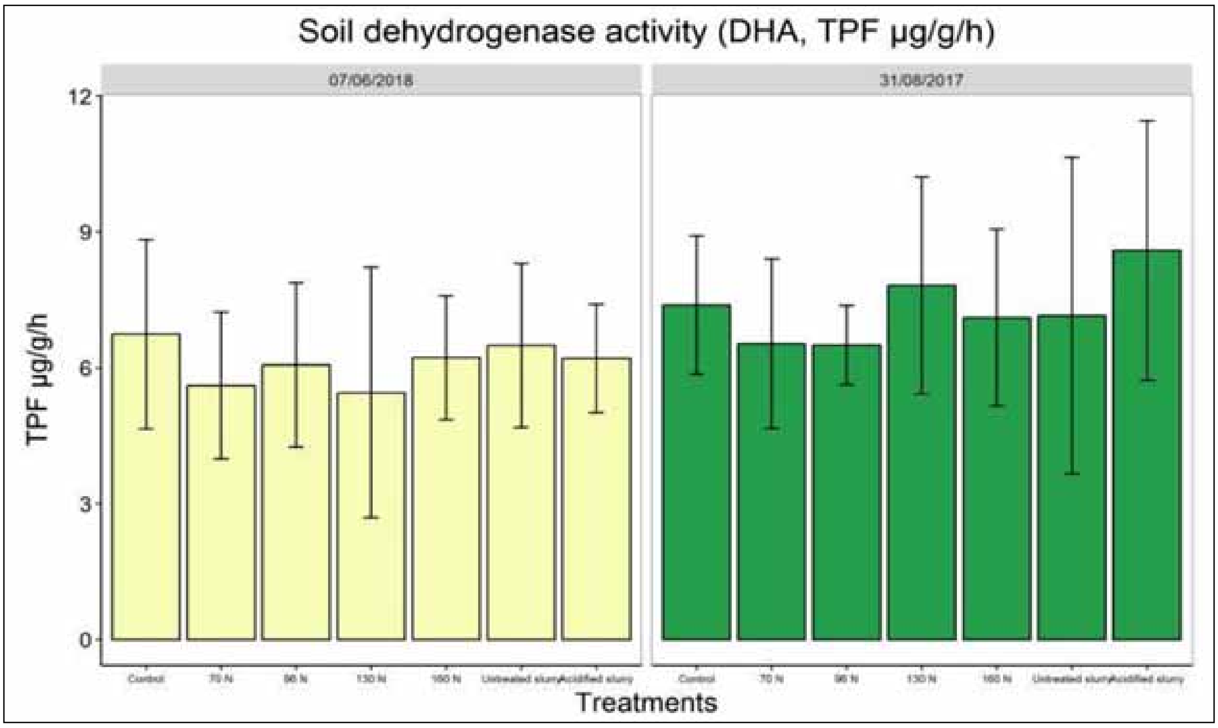

Figure 10. *Soil dehydrogenase activity (DHA, TPF µg/g/h). DHA of trial area was 7.64 on 10 April before fertilization. The error bar refers to the standard deviation of the mean (n=4).*

Diseases occurrence on plant leaves and Fusarium incidence on kernels

Using animal slurry may reduce the infection of plant diseases and decrease occurrence of diseases. Disease of plant leaves was measured on 14.06.2017 during the time of winter wheat heading (GS 56-58).

Plants of winter wheat were contaminated with septoria leaf spot (*Septoria tritici*), tan spot (*Dreschlera tritici-repentis*) and powdery mildew (*Blumeria graminis*) on 14 June at 2017 (GS 56-58). The occurrence of plant diseases was different, depending on treatments.

The occurrence of septoria leaf spot was the highest in plots with mineral fertilizer and the lowest in the plots with slurry treatments (untreated and acidified slurry) (Figure 11).

The occurrence of tan spot (Figure 12) was the highest in the N70 (3.9 %) and N160 (3.8 %) treatments. The lowest occurrence of ran spot was in the treatment of acidified pig slurry (0.3 %). In other treatments, the occurrence of tan spot was intermediate.

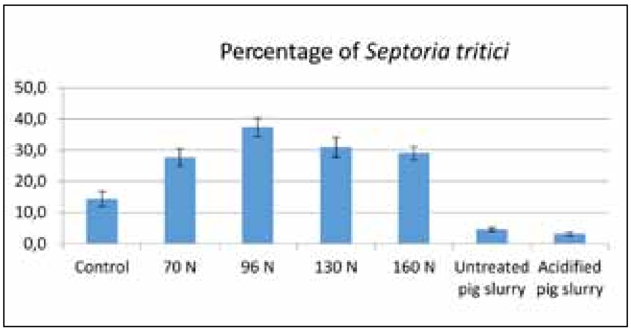

Figure. 11. *The occurrence of septoria leaf spot (Septoria tritici) in winter wheat field trial. The error bar refers to the standard deviation of the mean.*

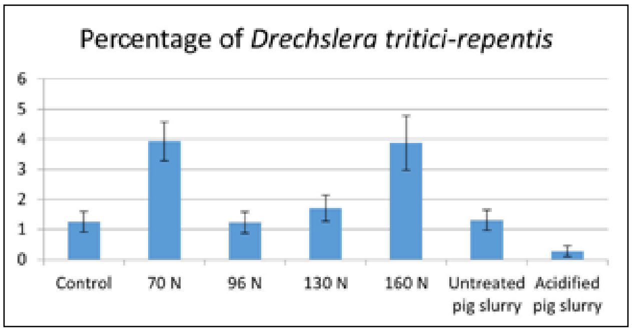

Figure 12. *The occurrence of tan spot (Dreschlera tritici-repentis) in winter wheat field trial. The error bar refers to the standard deviation of the mean.*

The occurrence of powdery mildew (Figure 13) was the highest in the treatment of untreated pig slurry (3.4 %), followed the treatment with mineral fertilizer N96 (1.8 %). The lowest occurrence of mildew powdery was in control.

The winter wheat fertilization with acidified slurry reduced the occurrence of leaf diseases in 2017. There was no effect in the occurrence of powdery mildew.

The incidence of *Fusarium* did not differ clearly between the treatments (Figure 14). The lowest level of *Fusarium* was found in control and N70 and N130. The highest incidence of *Fusarium* was evaluated in acidified slurry treatment. Therefore, acidified slurry increased the incidence of *Fusarium* in kernels compared to untreated slurry.

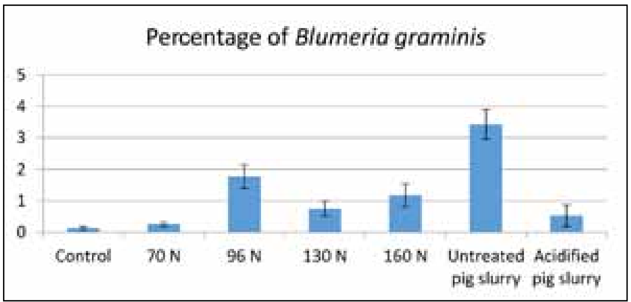

Figure 13. *The occurrence of powdery mildew (Blumeria graminis) in winter wheat field trial. The error bar refers to the standard deviation of the mean.*

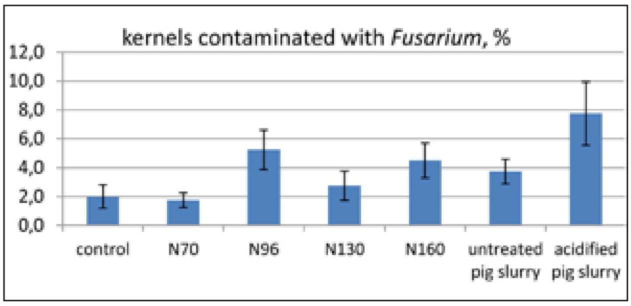

Figure 14. *The incidence of Fusarium spp. in winter wheat kernels. The error bar refers to the standard deviation of the mean (n=4).*

Fusarium fungi in kernel could produce mycotoxins. The main mycotoxin is deoxynivalenol (as an abbreviation DON). The deoxynivalenol causes the health problems for humans and animals. Therefore, it is important to follow all agronomic practises to ensure production of mycotoxins free crops. In winter wheat kernels the mycotoxin DON (deoxynivalenol) did not occurre.

Our results showed that pig slurry application reduced the occurrence of leaf diseases, such as septoria leaf spot and septoria tan spot in 2017. Similar effect of pig slurry was found in earlier research (Bailey and Lazarovits, 2003). But there was no effect on the occurrence of powdery mildew.

Reporting form: 2017, winter wheat *(please, activate the link below)*
https://www.dropbox.com/s/nqikyk5ul1pu4iv/Estonia%20WP4%20winter%20wheat%252C%20 2017%2528Final%2529.xls?dl=0

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2018, grassland

Written by: Kalvi Tamm, Taavi Võsa, Liina Edesi, Elina Akk, Tiina Talve, Raivo Vettik

Study site

The location is the same as it was in 2017.

Permanent grassland with 30 different plant species was determined (of which 10 were grass species, 4 legumes and 16 other species).

Due to the very low phosphorus content of the soil (average 18.1 mg/kg, Table 3), whole trial area was fertilised on 17 May 2018 with mineral fertilizer Superphosphate (PS 19-10), amount 421.7 kg/ha (Table 1).

Field trials were conducted with 4 variants of treatment (the same order as in 2017). Every variant had 4 replications. The treatments were: (1) control (unfertilized), (2) mineral fertilizer (+65 N), (3) untreated cattle slurry and (4) acidified cattle slurry (Table 2, Table 5). Plot sizes were 2.5 X 10 m (25 m^2). The placement of variants/replications was randomized.

Table 1. *Amounts of added chemical elements with mineral fertilizer `Superphosphate`*

	P_2O_5 (P)	S
Element content in fertiliser, %	19.0 (8.36)	10.0
Element amounts, kg/ha	80.1 (35.25)	42.2

Table 2. *Variants on grassland trial*

Variant no	Variant description
1	Control (unfertilized)
2	+65 N with mineral fertilizer
3	untreated cattle slurry
4	acidified cattle slurry

Soil samples were taken before fertilization from 0–20 cm layer of soil on 25.04.2018 to determine initial content of chemical elements (Table 3).

Table 3. *Content of chemical elements in soil samples (0–20 cm) before fertilization (25.04.2018) (n=4)*

Treatments	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg
Control/Untreated	6.50	0.39	17.75	114.25	8.53	3698.00	182.75
Mineral fertilizer:	6.53	0.38	18.50	114.50	8.28	3692.50	185.50
Untreated slurry	6.43	0.38	18.25	111.50	8.43	3715.25	183.25
Acidified slurry	6.40	0.38	18.00	114.00	8.33	3649.00	179.75

Analysis of slurry component and titration

About 1 m^3 cattle slurry was collected to IBC tank from cattle farm (OÜ Kaiu LT) in June and transported to the ECRI, Saku, Harjumaa. Components of initial slurry, untreated slurry (during spreading) and acidified slurry (during spreading) were determined (dry matter – gravimetric method; N_{tot} – Kjeldahl method; pH_{KCl} – GOST 27979-88; NO_3-N – Foss Tecator AN 5232; NH_4-N – Foss Tecator AN 5226; P, K, Ca –ICP/OES; S – PMK-JJ-4C; Corg – ISO 10694 : 1995) in accredited laboratory of Agricultural Research Centre, Estonia (Table 4).

Table 4. *Cattle slurry properties after bringing from farm (initial slurry), and during spreading (untreated slurry and acidified slurry)*

Slurry	pH_{KCl}, (labor)	pH_{H2O}, (field)	Dry matter, %	C_{org}, %	Ca, kg/m³	S, %	N_{tot}, kg/m³	NH_4-N, kg/m³	P, kg/m³	K, kg/m³
Initial analysis	7.9	–	6.25	37.5	0.98	0.024	2.7	1.50	0.46	2.10
Untreated Slurry	7.8	6.4	6.20	37.8	0.95	0.028	2.6	1.55	0.56	1.95
Acidified slurry	6.9	5.8	6.15	37.9	0.96	0.100	2.7	1.60	0.56	2.00

Slurry acidification

In total, 1.2 l/m³ of Sulphuric acid (96%) was added.

Calculation from titration showed that 1.2 l sulphuric acid (96%) per m³ of cattle slurry was needed to reach the target pH of 6.0. Mixed cattle slurry was divided into two IBC tanks on 19.06.2018. The pH was measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Composition of non-acidified and acidified slurries was measured in lab.

Slurry spreading

Slurry spreading was made on 20.06.2018, from 11.00 until 13.00. Weather on spreading time: 14.7° C, partly sunny, wind 6.3 m/s, no precipitations (EMHI, Harku weather station).

Each plot of variants 3 and 4 got 108.3 l of slurry (43.3 m³/ha). Slurry was spread with 10 l plastic watering cans. Slurry was measured to the watering cans in 6.77 l portions; each portion was spread to 5 m distance. Spreading was made by two persons, in the same way as in 2017.

Table 5. *Plant nutrient supply. Mineral fertilizer (Axan 27-4) and cattle slurry were applied on 20 June after the first cut*

Treatments	Fertilization rate, t/ha	N, (NH_4-N)	P, kg/ha	K, kg/ha	S, kg/ha
Control	–	–	–	–	–
Mineral fertilizer (Axan)	0.24	65.0	–	–	8.9
Untreated cattle slurry	43.3	67.1	24.25	84.4	12.1
Acidified cattle slurry	43.3	69.3	24.25	86.6	43.3

Harvesting

First cut was taken before fertilization on 15 June. Total yield was calculated over the trial area (16 replications) Dry mass (DM) was 3072+-278 kg/ha and content of crude protein in DM was 8.1%. The second cut was harvested on 9 August and third on 18 September with bar mover.

Data analysis

Soil samples (0.5 kg) from each treatment in four replications from the 0–20 cm soil layers were taken with a 16 mm diameter auger. Soil samples were taken before fertilization (25.04.2018), two weeks after the slurry application (2.07.2018) and after the second (09.08.2018) and third (18.09.2018) harvest.

Soil samples were determined (pH-ISO 10390; P, K, Ca, Mg –Mehlich III; N – ISO 11261; NO_3-N, NH_4-N – 1n KCl; SO_4 – ISO 11048) in accredited laboratory of Agricultural research centre, Estonia.

For soil microbial analyses the soil samples were sieved (2 mm) and stored at 4 °C until analysis in laboratory.

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Measurements of soil dehydrogenase activity (DHA) were based on Tabatabai (1982). Soil samples (5 g) were incubated at 30 °C for 24 h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product (triphenylformazan) was extracted with acetone and measured in a spectrophotometer at 546 nm.

Phospholipid fatty acids (PLFA) are the main structural component of all microbial membranes. As the phospholipids of different groups of bacteria and fungi contain a variety of unique fatty acids, they can be Changes in the structure of the microbial community were determined using phospholipid fatty acid (PLFA) extraction according to the modified (Bligh & Dyer, 1959) method, described in details by Moeskops et al. 2010. Briefly, all lipids are extracted from soil with a chloroform-methanol-phosphate buffer. Then phospholipids were separated from neutral and glycolipids using the solid-phase extraction columns (Chromabond, Macherey-Nagel GmbH, Düren, Germany). Finally, they were converted to fatty acid methyl esters (FAMEs). Individual methyl esters can identify and quantify by Gas Chromatography. PLFAs were determined by GC-MS on an Agilent Technologies 7890A GC system in electron ionization mode. Overall, we estimated 14 different methyl esters from seven microbial groups. The sums of markers fatty acid concentrations for selected microbial groups were calculated as follows (Ameloot et al. 2015, Gebremikael et al. 2015). For Gram-positive bacteria the sum of i15:0, a15:0, i17:0 an a17:0; for Gram-negative bacteria cy17:0, cy19:0 and C16:1ω7; for the actinomycetes the sum of 10-methyl branched saturated fatty acids (17:0 10-Met and 18:0 10-Met). For the total bacterial community, in addition to Gram-positive and Gram-negative bacteria, the fatty acids 15:0 and 17:0 were also included. For saprotrophic fungi the marker PLFAs 18:2ω6c and 18:1ω9, and for arbuscular mycorrhizal fungi (AMF) 16:1ω5c were considered. In general, Gram-positive bactera give a positive result with the Gram stain test because they have thick peptidoglycan layer in the cell wall. Despite the thicker layer, this group of bacteria are more sensitive to antibiotics because they do not have outer membrane. They tend to resist water stress. Gram-negative bacteria give a negative result wiht the Gram stain test. They are small bacteria and are sensitive to drought and water stress. Actinomycetes are important type of bacteria in soil. They have three important functions as nitrogen fixing bacteria and decomposer. Saprotrophic fungi are important group for decomposing different carbon sources, for example plant matter. An arbuscular mycorrhiza fungi (AMF) help plants to pick up phosphorus, sulfur, nitogen and micronutrients from the soil.handling as biomarkers for such groups.

Final yields were calculated at harvest: dry mass (DM) and percentage of crude protein.

The data was analysed by ANOVA, the Tukey-Kramer Honest Significant Difference (HSD) test was used via the software *JMP 5.0.1.2* (SAS, 2002).

Results and discussion

Soil samples

Soil samples from each plot were taken before fertilization (25.04.2018), two weeks after the slurry application (2.07.2018, Table 6) and after the second and third harvest (09.08.2018, Table 7 and 18.09.2018, Table 8). From all soil samples the pHKCl and the content of P, K, Ca, Mg, N%, and SO_4 were alalysed. NO_3-N, NH_4-N were analysed only on the soil samples that were taken after fertilization and after harvest. Nmin is mineralized N in soil (Nmin = NO_3 + NH_4 concentrations) (Figure 10).

Results showed no significant differences ($p<0.05$) of pH, percentage of N_{tot}, P , K, Ca, Mg, NO_3-N and NH_4-N regardless of treatment (Tables 6, 7, 8, Figures 1, 2, 3, 4, 5, 7, 8, 9, 10). Fertilization of acidified slurry showed significantly ($p<0.05$) higher value of SO_4 after slurry spreading and after the second and third cut (Tables 6, 7, 8, Figure 7).

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Table 6. *Soil analyses two weeks after slurry spreading (2.07.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	6.35[a]	0.42[a]	28.25[a]	107.00[a]	9.10[b]	4118.75[a]	228.50[a]	22.28[a]	0.75[a]
Mineral fertilizer	6.43[a]	0.42[a]	27.50[a]	111.00[a]	15.68[a]	4201.25[a]	234.25[a]	29.98[a]	0.73[a]
Untreated slurry	6.38[a]	0.41[a]	27.50[a]	114.00[a]	8.43[b]	4151.25[a]	233.50[a]	26.57[a]	0.63[a]
Acidified slurry	6.40[a]	0.44[a]	28.75[a]	127.50[a]	21.48[a]	4028.75[a]	226.25[a]	24.56[a]	0.81[a]

Table 7. *Soil analyses after the second cut (9.08.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	6.17[a]	0.44[a]	28.33[a]	111.00[a]	12.07[b]	3558.33[a]	186.33[a]	21.60[a]	4.27[a]
Mineral fertilizer	6.33[a]	0.43[a]	27.00[a]	110.00[a]	10.88[b]	3658.50[a]	198.00[a]	22.85[a]	5.40[a]
Untreated slurry	6.20[a]	0.43[a]	28.00[a]	115.25[a]	14.50b	3620.25[a]	193.75[a]	24.80[a]	6.05[a]
Acidified slurry	6.18[a]	0.44[a]	30.00[a]	128.50[a]	24.63[a]	3578.50[a]	193.75[a]	20.40[a]	5.30[a]

Table 8. *Soil analyses after the third cut (18.09.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	6.33[a]	0.43[a]	25.50[a]	124.75[a]	11.88[b]	3802.00[a]	208.50[a]	10.80[a]	2.33[a]
Mineral fertilizer	6.43[a]	0.43[a]	24.25[a]	127.25[a]	11.00[b]	3895.25[a]	215.00[a]	12.05[a]	2.10[a]
Untreated slurry	6.35[a]	0.41[a]	26.50[a]	127.75[a]	14.25[b]	3824.50[a]	205.00[a]	11.00[a]	2.10[a]
Acidified slurry	6.28[a]	0.43[a]	26.00[a]	135.25[a]	23.25[a]	3691.50[a]	201.75[a]	11.15[a]	2.05[a]

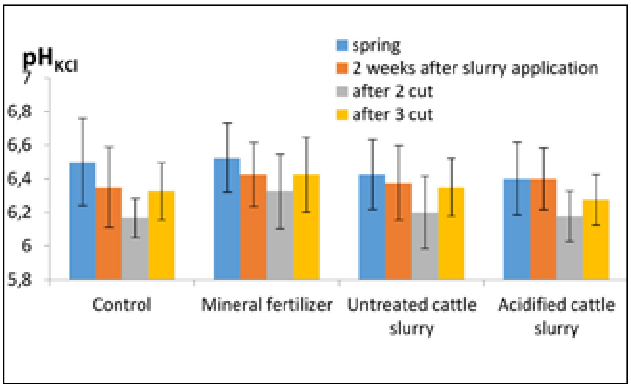

Figure 1. *Soil pHKCl during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

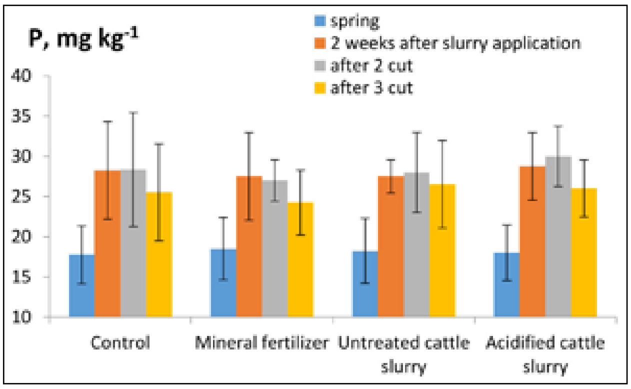

Figure 2. *Amount of P in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

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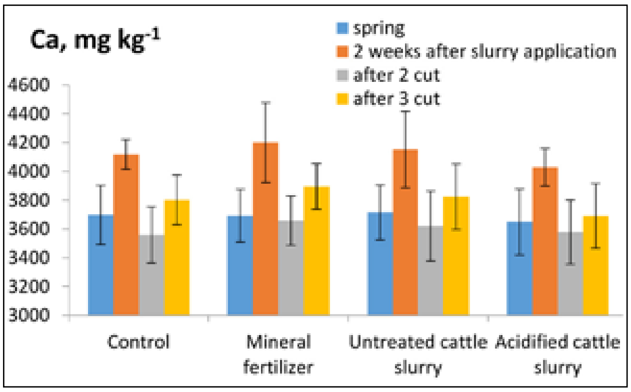

Figure 3. *Amount of Ca in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

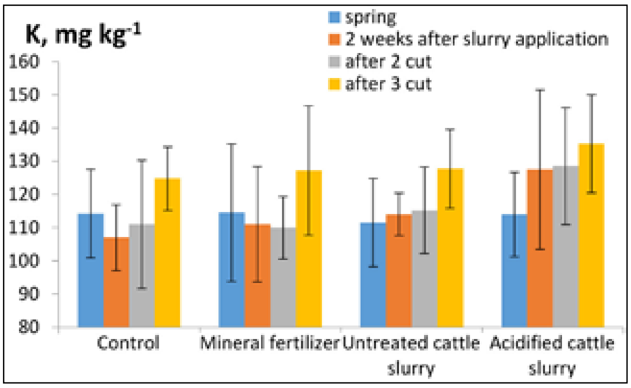

Figure 4. *Amount of K in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

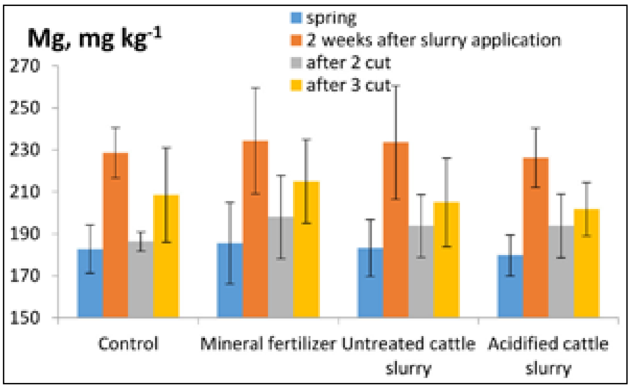

Figure 5. *Amount of Mg in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

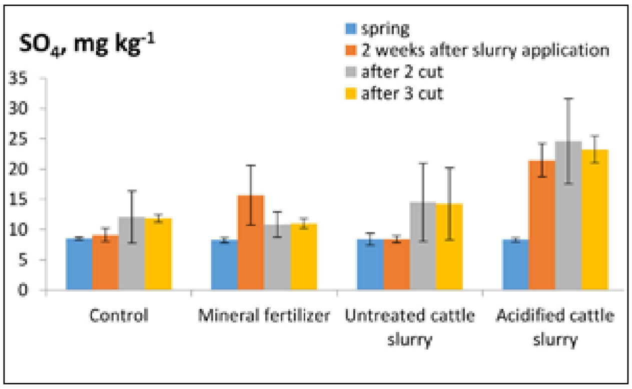

Figure 6. *Amount of SO_4 in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

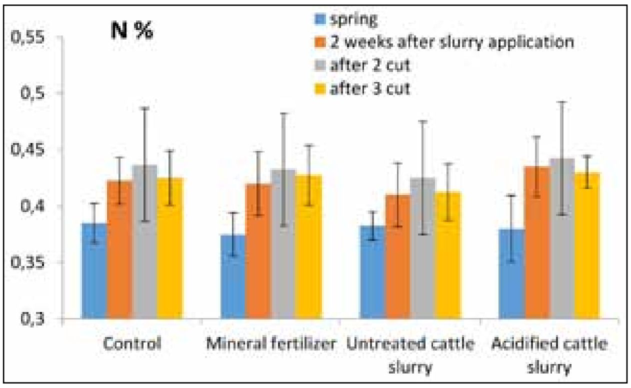

Figure 7. *Percentage of total N during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

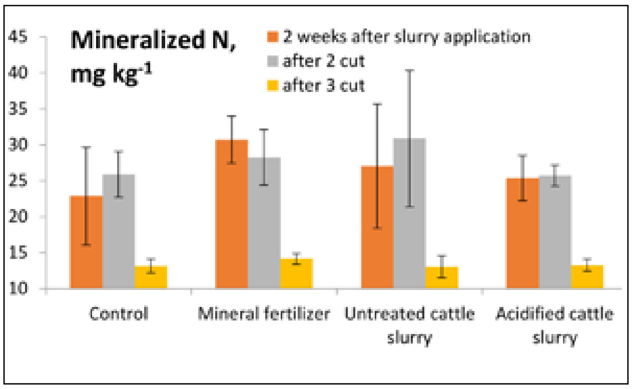

Figure 8. *Amount of mineralized N (N_{min} = NO_3 + NH_4 concentrations) in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

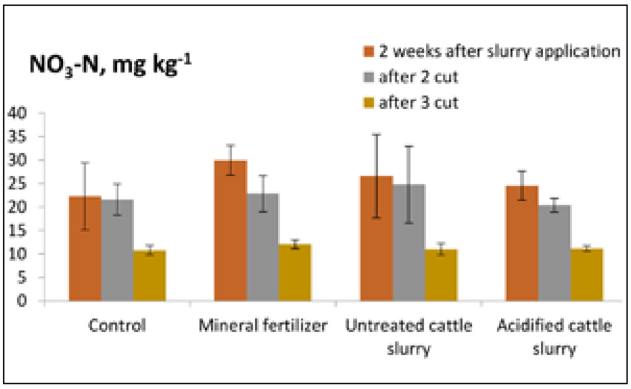

Figure 9. *Amount of NO_3-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

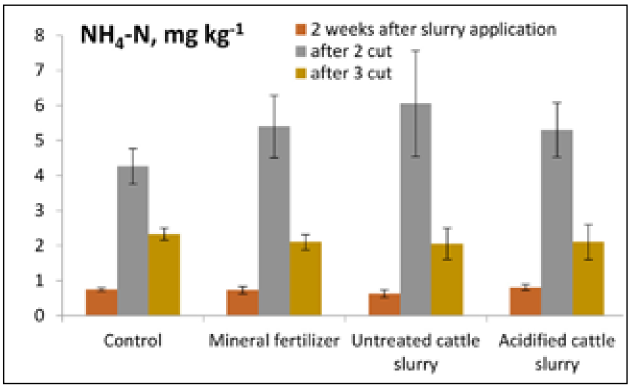

Figure 10. *Amount of NH_4-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

Yield and raw protein after the harvest

The second cut was harvested on 9 August and third on 18 September.

Results of the second and third cut yield showed significant ($p<0.05$) differences only between the control and fertilized treatments (Table 9, Figure 11). Significantly lower crude protein % was observed only on second cut yield in control treatment (Table 9).

Table 9. *The yield at harvest. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Yield, DM t/ha Second cut (9.08.2018)	Yield, DM t/ha Third cut (18.09.2018)	Crude protein, % Second cut (9.08.2018)	Crude protein, % Third cut (18.09.2018)
Control	0.61^{b}	0.73^{b}	10.75^{b}	13.21^{a}
Mineral fertilizer	1.24^{a}	1.30^{a}	12.84^{a}	13.06^{a}
Untreated cattle slurry	1.02^{a}	1.05^{ab}	11.84^{ab}	13.31^{a}
Acidified cattle slurry	1.14^{a}	1.21^{a}	12.10^{a}	13.12^{a}

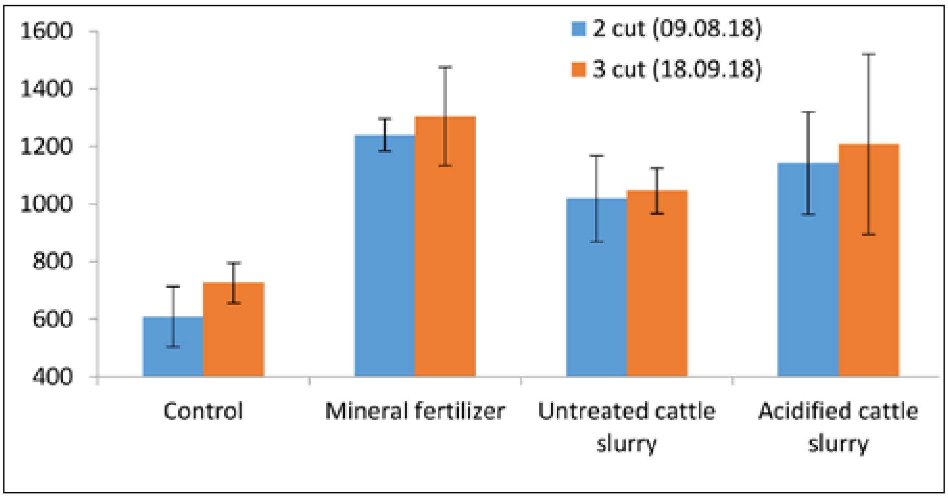

Figure 11. *The DM yield kg/ha of the second and third cut. The error bar refers to the standard deviation of the mean (n=4).*

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Soil dehydrogenase activity (DHA)

Results showed higher microbial activity in all treatments in spring before fertilization (25.04.2018) and after the 3 cut (18.09.2018) (Table 10, Figure 12). Lower microbial activity occurred after slurry application (2.07.2018) and after the 2 cut (9.08.2018). It was probably linked with the amount of precipitations during the vegetation period, which in turn affected the soil humidity and microbial activity. The average humidity % of soil samples in April and September was 25–30 %, at the same time after slurry application in July it was 22 % and after the 2 cut at the beginning of August even 10 %. The low soil DHA in August was probably influenced by the total amount of precipitations in July, what was only 6.8 mm.

Compared to the control treatment, significantly higher soil DHA was measured in July in plots with mineral fertilizer and in September in acidified slurry plots (Table 10, Figure 12). In the beginning of the experiment (25.04.18) and after the 2 cut (9.08.2018) no significant differences between treatments were identified.

Table 10. *Soil dehydrogenase activity (DHA, TPF µg/g/h). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Spring 25.04.2018	2 weeks after slurry application 2.07.2018	After 2 cut 9.08.2018	After 3 cut 18.09.2018
Control	19.42[a]	9.26[b]	8.46[a]	20.13[b]
Mineral fertilizer	18.76[a]	11.49[a]	9.85[a]	21.96[ab]
Untreated slurry	19.26[a]	10.54[ab]	9.13[a]	22.64[ab]
Acidified slurry	17.54[a]	11.02[ab]	8.70[a]	24.28[a]

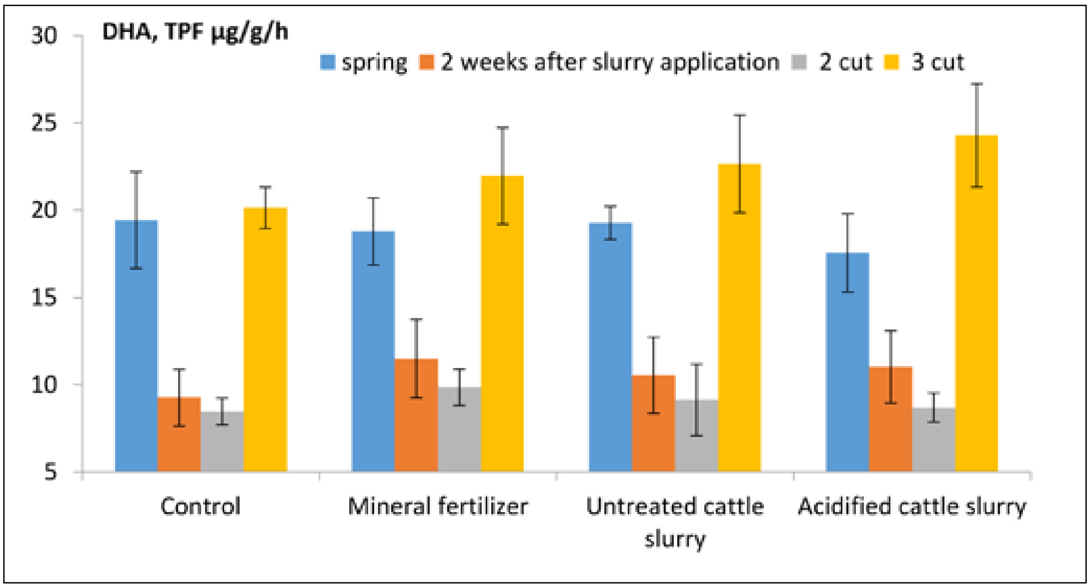

Figure 12. *Soil dehydrogenase activity (DHA, TPF µg/g/h). The error bar refers to the standard deviation of the mean (n=4).*

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Analysis of Soil Phospholipid Fatty Acid (PLFA)

In this study, we determined total bacteria, gram-positive and gram-negative bacteria, Actinobacteria, saprotrophic fungi and arbuscular mycorrhizal fungi.

In general, PLFAs profile was accordant with results of soil dehydrogenase activity. The highest concentration of PLFAs was found in spring (Table 11). The concentrations of all marker PLFAs start to decrease in summer (Table 12, Table 13) and were the lowest after the the second cut in August (Table 14). These results are related to extreme dryness of soil because of low level of precipitation during the growing season.

Overall, no significant differences between plots were identified in spring before adding any fertilizer to determine the homogeneity of our study site (Table 11).

Table 11. *Concentrations of marker PLFAs (nmol g-1 dry soil) of microbial groups in spring 2018 (25.04.2018)*

Treatment	Control	Mineral fertiliser	Untreated slurry	Acidified slurry	*Prob > F*
Total	31.51	35.62	32.22	31.80	*ns*
Bacteria	20.02	22.78	20.86	20.30	*ns*
Gram+	10.52	11.90	11.35	10.57	*ns*
Gram-	8.62	9.92	8.59	8.84	*ns*
Actinomycetes	3.06	3.28	2.80	2.94	*ns*
AMF	3.19	3.64	3.23	3.30	*ns*
Saprotrophic fungi	5.23	5.91	5.33	5.25	*ns*

Still, no significant differences in microbial groups PLFA concentrations were found also 2 weeks after slurry application (Table 12, Figure 13) or in August after the second cut (Table 14, Figure 14). However, when we compare our means results we can see tendency of slightly higher concentrations of PLFA markers with untreated and acidified slurry (Table 12, Table 13, Table 14; Figure 13, Figure 14). Some water added with slurry application and this could have positive effect to all microbial groups during this dry season. In addition, concentrations of PLFA markers were the lowest in plots with mineral fertiliser. These results are in accordance with previous results where negative impact of mineral fertiliser to microbial communities has been shown.

Table 12. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from microbial groups two weeks after slurry application (02.07.2018)*

Treatment	Control	Mineral fertiliser	Untreated slurry	Acidified slurry	*Prob > F*
Total	22.86	22.42	23.60	23.10	*ns*
Bacteria	14.45	14.19	14.87	14.62	*ns*
Gram+	6.99	6.84	7.15	7.04	*ns*
Gram-	5.55	5.45	5.78	5.64	*ns*
Actinomycetes	2.61	2.56	2.67	2.64	*ns*
AMF	2.08	2.02	2.14	2.10	*ns*
Saprotrophic fungi	3.71	3.65	3.92	3.75	*ns*

When we compared separately each markers fatty acid concentrations (Table 13) we found one significant marker (18:0 10-Met). This marker belongs to Actinomycetes. Actinomycetes are important type of bacteria in soil. They have three important functions as nitrogen fixing bacteria and decom-

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poser. The highest values were counted in plots with untreated slurry and the lowest values were with mineral fertiliser. Results with acidified slurry and control were intermediate.

Table 13. *Concentrations of separate FAMEs (nmol g^{-1} dry soil) of PLFAs after the second cut (02.07.2018)*

Treatment	Control	Mineral fertiliser	Untreated slurry	Acidified slurry	*Prob > F*
iso15:0	2.43	2.36	2.49	2.45	*ns*
anteiso15:0	2.13	2.09	2.20	2.16	*ns*
15:00	1.01	1.00	1.02	1.02	*ns*
16:1 w7c	2.59	2.53	2.75	2.66	*ns*
16:1 w5c	2.08	2.02	2.14	2.10	*ns*
iso17:0	1.23	1.21	1.24	1.23	*ns*
anteiso17:0	1.19	1.18	1.21	1.20	*ns*
17:0 cyclo	1.51	1.49	1.54	1.52	*ns*
17:00	0.90	0.90	0.92	0.91	*ns*
17:0 10-Met	1.31	1.27	1.31	1.30	*ns*
18:2 w6c	1.35	1.32	1.39	1.34	*ns*
18:1 w9c	2.36	2.33	2.52	2.41	*ns*
18:0 10-Met	1,31ab	1,29b	1,37a	1,34ab	*0.023*
19:0 cyclo	1.45	1.44	1.49	1.46	*ns*

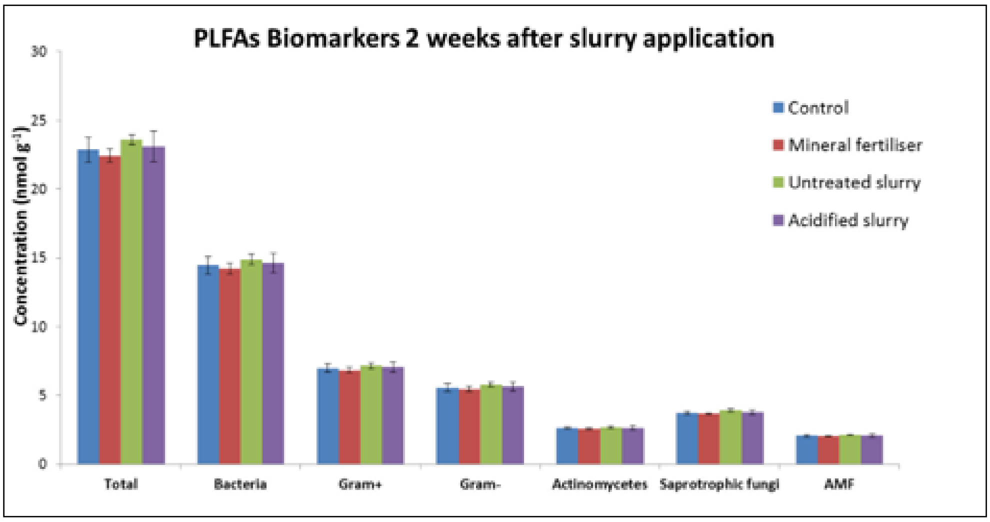

Figure 13. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from different microbial groups two weeks after slurry application (02.07.2018) between treatments. The error bar refers to the standard deviation of the mean (n=4).*

Table 14. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from microbial groups after second cut (09.08.2018)*

Treatment	Control	Mineral fertiliser	Untreated slurry	Acidified slurry	*Prob > F*
Total	19.61	19.84	20.03	20.68	*ns*
Bacteria	12.21	12.37	12.45	12.88	*ns*
Gram+	5.84	5.89	5.96	6.15	*ns*
Gram-	4.69	4.79	4.80	5.02	*ns*
Actinomycetes	2.43	2.45	2.46	2.53	*ns*
AMF	1.71	1.72	1.74	1.79	*ns*
Saprotrophic fungi	3.27	3.32	3.38	3.47	*ns*

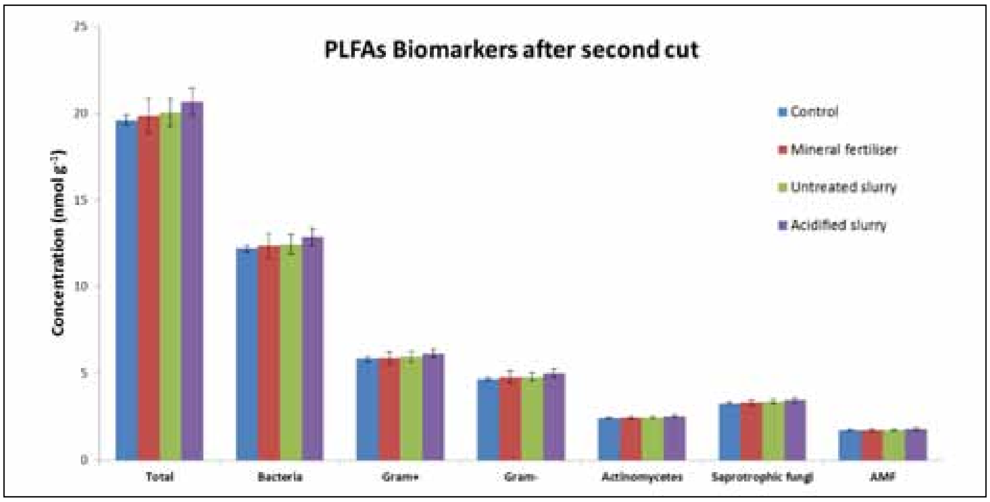

Figure 14. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from different microbial after the second cut.*

This study showed that slurry acidification had no significant impact to microbial group's composition in grassland. Overall, cattle slurry application (untreated and acidified) increased slightly the concentrations of marker PLFAs from different microbial groups. Still, these results are based on one year experiment and more study is needed for final conclusions.

Reporting form: 2018, grassland *(please, activate the link below)*
https://www.dropbox.com/s/j1a04ad6wyzb3n0/Estonia%20WP4%20grassland%252C%20 2018%2528Final%2529.xls?dl=0

2018, winter wheat

Written by: Kalvi Tamm, Taavi Võsa, Liina Edesi, Elina Akk, Tiina Talve, Raivo Vettik from Estonian Crop Research Institute

Study site

The field trial was carried out between April and August 2018. The site of experiment was located in the same place as in 2017.

Whole trial area was fertilised in autumn 2017 with mineral fertilizer `YaraMila 7-12-25 + S B Mg`, amount 300 kg/ha (Table 1).

Table 1. *Amounts of added chemical elements with mineral fertilizer `YaraMila 7-12-25 + S B Mg`*

	N	P	K	S	B	Mg
Element content in fertiliser, %	7	5.2	20.8	2.6	0.02	1.2
Element amounts, kg/ha	21	15.6	62.4	7.8	0.06	3.6

Field trials were conducted exactly the same way as in 2017.

Samples were taken before fertilization from 0–20 cm layer of soil on 17.04.2018 to determine initial content of chemical elements (Table 2).

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Table 2. *Content of chemical elements in soil samples before fertilization (17.04.2018)(n=4)*

Variants	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg
Control/Untreated	7.15	0.19	198.00	179.75	2.63	3283.25	46.00
Mineral fertilizer (MA1):	7.13	0.20	196.00	185.25	2.75	3443.25	48.25
Mineral fertilizer (MA2):	7.20	0.19	196.25	173.75	2.78	3541.25	47.00
Mineral fertilizer (MA3):	7.08	0.20	197.75	182.00	2.85	3255.00	48.00
Mineral fertilizer (MA4):	7.15	0.20	197.25	171.75	2.88	3326.00	45.50
Untreated slurry	7.18	0.20	197.00	178.00	2.85	3507.25	48.50
Acidified slurry	7.23	0.20	199.75	178.75	2.83	3779.50	48.75

Analysis of slurry component and titration

About 1 m^3 pig slurry was collected to IBC tank from pig farm (Triigi Seakasvatuse OÜ) on 15.05.2018 and transported to the ECRI, Saku, Harjumaa. Components of initial slurry, untreated slurry and acidified slurry were determined (dry matter –gravimetric method; Ntot – Kjeldahl method; pH_{KCl} – GOST 27979-88; NO_3-N – Foss Tecator AN 5232; NH_4-N – Foss Tecator AN 5226; P, K, Ca – ICP/OES; S – PMK-JJ-4C; C_{org} – ISO 10694 : 1995) in accredited laboratory of Agricultural Research Centre, Estonia (Table 3).

Table 3. *Pig slurry properties after bringing from farm (initial slurry) and during spreading (untreated slurry and acidified slurry)*

	pH_{KCl}, (labor)	pH_{KCl}, (field)	DM, %	N_{tot}, %	NH_4-N, kg/m^3	C_{org}, %	S, %	P, kg/m^3	K, kg/m^3	Ca, kg/m^3
Initial slurry	8.2	–	5.10	5.1	3.35	37.3	0.026	0.97	2.15	1.05
Untreated slurry	8.2	7.2	6.15	5.2	4.35	35.9	0.032	1.25	2.2	1.5
Acidified slurry	7.2	5.9	5.40	5.0	4.45	28.6	0.310	0.96	2.1	1.05

Slurry acidification

Calculation from titration showed that 6.3 l sulphuric acid (96%) per m^3 of pig slurry was needed to reach the target pH of 6.0.

Mixed pig slurry was divided into two IBC tanks on 28.05.2018. In one tank the amount of 360 l of slurry was mixed with 2.2 l concentrated H2SO4 on 28.05.2018.

Slurry spreading

Slurry spreading was performed on 29.05.2018 from 11.00 until 14.00. Growth stage of winter wheat was beginning of stem elongation (GS 30). Weather on spreading time: 17.5° C, partly sunny, average wind 3.4 m/s, no precipitations (EMHI, Harku weather station).

Amount of slurry being spread was 29 m^3/ha (Table 5). The pH values were measured before spreading for both untreated slurry and acidified slurry being 7.19 and 5.93 correspondingly. The pH and sample temperatures were measured with Hanna Instruments HI2202-02 edgeblue Bluetooth® pH meter and HI11102 Bluetooth® pH electrode. Slurry subsamples were taken during slurry spreading, mixed, and average samples from both types were sent to the laboratory for component analyses.

Each plot of variants 6 and 7 got 72.73 l of slurry. Slurry was spread with 10 l plastic watering cans. Slurry was measured to the watering cans in 7.273 l portions; each portion was spread to 10 m distance. Spreading was made in the same way as in 2017.

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Mineral fertilizer spreading

First mineral fertilizer was spread on 29.05.2018 by hand to the variants 2, 3, 4 and 5 with fertiliser ´NS 27-4´. Growth stage of winter wheat was stem elongation (GS 33). Additional N was added to the variants of 4 and 5 on 20.06.2018 (Table 4; Table 5). Growth stage of winter wheat was early milk (GS 73).

Table 4. *Amounts of N with mineral fertilizer to the variants 2, 3, 4 and 5*

Variant No	Applied on 29.05.2018 N kg/ha	Additional N on 20.06.2018 N kg/ha
2	70	-
3	96	-
4	96	+34
5	96	+64

Table 5. *Plant nutrient supply. Mineral fertilizer (Axan 27-4) was applied on 29 May (GS 33) and the second mineral fertilizer treatment (N 130 and 160) got additional N in on 20 June (GS 73). Pig slurry was applied on 29 May*

Treatment	Fertilization Rate, t/ha	N, (NH_4-N) kg/ha	P, kg/ha	K, kg/ha	S, kg/ha
Control	-	-	-	-	-
Mineral fertilizer 70 N	0.26	70	-	-	9.6
Mineral fertilizer 96 N	0.356	96	-	-	13.2
Mineral fertilizer 130 N	0.482	130	-	-	17.8
Mineral fertilizer 160 N	0.593	160	-	-	21.9
Untreated pig slurry	29	126.2	36.3	63.8	9.3
Acidified pig slurry	29	129.1	27.8	60.9	89.9

Harvesting

The trial plots were harvested with combine in 2 August. Before combine harvest sheaf samples of 0.25 m2 from each plots were taken.

Data collection and analysis

Soil samples (0.5 kg) from each treatment in four replications from layer 0–20 cm were taken with a 16 mm auger. Soil samples were taken before fertilization (17.04.2018), 2 weeks after slurry spreading (11.06.2018) and before the combine harvest (30.07.2018).

Soil samples were determined (pH-ISO 10390; P, K, Ca, Mg –Mehlich III; N – ISO 11261; NO_3-N, NH_4-N – 1n KCl; SO_4 – ISO 11048) in accredited laboratory of Agricultural Research Centre, Estonia.

Leaf chlorophyll was measured on the field by SPAD-502 twice. The first measurement was performed on 4.06.2018 during the time of heading and the second measurement on 11.06.2018 at the end of heading.

For soil microbial analyses the soil samples were sieved (2 mm) and stored at 4 °C until analysis in laboratory. Measurements of soil dehydrogenase activity (DHA) were based on Tabatabai (1982). Soil samples (5 g) were incubated at 30°C for 24h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product (triphenylformazan) was extracted with acetone and measured in a spectrophotometer at 546 nm.

Overall, we estimated 14 different methyl esters from seven microbial groups. The sums of markers fatty acid concentrations for selected microbial groups were calculated as follows (*Ameloot et al.* 2015, Gebremikael et al. 2015). For Gram-positive bacteria the sum of i15:0, a15:0, i17:0 an a17:0; for Gram-negative bacteria cy17:0, cy19:0 and C16:1ω7; for the actinomycetes the sum of 10-methyl branched saturated fatty acids (17:0 10-Met and 18:0 10-Met). For the total bacterial community,

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in addition to Gram-positive and Gram-negative bacteria, the fatty acids 15:0 and 17:0 were also included. For saprotrophic fungi the marker PLFAs 18:2ω6c and 18:1ω9, and for arbuscular mycorrhizal fungi (AMF) 16:1ω5c were considered.

Final yields were calculated at harvest: total yield (at 14% humidity), wet gluten, gluten index, volume weight, falling number and 1.000-kernel weight.

Disease assessment key were used to determine levels of damage on leaves and stem (Lane, 2012). In total, 10 plants in each plot, 40 plants in each treatment were measured. Occurrence of average diseases in each treatment was calculated. *Fusarium* fungi occurrence was evaluated on harvested grain (Leslie and Summerell, 2006). Hundred kernels from each treatment were placed on *Fusarium* selective broth. The infected kernels were counted and incidence of *Fusarium* calculated after 7 days. Mycotoxin deoxynivalenol (DON) in harvested kernels was measured by gas-cromatography with mass spectrometry (GC-MS, Agilent) according to the method Saastamoinen and Saloniemi, 1997.

Results and discussion

Soil samples

Soil samples to determine content of chemical elements (pH_{KCl}, P, K, Ca, Mg, N% and SO_4) were taken before fertilization (17.04.2018), two weeks after the slurry spreading (11.06.2018) and before combine harvest (30.07.2018). NO_3-N and NH_4-N were analysed only on the soil samples that were taken after fertilization and before harvest. N_{min} is mineralized N in soil ($N_{min} = NO_3 + NH_4$ concentrations) (Figure 8)

The measurements of pH, P, Ca and N_{tot} showed no significant differences between treatments (Tables 6, 7, Figures 1, 3, 6 and 7).

All treatments with fertilizers showed higher rate of NO_3-N, NH_4-N and Nmin than control (Table 6, 7, Figures 9. 10). Compared to the control and other treatments the N_{min} content in soil was the highest in mineral fertilizer treatments (N_{130} and N_{160}) just couple of days before combine harvest. That means that in these treatments due to droughty vegetation period the large amount of nitrogen applied by mineral fertilizer was not used for yield formation.

Two weeks after slurry application and before harvest the K and Mg content in soil were higher in the slurry treatments (Tables 6, 7, Figures 4, 5).

Fertilization of acidified slurry showed significantly higher value of SO_4 two weeks after slurry spreading as well as before harvest (Tables 6, 7, Figure 2). Before harvest, level of SO_4 in soil was almost five times higher compared to other treatments.

Table 6. *Soil analyses two weeks after slurry spreading (11.06.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	7.18^{a}	0.16^{a}	214.25^{a}	181.5^{ab}	3.08^{b}	3753.75^{a}	53.0^{ab}	1.73^{d}	1.70^{b}
Mineral fertilizer 70 N	7.28^{a}	0.19^{a}	202.00^{a}	170.3^{b}	5.15^{b}	3848.75^{a}	53.0^{ab}	7.14^{bcd}	5.52^{b}
Mineral fertilizer 96 N	7.28^{a}	0.18^{a}	207.75^{a}	169.5^{b}	4.03^{b}	3896.25^{a}	51.3^{b}	10.15^{abc}	7.99^{b}
Mineral fertilizer 130 N	7.20^{a}	0.18^{a}	207.25^{a}	177.8^{ab}	5.28^{b}	3741.25^{a}	53.5^{ab}	14.26^{a}	11.10^{ab}
Mineral fertilizer 160 N	7.23^{a}	0.16^{a}	211.50^{a}	169.8^{b}	5.85^{b}	3771.25^{a}	53.0^{ab}	11.89^{ab}	9.96^{ab}
Untreated pig slurry	7.28^{a}	0.19^{a}	215.75^{a}	204.0^{ab}	3.75^{b}	3853.75^{a}	60.0^{a}	4.58^{cd}	20.52^{a}
Acidified pig slurry	7.30^{a}	0.18^{a}	218.50^{a}	211.5^{a}	41.13^{a}	4133.75^{a}	58.5^{a}	3.88^{cd}	20.11^{a}

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Table 7. *Soil analyses before harvest (30.07.2018). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	pH_{KCl}	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	NO_3-N, mg/kg	NH_4-N, mg/kg
Control	7.15^{a}	0.20^{a}	211.50^{a}	178.50^{b}	1.90^{b}	3902.50^{a}	57.50^{bc}	3.52^{d}	1.77^{b}
Mineral fertilizer 70 N	7.15^{a}	0.20^{a}	208.75^{a}	183.50^{ab}	4.08^{b}	4192.50^{a}	57.25^{bc}	16.68^{c}	2.75^{b}
Mineral fertilizer 96 N	7.23^{a}	0.21^{a}	214.50^{a}	171.00^{b}	4.38^{b}	4263.75^{a}	56.00^{c}	22.78^{c}	3.67^{ab}
Mineral fertilizer 130 N	7.08^{a}	0.21^{a}	213.50^{a}	184.00^{ab}	7.20^{b}	3727.00^{a}	58.75^{bc}	34.73^{b}	6.84^{a}
Mineral fertilizer 160 N	7.13^{a}	0.21^{a}	217.00^{a}	178.50^{b}	6.73^{b}	4100.00^{a}	57.00^{bc}	46.74^{a}	5.27^{ab}
Untreated pig slurry	7.18^{a}	0.20^{a}	216.25^{a}	210.75^{a}	2.48^{b}	4253.75^{a}	66.25^{a}	12.28^{cd}	2.60^{b}
Acidified pig slurry	7.23^{a}	0.23^{a}	220.00^{a}	209.25^{a}	33.75^{a}	4568.75^{a}	63.50^{ab}	19.66^{c}	3.14^{ab}

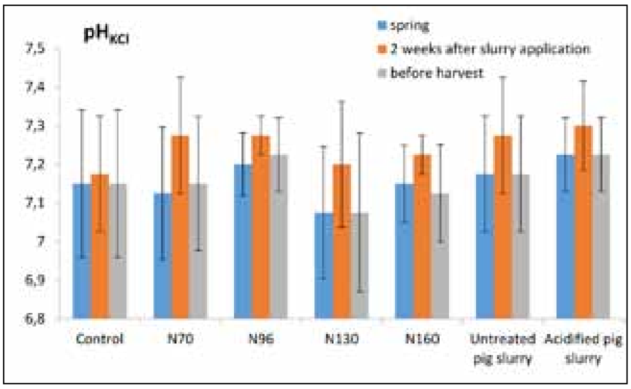

Figure 1. *Soil pH_{KCl} during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

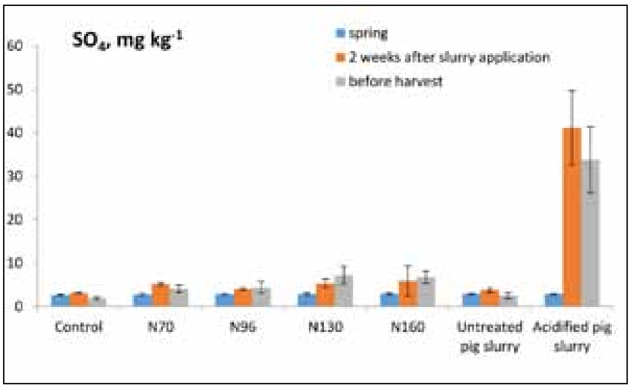

Figure 2. *Amount of SO_4 in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

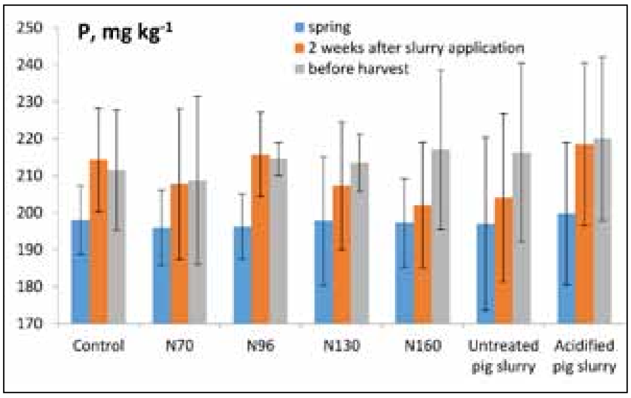

Figure 3. *Amount of P in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

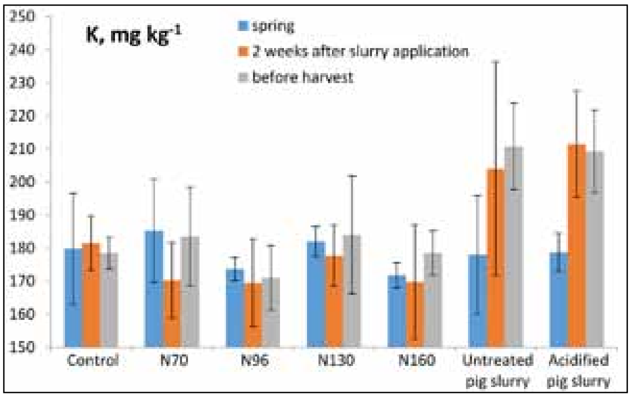

Figure 4. *Amount of K in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

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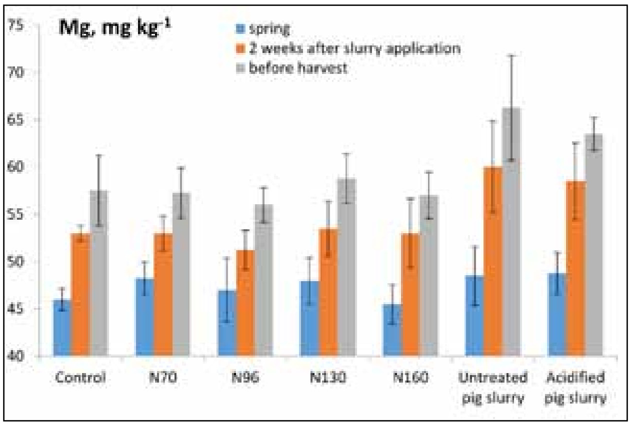

Figure 5. *Amount of Mg in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

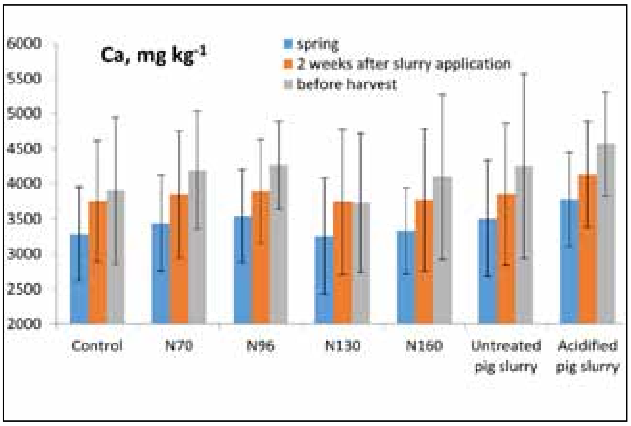

Figure 6. *Amount of Ca in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

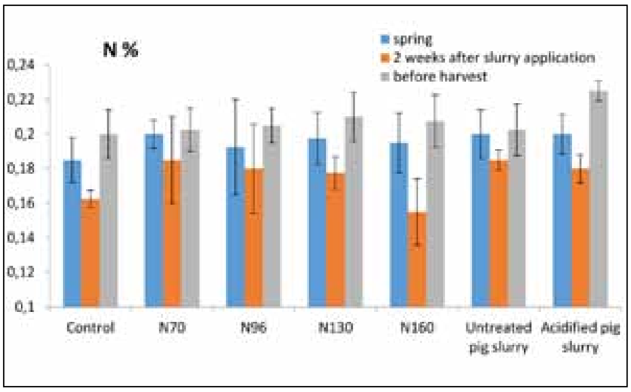

Figure 7. *Percentage of total N during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

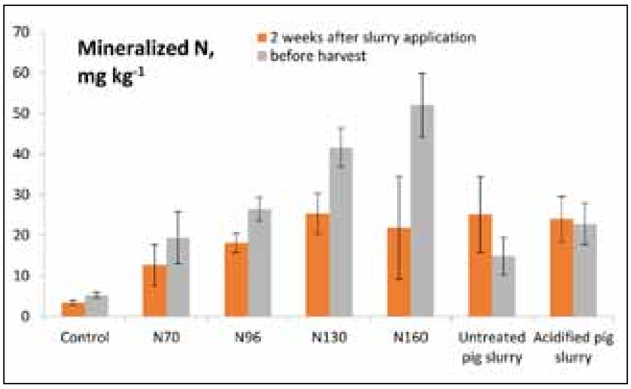

Figure 8. *Amount of mineralized N (N_{min} = NO_3 + NH_4 concentrations) in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

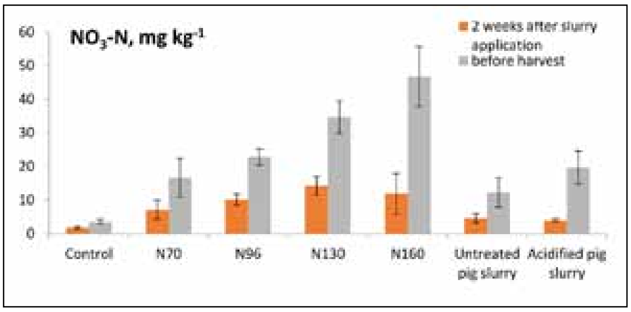

Figure 9. *Amount of NO_3-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

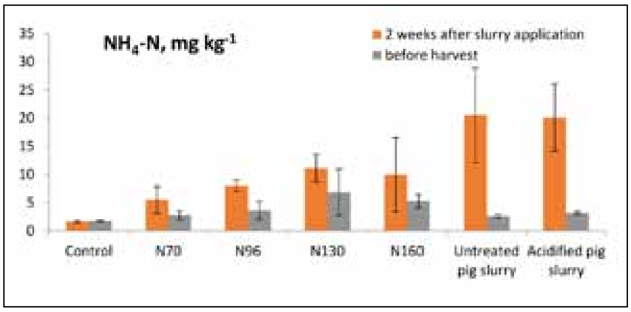

Figure 10. *Amount of NH_4-N in soil during the experiment between treatments. The error bar refers to the standard deviation of the mean (n=4).*

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Leaf chlorophyll content

Leaf chlorophyll content in leaves was measured twice: on 4.06.2018 during the time of heading and on 11.06.2018 at the end of heading (Figure 11). Leaf chlorophyll content in 04.6.2018 and 11.06.2018 in all treatments was similar and statistical differences between treatments did not occurr. It indicates that in the context of drought, nutrient uptake was inhibited.

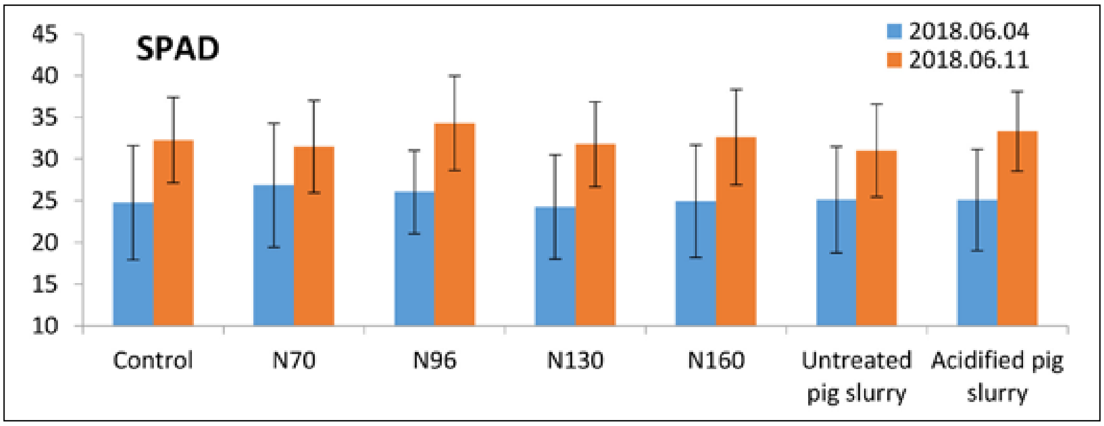

Figure 11. *Leaf chlorophyll content in leaves during the time of heading (4.06.2018) and at the end of heading (11.06.2018). The error bar refers to the standard deviation of the mean (n=4).*

Harvest

In 2018 the harvesting was done about a month earlier than in 2017. Results of yield showed no significant differences between the treatments (Table 8, Figure 12). It indicates that in the context of drought, nutrient uptake was inhibited. This is also confirmed by the high N_{min} content in fertilized treatments soil, just before harvest (Figure 8). The plots yield by combine harvest was so low that only one sample obtained for quality analysis. Therefore, the quality analysis is only in one replicate and not statistically processed.

Table 8. *The yield and quality at harvest. Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Volume weight, g/l	Proteins, % of DM	Wet glutene	Gluten Index	Falling number	1.000-kernel weight, g	Yield (2.08.2018, combine harvest at 14% humidity), t/ha	Yield (24.07.2018, sheaf harvest, 0.25 m² at 14% humidity), t/ha
Control	872.8	13.16	28.5	46	565	44.71d	1.08[a]	2.51[a]
70 N	877.5	13.39	33.0	42	548	46.19ab	1.36[a]	2.83[a]
96 N	875.9	13.67	33.7	43	512	46.54a	1.44[a]	3.02[a]
130 N	879.1	13.97	33.2	45	461	45.75bc	1.07[a]	2.75[a]
160 N	884.1	12.93	30.4	44	544	45.33cd	1.28[a]	2.93[a]
Untreated pig slurry	876.2	12.67	31.0	49	466	44.83d	1.31[a]	2.84[a]
Acidified pig slurry	875.3	13.60	34.1	42	459	46.20ab	1.54[a]	2.82[a]

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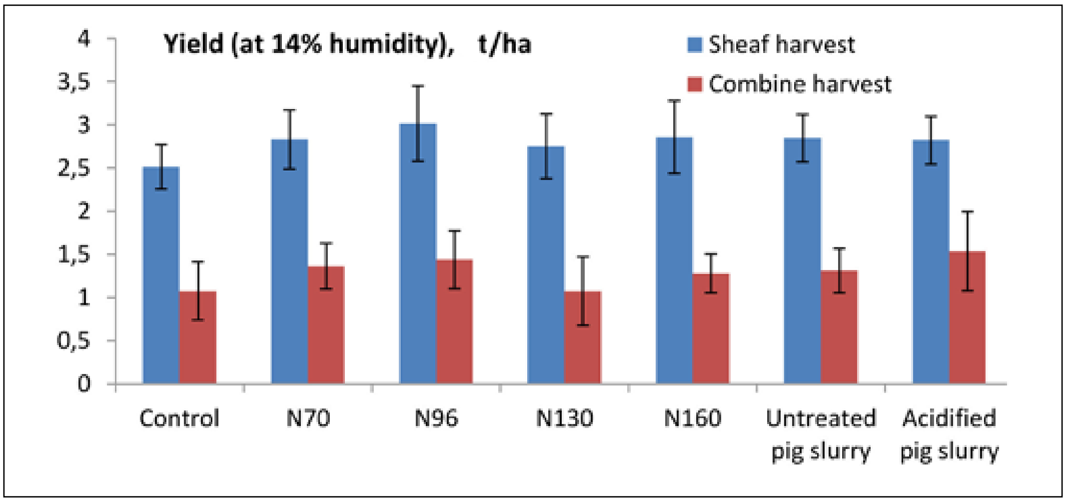

Figure 12. *The winter wheat yield t/ha (at 14% humidity. combine and sheaf harvest). The error bar refers to the standard deviation of the mean (n=4).*

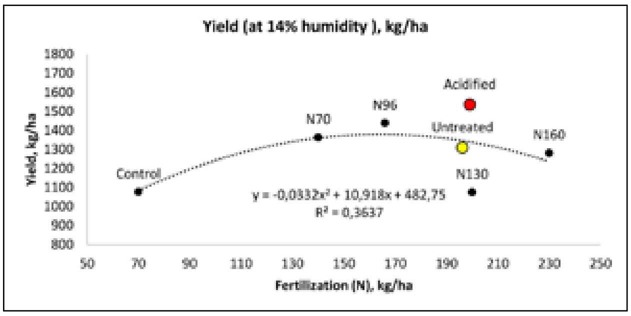

Figure 13. *Analyses of regression between yield (combine harvest) and fertilization rate. Red dot shows the fertilisation with untreated slurry and yellow dot acidified slurry.*

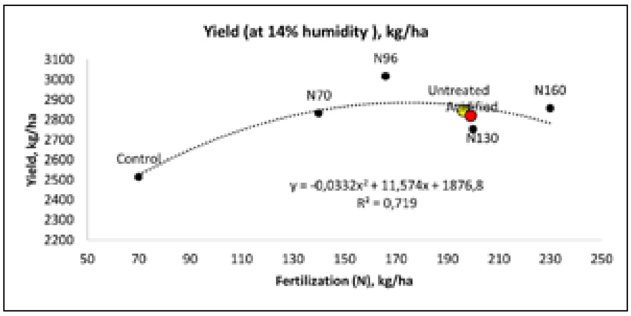

Figure 14. *Analyses of regression between yield (sheaf harvest, 0.25 m²) and fertilization rate. Red dot shows the fertilisation with untreated slurry and yellow dot acidified slurry.*

Plant diseases, incidence of Fusarium and mycotoxin DON on kernels

In 2018, the plant diseases did not occur because the weather was very dry and hot and not favourable for fungal plant disease. On the plant leaves only the drought caused physiological spots occurred. Incidence of *Fusarium* in mineral fertilizer N 160 was the lowest compared to other treatments, but not statistical significant (Figure 15).

In winter wheat kernels the mycotoxin DON (deoxynivalenol) did not occurr.

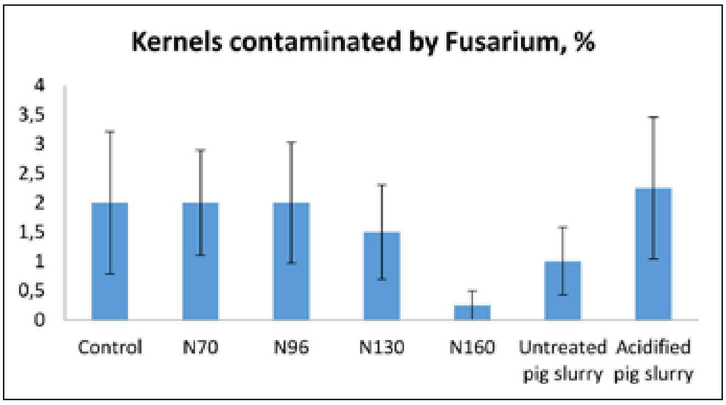

Figure 15. *The incidence of Fusarium in winter wheat kernels. The error bar refers to the standard deviation of the mean (n=4).*

Soil dehydrogenase activity (DHA)

Results showed higher soil DHA in all treatments in spring before fertilization (17.04.2018) (Table 9, Figure 16). During the next two measurements (11.06.2018, 30.07.2018) the soil DHA decreased drastically. It was probably caused by the extraordinary dry and hot June and July which reduced the soil moisture content. The average soil moisture content on 11.06.2018 and 30.07.2018 soil samples was only 3–4 %. Two weeks after slurry application significant (*p<0.05*) differences occured only between untreated slurry and N 160 treatment, but it was still noticeable that compared to the other treatments the soil DHA was higer in slurry treatments. The one reason why the soil DHA in these treatments increased was probably water which was applied with untreated and accidified slurry (about 27 t/ha, Tables 3, 5).

Before harvest (30.07.2018) the mean value of soil DHA was still higher in slurry treatment plots as well as in N 70 treatment and significantly (p<0.05) lower in control and N 160 treatments. In addition, this year under the extraordinary dry and hot weather condition in June and July the negative relationship between soil DHA and amount of mineral fertilizers was quite noticeable (Table 9, Figure 16).

Table 9. *Soil dehydrogenase activity (DHA. TPF µg/g/h). Different letters behind the mean values (n=4) indicate significant differences (p<0.05) in a category*

Treatment	Spring 17.04.2018	2 weeks after slurry application 11.06.2018	Before harvest 30.07.2018
Control	8.30[a]	3.72[ab]	2.00[c]
Mineral fertilizer 70 N	9.39[a]	4.40[ab]	4.33[a]
Mineral fertilizer 96 N	9.31[a]	4.53[ab]	3.31[abc]
Mineral fertilizer 130 N	8.94[a]	4.02[ab]	3.73[ab]
Mineral fertilizer 160 N	9.01[a]	3.33[b]	2.35[bc]
Untreated slurry	9.06[a]	6.04[a]	4.48[a]
Acidified slurry	9.33[a]	5.08[ab]	4.26[a]

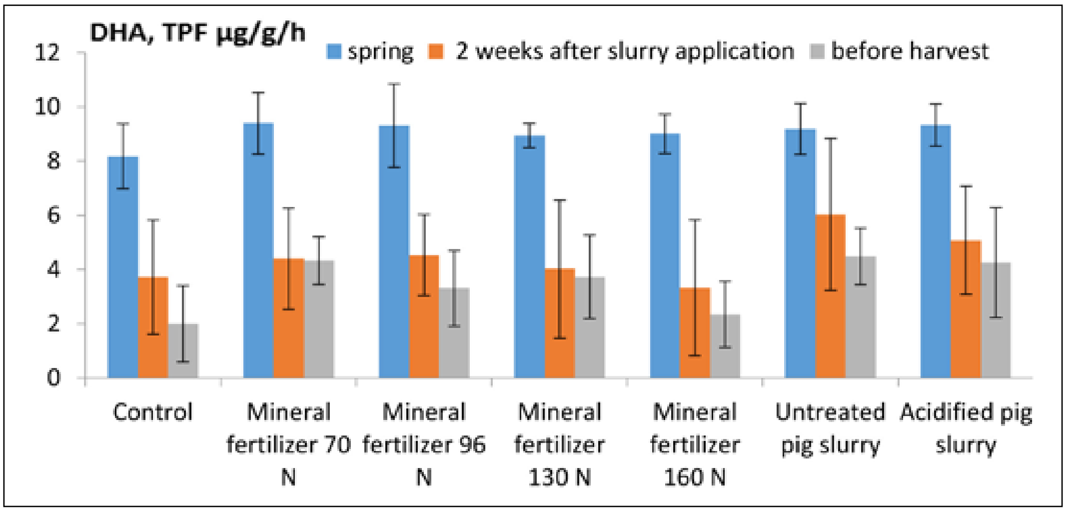

Figure 16. *Soil dehydrogenase activity (DHA, TPF µg/g/h). The error bar refers to the standard deviation of the mean (n=4).*

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Analysis of Soil Phospholipid Fatty Acid (PLFA)

In this study, we determined total bacteria, gram-positive and gram-negative bacteria, Actinobacteria, saprotrophic fungi and arbuscular mycorrhizal fungi.

In general, PLFAs profile was accordant with results of soil dehydrogenase activity. The highest concentration of PLFAs was found in spring (Table 10). The concentrations of all marker PLFAs started to decrease in summer (Table 11, Table 12) and were the lowest before harvesting at the end of July (Table 13). These results are related to extreme dryness of soil because of low level of precipitation during the growing season.

Overall, no significant differences between plots were identified in spring before adding any fertilizer to determine the homogeneity of our study site (Table 10).

Table 10. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) of microbial groups in spring 2018 (17.04.2018)*

Treatment	Control	N70	N96	N130	N160	Untreated slurry	Acidified slurry	*Prob > F*
Total	17.25	18.63	17.97	17.39	18.20	19.12	17.49	*ns*
Bacteria	10.88	11.79	11.24	10.73	11.36	11.98	11.03	*ns*
Gram+	5.46	5.82	5.55	5.13	5.60	5.95	5.55	*ns*
Gram-	4.83	5.36	5.08	5.02	5.17	5.40	4.88	*ns*
Actinomycetes	1.60	1.70	1.73	1.66	1.64	1.73	1.65	*ns*
AMF	1.68	1.88	1.75	1.75	1.83	1.85	1.70	*ns*
Saprotrophic fungi	3.09	3.27	3.25	3.24	3.37	3.56	3.11	*ns*

According to results, no significant differences in the sum of microbial groups PLFA concentrations were found from two weeks after slurry application, (Table 11, Figure 17) or at the end of July before harvesting (Table 13, Figure 18).

Table 11. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) of microbial groups two weeks after slurry application (11.06.2018)*

Treatment	Control	N70	N96	N130	N160	Untreated slurry	Acidified slurry	*Prob > F*
Total	14.75	14.57	13.54	14.09	14.51	14.07	14.57	*ns*
Bacteria	9.52	9.42	8.70	8.87	9.30	9.09	9.39	*ns*
Gram+	5.23	5.20	4.74	4.75	5.09	5.01	5.15	*ns*
Gram-	3.74	3.66	3.42	3.57	3.65	3.54	3.68	*ns*
Actinomycetes	1.32	1.28	1.27	1.26	1.31	1.30	1.31	*ns*
AMF	1.38	1.32	1.24	1.28	1.34	1.30	1.35	*ns*
Saprotrophic fungi	2.54	2.55	2.34	2.66	2.57	2.38	2.53	*ns*

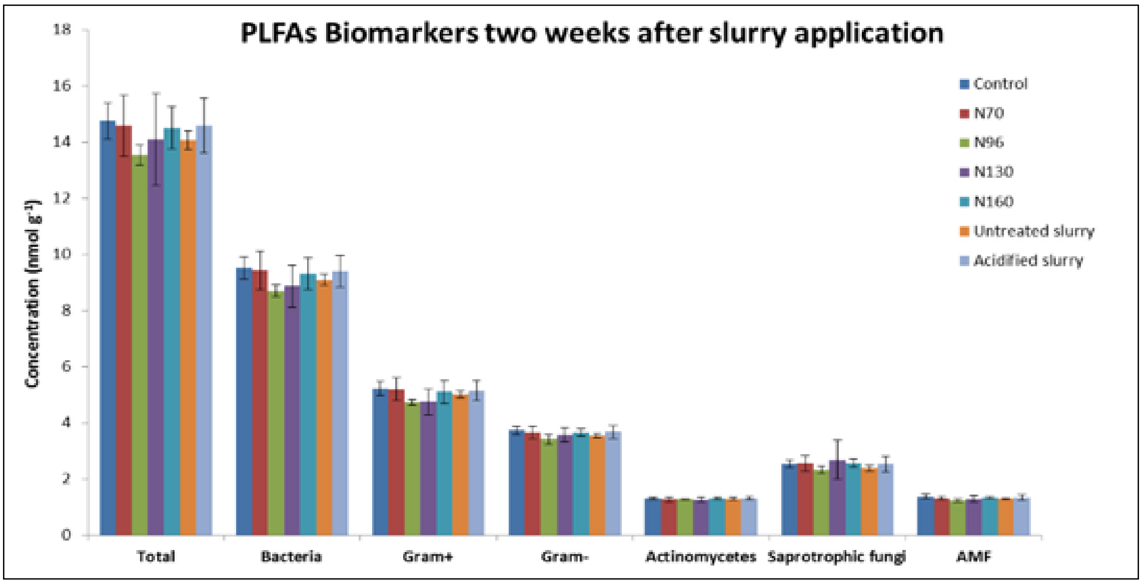

Figure 17. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from different microbial groups two weeks after slurry application (11.06.2018) between treatments. The error bar refers to the standard deviation of the mean (n=4).*

However, when we compare our means results we can see tendency of slightly lower concentrations of PLFA markers in treatments with mineral fertilizer (Table 11, Table 13; Figure 17, Figure 18). These results are in accordance with previous results where negative impact of mineral fertiliser to microbial communities have been shown.

In addition, we conducted comparison of each PLFAs marker and found some significant differences (Table 12, Table 14). Firstly, two weeks after big slurry application, there were two markers (anteiso 15:0 and 15:0) that were significantly higher in plots with untreated slurry. Those two markers were intermediate in plots with acidified slurry and the lowest with mineral fertilizer. Marker anteiso 15:0 belonging to the group of Gram-positive bacteria and marker 15:0 describes group of all bacteria.

Table 12. *Concentrations of separate FAMEs (nmol g^{-1} dry soil) of PLFAs two weeks before big slurry application (11.06.2018)*

Treatment	Control	N70	N96	N130	N160	Untreated slurry	Acidified slurry	*Prob > F*
iso15:0	1.982	1.952	1.946	1.879	1.869	2.078	1.947	*ns*
anteiso15:0	1,30^{ab}	1,27^{b}	1,27^{b}	1,22^{b}	1,22^{b}	1,49^{a}	1,41^{ab}	*0.003*
15:0	0,30^{b}	0,29^{b}	0,29^{b}	0,29^{b}	0,29^{b}	0,33^{a}	0,31^{ab}	*0.0025*
16:1 w7c	1.864	1.863	1.849	1.797	1.783	1.968	1.880	*ns*
16:1 w5c	1.337	1.347	1.307	1.275	1.288	1.332	1.314	*ns*
iso17:0	0.597	0.625	0.612	0.609	0.581	0.642	0.635	*ns*
anteiso17:0	1.176	1.148	1.143	1.105	1.136	1.207	1.120	*ns*
17:0 cyclo	0.862	0.866	0.849	0.864	0.833	0.869	0.876	*ns*
17:0	0.250	0.248	0.240	0.247	0.244	0.264	0.257	*ns*
17:0 10-Met	0.526	0.523	0.513	0.531	0.517	0.534	0.534	*ns*
18:2 w6c	0.566	0.535	0.523	0.515	0.515	0.782	0.533	*ns*
18:1 w9c	1.946	1.911	1.899	1.837	1.841	2.169	2.003	*ns*
18:0 10-Met	0.773	0.763	0.758	0.762	0.750	0.793	0.773	*ns*
19:0 cyclo	0.916	0.913	0.883	0.889	0.852	0.924	0.873	*ns*

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***Table 13.** Concentrations of marker PLFAs (nmol g^{-1} dry soil) of microbial groups before harvesting (30.07.2018)*

Treatment	Control	N70	N96	N130	N160	Untreated slurry	Acidified slurry	*Prob > F*
Total	13,10	12,91	12,59	12,89	12,98	13,43	12,80	*ns*
Bacteria	8,44	8,31	8,10	8,30	8,38	8,63	8,25	*ns*
Gram+	4,02	3,96	3,85	3,96	4,00	4,12	3,92	*ns*
Gram-	2,94	2,89	2,81	2,89	2,92	3,03	2,88	*ns*
Actinomycetes	1,60	1,57	1,54	1,58	1,58	1,62	1,56	*ns*
AMF	1,04	1,03	1,00	1,03	1,03	1,08	1,01	*ns*
Saprotroph fungi	2.02	2.00	1.95	1.98	1.98	2.10	1.97	*ns*

Comparison of each PLFAs marker before harvesting showed more significantly different markers (Table 14). In total, nine markers were significantly different. Most of the markers were the highest in plots with untreated slurry. Two markers (iso 17:0 for Gram-positive bacteria and 17:0 fro bacteria) showed higher values in control. Overall, concentrations from plots with acidified slurry showed similar results as concentrations in treatments with mineral fertilizer.

***Table 14.** Concentrations of separate FAMEs (nmol g^{-1} dry soil) of PLFA before harvesting (30.07.2018)*

Treatment	Control	N70	N96	N130	N160	Untreated slurry	Acidified slurry	Prob > F
iso15:0	1.296	1.234	1.251	1.235	1.251	1.322	1.223	*ns*
anteiso15:0	1,11^{ab}	1,07^{b}	1,09^{ab}	1,08^{ab}	1,08^{ab}	1,15^{a}	1,08^{ab}	*0.036*
15:0	0,774^{ab}	0,763^{c}	0,764^{c}	0,762^{c}	0,761^{c}	0,777^{a}	0,765^{bc}	*0.037*
16:1 w7c	1,22^{ab}	1,20^{ab}	1,19^{ab}	1,18^{b}	1,20^{ab}	1,30^{a}	1,20^{ab}	*0.045*
16:1 w5c	1.059	1.016	1.019	1.022	1.016	1.084	1.010	*ns*
iso17:0	0,825^{a}	0,795^{ab}	0,800^{ab}	0,797^{ab}	0,798^{ab}	0,821^{ab}	0,791^{b}	*0.018*
anteiso17:0	0,831^{ab}	0,811^{c}	0,815^{bc}	0,810^{c}	0,813^{c}	0,836^{a}	0,810^{c}	*0.029*
17:0 cyclo	0,906^{ab}	0,875^{bc}	0,877^{bc}	0,879^{bc}	0,879^{bc}	0,923^{a}	0,873^{c}	*0.024*
17:0	0,702^{a}	0,690^{c}	0,690^{c}	0,690^{c}	0,689^{c}	0,701^{ab}	0,691^{bc}	*0.045*
17:0 10-Met	0.792	0.766	0.775	0.770	0.778	0.787	0.764	*ns*
18:2 w6c	0,790^{ab}	0,772^{b}	0,769^{b}	0,775^{ab}	0,784^{ab}	0,825^{a}	0,774^{b}	*0.023*
18:1 w9c	1.228	1.189	1.196	1.192	1.205	1.302	1.193	*ns*
18:0 10-Met	0,815^{ab}	0,792^{b}	0,794^{ab}	0,799^{ab}	0,796^{ab}	0,838^{a}	0,792^{b}	*0.025*
19:0 cyclo	0.828	0.806	0.810	0.792	0.801	0.830	0.797	*ns*

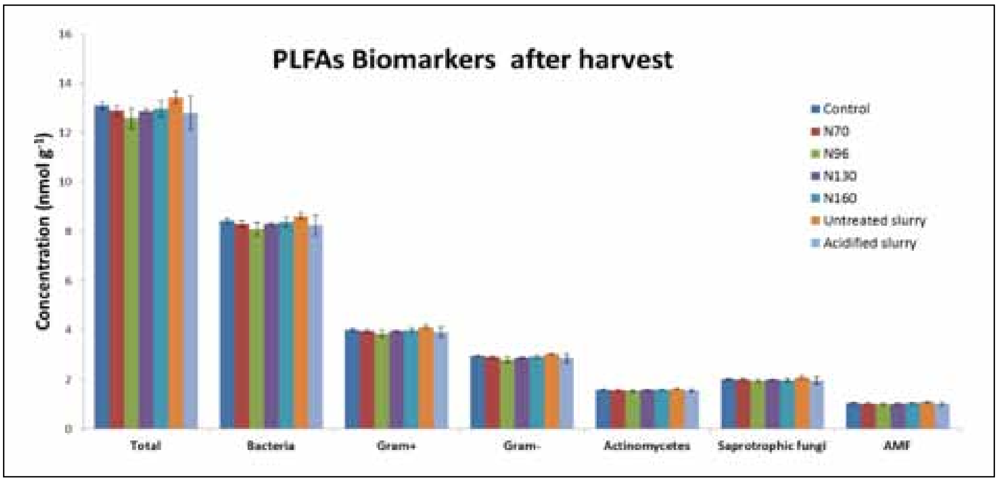

***Figure 18.** Concentrations of marker PLFAs (nmol g^{-1} dry soil) from different microbial groups before harvesting (09.08.2018) between mean treatments. The error bar refers to the standard deviation of the mean (n=4).*

This study showed that slurry acidification had no significant impact to microbial group's composition in winter wheat trial. Overall, untreated pig slurry application increased slightly the concentrations of marker PLFAs from different microbial groups. General, all treatments showed similar microbial community structure two weeks after slurry application and before harvesting. Still, these results are based on one year experiment and more study is needed for final conclusions.

Reporting form: 2018, winter wheat *(please, activate the link below)*
https://www.dropbox.com/s/i7cv49zwb8wcfro/Estonia%20WP4%20winter%20wheat%252C%20 2018%2528Final%2529.xls?dl=0

Conclusions

The use of acidified cattle slurry compared to the untreated slurry had not significant impact on the grassland yield neither in year 2017 nor in 2018. The spreading of acidified slurry increased the sulphur content in the soil in both years. The sulphur amount applied to the soil with acidified slurry was high (78.13 kg/ha in 2017, 43.3 kg/ha in 2018) compared to the recommendations in Estonia (in grassland max 40 kg S per ha, Väetamise ABC). The same can be said about acidified slurry sprayed on winter wheat: 52.8 kg S/ha in 2017 and 89.9 kg S/ha in 2018 (recommendation in winter cereals max 25 kg S per ha. Väetamise ABC, 2014).

The use of acidified slurry increased the sulphur content in soil, thus causing a risk for leaching and contamination of the groundwater and waterbodies. However, sulphur is important nutrient for plants, thus it is important to adjust the use of acidified slurry by the sulphur demand of crops.

The use of acidifyed slurry had no significant impact to the winter wheat yield and yield quality neither in year 2017 and in 2018.

Results showed that winter wheat fertilization with pig slurry reduced the occurrence of leaf diseases, as septoria leaf spot and septoria tan spot in 2017. There was a tendency that incidence of *Fusarium* in kernels increased with application of acidified slurry.

Based on test results of two year (2017 and 2018), it can be concluded that compared to the untreated slurry the use of acidified slurry did not affect the soil dehydrogenase activity and thus the microbiological activity of soil. As well as the slurry acidification had no significant impact to soil microbial group's composition (PLFA). Still, the results of PLFAs are based on one year experiment and more study is needed for final conclusions.

In-field slurry acidification device SyreN Min trial on ECRI grassland

Written by: Kalvi Tamm, Liina Edesi, Tiit Plakk, Tiina Talve

Aim

The aim of this trial was to test in-field slurry acidification device SyreN Mini on Estonian grassland and learn the effect of acidified cattle slurry on soil chemical and microbiological properties treated with the device in autumn.

Materials and methods

Study site

Slurry spreading time: 16.10.2018, 15.00-17.00.

Location: Near to Jõgeva, ECRI trial field

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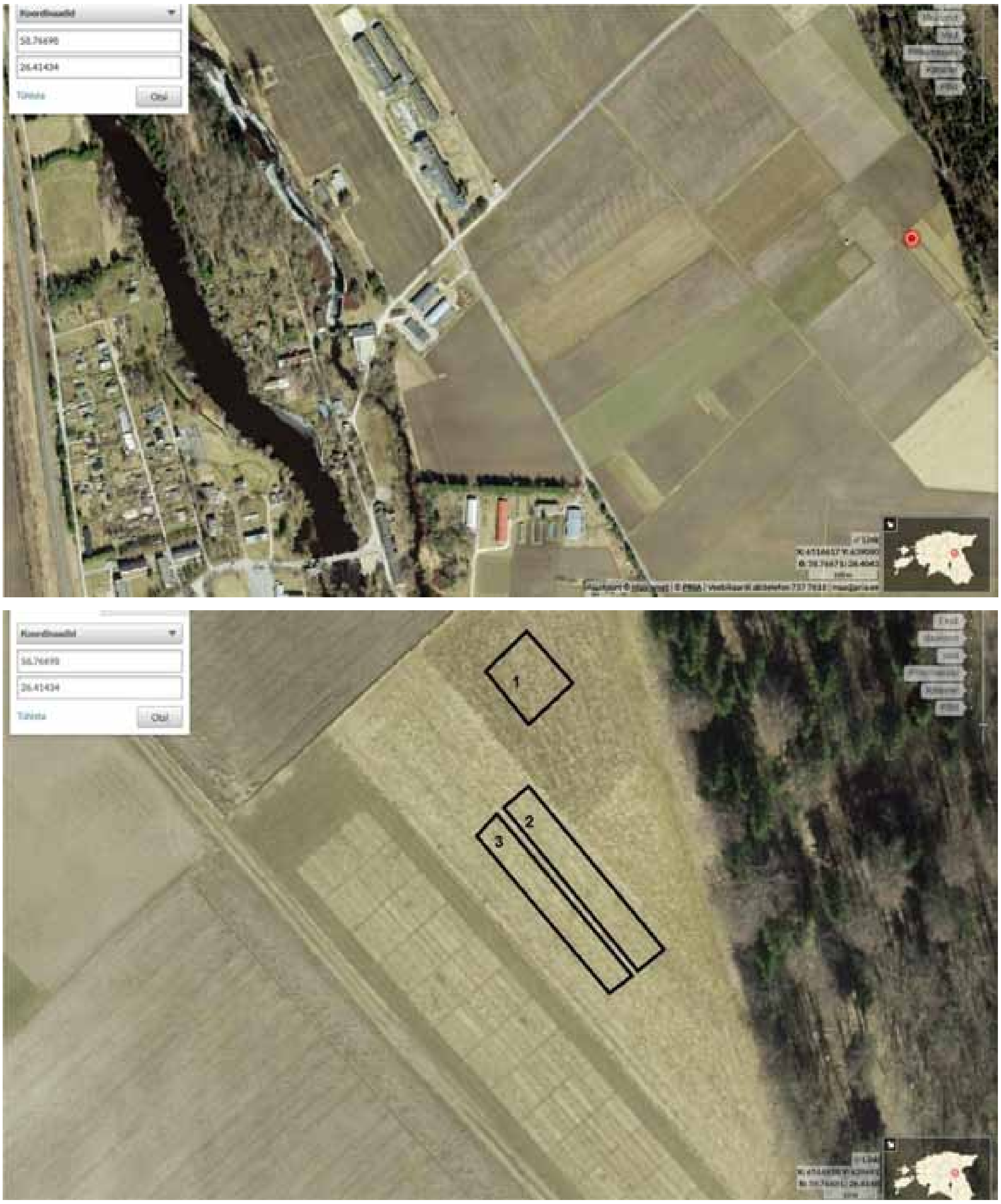

Figure 1. *Location of demonstration trial in Jõgeva, Estonia. Picture from digital map managed by Estonian Land Board.*

Variants:

1. Control
2. Cattle slurry
3. Acidified cattle slurry

Crop: Grassland, rich of grasses.

Figure 2. *View to the demonstration trial in Jõgeva, Estonia. 17.10.2018. Picture by Kalvi Tamm.*

Weather: Sunny, no clouds, no precipitation, wind 2.5 (5.7) m s^{-1}, 15 °C.

Table 1. *Weather data in trial area*

Date	16.Oct	17. Oct	18. Oct	19. Oct	20. Oct
Min air temp, °C	6.1	2.2	3.3	0.8	-1.2
Max air temp, °C	16	16.6	16.9	12.2	7.6
24h avg air temp, °C	10.1	8	9.6	7.6	2.7
Prec., mm	0	0	0	1.4	0
Max wind speed, m/s	5.8	4.3	6.9	8.2	3.9
Min wind speed, m/s	1.7	1.1	1.7	2.3	0.8
Sun-shine duration, h	8.2	7.8	3.6	7.8	1.6
Min air rel. humidity, %	66	58	60	51	86
Avg air rel. humidity, %	77	86	85	79	95

Spreader. Joskin slurry tanker Modulo2 8400ME and Joskin injection spreader Solodisc 3010_14SD (Figure 3). Tank volume 8.4 m^3 and spreader work width 3 m.

The in-field acidification system SyreN Mini was mounted to the spreader and tractor.

Figure 3. *ECRI slurry spreader with SyreN in-field acidification system on demonstration trial field in Jõgeva, Estonia. Picture by Kalvi Tamm.*

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Slurry: Cattle slurry from a dairy farm locating 15 km from field.

Two samples were collected during spreading from both type of slurries. Slurry samples were stored in coolbox with coolbatteries until samples were given over to accredited laboratory for analyses.

***Table 2.** Cattle slurry properties*

Sample Nr	Dry matter content	Total N, kg/m³	NH4-N, kg/m³	P, kg/m³	K, kg/m³	S*, kg/m³	pH* in accred-ited labor, (KCl)	pH in ECRI labor, (Hanna pH-mete)	pH on the field, (SyreN pH-mete)	Ca, kg/m³	C in dry matter, %
Slurry sample 1	9.6	4.1	2.7	0.53	2.4	1.2	8.1	6.7	6.8	1.7	18.4
Slurry sample 2	10.4	3.9	2.5	0.53	2.4	1.1	8.0	6.7	6.8	1.8	17.9
Average	**10.0**	**4.0**	**2.6**	**0.53**	**2.4**	**1.2**	**8.1**	**6.7**	**6.8**	**1.8**	**18.2**
Acidified slurry sample 1	11.8	3.9	2.8	0.53	2.3	1.5	7.8	6.43	6.3	1.8	18.1
Acidified slurry sample 2	11.2	3.9	2.7	0.53	2.3	1.5	7.8	6.4	6.3	1.8	17.1
Average	**11.5**	**3.9**	**2.8**	**0.53**	**2.3**	**1.5**	**7.8**	**6.4**	**6.3**	**1.8**	**17.6**

DM: gravimetry ; N_{tot}: Kjeldahl; NO_3: Foss Tecator AN 5232; NH_4: Foss Tecator AN 5226; P_{tot}, K_{tot}, Ca: Wet ash + ICP/OES; S: PMK-JJ-4C; pH KCl: GOST 27979-88; C_{org}: ISO 10694 : 1995;

*parameter method is not accredited

Amount of slurry 30 t ha^{-1}.

***Table 3.** Plant nutrient supply*

	Slurry amount t ha^{-1}	N, (NH_4-N)	N_{tot}, kg ha^{-1}	P, kg ha^{-1}	K, kg ha^{-1}	S, kg ha^{-1}
Untreated cattle slurry	30	78.0	120.0	15.9	72.0	36
Acidified cattle slurry	30	84.0	117.0	15.9	69.0	45

Acid: 96% sulphuric acid.

Acid flow from acid pump 3 l min^{-1}.

Driving speed during spreading: 7 km h^{-1}.

Weight of slurry container before acidification 45.85 kg. The container contained 24 l of acid before spreading. Weight of slurry container after acidification 8.3 kg. Acid consumption during spreading was 37.55 kg or 20.5 l. Acidified slurry amount 6.83 m^3 and it was spread to area 0.228 ha.

Calculated acid consumption was 3 l m^{-3}.

Slurry pH during acidification 6.3, SyreN board computer.

Slurry pH during non-acidification 6.8, SyreN board computer.

Figure 4. *ECRI slurry spreader with SyreN in-field acidification system on demonstration trial field in Jõgeva, Estonia. Picture by Kalvi Tamm.*

Soil

Twenty subsamples were collected with 2 cm diameter soil auger from 0–25 cm layer, on Z-track over plot and mixed to one bigger sample. Soil samples were collected from 3 plots on 17.10.2018 afternoon and sent to the laboratory for chemical analyses. Soil samples were also taken from 0–10, 10–20, 20–30 and 30–40 cm soil layers one month after slurry application (16.11.2018). Soil samples were stored in cool box with cool batteries until samples were given over to accredited laboratory for analyses. Soil samples were determined (pH-ISO 10390; P, K, Ca, Mg –Mehlich III; N – ISO 11261; NO_3-N, NH_4-N – 1n KCl; SO_4 – ISO 11048) in accredited laboratory of Agricultural Research Centre, Estonia.

One day after the slurry application compared to the control, the results of soil chemical analyses showed higher amount of P, SO_4 NO_3 and NH_4 in slurry treatments (Table 4). At the same time, although the content of P, K and NH_4 in untreated and acidified slurry was similar (Table 3), their content was higher in soil treated with acidified slurry. Also, the content of SO_4 and Ca in soil remained higher in acidified slurry treatment (Table 4).

Table 4. *Soil analyses next day after slurry spreading at a depth 0–25 cm (17.10.2018)*

Variant	pH_{KCl}	P, mg kg^{-1}	K, mg kg^{-1}	Ca, mg kg^{-1}	Mg, mg kg^{-1}	N %	SO_4, mg kg^{-1}	NO_3-N, mg kg^{-1}	NH_4-N, mg kg^{-1}
Control	5.5	187	216	1120	50	0.14	5.2	3.6	2.1
Cattle slurry	5.4	208	207	1160	46	0.14	12	10.2	6.2
Acidified cattle slurry	5.5	205	235	1472	53	0.15	28	13.2	11.3

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One month after slurry application, compared to the control results of soil chemical analyses showed higher amount of P, K, SO_4, NO_3 and NH_4 in slurry treatments (Table 5, Figure 5). Compared to the untreated slurry treatment the content of NH4 in the 0–10 and 10–20 cm and NO_3 in the different soil layers at 0–40 cm was remarkably higher in acidified slurry treatment (Table 5, Figure 5). Also, the SO_4 content was the highest in acidified slurry treatment, especially in the soil layer 10–20 cm. In addition, compared to the control and untreated slurry variants the soil analyses showed the highest P, K, Ca, Mg content in the acidified variant (Table 5).

Table 5. *Soil analyses one month after slurry spreading at depth of 0–10, 10–20, 20–30 and 30–40 cm (16.11.2018)*

Variant	Depth, cm	pH_{KCl}	P, mg kg^{-1}	K, mg kg^{-1}	Ca, mg kg^{-1}	Mg, mg kg^{-1}	N %	SO_4, mg kg^{-1}	NO_3-N, mg kg^{-1}	NH_4-N, mg kg^{-1}
Control	0–10	5.4	181	343	1036	51	0.16	4.1	3.7	4.6
Control	10–20	5.4	169	125	1095	38	0.13	3.6	2.2	1.6
Control	20–30	5.4	113	109	826	32	0.09	3.8	1.3	1.5
Control	30–40	5.3	66	99	514	27	0.05	4.2	0.3	0.7
Average	**0–40**	**5.4**	**132.3**	**169**	**867.8**	**37**	**0.11**	**3.9**	**1.9**	**2.1**
Cattle slurry	0–10	5.3	195	366	1026	52	0.15	18	13.3	16.8
Cattle slurry	10–20	5.3	193	145	1090	39	0.14	9	6.3	2
Cattle slurry	20–30	5.3	169	145	948	35	0.11	4.4	3.7	1.6
Cattle slurry	30–40	5.2	82	120	477	23	0.06	4.1	2.6	1.2
Average	**0–40**	**5.3**	**159.8**	**194**	**885.3**	**37.3**	**0.12**	**8.9**	**6.5**	**5.4**
Acidified cattle slurry	0–10	5.3	194	427	1105	70	0.17	24	25.5	20.9
Acidified cattle slurry	10–20	5.3	187	181	1242	42	0.14	49	15.8	4.1
Acidified cattle slurry	20–30	5.6	179	150	1231	40	0.12	14	8	1.7
Acidified cattle slurry	30–40	5.6	111	139	791	31	0.07	4.8	6.9	1
Average	**0–40**	**5.5**	**167.8**	**224.3**	**1092.3**	**45.8**	**0.13**	**23.0**	**14.1**	**6.9**

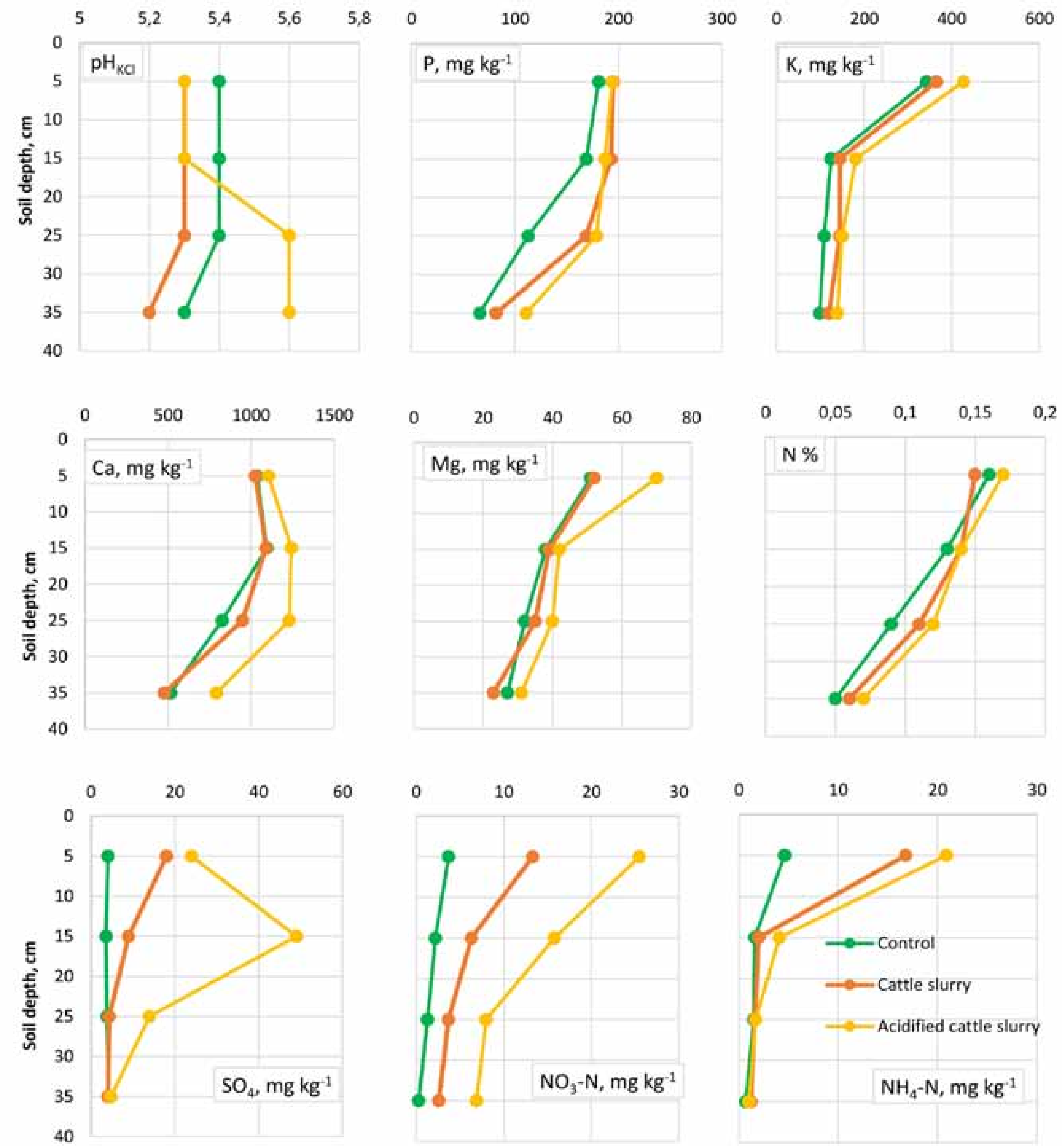

Figure 5. *Soil* pH_{KCl}*, amount of P, K, Ca, Mg, N%,* NO_3*-N,* NH_4*-N and* SO_4 *at a depth 0–10, 10–20, 20–30 and 30–40 cm, one month after slurry spreading (16.11.2018).*

Percostation measurements

Two percostations with total 8 sensors for continuous measurement of soil electrical parameters were installed at Jõgeva trial field on 26.10.2018, one week after the slurry was applied to trial plots. The measurements started at 15.36 26.10.2018. The preliminary investigation of soil electrical conductivity indicated that most of added nutrients were still located in the soil upper layer 0-10 cm.

The 8 sensors were installed this way: 3 sensors on plot with acidified slurry (trial variant 3) on depths of 5 cm, 15 cm and 25 cm close to each other on the slurry row (see the table 6 below). The sensors measured soil apparent electrical conductivity ECa, dielectric constant Er and soil temperature with pre-set interval (1h in the beginning and 2 h later on) and sent the information to the Internet database.

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Table 6. *The codes of percostation sensors and layout on trial plots*

Sensor depth, cm	Sensor codes on control plot (1)	Sensor codes on plot with cattle slurry (2)	Sensor codes on plot with acidified cattle slurry (3)
5	K_5	2_5	3_5
15	K_15	2_15	3_15
25		2_25	3_25

The soil salinity measured with hand-percometer (Figure 6) in all layers 0–30 cm before treatment was very low, apparent conductivity ECa ca 30 µScm^{-1} which accords to ca 70 when transferred to salinity ECe. Only on depths of 30–40 cm of control area a small rise of ECa to around 40 µScm^{-1} was found. However, together with stable and high volumetric water content (average ca 35 % Wv) in all soil profile, the test conditions appeared close to ideal: clean, "washed out" soil for observing the behaviour and movement of soil nutrients due to applied slurry.

Figure 6. *Hand-percometer for single-measurements.*

Due to high and stable moisture content the apparent electrical conductivity ECa values are directly comparable to each other, but for getting general applicable indicator of nutrient content, ECa is transferred also into salinity ECe values. The somewhat bigger unevenness of ECe graph is due to some break points in ECa>ECe at algorithms, but they do not change the basic circumstances found in nutrients behaviour. When evaluating and interpreting the results of measurements must be kept in mind that the soil at Jõgeva trial plot is glay-soil and therefore, the movement of ions in soil solution differs somewhat from normal mineral soil.

The time and depth graphs of the ECa (Figure 9) and ECe (Figure 11) show clear difference among all trial variants. Some points clearly visible from graphs can be noted (the analysis is done based on direct ECa values, but due to stable moisture content is directly valid also for salinity):

Figure 7. *Percostations on field trial.*

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Figure 8. *Sensors on cattle slurry (2) plot. From left: 15 cm sensor, 5 cm sensor and 25 cm sensor.*

- During the measurement period from 26.10–02.12.2018 the ECa values of control plot sensors at 5 and 15 cm (probes k_5 and k_15) are stable around 30 µScm-1. At 28.11 evening, the freezing process of upper soil layers begins (Figure 10) and EC values after that are not suitable to interpret as salinity indicator.
- ECa and ECe values in layer 25 cm case of slurry are almost stable throughout the whole measurement period both for acidified (sensor 3_25) and not treated slurry (sensor 2_25) whereas the starting value for trial variant 2 is 52 and for acidified slurry is 80 (reference value is ca 35). This indicates that during the week before measurement started some more mobile components from slurry had travelled to soil layer 25 cm and probably further.
- At the starting point of measurements the EC values of 15 cm layer are smaller than these of 25 cm for both variants 2 (smaller difference) and variant 3 (significant difference) indicating that acidified slurry contributes to bigger amount of fast moving component.

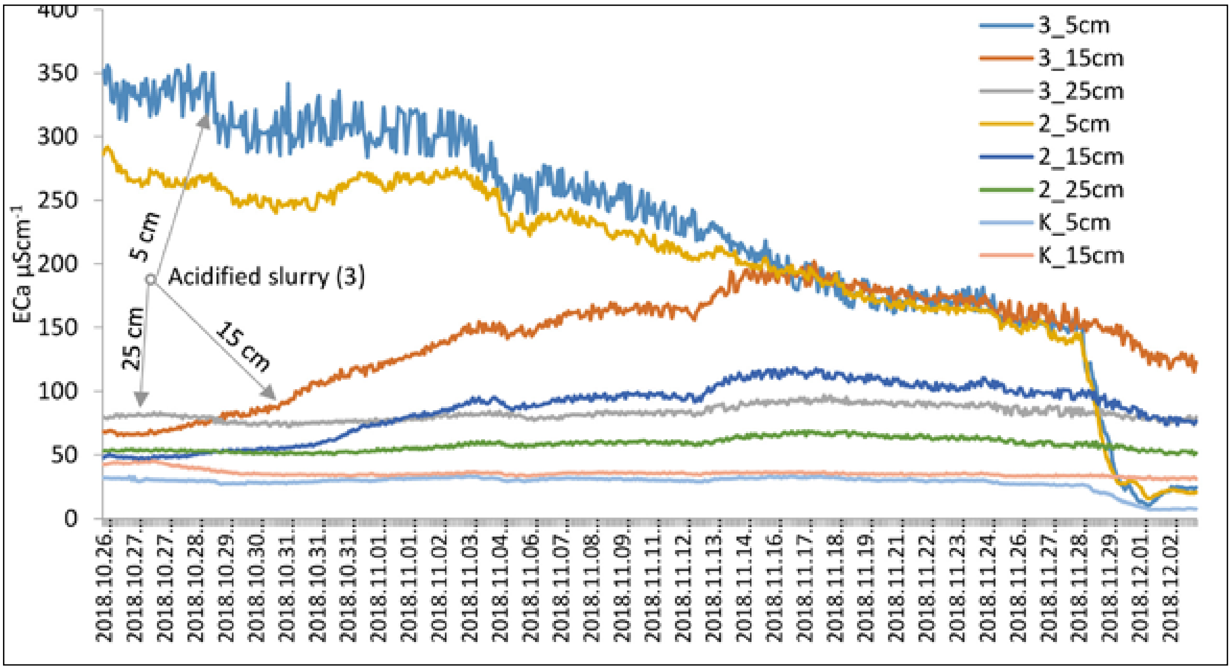

Figure 9. *Depth and time dynamics of soil apparent conductivity ECa due to slurry (2) and acidified slurry (3) vs. control (K) from Percostation data at Jõgeva trial field, BSA project.*

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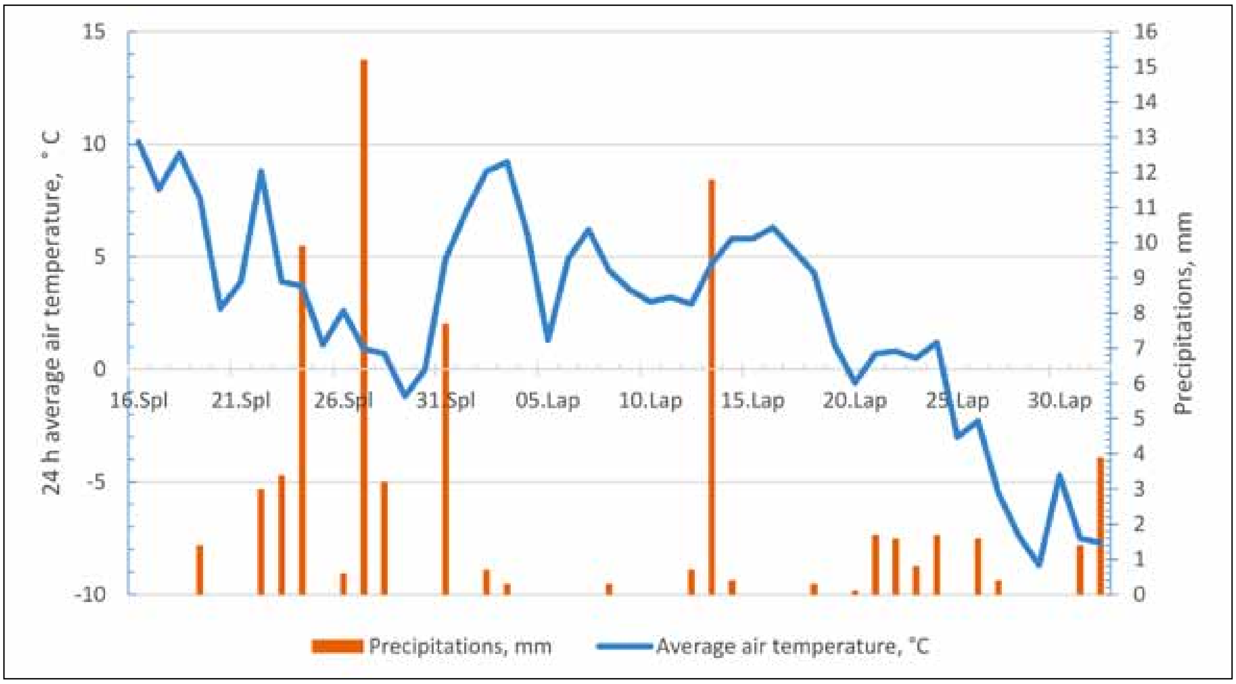

Figure 10. *Average air temperature and precipitation on Jõgeva trial site 16.10.2018-1.12.2018.*

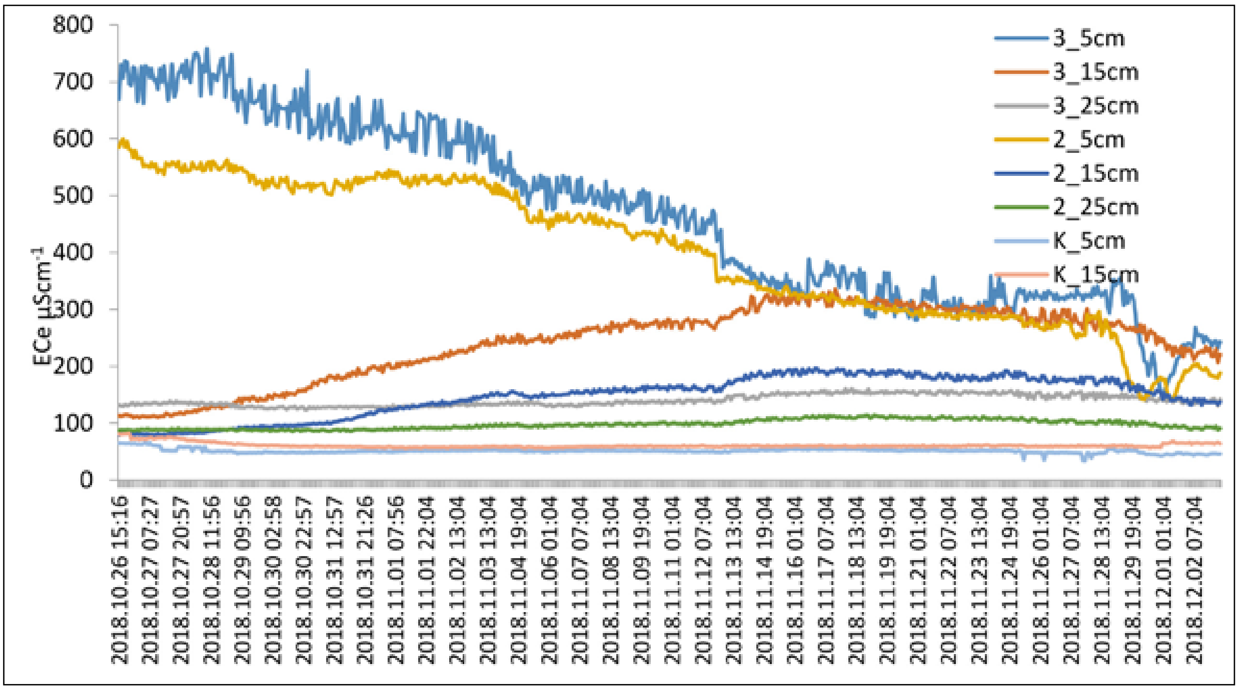

Figure 11. *Depth and time dynamics of total dissolved nutrients (Ece) in soil layers due to slurry (2) and acidified slurry (3) vs. control (K) from Percostation data at Jõgeva trial field, BSA project.*

- The initial value (after one week of rain) of ECa of not treated slurry in layer 5 cm is ca 270 and of acidified slurry is 350 indicating near 20 % difference of induced into soil soluble salts. The majority of nutrients are still in the soil upper layer 0–10 cm despite of moderate rainfalls on test site. Both initial values indicate that the content of dissolved salts in soil solution due to slurry application exceeds the control values about 10 times
- During the test period, the EC values of upper 5 cm layer gradually decrease, the decrease is slightly faster for acidified slurry. At the same time, EC of 15 cm layers rises for 10 days, EC values of sensor 3_15 cm reach those of 3_5 and 2_5, but sensor 2_15 is clearly lower. After 19 days of measurements, all EC values start to decrease slowly.

Soil dehydrogenase activity (DHA)

The acidified slurry induces clearly (up to 20%) more soluble salts into soil solution compared to untreated slurry. Some of these compounds are more movable, which causes danger of faster leaching. In case of Jõgeva clay soil the most of slurry soluble components are still present in soil upper layer after one week from application. Fast moving components show accumulation effect in deeper soil layers (25–30 cm).

Soil microorganisms participate in the processes that are crucial for long-term sustainability of agricultural systems (Nannipieri et al., 2003). Soil enzymatic activity is a sensitive indicator to evaluate the influence of different agricultural practices on the soil processes that are carried out by microorganisms (Watts et al., 2010). Dehydrogenase is an enzyme that occurs in all viable microbial cells (Watts et al., 2010) and therefore, important bioindicator relating to soil fertility (Wolinska and Stepniewska, 2012).

Soil samples (ca 0.5 kg) from each treatment from the 0–10, 10–20, 20–30 and 30–40 cm soil layers were taken with a 20 mm diameter auger on 16.11.2018. Samples were sieved (2 mm) and stored at 4 °C until analysis in laboratory. Measurements of soil dehydrogenase activity (DHA) based on Tabatabai (1982). Soil samples (5 g) were incubated at 30 °C for 24 h in the presence of an alternative electron acceptor (triphenyltetrazoliumchloride). The red-tinted product (triphenylformazan) was extracted with acetone and measured in a spectrophotometer at 546 nm (Figure 12).

Compared to the control treatment 0–40 cm and untreated slurry treatment 0–30 cm soil layers, results of analysis of soil dehydrogenase activity showed higher soil microbial activity in acidified slurry treatment (Figure 13). It was probably caused by the higher amount of soluble salts in acidified treatment soil than in other treatment (Table 4, Figure 5).

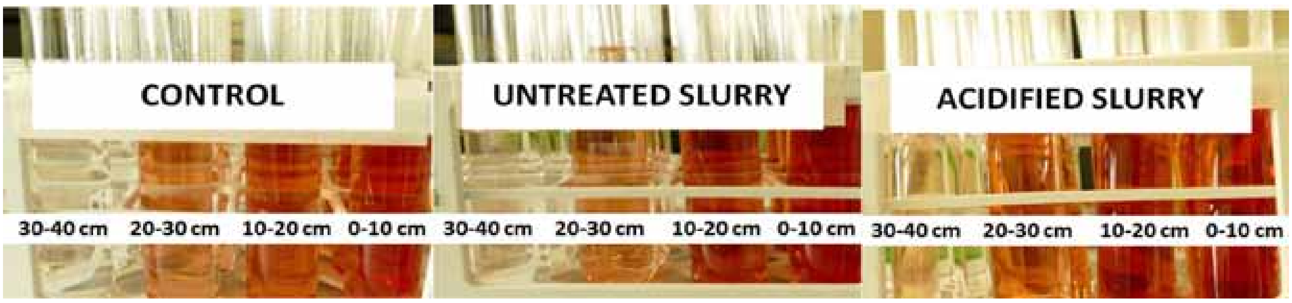

Figure 12. *The red-tinted product triphenylformazan (TPF) in the samples.*

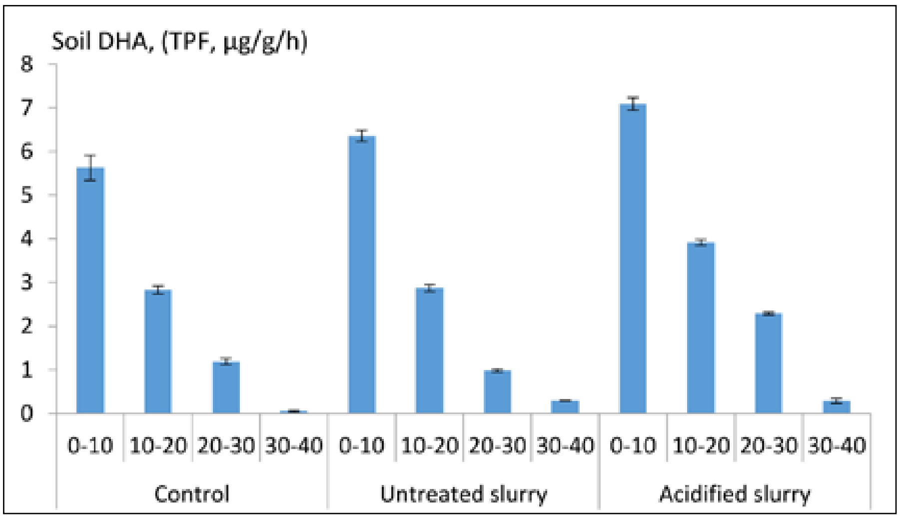

Figure 13. *Soil dehydrogenase activity (DHA, TPF μg/g/h).*

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Phospholipid fatty acid analysis (PLFA)

Phospholipid fatty acids (PLFA) are the main structural component of all microbial membranes. As the phospholipids of different groups of bacteria and fungi contain a variety of unique fatty acids, they can be handled as biomarkers for such groups. Changes in the structure of the microbial community were determined using phospholipid fatty acid (PLFA) extraction according to the modified (Bligh & Dyer, 1959) method, described in details by Moeskops et al. 2010. Briefly, all lipids are extracted from soil with a chloroform-methanol-phosphate buffer. Then, phospholipids were separated from neutral and glycolipids using the solid-phase extraction columns (Chromabond, Macherey-Nagel GmbH, Düren, Germany). Finally, they were converted to fatty acid methyl esters (FAMEs). Individual methyl esters can be identified and quantified by Gas Chromatography. PLFAs were determined by GC-MS on an Agilent Technologies 7890A GC system in electron ionization mode.

Overall, we estimated 14 different methyl esters from seven microbial groups. The sums of markers for fatty acid concentrations for selected microbial groups were calculated as follows (Ameloot et al. 2015, Gebremikael et al. 2015). For Gram-positive bacteria the sum of i15:0, a15:0, i17:0 an a17:0; for Gram-negative bacteria cy17:0, cy19:0 and C16:1ω7; for the actinomycetes the sum of 10-methyl branched saturated fatty acids (17:0 10-Met and 18:0 10-Met). For the total bacterial community, in addition to Gram-positive and Gram-negative bacteria, the fatty acids 15:0 and 17:0 were also included. For saprotrophic fungi the marker PLFAs 18:2ω6c and 18:1ω9, and for arbuscular mycorrhizal fungi (AMF) 16:1ω5c were considered.

In general, Gram-positive bacteria give a positive result with the Gram stain test because they have thick peptidoglycan layer in the cell wall. Despite the thicker layer, this group of bacteria are more sensitive to antibiotics because they do not have outer membrane. They tend to resist water stress. Gram-negative bacteria give a negative result with the Gram stain test. They are small bacteria and are sensitive to drought and water stress. Actinomycetes are important type of bacteria in soil. They have three important functions as nitrogen fixing bacteria and decomposer. Saprotrophic fungi are important group for decomposing different carbon sources, for example plant matter. An arbuscular mycorrhiza fungi (AMF) help plants to pick up phosphorus, sulphur, nitrogen and micronutrients from the soil.

Soil samples from field were taken together with dehydrogenase activity (DHA) analysis. Approximately 4 g of soil were weighted for PLFA analysis.

Overall, treatments with untreated and acidified slurry showed higher level of PLFAs biomarkers in all layers (0–10 cm, 10–20 cm, 20–30 cm and 30–40 cm) (Figure 14). Soil samples with acidified slurry treatment showed slightly higher microbial concentrations compared to samples of untreated slurry treatment. The concentrations of different microbial groups decreased with depth where the lowest results were found in 30–40 cm in all treatments. PLFAs results are in accordance with dehydrogenase activity (DHA) analysis.

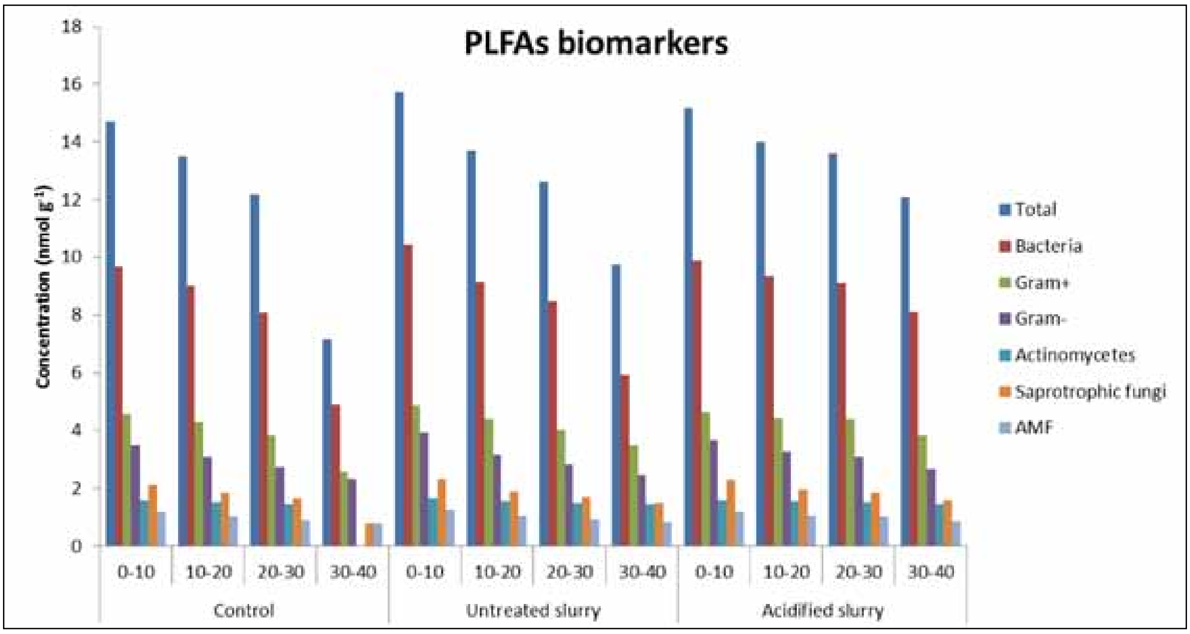

Figure 14. *Concentrations of marker PLFAs (nmol g^{-1} dry soil) from different microbial groups between treatments.*

References

Ameloot, N.; Sleutel, S.; Das, K.C.; Kanagaratnam, J.; De Neve, S. 2015. Biochar amendment to soils with contrasting organic matter level: effects on N mineralization and biological soil properties. GCB Bioenergy, 7: 135–144.

Bailey, K.L.; Lazarovits, G. 2003. Suppressing soil-born diseases with residue management and soil organic amendments. Soil &Tillage Reserach 72: 169-180.

Bligh, E.G.; Dyer, W.J. 1959. A rapid method of total lipid extraction and purification. Canadian Journal Biochemistry and Physiology, 37: 911–917.

Buchan, D.; Gebremikael, M.T.; Ameloot, N.; Sleutel, S.; De Neve S. 2013. The effect of free-living nematodes on nitrogen mineralisation in undisturbed and disturbed soil cores. Soil Biology & Biochemistry, 60: 142–155.

Gebremikael, M.T.; Steel, H.; Bert, W.; Maenhout, P.; Sleutel, S.; De Neve, S. 2015. Quantifying the contribution of entire free-living nematode communities to carbon mineralization under contrasting C and N availability, Plos One 10.

Lane, C. 2012. Fungal Plant Pathogens. Edited by Charles Line, Paul Beales, Kelvin Highes. p.16.

Moeskopes, B.; Sukristiyonubowo Buchan, D.; Sleutel, S.; Herawaty, L.; Husen, E.; Saraswati, R.; Setyorini, D.; De Neve, S. 2010. Soil microbial communities and activities under intensive organic and conversional vegetable farming in West Java, Indonesia, 45: 112–120.

Nannipieri, P.; Ascher, J.; Ceccherini, M.T.; Landi, L.; Pietramellara, G.; Renella, G. 2003. Microbial diversity and soil functions. European Journal of Soil Science, 54: 655–670.

Tabatabai, M.A. 1982. Soil enzymes. In: Page A.L., Miller R.H., Keeney D.R. (eds.). Methods of Soil Analysis. Part 2. American Society of Agronomy & Soil Science Society of America. Madison. Wisconsin.

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Kanger, K. J.; Kevvai, T.; Kevvai, L.; Kärblane, H.; Astover, A.; Ilumäe, E.; Lauringson, E.; Loide, V.; Penu, P.; Rooma, L.; Sepp, K.; Talgre, L.; Tamm, U. 2014. Väetamise ABC. Väävlitarve. lk 14. Põllumajandusuuringute Keskus. Toimetaja: Jaan Kanger. 50. (in Estonian).

Watts, D.B.; Torbert, H.A.; Feng, Y.; Prior, S.A. 2010. Soil Microbial Community Dynamics as Influenced by Composted Dairy Manure. Soil Properties. and Landscape Position. Soil Science. 175: 474–486.

Wolinska, A.; Stepniewska, Z. 2012. Dehydrogenase Activity in the Soil Environment. In: http://www.ebook3000.com/ “Dehydrogenases” Edited by Rosa Angela Canuto. 366 pp.

Material about Informational event

Event: Demonstration of in-field acidification system SyreN on field –day.

Description: The demonstration was made in Voore Farm as one of activities of bigger field day for farmers. We demonstrated the work of slurry spreader and also inactive acidification system. The slurry spreader had functional problems and we found that it was too big a risk to demonstrate activated acidification system. However, the overview about the Baltic Slurry Acidification project, SAT-s and SyreN in-field acidification system was given.

Date: 19.07.2018.

Place: Voore Farm, Lääne Virumaa county, Estonia.

Number of participants: 25.

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FINLAND

General information:

Project partner	Contact person	Type of activity in Field Trial	2017-2018	Ammonia emission
Association of ProAgria Centres	Sari Peltonen sari.peltonen@proagria.fi	Scientific	Spring wheat Pig slurry	Ammonia losses were not measured

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

Report of Association of ProAgria Centres

Written by: Sari Peltonen and Karoliina Yrjölä

Summary

The field experiment of this study was done in summer 2017 in Helsinki Viikki experimental farm. The experiment was repeated in summer 2018. In both years the cultivated plant was spring wheat and the slurry used was from a sow piggery. In 2017 there were four treatments in the experiment: unfertilized zero plot, NPK-control plot, a plot with unacidified slurry and a plot with acidified slurry. In 2018 besides these four treatments there were also a fifth treatment, which was the slurry control: to these plots the untreated slurry was spread before sowing. The amount of sulphuric acid needed to acidify the slurry to reach the pH value 6 was calculated on the strength of the titration tests. The result in 2017 was 3,25 l acid per ton slurry and in 2018 almost the same, 3,225 l acid per ton slurry. The slurry was spread on the field surface when the crop was at 2 - 3 leaf stage. The slurry was acidified just before the spreading.

According to results, in 2017 the yield of spring wheat in acidified slurry plots was sligthly higher than in unacidified slurry plots and the same as in NPK fertilized plots but the difference was not statistically significant. The yield increase might have been due to the increased availability of nitrogen or the increased amount of sulphur in acidified slurry. There were either no or only slight statistical differences in other grain quality parameters like hectoliter weight, thousand grains weight or protein content between the fertilized treatments. The slurry acidification did not increase leaf chlorophyll content nor leaf area units.

In 2018, the results of the field experiment were like in 2017, and no differences between the fertilized treatments were observed. However, it must be taken into account that the weather conditions in the growing season 2018 were very different from those in 2017. The summer was very dry and caused uneven germination of the seeds in the field plots and poor growing of shoots. As a result, the yield level was much lower in 2018 than in 2017.

Aim

The aim of this study was to find out if the acidification of slurry improves the nitrogen uptake of the crop by minimizing ammonia emissions.

Materials and methods

Field trials

2017, spring wheat

The field trial was done in Viikki experimental farm, Helsinki. The experimental plots were sown 19.5.2017. The crop used in the experiment was spring wheat, cv Marble. There were four treatments with four replications:

1. zero plot (no fertilization at all)
2. NPK control (100 kg N in sowing)
3. untreated slurry (60 kg N in sowing + 40 kg N from slurry at 2 - 3 leaf stage)
4. acidified slurry (60 kg N in sowing + 40 kg N from slurry at 2 - 3 leaf stage)

Protective plot	Protective plot	Protective plot	Protective plot
3	1	4	2
2	3	1	4
4	2	3	1
1	4	2	3
Protective plot	Protective plot	Protective plot	Protective plot

Figure 1. *Map of the field experiment 2017. The codes of the numbers are indicated above in the text.*

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2018, spring wheat

The field trial was done in Viikki experimental farm, Helsinki. The experimental plots were sown 12.5.2018. The crop used in the experiment was spring wheat, cv Demonstrant. There were five treatments with four replications:

1. zero plot (no fertilization at all)
2. NPK control (100 kg N in sowing)
3. untreated slurry (60 kg N in sowing + 40 kg N from slurry at 2 - 3 leaf stage)
4. acidified slurry (60 kg N in sowing + 40 kg N from slurry at 2 - 3 leaf stage)
5. slurry control (40 kg N from untreated slurry before sowing + 60 kg N in sowing)

Protective plot	Protective plot	Protective plot	Protective plot
2	5	3	1
5	3	2	4
4	1	4	5
3	2	1	2
1	4	5	3
Protective plot	Protective plot	Protective plot	Protective plot

Figure 2. *Map of the field experiment 2018. The codes of the numbers are indicated above in the text.*

Figure 3. *Viikki experimental field just before sowing 2017. Photo: Karoliina Yrjölä.*

Figure 4. *The experimental plots were 8 x 1,25 m in size and sown with a specific sowing machine. Photo: Karoliina Yrjölä.*

Table 1. *Nutrient status of soil (analysis made 11.11.2014). This analysis was valid for both years, because the field used in both experiments was the same and the analysis was not renewed between these years*

Analysis	Results
Soil type	Sandy clay, organic matter 7 %
pH	5,9
Ca	3300 mg/l
P	18 mg/l
K	230 mg/l
Mg	340 mg/l
S	47 mg/l

Slurry acidification

The amount of acid needed to lower the slurry pH was investigated by laboratory tests. The slurry used in these experiments was from the same sow piggery in both years. The slurry was acidified with >95 % sulphuric acid and the aim was to lower the pH to 6.0. The acid was added step by step into the slurry while a magnetic mixer was used to improve mixing and to decrease foaming.

In 2017 the original pH of the slurry was 7. The titration gave the result that 3,25 litres of sulphuric acid must be added per ton slurry to achieve pH 6,0. In 2018 the original pH of the slurry was 6,9 and the titration showed that 3,225 litres of sulphuric acid must be added per ton slurry to achieve pH 6,0.

Figure 5. *Measuring pH of the slurry. Photo: Karoliina Yrjölä.*

Table 2. *Results of analysis of slurry nutrient before and after acidification 2017*

Analysis	Results before acidification	Results after acidification
N, total	3200 mg/l	3300 mg/l
N, soluble	2400 mg/l	2700 mg/l
P, total	700 mg/l	990 mg/l
P, soluble	460 mg/l	620 mg/l
K, total	1700 mg/l	1700 mg/l
K, soluble	1300 mg/l	1400 mg/l
S, total	400 000 µg/l	2 200 000 µg/l
S, soluble	69 000 µg/l	1 180 000 µg/l
Solid matter	3,5 %	4,1 %
pH	7,0	6,0

Table 3. *Results of analysis of slurry nutrient before and after acidification 2018*

Analysis	Results before acidification	Results after acidification
N, total	3800 mg/l	3600 mg/l
N, soluble	2900 mg/l	2700 mg/l
P, total	790 mg/l	860 mg/l
P, soluble	620 mg/l	730 mg/l
K, total	1800 mg/l	2000 mg/l
K, soluble	1800 mg/l	1900 mg/l
S, total	410 000 µg/l	2 400 000 µg/l
S, soluble	80 000 µg/l	2 100 000 µg/l
Solid matter	3,1 %	3,1 %
pH	6,9	6,1

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Slurry spreading

The spreading of slurry was done at 2 - 3 leaf stage (GS 12 - 13) of spring wheat. The acid was added to the slurry about half an hour before spreading. Because of the foaming the volume of the slurry increased about 30 %.

In 2017 the slurry acidification and spreading were done 7.6.2017. The weather was sunny and the temperature was 19 °C. In 2018 the slurry acidification and spreading were done 25.5.2018. The weather was sunny and the temperature was 20 °C.

Figure 6. *Mixing sulphuric acid to the slurry. Photo: Sari Peltonen.*

Figure 7. *The slurry was spread by hand to the experiment plots with watering cans. Photo: Sari Peltonen.*

Figure 8. *The slurry was spread to the middle of every other row. Photo: Sari Peltonen.*

Figure 9. *The slurry must be mixed all the time while spreading so that the dry matter does not sink to the bottom of the tub. Photo: Sari Peltonen.*

Table 4. *Amount of nutrients given in each treatment 2017*

Plots	Area, m^2	Fertilization rate kg/ha	N, kg/ha	P, kg/ha	K, kg/ha	S, kg/ha
Untreated	44	0	0	0	0	0
NPK control	44	500	100	15	40	15
Kevätviljan Hiven Y (20-3-8)						
Untreated slurry	44					
Belor Premium Typpi 27 + Se		224	60	0	0	0
Pig slurry		12,5 m^3/ha	40	12	29	3,4
Acidified slurry	44					
Belor Premium Typpi 27 + Se		224	60	0	0	0
Pig slurry		12,5 m^3/ha	40	12	29	27,5

Table 5. *Amount of nutrients given in each treatment 2018*

Plots	Area, m^2	Fertilization rate kg/ha	N, kg/ha	P, kg/ha	K, kg/ha	S, kg/ha
Untreated	44	0	0	0	0	0
NPK control	44	376	100	4,9	16	0
Yara Mila Y1 (20-3-8)						
Untreated slurry	44					
Yara Bela Suomensalpierari		224	60	0	0	0
Pig slurry		13,8 m^3/ha	40	9	25	1
Acidified slurry	44					
Yara Bela Suomensalpierari		224	60	0	0	0
Pig slurry		13,8 m^3/ha	40	10	26	29
Slurry Control	44					
Yara Bela Suomensalpierari		224	60	0	0	0
Pig slurry		13,8 m^3/ha	40	9	25	1

Table 6. *Weather conditions in the spreading day and 1 - 5 days after that in 2017*

Day	Temperature (oC)	Wind (m/s)	Rainfall (mm)
Spreading day	19	6	0
1 day after spreading	15	3	10
2 days after spreading	18	4	0
3 days after spreading	22	3	0
4 days after spreading	24	2	0
5 days after spreading	12	7	8

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Table 7. *Weather conditions on the spreading day and 1 - 5 days after that in 2018*

Day	Temperature (oC)	Wind (m/s)	Rainfall (mm)
Spreading day	20	4	0
1 day after spreading	23	3	0
2 days after spreading	21	4	0
3 days after spreading	20	5	0
4 days after spreading	24	5	0
5 days after spreading	23	4	8

Measurements during the growing season

During the growing season, leaf chlorophyll content and leaf area index were measured. 10 measurements per each plot were done. Yield per hectare, hectoliter weight, thousand grains weight and protein content were also measured after harvest from the experimental plots. Also the number and weight of grains per ear was determined by individually harvesting 60 ears per treatment in 2017 and 40 ears per treatment in 2018.


Figure 10. *Field plots at GS 21 (19.6.2017). Photos: Karoliina Yrjölä.*


Figure 11. *Field plots at GS 32 (29.6.2017). Photos: Karoliina Yrjölä.*


Figure 12. *Field plots at flag leaf stage GS 37 (6.7.2017). Photos: Karoliina Yrjölä.*

Figure 13. *Field plots at heading GS 58 (20.7.2017). Photos: Karoliina Yrjölä.*

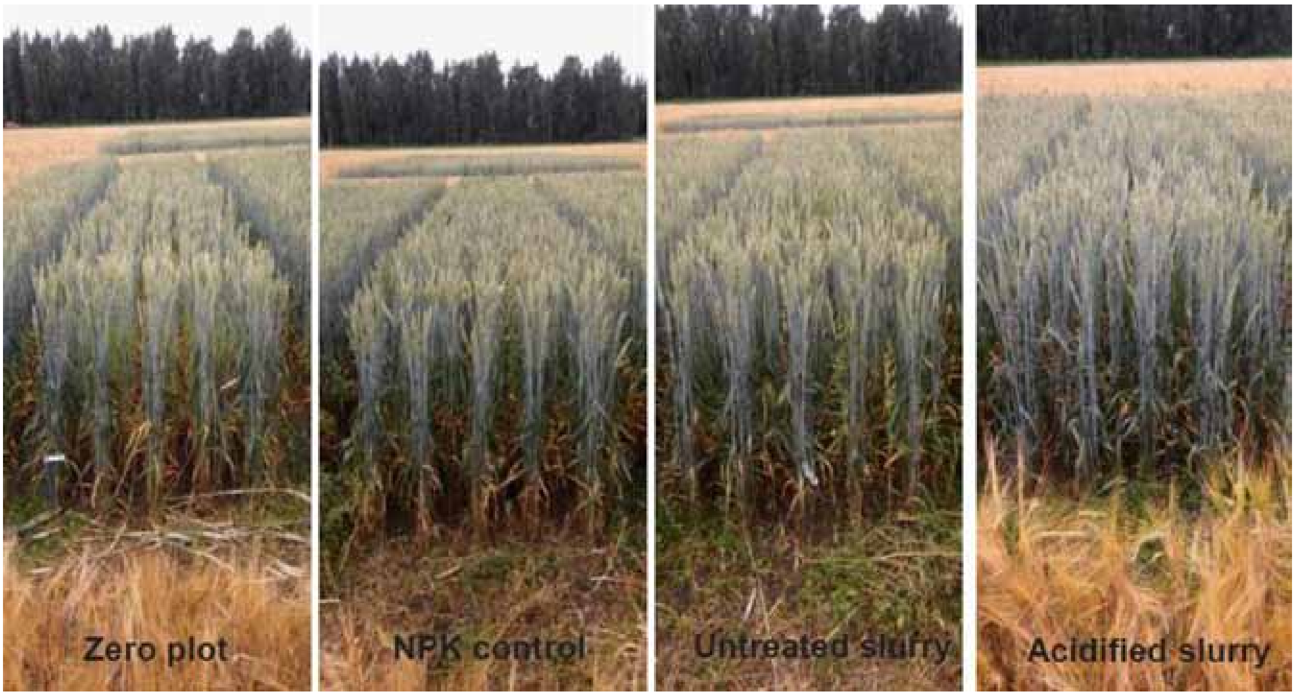

Figure 14. *Field plots at grain filling stage (22.8.2017). Photos: Karoliina Yrjölä.*

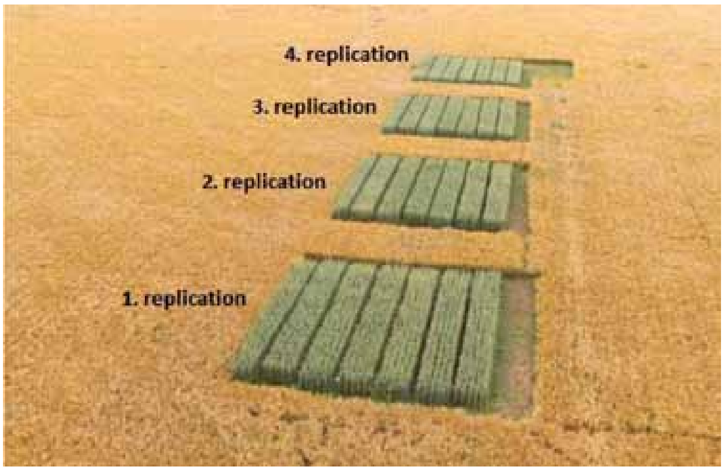

Figure 15. *Field plots at grain filling stage (22.8.2017). Photo: Juho Kotala.*

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In contrast to 2017, the experimental plots suffered from drought and tillering was poor in 2018 shown in Figures 16 – 19.


Figure 16. *Field plots 25.6.2018.*


Figure 17. *Field plots 25.6.2018.*


Figure 18. *Field plots 9.7.2018.*


Figure 19. *Field plots 9.7.2018.*

Harvesting the plots

In 2017 the harvesting of the plots was done quite late, 28.9. due to very rainy autumn. In 2018 the harvesting was done about a month earlier, 24.8. The grains were dried to the moisture level of 14 %.

Figure 20. *The crop in experimental plots few days before harvesting in 2017. Photo: Karoliina Yrjölä.*

Figure 21. *The crop in experimental plots few days before harvesting in 2018. Because of the dry and hot growing season the tillering of the crop stand was poor. Photo: Karoliina Yrjölä.*

Figure 22. *Harvesting of the experimental plots in 2017. The same harvester was used in 2018. Photo: Karoliina Yrjölä.*

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Results

In 2017 there were no significant differences in leaf chlorophyll content and leaf area index between the treatments except the unfertilized control where the measured values were lower than in other treatments (Figures 23 and 25). There was variation in leaf chlorophyll content during the growing season between different measurement times which could not been fully explained but can be e.g. due to the variation in weather or daylight conditions.

In 2018 only three chlorophyll content and leaf area index measurements were done during the growing season. The results were very similar to 2017 and only the unfertilized control had lower values than the other treatments (Figure 24 and 26).

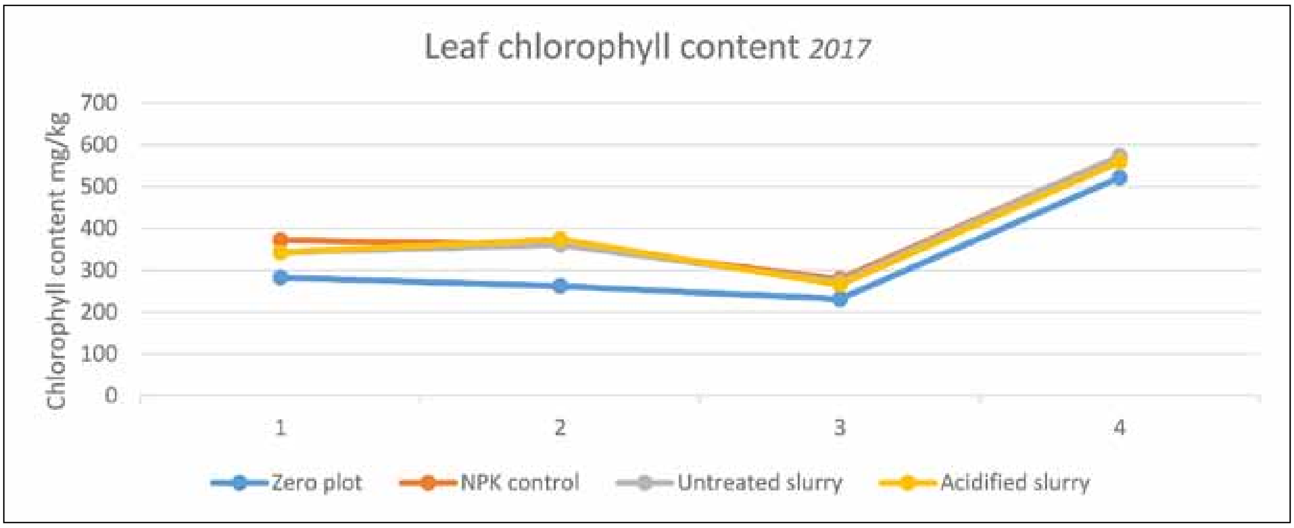

Figure 23. *Change of the leaf chlorophyll content measured during the growing season 2017. The chlorophyll value is indicated as mg/kg measured by APOGEE MC-100 chlorophyll meter. Four measurements were taken 19.6.17 (=1), 29.6.17 (=2), 10.7.17 (=3) and 20.7.17 (=4).*

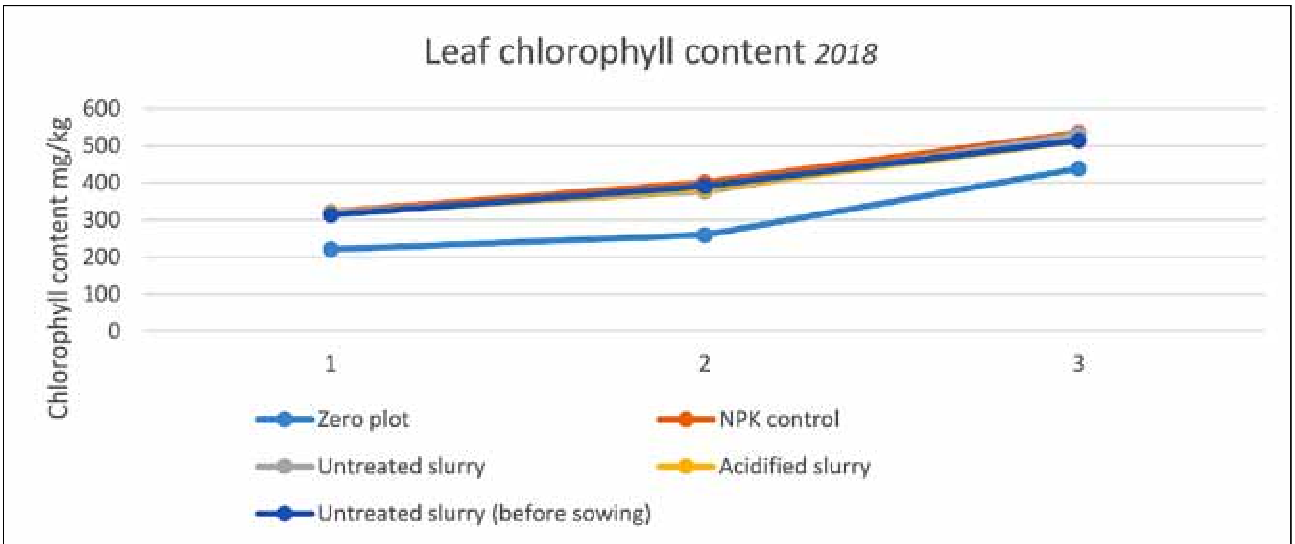

Figure 24. *Change of the leaf chlorophyll content measured during the growing season 2018. The chlorophyll value is indicated as mg/kg measured by APOGEE MC-100 chlorophyll meter. Three measurements were taken 25.6.18 (=1), 9.7.18 (=2), and 23.7.18 (=3).*

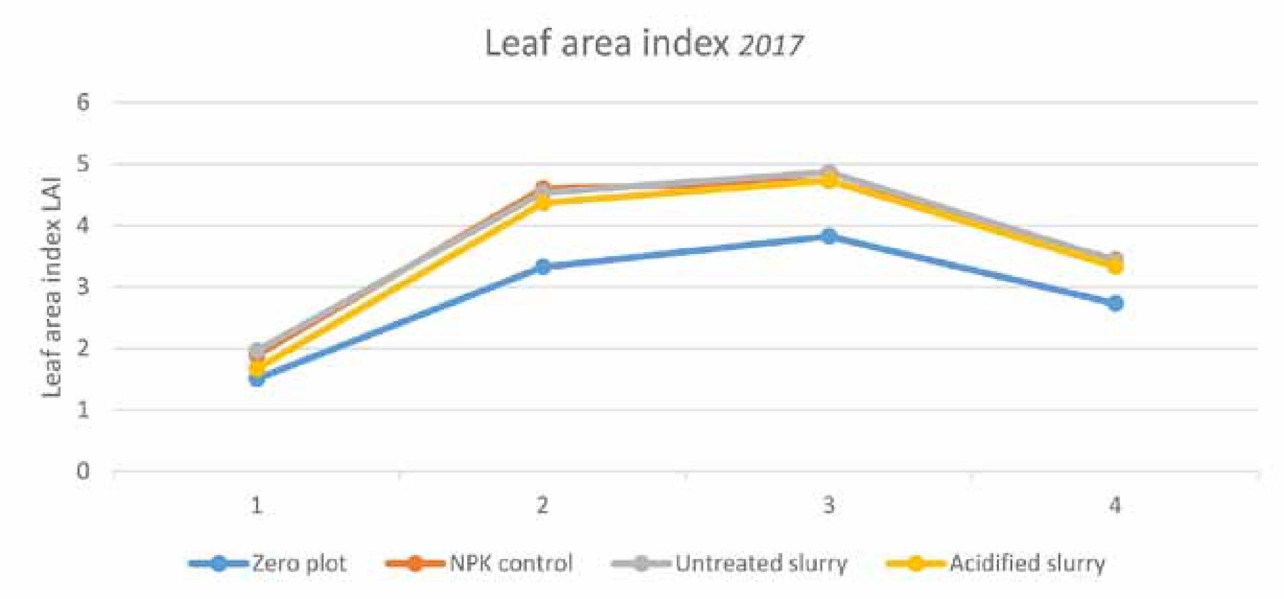

Figure 25. *Leaf area index measured as LAI units by ACCUPAR LP-80 meter during the growing season 2017. Four measurements were taken 19.6.17 (=1), 29.6.17 (=2), 10.7.17 (=3) and 20.7.17 (=4).*

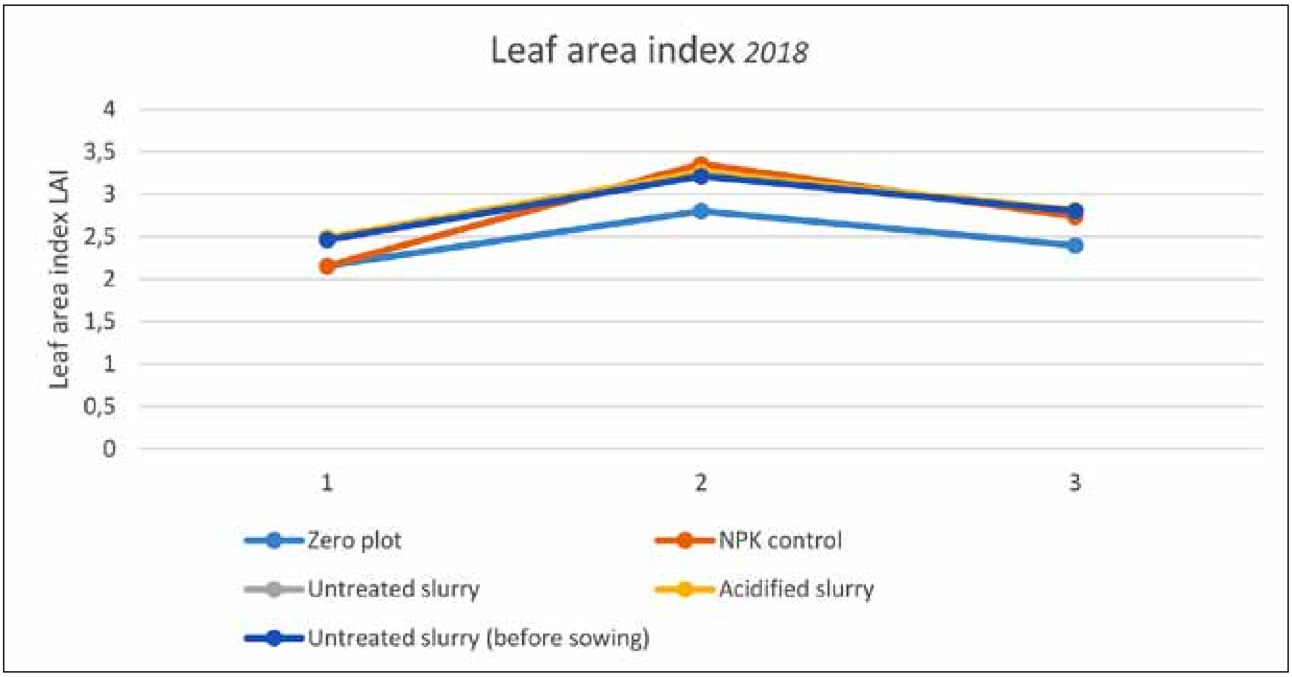

Figure 26. *Leaf area index measured as LAI units by ACCUPAR LP-80 meter during the growing season 2018. Three measurements were taken 25.6.18 (=1), 9.7.18 (=2), and 23.7.18 (=3).*

In 2017 the weight and number of grains per one ear were the highest in plots treated with acidified slurry but the difference was not significant with other fertilized treatments (Figures 27 and 29). Only in the control plots the weight and number of grains per one ear was significantly lower than that in other treatments. Statistical analysis made from the year 2017, however, showed that only zero plot had significantly lower values compared to other treatments and the fertilized treatments had no significant differences among each other. In 2018 NPK control had higher weight of grains per one ear than the other treatments but statistically it did not differ from acidified slurry treatment (Figure 28). Both untreated slurry treatments had significantly lower weight of grains per one ear compared to NPK control, but among the slurry treatments there were no differences. Zero plot had significantly lower weight of all treatments.

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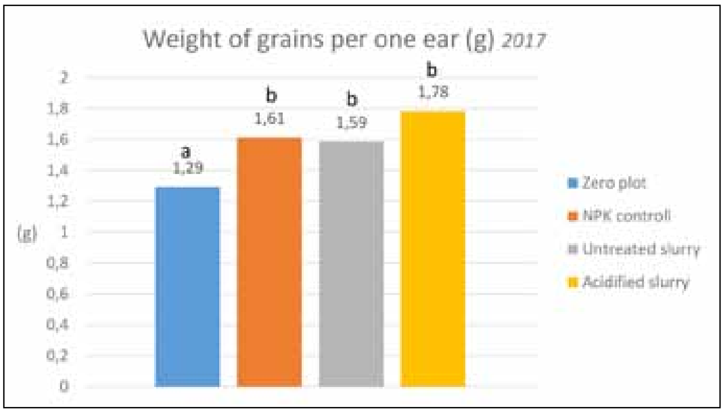

Figure 27. *Weight of grains per one ear in 2017. The means marked with same letter do not have significant differences (P < 0,05).*

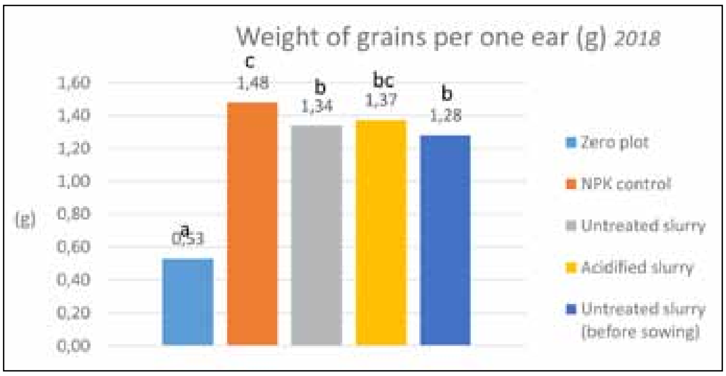

Figure 28. *Weight of grains per one ear in 2018. The means marked with same letter do not have significant differences (P < 0,05).*

Neither had the amount of grains per ear significant differences between NPK control, untreated slurry and acidified slurry treatments in 2017 or in 2018 (Figures 29 and 30). Only unfertilized zero plot showed significantly lower values in the amount of grains per ear than the fertilized treatments.

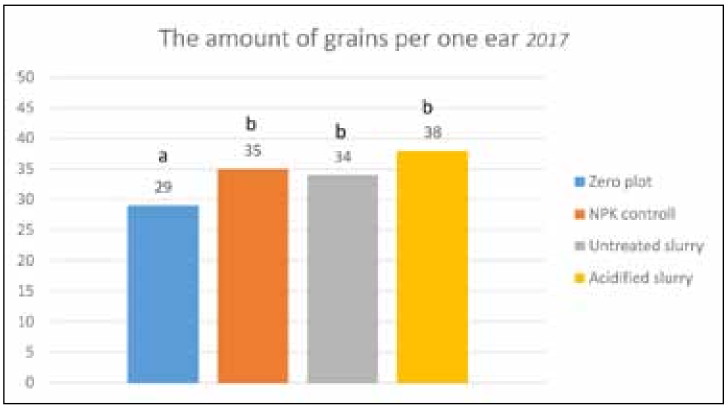

Figure 29. *The amount of grains per one ear in 2017. The means marked with the same letter do not have significant differences (P < 0,05).*

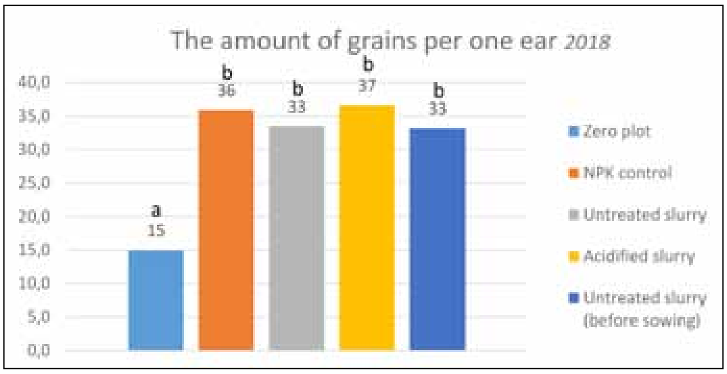

Figure 30. *The amount of grains per one ear in 2018. The means marked with the same letter do not have significant differences (P < 0,05).*

There were no significant differences between the treatments in the hectoliter weight of the grains in 2017 and 2018 (Figures 31 and 32). In 2017 the hectoliter weight was, however, slightly higher in zero plot, which can probably be explained by the smaller grain size.

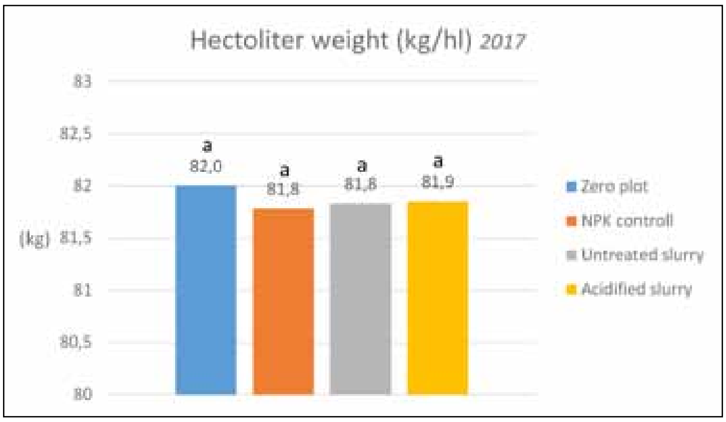

Figure 31. *Hectoliter weight of the grains in 2017. There were no significant differences between the treatments (P < 0,05).*

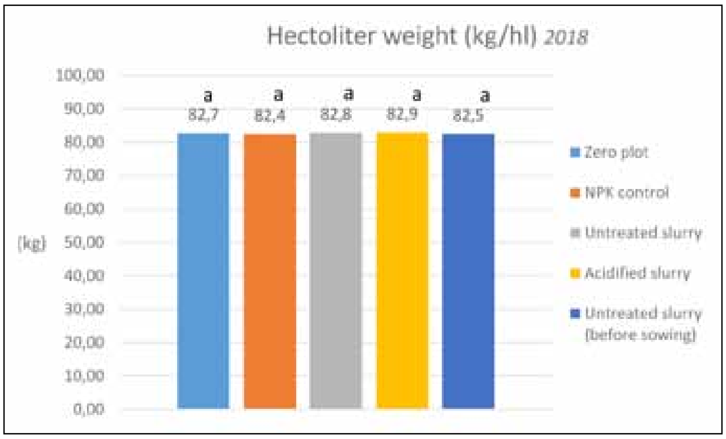

Figure 32. *Hectoliter weight of the grains in 2018. There were no significant differences between the treatments (P < 0,05).*

In 2017 the yield level of the experimental plots was relatively high in Finnish growing conditions, approximately 8 tn per hectare. The average yield level in spring wheat in Finland is 4,5 tn/ha. The high yield level, also measured in zero plot, can be explained by the high amount of easily available nitrogen present in the soil, due to the heavy rains in the growing season. This can also explain why there were no statistical differences in yield results between the treatments (Figure 33). The yield was, however highest in acidified slurry plots, nearly as high as in NPK control plots.

In contrast, in 2018 the yield level in experimental plots was clearly smaller than what is the average. In zero plot the yield level was nearly 1 ton per hectare smaller than in fertilized treatments. Also, the slurry which was spread before sowing yielded less than the treatments where slurry was spread at 2-3 leaf stage. According to the statistical analysis, untreated slurry had significantly higher yield than zero plot and untreated slurry that had been spread before sowing but did not have significant differences between NPK control and acidified slurry (Figure 34).

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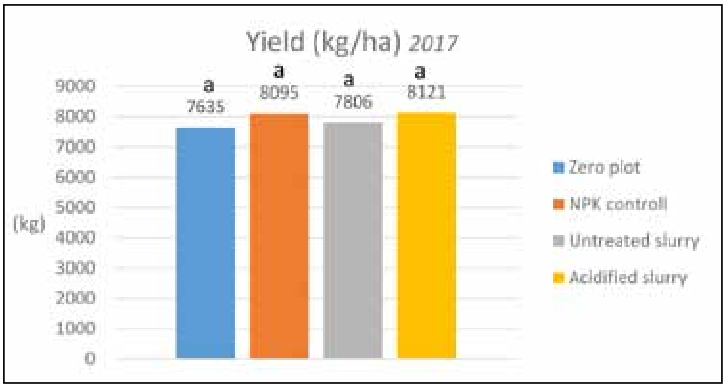

Figure 33. *The yield of the experimental plots in 2017. There were no significant differences in yield results between the treatments (P < 0,05).*

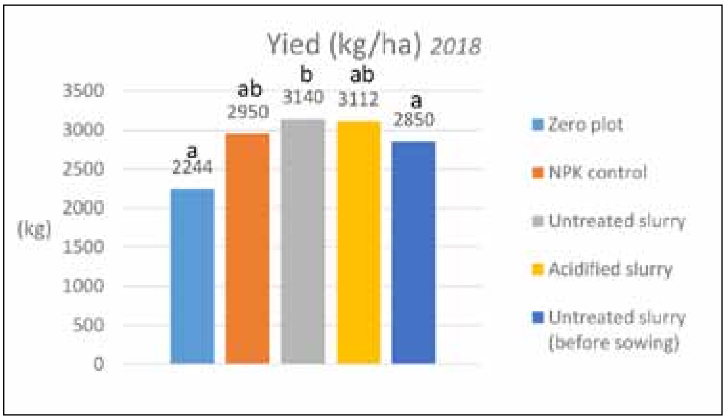

Figure 34. *The yield of the experimental plots in 2018. The means marked with the same letter do not have significant differences (P < 0,05).*

In 2017 weight of a thousand grains was statistically higher in NPK control and unacidified slurry plots compared with acidified slurry plots (Figure 35). This can be explained by the higher number of grains per ear in acidified slurry plots which can result in lower weight of a thousand grains. In 2018 the differences between the treatments were even smaller than in 2017 and there were no significant differences in results between the treatments (Figure 36).

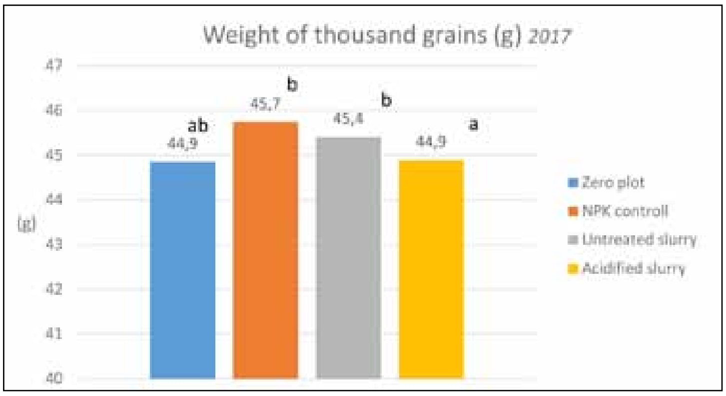

Figure 35. *Weight of a thousand grains in the field trial in 2017. The means marked with same letters do not have significant differences (P < 0,05).*

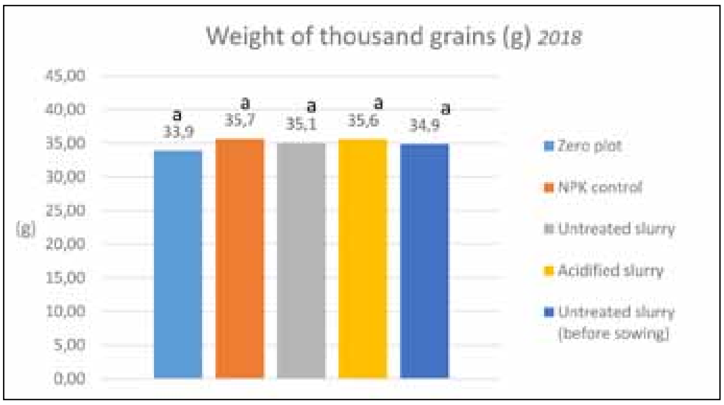

Figure 36. *Weight of a thousand grains in the field trial in 2018. There were no significant differences in results between the treatments (P < 0,05).*

In 2017 the protein content in the zero plot was significantly lower than in fertilized tretaments, but there were no differences between the treatments of fertilized plots (Figure 37). In 2018 the protein content was the highest in NPK control plots and there were no differences between the slurry treatments (Figure 38). As in 2017, the zero plot had the lowest protein content of all. The protein level was clearly higher in 2018 compared to that in 2017.

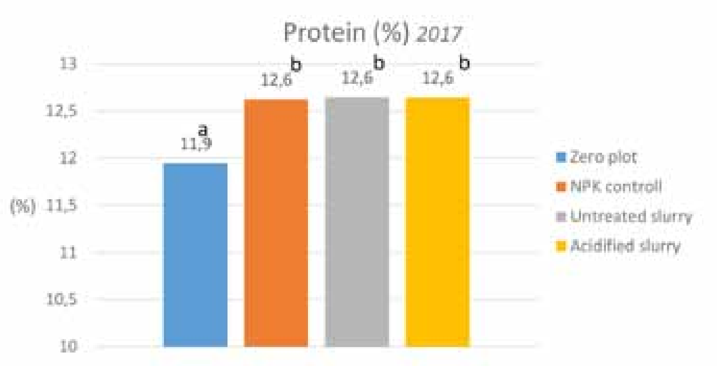

Figure 37. *Protein content of the grains in the field trial in 2017. The means marked with same letters do not have significant differences (P < 0,05).*

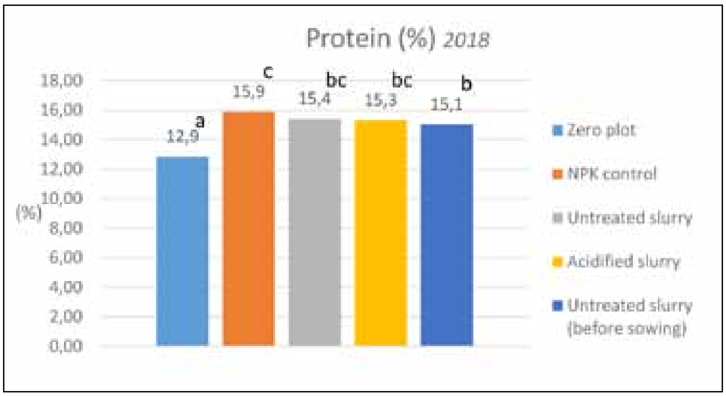

Figure 38. *Protein content of the grains in the field trial in 2018. The means marked with same letters do not have significant differences (P < 0,05).*

Reporting form: 2017, spring wheat *(please, activate the link below)*
https://www.dropbox.com/s/s53w6tnol3ryov8/Finland%202017.xlsx?dl=0

Reporting form: 2018, spring wheat *(please, activate the link below)*
https://www.dropbox.com/s/6nc2pe71yxwj8f1/Finland%20WP4_Report_final_version_2018.xlsx?dl=0

Discussion

According to the results from 2017 and 2018, acidification of the slurry neither affected the yield nor the grain quality parameters of spring wheat. It should, however, be noted that the growing seasons both in 2017 and 2018 were unexceptionally concerning the weather conditions. In 2017 the yield level was exceptionally high in the experimental field and due to enough moist and temperature mineral nitrogen was abundantly available in soil. On the opposite, the growing season 2018 was extraordinary dry and hot and crops suffered from drought and poor tillering which resulted in very low yield levels. The experiments however, showed that addition of sulphur acid into the slurry did not damage the plants and the growth of plants as well as the yield and quality formation was normal.

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Conclusions

The acidification of the slurry reduces the ammonia emissions in slurry spreading and this can have an increased role in the future climate conditions. Acidification may improve the nitrogen available in slurry to plants, but the benefit varies between the years and is much dependent on the wheather conditions during the growing season. Also, the soil nitrogen status affects the N use efficiency of the crop. In acidified slurry, the increased sulphur content may also have positive yield impacts. The cost efficiency of slurry acidification techniques is dependent on the yield impact contra the extra costs caused by sulphur acid treatments. Also, the working efficiency of different spreading techniques affects the results. Acidification allows the use of surface spreading techniques which have clearly wider working widths than other spreading techniques. The results show that the use of acidification requires compensation for farmers because of extra costs and without clear yield benefits. Acidification can be regarded as one tool for farmers to mitigate ammonia emissions when spreading conditions are unfavorable.

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Material about Informational events

Event: Farmari exhibition.

Description: The event was for farmers and stakeholders.

Date: 14.-17.6.2017.

Place: Seinäjoki.

Number of participants: 94 000 visitors in total.

Event: Peltopäivä field day.

Description: The event was for farmers and stakeholders.

Date: 6.7.2017.

Place: Inkoo.

Number of participants: 3000 visitors in total.

Event: Presentation of the project and outcomes of field trials.

Description: The event was for stakeholders in ministries of agriculture and environment.

Date: 23.8.2017.

Place: Helsinki.

Number of participants: 15.

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Event: KoneAgria exhibition.

Description: The event was for farmers and stakeholders.

Date: 12.-14.10.2017.

Place: Tampere.

Number of participants: 20 000 visitors in total.

Event: Scientific Agricultural days.

Description: The event was for researchers, stakeholders, students, teachers, …

Date: 10.-11.1.2018.

Place: Helsinki.

Number of participants: 500 participants in total.

Event: Sarka exhibition.

Description: The event was for farmers and stakeholders.

Date: 2.-3.2.2018.

Place: Seinäjok.

Number of participants: 10 000 visitors in total.

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Event: Okra exhibition.

Description: The event was for farmers and stakeholders.

Date: 4.-7.7.2018.

Place: Oripää.

Number of participants: 80 000 visitors in total.

Event: Pohjanmaan peltopäivä field day.

Description: The event was for farmers and stakeholders.

Date: 26.7.2018.

Place: Ylistaro.

Number of participants: 1300 visitors in total.

Event: Grass seminar.

Description: The event was for researches, farmers and stakeholders.

Date: 6.9.2018.

Place: Vantaa.

Number of participants: 65.

Event: KoneAgria exhibition.

Description: The event was for farmers and stakeholders.

Date: 11.-13.10.2018.

Place: Jyväskylä.

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GERMANY

General information:

Project partner	Contact person	Type of activity in Field Trail	2017		2018		Ammo-nia emission
State Agency for Agriculture, Environment and Rural Areas of the German Federal State Schleswig-Holstein	Sebastian Neumann sneumann@gfo.uni-kiel.de	Scientific	Winter wheat	Permanent Grassland	Winter wheat	Permanent Grassland	Ammonia losses were measured
Christian-Albrechts-University Kiel, Institute for Crop Science and Plant Breeding	Thorsten Reinsch t.reinsch@gfo.uni-kiel.de		Digestates				

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

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Report of LLUR and CAU Kiel

Written by: Sebastian Neumann[1], Dr. Thorsten Reinsch[2],Christof Kluß[2], Mareike Zutz[1]

1- State Agency for Agriculture, Environment and Rural Areas of the German Federal State Schleswig-Holstein

2- Christian-Albrechts-University Kiel, Institute for Crop Science and Plant Breeding

Introduction

Since 2004, the use of energy crops for biogas production became continuously important in northern Germany (Neumann, 2017). Consequently, the availability of digestates increased and next to cattle and pig slurries they are one of the most important organic fertilizers. Due to the expected high pH-value of digestates volatile ammonia emissions are more likely in comparison to other slurries from animal households with currently low potential for mitigation in Germany. To achieve better knowledge about the slurry acidification technique and its potential for nitrogen loss mitigation during field application, a micro-plot field experiments were conducted on permanent grassland (5 silage cuts) and winter wheat during the years 2017/18 in the federal state of Schleswig-Holstein, Germany. In the framework of the "Baltic Slurry Acidification" project (Work-Package 4) the aim of these trials was to compare acidified vs non-acidified digestates regarding their nitrogen loss potential and effects on plant nitrogen use efficiency.

Material and methods

Trial location

All field trials in Germany were conducted in the federal state of Schleswig-Holstein; nearby the experimental farm Lindhof, belonging to the Christian-Albrechts-University (CAU), close to Kiel. The distance to the Baltic Sea is about 2 km.

Figure 1. *Grassland and Wheat trial 2017 with view on the Baltic Sea (Source: Dr. Frank Steinmann, LLUR).*

Fertilization

Following parameters were tested and measured:

- Dry matter and nitrogen yield of aboveground biomass
- Ammonia emissions after application
- Nitrous oxide emissions

Next to the digestates a control (non-N-fertilizer) as well as mineral fertilizers (Calcium-Ammonium-Nitrate (CAN), Urea and Urea + nitrification inhibitor) were tested in grassland. In winter wheat the digestates were compared with CAN and a control only (Table 1). In both crops three different nitrogen rates were used (Table 2 and Table 3). Both experiments were arranged as a randomized block

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experiment with four replicates. Thus, 64 plots with a plot size of 2,5 m x 2,5 m in grassland and 2 x 2,5 m in winter wheat were investigated. Crop protection (fungicides, herbicides, etc.) in winter wheat were done according to the common agricultural practice recommended by the federal state chamber of agriculture. In pre-treatment the experimental sites were limed with 1500 kg/ha and fertilized with 30 kg/ha S, 300 kg/ha K_2O and 53 kg/ha P_2O_5. in order to avoid nutrient deficient with the exception of nitrogen in both years. After each digestate dressing phosphate and potassium amendments were conducted in the control and mineral fertilizer treatments according to the digestate treatments to ensure a balanced nutrient status for K_2O and P_2O_5 respectively. Additionally, sulphur was applied in all non-acidified treatments to avoid biased results on the nitrogen use efficiency.

Table 1. *Different treatments in grassland and winter wheat*

Grassland	Wheat
Digestate	Digestate
Digestate H2SO4	Digestate H2SO4
CAN	CAN
Urea	Control
Urea stabilized	
Control	

Table 2. *Tested N-rates in grassland*

Grassland – 3 different N-levels	4 dressings
360 kg N/ha	120/100/100/40
240 kg N/ha	90/60/60/30
120 kg N/ha	60/40/20/0

Table 3. *Tested N-rates in winter wheat (Variety "Colonia")*

Wheat – 3 different N-levels	3 dressings
300 kg N/ha	100/100/100
200 kg N/ha	100/50/50
100 kg N/ha	50/5/0

In the Grassland experiment fertilization was shared out in four dressings. In winter wheat it was shared out in three dressings.

In all cases the fertilization is NH_4^+- N based. In consequence the amount of digestate was calculated based on the NH_4^+-N content. Contents of nutrients and pH-values of digestates used in grassland and winter wheat are presented in Table 4.

Table 4. *Results of digestate analysis in 2017 and 2018*

	2017		2018
	First dressing	Other dressings	
pH	8,7	8,6	8,3
DM	7,6 %	5,1 %	5,7 %
Total-N	6,19 %	8,16 %	7,01 %
NH_4-N	2,51 %	4,78 %	3,25 %
P_2O_5	2,72 %	4,08 %	2,57 %
K_2O	6,00 %	7,28 %	8,7 %

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***Table 5.** Dates of fertilization and growth stage (EC) in 2017*

Wheat	Grassland
1. fertilization: 21.03.2017 (EC 30)	1. fertilization: 14.03.17
2. fertilization: 24.04.2017 (EC 32)	2. fertilization: 22.05.17
3. fertilization: 06.06.2017 (EC 61)	3. fertilization: 05.07.17
	4. fertilization: 14.08.17

***Table 6.** Dates of fertilization and growth stage (EC) in 2018*

Wheat	Grassland
1. fertilization: 03.04.2018 (EC 25)	1. fertilization: 27.03.18
2. fertilization: 23.04.2018 (EC 31)	2. fertilization: 04.06.18
3. fertilization: 28.05.2018 (EC 39)	3. fertilization: 09.07.18
	4. fertilization: 21.08.18

Fertilization was done with the start of the vegetation period and after each silage cut in permanent grassland (Table 5). Also in winter wheat (Table 6) the first fertilization was done with start of the vegetation period. The second fertilization was shared out with the beginning of stem elongation, the third fertilization with the end of stem elongation and with beginning of heading. Also last fertilization in 2017 was planned in EC 39 but due to very fast growing based on high temperatures it was delayed and shared out with start of flowering.

Acidification

Acidification was done with sulphuric acid immediately before applying the digestate. pH was decreased down to 5,5 – 6 in several steps, pH-values were proofed continuously during acidification. Digestate application was done with watering cans by imitating trailing hoses (Figure 2).

***Figure 2.** Micro-plot after digestate application in grassland 2017 (Source: Sebastian Neumann, LLUR).*

***Figure 3.** Micro-Plot winter-wheat experiment in 2017 (Source: Sebastian Neumann, LLUR).*

Measurement methods

Ammonia emissions

Ammonia emissions are measured by passive samplers (acid traps).

The passive samplers are filled with dilute sulfuric acid (0.05 M H_2SO_4) and are placed in the centre of the plots. The solution in the passive samplers continuously absorbs ammonia, and is replaced regularly depending on the expected intensity of the emissions. On the first day, the day of fertilization they are replaced every second hour because of expected high ammonia fluxes.

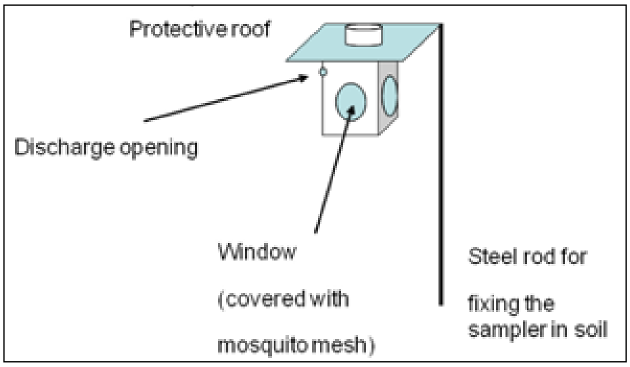

***Figure 4.** Set up of a passive sampler (acid trap), Pacholski, 2016.*

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On the following days the duration of replacement intervals were increased. Passive samplers are mounted at 0.15 m above canopy surface. NH_4^+ concentrations in the sampling solution were determined photometrically using a dual channel continuous flow analyzer (Skalar Analytical Instrument, Breda, the Netherlands).

Figure 5. *Used acid trap to capture volatile ammonium on a grassland plot (Source: Sebastian Neumann, LLUR).*

The main part of the sampler consists of an acid proof bottle with 1-2 windows at each side (size depends on size of the bottle). A drill hole at an upper edge is used to drain the bottle. Therefore, windows are slightly shifted from this corner of this edge of the bottle to allow easy handling while draining. The bottle is filled through the mouth at the top with sampling solution and fixed with the mouth to the lid which is screwed to the stainless steel roof. Roofs can be attached by a flexible screw fixing to the steel rod to allow adjustment to different canopy heights by using only one length of the steel rod. Cumulative qualitative NH3 losses (ppm sum) from passive samplers are calculated by adding up collected NH_4^+-concentrations (ppm) on a plot within an experimental campaign. This is feasible because under identical volume and measurement temperatures, ppm values directly translate into captured amounts of ammonia (Pacholski 2016). In the BSA field trials ammonia emissions only were measured at the 240 kg N/ ha rate (permanent grassland) and 200 kg N/ha (winter wheat) rate respectively. Ammonia was measured daily, several times per day up to seven days after fertilization. Measurements were conducted with four replications. For the construction of the sampler please also see Figure 5.

Nitrous oxide measurements

Nitrous oxide was measured on all treatments among the year. In the weeks of digestate and fertilizer application it was measured four times a week, to catch up the expected peak of nitrous oxide emissions immediately during the days after application. For nitrous oxide measurements the "static-closed-chamber" method was used (Hutchinston und Moisier, 1981). In the winter wheat experiment, chamber extensions were used with increasing canopy height (Figure 6). Samples from the closed chamber were taken in an interval of 0, 20, 40, 60 minutes. Samples were taken with a syringe and transferred into evacuated glass vials. Gas samples were analyzed for N_2O through a gas chromatograph (SCION 456-GC, Bruker, Leiderdorp, Netherlands). Calibration of the gas chromatograph was carried out by using a minimum of three certified gas standards. Samples were injected by using an autosampler (model 271 LH, Gilson Inc., Midleton, USA). Data was processed using the software Compass CDS (Version 3.0.1). The change of gas concentration (N_2O) in chamber headspace during the measurement was calculated by linear regression.

Yield sampling

Yield sampling was done shortly before each silage cut or winter wheat harvest, respectively, on a 0,25 m² square. Dry matter yields were estimated after oven drying of biomass samples at 48°C. To determine quality parameters samples were grinded and analysed by near infrared spectroscopy. In winter wheat yield samples were taken at two different dates. The first sampling was done as whole plant silage in the late milk maturity. The second sample was taken as threshing sample for the kernel yield measurements.

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Figure 6. *Measurement of nitrous oxide with the usage of extensions in wheat by the "closed chamber". technique (Source: Sebastian Neumann, LLUR).*

Figure 7. *Yield sampling by hand (Source: Dr. Thorsen Reinsch, CAU Kiel).*

Results and discussion of the winter wheat experiment 2017/2018

Winter wheat DM - yields 2017/2018

The whole plant DM-yields (without stubbles) of winter wheat within the two experimental years (2017 and 2018) are presented in Figure 8. Biomass samplings for whole crop-silage were conducted on the 06.07.2017 and on the 27.06.2018.

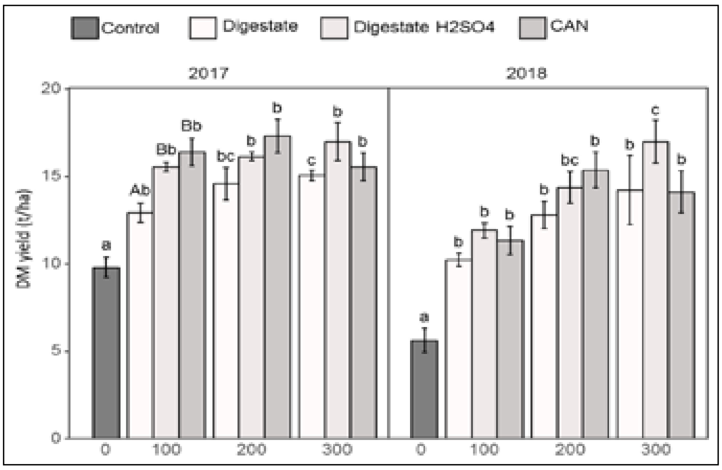

Figure 8. *Whole plant DM-yields (without stubbles) of all different treatments in 2017 and 2018. Sampling was conducted on 06.07.2017 and on 27.06.2018. (Different lowercase letters indicated significant differences between the different N-rates, different capital letters indicated differences between different fertilizer treatments).*

In general, smaller yields were observed in the second experimental year due to heavy droughts in summer 2018. The control treatment reached the lowest yields in both experimental years (9,8 t/ha in 2017 and 5,6 t/ha in 2018). Acidified digestates ("digestate H_2SO_4") reached on average at each N-rate and experimental year higher DM-yields compared to the non-acidified treatment. However, only in the first experimental year at the lowest N-rate the yield of the acidified treatment (15,5 t/ha) was significantly different compared to the non-acidified treatments (12,9 t/ha). At higher nitrogen rates, however, this effect is reduced due to the higher nitrogen availability reducing the impact of ammonia mitigation. Moreover, "Digestates H_2SO_4" reached, with the exception of one year and N-rate, respectively, similar yields compared to the mineral fertilizer. A higher yield in "Digestate H_2SO_4" than in CAN was reached on highest N-fertilization rate in 2018. In both experimental years there is clear indication that at the highest N-rate the N-demand of winter wheat is exceeded, which resulted in no further beneficial DM-yields.

The kernel yield of both experimental years is presented in Figure 9. Threshing was conducted at the 03.08.2017 and on the 26.07.2018.

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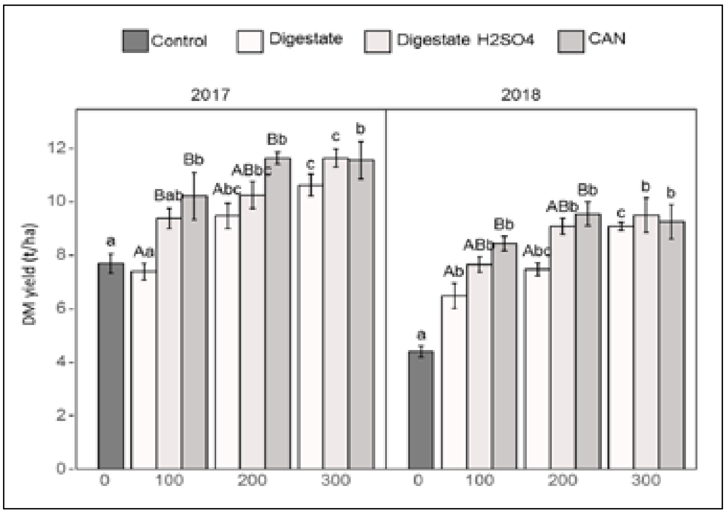

Figure 9. *Kernel DM yields of the different treatments in 2017 and 2018. Sampling was conducted on 03.08.2017 and on 26.07.2018. (Different lowercase letters indicated significant differences between the different N-rates, different capital letters indicated differences between different nitrogen fertilizers).*

Corresponding to the dry matter results the kernel DM-yields showed a lower yield level in the second experimental year. On average the lowest yields were observed in the "Digestate 100" treatment and in the control, respectively. Significant differences between acidified treatments and non-acidified treatments could be observed at the lowest N-rate (100 kg N/ ha) in 2017. Here, "Digestate 100 H_2SO_4" reached kernel yields of 9,38 t/ha, which is an additional yield of nearly 2 t/ha due to acidification in comparison to "Digestate 100" (7,39 t/ha). This positive yield effect due to acidification was also observed in the second experimental year and at higher N-rates, however, with no significant differences.

When comparing the acidified digestates and mineral fertilizer in both years it is noticeable that the additional yield for whole crop silage and kernel, respectively, at N-rates of 100 and 200 kg N/ha was not significant. Moreover, at the 300 kg N/ ha the acidified treatment resulted in even slightly higher kernel yields than the CAN treatment indicating the high ammonium-N-efficiency of treated digestates.

Kernel nitrogen yield

After threshing and yield measurements the kernels were analysed for nitrogen yield. Results are shown in the following figure.

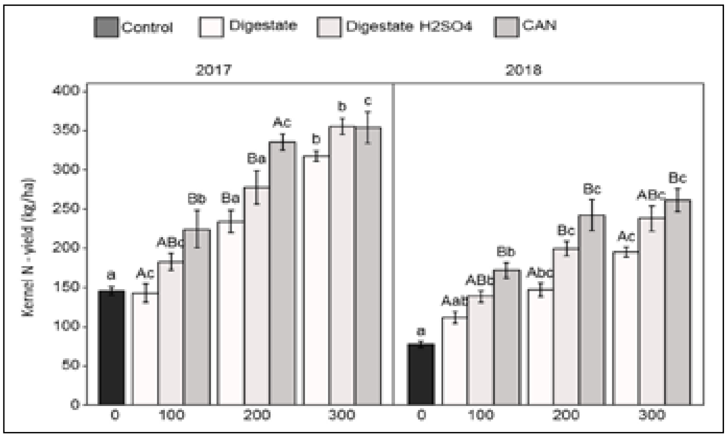

Figure 10. *Kernel nitrogen yields of the different treatments in 2017 and 2018. Sampling was conducted on 03.08.2017 and on 26.07.2018. (Different lowercase letters indicated significant differences between the different N-rates, different capital letters indicated differences between different nitrogen fertilizers).*

Calculation and analysis by NIRS pointed out that the results of the dry matter measurements are mainly confirmed by the results of nitrogen yields. Correspondingly to dry matter yields, nitrogen yields were lower in 2018 than in 2017. In both years acidification of digestates resulted in higher nitrogen uptake, leading to higher kernel N-yields than in the non-acidified treatments. Significant differences between treatments were obvious only at fertilization rate 200 in 2018. In this year the acidification reached significant higher yields than non-acidified treatment. Additionally, acidification reached in 2018 at each nitrogen rate comparable and not significant lower N-yields compared to CAN. Also in 2017 significantly higher nitrogen yields of mineral fertilization were visible only at 200 treatments.

Ammonia emissions

In the Figure 11 the results for cumulated ammonia emissions in 2017 and 2018 are shown. The results have to be understood as cumulated NH4+ concentrations for the fertilization events in winter-wheat for each experimental year. Differences for volatile ammonia releases after application of digestates and mineral fertilizers were measured by passive samplers (acid traps) with four replications indicating the potential for mitigation among the different treatments.

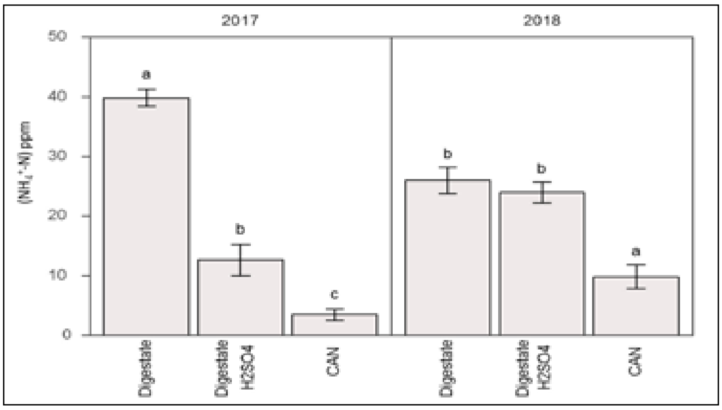

Figure 11. *Measured cumulated ammonia emissions by acid traps expressed as ppm (NH4-N) over three fertilizations in each trial year 2017 and 2018. (differences in letters indicated differences between treatments).*

In both experimental years the ammonia releases of digestates after application was below the expected level at given N-rate. However, the figures of emissions in the CAN treatments are typical and in accordance with literature values. In 2017, acidification of digestates resulted in a significant reduction of ammonia emissions in comparison to the non-acidified treatments of 68 % (2017). On the contrary, acidification resulted in a reduction of ammonia emissions of only 8 % during the second experimental year (2018). In comparison to 2017, this reduction was not significant. Reasons for this low reduction potential in 2018 have to be located mainly in the measurements of the first dressing of digestates, where higher emissions of the acidified treatment were observed. The second and third application showed a clear reduction in emissions due to acidification in comparison to the non-acidified substrate. It has to be considered that technical problems might be the reason for the unexpected emissions during the first dressing. With regards to the course of emissions over time, it clearly turned out that the main emissions of the digestates take place during the first twenty-four hours after application (Figure 12).

The peak of emissions within 24-hours is typical after application of organic manures. Especially the non-acidified treatment showed during the first and second digestate dressing high emissions immediately after the application. The differences in the level of ammonia losses between the first, second and third application, respectively, can be explained by the lower total amount of applied N. The highest amounts of N were applied for the first dressing according to the highest N-demand of plants during the early growth stage. Additional reasons for the very small emissions during the third dressing in winter wheat (Figure 12) could be found in the comparably high crop length, which resulted in shading with reduced radiation and reductions in wind speed close to the soil surface due to the close and dense crop canopy.

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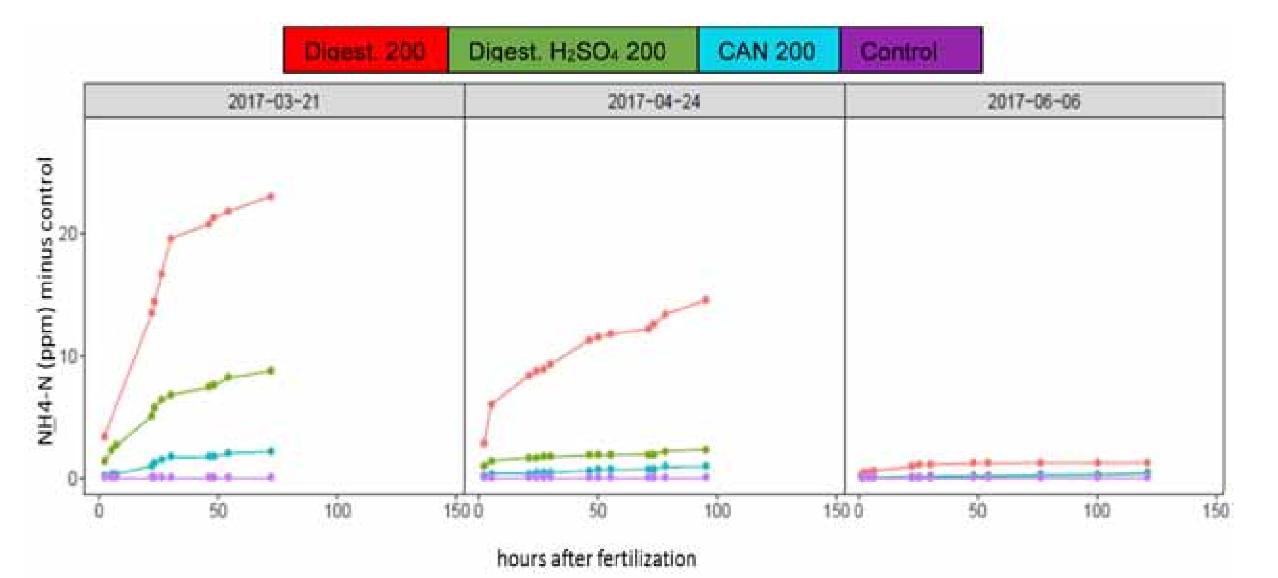

Figure 12. *Flux rates of ammonia emissions of the different tested treatments in hours after application (illustrated are three application events in winter wheat 2017).*

Nitrous oxide emissions

Accumulated nitrous oxide emissions (N_2O) in winter wheat during the two experimental years are presented in figure 13. Measurements were conducted weekly during the complete experimental period. The illustrated time span is 01.03.17-01.09.17 and 01.03.18-01.09.18. In the weeks of fertilizer application four measurements were conducted to cover expected emission peaks. Because of the high global warming potential of N_2O, it is very important to analyze N_2O emissions next to ammonia emissions, which have an indirect climate sensitive behavior due to deposition of ammonia and the possibility of transformation to nitrous oxide. Moreover, acidification techniques may reduce ammonia emissions on the one hand but on the other hand they might increase N_2O emissions from the soil due to a higher expected soil N-status, which has to be evaluated as possible trade-off. Comparing the two experimental years, it is obvious that the emissions were in general much lower in the experimental year 2018. Main reasons are lower rainfall and soil water contents during that time, inhibiting de-nitrification in soil of which N_2O is an important by-product. The prevailing environmental conditions, with more rainfall in 2017, explaining the large differences between the two experimental years. Significant differences between the treatments could be detected at a N-rate of 300 kg N/ha. The "Digestate" treatment reached significantly higher emissions than CAN treatment on this level. If comparing "Digestate" and "Digestate H_2SO_4" treatments, it is obvious that the non-acidified treatments reached in general higher emissions than the acidified treatments, however, these differences are not significant. In the two experimental years it could be not observed in all cases, that the nitrous oxide emissions increased with increasing nitrogen fertilization, this would be a typical behavior of N-response tests. A possible reason might be very good growing conditions in 2017. Sufficient rain and moderate growing temperatures lead to high nitrogen uptake, which resulted in comparably low soil born emissions especially in the CAN treatment. Increased nitrous oxide emissions with increasing nitrogen fertilization could be observed best in the non-acidified digestate treatments. Surprisingly the control treatment reached comparable nitrous oxide emissions like the 100 kg N/ ha treatments. This might indicate that next to the soil nitrate availability, especially in 2017, other influencing factors had an impact on emissions but determination of these influencing factors is not fully clarified yet. Main outcome of the experimental year 2017 is that no higher N_2O emissions due to acidification could be detected. In contrast, in the "Digestate 300" treatment reached significantly higher emissions compared to the "Digestate 300 H_2SO_4" treatment. However, in front of the presented results we cannot exclude that acidification has an effect on soil microbial communities such as soil nitrifiers and

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denitrifiers. Maybe, the loss on easy decomposable carbon fractions after acidification has also an effect as the availability of carbon for heterotrophic soil denitrifiers favour the release of N_2O from soil.

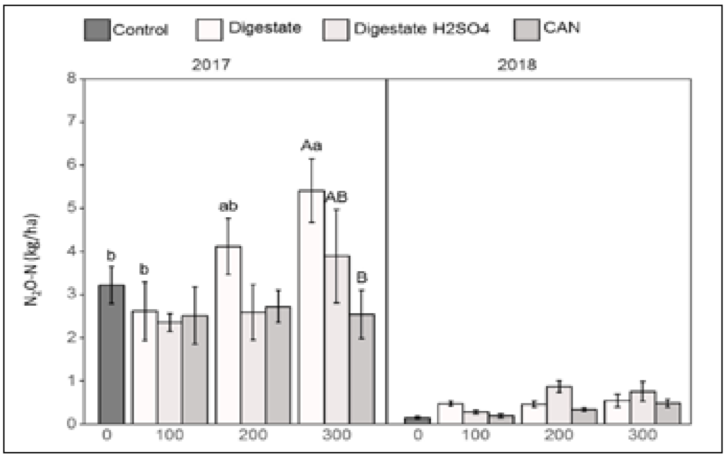

Figure 13. *Cumulated nitrous oxide emissions, measured with the "closed chamber" technique in 2017 (01.03.17-01.09.17) and 2018 (01.03.18-01.09.18) in winter wheat. Different lowercase letters indicated significant differences among different N-rates, different capital letters indicated differences between different fertilizer treatments.*

Results and discussion of the permanent grassland experiment 2017/2018

Grassland DM - yield 2017/2018

In Figure 14 cumulated dry matter yields of the permanent grassland experiment are illustrated. The experiments were characterized by prevailing environmental conditions among the two experimental years. The spring and summer 2017 were characterized by very good growing conditions until late autumn. 5 silage cuts were conducted. The autumn and winter 2017/2018 were very wet until the late spring. Since late April 2018 the climate was characterized by heavy droughts, which led to a strong yield decrease in comparison to 2017. Because of an extremely low yield the 3rd silage cut was conducted as a mulch cut instead. Thus, only 4 silage cuts were harvested in 2018, leading to clearly lower yields in 2018 (Figure 14).

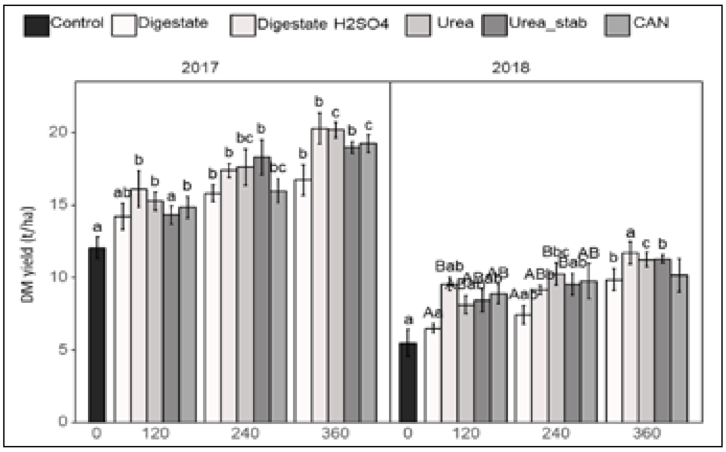

Figure 14. *Cumulated DM-yields of the different treatments on permanent grassland in 2017 (5 silage cuts) and 2018 (4 silage cuts). (Different lowercase letters indicated significant differences between the different N-rates, different capital letters indicated differences between different nitrogen fertilizers).*

Due to the predominant good growing conditions and the sufficient N-supply especially in the beginning of the growing season 2017 the control treatment was able to reach high yields (>8 t DM ha^{-1} $year^{-1}$). Nevertheless, the control treatment without any nitrogen fertilization reached the lowest yields in both experimental years. In general, higher N-rates resulted in increased DM-yield in both experimental years. In every case, the acidified digestate reached higher yields than the non-acidified treatments, whereby significant differences between these treatments could only be observed at the lowest N-rate in 2018. In both years, acidification of digestate resulted in maximum DM-yields at the lowest (120) and highest (360) N-rate, even though this additional yield was not significantly higher in comparison to mineral treatments.

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N-yields

Cumulated N-yields for the 5 silage cuts 2017 and the 4 silage cuts in 2018 are shown in Figure 15.

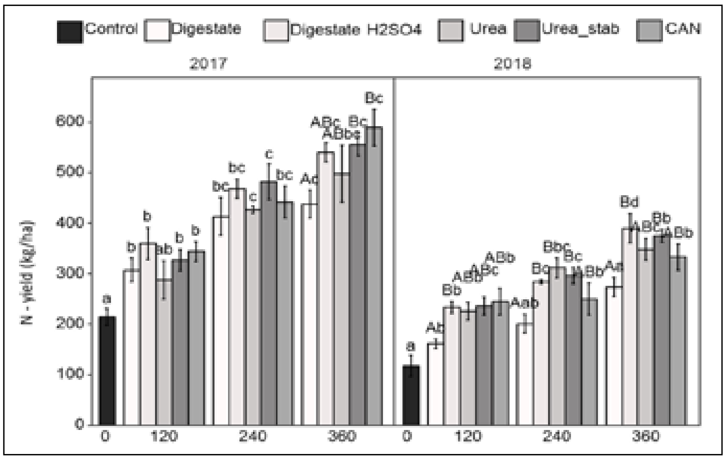

Figure 15: *N-yields of the different fertilizer treatments on permanent grassland in 2017 (5 silage cuts) and 2018 (4 silage cuts). (Different lowercase letters indicated significant differences between the different N-rates, different capital letters indicated differences between different nitrogen fertilizers).*

N-yields were smaller in 2018 compared to 2017. This is in accordance to the DM-yield results. The comparison between the acidified and non-acidified treatments showed significant higher N-yields by acidification in 2018. However, no significant differences could be observed in 2017. It has to be concluded that especially in 2018, where ammonia emissions in the grassland experiment were in general higher compared to 2017 (see 4.3.), mitigation of ammonia emissions by acidification increased plant available nitrogen in the soil, which resulted in higher N-uptake and higher N-yield, respectively. This clearly demonstrates that acidification techniques are best suited at hot and dry weather conditions.

Ammonia emissions

After each of the four dressings NH3-emissions were measured by acid traps up to seven days. In Figure 16, the accumulated results for all treatments and both experimental years are shown.

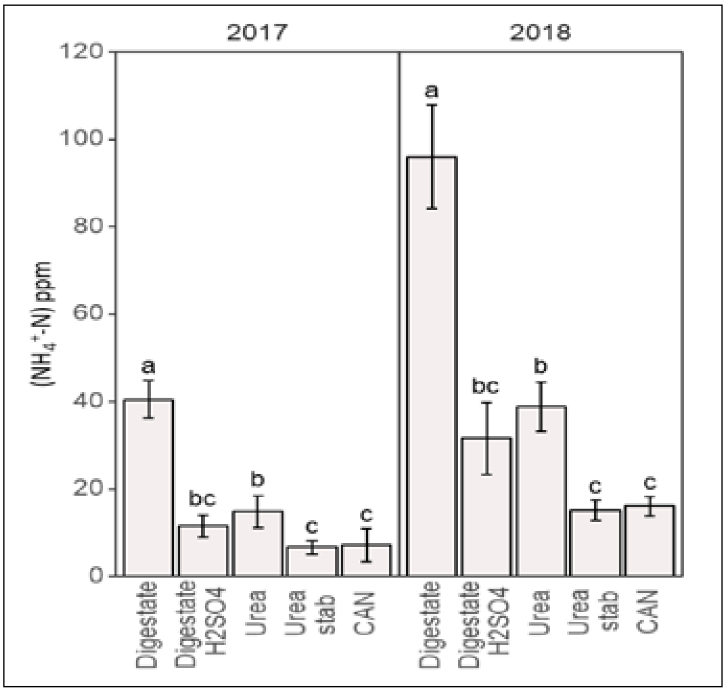

Figure 16: *Accumulated ammonia emissions expressed as ppm (NH4-N) for the experimental years 2017 and 2018. (Different letters indicated significant differences between treatments).*

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Measurements were conducted after each of the four fertilization events in the 240 kg N/ha treatment as well as in the control treatment. Obviously, ammonia emissions were in general higher in the second experimental year. “Digestate” reached as twice as much higher emissions in 2018, when compared to the “Digestate” treatment in 2017. The relative reduction potential due to acidification was approximately 71 % in 2017 and 67 % in 2018. Comparing the mineral fertilizer treatments, the stabilization of Urea was able to reduce ammonia emissions significantly in comparison to the non-stabilized fertilizer. Between “Urea stab.” and “CAN” no differences in emissions could be observed.

Nitrous oxide emissions

In Figure 17, measured accumulated nitrous oxide emissions for the time period 01.03.17-01.09.17 and 01.03.18-01.09.18 are illustrated.

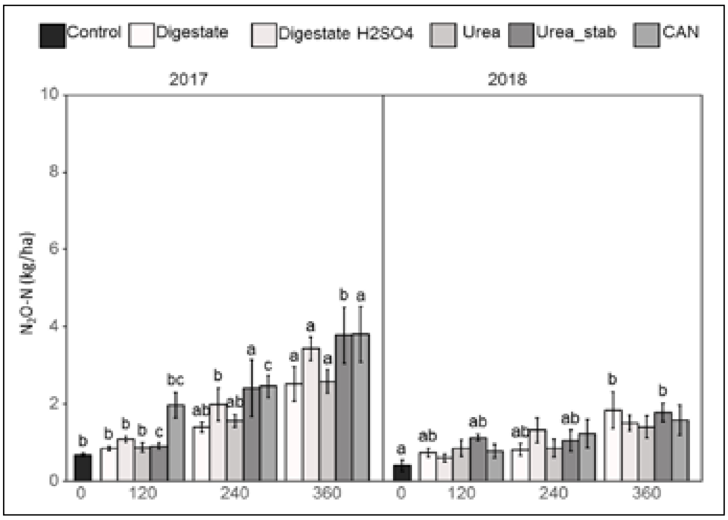

Figure 17: *Accumulated nitrous oxide emissions, measured with the “closed chamber” method in 2017 (01.03.17-01.09.17) and 2018 (01.03.18-01.09.18). Different lowercase letters indicated significant differences between N-rates, different capital letters indicated differences between different fertilizer treatments.*

Comparing the two experimental years, it is obvious that the emissions on permanent grassland were in general much lower in 2018. Main reasons are also here lower rainfall and soil water contents during that time, inhibiting de-nitrification in soil of which N_2O is an important by-product. Between fertilizers no significant differences in emissions could be detected. In 2018 differences between N-rates were only present between the non-fertilized control and the 360 kg N/ha treatment. In 2017 differences in N_2O emissions at different N-rates are significant. Stabilized urea showed significant differences among each N-rate. The acidified treatments showed at each N-rate slightly higher N_2O-emissions compared to the non-acidified treatments in 2017 with increasing figures at higher N-rates. However, in 2018 the differences of N_2O emissions were small.

Conclusions

Results confirmed the potential of acidification with sulphuric acid as an efficient way to reduce ammonia emissions during field application in standing plant biomass. In winter wheat a reduction potential for ammonia volatilization of 68 % was measured during the first experimental year. This trend was not confirmed during the second experimental year. However, acidified digestates achieved higher kernel DM-yields and N-yields in winter wheat in both experimental years with highest yield differences at the lowest N-rate (100 kg N ha-1 year-1). The grassland experiment showed high reduction potentials by acidification of 71 % (2017) and 67 % (2018) in both experimental years. In every case acidification reached higher DM- and N-yields in comparison to the non-acidified treatment, whereby significant differences between these treatments were again only observed at the lowest N-rate.

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Possible trade-offs due to acidification on greenhouse gas emissions could not be confirmed.

In no case nitrous oxide emissions were higher in the acidified treatment in winter wheat as well as in grassland.

Hence, acidification technologies, along with other near-ground application techniques, are an important instrument for significantly reducing ammonia losses during fertilizer application and thus saving mineral N fertilizer. Those techniques are best suited in standing crops during unfavourable weather conditions or on sites where soil conditions do not allow other methods such as injection.

Reporting form: 2017, grassland, winter wheat *(please, activate the link below)*
https://www.dropbox.com/s/e4dax2dgkpml7jj/Germany%202017.xlsx?dl=0

Reporting form: 2018, winter wheat *(please, activate the link below)*
https://www.dropbox.com/s/g2wck24dwq7oluj/Germany%20FT_RF_SCIENTIFIC_2018_Wheat-1.xlsx?dl=0

Reporting form: 2018, grassland *(please, activate the link below)*
https://www.dropbox.com/s/13b2ufnzb96u58x/Germany%20FT_RF_SCIENTIFIC_2018_Grassland.xlsx?dl=0

References

Hutchinston, G.L.; Moisier, A. R. 1981. Improved Soil Cover Method for Field Measurement of Nitrous Oxide Fluxes. Soil Science Society of America. 45, 311-316.

Neumann, S.; Zacharias, M.; Stauß, R.; Foged, H. L. 2017. Market potential analysis- Slurry acidification technologies in the Baltic Sea Region. Report 6.1.

Pacholski, A. 2016. Calibrated Passive Sampling - Multi-plot Field Measurements of NH3 Emissions with a Combination of Dynamic Tube Method and Passive Samplers. Journal of Visualized Experiments. 109, 1-15.

Material about Informational events

Event: Visit of the Minister of culture.

Description: Presentation of the Project.

Date: 23.08.2016.

Place: in Blunk GmbH.

Number of participants: 9 participants.

Event: Insider day Blunk GmbH.

Description: BSA-Project Presentation and SyreN Presentation.

Date: 26.01.2017.

Place: in Blunk GmbH.

Number of participants: 500 participants.

Event: Agricultural Conference.

Description: BSA poster Presentation.

Date: 02.02.2017.

Place: CAU Kiel.

Event: Insider day Blunk GmbH.

Description: BSA-Project Presentation and SyreN Presentation.

Date: 31.01.2018.

Place: in Blunk GmbH.

Number of participants: 500 participants.

Event: Agricultural Conference.

Description: BSA poster Presentation.

Date: 01.02.2018.

Place: CAU Kiel.

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Event: Agricultural Conference.

Description: SyreN information and demonstration.

Date: 31.08.2018.

Place: Lindhof CAU Kiel.

Number of participants: 100 participants.

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POLAND

General information:

<table>
<tr><th>Project partner</th><th>Contact person</th><th>Type of activity in Field Trail</th><th>2017</th><th colspan="2">2018</th><th>Ammonia emission</th></tr>
<tr><td rowspan="2">Institute of Technology and Life Sciences</td><td rowspan="2">Marek Kierończyk
m.kieronczyk@itp.edu.pl</td><td rowspan="2">Scientific</td><td>Grassland</td><td colspan="2">Grassland</td><td rowspan="2">Ammonia losses were measured</td></tr>
<tr><td>Cattle slurry</td><td colspan="2">Cattle slurry</td></tr>
<tr><td rowspan="2">Agricultyral Advisory Center in Brwinow Branch Office in Radom</td><td rowspan="2">Mateusz Sekowski
m.sekowski@cdr.gov.pl</td><td rowspan="2">Demonstration</td><td>Winter barley</td><td>Spring barley</td><td>Faba bean</td><td rowspan="2">Ammonia losses were not measured</td></tr>
<tr><td>Pig slurry</td><td>Cattle slurry</td><td>Pig slurry</td></tr>
</table>

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

The report on field trials carried out in Poland consists of two parts. The first part contains material submitted by Institute of Technology and Life Sciences and the second one – material submitted by Agricultyral Advisory Center in Brwinow Branch Office in Radom.

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Report of Institute of Technology and Life Sciences

Written by: Marek Kierończyk, Kamila Mazur, Jan Barwicki, Renata Wiśniewska,Bernadeta Fligiel

Aim

The scientific aim of this study was to assess the effect of acidification of cattle slurry on yields, soil parameters and ammonia emissions.

Materials and Methods

Research was conducted as field trials and was carried out under real planting conditions in 2017 and 2018. Meteorological conditions of experiments were different in temperature, humidity of air and soil and precipitation. In 2017, precipitation was very high than the average, but in 2018 precipitation was strongly below the average. In 2017, three replications of slurry treatment at grassland were carried out in the fields of the Experimental Farm in Falenty. In June 2017 after the first cut and preparation of the research objects, acidified and non acidified slurry was spread on a surface ca. 500 m^2 in the variant of fertilization with cattle manure and acidified cattle manure with sulphuric acid, previously obtaining a pH of 5.5 during pre-storage of slurry on the farm for two weeks in a concrete sealed tank.

Figure 1. *Location of ITP Centrum in Falenty, Poland Coordinates: 52.13.83 N: 20.9103 (alt. 104 m sea level).*

Repetition of fertilization on other research facilities as a further field trial under action in WP 4 was carried out on permanent grassland in July after the first cut and preparation of further research facilities fertilization was carried out on a surface of 500 m^2 on permanent grassland in the two variants of fertilizing with cattle slurry and acidified cattle slurry using sulphuric acid previously obtained a pH about 5.5 during pre-storage of slurry in a concrete, sealed tank on experimental farm for two weeks.

Soil samples were collected in accordance with the accepted standard from a depth of 0-30 cm, i.e. throughout the soil profile directly accessible to plant on permanent grassland. Previous studies have been carried out by taking soil samples from a depth of 0-10; 10-20 and 20-30 cm and from the entire soil profile 0-30 cm.

During the study period, permanent grassland was covered by the following grass species: common cockscomb, meadow grass fescue, persistent ryegrass and timothy grass, and occupied from 65 to 95% of the experimental plots.

In 2015, prior to field trials, meadows were fertilized in spring with cattle slurry at a dose of about 50 m^3/ha, which in terms of nitrogen content ranged from 100 to 120 kg N. The yield of green mass after three cuts was around 30 t/ha. After application of calcium carbonate lime in the first decade of November, 2016 in the amount of 1.8 to 2.5 tonne $CaCO_3$ and carrying out fertilization on 500 m^2 plots at doses of approximately 150 and 160 kg N /ha obtained yield at the level of approximately 11 tonne per ha in all three cuts. The yield of green mass of grass from the three cuts in 2017 on the non-fertilized plots was at the level of about 27 tonne per ha, while the fertilized plots using slurry was

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around 22 tonne per ha. The lowest yields after the use of acidified cattle slurry were at the level of 30,5 tonne per ha, and the highest ones were as much as 45 tone per ha in three cuts during the term of vegetation. Detail analysis of yields green and dry matter in two years of experiment with two doses of nitrogen was attached in tables 26 to 29.

Figure 2. *Soil sampling, Autumn 2016.*

Figure 3. *Planning field plots 2016.*

The value of soil pH, i.e. pH, was ranging from 6.4 (on plots without acidification) on selected plots and 6.5 (on plots subjected to acidic manure application). In statistical terms, these were not significant different. Acidification did not significantly affect the level of soil pH. This parameter, and despite conducting tests on mineral soils, the soil sorption complex combined with its buffer properties, the acidification process did not reduce the pH value, making the acidification process safe for plants and the soil environment. released phosphorus contained in the soil and inaccessible to plants.

Figure 4. *Field plots 2017.*

In turn, the content of total nitrogen on the discussed research plots was at the level of 0.2 to 0.3% in the case of plots where cattle slurry was utilized without acidification and in the range from 0.3 to 0.4%. Objects subjected to fertilization with cattle slurry were characterized by a very similar content of other nutrients. The content of phosphorus in terms of pure component ranged from 0.3 to 0.4 mg P/kg for not acidified plots and in the range of 0.2-0.3 mg /kg for plots where acidified slurry was utilized.

Figure 5. *Experimental Farm in Falenty (ITP) in-storage slurry acidification automatic system before application on grasslands (in WP 4).*

Figure 6. *Slurry after acidification process in ITP experimental stand in Falenty.*

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The potassium content (K) in the soil before fertilization was at the average level for the experimental conditions and ranged from 0.45 to 0.48 mg /kg for plots intended for the application of non-acidified slurry and 0.4 to 0.45w mg / kg for acidified slurry using sulphuric acid. The results of soil analysis are presented in the tables below.

Table 1. *Results of chemical analysis of soil in 2017*

Soil sample	Plot	Date	pH	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	Mn, mg/kg	Zn, mg/kg	Humus, %	Soil org. matter	Soil org. C, %	Diss. organic carbon	Depth, cm	B, mg/kg	Cu, mg/kg
Before using bovine slurry	I plot	2017-05-10	6.4	0.2-0.25	0.3-0.4	0.45-0.48	2	2100	55	30	2.1		1.6	n.a.		0-30	-	0.5
Before using acidified bovine slurry	II plot	2017-05-10	6.5	0.3-0.4	0.2-0.3	0.4-0.45	2	2000	52	34	2.3		1.9	n.a.		0-30	-	0.2
Before using bovine slurry	III plot	2017-06-10	6.4	0.25-0.3	0.3-0.4	0.45-0.48	1.5	1800	53	35	2.3		2	n.a.		0-30	-	0.3
Before using acidified bovine slurry	IV plot	2017-06-10	6.5	0.3-0.4	0.2-0.3	0.4-0.45	1.3	1900	58	35	2.3		1.4	n.a.		0-30	-	0.4

Cattle slurry was taken from the ITP Experimental Farm in Falenty and was stored in closed tight tanks for the period of about one month before the application for permanent grassland located on mineral soils with a significant content of nutrients. The utilization of cattle slurry using trailing hoses was carried out in June and July.

Table 2. *Results of chemical analysis of slurry prepared for application on field trials in 2017*

The way of implementation	Dry matter content	Total N kg/m^{-3}	NH_4-N, kg/m^{-3}	P, kg/m^{-3}	K, kg/m^{-3}	S, %	pH on field surface	Ca, kg/m^{-3}	C in dry matter, %
Cattle slurry	6.5	3.6	1.8	0.9	2.7	0.2	7.2	0.8	40
Acidified cattle slurry	6.7	3.6	1.9	0.9	2.9	3.0	5.86	0.85	34
Cattle slurry	7.2	3.4	2.0	0.9	2.7	0.3	5.7	0.7	41
Acidified cattle slurry	7.5	3.6	1.8	0.9	2.6	3.0	5.9	0.63	36

In the first weeks after the use of cattle slurry acidified with sulphuric acid soil pH in permanent grassland in the soil layer of 5-10 cm was at the level of 6.3 and after the first and second cut the crop dropped slightly to 5.8 which could suggest a temporary disturbance in the buffer system of soil on selected research plots.

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Table 3. *Results of chemical analysis of cattle slurry*

	Date	pH	N_{min}	P (P_2O_5)	K (K_2O)	S	Ca	Mg	Mn	Zn	Humus, %	Soil organic matter	Soil organic carbon	Dissolved organic carbon
After first cut	20-06-2017	5.8	0.16	0.06	0.16	n.a	1600	0.07	<0.01	0.01	-	0.8	-	-
After second cut	21-07-2017	5.9	0.13	0.05	0.14	n.a.	1480	0.06	<0.01	0.01	-	0.7	-	-

It should be noted that the experiment was performed in conditions of relatively high air temperatures as well as soil surface at moderate air speed. Atmospheric precipitation in the form of rain occurred about 6 hours after the end of application of slurry on grassland.

Table 4. *Meteorological data during slurry application*

Date	Date of sampling data	Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2017-06-06	Spreading day	27-28	2-5	5
2017-06-07	After spreading 1^{st} d.	23-25	2-4	2
2017-06-08	After spreading 2^{nd} d.	18-23	3-4	0
2017-06-09	After spreading 3^{th} d.	18-22	1-3	0

It should be noted that the experiment was performed in conditions of relatively high air temperatures as well as soil surface at moderate air speed. Atmospheric precipitation in the form of rain occurred about 8 hours after the end of slurry application grassland. In turn on the last day of research similar precipitation occurred as during the first June experiment (at the level of 5 mm).

Table 5. *Meteorological data on spreading day*

Date		Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2017-07-18	Spreading day	22-23	0-2	2
2017-07-19	After spreading 1^{th} d.	21-22	2-4	0
2017-07-20	After spreading 2^{nd} d.	19-20	2-4	0
2017-07-21	After spreading 3^{th} d.	19-20	2-3	5

The analysis of yields indicates relatively significant differences in the quantitative and qualitative approach. Plots without fertilization reached a yield of about 8 tonne per ha while plots fertilized with cattle slurry reached a yield of about 16 tonne per ha and plots fertilized with cattle slurry previously acidified at the level of 17 readed a yield of about 25 tonne per ha.

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Results of ammonia emission in 2017 during field trials on permanent grassland

In 2017 four repetitions were carried out. After the first cut was carried out on permanent grassland

Table 6. *N losses after application of non-acidified slurry on grass Rate 160 kg N per ha (Plot GR3)*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	26.2	16.4	27.3	17.1
II	7.3	4.6	6.4	4.0
III	1.4	0.9	2.3	1.4
IV	1.1	0.7	0.6	0.4
Sum:	36.0	22.5	36.6	22.9

Table 7. *N losses after application of non-acidified slurry on grass Rate 150 kg N per ha (Plot GR3 A)*

Day after application	Losses of N_{tot}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	24.4	16.3	23.4	15.6
II	4.5	3.0	4.8	3.2
III	1.4	0.9	1.6	1.1
IV	0.6	0.4	0.3	0.2
Sum:	30.9	20.6	30.1	20.1

Table 8. *N losses after application of acidified slurry on grass Rate 160 kg N per ha (Plot GR1)*

Day after application	Losses of N_{tot}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	2.8	1.8	2.2	1.4
II	1.2	0.8	1.1	0.7
III	0.3	0.2	0.2	0.1
IV	0.1	0.1	0.05	0.0
Sum:	4.4	2.8	6.23	2.2

Table 9. *N losses after application of acidified slurry on grass Rate 150 kg N per ha (Plot GR1A)*

Day after application	Losses of N_{tot}			
	kg N per ha	% N_{total}	kg N per ha	% N_{tot}
I	2.3	1.5	2.0	1.3
II	0.9	0.6	0.7	0.5
III	0.1	0.1	0.2	0.1
IV	0.0	0.0	0.0	0.0
Sum:	3.3	2.2	2.9	1.9

Table 10. *Results of chemical analysis of soil 2018*

Soil sample	Plot	Date	pH	N_{tot}, %	P, mg/kg	K, mg/kg	SO_4, mg/kg	Ca, mg/kg	Mg, mg/kg	Mn, mg/kg	Zn, mg/kg	Humus, %	Soil org. matter	Soil org. C. %	Diss. organic carbon	Depth, cm	B, mg/kg	Cu, mg/kg
Before using bovine slurry	I plot	2018-06-20	6.3	0.4-0.45	0.3-0.4	0.45-0.48	2	2000	29	18	2.1		1.6	n.a.		0-30	-	0.5
Before using acidified bovine slurry	II plot	2018-06-20	6.5	0.35-0.45	0.2-0.3	0.4-0.45	2	2000	30	34	2.3		1.9	n.a.		0-30	-	0.2
Before using bovine slurry	III plot	2018-08-18	6.4	0.30-0.35	0.3-0.4	0.42-0.43	1.5	1820	53	35	2.3		2	n.a.		0-30	-	0.3
Before using acidified bovine slurry	IV plot	2018-08-18	6.5	0.3-0.4	0.2-0.3	0.4-0.42	1.3	1860	58	35	2.3		1.4	n.a.		0-30	-	0.4

Table 11. *Results of chemical analysis of slurry prepared for application on field trials in 2018*

The way of implementation	Dry matter content	Total N kg/m-3	NH_4-N, kg/m-3	P, kg/m-3	K, kg/m-3	S, %	pH on field surface	Ca, kg/m-3	C in dry matter, %
Cattle slurry	6.5	3.6	1.8	0.9	2.7	0.2	7.2	0.8	39
Acidified cattle slurry	6.7	3.6	1.9	0.9	2.9	3	5.86	0.85	34
Cattle slurry	7.2	3.4	2.0	0.9	2.7	0.3	5.7	0.7	41
Acidified cattle slurry	7.5	3.6	1.8	0.9	2.6	3.0	5.9	0.63	36

In the first weeks after the use of cattle slurry acidified with sulphuric acid soil pH in permanent grassland in the soil layer of 5-10 cm was at the level of 6.2 and after the first and second cut the crop dropped slightly to 6.0.

Table 12. *Results of chemical analysis of cattle slurry 2018*

	Date	pH	N_{min}	P (P_2O_5)	K (K_2O)	S	Ca	Mg	Mn	Zn	Humus, %	Soil organic matter	Soil organic carbon	Dissolved organic carbon
After the first cut	20-06-2017	6.0	0.18	0.06	0.16	n.a	1600	0.07	<0.01	0.01	-	0.8	-	-
After the second cut	21-07-2017	6.1	0.12	0.05	0.14	n.a.	1480	0.06	<0.01	0.01	-	0.7	-	-

Results of ammonia emission in 2018 during field trials on permanent grassland

Table 13. *Meteorological data on slurry application day Non acidified*

Date	Description of day	Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2018-07-03	Spreading day	23-25	0-3	0
2018-07-04	After spreading 1st d.	23-24	2-5	0
2018-07-05	After spreading 2nd d.	26-27	2-5	0
2018-07-06	After spreading 3th d.	27-28	0-4	0
2018-07-07	After spreading 4th d.	24-25	3-6	0

Table 14. *Meteorological data on slurry application day Acidified*

Date	Description of day	Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2018-07-03	Spreading day	22-26	2-5	0
2018-07-04	After spreading 1st d.	23-24	0-5	0
2018-07-05	After spreading 2nd d.	27-28	0-5	0
2018-07-06	After spreading 3th d.	27-28	0-4	0
2018-07-07	After spreading 4th d.	24-25	3-6	0

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Table 15. *N losses after application of non-acidified slurry on grass Rate 160 kg N per ha (Plot GR3)*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	25.4	15.9	21.5	13.4
II	5.9	3.7	5.8	3.6
III	0.9	0.5	1.3	0.8
IV	0.7	0.4	0.7	0.5
Sum:	32.9	20.6	29.3	18.3

Table 16. *N losses after application of non-acidified slurry on grass Rate 150 kg N per ha Plot GR3 A*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	22.5	15.0	25.4	16.9
II	6.1	4.1	5.1	3.4
III	1.5	1.0	1.2	0.8
IV	1.2	0.8	0.7	0.5
Sum:	31.2	20.8	32.3	21.5

Table 17. *N losses after application of acidified slurry on grass Rate 160 kg N per ha (Plot GR1)*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	4.9	3.06	4.4	2.8
II	2.4	1.5	1.8	1.1
III	0.04	0.03	0.03	0.02
IV	0.0	0.0	0.0	0.0
Sum:	7.34	4.6	6.23	3.9

Table 18. *N losses after application of acidified slurry on grass Rate 150 kg N per ha (Plot GR1A)*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{total}	kg N per ha	% N_{tot}
I	4.00	2.67	4.78	3.2
II	1.67	1.11	2.22	1.5
III	0.03	0.02	0.07	0.0
IV	0.00	0.00	0.00	0.0
Sum:	5.69	3.80	7.07	4.7

Cattle slurry was taken from the ITP Experimental Farm in Falenty and was stored in closed tight tanks for the period of about one month before the application for permanent grassland located on mineral soils with a significant content of nutrients. The utilization of cattle slurry using trailing hoses was carried out in June and July.

Meteorological data from second field trials carried out in Poland

Table 19. *Meteorological data on slurry application day Non acidified*

Date	Description of day	Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2018-09-17	Spreading day	22-21	2-5	0
2018-09-18	After spreading 1st d.	20-21	2-4	0
2018-09-19	After spreading 2nd d.	18-23	3-4	0
2018-06-20	After spreading 3th d.	18-22	1-3	0
2018-09-21	After spreading 4th d.	24-25	3-6	0

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Table 20. *Meteorological data on slurry application day Acidified*

Date	Description of day	Temperature, °C	Wind speed, [m/s]	Percipitation, mm
2018-09-17	Spreading day	24-28	2-5	5
2018-09-18	After spreading 1st d.	23-25	2-4	2
2018-09-19	After spreading 2nd d.	18-23	3-4	0
2018-06-20	After spreading 3th d.	18-22	1-3	0
2018-09-21	After spreading 4th d.	24-25	3-6	0

Table 21. *N losses after application of non-acidified slurry on grass Rate 160 kg N per ha Plot GR2*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{total}	kg N per ha	% N_{tot}
I	15.1	9.4	15.6	9.75
II	6.2	3.9	6.42	4.01
III	1.7	1.1	2.3	1.44
IV	0.6	0.4	0.45	0.28
Sum:	23.6	14.8	24.77	15.48

Table 22. *N losses after application of non-acidified slurry on grass Rate 150 kg N per ha Plot GR2 A*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	14.5	9.7	13.5	9.0
II	5.2	3.5	5.2	3.5
III	1.3	0.9	1.3	0.9
IV	0.6	0.4	0.6	0.4
Sum:	21.6	14.4	20.5	13.6

Table 23. *N losses after application of acidified slurry on grass Rate 160 kg N per ha (Plot GR4)*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	4.9	3.06	4.4	2.8
II	2.4	1.5	1.8	1.1
III	0.04	0.03	0.03	0.02
IV	0.0	0.0	0.0	0.0
Sum:	7.34	4.6	6.23	3.9

Table 24. *N losses after application of acidified slurry on grass Rate 150 kg N per ha Plot GR4*

Day after application	Losses of N_{total}			
	kg N per ha	% N_{tot}	kg N per ha	% N_{tot}
I	4.0	2.67	3.8	2.5
II	1.7	1.11	2.1	1.4
III	0.05	0.03	0.1	0.1
IV	0.0	0.0	0.0	0.0
Sum:	5.75	3.81	6.0	4.0

Changes in pH values in selected plots were slight. In all plots liming was applied in 2016 and maybe it had influence on pH data. During field trials, every four days decreasing or increasing pH was not observed.

Table 25. *Changes of pH value in selected plots in WP 4 on permanent grassland*

Date	Plot				
	GR0	GR1 (GR1A) acidif	GR2 GR2A	GR3 GR3A	GR4 GR4A acidif
	5.63	5.57	5.42	5.18	5.72
04_18	6.47	6.54	5.44	5.31	5.53
05_18	5.86	6.26	5.01	4.93	5.44
06_18	5.92	5.13	6.02	5.53	5.0
Fertilization		acid	-	Non acid-	-
07_18	5.95	5.02	6.15	5.96	5.69
08_18	5.97	5.25	6.25	6.31	5.85
Fertilization	-	-	Non acid	-	acid
09_18	6.05	5.35	6.24	6.41	6.26

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Yields of grass

Yields of grass from plots included to WP 4 were summarized in the next two tables. Differences between control and fertilized plots were high and very high. It could be crossed impact of liming with calcium carbonates in 2016 and fertilization of acidified slurry in 2017 and next year 2018.

Table 26. *Results of grassland yields in cuts after acidified and not acidified cattle slurry for fertilization 160 kg N per ha in 2017*

Plots	Cuts						sum	
	I		II		III			
	GM	DM	GM	DM	GM	DM	GM	DM
	[tonne per ha]							
GR0	8.40	2.44	11.20	3.02	6.80	1.33	26.40	6.79
	9.70	2.72	11.20	2.80	6.70	1.41	27.60	6.92
	9.90	2.67	12.00	3.12	6.20	1.30	28.10	7.10
Average:	9.33	2.61	11.47	2.98	6.57	1.35	27.37	6.93
		Acid						
GR1 Acid	31.00	9.30	43.00	13.00	10.00	2.98	84.00	25.28
	30.00	7.50	45.00	13.95	13.70	3.70	88.70	25.15
	29.00	7.54	40.60	11.60	11.80	2.60	81.40	21.74
Average:	30.00	8.11	42.87	12.85	11.83	3.09	84.70	24.06
Changes according to control plots							309.5%	346.9%
GR2	22.30	6.38	9.50	2.2	14.50	3.42	46.30	11.99
	20.50	5.29	11.70	2.7	16.80	3.76	49.00	11.72
	23.50	6.72	13.70	3.1	12.50	2.73	49.70	12.53
Average:	22.10	6.13	11.63	2.65	14.60	3.30	48.33	12.08
Changes according to control plots							176.61%	174.20%
GR3	18.00	4.68	17.00	4.18	6.80	1.56	41.80	10.43
	19.70	5.08	24.00	6.14	4.20	1.03	47.90	12.26
	22.60	6.03	26.00	7.23	5.40	1.28	54.00	14.54
Average:	20.10	5.27	22.33	5.85	5.47	1.29	47.90	12.41
Changes according to control plots							175.03%	178.93%
				Acid				
GR4 Acid	27.00	7.13	11.50	2.88	16.50	3.76	55.00	13.77
	25.80	6.89	12.70	3.05	16.40	3.71	54.90	13.64
	37.00	10.69	13.00	3.64	15.60	3.56	65.60	17.89
Average:	29.93	8.24	12.40	3.19	16.17	3.68	58.50	15.10
Changes according to control plots							213.76%	217.74%
Average for acidified slurry according to control plots							250.41%	261.63%
Average for non acidified cattle slurry to control plots							170.60%	175.82%
Changes between fertilized with acid and fertilized							146.78%	148.80%

GM green mass; Recalculated GM to DM (dry matter)

The first cut was carried out in the middle of May. The second cut in the end of June and the third cut was carried out in the middle of August 2017.

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Table 27. *Results of grassland yields in cuts after acidified and not acidified cattle slurry for fertilization 150 kg N per ha in 2017*

Plots	**Cuts**						**sum**	
	I		**II**		**III**			
	GM	**DM**	**GM**	**DM**	**GM**	**DM**	**GM**	**DM**
	[tonne per ha]							
GR0	8.40	2.44	11.20	3.02	6.80	1.33	26.40	6.79
	9.70	2.72	11.20	2.80	6.70	1.41	27.60	6.92
	9.90	2.67	12.00	3.12	6.20	1.30	28.10	7.10
Average:	9.33	2.83	11.47	3.36	6.57	1.35	27.37	6.93
		Acid						
GR1 Acid	24.00	6.89	14.50	11.50	6.60	1.82	45.10	20.20
	23.00	6.83	45.00	12.51	12.50	1.82	80.50	21.16
	21.00	6.78	32.00	12.50	9.40	2.37	62.40	21.66
Average:	22.67	7.35	30.50	9.28	9.50	2.00	62.67	21.01
Changes according to control plots							229.0%	302.9%
GR2	22.00	6.29	8.20	1.89	13.40	2.44	43.60	10.63
	21.00	5.99	9.50	2.17	14.20	3.17	44.70	11.32
	24.00	6.86	10.50	2.36	11.80	2.22	46.30	11.45
Average:	22.33	6.38	9.40	2.14	13.13	2.61	44.87	11.13
Changes according to control plots							163.95%	160.49%
GR3	16.00	5.09	17.00	5.49	6.80	1.33	39.80	11.91
	20.00	6.34	24.00	7.87	4.20	0.77	48.20	14.99
	23.00	7.27	26.00	8.48	5.40	1.25	54.40	17.00
Average:	19.67	6.23	22.33	7.28	5.47	1.12	47.47	14.63
Changes according to control plots							173.45%	210.96%
				Acid				
GR4 Acid	25.00	6.60	10.00	2.36	18.80	2.50	53.80	11.46
	23.00	6.14	11.00	2.62	14.80	2.05	48.80	10.81
	34.00	9.15	13.00	3.09	14.20	2.17	61.20	14.41
	27.33	7.30	11.33	2.69	15.93	2.24	54.60	12.23
Changes according to control plots							199.51%	176.34%
Average for acidified slurry according to control plots							205.08%	214.251%
Average for non acidified cattle slurry to control plots							164.88%	168.70%
Changes between fertilized with acid and fertilized							124.38%	127.00%

GM green mass; Recalculated GM to DM (dry matter)

First cut was carried out in the middle of May. second cut in the end of June and the third was in the middle of August 2017.

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Table 28. *Results of grassland yields in cuts after acidified and not acidified cattle slurry for fertilization 160 kg N per ha in 2018*

Plots	Cuts						sum	
	I		II		III			
	GM	DM	GM	DM	GM	DM	GM	DM
	[tonne per ha]							
GR0	11.00	3.31	11.20	3.32	6.50	1.37	28.70	8.00
	10.00	3.04	11.20	3.30	5.80	1.26	27.00	7.61
	11.00	3.37	12.00	3.47	6.00	1.42	29.00	8.26
Average:	10.67	3.24	11.47	3.36	6.10	1.35	28.23	7.95
		Acid						
GR1 Acid	36.00	11.66	42.00	13.00	8.50	2.34	86.50	27.00
	32.00	5.80	45.00	13.73	13.40	1.82	90.40	21.34
	33.00	8.95	32.00	11.60	10.40	2.62	75.40	23.18
Average:	33.67	8.80	39.67	12.78	10.77	2.26	84.10	23.84
Changes according to control plots							297.9%	299.8%
GR2	23.00	6.58	6.60	1.5	13.40	2.44	43.00	10.54
	21.00	5.42	13.00	3.0	16.80	3.17	50.80	11.54
	25.00	7.15	15.00	3.4	11.80	2.22	51.80	12.75
Average:	23.00	6.38	11.53	2.62	14.00	2.61	48.53	11.61
Changes according to control plots							171.90%	145.99%
GR3	17.00	5.41	17.00	5.49	6.80	1.33	40.80	12.23
	20.00	6.34	24.00	7.87	4.20	0.77	48.20	14.99
	23.00	7.27	26.00	8.48	5.40	1.25	54.40	17.00
Average:	20.00	6.34	22.33	7.28	5.47	1.12	47.80	14.74
Changes according to control plots							169.30%	185.29%
				Acid				
GR4 Acid	28.00	7.39	12.00	2.83	18.80	2.50	58.80	12.73
	26.00	6.94	11.00	2.64	16.50	2.29	53.50	11.87
	31.00	8.34	13.00	3.09	15.60	2.38	62.60	14.62
Average:	28.33	7.56	12.00	2.86	16.97	2.39	57.30	12.81
Changes according to control plots							202.95%	161.02%
Average for acidified slurry according to control plots							250.41%	230.39%
Average for non acidified cattle slurry to control plots							170.60%	165.64%
Changes between fertilized with acid and fertilized							146.78%	139.09%

GM green mass; Recalculated GM to DM (dry matter)

The first cut was carried out in the middle of June. The second cut was carried out in the end of August and the third one was performed in the middle of October.

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Table 29. *Results of grassland yields in cuts after acidified and not acidified cattle slurry for fertilization 150 kg N per ha in 2018*

Plots	Cuts						sum	
	I		II		III			
	GM	DM	GM	DM	GM	DM	GM	DM
	[tonne per ha]							
GR0	11.00	3.31	11.20	3.32	6.50	1.37	28.70	8.00
	10.00	3.04	11.20	3.30	5.80	1.26	27.00	7.61
	11.00	3.37	12.00	3.47	6.00	1.42	29.00	8.26
Average:	10.67	3.24	11.47	3.36	6.10	1.35	28.23	7.95
		Acid						
GR1 Acid	29.00	8.41	26.50	7.42	6.60	1.82	62.10	17.65
	27.00	8.37	29.00	8.41	7.90	1.82	63.90	18.60
	28.60	8.58	31.00	8.68	9.80	2.37	69.40	19.63
Average:	28.20	9.14	28.83	8.77	8.10	2.00	65.13	18.63
Changes according to control plots							230.7%	234.2%
GR2	20.00	5.72	8.50	1.96	14.60	2.44	43.10	10.12
	19.00	5.42	9.90	2.26	15.20	3.17	44.10	10.84
	21.80	6.23	12.00	2.70	12.80	2.22	46.60	11.16
Average:	20.27	5.79	10.13	2.30	14.20	2.61	44.60	10.71
Changes according to control plots							157.97%	134.61%
GR3	19.00	6.04	18.00	5.81	6.10	1.33	43.10	13.18
	20.00	6.34	24.00	7.87	4.20	0.77	48.20	14.99
	22.60	7.14	26.00	8.48	5.60	1.25	54.20	16.87
Average:	20.53	6.51	22.67	7.39	5.30	1.12	48.50	15.01
Changes according to control plots							171.78%	188.78%
				Acid				
GR4 Acid	24.00	6.34	8.90	2.10	14.30	2.50	47.20	10.94
	23.00	6.14	9.50	2.26	13.50	2.05	46.00	10.46
	34.00	9.15	10.60	2.52	14.20	2.17	58.80	13.84
Average:	27.00	7.21	9.67	2.29	14.00	2.24	50.67	11.74
Changes according to control plots							179.46%	147.68%
Average for acidified slurry according to control plots							205.08%	190.94%
Average for non acidified cattle slurry to control plots							164.88%	161.69%
Changes between fertilized with acid and fertilized							124.38%	118.09%

GM green mass; Recalculated GM to DM (dry matter)

The first cut was carried out in the middle of June. The second cut was performed in the end of August and the third one was carried out in the middle of October 2018.

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Conclusions and recommendation

After field trials had been carried out in 2017 and 2018, the conclusions were made:

1) pH level (values) was not changed significantly after spreading of acidified cattle slurry,
2) yields were higher after every fertilization of grasslands every year,
3) quality of plants was better than it was before field trials and the growth was higher every year.

Acidification of slurry could help farmers to improve economical situation of their farms.

Reporting form *(please, activate the link below)*
https://www.dropbox.com/s/0xg8f7j94nkmtxi/Poland%20ITP%20final.xlsx?dl=0

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Material about Informational events

Event: Seminar.

Description: It was one of information day for Field Trials. Presentations about the BSA project were shown, activities and results of field trials were presented. The seminar was attended by agricultural advisors, members of farmers' associations.

Date: 15.05.2018.

Place: Institute of Technology and Life Sciences, Branch in Warsaw.

Number of participants: 30.

Event: Educational Seminar "Science for Agricultural Advisory".

Description: Seminar was organized for the wide audience of workers of Agricultural Centres from all voivodeships in Poland and workers from Ministry of Agriculture and Rural Development.

On 11th September 2018: presentations made by prof. dr hab. Eng. Wacław Romaniuk "Modern livestock buildings for dairy and beef cattle" and PhD eng. Witold Wardal "Management, usage and components of liqiud manure and slurry based on newest research results held in Poland".

On 12th September 2018: the workers from Agricultural Centres from all voivodeships in Poland and from the Ministry of Agriculture and Rural Development visited Research farm in Biebrza, Ørum acidification equipment was presented and Kamila Mazur introduced the topic "Slurry acidification for ammonia emissions reduction".

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On 13th September 2018: educational films were shown, including our project's video "Slurry Acidification Technologies" (Kamila Mazur as a main lecturer for discussion with audience), ITP's station for preparation of slurry acidification in Research Farm in Falenty was visited, crops were shown where acidified and non-acidified slurry were used.

Date: 11-13.09.2018.

Place: Institute of Technology and Life Sciences (Falenty and Biebrza).

Number of participants: 50.

Event: International scientific conference.

Description: Kamila Mazur had presentation about the BSA project, presenting all WPs. This Conference was attended by Minister of Agriculture and Rural Development, Jan Krzysztof Ardanowski. It was the first step to implement WP6 aims, (1st step for "round-table").

Date: 25-26.09.2018.

Place: Institute of Technology and Life Sciences, Branch in Warsaw.

Number of participants: 80.

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Event: Conference: “Reducing of nitrogen pollution from agriculture as a method of improving waters quality”.

Description: Conference was held as a part of a wide educational campaign “Reducing of nitrogen pollution from agriculture as a method of improving waters quality”, co-financed by National Fund for Environmental Protection and Water Management. In this conference, in discussion panel, Witold Wardal spoke about the Baltic Slurry Acidification project.

Date: 07.11.2018.

Place: Zielna Center, Warsaw.

Number of participants: 136.

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Report of Agricultyral Advisory Center in Brwinow Branch Office in Radom

Written by: Mateusz Sekowski, Andrzej Szymanski

Summary

The demonstation field trials with winter barley, spring barley and faba bean were carried out between September 2017 and September 2018. The experiment was located in three parts of Poland, in farmers' entities characteristic of a given region in terms of production of natural fertilizers and plant production. The experiments were of a demonstration nature, aimed at presenting one of the techniques for acidifying slurry and investigating adaptation and feasibility of those techniques in farm conditions.

Aim

The aim of this study was to evaluate the effect of acidification of slurry on soil and the crop yield treated with that slurry.

Materials and methods

Study site

In 2017-2018, 3 demonstration field trials were held. One of them was carried out in Borzęciczki, Wielkopolska region (pig slurry), the second one in Werbkowice, Lubelskie region (cattle slurry), the third one in Kruklanki, Warminsko-Mazurskie region (pig slurry).

Figure 1. *The lcocation of demonstration field trials (1. pig slurry, 2. cattle slurry, 3. pig slurry).*

Specification of sulfuric acid and safety issues

Concentrated (96%) sulfuric acid was used for acidifying the slurry. Subsequent acidification of the slurry used in the field trials was carried out outside near the area of experiment.

Figures 2 and 3. *Safety features during acid handling.*

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Persons handling sulphuric acid were aware of safety issues and equipped with protective clothing with a mask with an absorber. The handling of sulfuric acid was manual with a suitable pump to pump acid in appropriate portions.

Soil Analyses

Prior to the experiment, soil samples were taken. The samples were taken from a depth of 0-30 cm and 30-60 cm. The samples were analyzed in the laboratory in the scope of: pH, N min, P (P_2O_5), K (K_2O), S, Ca, Mg, Mn, Zn, humus %, soil organic matter, soil organic carbon.

Figures 4 and 5. *Collection of soil samples before the experiment.*

2017, winter barley

The experiment was carried out in the farm of a commercial farmer, in Borzeciczki, Wielkopolskie region (central-west Poland). The start date of the field trial was September 2017. Soil in the area of field trials is characterized as a clay soil. Pre-crop was maize, fertilized with nitrogen from digestate plus liming (2 t/ha CaO).

Figures 6 and 7. *Location of the field trial (Borzeciczki, Wielkopolskie region).*

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Weather data

Temperature, precipitation and average daily wind speed from the day for spreading and five days thereafter of the field trial are shown in Figures 8, 9, 10.

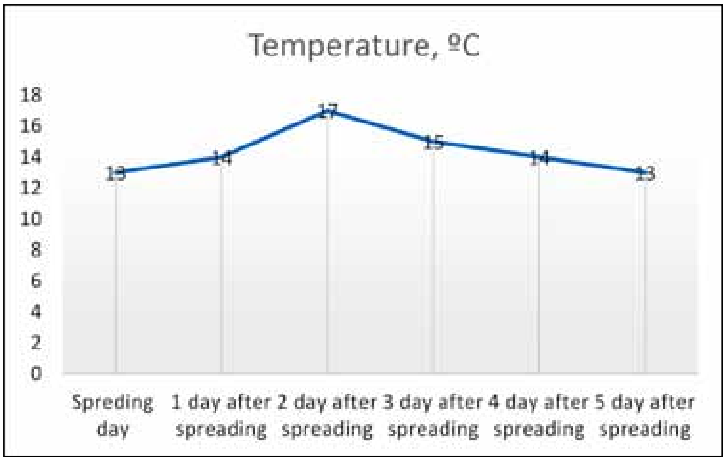

Figure 8. *Temperature, °C on field trial field (six consecutive days).*

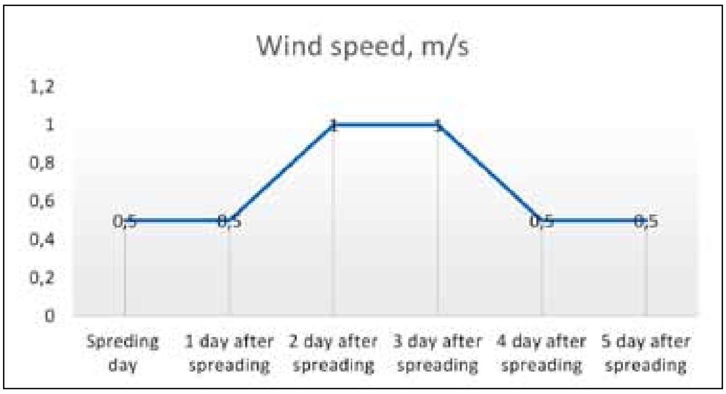

Figure 9. *Wind speed, m/s on field trial field (six consecutive days).*

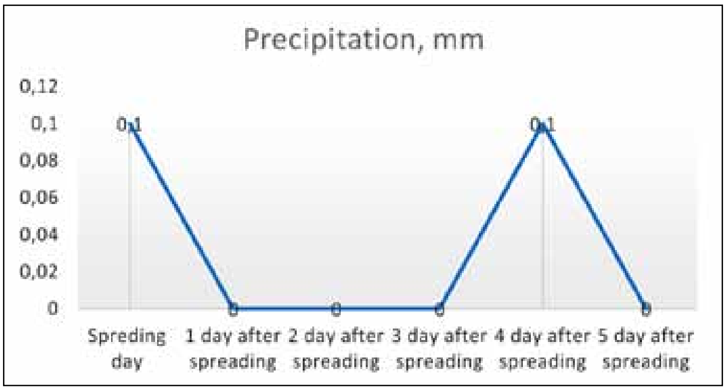

Figure 10. *Precipitation, mm on field trial field (six consecutive days).*

Soil samples

Soil samples were taken before the slurry spreading on 6th September 2017 to determine content of chemical elements. Results of soil analysis are shown in Table 1.

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Table 1. *Content of chemical elements in soil samples before spreading*

Layer cm	pH_{KCl}	Nmin, kg/ha	C_{org}, %	SO_4 mg/100 g	P_2O_5 mg/100 g	K_2O mg/100 g	MgO mg/100 g	Cu, mg/kg	Mn, mg/kg	Zn, mg/kg	Humus, %
0-30, 30-60 (mixed)	4.9	160.8	0.81	0.42	9.6	18.4	6.3	3.2	59.0	11.1	1.4

Slurry acidification

Before spreading slurry onto the field, slurry was treated with concentrated sulfuric acid (96% H_2SO_4) in a slurry tank in order to reach the desired pH level (around 5-6 pH). The slurry output level was 7.4 pH.

Figures 11 and 12. *Acidification process in a slurry tank.*

Samples of slurry, acidified and not acidified, were subjected to laboratory analysis. The results of the analysis are presented in Table 2. The pH of the slurry was tested on the spot by pH meter.

Table 2. *Slurry properties before spreading (Untreated slurry and Acidified slurry)*

	Dry matter content	Total N	P	K	S	pH
Untreated slurry	4.3	0.3	0.2	0.2	0.4	7.4
Acidified slurry	5.2	0.4	0.2	0.2	0.05	5.0

Slurry spreading

The field experiment was carried out in two replicates, one of them with untreated slurry (reference sample), the other with acidified slurry. Slurry was spread on 7th September 2017. The process began by mixing slurry in the slurry tank with the internal mixer. Once slurry was mixed, slurry samples were taken from the tank for analysis. Thereafter, the untreated slurry was spread on the field. A full slurry tank with a capacity of 18 000.00 liters was spread on the surface of 0.5 ha.

Then, the slurry tank was refilled with slurry. Slurry was treated with the sulfuric acid (as described above) up to the desired pH level. The tank with acid was placed on the platform, at the height of the inlet in the slurry tanker. With the help of a pump, the right amount of acid was introduced into the tank filled with slurry. Slurry was mixed several times along with continuous measurement of the pH level until the desired one was obtained.

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Then, slurry samples were taken from the tank for analysis. Then, acidified slurry was spread in the field, also on the area of 0.5 ha.

Figures 13 and 14. *Slurry spreading into the field.*

Crop development

Winter barley was sown in the field. Between slurry application and the harvest, the trial field was visited for crop development inspection – April 2018 (Figures 15 and 16).

Figure 15. *Inspection of the development of crop.*

Figure 16. *Visual differences in plants, right side – acidified slurry, left side - untreated slurry.*

Harvest

The crop was harvested in July 2018. The plant material was subjected to chemical analysis of: i.a. moisture content and protein content.

The results of yield, protein content and nitrogen efficiency in relation to the control are presented in Table 3.

Table 3. *Chemical analysis of yield, comparison of yields from acidified and untreated slurry*

	Dry matter content	Protein content	Total N	P	K	Ca	Mg	S, %	Yield (t/ha)
Untreated slurry	89	12.25	1.96	0.4	0.58	0.09	0.12	0.19	5,7
Acidified slurry	90	13.25	2.17	0.4	0.57	0.09	0.13	0.22	9,6

The values of dry matter and protein content show that the acidification caused a slight yield increase (i.e. +1%), compared to untreated slurry. However, the increase in total yield was significant, around 40%. The acidification resulted in increased nitrogen efficiency, however to a small extent. Sulfur content in the yield increased slightly as a result of the acidification process.

Repetition of the procedure

After the harvest, sulfuric acid was re-applied to the fields in the same procedure as before. The field was sown with aftercrop: mustard seed, followed by the maize.

Soil analysis was carried out simultaneously. Results of soil analysis are shown in Table 4.

Table 4. *Content of chemical elements in soil samples before spreading*

Layer cm	pH_{KCl}	Nmin, kg/ha	C_{org}, %	SO_4 mg/100 g	P_2O_5 mg/100 g	K_2O mg/100 g	MgO mg/100 g	Cu, mg/kg	Mn, mg/kg	Zn, mg/kg	Humus, %
Untreated slurry	6.6	51.1	0.81	0.5	16.6	12.1	7.5	3.6	56.9	14.5	1.4
Acidified slurry	5.6	56.3	0.87	0.5	22.8	19.4	7.5	4.4	68.5	23.2	1.5

Samples of slurry, acidified and not acidified, were subjected to laboratory analysis. The results of the analysis are presented in Table 5.

Table 5. *Slurry properties before spreading (Untreated slurry and Acidified slurry)*

	Dry matter content	Total N	P	K	pH
Untreated slurry	1.7	0.19	0.07	0.12	7.0
Acidified slurry	1.45	0.22	0.08	0.17	5.6

The yields will be harvested in the spring of 2019. The farmer is willing to continue cooperation by providing yield and analysis results.

Reporting form: 2017, winter barley *(please, activate the link below)*
https://www.dropbox.com/s/9sswwn8de3ar8ge/Poland%20%28Mateusz%29%202017%20%28winter%20barley%29.xlsx?dl=0

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2018, spring barley

The experiment was carried out in the farm of The Institute of Soil Science and Plant Cultivation, in Werbkowice, Lubelskie region (Eastern Poland). The start date of the field trial was September 2017. Soil in the area of field trials is characterized as Albeluvisoils. Pre-crop was beetroots, fertilized with slurry (36 t/ha).

Figures 17 and 18. *Location of the field trial (Werbkowice, Lubelskie region).*

Weather data

Temperature, precipitation and average daily wind speed from the day for spreading and five days thereafter of the field trial are shown in Figures 19, 20, 21.

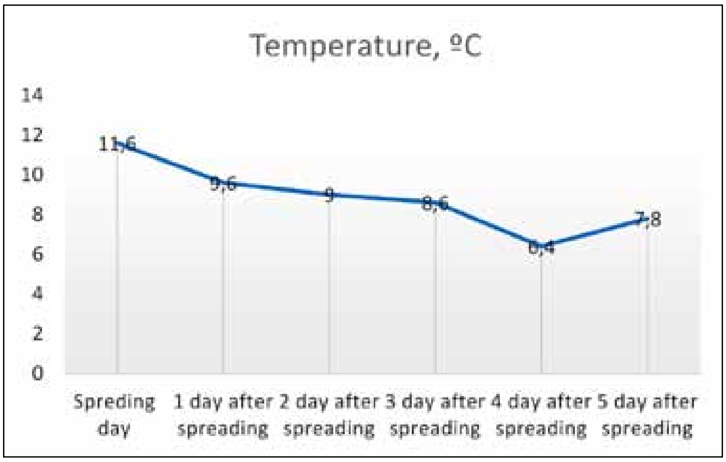

Figure 19. *Temperature, °C on field trial field (six consecutive days).*

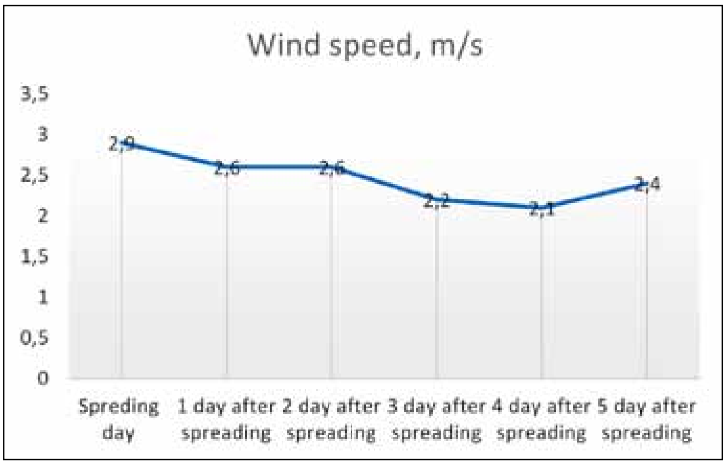

Figure 20. *Wind speed, m/s on field trial field (six consecutive days).*

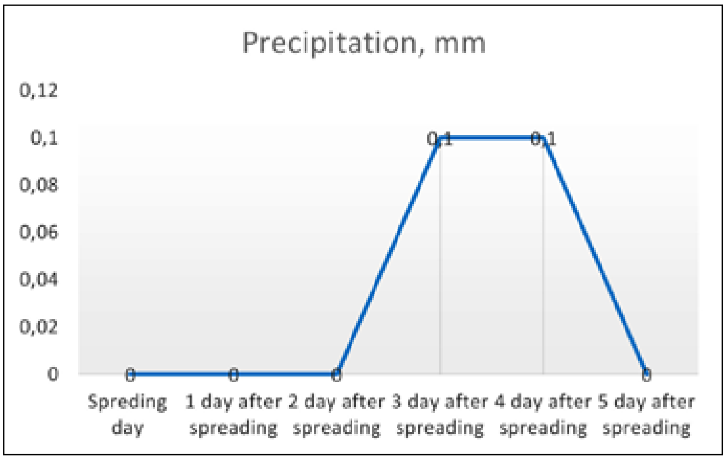

Figure 21. *Precipitation, mm on field trial field (six consecutive days).*

Soil samples

Soil samples were taken before slurry spreading on 27th September 2017 to determine content of chemical elements. Results of soil analysis are shown in Table 6.

Table 6. *Content of chemical elements in soil samples before spreading*

Layer cm	pH_{KCl}	Nmin, kg/ha	SO_4, mg/100 g	P_2O_5 mg/100 g	K_2O, mg/100 g	MgO, mg/100 g	Humus, %	Soil org. C
0-30, 30-60 (mixed)	6.5	65.7	0.1	8.2	24.2	6.8	2.8	1.6

Slurry acidification

Before spreading slurry onto the field, slurry was treated with concentrated sulfuric acid (96% H_2SO_4) in a slurry container in order to reach the desired pH level (around 5-6 pH). The slurry output level was 7.2 pH.

Figures 22 and 23. *Acidification process in a slurry container.*

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Samples of slurry, acidified and not acidified, were subjected to laboratory analysis. The results of the analysis are presented in the Table 7.

Table 7. *Slurry properties before spreading (Untreated slurry and Acidified slurry)*

	Dry matter content	Total N	NH_4-N	P	K	S	pH
Untreated slurry	2.4	0.1	0.03	0.05	0.05	0.01	7.2
Acidified slurry	2.2	0.1	0.04	0.05	0.06	0.1	5.0

Slurry spreading

The field experiment was carried out in two replicates, one of them with untreated slurry (reference sample), the other with acidified slurry. The slurry was spread on 27th September 2017. The process began by mixing slurry in the slurry tank with the internal mixer. Once slurry was mixed, slurry samples were taken from the tank for analysis. Thereafter, the untreated slurry was spread on the field. A full slurry tank with a capacity of 18 000.00 liters was spread on the surface of 0.5 ha.

Then, the slurry tank was refilled with slurry. Slurry was treated with the sulfuric acid (as described above) up to the desired pH level. With the help of a pump, the right amount of acid was introduced into the tank filled with slurry. The acidified slurry was pumped several times from one tank to another using a pump section to thoroughly mix acid with slurry, along with continuous measurement of the pH level until the desired one was obtained.

Then, slurry samples were taken from the tank for analysis. Then, the acidified slurry was spread in the field, also on the area of 0.5 m^3.


Figures 24 and 25. *Slurry spreading into the field.*

Crop development

Winter barley was sown in the field. Due to unfavorable weather conditions the crop was completely frost, it was not possible to harvest.

Therefore, in the spring of 2018, the acidification process was repeated. The same field was acidified in a similar procedure as before. Spring barley was sown in the field. At the same time, the analysis of slurry was carried out. The results can be found in Table 8.

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Table 8. *Slurry properties before spreading (Untreated slurry and Acidified slurry)*

	Dry matter content	Total N	P	K	S	pH
Untreated slurry	1.06	0.08	0.03	0.08	0.005	7.4
Acidified slurry	0.96	0.08	0.03	0.09	0.036	5.4

Between slurry application and the harvest, the trial field was visited for crop development inspection (Figures 26 and 27).

Figure. 26. *Inspection of plant development.*

Figure 27. *Information board on the field.*

Harvest

The crop was harvested in summer 2018. The plant material was subjected to chemical analysis of: i.a. moisture content and protein content.

The results of yield, protein content and nitrogen efficiency in relation to the control are presented in Table 9.

Table 9. *Chemical analysis of yield, comparison of yields from acidified and untreated slurry*

	Dry matter content	Protein content	Yield (t/ha)
Untreated slurry	11.9	11.2	4.9
Acidified slurry – autumn 2017	11.6	11.7	5.3
Acidified slurry – spring 2018	11.7	11.8	5.5

The analysis of plant material showed a significant increase in yield in comparison with the un-acidified field, and one-time acidification (autumn 2017) + 8% yield increase and acidified twice (autumn 2017 + spring 2018) + 11% yield increase.

Repetition of the procedure

After the harvest, sulfuric acid was re-applied to the fields in the same procedure as before. The field was sown with aftercrop (mustard with spring barley).

Soil analysis was carried out simultaneously. Results of soil analysis are shown in Table 10.

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Table 10. *Content of chemical elements in soil samples before spreading*

Soil	pH_{KCl}	Nmin, kg/ha	P_2O_5, mg/100 g	K_2O, mg/100 g	MgO, mg/100 g	Cu, mg/kg	Mn, mg/kg	Zn, mg/kg
Untreated slurry	6.9	72.3	8.4	16.9	12.6	4.8	154.0	9.1
Acidified slurry	5.5	105.2	12.2	10.6	10.7	4.8	148.8	7.4

Slurry (acidified and untreated) will be applied to the field in the spring of 2019 for beetroots.

Reporting form: 2018, spring barley *(please, activate the link below)*
https://www.dropbox.com/s/nxgqqgx8zcmberh/Poland%20%28Mateusz%29%202018%20%28spring%20barley%29.xlsx?dl=0

2018, faba bean

The experiment was carried out in the farm of a commercial farmer, in Kruklanki, Warminsko-Mazurskie region (north-east Poland). The start date of the field trial was April 2018. A soil in the area of field trials is characterized as a heavy, clay soil. Pre-crop was common wheat, fertilized with pig slurry.

This field trial was an additional activity, initiated by an independent farmer who was interested in the project activities to date, and asked to conduct an experiment in his field. The main motivations of the farmer were the willingness to effectively use nitrogen retained in the soil and the reduction of odours occurring during the application of slurry.

Figures 28 and 29. *Location of the field trial (Kruklanki, Warminsko-Mazurskie region).*

Weather data

Temperature, precipitation and average daily wind speed from the day for spreading and five days thereafter of the field trial are shown in Figures 29, 30, 31.

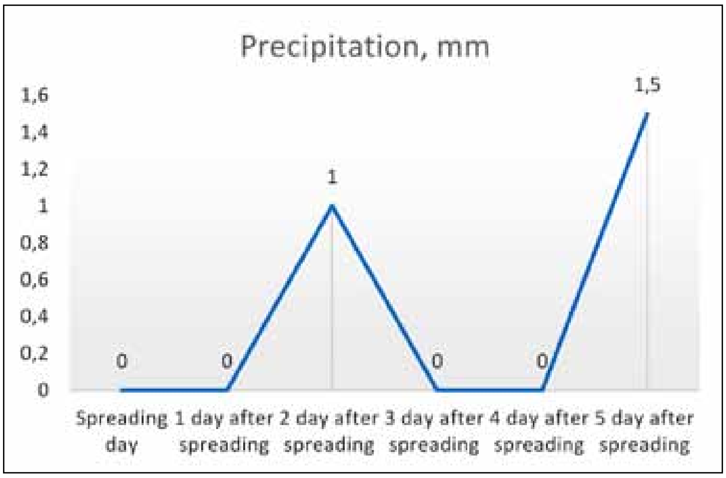

Figure 30. *Temperature, °C on field trial field (six consecutive days).*

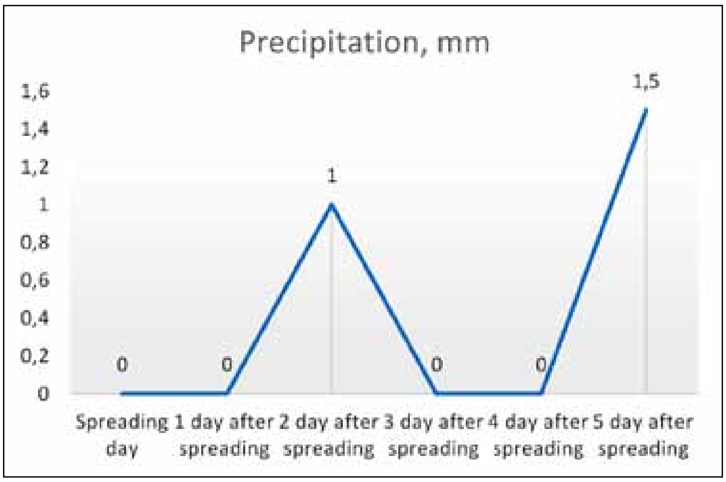

Figure 31. *Wind speed, m/s on field trial field (six consecutive days).*

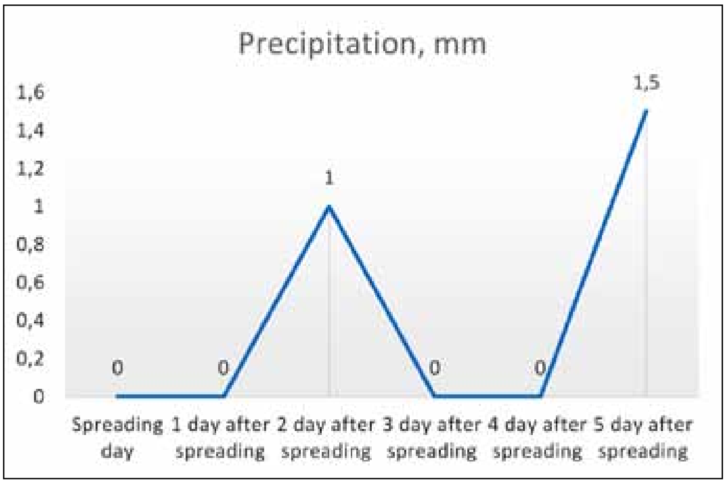

Figure 32. *Precipitation, mm on field trial field (six consecutive days).*

Soil samples

Soil samples were taken before slurry spreading on 12th April 2018 to determine content of chemical elements. Results of soil analysis are shown in Table 11.

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Table 11. *Content of chemical elements in soil samples before spreading*

Layer cm	pH_{KCl}	Nmin, kg/ha	SO_4, mg/100 g	P_2O_5, mg/100 g	K_2O, mg/100 g	MgO, mg/100 g	Cu, mg/kg	Mn, mg/kg	B, mg/kg	Soil org.C	Humus, %
0-30, 30-60 (mixed)	5.9	120.7	<0.5	18	19	3.4	2	78.5	0,8	1.45	2,5

Slurry acidification

Before spreading slurry into the field, slurry was treated with concentrated sulfuric acid (96% H_2SO_4) in a slurry container in order to reach the desired pH level (around 5-6 pH). The slurry output level was 7.4 pH.

Figures 33 and 34. *Acidification process in a slurry container.*

Samples of slurry, acidified and not acidified, were subjected to laboratory analysis. The results of the analysis are presented in the Table 12.

Table 12. *Slurry properties before spreading (Untreated slurry and Acidified slurry)*

	Dry matter content	Total N %	P %P_2O_5	K %K_2O	Ca %CaO	Mg %MgO	pH
Untreated slurry	10.9	0.74	0.70	0.34	0.5	0.38	7.4
Acidified slurry	11.1	0.66	0.44	0.37	0.38	0.26	6.4

Slurry spreading

The field experiment was carried out in two replicates, one of them with untreated slurry (reference sample), the other one with acidified slurry. The slurry was spread on 13th April 2018. The process began by mixing slurry in a slurry tank with an internal mixer. Once slurry was mixed, slurry samples were taken from the tank for analysis. Thereafter, the untreated slurry was spread on the field. A full slurry tank with a capacity of 18 000.00 liters was spread on the surface of 0.5 ha.

Then, the slurry tank was refilled with slurry. Slurry was treated with the sulfuric acid (as described above) up to the desired pH level. The tank with acid was placed on the platform, at the height of the inlet in the slurry tanker. With the help of a pump, the right amount of acid was introduced into the tank filled with slurry. Slurry was mixed several times along with continuous measurement of the pH level until the desired one was obtained.

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Then, slurry samples were taken from the tank for analysis. Then, the acidified slurry was spread in the field, also on the area of 0.5 m^3.

Figures 35 and 36. *Slurry spreading into the field.*

Crop development

Faba bean was sown in the field. Due to unfavorable weather conditions - strong drought causing 80% loss in yield, it was not possible to harvest.

Despite the lack of qualitative results of crop analysis, the farmer shows promising results of the acidification process, resulting in a significant reduction of the odor emitted during the application of slurry.

The farmer is willing to continue cooperation by providing yield, soil and slurry analysis results.

Reporting form: 2018, faba bean *(please, activate the link below)*
https://www.dropbox.com/s/gcoh5vst4hxsvmm/Poland%20%28Mateusz%29%202018%20%28Faba%20bean%29.xlsx?dl=0

Conclusions

1. Four liters of concentrated sulfuric acid per ton of slurry was added which resulted in excessive reduction of the pH-value from ~ 7.2-7.4 to ~ 5.5-6.5
2. The results of the experiment showed a significant increase in yields in crops treated with the acidification process.
3. The results of the experiment showed a higher concentration of nitrogen available to plants, resulting from the reduction of ammonia emissions during the application of slurry.
4. A significant reduction of odors emitted during the application of slurry was observed.
5. An important issue related to the handling of the acid is security. All safety measures recommended for the acidification process have worked well.
6. An important issue is also the precision in acid application to achieve the desired pH level.

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Material about Informational events

Event: AGROTECH fairs 2017.

Date: 17-19.03.2017.

Place: Kielce.

Number of participants: 200.

Event: II Forum on Knowledge and Innovation.

Date: 29-30.10.2017.

Place: Nadarzyn.

Number of participants: 180.

Event: Challenges fo agricultural advisory after 2020 conference/ EUFRAS meeting.

Date: 21-22.02.2018.

Place: Warsaw.

Number of participants: 160.

Event: AGROTECH fairs 2018.

Date: 16-17.03.2018.

Place: Kielce.

Number of participants: 200.

Event: Showcase event at “Challenges of water management in rural areas” conference.

Date: 17-19.09.2018.

Place: Polanica Zdroj.

Number of participants: 100.

Event: III Forum on Knowledge and Innovation.

Date: 14-15.11.2018.

Place: Warsaw.

Number of participants: 200.

Event: National Agricultural Exhibition.

Date: 30-12-2018.

Place: Poznan.

Number of participants: 2000.

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LATVIA

LATVIJAS LAUKU KONSULTĀCIJU UN IZGLĪTĪBAS CENTRS

General information:

Project partner	Contact person	Type of activity in Field Trial	2018				Ammonia emission
Latvian Rural Advisory and Training Centre	Laura Kirsanova laura.kirsanova@llkc.lv	Demonstration	Winter wheat with spring barley	Rye	Maize	Winter oil seed rape	Ammonia losses were measured
			Pig slurry			Digestate	

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

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Report of Latvian Rural Advisory and Training Center

Written by: Laura Kirsanova

Aim

To try acidification of slurry using in-field acidification tehnology, in Latvian conditions and to compare the effectiveness of using acidified and non-acidified manure for fertilization of different crops.

Materials and methods

Field trial location

The demonstration trials were done in summer 2018 in Zemgale region (Auces districtiion, Īles parish) LTD “Lauku Agro”. The region of Zemgale is situated in the central part of Latvia. The southern border of the region is also the state border with Lithuania. Approximately 24% of Latvia’s agricultural land is in Zemgale. Agriculture dominates land use, followed by forests. The rest of the region’s territory is covered in approximately equal parts by bogs, water, roads and brushwood.

Demonstration was arranged in four crops:

1. Winter wheat and spring barley mixture;
2. Rye;
3. Maize;
4. Winter rape.

Figure 1. *Location of demonstration trials.*

In all crops used IN-FIELD slurry acidification system, band spreaders: Trailing hose application technology. Acidification using 98% sulfuric acid was applied.

For corn, winter wheat and spring barley mixture and rye fertilization used pig slurry, but for winter rape fertilization pig slurry digestate was used.


Figure 2. *The technique used for dispersing and acidifying slurry.*

Meteorological conditions

In the field trial area in Ile, like in the whole of Latvia, the vegetation period was drier and hotter than usual (Figure 3). Insufficient rainfall significantly influenced the crop’s ability to absorb dispersed fertilizer. In May, just as in April, it turned out to be surprisingly warm, reaching an average temperature of 16.2 °C, which was 4.7 °C above the long-term generated. The precipitation of this month was only 36% of the norm. In contrast to last July’s cold July, this July was one of the warmest months of the decade, reaching an average temperature of 20.5 °C, but did not provide the required precipitation - 69% of the norm.

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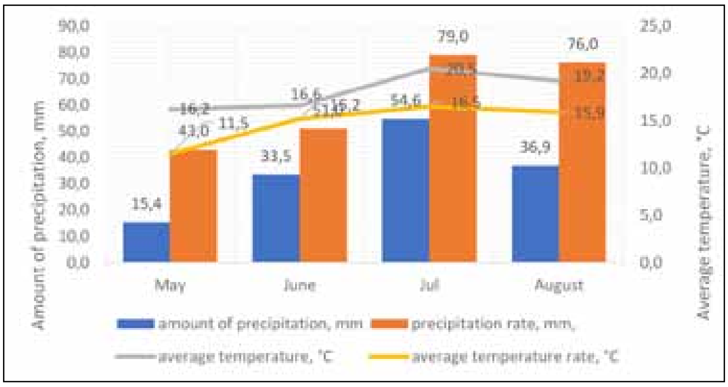

Figure 3. *Meteorological conditions.*

Measurements of ammonia emissions

Emissions measured in cooperation with the scientists from Latvia University of Life Sciences and Technologies. Ammonia emissions were measured in maize, winter rape and winter wheat and spring barley mixture using Picarro G2508.

Picarro has developed high-resolution scientific equipment for measuring gas concentrations. The Picarro G2508 can simultaneously detect five gases in the form of steam in the form of N_2O, CH_4, CO_2, NH_3 and H_2O. Water vapor measurement provides for the determination of the dry molecular concentrations of N_2O, CO_2 and CH_4 gases (Fleck et al., 2013).

The technology is based on the fact that any small molecule gas has a unique infrared light absorption spectrum at a pressure lower than the atmosphere. Under these conditions, the light absorption spectrum consists of a series of closely spaced, well-identifiable, sharp lines that are each with its own characteristic wavelength, which is a prerequisite for the development of this methodology, because after absorption strength, this is when measuring a certain absorption peak, the concentration of any gas can be determined . The disadvantage of traditional infrared spectrometers is that it is impossible to determine the concentration of gases due to the low absorption of gases and the measuring instrument is able to detect concentrations only in ppm. The CRDS (Cavity Ring-Down Spectroscopy) technology developed by Picarro reduces the minimum detectable concentration to ppb using an efficient laser beam that can reach up to many kilometers in instrument measurement chamber with a measurement frequency of several times (Picarro, 2018). The beam from a single frequency laser diode is driven by 3 measuring mirrors through the instrument's measuring chamber, thus ensuring continuous circular laser movement. The photodetector captures the amount of light emitted through one of the mirrors, which is proportional to the intensity of the measurement chamber. At a moment when the photodetector signal reaches the threshold level (within a few tens microseconds), the continuous laser beam is suddenly turned off. The light rays already in the instrument measuring chamber continue to reflect on the mirrors (around 100,000 times), but because the reflectivity is less than 100% (99.99%), the light intensity in the measurement chamber is gradually decreasing and exponentially decreasing to 0. This leap down the photometer in time unit (Picarro, without a year).

The situation described above was described in an empty measurement enclosure in the instrument, but when the gas mixture, the concentration of which is to be introduced, is introduced into the instrument, the gas in the instrument measuring chamber accelerates the time the laser beam passes after the laser diode has stopped working. According to the laser erosion time, Piccaro has developed a calculation algorithm for determining the concentration of specific gases (Picarro, 2018).

Ammonia measurements with this multispectometer coupled with water vapour measurement are more difficult to interpret than CO_2, NH_4 and N_2O. NH_3 can be deposited in both tubes and other compounds (Fleck et al., 2013).

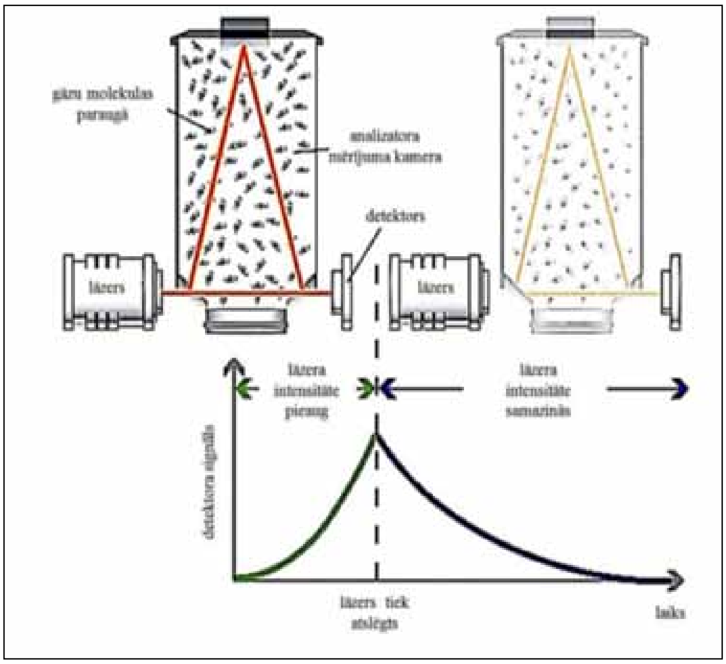

Figure 4. *Principle of the Picarro spectrometer (Picarro, 2018).*

Calculation of ammonia emission

In order to convert the Picarro G2508 concentration measurements into ammonia emissions per hectare, a multi-level algorithm was used for calculating (see Figure 5).

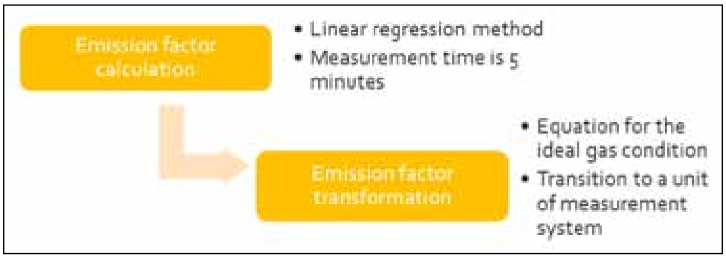

Figure 5. *Schematic representation of the algorithm for measuring the transformation of ammonia concentrations.*

Ammonia emissions are characterized by the rate and direction of concentration change in an isolated chamber. The calculation of the emission factor is based on linear regression (see Formula 1) using the least squares method, where the amount of emissions is characterized by the regression coefficient (see Formula 2), while the free member (see Formula 3) describes the initial concentration of the measurements. The accuracy is characterized by the determination coefficient R2 (see Formula 4). For the calculation of linear regression, the first five minutes of measurements were used.

$$y=mx+b, \text{ where} \quad (1)$$

y - the concentration in ppm / s;
x - time in seconds;
m - the regression coefficient;
b - free member

$$m = \frac{n\sum(xy) - \sum x \sum y}{n\sum(x^2) - (\sum x)^2}, \text{ where} \quad (2)$$

m - the regression coefficient;
y - the concentration in ppm / s;
x - time in seconds;
n - the number of measurements.

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$$b = \frac{\sum y - m \sum x}{n}, \text{ where} \quad (3)$$

b - free member;
y - concentration;
x - time in seconds;
m - the regression coefficient;
n - the number of measurements.

$$R^2 = \left(\frac{n\sum(xy) - \sum x \sum y}{\sqrt{[n\sum(x^2) - (\sum x)^2]\,[n\sum(y^2) - (\sum y)^2]}}\right)^2, \text{ where} \quad (4)$$

R^2 - the determination coefficient;
y – concentration;
x - the time in seconds;
n - the number of measurements.

An ideal gas equation was used to convert the emission factor to the concentration per day per hectare (see Formula 5).

$$F = p \cdot \frac{V}{A} \cdot \frac{\Delta c}{\Delta T} \cdot \frac{273}{T+273}, \text{ where} \quad (5)$$

F - volume of emissions from soil (g/ha/dnn);
p - gas density in mg/m^3;
V - volume of the chamber m^3;
A - camera area m^2;
Δc / ΔT- at the mean change in concentration in ppm/s;
T - camera temperature OC.

It is very important to keep a unit of measurement system in the process of transformation. Picarro G2508 produces gaseous molar concentrations, so a transition from molar concentration to mass concentration is required.

Results

2018, winter wheat and spring barley mixture

Field trial scheme:

1. Mineral fertilizers + Untreated pig slurry.
2. Mineral fertilizers +Acidified pig slurry (H_2SO_4 0,5 l/m^3).
3. Mineral fertilizers +Acidified pig slurry (H_2SO_4 1,0 l/m^3).
4. Mineral fertilizers +Acidified pig slurry (H_2SO_4 1,5 l/m^3).
5. Mineral fertilizers +Acidified pig slurry (H_2SO_4 2,0 l/m^3).
6. Mineral fertilizers +Acidified pig slurry (H_2SO_4 2,5 l/m^3).
7. Mineral fertilizers +Acidified pig slurry (H_2SO_4 3,0 l/m^3).

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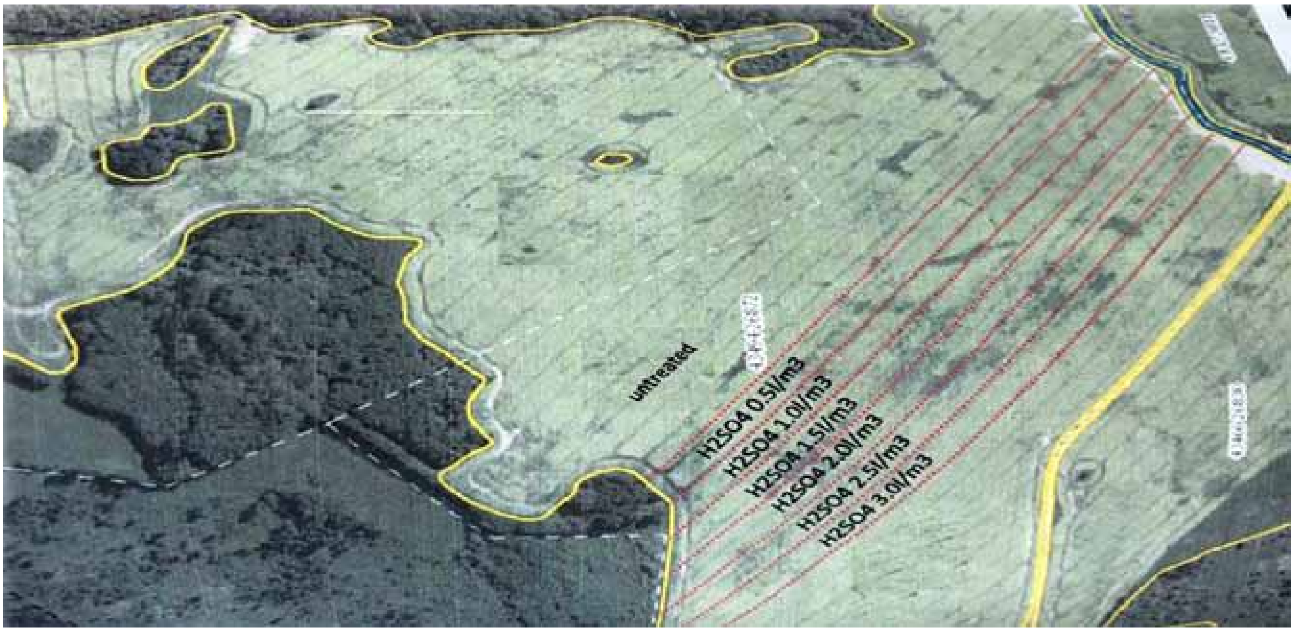

Figure 6. *Winter wheat and spring barley mixture field trial scheme.*

Measurements in treatments:

1. Ammonia emissions (in all treatments).
2. Nitrogen content on winter wheat and spring barley leaves using YAR N tester (in all treatments).
3. Winter wheat leaves analysis, carried out in the laboratory (treatments – 1; 4; 7)
4. Slurry analysis (treatments – 1; 2; 4; 7).
5. Soil analysis in spring and autumn (treatments – 1; 2; 4; 7).

Winter wheat sown on 09/28/2017, variety - ‘Schegen’. In the spring it was found that winter wheat was badly wintered, insufficient plant density, a decision was made to make spring barley sowing, on April 30, 2018.

Table 1. *Fertilization plan*

Treatment Nr.	Name of the treatment	Fertilazers	Dose, kg/ha	Date (dd/mm/yy)	Crop Growing Stage (BBCH)
1	Mineral fertilizers + Untreated pig slurry	NS 30-7	290	16.04.2018	30
		pig slurry	30000	17.05.2018.	37
2	Mineral fertilizers +Acidified pig slurry (H_2SO_4 0,5 l/m^3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37
3	Mineral fertilizers +Acidified pig slurry (H_2SO_4 1,0 l/m^3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37
4	Mineral fertilizers +Acidified pig slurry (H_2SO_4 1,5 l/m^3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37
5	Mineral fertilizers +Acidified pig slurry (H_2SO_4 2,0 l/m_3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37
6	Mineral fertilizers +Acidified pig slurry (H_2SO_4 2,5 l/m^3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37
7	Mineral fertilizers +Acidified pig slurry (H_2SO_4 3,0 l/m^3)	NP 33-3	270	16.04.2018.	30
		Pig slurry	30000	17.05.2018.	37

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Table 2. *Data from slurry*

Measure	Untreated slurry	Acidified slurry, H_2SO_4 0,5 l/m³	Acidified slurry, H_2SO_4 1,5 l/m³	Acidified slurry, H_2SO_4 3,0 l/m³
Dry matter content, %	4,7	3,8	4,8	4,3
pH, 20 °C	7,9	7,6	6,4	6,0
Total N kg/t	4,8	4,9	4,6	4,6
NH_4-N kg/t	3,5	3,5	3,6	3,7
P_2O_5 kg/t	3,2	3,0	3,1	3
K_2O kg/t	3	3,1	3	3,4
S kg/t	0 *	0,2	0,9	2

* too low level to determine

Results of ammonia emissions

Ammonia emission measurements for various doses of sulfuric acid in wintew wheat and spring barley mixture were performed on May 17, 2018 and May 18, 2018.

Immediately after the dispersal of the slurry, the highest emissions are the 3174 g h^{-1} ha^{-1} sulfuric acid additive and the lowest ammonia emissions of 394 g h^{-1} ha^{-1} slurries with 3 liters per tonne of sulfuric acid (see Figure 7)

Figure 7. *Ammonia emissions after the dispersal of slurry g h^{-1} ha^{-1} at different doses of sulfuric acid per tonne of slurry.*

Ammonia emissions one day after the dispersal of slurry are depicted in Figure 8. It is evident that after 24 hours the emission of ammonia in the acid-free sample plot has decreased three times. The emission of ammonia in the plot with 3 liters of sulfuric acid per hectare is, however, three-quarters, which is explained by the ability of wheat to absorb a portion of ammonia emissions.

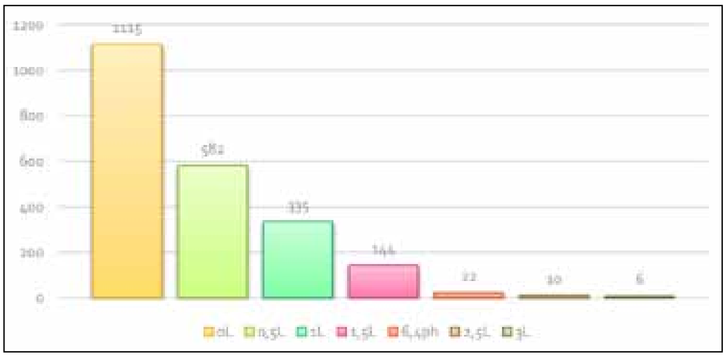

Figure 8. *Ammonia emissions twenty-four hours after the slurry dispersal g h^{-1} ha^{-1} at different doses of sulfuric acid per tonne of slurry.*

The cumulative ammonia emissions from the plots with different amounts of acid per tonne of slurry are presented in Figure 9. The cumulative emission of free sulfuric liquids over a period of 24 hours is 12500 g ha^{-1}, while the cumulative emission is 24 hours from the plot with slurries with 3 liters per tonne of sulfuric acid 1750 g ha^{-1}.

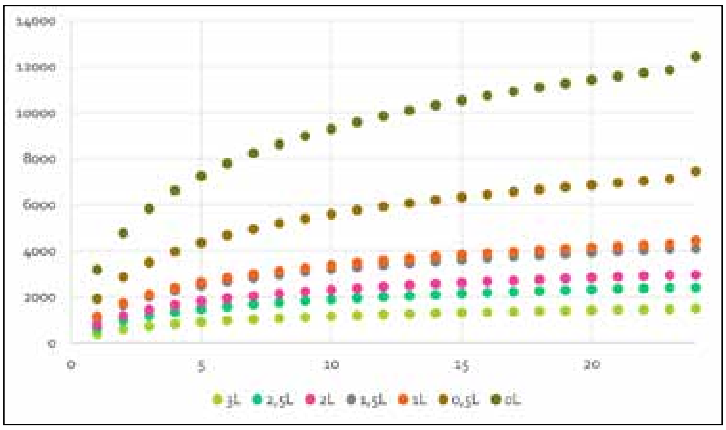

Figure 9. *Ammonia cumulative emissions within twenty-four hours after the delivery of slurry g h^{-1} ha^{-1} at various doses of sulfuric acid per tonne of slurry.*

Nitrogen content on winter wheat and spring barley leaves using YAR N tester

Determination of nitrogen content on wheat leaves using the Yara N tester was performed before the dispersal of slurry (17.05.2018.), 7 days after the dispersal of slurry (24.05.2018) and 14 days after the dispersal of slurry (01.06.2018). All variants showed similar results - lack of nitrogen fertilizer, nitrogen deficiency was detected before the spreading of slurry and in both measurements after the dispersal of slurries. The reason for this is shown in Figure 10 - at such a small rainfall, plants were unable to absorb nitrogen dispersed with slurry.

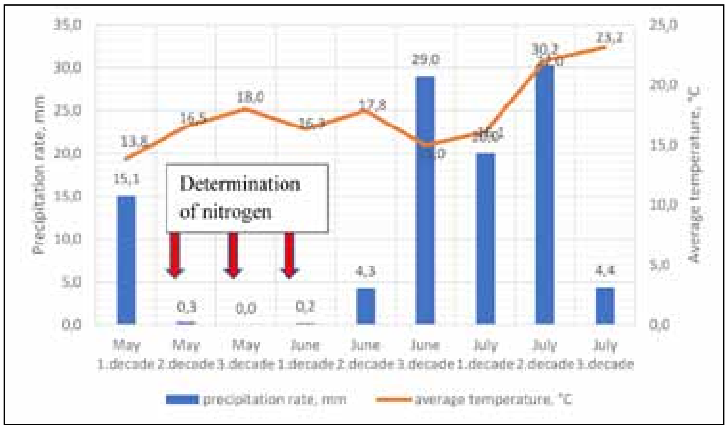

Figure 10. *Meteorological conditions during and after slurry dispersal.*

Figure 11. *Wheat/barley 17.05.2018.* *25.05.2018.* *01.06.2018.*

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Analysis of leaves of winter wheat

Winter wheat leaves were analyzed seven days after the spread of slurry, 25.05.2018. Samples were taken from three treatments - Untreated pig slurry, Acidified pig slurry, H_2SO_4 1,5 l/m^3 and Acidified pig slurry, H_2SO_4 3,0 l/m^3. Leaf analysis was carried out in the laboratory of plant analysis at the University of Latvia. The results are summarized in the table.

Table 3. *Analysis of leaves of winter wheat*

	Untreated pig slurry	**Acidified pig slurry, H_2SO_4 1,5 l/m^3**	**Acidified pig slurry, H_2SO_4 3,0 l/m^3**
N, %	2,95	2,9	2,95
P,%	0,3	0,3	0,38
K,%	2,68	2,16	2,18
Ca,%	0,21	0,16	0,18
Mg,%	0,11	0,08	0,09
S,%	0,19	0,19	0,19
Fe, mg/kg	66	46	72
Mn, mg/kg	16	16,8	14,4
Zn, mg/kg	13,8	10,4	11
Cu, mg/kg	6,4	4,6	4,4
Mo, mg/kg	0,7	0,8	1,3
B, mg/kg	2,5	3	3

element deficiency

Slurry analysis

Samples were taken during the dispersal of slurry. Analysis was made in laboratory for treatments - Untreated slurry, Acidified slurry, H_2SO_4 0,5 l/m^3 , Acidified slurry, H_2SO_4 1,5 l/m^3, Acidified slurry, H_2SO_4 3,0 l/m^3. For other treatments only pH level is specified.

Table 4. *Slurry analyzes*

Measure	**Untreated slurry**	**Acidified slurry, H_2SO_4 0,5 l/m^3**	**Acidified slurry, H_2SO_4 1,5 l/m^3**	**Acidified slurry, H_2SO_4 3,0 l/m^3**
Dry matter content, %	4,7	3,8	4,8	4,3
pH, 20 0C	7,9	7,6	6,4	6,0
Total N kg/t	4,8	4,9	4,6	4,6
NH_4-N kg/t	3,5	3,5	3,6	3,7
P_2O_5 kg/t	3,2	3,0	3,1	3
K_2O kg/t	3	3,1	3	3,4
S kg/t	0 *	0,2	0,9	2

* too low level to determine

For other treatments only pH level is specified.

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Table 5. *Slurry pH level at different doses of acid*

	untreated	H_2SO_4 0,5 l/m³	H_2SO_4 1,0 l/m³	H_2SO_4 1,5 l/m³	H_2SO_4 2,0 l/m³	H_2SO_4 2,5 l/m³	H_2SO_4 3,0 l/m³
pH	7.9	7.6	6.5	6.4	6.3	6.2	6.0

Soil analysis in spring and autumn

Performing soil analysis before to the installation of the demonstration and after harvest no significant changes were found in any of the soil analysis indices.

Table 6. *Soil analysis in spring and autumn*

	Untreated pig slurry		Acidified pig slurry (H_2SO_4 0,5 l/m³)		Acidified pig slurry (H_2SO_4 1,5 l/m³)		Acidified pig slurry (H_2SO_4 3,0 l/m³)	
	before applying slurry	after harvest	before applying slurry	after harvest	before applying slurry	after harvest	before applying slurry	after harvest
Soil samples depth, cm	0 - 20	0 - 20	0 - 20	0 - 20	0- 20	0- 20	0- 20	0- 20
pH	6	6	6,1	6,1	6,2	6,3	6,4	6,4
P_2O_5 mg/kg	118	126	103	111	307	306	151	160
K_2O mg/kg	116	116	127	125	180	175	184	183
S -SO_4 mg/kg	< 0,7	< 0,7	< 0,7	< 0,7	< 0,7	< 0,7	< 0,7	< 0,7

Harvest

Winter wheat and spring barley mixture was harvested on 08.08.2018, the harvest was low, on average 3.4 tons ha^{-1} and did not significantly differ between variants.

Table 7.

	Untreated	H_2SO_4 0,5 l/m³	H_2SO_4 1,0 l/m³	H_2SO_4 1,5 l/m³	H_2SO_4 2,0 l/m³	H_2SO_4 2,5 l/m³	H_2SO_4 3,0 l/m³
Yield	3.3	3.3	3.3	3.4	3.5	3.8	3.4

Figure12. *Winter wheat and spring barley mixture harvest, 08.08.2018.*

Reporting form: 2018, winter wheat and spring barley mixture *(please, activate the link below)*
https://www.dropbox.com/s/g8uimvmpyn7ew9w/Latvia%20FT_%20RF_DEMONSTRATION_wheat_barley_2018.xlsx?dl=0

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2018, rye

Field trial scheme:

1. Only mineral fertilizers.
2. Mineral fertilizers + Untreated pig slurry.
3. Mineral fertilizers + Acidified pig slurry (H_2SO_4 1,5 l/m^3).

Measurements in treatments:

1. Nitrogen content on winter wheat and spring barley leaves using YAR N tester.
2. Slurry analysis.
3. Yield.

Rye sowing was made on August 31, 2017, the variety 'Binntto'.

Table 8. *Fertilization plan*

Treatment	Fertilizers	Dose, kg/ha	Date/hour *(dd/mm/yy)*	Crop Growing Stage (BBCH)
Only Mineral fertilizers	NP 12-52	80	01.09.2017	with sowing
	NS 30-7	280	29.03.2018	29/30
	NP 33-3	200	03.05.2018	33
Mineral fertilizers + Untreated pig slurry	NP 12-52	80	31.08.2017	with sowing
	NS 30-7	290	15.04.2018	29/30
	Pig slurry	3000	08.05.2018	43
Mineral fertilizers + Acidified pig slurry	NP 12-52	80	31.08.2017	with sowing
	NP 30-33	270	16.04.2018	29/30
	Acidified pig slurry	3000	09.05.2018	43

Pig slurry was also used for rye fertilization. Acidification was done by adding 98% sulfuric acid 1.5 l/m^3. During the dispersal of slurry, samples were taken and analyzed.

Table 9. *Results of slurry analysis*

Measure	Untreated slurry	Acidified slurry
Dry matter content, %	4,7	4,8
pH, 20 ^oC	7,9	6,4
Total N kg/t	4,8	4,6
NH_4-N kg/t	3,5	3,6
P_2O_5 kg/t	3,2	3,1
K_2O kg/t	3	3
S kg/t	0 *	0,9

* too low level to determine

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Harvest

Rye harvesting was done on 07/26/2018. In the course of vegetation, the development of rye in all variants was similar and no significant differences were observed between the treatments, while during the harvesting, the highest yield was obtained from the variant where only fertilizers were used - 7.5 t ha^{-1} were used for fertilization acidified and utreated slurry - 7.0 t ha^{-1}.

Figure 13. *Rye, 24.05.2018.*

Figure 14. *Rye, 23.07.2018.*

Reporting form: 2018, rye *(please, activate the link below)*
https://www.dropbox.com/s/49pcfug43jatqea/Latvia%20FT_%20RF_DEMONSTRATION_rye_2018.xlsx?dl=0

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2018, maize

Field trial scheme:

1. Untreated pig slurry.
2. Acidified pig slurry.

Measurements in treatments:

1. Ammonia emissions.
2. Slurry analysis.
3. Maize leaves analysis, carried out in the laboratory (before and after slurry spreading).
4. Yield.

Maize was sown on 05.09.2018, the variety 'Amagrano'. Mineral fertilizers and slurries were used for fertilization.

Table 10. *Fertilization plan*

Treatment	Fertilazer	Dose, kg/ha	Date/hour *(dd/mm/yy)*	Crop Growing Stage (BBCH)
Untreated pig slurry	NP 12-52	80	09.05.2018	sowing
	NP 33-3	140	11.05.2018	12
	PIG SLURRY	30000	16.06.2018	32
Mineral fertilizers +Acidified pig slurry (H_2SO_4 3,0 l/m^3)	NP 12-52	80	09.05.2018	sowing
	NP 33-3	140	11.05.2018	12
	PIG SLURRY	30000	16.06.2018	32

In the maize, slurry was dispersed on June 15, when corn had reached 32 growing stage, slurry was used from another lagoon, its pH was 8.1 before acid addition, and in order to reach pH 6.5 it was necessary to add sulfuric acid 3.0 l m^{-3}.

Table 11. *Results of slurry analyzes*

Measure	Untreated slurry	Acidified slurry, H2SO4 3,0 l/m^3
Dry matter content, %	3.0	3,5
pH, 20 0C	8,1	6,5
Total N kg/t	4,0	4,2
NH_4-N kg/t	3,2	3,4
P_2O5 kg/t	2,4	3,2
K_2O kg/t	2,9	2,9
S kg/t	0 *	1,6

* too low level to determine

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Analysis of maize leaves

The analysis of maize leaves was carried out before the spreading of slurry and seven days after it. Leaves analysis was carried out in the laboratory of plant analysis at the University of Latvia. The results are summarized in the table.

Table 12. *Analysis of maize leaves*

Measure	Before slurry spreading (15.06.2018)	After slurry spreading(21.06.2018)	
		Untreated pig slurry	Acidified pig slurry
N, %	2,62	2,67	2,89
P,%	0,21	0,29	0,35
K,%	2,38	1,72	1,98
Ca,%	0,22	0,25	0,25
Mg,%	0,17	0,19	0,2
S,%	0,11	0,11	0,13
Fe, mg/kg	126	320	212
Mn, mg/kg	38	44	38
Zn, mg/kg	15,4	20	16,8
Cu, mg/kg	4	5,6	4,6
Mo, mg/kg	0,75	0,8	0,75
B, mg/kg	5	5	4,5

(highlighted) element deficiency

It can be seen that in the treatment where dispersed acidified slurry was used plants have been able to better absorb the main nutrient elements - nitrogen, phosphorus, potassium and sulfur.

Ammonia emissions

Measurements of ammonia emissions in maize produced similar results, such as winter wheat - acidifying significantly reduced emissions. Ammonium emissions were also measured between the rows of maize, without vegetation.

After the dispersal of slurry, the highest emissions were slurries without vegetation and the lowest emissions of ammonia were acidified in slurries with vegetation (see Figure 15).

Figure 15. *Ammonia emissions after the spreading of slurry g h^{-1} ha^{-1}.*

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Twenty-four hours after the slurry dispersal, ammonia emissions have decreased by twenty times the non-vegetation slurry (see Figure 16).

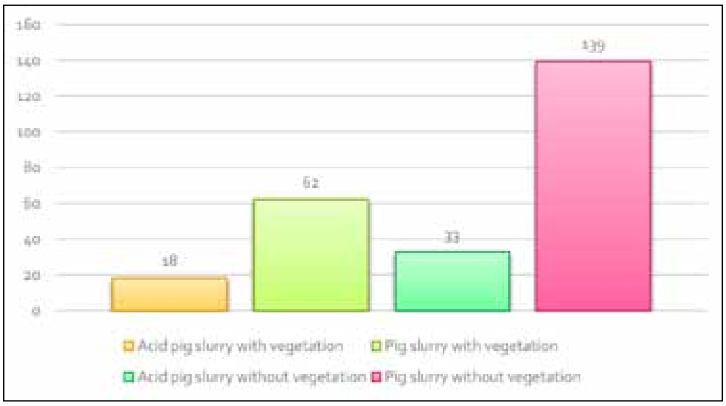

Figure 16. *Ammonia emissions twenty-four hours after the slurry dispersal g h^{-1} ha^{-1}.*

Emissions of cumulative ammonia over the course of twenty-four hours with different technologies are shown in Figure 17 where slurry generates 10,000 g ha^{-1} of ammonia overnight, while acidified slag causes about 1000 g ha^{-1} of ammonia emissions.

Figure 17. *Ammonia cumulative emissions within twenty-four hours after the spreading of slurries g h^{-1} ha^{-1}.*

Harvest

Since the weather has prompted rapid aging of maize this year, it was decided not to use maize for silage preparation, as originally intended, but for grain harvesting. Corn harvest was carried out on 26 September. The higher yield was obtained in the treatment whith acidic slurries - 9.9 t ha^{-1}, in the treatment with untreated pig slurry the yield was 0.3 t ha^{-1} lower - 9.6 t ha^{-1}.

Figure 18. *Maize 15.06.2018.* *21.06.2018*

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Figure 19. *Maize 23.07.2018.*

Figure 20. *Measurements of ammonia emissions.*

Figure 21. *Dispersal of slurry.*

Reporting form: *2018, maize (please, activate the link below)*
https://www.dropbox.com/s/heu650fc9wg7wwn/Latvia%20FT_%20RF_DEMONSTRATION_maize_2018.xlsx?dl=0

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2018, winter oil seed rape

Measurements in treatments:

1. Ammonia emission measurements using acidified and untitred digestate.

Winter oil seed rape sown in 17.08.2017, variety DK Exalte. Digestate was used for fertilization, the main ingredient - pig slurry. Digestate dispersion made on 30.04.2018 (GS 33). Measurements of ammonia emissions were made immediately after dispersal, two hours, four hours and 24 hours after it. 98% sulfuric acid was used for acidification, 1.5 l m^{-3}. Dose of digistate was 30 t ha^{-1}.

Table 13. *Digestate analysis*

Measure	Untreated slurry	Acidified slurry, H_2SO_4 1,5 l/m^3
Dry matter content, %	5,2	5,3
pH, 20 ^oC	8,1	6,5
Total N kg/t	4,7	5
NH_4-N kg/t	3,2	3,5
P_2O_5 kg/t	3,5	3,5
K_2O kg/t	3	3
S kg/t	1	1,5

Ammonia emission

Immediately after dispersal of digestate. The highest emission of 4500 g h^{-1} ha^{-1} was found in a plots without vegetation. Increased ammonia emissions can be explained by high pH 8.1 in the digestate. The lowest ammonia emission of 710 g h^{-1} ha^{-1} was found on the plot where the acidified digestate was spread and was the winter rape plantations due to the lowered pH 6.5 and the ability to absorb ammonia in winter rape. Without vegetation, digestate showed about twice as high ammonia emissions as digestate with a vegetation. The acidified vegetation digestate shows a threefold reduction in ammonia emissions from acidified vegetation digestate.

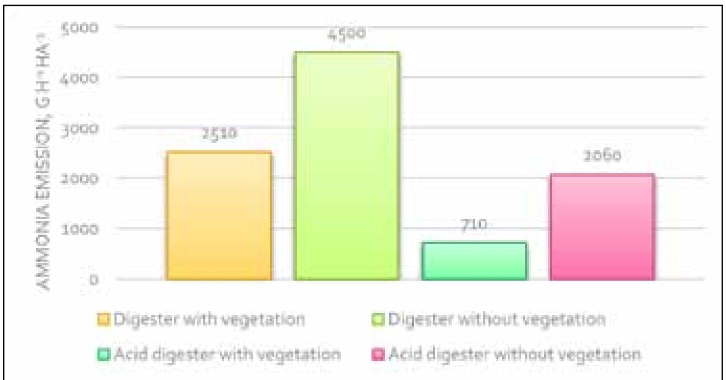

Figure 22. *The ammonia emissions after pig slurry digestate application g h^{-1} ha^{-1}.*

Ammonia emissions from various technologies of the application two hours after the dispersal of the digestate are shown in Figure 23. The highest emission of 3160 g h^{-1} ha^{-1} was found in plots without vegetation. The lowest ammonia emission of 718 g h^{-1} ha^{-1} was found in the plots where the acid digestate was spread and where winter plantings of rape were. Besides vegetation, the digestate showed about one and a half times higher ammonia emissions than a digestate with a vegetation. The acidified vegetation digestate shows a double reduction in ammonia emissions from acidified digestate without vegetation. Compared to the volume of emissions immediately after the digestate has been incorporated, the acidified digestate shows the same amount of emissions, while the digestate shows emission reductions.

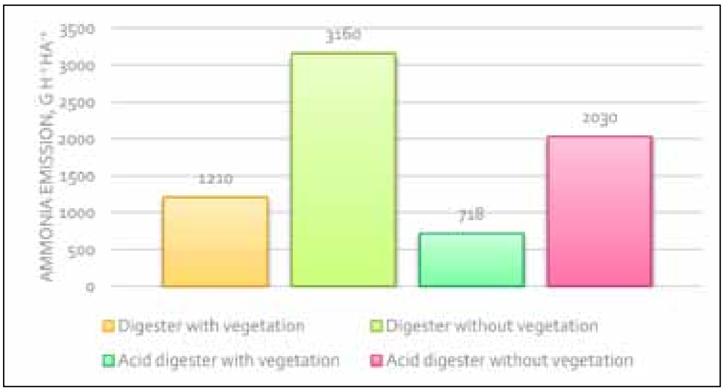

Figure 23. *The ammonia emissions after two hours of pig slurry digestate application g h^{-1} ha^{-1}.*

Four hours after the digestate has been dispersed, ammonia emissions have decreased in all technologies, see Figure 24, however, there remain significant differences between the application technologies.

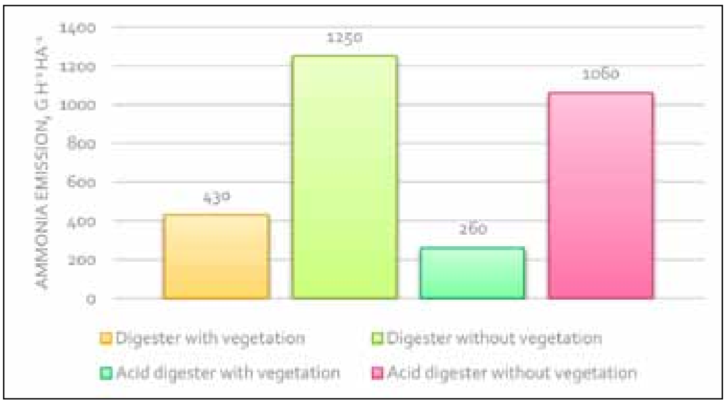

Figure 24. *The ammonia emissions after four hours of pig slurry digestate application g h^{-1} ha^{-1}.*

Within 24 hours (see Figure 25), ammonia emissions were reduced by 30, but this can be explained by a strong rain during night-time between measurements.

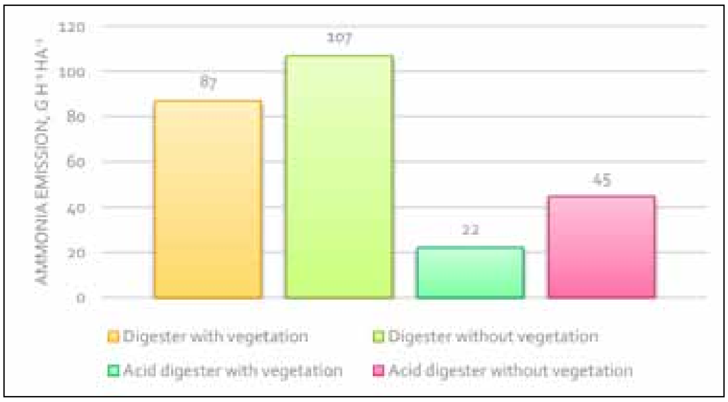

Figure 25. *The ammonia emissions after 24 hours of pig slurry digestate application g h^{-1} ha^{-1}.*

Cumulative ammonia emissions per hour are given in Figure 26, where it can be seen that ammonia emissions to a digestate without vegetation over a period of 24 hours equal up to 13 kg ha^{-1} of acidified digestate without vegetation reaching 8.5 kg ha^{-1} while an acidified digestate with vegetation in 24 hours reaches 2.5 kg ha^{-1} of ammonia emissions, which is five times lower than that of non-vegetation.

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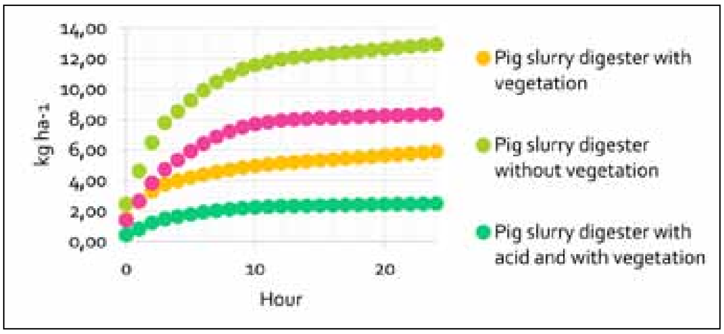

Figure 26. *Cumulative ammonia emissions per hour.*

Figure 27. *Measurement of ammonia emissions in winter rape.*


Figure 28. *Digestate dispersion in winter rape.*

Conclusions

1. With regard to weather conditions, this year was not suitable for fertilizer efficiency studies, due to low rainfall and high temperatures plants could not use fertilizer and only a one-year demonstration results is not enough to evaluate the suitability of a new technology.
2. Acidification of the slurry did not result in lowering the soil pH level, not in the winter wheat treatments, where different doses of sulfuric acid were used and not in rye, where for acidification used sulfuric acid 1.5 l m^{-3}. Other changes in soil characteristics are also not observed.
3. Analysis of maize leaves shoved that in the treatment where dispersed acidified slurry was used plants have been able to better absorb the main nutrient elements - nitrogen, phosphorus, potassium and sulphur.
4. The use of acidified slurry did not increase harvest of winter wheat and rye, but about 0.3 t ha^{-1} increased the yield of corn grain.
5. Acidification of slurry significantly reduces the amount of ammonia emissions. Winter wheat, depending on the dose of sulfuric acid used, the amount of cumulative emissions decreased by 40-88% within 24 hours. In maize, using acidified manure, cumulative emission after 24 hours was by 82% lower than in the treatment where acid-free slurry was added.
6. Cumulative ammonia emissions - digestate without vegetation over a period of 24 hours equal up to 13 kg ha^{-1} of acidified digestate without vegetation reaching 8.5 kg ha^{-1} while an acidified digestate with vegetation in 24 hours reaches 2.5 kg ha^{-1} of ammonia emissions, which is five times lower than that of non-vegetation. The largest amount of emissions is observed within the first four hours after digestion dispersal.

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Material about Informational event

Event: Field day.

Description: Demonstration event was organised by LRATC in close co-operation with Farmers Parliament and Lauku Agro. It was successfully held on 20th of June 2018 in Īle, Auce municipality on fields of Lauku Agro.

Date: 20/06/2018.

Place: Īle, Auce Municipality, Latvia.

Number of participants: 14.

LITHUANIA

General information:

Project partner	Contact person	Type of activity in Field Trail	2018					Ammonia emission
Lithuanian University of Health Sciences (Institute of Animal Sciences)	Artūras Šiukščius Arturas.Siukscius@lsmuni.lt	Demonstration	Barley	Corn	Grass-land	Oats	Spring wheat	Ammonia losses were not measured
In cooperation with Lithuanian Agricultural Advisory Service	Rimas Magyla Rimas.Magyla@lzukt.lt		Pig slurry		Cattle slurry			

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

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Report of Lithuanian University of Health Sciences

Written by: Dr. Artūras Šiukščius, Giedrius Šarauskas, Rasa Šiukščiuvienė, Monika Gerulienė

Summary

The field trials in Lithuania were organised by PP18, Animal Science Institute of Lithuanian University of Health Sciences, in cooperation with PP06, Lithuanian Agricultural Advisory Service. LUHS used in-field slurry acidification technology, when slurry is acidified during the spreading. They used slurry spreader tanker with a capacity of 20 m^3 with 12 m trailing hoses. There were five field trial plots, and crops grown on each plot were: barley (which was spread with cattle slurry), corn (which was spread with cattle slurry), grassland (which was spread with pig slurry), oats (which were spread with pig slurry) and spring wheat (which was spread with cattle slurry). The field trials were carried out in 2018.

Slurry Analyses

For slurry titration it was taken 1000 ml examples and titrated with 98 % concentrated sulphur acid. After doing slurry titration it was set that it is needed approximately 2,36 ml concentrated sulphur acid to reach lower than 5,5 pH. Also, while titrating it was noticed that till 6,4 pH and till 6,0 pH it was needed approximately 0,8 ml concentrated acid and that shows a steady decline of pH. After that reducing lower as 5,5 pH, needed less concentrated sulphur acid and it was used 0,78ml. After recalculating the results of titration it was noticed that for 1 cubic metre of separated slurry acidification increase lower 5,5 pH it is needed 2,36 litres of concentrated sulphur acid 98%.

Table 1. *Analysis of pig slurry*

Quality of the material to be treated:	Values	
Content of ammonium (NH_4+-N)	2,18	kg/ton
Content of total N (N_{tot})	3,29	kg/ton
Content of dry matter (DM)	5,98	%
Content of P (optional)	0,21	kg/ton
Content of K (optional)	1,61	kg/ton
Content of S (optional)	0,18	kg/ton
pH	6,83	

Table 2. *Analysis of cattle slurry*

Quality of the material to be treated:	Values	
Content of ammonium (NH4+-N)	2,39	kg/ton
Content of total N (Ntot)	3,79	kg/ton
Content of dry matter (DM)	6,31	%
Content of P (optional)	0,39	kg/ton
Content of K (optional)	2,61	kg/ton
Content of S (optional)	0,11	kg/ton
pH	7,57	

Soil Analyses

The samples of soil were analyzed in the laboratory of: pH, N min, P (P_2O_5), K (K_2O), humus %.

Table 3. *Content of chemical elements in soil samples before applying slurry (barley)*

Quality of the material to be treated:	Values	
Content of ammonium N	3,4	mg/kg
Content of P (P_2O_5),	74	mg/kg
Content of K (K_2O),	97	mg/kg
Humus	3,4	%
pH	6,2	

Table 4. *Soil analyses after harvest (barley)*

	Barley No 1 (CONTROL)	Barley No 2 (Mineral fertilizers)	Barley No 3 (Untreated slurry)	Barley No 4 (Acidified slurry)
Date	2018-10-15	2018.10.15	2018.10.15	2018.10.15
pH	6,1	6,0	6,1	5,8
N min (mg/kg)	2,01	2,56	2,63	2,81
P (P_2O_5) mg/kg	72	98	84	79
K (K_2O) mg/kg	86	102	112	109

After doing the research of soil before the barley fertilizing and after it was established that pH of soil has changed fractionally. Fertilizing with the mineral fertilizers decreased the acidity of the soil to 1,64 percent, fertilizing with non-acidified slurry pH have not changed and inserting acidified slurry in soil decreased pH 4,9 percent. The amount of phosphorus and potassium have also changed fractionally, the amount of these elements in soil increased from 10 to 20 percent.

Table 5. *Content of chemical elements in soil samples before applying slurry (corn)*

Quality of the material to be treated:	Values	
Content of ammonium N	2,72	mg/kg
Content of P (P_2O_5),	73	mg/kg
Content of K (K_2O),	266	mg/kg
Humus	3,4	%
pH	6,2	

Table 6. *Soil analyses after harvest (corn)*

	Corn, no fertilizers No 1	Corn, NPK 6-18-34 and carbamide No 2	Corn, Untreated slurry No 3	Corn, Acidified Slurry No 4
Date	2018.10.15	2018.10.15	2018.10.15	2018.10.15
pH	5,8	5,6	6	5,76
N min (mg/kg)	1,76	2,01	1,98	2,21
P (P_2O_5) mg/kg	65	67	86	83
K (K_2O) mg/kg	249	201	231	245

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The research of soil in the corn fields have shown that pH changed fractionally, it decreased 9,76 percent after fertilizing with mineral fertilizers and after fertilizing with the acidified slurry the acidity of the soil decreased just 7,01 percent. Counting the change of phosphorus and potassium in soil, it was established that while fertilizing corns with acidified slurry the nitrogen was found 11,61 percent more than in the soil in which the non-acidified slurry have been inserted.

Table 7. *Content of chemical elements in soil samples before applying slurry (grassland)*

Quality of the material to be treated:	Values	
Content of ammonium N	1,97	mg/kg
Content of P (P_2O_5),	67	mg/kg
Content of K (K_2O),	106	mg/kg
Humus	3	%
pH	6	

Table 8. *Soil analyses after harvest (grassland)*

	Grassland, no fertilizers No 1	Grassland, ammonium nitrate No 2	Grassland, untreated pig slurry No 3	Grassland, acidified Slurry No 4
Date	2018-10-15	2018-10-15	2018.10.15	2018.10.15
pH	6,1	6	5,9	5,75
N min (mg/kg)	1,87	2,05	1,98	2,16
P (P_2O_5) mg/kg	65	68	76	79
K (K_2O) mg/kg	96	97	106	18

The results of fertilizing grassland with the acidified slurry have shown that the effect on the acidity of soil was fractional and formed 4,17 percent and while spreading with the non-acidified slurry, pH of the soil decreased just 1,67 percent compared to pH of soil before the sowing. However, in soil with the acidified slurry the amount of nitrogen was 9,09 percent bigger than in soil fertilized with non-acidified slurry.

Table 9. *Content of chemical elements in soil samples before applying slurry (oats)*

Quality of the material to be treated:	Values	
Content of ammonium N	3,4	mg/kg
Content of P (P_2O_5),	64	mg/kg
Content of K (K_2O),	97	mg/kg
Humus	3,4	%
pH	6,2	

Table 10. *Soil analyses after harvest (oats)*

	Oats No 1 (CONTROL)	Oats No 2 (Mineral fertilizers)	Oats No 3 (Untreated slurry)	Oats No 4 (Acidified slurry)
Date	2018-10-15	2018.10-15	2018.10.15	2018.10.15
pH	5,95	5,9	6,01	5,81
N min (mg/kg)	2,97	3,02	3,3	3,45
P (P_2O_5) mg/kg	76	84	98	96
K (K_2O) mg/kg	105	112	115	109

After doing the analyses of soil in the fields after harvesting it was established that after using mineral fertilizers pH of soil decreased 4,84 percent and using the acidified slurry the indicator was 6,29 percent smaller compared to soil before fertilizing. Comparing the change of the nitrogen it was set that the biggest amount of nitrogen in soil was accumulated after using the acidified slurry and it was 12,46 percent bigger than fertilizing oats with the mineral fertilizers.

Table 11. *Content of chemical elements in soil samples before applying slurry (spring wheat)*

Quality of the material to be treated:	Values	
Content of ammonium N	3,28	mg/kg
Content of P (P_2O_5),	61	mg/kg
Content of K (K_2O),	103	mg/kg
Humus	2,8	%
pH	5,9	

Table 12. *Soil analyses after harvest (spring wheats)*

	Spring wheat No 1 (CONTROL)	Spring wheat No 2 (Mineral fertilizers)	Spring wheat No 3 (Untreated slurry)	Spring wheat No 4 (Acidified slurry)
Date	2018-10-15	2018.10.15	2018.10.15	2018.10.15
pH	5,85	5,80	6,01	5,75
N min (mg/kg)	2,84	2,98	3,04	3,21
P (P_2O_5) mg/kg	78	81	96	93
K (K_2O) mg/kg	96	102	125	121

After establishing pH of soil where spring wheat was sown it was set that pH of soil after using mineral fertilizers and after fertilizing spring wheat with the acidified slurry changed similarly. After fertilizing with the fertilizers pH decreased 1,69 percent and after fertilizing with the acidified slurry – 2,54 percent. However, fertilizing with the acidified slurry after harvesting it was 7,17 percent more nitrogen compared to soil which was fertilized with the mineral fertilizers.

Slurry acidification

In-field technology was chosen for acidification of slurry. During slurry spreading, the container with Sulphur acid was attached to the tractor's front and carried to the fields together with slurry. The distance from slurry loading to its spreading will be 3-8 km. This system requires a yard for storage of the containers with 1500 kg concentrated acid.

Containers for storage of slurry acid were installed in concreted 50 square meters platform fenced in with 1.8 m high fence with locked up gate. The place with containers was locked and protected from rain and precipitations.

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2018, barley

Expected yield 5,5 t/ha;

Type of Slurry: cattle slurry;

Installed slurry acidification system: in field;

Slurry application technology, band spreaders: trailing hoses;

Plot size - 60 ha.

Table 13. *Field trial scheme (barley)*

Treatments	Fertilization (description)	N (mineral fertilizers, kg/ha); NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Barley No 1 (CONTROL)	Without fertilization	-	-	-	-
Barley No 2 (Mineral fertilizers):	NPK 20-10-10, ammonium nitrate	108,8	20	20	0
Barley No 3 (Untreated slurry):	Cattle slurry	106,12	10,92	73,08	3,08
Barley No 4 (Acidified slurry):	Acidified cattle slurry	106,12	10,92	73,08	26,25

Table 14. *Harvest information (barley)*

Treatments	Date of harvest	Grain yield, t/ha	Moisture content, % at harvest time	Proteins (cereals), % of DM
Barley, without fertilization No 1:	2018-08-18	3,26	12,8	9,86
Barley, mineral fertilizers No 2:		4,26	13,5	10,32
Barley, cattle slurry No 3:		4,31	12,9	10,97
Barley, acidified cattle slurry No 4:		4,96	13,9	11,36

After doing barley harvesting it is determined, that barley which was fertilized with acidified slurry gave the biggest harvest and this indicator was 13,1 percent bigger than in the fields fertilized with non-acidified slurry. After comparing barley harvest after fertilizing with acidified slurry with barley which was fertilized with mineral fertilizers, the results have shown that the harvest fertilized with acidified slurry was 14,11 percent bigger than that fertilized with mineral fertilizers. Also, in barley fertilized with acidified slurry the amount of proteins was bigger 3,43 percent than in barley fertilized with non-acidified slurry and 9,15 percent than fertilized with mineral fertilizers.

Reporting form: 2018, barley *(please, activate the link below)*
https://www.dropbox.com/s/rz6qwdpb4pmqcyv/Lithuania%20LUHS%20PP18%20FT_%20RF_DEMONSTRATION_2018%20barley.xlsx?dl=0

2018, corn

Expected yield 60 t/ha green mass;

Type of Slurry: cattle slurry;

Installed slurry acidification system: in field;

Slurry application technology, band spreaders: trailing hoses;

Plot size - 80 ha.

Table 15. *Field trial scheme (corn)*

Treatments	Fertilization (description)	N (mineral fertilizers, kg/ha); NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Corn No 1 (CONTROL)	Without fertilization	-	-	-	-
Corn No 2 (Mineral fertilizers):	NPK 6-18-34, carbamide	105	36	68	0
Corn No 3 (Untreated slurry):	Cattle slurry	106,12	10,92	73,08	3,08
Corn No 4 (Acidified slurry):	Acidified cattle slurry	106,12	10,92	73,08	26,25

Table 16. *Harvest information (corn)*

Treatments	Date of cut	Green mass yield, First cut, t/ha	DM (dry matter) yield, First cut, t/ha
Corn, no fertilizer No 1 (Specify):	2018-10-14	35,7	10,71
Corn, NPK 6-18-34 and carbamide No 2 (Specify):		56,8	17,04
Corn, Untreated slurry No 3 (Specify):		49,7	14,91
Corn, Acidified Slurry No 4 (Specify):		55,9	16,77

After establishing green mass of corns, it was found that the most green mass was in the field fertilized with acidified slurry and it was 11,09 percent bigger than in the field fertilized with non-acidified slurry. Compared to harvest from the fields fertilized with mineral fertilizers the amount of green mass was smaller just 1,58 percent than in the fields fertilized with acidified slurry.

Reporting form: 2018, corn *(please, activate the link below)*
https://www.dropbox.com/s/htq02vujqlirwbk/Lithuania%20LUHS%20PP18%20FT_%20RF_DEMONSTRATION_2018%20corn.xlsx?dl=0

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2018, grassland

Expected yield 30 t/ha green mass;

Type of Slurry: pig slurry;

Installed slurry acidification system: in field;

Slurry application technology, band spreaders: trailing hoses;

Plot size - 150 ha.

Table 17. *Field trial scheme (grassland)*

Treatments	Fertilization (description)	N (mineral fertilizers, kg/ha); NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Grassland No 1 (CONTROL)	Without fertilization	-	-	--	-
Grassland No 2 (Mineral fertilizers):	Ammonium nitrate	86	0	20	0
Grassland No 3 (Untreated slurry):	Pig slurry	87,19	5,56	42,67	4,77
Grassland No 4 (Acidified slurry:	Acidified pig slurry	87,19	5,56	42,67	29,68

Table 18. *Harvest information (corn)*

Treatments	FIRST CUT				SECOND CUT				IN TOTAL		
	Date of First cut	Green mass yield, First cut, t/ha	DM (dry matter) yield, First cut, t/ha	Crude protein content, First cut, % of DM	Date of First cut	Green mass yield, First cut, t/ha	DM (dry matter) yield, First cut, t/ha	Crude protein content, First cut, % of DM	Green mass yield, t/ha	DM yield t/ha	Crude protein content, % of DM
Grassland, no fertiliser No 1:	2018-05-26	17,3	4,33	11,2	2018.07.25	5,2	1,3	10,9	22,5	5,63	11,05
Grassland, ammonium nitrate No 2:		20,3	5,08	12,4	2018.07.25	9,5	2,36	12,01	29,8	7,44	12,21
Grassland, untreated pig slurry No 3:		19,8	4,95	12,3	2018.07.25	9,2	2,3	11,5	29,0	7,25	11,9
Grassland, acidified Slurry No 4:		23,8	5,95	14,2	2018.07.25	10,3	2,56	13,9	34,1	8,51	14,05

After establishing green mass of grassland, it was found that the most green mass was in the field fertilized with acidified slurry and it was 14,96 percent bigger than in the field fertilized with non-acidified slurry. Compared to harvest from the fields fertilized with mineral fertilizers the amount of green mass was smaller just 15,30 percent than in the fields fertilized with acidified slurry.

Reporting form: 2018, grassland *(please, activate the link below)*
https://www.dropbox.com/s/e7naklm4kij7r60/Lithuania%20LUHS%20PP18%20FT_%20RF_DEMONSTRATION_2018%20grassland%20corrected%282%29.xlsx?dl=0

2018, oats

Expected yield 5,0 t/ha;

Type of Slurry: pig slurry;

Installed slurry acidification system: in field;

Slurry application technology, band spreaders: trailing hoses;

Plot size - 40 ha.

Table 19. *Field trial scheme (oats)*

Treatments	Fertilization (description)	N (mineral fertilizers, kg/ha); NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Oats No 1 (CONTROL)	Without fertilization	-	-	-	-
Oats No 2 (Mineral fertilizers):	NPK 20-10-10, ammonium nitrate	87,6	18	18	0
Oats No 3 (Untreated slurry):	Pig slurry	87,19	5,56	42,67	4,77
Oats No 4 (Acidified slurry):	Acidified pig slurry	87,19	5,56	42,67	29,68

Table 20. *Harvest information (oats)*

Treatments	Date of harvest	Grain yield, t/ha	Moisture content, % at harvest time	Proteins (cereals), % of DM
Oats No 1 (CONTROL)	2018-08-20	3,65	13,8	10,21
Oats No 2 (Mineral fertilizers):		4,56	14,2	12,09
Oats No 3 (Untreated slurry):		4,31	13,9	11,96
Oats No 4 (Acidified slurry):		4,51	14,1	12,14

The research of the harvest in the oat fields has shown that the best harvest was get fertilizing fields with the mineral fertilizers and it was just 1,09 percent bigger than fertilizing fields with acidified slurry. Harvest of fields fertilized with acidified slurry was 4,43 percent bigger compared to harvest from the fields fertilized with non-acidified slurry. The research of the oats proteins has shown that the amount of proteins was the biggest in the fields fertilized with the acidified slurry and it was 1,48 percent bigger than in the fields fertilized with the non-acidified slurry and just 0,41 percent bigger in the fields acidified with the mineral fertilizers.

Reporting form: 2018, oats *(please, activate the link below)*
https://www.dropbox.com/s/ldej7epd4y7yodz/Lithuania%20LUHS%20PP18%20FT_%20RF_DEMONSTRATION_2018%20oats%20corrected%281%29.xlsx?dl=0

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2018, spring wheat

Expected yield 6,0 t/ha;

Type of Slurry: cattle slurry;

Installed slurry acidification system: in field;

Slurry application technology, band spreaders: trailing hoses;

Plot size - 80 ha.

Table 21. *Field trial scheme (spring wheat)*

Treatments	Fertilization (description)	N (mineral fertilizers, kg/ha); NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Spring wheat No 1 (CONTROL)	Without fertilization	-	-	--	
Spring wheat No 2 (Mineral fertilizers):	NPK 20-10-10, ammonium nitrate	108,8	20	20	0
Spring wheat No 3 (Untreated slurry/digestate):	Cattle slurry	106,12	10,92	73,08	3,08
Spring wheat No 4 (Acidified slurry):	Acidified cattle slurry	106,12	10,92	73,08	26,25

Table 22. *Harvest information (spring wheat)*

Treatments	Date of harvest	Grain yield, t/ha	Moisture content, % at harvest time	Proteins (cereals), % of DM
Spring wheat No 1 (CONTROL)	2018-08-15	3,56	12,5	14,02
Spring wheat No 2 (Mineral fertilizers):		4,87	13,7	15,89
Spring wheat No 3 (Untreated slurry/digestate):		4,93	12,8	15,95
Spring wheat No 4 (Acidified slurry:		5,12	13,2	16,02

The harvest research of spring wheat has shown that the best harvest of spring wheat was of the fields fertilized with acidified slurry and it was 3,17 percent bigger than in the fields fertilized with non-acidified slurry. And after comparing the harvest of spring wheat to the fields fertilized with acidified slurry and the fields fertilized with mineral fertilizers, the results have shown that the harvest in the fields fertilized with acidified slurry was 4,88 percent bigger than in the fields fertilized with mineral fertilizers. The research of proteins of spring wheat has shown that in the spring wheat fertilized with acidified slurry the amount of proteins was just 0,44 percent bigger compared to the fields fertilized with non-acidified slurry and 0,81 percent compared to the fields fertilized with mineral fertilizers.

Reporting form: 2018, spring wheat *(please, activate the link below)*
https://www.dropbox.com/s/rup9ansirjs8pqs/Lithuania%20LUHS%20PP18%20FT_%20RF_DEMONSTRATION_2018%20spring%20wheat.xlsx?dl=0

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Conclusions

1. Fertilization of fields with acidified slurry increased fertility of wheat 13,1 percent, the green mass of the corns – 11,09 percent, the green mass of the grasslands – 14,96 percent, oats – 4,43 percent and the spring wheat – 3,71 percent compared to the fields fertilized with non-acidified slurry.
2. Fertilizing fields with acidified slurry increased the amount of proteins in wheat 3,43 percent, green mass of the grasslands – 15,30 percent, oats – 1,48 percent, spring wheats – 0,44 percent, compared to the fields fertilized with non-acidified slurry.
3. Fertilization of fields with acidified slurry did not have essential influence on pH of soil because after fertilizing fields with acidified slurry, pH decreases at an average about 4,36 percent and using non-acidified slurry in the fields, pH decreases 3,06 percent, using the mineral fertilizers for the fertilizing fields 3,57 percent.
4. Fertilizing fields with acidified slurry of an average, the amount of nitrogen increases 9,44 percent compared to fields fertilized with non-acidified slurry and compared to fields fertilized with mineral fertilizers the amount of nitrogen in soil increased 9,41 percent.

References

Abedi, T.; Alemzadeh, H.; Kazemeini, S.A. 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. *Australian Journal of Crop Science* 4:6: 384̃389 p.

Čiuberkis, S.; Čiuberkienė, D.; Končius, D.; Lapinskas, E.; Ambrazaitienė, D.; Piaulokaitė-Motuzienė, L. 2005. Effect of liming and fertilizing systems on soil properties and productivity of agrocenoses. *Agricultural sciences.* 2: 1-2 p.

Dhital, S.; Raun, W.R. 2016. Variability in optimum nitrogen rates for maize. *Agronomy Journal* 108(6):2165̃2173. doi:10.2134/agronj2016.03.0139.

Janušauskaitė, D.; Šidlauskas G. 2004. Nitrogen fertilizer efficacy in winter wheat in relation to weather conditions in central Lithuania. *Žemdirbystė-Agriculture.* Scientific Articles. 4, 88, 34-47 p.

Jones, B. J. 2012. Plant Nutrition and Soil Fertility Manual, Second Edition. Taylor & Francis Group.

Imran, M.; Gurmani, Z. A. 2011. Role of macro and micro nutrients in plant growth and development. Science, *Technology & Development,* vol. 30, no. 3, 36–40 p.

Mašauskas, V. 2009. Environmental and fertilization planning. *The training tool.* Lithuanian Ministry of Agriculture.

Mažvila, J. (Edit.) 1998. Agrochemical properties of Lithuanian soils and their change. Kaunas. 130-174 p. (in Lithuanian, summary in English).

Staugaitis, G.; Brazienė, Z.; Marcinkevičius, A.; Mažeika, R.; Antanaitis, Š.; Staugaitienė, R. 2014. Spring barley as affected by nitrogen and sulphur fertiliser rates calculated using different diagnostic methods. *Žemdirbystė-Agriculture*. 101 (4): 373-380 p.

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Valkama, E.; Rankinen, K.; Virkajärvi, P.; Salo, T.; Kapuinen, P.; Turtola, E. Nitrogen fertilization of grass leys: Yield production and risk of N leaching. *Agriculture, Ecosystems & Environment.* Volume 230, 16 August 2016, 341-352 p.

Žičkienė, L.; Staugaitis, G.; Mažvila, J.; Masevičienė, A.; Narutytė, I. 2015. Mineral nitrogen content fluxes in different texture soils on a rolling to hilly landscape. *Agricultural sciences*. T. 22. Nr. 4. 198–208 p.

Žydelis, R.; Lazauskas, S.; Povilaitis, V. 2018. Biomass accumulation and N status in grain maize as affected by mineral and organic fertilisers in cool climate. *Journal of Plant Nutrition* (in press). doi.org/10.1080/01904167.2018.1527933.

Material about Informational events

Event: Scientific conference "Challenges of climate change in animal husbandry and measures to reduce negative effects".

Description: This event included reports on climate change issues and the presentation of the BSA project. The application of slurry acidification technology was also presented in the field.

Date: 12.06.2018.

Place: Animal Science Institute, Baisogala, Radviliškio r.

Number of participants: 20 (fixed in participants` list).

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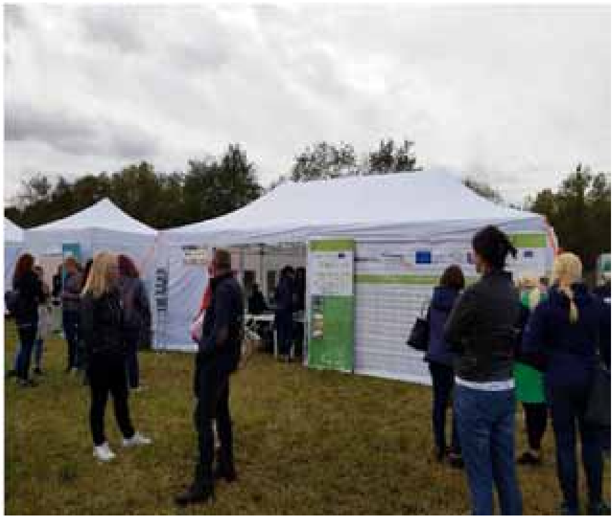
Event: Lithuanian Plowmen Contest 2018 / Maize Day 2018.

Description: Presentation (poster, flyers) of the BSA project.

Date: 13.09.2018.

Place: Kedainiai district, Liepos village.

Number of participants: 605 visitors.



Event: Exhibition of breeding animals.

Description: Presentation (poster) of the BSA project.

Date: 15-16.09.2018.

Place: Panevezys district, Algirdiskiai village.

Number of participants: 2000 visitors.

SWEDEN

General information:

Project partner	Contact person	Type of activity in Field Trial	2016	2017	2018	Ammonia emission
RISE Research Institutes of Sweden	Gunnar Lundin gunnar.lundin@ri.se	Scientific	Grassland Cattle slurry	Grassland Cattle slurry	Grassland Cattle slurry	Ammonia losses were not measured
The Rural Economy and Agricultural Society	Line Strand line.strand@hush.se	Scientific			Spring barley Digestates	

Note! The activated links will redirect you to the relevant text (Field trial) of the report.

The report on field trials carried out in Sweden consists of two parts. The first part contains material submitted by Research Institutes of Sweden and the second one – material submitted by The Rural Economy and Agricultural Society.

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Report of RISE Research Institutes of Sweden

Written by: Gunnar Lundin, RISE Research Institutes of Sweden

Summary

The Swedish field trials in the BSA project started in 2016 and ended in 2018. The objective was to clarify to what extent the acidification of cattle slurry improves nitrogen utilization when spread on ley.

The field trials were carried out at the brothers Odhner dairy farm in Mjölsta, Alunda northeast of Uppsala. The crop was a fourth year grass-dominated ley with touches of red and white clover and alfalfa. The field trials were restrictected to the second cut and had randomized block designs with four repetitions. The nitrogen utilization for acidified slurry was compared to untreated slurry and to three mineral fertilizer treatments with stepwise increasing nitrogen application rates.

The used cattle slurry (from the brothers Odhner dairy farm) had a dry matter content of about 8 %. During each year different ammounts of concentrated sulphuric acid was added to the slurry according to below.

In 2016: 5.0 litres per ton which decreased slurry pH from 7.1 to 5.2.
In 2017: 3.25 litres per ton which decreased slurry pH from 7.0 to 6.4.
In 2018: 4.2 litres per ton which decreased slurry pH from 7.1 to 6.0.

Both untreated and acidified slurry was band spread at a rate of 24 tons per hectare. In 2016 and in 2017 spreading was performed on 14th June and in 2018 it was done on 15th June. Every year the weather conditions were monitored during spreading and the five next following days, but ammonia emissions were not measured. However, it can be said that weather conditions favored ammonia losses.

The acidified slurry treatments resulted in yield increases of 8% compared to untreated slurry in 2016 and 2018, however they were not significant. By the way, the yields were very poor in general in 2018 due to dry and extremely warm weather.

Aim

The aim of the study was to examine to which extent the acidification of cattle slurry improves the nitrogen uptake when spread on ley.

Material and methods

The soil at the experimental site was classified as a clay soil and the crop rotation consisted of 3-4 years grassland followed by winter wheat and barley.

The current crop was a fourth year grass-dominated ley with touches of red and white clover and alfalfa. Regularly on the farm, and so even on the trial field, slurry was used as a plant nutrient source in the ley cultivation. In addition, nitrogen and sulphur were supplied as mineral fertilizer.

In the years prior to every field trial, 80-90 kg nitrogen per hectare was added in the spring as the mineral fertilizer Axan (NS 27-4) and then - after the first harvest - 25-30 m^3 per hectare of cattle slurry was applied.

In the spring of every trial year, mineral fertilizer Axan (NS 27-4) was applied to the trial field: 80-90 kg N per hectare in 2016, 77 kg N per hectare in 2017, and 78 kg N per hectare in 2018. The first harvest took place in the beginning of June in every year. The field trials were restricted to the second cut.

The trial was designed as a randomized block design with four repetitions for each treatment. There were six treatments: untreated cattle slurry, acidified cattle slurry, three step-wise increasing levels of mineral nitrogen and a control, Table 1. Plot sizes were 3 x 12 meters and there was a total of 24 plots.

Table 1. *Trial design, target plant nutrient rates to the second cut. In the experimental treatments with slurry the nitrogen application refers to the amount of ammonium nitrogen*

Experimental treatment, designation	Fertilizer	Nitrogen applied (target), kg/ha	Remark
A	Mineral fertilizer PKS	-	Control[1)]
B	Mineral fertilizer NPKS	30	
C	Mineral fertilizer NPKS	60	
D	Mineral fertilizer NPKS	90	
E	Slurry, untreated	60	Ammonium-N
F	Slurry, acidified	60	Ammonium-N

[1)] In 2016 the control treatment was not fertilized at all

The step-wise mineral fertilizer treatments were included to estimate the effects of differences in weather conditions between years on the crop nitrate usage. Crop requirements of phosphorus, potassium and sulphur were added to the plots so that nitrogen would be the limiting factor in the field trial. Magnesium was also added in 2016.

Specifications for sulphuric acid and safety issues

Concentrated sulphuric acid (96%) was used for acidifying slurry. The density was 1.84 kg/l. The acid was packaged in plastic cans of five litres that were transported to the experimental farm by the acid distributor.

All the staff that handled the sulphuric acid in the experiment had undergone safety training and was equipped with protective clothing and respiratory protection in the form of a full face mask. The staff had also previously been involved in similar experiments at which slurry was acidified, so they were routine in the safety procedures.

The handling of sulphuric acid, as it was applied in the trial, forced rigorous safety arrangements. Such manual handling should never be recommended to farmers.

Slurry for titration

In Denmark acidification to pH = 6.4 is applied for systems where the acid is added in the same moment as the spreading (SEGES, 2015). Regarding applications with residence time up to 24 hours between adding and spreading a lowering of pH to 6.0 is used to allow room for the gradual rise in pH that occurs in acidified slurry. In the present experimental settings the lap of time between adding and spreading was proposed to amount to some hour (2016, 2017) or up to 24 hours (2018).

A titration was performed to estimate the amount of sulphuric acid needed to lower the pH (to 5.7 in 2016, to 6.0 in 2017 and 2018). For this purpose, samples were taken from the slurry storage on 10th June in 2016, and in 2017 and 2018 it was done on 12th June. By lowering a bucket into the storage two samples of one liter each were taken. The slurry in the storage had previously been mixed (in 2016, 2018). Sulphuric acid titrations were performed on one of the samples, and the other was stored as a reserve at room temperature. During the titration, the slurry was mixed with a magnetic stirrer

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while pH and temperature were measured. When pH was lowered to a required level, the volume of acid added to the slurry was documented.

2016, grassland

Slurry spreading

Slurry was spread on 14th June, on the stubble after the first harvest. The process began by mixing slurry in the slurry storage with a propeller stirrer (Figure 1). When the storage was well mixed, the trial slurry spreader (volume approximately 3 m^3) was filled.

Figure 1. *Before the slurry spreader was filled, the slurry was mixed using a propeller stirrer. Photo: Gunnar Lundin*

Once the slurry spreader was filled, slurry samples were taken from the tank according to below.

- Before slurry spreading started, a sample was taken to determinate the content of ammonium nitrogen in the slurry. The sample was analyzed using a nitrogen-meter manufactured by Agros, Figure 2. Based on the result from the Agros equipment, the slurry application rate was calculated to achieve the targeted nitrogen application rate.
- Before spreading untreated as well as acidified slurry, samples were taken and sent to the laboratory Agrilab, Uppsala for standard manure analyses (DM, TN, TAN, C, P, K, S, Na, Ca, Mg) plus pH.

Figure 2. *Nitrogen-meter "Agros", used for quick analysis of ammonium-nitrogen content in field.*

The slurry samples were taken from the spreader tank through the top inspection opening with a sub-surface sample grabber attached to a long handle.

The slurry spreader was equipped with a ramp with band spreading nozzles that were adjusted to a height of some centimeters above the ground level, Figure 3.

Before spreading slurry in the trial plots, a calibration of the slurry flow was carried out on the surrounding field. Thereafter, spreading untreated slurry started at 11 am and took approximately 15 minutes.

Once untreated slurry was spread, the depth of the remaining slurry in the spreader tank was measured using a graduated rod. The remaining volume of slurry in the tank was then obtained out from a conversion table. This volume was used in combination with the titration result to calculate the expected amount of acid required to reach the desired pH.

For the acidifying, the acid was emptied from its five liters plastic cans into a slightly larger one. This can was in turn placed on a platform scale and connected to an electric pump, manufactured by Clipton dimensioned for pumping acids (Cliptonpumpen, 2017). The acid was then pumped through a hose that was attached to an iron pipe which was directed towards the bottom of the spreader tank, close to the recirculation outlet of the spreader pump for mixing slurry in the tank. The spreader pump was activated while acid was added in order to obtain a continuous mixing of the slurry (Figure 4).

Figure 3. *The spreader placed the slurry in bands on top of the stubble. Note that the discs were also above the crop and not in contact with the soil. Photo: Lena Rodhe respectively Gunnar Lundin*

Figure 4. *Left picture. The acid container was placed on a scale in order to determine the acid addition and connected to an electric acid pump. Right picture. The acid was pumped through a tube into an iron rod which ended at the recirculation outlet of the spreader pump for mixing the slurry in the tank. Photo: Gunnar Lundin*

The addition of acid was carried out between 12.40 and 13.25, i.e. during 45 minutes. Extensive foaming occurred which limited acid addition tempo (Figure 5). No foaming inhibitor was added. Fifteen minutes after the acidification was completed, the foam regressed.

During the addition of sulphuric acid slurry temperature and pH were measured with approximately ten minute intervals. A digital measuring device with an associated temperature / pH sensor was used for this purpose. This instrument, Hanna Edge model HI – 2002, was used in field as well as in the laboratory (Hannainstruments, 2017).

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***Figure 5.** Extensive foaming occurred in the spreader tank while adding the acid, almost all the way to the top. The iron pipe used to add acid at the bottom of the tank can be seen on the left hand side of the picture. Photo: Lena Rodhe*

As slurry samples were taken from the spreader tank, the sensor was dipped into the sampling vessel at which the temperature and pH could be read. The sensor was cleaned in deionized water between the measurements (Figure 6).

The spreading of acidified slurry started at 2 pm and took about 15 minutes (Figure 7).

***Figure 6.** The slurry pH and temperature were measured several times by sinking the sensor into the sampling vessel. Photo: Gunnar Lundin*

***Figure 7.** Spreading of acidified slurry. Photo: Gunnar Lundin*

To assess the potential for ammonia emissions, air temperature and wind speed data were collected from the nearest meteorological station at the day for spreading and the five next days. Precipitation was registered on site by the trial host.

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Mineral fertilizer application

The day after slurry spreading, (i.e. June 15th), plant nutrients were added as mineral fertilizer for the stepwise increasing nitrogen rate (experimental treatment B-D). The composition of the fertilizer is given in Table 1.

Table 1. *Plant nutrient content in the mineral fertilizer used for the second cut according to data from the manufacturer (Värmlant, 2017)*

Fertilizer, designation	Plant nutrient content, %				
	N	P	K	S	Mg
Balans 22-4-9	21.6	3.6	8.6	3	0.4

Crop development and harvest

Between slurry application and the harvest, the trial field was visited twice for documentation of the growth of the ley crop. On these occasions, the 8th and 30th July, photographs of the experimental treatments were taken and the crop heights were measured.

The experimental plots were harvested on 5th August. The harvested area of each plot was 1.2 * 9.8 meters i.e. 11.8 m^2. The yield was recorded and from each plot samples were taken for determination of the dry matter and protein content. In addition, an estimate of the proportion of legumes in each plot was made by visual inspection.

Results

Slurry for titration

The laboratory analyses of the samples taken from the slurry storage on 10th June showed that pH was between 6.9 and 7.0.

The titration of the slurry sample showed that 3.5 liters of sulphuric acid (96%) per ton slurry was required to reduce pH to about 5.7.

Slurry spreading

The result from the slurry samples taken on 14th June, analyzed at the external laboratory is given in Table 2.

Table 2. *Results from the analyses of slurry samples performed by Agrilab, Uppsala. Unit if not showed within brackets = kg/ton*

Parameter	Untreated slurry	Acidifie slurry
Dry matter (%)	8.0	8.6
Total nitrogen	3.9	4.9
Ammonium nitrogen	2.1	2.1
Total carbon	33.0	32.4
Tot-C/Tot-N (ratio)	8.4	6.6
Total phosphorus	0.49	0.53
Total potassium	3.97	4.02
Total magnesium	0.45	0.48
Total calcium	1.25	1.34
Total sodium	0.22	0.22
Total sulphur	0.43	3.05
Loss on ignition (% of DM)	81.0	77.9
pH (value)	7.1	5.5

The in-field analysis performed with Agro's nitrogen meter showed an ammonium nitrogen content of about 2.5 kg / ton. The required slurry needed to reach 60 kg N / ha was calculated from this measurement and according to the expression:

$$60\ kg/ha \big/ 2.5\ kg/ton = 24\ ton/ha$$

This rate was then used at the spreading.

The remaining amount of slurry in the experimental spreader after the spreading of untreated slurry was 1 800 liters or equivalent to approximately 1.8 tons. This amount in combination with the previously calculated dose needed to reach pH of 5.7 gave the required acid to be added according to the expression:

$$1.8\ tons * 3.5\ l/ton = 6.3\ l.$$

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In total 9.1 liters of sulphuric acid were added or the equivalent of 5.0 liters per ton of slurry. That was 44% more than what was originally estimated. Twenty minutes after adding acid to the slurry tank pH was 5.2, which was lower than originally intended. The slurry sample that was later analyzed at the laboratory had pH of 5.5 (Table 2).

The nutrient application rates at the start of the trial for all treatments are shown in Table 3. Regarding the nutrient content in the mineral fertilizer the data from the manufacturer have been used (Table 1). For the experimental treatments with slurry the laboratory analyses in Table 2 were used.

Table 3. *Supplied rates of plant nutrients to the second cut. In the experimental treatments with slurry, the nitrogen supply refers to ammonium (P is indicated as phosphorus, i.e. not as phosphate, etc.)*

Experimental treatment	Fertilizer	Rate					
		Total, kg/ha resp. tons/ha	Plant nutrient, kg/ha				
			N	P	K	S	Mg
A	Unfertilized	-	-	-	-	-	-
B	Mineral fertilizer	137	30	5	12	4	0,5
C	Mineral fertilizer	274	59	10	24	8	1,1
D	Mineral fertilizer	411	89	15	35	12	1,6
E	Slurry, untreated	24	50	12	95	10	11
F	Slurry, acidified	24	51	13	97	73	12

Weather data

Temperature, precipitation and average daily wind speed from the first six days of the field trial are shown in Figure 8 and Table 4.

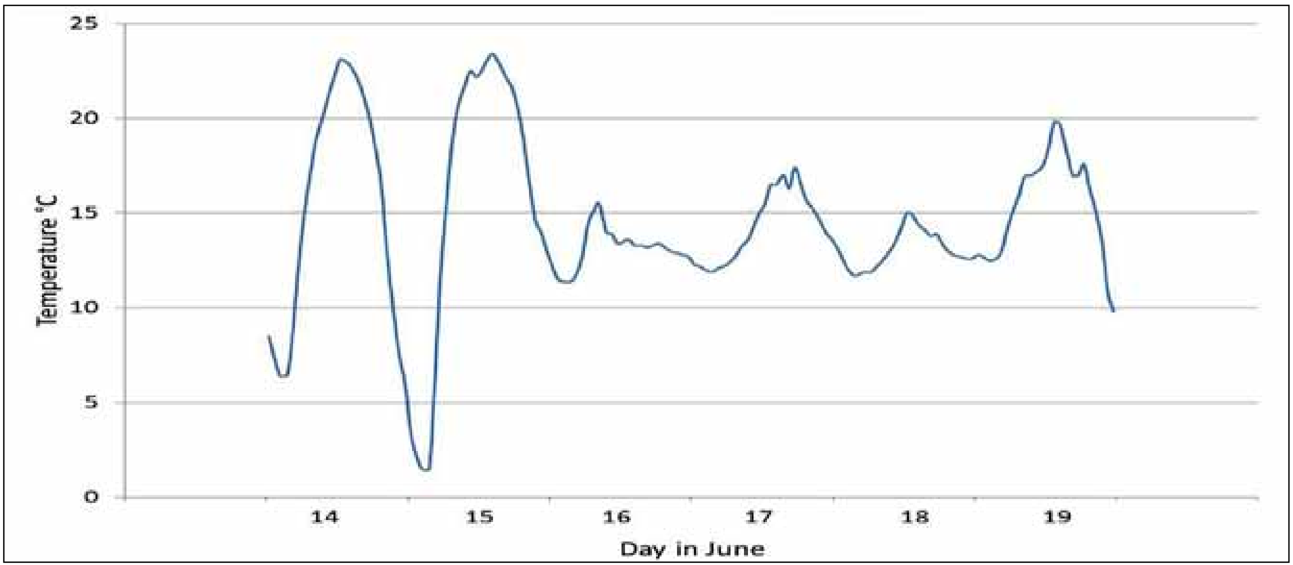

Figure 8. *Air temperature June 14th – June 19th.*

Table 4. *Precipitation and average wind speed at the day for slurry spreading and the five following days*

Parameter	Day in June					
	14	15	16	17	18	19
Precipitation, mm	-	-	10	3	21	-
Windspeed, m/s	1.6	2.3	1.0	1.2	2.1	1.7

Crop development

From the first field inspection on 8th July is in Figure 9 - Figure 10 shown the crop appearance in plots supplied with untreated and acidified slurry respectively. Crop heights at the inspections are shown in Table 5.

Figure 9. *Field inspection on 8th July. Experimental treatment E, untreated slurry. Photo: Gunnar Lundin*

Figure 10. *Field inspection on 8th July. Experimental treatment F, acidified slurry. Foto: Gunnar Lundin*

During the field inspections variations in the proportion of legumes in the ley crop were noted. This was shown in the field trial as two of the four blocks contained relatively more legumes. In these blocks the higher legume element likely evened out some of the nitrogen effect that was expected between the treatments.

The in-field variations regarding legumes proportion remained even at the plot-wise assessment made at the time of harvest. Accordingly, large confidence intervals were obtained for this parameter, Table 6.

Table 5. *Crop height at field inspections, cm*

Date	Experimental treatment					
	A	B	C	D	E	F
July 8th	22	25	28	30	25	25
July 30th	45	52	60	62	50	50

Table 6. *Proportion of legumes in the crop at the time of harvest. Mean values and 95 percent confidence intervals regarding four repetitions*

Experimental treatment	Legume proportion, % of plant stand	
	Mean value	Confidence interval
A	8	5.4 - 10.1
B	8	5.1 - 9.9
C	6	3.4 - 8.1
D	3	0.9 – 5.6
E	6	3.9 – 8.6
F	5	2.6 – 7.4

Harvest

The results of yield, protein content and nitrogen efficiency in relation to the control are presented in Table 7.

Table 7. *The outcome at harvest, averages of four repetitions. Yield levels with different letters are significantly different (p = 0.05)*

Experimental treatment	Yield,		Protein content, % of DM	Nitrogen efficiency, kg DM/kg N[2)]
	Kg DM/ha[1)]	Relative number		
A	3870[d]	100	9,3	
B	4810[b]	124	10,1	31,3
C	5210[a]	135	10,1	22,7
D	5260[a]	136	10,3	15,6
E	4370[c]	113	9,9	10,0
F	4730[bc]	122	9,9	16,9

1) Least significant difference = 380 kg DM / ha
2) Nitrogen efficiency: (kg DM in actual experimental treatment - kg DM in control) / kg supplied nitrogen

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The values in Table 7 show that the acidification caused a yield increase of 360 kg DM / ha (i.e. +8%), compared to untreated slurry. The increase in yield was however, not significant.

Regarding the protein contents, no difference was seen between the slurry treatments.

The acidification resulted in increased nitrogen efficiency.

The achieved yields are also presented graphically in Figure 11.

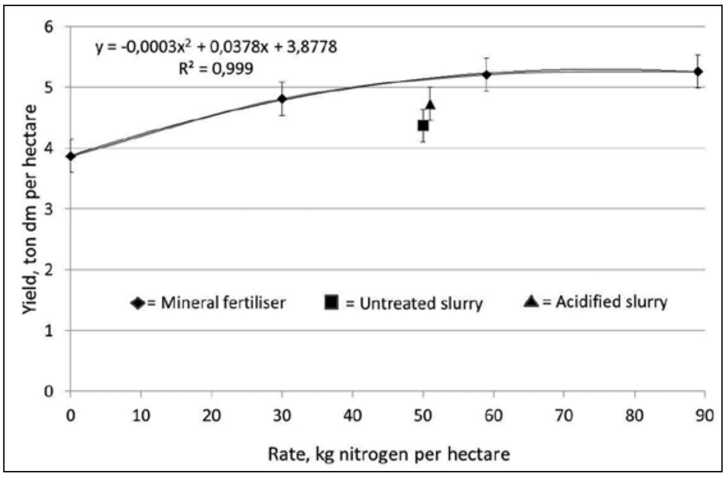

***Figure 11.** Yield including 95 percent confidence interval for the various experimental treatments. Regarding the stepwise increasing nitrogen supply (the experimental treatments supplied with 0 - 90 kg mineral nitrogen per hectare) the result of the performed regression analysis is also shown.*

The equation for the stepwise increasing nitrogen supply in Figure 11 was estimated through regression analysis as a polynomial of second degree.

The average yield in the experimental treatment with untreated slurry corresponded to 87% of the estimated yield for the same nitrogen rate with mineral fertilizer. The corresponding utilization for the acidified slurry was 94%.

Discussion

The yield was on average 8 percent higher where the slurry was acidified compared to the outcome with untreated slurry. However, the difference was not significant depending on the variation between the repetitions.

In the present study ammonia losses were not measured, however, it is well established that acidifying slurry to pH below 6.4 can decrease ammonia loss from the spread slurry (SEGES, 2015). In a previous Swedish study on the effects of slurry acidification a reduction of ammonia emission by 50 to 75% was achieved (Rodhe et al., 2015). The warm and sunny conditions during spreading and the following day after were also conducive for significant ammonia losses. However, the relatively high nitrogen utilization seen in the untreated slurry suggests that ammonia emissions were not that high. None the less, acidification increased yields and nitrogen utilization which support the conclusion that ammonia emissions were reduced due to the slurry acidification.

The yield results followed a similar pattern as the crop heights measurements from the two field inspections, with the exception that no height differences were found between untreated and acidified slurry.

During the field inspections and at the time of harvest, differences between the blocks with respect to the proportion of legumes in the ley crop were observed. As legumes have the ability to fix nitrogen from the air, a high proportion of legumes would be expected to level out some of the effects of various nitrogen treatments. Accordingly, the variations between the repetitions increased.

Within the field trial the proportion of legumes followed an expected pattern. Namely, that an increasing nitrogen supply increases the grasses relative competitiveness.

The portable nitrogen meter used to determine the content of nitrogen in the slurry overestimated the content of ammonium nitrogen compared with the outcome from the laboratory analysis. This led to a reduced nitrogen rate in the experimental treatments with slurry of approximately 10 kg per hectare. The outcome was not entirely surprising since the current field meter was designed for rapid, orienting analyses. One possible way to reduce this source of error could be that, as a complement to the nitrogen meter, in advance perform laboratory analyses regarding the ammonium nitrogen content in samples from the slurry batch to be spread.

Concerning the laboratory analyses, there were differences in total nitrogen content between untreated and acidified slurry. To some degree this reflected variations in dry matter content on small subsamples of slurry due to the addition of bedding materials to the manure in the cow shed. In spite of that difference, however, the ammonium nitrogen contents were similar.

The methodology used for acidifying the slurry in the spreader tank to the target pH proved problematic. When the pre-calculated amount of acid was added, the measured pH had still not reached the target pH so more acid was added.

The outcome shows the difficulty to obtain the target pH in practice. Part of the reason is likely explained by inertia of the chemical reactions and buffering taking place during acidification. Also, due to the shape of the slurry tank and position of the recirculation outlet from the slurry pump, mixing may not be entirely homogenous throughout the tank. Moreover, that the technique used for the determination of pH was not continuous but performed after first removing a small sample and then measuring pH in the sample; a method which proved to be cumbersome.

In addition to the above, the accuracy of pH measurements in connection with acid addition could be increased by improving the design of the sampling equipment. As stated earlier, the used cylindrical vessel upper end was open and thus began to be filled as soon as it was submerged in the slurry. By providing the vessel with a lid that can be held closed until the vessel reaches the desired depth the representativeness of the sample could be improved.

To facilitate achieving the targeted pH in future studies when adding sulphuric acid, an alternative approach could be to control the dosage entirely based on the results of the titration test. Or, even better, by combining the results from the titration with repeated pH - measurements during the adding. Practically, this would preferably be done by slowing down the tempo of the addition when the supplied acid amount approaches the dose that emerged during titration. This is to get time for the slurry mass to homogenize so that the samples collected for the pH measurements become more representative.

In this study, the target pH of 5.7 was chosen to provide a safety margin to pH 6.0. As mentioned earlier, in Denmark acidification to pH = 6.4 is applied for systems where acid is added in the same moment as the spreading (SEGES, 2015). Regarding applications with residence time up to 24 hours between adding and spreading a lowering of pH to 6.0 is used to allow room for the gradual rise in pH that occurs in acidified slurry. This level would be fully adequate (i.e. would not require any additional safety margins) in the present experimental settings where the laps of time between adding and spreading just amounts to some hour.

In comparison with the commercial systems for slurry acidification of today, the manual handling of sulphuric acid in the experiment described in this report could have meant an increased risk for accidents. The handling of acid, however, proceeded well and the equipment used for adding worked as it was supposed to. In this context, it was advantageous that the staff involved had routine from earlier experiments with acidification of slurry.

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Conclusions 2016

1. Five liters of concentrated sulphuric acid per ton of slurry was added which resulted in excessive reduction of the pH-value from 7.1 to 5.2.

2. The acidification caused a yield increase of 360 kg DM / ha (i.e. + 8%). The result suggests an improved nitrogen-utilization due to reduced ammonia emissions during the time directly after the spreading.

3. The average yield for the experimental treatment with untreated slurry corresponded to 87% of the calculated yield for the same nitrogen rate with mineral fertilizer. The corresponding utilization for the acidified slurry was 94%.

4. The handling of acid proceeded well. The safety arrangements and the equipment used for adding worked as they were supposed to.

5. At coming field trials, it is essential to achieve higher precision regarding attaining desired pH-value in the acidified slurry. The experiences from the present study will be useful for this task.

2017, grassland

Slurry spreading

The slurry was spread on 14th June, on the stubble after the first harvest. The process began by mixing the slurry in the slurry storage with a propeller stirrer. When slurry was homogeneous, the trial slurry spreader (volume approximately 3 m^3) was filled.

Once the trial spreader was filled, slurry samples were taken from the tank according to below.

- Before slurry spreading started, a sample was taken to determinate the content of ammonium nitrogen in slurry. The sample was analyzed in-field using a nitrogen-meter manufactured by Agros (the same as used in 2016). Based on this result, the slurry application rate was calculated to achieve the targeted nitrogen application rate.
- Before spreading untreated as well as acidified slurry, samples were taken for standard manure analyses (DM, TN, TAN, Organic N, C, P, K, S, Na, Ca, Mg) plus pH. The samples were sent to the laboratory Agrilab, Uppsala on September 28th.

The slurry samples were taken from the spreader tank through the top inspection opening. Hereby two types of sampling devices, consisting of cylindrical wessels, were compared. One which upper end was open and thus began to be filled as soon as it was submerged in the slurry. The other was equipped with a lid that could be held closed until the vessel reached the desired depth. The latter was expected to improve the representativeness of the sample.

The trial spreader was equipped with a band spreading ramp with nozzles that were adjusted to a height of some centimeters above the ground level, Figure 1.

Before spreading slurry in the plots, a calibration of the slurry flow was carried out on the surrounding field. Thereafter, spreading untreated slurry started at 12.55 and took approximately 5 minutes.

Once the untreated slurry was spread, the depth of the remaining slurry in the spreader tank was measured using a graduated rod. The remaining volume of slurry in the tank was then obtained out from a conversion table. This volume together with the titration result was used to calculate the expected amount of acid required to reach the desired pH.

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Table 6. *Proportion of legumes in the crop on 11th August. Values are based on visual judgements, averages of four repetitions*

Experimental treatment	Legume proportion, % of plant stand
A	64
B	55
C	50
D	48
E	56
F	48

Table 7. *Yields, protein contents and nitrogen efficiencies, averages of four repetitions*

Experimental treatment	Yield,		Protein content, % of DM	Nitrogen efficiency, kg DM/kg N[1)]
	Kg DM/ha	Relative number		
A	5480	100	10.2	
B	5650	103	10.5	5.7
C	4840	88	11.8	-10.7
D	5380	98	11.2	-1.1
E	5700	104	10.6	3.6
F	5350	98	10.5	-2.2

[1)] Nitrogen efficiency: (kg DM in actual experimental treatment - kg DM in control) / kg supplied nitrogen

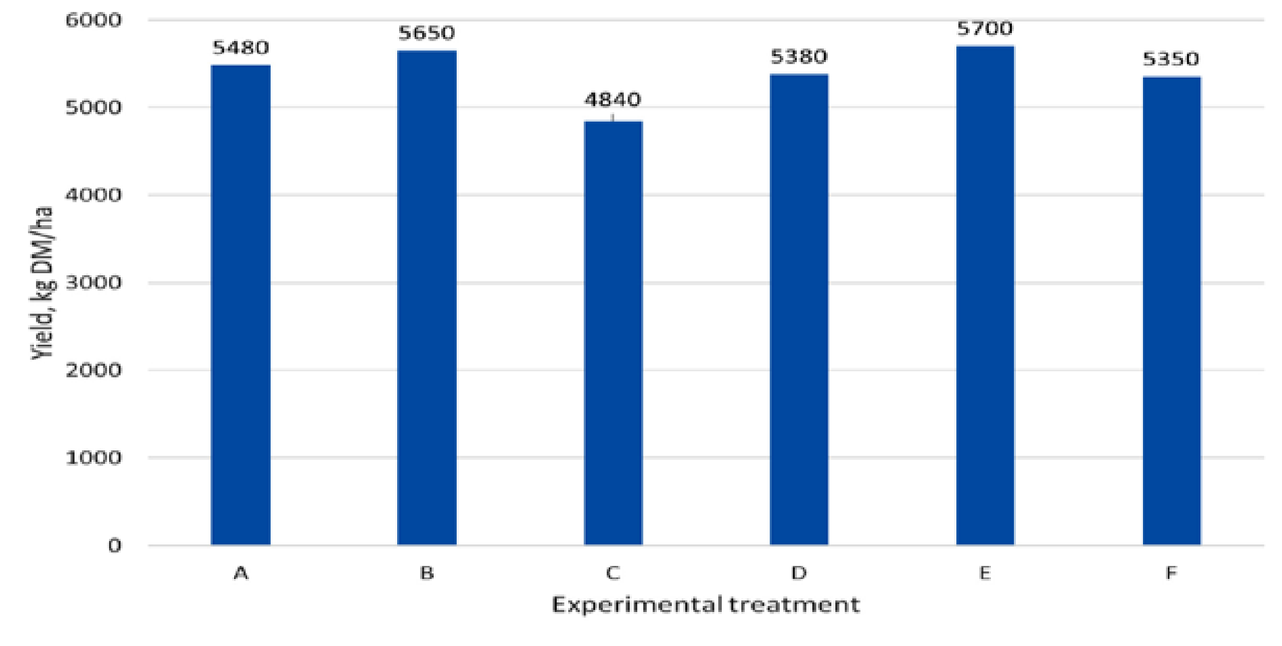

Figure 7. *Yields, averages of four repetitions.*

Discussion

At acidification, 3.25 liters of concentrated sulphuric acid per ton of slurry was added which resulted in reduction of the pH-value from 7.0 to 6.4. These values can be compared to those measured at national field trials in Denmark in 2013 and 2014. Hereby when acidifying to pH 6.4, an average of 2.3 litres of sulphuric acid per ton slurry was used, while acidifying to pH 6.0 required 4 litres of acid per ton slurry (SEGES, 2015).

The titration prior spreading showed that the acid requirement was only 1.2 liters per ton to reach a pH of 6.0. One reason why the measured acid requirement at the titration was so low could be that slurry in the storage was not mixed before the samples were taken for titration.

Based on harvest data, it can be concluded that the supplied plant nutrients, either as mineral fertilizer or slurry, did not have any clear impact on the yield. And, consequently, no significant differences were established between untreated and acidified manure.

One of the reasons for the above would be the high base yield achieved in the control treatment, 5 480 kg / ha. The obviously good initial nutritional status of the experimental field reduced the potential for yield increases through the supply of additional nutrients.

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Furthermore, the lack of yield differences between the experimental treatments would be largely influenced by the dry weather that prevailed during the experiment. The total accumulated rainfall, 53 mm, represented only half of what is normal in the area (SMHI, 2018 a). The amount of available water at the test site therefore seems to have had a greater influence on the crop growth than the applied plant nutrients.

In this context, it should also be emphasized that prevailing soil and weather conditions at the test site greatly favored the growth of clover and alfalfa at the expense of grass. As legumes have ability to fix nitrogen from the air, a high proportion of legumes would be expected to level out some of the effects of various nitrogen supply.

Regarding the different proportion of legumes observed in the experimental treatments, it to some extent followed an expected pattern. Namely, that at an increasing nitrogen supply increased the grasses' relative competitiveness.

In the present study, ammonia losses were not measured. However, it is well established that acidifying slurry to pH below 6.4 can decrease ammonia loss from the spread slurry (SEGES, 2015). In a previous Swedish study on the effects of slurry acidification a reduction of ammonia emission by 50 to 75% was achieved (Rodhe et al., 2015). In the present study, weather observations indicated conditions that favored ammonia losses. However, since the differences in applied amounts of plant nutrients did not result in any clear results in terms of growth and yields, it was either not possible to estimate an eventual reduction of ammonia emissions because of the acidification.

The outcome regarding the compared sampling devices from the slurry tank, i.e. no differences were observed, suggests that similar conditions regarding pH values occurred immediately below the surface of slurry and in more central parts of the lot.

Conclusions 2017

1. At acidification, 3.25 liters of concentrated sulphuric acid per ton of slurry was added which resulted in reduction of the pH-value from 7.0 to 6.4.
2. Weather conditions during spreading and the following days indicated conditions that favored ammonia losses.
3. Supplied plant nutrients, either as mineral fertilizer or slurry (untreated as well as acidified), did not have any clear impact on the yield.
4. The unclear effect of added plant nutrients may have been caused by initially good plant nutrient status of the experimental field and by the dry weather during the actual period.
5. Extensive growth of clover and alfalfa leveled out some of the effects of various nitrogen supply.
6. Regarding devices for sampling of slurry from the tank of the trial spreader, no differences in the readable pH-values between a captured sampler and an open one were observed.

Reporting sheet: 2017, grassland *(please, activate the link below)*
https://www.dropbox.com/s/mar4gl0pem8das8/Sweden%20Reporting%20Form%202017%20October%207th%202017.xlsx?dl=0

2018, grassland

Slurry acidifying

Acidification was performed in a separate tank on 14th June, i.e. the day before spreading. The addition of acid was done from 15.30 to 18.45.

The tank was 100 cm high and had a total volume of 2.8 m^3. Into the tank 2.2 m^3 of slurry was filled, giving a filling height of 80 cm.

For the acidifying acid was refilled from the five-litres plastic cans into a slightly larger one. This can was in turn placed on a platform scale and connected to an electric pump, manufactured by Clipton and dimensioned for pumping acids (Cliptonpumpen, 2017). Acid was then pumped through a hose that was attached to an iron pipe, directed towards the central parts of the tank. An electric driven stirrer was used for mixing acid into slurry, Figure 1.

Figure 1. *Acidification was performed in a separate tank the day before spreading. An electric driven stirrer was used for mixing acid into slurry. Photo: Marianne Tersmeden*

The extensive foaming that occurred limited the acid addition tempo. No foaming inhibitor was added.

During the addition of sulphuric acid, slurry temperature and pH were measured at approximately ten-minute intervals. A digital measuring device with an associated sensor was used for this purpose. The sensor was immersed into slurry at which temperature and pH could be read (Figure 3). Between measurements the sensor was cleaned in deionized water. The instrument, Hanna Instruments model HI 83141, was used in field as well as in laboratory.

Slurry spreading

Slurry was spread on 15th June, on the stubble after the first harvest. The process began by mixing slurry in the slurry storage with a propeller stirrer. When slurry was considered homogeneous, about 2.5 m^3 was filled into the experimental spreader.

Before slurry spreading started, a sample was taken from the experimental spreader to determinate the content of ammonium nitrogen in slurry. The sample was taken with a vessel through the top inspection opening, and then analyzed in-field using a nitrogen-meter manufactured by Agros (the same as in 2016, 2017). Based on this result, the slurry application rate was calculated to achieve the targeted nitrogen application rate.

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Before spreading, samples of untreated as well as acidified slurry were taken for standard manure analyses (DM, TN, TAN, Organic N, C, P, K, S, Na, Ca, Mg) plus pH. Slurry samples were sent to the laboratory Agrilab, Uppsala on 20th September.

Spreading of untreated slurry was performed from 10.00 to 10.10. Before spreading in the plots, a calibration of the slurry flow was made on the surrounding field.

The trial spreader was equipped with a band spreading ramp with nozzles that were adjusted to a height of some centimeters above the ground level, Figure 2.

Figure 2. *The experimental spreader placed slurry in bands on the ground. Spreading of untreated slurry. Photo: Gunnar Lundin*

Before filling of the experimental spreader with acidified slurry, it was once again stirred and pH was measured, Figure 3.

Figure 3. *Stirring of acidified slurry and measuring of pH just before spreading. Photo: Gunnar Lundin*

Spreading of acidified slurry was performed from 11.05 to 11.15, Figure 4.

Figure 4. *Spreading of acidified slurry. Photo: Gunnar Lundin*

Mineral fertilizer spreading

On the same day as slurry was spread, also mineral fertilizer was added to the experimental treatments A - D. This spreading was performed from 12.30 – 13.00, Figure 5.

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Figure 5. The application of mineral fertilizer was performed with an experimental spreader. Photo: Gunnar Lundin

The composition of mineral fertilizers is given in Table 1.

Table 1. Plant nutrient content in mineral fertilizers used for the second cut according to data from the manufacturer Yara

Fertilizer	Plant nutrient content, %				Experimental treatment
	N	P	K	S	
PK 11 - 21	-	11,0	21,0	1,5	A - D
N 27	27,0	-	-	-	B - D

Weather data

To assess the potential for ammonia emissions, air temperature and wind speed data were obtained from the nearest meteorological station from the day of spreading and five following days. Precipitation was registered on site by the trial host.

Irrigation

The experimental plots were irrigated on 17th July, Figure 6. The rate was 35 tons of water per hectare which corresponded to a precipitation of 3.5 mm. Due to difficulties of getting water, no further irrigation was performed.

Crop development

Between the slurry application and the harvest, the experimental field was inspected on 11th July and on 14th August for documentation of crop growth. Photos of each experimental treatment were taken and at the last visit also crop heights were measured. The measurements of heights were performed at four places in each experimental plot.

Figure 6. Irrigation of the experimental field on 17th July. For this purpose, a slurry spreader equipped with trailing hoses was used. Photo: Anders Ringmar

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Harvest

The crop was harvested on 29th August with a plot harvester. The harvested area of each plot was 1.2 * 9.8 meters i.e. 11.8 m^2. The yield was recorded and samples were taken from each plot for determination of protein and dry matter content.

Results

Slurry titration and acidification

The titration of the slurry sample taken on 12th June showed that 3.9 liters of sulphuric acid (96%) per ton slurry was required to reduce the pH value from 7.2 to 6.0

At acidification on 14th June, 4.2 litres per ton slurry was added which decreased pH from 7.1 to 6.0. The day after, just before spreading, the pH value was 6.1.

Slurry spreading

The in-field analysis performed with Agro's nitrogen meter showed an ammonium nitrogen content of about 2.5 kg / ton. The required slurry needed to reach 60 kg N / ha was calculated from this measurement and according to the expression:

$$60\ kg/ha \big/ 2.5\ kg/ton = 24\ ton/ha$$

This rate was then used at the spreading.

The results from laboratory analysis regarding untreated and acidified slurry respectively are shown in Table 2.

Table 2. *Results from the analysis of slurry samples performed by Agrilab, Uppsala. Unit, if not otherwise stated within brackets = kg/ton slurry*

Parameter	Untreated slurry	Acidified slurry
Dry matter (%)	7.7	8.0
Total nitrogen	4.3	4.7
Organic nitrogen	1.9	2.2
Ammonium nitrogen	2.3	2.4
Total carbon	36.5	35.0
Tot-C / Tot-N (ratio)	8.5	7.5
Total phosphorus	0.57	0.57
Total potassium	4.08	3.93
Total magnesium	0.52	0.51
Total calcium	1.48	1.49
Total sodium	0.2	0.19
Total sulphur	0.52	2.67
Loss on ignition (% of DM)	81.2	77.9
pH (value)	7.2	6.4

Supplied plant nutrient rates for all treatments are shown in Table 3. Regarding the nutrient content in the mineral fertilizer, data from the manufacturer (Table 1) were used to calculate the rates. For the experimental treatments with slurry, values from the laboratory analyses in Table 2 were used.

Table 3. *Supplied rates of plant nutrients to the second cut. In the experimental treatments with slurry, the nitrogen supply refers to ammonium*

Exp. treatment	Plant nutrient type	Rate, kg/ha				Remark
		N	P_2O_5	K_2O	SO_4	
A	Mineral fertilizer PKS	-	96	96	17	Control
B	Mineral fertilizer NPKS	30	96	96	29	
C	Mineral fertilizer NPKS	60	96	96	42	
D	Mineral fertilizer NPKS	90	96	96	54	
E	Slurry, untreated	55	31	118	37	ammonium-N
F	Slurry, acidified	58	31	113	192	ammonium-N

Weather data

Precipitation as well as average wind speed and temperature during the first six days of the field experiment are shown in Table 4.

Table 4. *Precipitation, average wind speed and temperature at the day for slurry spreading and the five following days*

Parameter	Day in June					
	15	16	17	18	19	20
Precipitation, mm	0	0	0	1	1	0
Average wind speed, m/s	3.7	1.7	1.7	3.5	5.1	3.4
Average air temperature, °C	18	17	16	16	17	14

Total precipitation during the field trial (June 15th - Aug 29th) amounted to 117 mm. Until 28th July the corresponding value was 14 mm.

During the field trial, daily average temperatures were according to below (°C, means per period, SMHI 2018 b).

June 15-31: 15.5
July 1-31: 21.0
August 1-29: 17.6

These values can be compared to normal daily average temperatures in this region according to below (°C, means per month, SMHI 2018 b).

June 1-30: 15.0
July 1-31: 16.4
August 1-31: 15.2

Crop development

Figure 7 and Figure 8 show examples of crop appearance on 11th July.

Figure 9 shows examples of crop appearance on 17th August.

Results from the measurements of crop heights are shown in Figure 10.

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Figure 7. *Field inspection on 11th July. Experimental treatments control to the left and acidified slurry to the right of the marking stick. Photo: Gunnar Lundin*

Figure 8. *Field inspection on 11th July. Untreated and acidified slurry to the left and to the right respectively. Photo: Gunnar Lundin*

Figure 9. *Field inspection on 17th August. Untreated and acidified slurry to the left and to the right respectively. Photo: Gunnar Lundin*

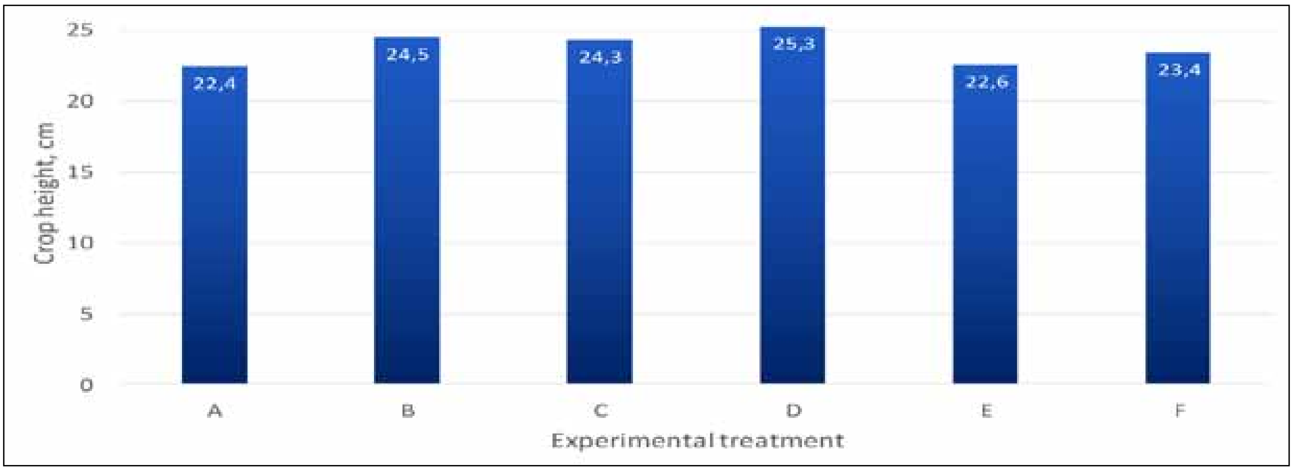

Figure 10. *Crop heights at field inspection on 14th August.*

Harvest

The outcome at harvest is presented in Table 5 and Figure 11. Regarding the dry matter yields there were no significant differences between the experimental treatments. Furthermore, it could be concluded that variations between the repetitions were extensive.

Table 5. *Yields (DM and nitrogen), protein contents and nitrogen efficiencies Averages of four repetitions*

Exp. treatm.	Yield, dry matter		Yield, nitrogen		Protein content, % of DM	Nitrogen efficiency[1)] Kg DM/kg N
	Kg DM/ha	Relative number	Kg N/ha	Relative number		
A	2 430	100	66.8	100	17.2	
B	2 740	113	76.7	115	17.5	10.3
C	2 890	119	88.4	132	19.1	7.7
D	3 140	129	97.3	146	19.4	7.9
E	2 240	92	67.2	101	18.8	-3.2
F	2 440	100	67.6	101	17.3	0.2

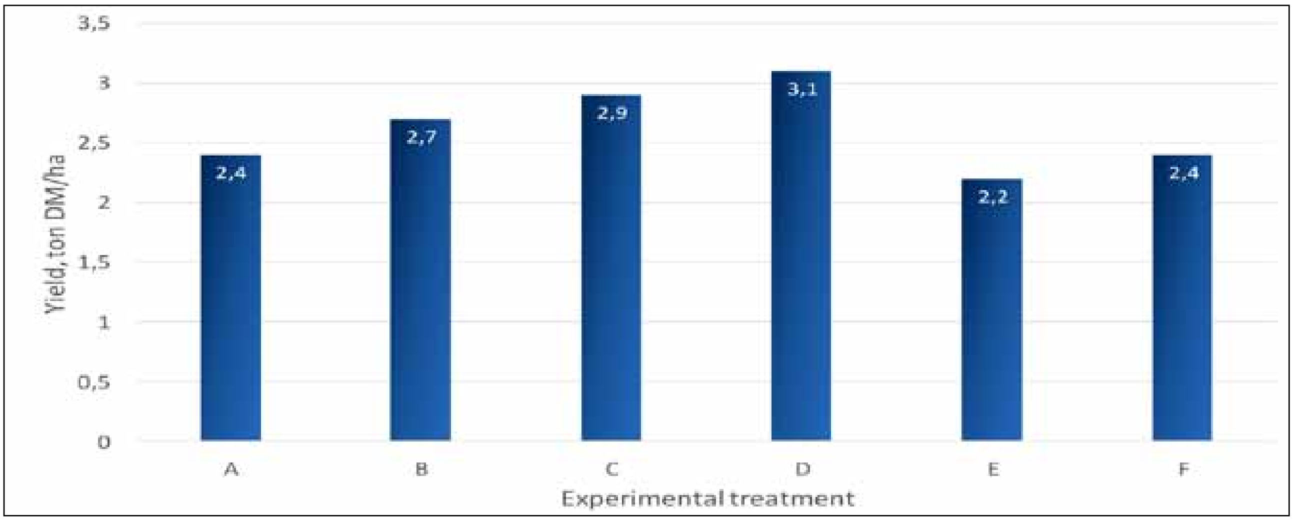

Figure 11. *Yields, averages of four repetitions.*

[1)] Nitrogen efficiency: (kg DM in actual experimental treatment - kg DM in control) / kg supplied nitrogen

The values in Table 5 show that the acidification resulted in a yield increase of 200 kg DM / ha (i.e. +8%), compared to untreated slurry.

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Discussion

The titration (June 12th) and the acidification (June 14th) showed that acid requirement was 3.9 and 4.2 liters respectively per ton slurry to reach pH of 6.0. These values correspond quite well to those measured at national field trials in Denmark in 2013 and 2014, where acidification to 6.0 required on average 4 litres acid per ton slurry. Acidifying to pH 6.4 required in the Danish trials 2.3 litres per ton slurry (SEGES, 2015).

The yields in this field trial only amounted to about half of what is normal in the region. This outcome was mainly due to the dry and extremely warm weather that prevailed during the main parts of the growing season. As an example, the average daily temperature in July and August exceeded the normal values with 4.6 and 2.4 degrees respectively.

Some yield differences between the treatments could be observed, however they were not significant. The lack of significance was related to the extensive variations between the repetitions, especially regarding the plots fertilized with slurry.

Regarding the treatments with mineral fertilizer, the yields increased with increasing nitrogen fertilization. Furthermore, some increases in protein content were achieved at increasing nitrogen rates. The nitrogen efficiency for the mineral fertilized treatments corresponded to slightly more than 30 kg dry matter per kg applied nitrogen.

Concerning the treatments with slurry, there were no yield increases compared to control treatment. Furthermore, the yield differences between the both slurry treatments were very small. Indeed, the dry matter yield was 8 % higher with acidified slurry than with untreated slurry, however from a very low level; the nominal yield increase was just 200 kg per hectare. On the other hand, protein content was a bit higher in the crop fertilized with untreated slurry which meant that the nitrogen yields were the same for both treatments.

In the present study, ammonia losses were not measured. However, it is well established that acidifying slurry to pH below 6.4 can decrease ammonia loss from the spread slurry (SEGES, 2015). In a previous Swedish study on the effects of slurry acidification, a reduction of ammonia emission by 50 to 75% was achieved (Rodhe et al., 2015). In the present study, weather observations indicated conditions that would favor ammonia losses. However, since the outcome differences between slurry treatments were so limited, it was not possible to estimate an eventual reduction of ammonia emissions caused by the acidification.

Conclusions 2018

1. At acidification, 4.2 liters of concentrated sulphuric acid per ton of slurry resulted in a reduction of the pH-value from 7.1 to 6.0.
2. The yields were only about half of what is normal in the region, mainly due to dry and extremely warm weather.
3. Registered yield differences between the treatments were not significant. This was related to extensive variations between the repetitions, especially regarding the plots fertilized with slurry.
4. Dry matter yields and protein contents increased with increasing mineral nitrogen fertilization rate.
5. No yield increases compared to control were achieved by fertilizing with slurry, either untreated or acidified.

6. The dry matter yield was 8 % higher with acidified slurry than with untreated slurry, however from a very low level. On the other hand, the nitrogen yields were the same for the both treatments.
7. Prevailing weather conditions indicated conditions that favored ammonia losses. However, because of the limited outcome differences between slurry treatments, it was not possible to estimate an eventual reduction of ammonia emissions caused by the acidification.

Reporting sheet: 2018, grassland *(please, activate the link below)*
https://www.dropbox.com/s/g7losz4s60htkqg/Sweden%20Reporting%20Form%202018%20November%2014th%202018.xlsx?dl=0

Conclusions

In two of the three years with field trials in grassland, acidification of slurry increased dry matter yield with 8% compared to untreated slurry. One year, the dry matter yield when using acidified slurry was 6% lower than for non-acidified slurry. However, none of these differences were statistically significant.

The nitrogen uptake efficiency for acidified slurry was higher than non-acidified in two of the three years, and lower in one year.

To summarize, the experiments showed a slight trend towards increased nitrogen utilization in two of the three years.

References

Cliptonpumpen. 2017. http://www.clipton.com/HomeGB/Contact-us/contact-us.html. (Brought 2017-03-02).

Hannainstruments. 2017. http://www.hannainstruments.co.uk/hi-2002-02-edge-reg-ph-hybrid-meter.html (Brought 2017-04-10).

Lantmet. 2018. http://www.ffe.slu.se/lm/LMHome.cfm?LMSUB=0&ADM=0 (Brought 2018-10-26).

Rodhe, L. S.; Delin, S.; Oostra, H. K.; Gustafsson, K. 2015. Acidification of cattle slurry – effect on ammonia emissions and nitrogen fertilizer replacement value of spreading non-digested and digested slurry on grassland. Ramiran2015, Hamburg, www.ramiran.net.

SEGES. 2015. Status, economy and consideration by acidification of slurry. Original report from SEGES in Danish. Translated to English and edited by Erik Sindhöj, RISE. Baltic Slurry Acidification. Interreg Baltic Sea Region.

SMHI 2018 a. Swedish Meteorological and Hydrological Institute. http://www.smhi.se (Brought 2018-07-03).

SMHI 2018 b. Swedish Meteorological and Hydrological Institute. http://www.smhi.se/klimatdata/meteorologi/temperatur/dataserier-med-normalvarden-1.7354. (Brought 2018-10-26).

Värmlant. 2017. Plant nutrient content in various mineral fertilizer products. http://www.varmlant.se/sv/vaxtodling_vaxtnaring_mineralgodsel.html (Brought 2017-03-02).

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Report of The Rural Economy and Agricultural Society

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Summary

Within the EU-project Baltic Slurry Acidification, field-trials with liquid manure and digestate where pH is reduced through the addition of sulfuric acid are performed from 2016 till 2018 in the countries around the Baltic Sea.

The Swedish field trials in the BSA project started in 2016. The objective was to clarify to what extent the acidification of cattle slurry improves nitrogen utilization when spread on ley. As a complement to that question a field trial showing the effect of acidification of digestate on spring barley and a field trial in Halland where one question was wether phosphorus becomes more available for maize if slurry is acidified was performed 2018.

The field trial with digestate and spring barley was carried out on a crop production farm outside Västerås called Brunnby. The experiment was designed as a randomized block design with four repetitions for each treatment. The nitrogen utilization for acidified digestate was compared to untreated digestate and to three mineral fertilizer treatments with stepwise increasing nitrogen application rates.

The digestate had a dry matter content of about 6.4 %. When acidifying the digestate, 5,47 liters of concentrated sulfuric acid per ton of digestate were added which lowered the digestate pH from 8,4 to 6.0.

Both untreated and acidified digestate was band spread at a rate of 24 tons per hectare on 24th May. Weather observations during spreading and the following days indicated conditions that favored ammonia losses.

The field trial was harvested on 23th August. Supplied plant nutrients had effect on the yield, both as mineral fertilizer or digestate (untreated as well as acidified). The yield increased with 120 kg/ha and the N-uptake in the grains was 3.3 kg higher with acidified slurry. The control yield was 4550 kg/ha and the yield was 1790 resp 1910 kg/ha higher for untreated resp acidified digestate.

Background

Within the EU-project Baltic Slurry Acidification, field-trials with liquid manure and digestate where pH is reduced through the addition of sulfuric acid are performed from 2016 till 2018 in the countries around the Baltic Sea. The goal of these trials is to increase the knowledge about the effect of slurry acidification on crop nutrient utilization. In the present report, experiences and results from the field trial in barley performed in Sweden 2018 are presented.

Aim

The aim of the study was to examine to which extent the acidification of digestate improves the nitrogen uptake when spread on spring barley.

Material and methods

The experiment was carried out at Hushållningssällskapets field trial farm Brunnby, east of Västerås. Soil at the experimental site was classified as a clay soil and the crop rotation consisted of 3-4 years of winter wheat and barley followed by winter rape seed.

Soil analysis	20-09-2017	Ca-AL	mg/100 g soil	275
		K-AL	mg/100 g soil	13,7
		Mg-AL	mg/100 g soil	41,9
		P-AL	mg/100 g soil	4,5
		PH		5,9
		HUMUS	% in soil 0-25 cm	5,2
		CLAY	% in soil 0-25 cm	42

The current crop was spring barley, seeded on 9th May. Slurry or other organic fertilizers have not been used the last 15 years at the field. Nitrogen, phosphorus, potassium and sulfur were supplied as mineral fertilizer. The pre-crop was winter wheat, which gave a good yield.

The experiment was designed as a randomized block design with four repetitions for each treatment. There were six treatments: untreated digestate, acidified digestate, three step-wise increasing levels of mineral nitrogen and a control (Table 1). Plot size was 3 x 12 meters and there was a total of 24 plots.

Table 1. *Trial design. In the experimental treatments with digestate the nitrogen application refers to the amount of ammonium nitrogen. (Field trial scheme)*

Treatments	Fertilization (description)	N (mineral fertilisers, kg/ha; NH4-N (in manure, kg/ha)	P (P_2O_5) kg/ha	K (K_2O) kg/ha	S (SO4), kg/ha
Mineral fertilizer (Control)		0	0	0	0
Mineral fertilizer	NPK 22-6-6, NS 27	40+30	25	13	28
Mineral fertilizer	NPK 22-6-6, NS 27	40+70	25	13	45
Mineral fertilizer	NPK 22-6-6, NS 27	40+110	25	13	62
Untreated digestate	NPK 22-6-6, Digestate	40+105	83	95	61
Acidified digestate	NPK 22-6-6, Acidified Digestate	40+105	83	95	326

The step-wise mineral fertilizer treatments were included to estimate the effects of different weather conditions between years on the crop nitrate usage. Crop requirements of phosphorus, potassium and sulfur were added to the plots so that nitrogen would be the limiting factor in the field trial.

Specifications for sulfuric acid and safety issues

Concentrated sulfuric acid (96%) was used to acidify slurry. The density was 1.84 kg/l. Acid was packaged in five litres plastic cans that had been transported to the experimental farm by the acid distributor.

All the staff that handled the sulfuric acid in the experiment had undergone safety training and was equipped with protective clothing and respiratory protection in the form of a full-face mask. The staff had also previously been involved in similar experiments with slurry acidification, so they were experienced in the safety procedures.

The handling of sulfuric acid, as it was applied in the trial, forced rigorous safety arrangements. Such manual handling should never be recommended to farmers.

Titration

The digestate was never titrated ahead of the acidification.

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2018, spring barley

Digestate spreading

The digestate was spread on 24th May, straight on soil in between the rows of the crop. The spring barley was in BBCH 21. The process began by adding fresh digestate from the biogas plant into a small slurry storage container, ca 2 m^3. Digestate was mixed with a propeller stirrer. When digestate was homogeneous, an IPC-tank was filled with digestate.

After that the rest of the volume in the container was acidified. Sulfuric acid 96% was used and 5,47 l acid/m^3 digestate was needed to lower pH from 8,4 to pH 6,0. Acid was added to digestate through a plastic hose and an electric pump. During the addition of sulfuric acid, slurry temperature and pH were measured at approximately ten-minute intervals. A digital measuring device with an associated temperature/pH sensor was used for this purpose. This instrument, Hanna Edge model HI – 2002, was used in field as well as in the laboratory (Hannainstruments, 2017).

Digestate was mixed meanwhile. After digestate had reached pH 6, an IPC-tank was filled. Limited foaming occurred, but nothing that paused the process.

The two IPC-tanks were brought to the field.

- While spreading untreated as well as acidified digestate samples were taken for standard manure analyses (DM, TN, TAN, Organic N, C, P, K, S, Na, Ca, Mg) plus pH. The samples were brought to the laboratory Agrilab, Uppsala on May 25th. They were stored in a fridge over the night.
- Digestate was spread by hand with a water pitcher, imitating a trailing hose system.
- Non-acidified digestate was spread first, it took about 40 minutes.
- Acidified digestate was spread after that, but as it had sedimented and the organic matter plugged the bottom tap, it had to be tilted before digestate started to flow from the tap. Because of this the organic matter was not homogenous in the sample.

As slurry samples were taken from the spreader tank, the sensor was immersed into the sampling vessel so that the temperature and pH could be registered. The sensor was rinsed in deionized water between measurements.

To assess the potential for ammonia emissions, air temperature and wind speed data were collected from the nearest meteorological station from the day of spreading and five following days. Precipitation was registered on site by the trial host.

Mineral fertilizer application and irrigation

Mineral fertilizer NPK 22-6-6 was applied corresponding to 40 kg nitrogen to all plots except the control, as the barley was seeded. The day after digestate was applied (May 25th) plot 2, 3 and 4 received 30, 70 and 110 kg N as NS 27-4. No rain or dew fell in between the two occasions.

The field trial was irrigated on 29th May with 15 mm, to make sure that digestate was washed down and fertilizer melted down in the soil profil.

Table 1. *Plant nutrient content in the mineral fertilizer used in the trial according to data from the manufacturer Yara*

Fertilizer	Plant nutrient content, %				Experimental treatment
	N	P	K	S	
PK 22-6-6	21,6	5,9	5,8	3	A - D
NS 27- 4	27,0	-	-	3,7	B - D

Crop development and harvest

Between the slurry application and the harvest, the experimental field was visited on 3th July for documentation of crop growth. All plots were measured with a handheld Yara N-tester and a Green seeker and the nitrogen uptake was calculated from those values with a simplified equation;

N uptake = Yara N-tester value x Green Seeker value x 0,2.

Table 2. *Values from Yara N-tester and Green Seeker measured 3rd July*

	Yara N-Tester (value)	NDVI-reflectans (value)
1	462	0,533
2	601	0,725
3	609	0,765
4	639	0,785
5	583	0,695
6	598	0,725

Development of the plots was very good compared to the spring barley in the district. It was possible with the bare eye to notice a difference in length, dense and green colour between the control, plot 4 with the highest N-additive and the rest of the plots.

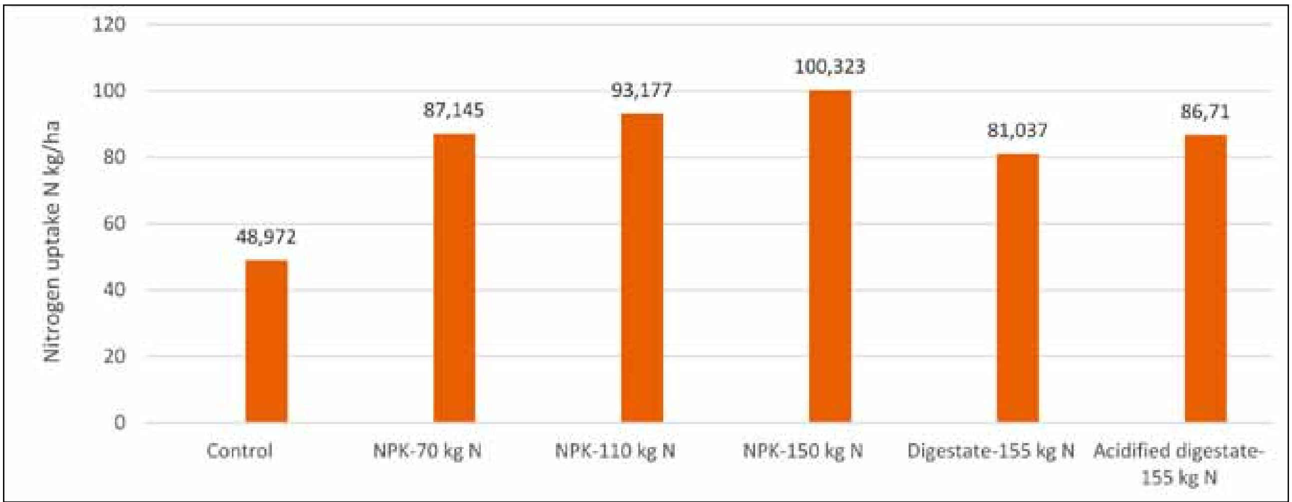

Diagram 1. *Calculated nitrogen uptake from handheld Yara N-tester and Green Seeker values from 3rd July.*

The experimental plots were harvested on 23th August. The yield was recorded and samples were taken from each plot for determination of yield, 1000 grain weight, crude protein and dry matter content. The N-content was calculated.

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Results

Digestate spreading

The pH-value in the untreated digestate, measured with the digital device before spreading, was 8.3.

The nitrogen content in digestate was much higher than the beforehand given value from the farmer, 2.5 kg N/ton. The required slurry needed to reach 60 kg / ha was calculated from this measurement and according to the expression: = *24 t/ha.* This rate was then used at the spreading.

The remaining amount of digestate in the container after the untreated digestate was pumped into the IPC-tank was 1.46 m^3. In total 8.0 l of sulfuric acid were added corresponding to 5,47 litres per ton of digestate. pH was stabilized at 6.0. The digestate was spread 2 hours later and no pH was measured at that time. Digestate was kept in a closed IPC-tank during those hours.

Acidified digestate sample that was analyzed at the end of September had a pH of 6.5 (Table 3).

Table 3. *Results from the analyses of digestate samples performed by Agrilab, Uppsala. Unit if not showed within brackets = kg/ton slurry*

	Untreated digestate	Acidified digestate
Dry matter (%)	6,4	6,8
Total nitrogen (kg/ton)	6,0	8,5
Organic nitrogen (kg/ton)	1,7	3,8
Ammonium nitrogen (kg/ton)	4,3	4,7
Total carbon (kg/ton)	27,1	22,8
Tot-C/Tot-N (ratio)	4,5	2,7
Total phosphorus (kg/ton)	0,66	0,64
Total potassium (kg/ton)	2,38	2,51
Total magnesium (kg/ton)	0,57	0,56
Total calcium (kg/ton)	1,30	1,30
Total sodium (kg/ton)	0,58	0,61
Totalt sulfur (kg/ton)	0,40	4,08
pH (value)	8,4	6,5

Supplied plant nutrient rates for all treatments are shown in Table 4. Regarding the nutrient content in the mineral fertilizer, data from the manufacturer was used (Table 2) to calculate the rates. For the experimental treatments with slurry, values from the laboratory analyses in Table 3 were used.

Table 4. *Supplied rates of plant nutrients to the second cut. In the experimental treatments with slurry, the nitrogen supply refers to ammonium*

Exp. treatment	Plant nutrient type	Rate, kg/ha				Remark
		N	P	K	S	
A	Mineral fertilizer control	-	-	-	-	Control
B	Mineral fertilizer NPKS	70	25	13	28	
C	Mineral fertilizer NPKS	110	25	13	45	
D	Mineral fertilizer NPKS	150	25	13	62	
E	Digestate, untreated	145	83	95	61	ammonium-N
F	Digestate, acidified	145	83	95	326	ammonium-N

Weather data

Temperature, precipitation and average daily wind speed for the first six days of the field experiment are shown in Table 5.

Table 5. *Precipitation, average wind speed and temperature at the day for slurry spreading and the five following days*

Parameter	Day in May					
	24	**25**	**26**	**27**	**28**	**29**
Precipitation, mm	0	0	0	0	0	0
Average wind speed, m/s	2.6	2.9	2.3	4.4	3.2	1.8
Average air temperature, °C	17.6	18.6	18	17.6	16.7	19.5

Total precipitation between the first and second cut (May 9th – September 4th) amounted to 54 mm.

Harvest

The outcome at harvest is presented in Table 6 and Diagram 2. Significant differences occurred for yield, protein content and N yield in grains. There were significant differences between the control and the rest of the treatments.

Table 6. *Yields, protein contents and nitrogen efficiencies, averages of four repetitions*

Experimental treatment	Yield,		Protein content, % of DM	N yield in grains
	Kg/ha 15% ts	**Relative number**		
1. 0 kg N	4550	100	9.8	60.6
2. 70 kg N	6660	146	11.3	102.6
3. 110 kg N	6830	150	11.6	108.3
4. 150 kg N	7200	158	12.7	124.6
5. 145 kg N untreated digestate	6340	139	11.2	97.1
6. 145 kg N acidified digestate	6460	142	11.4	100.4

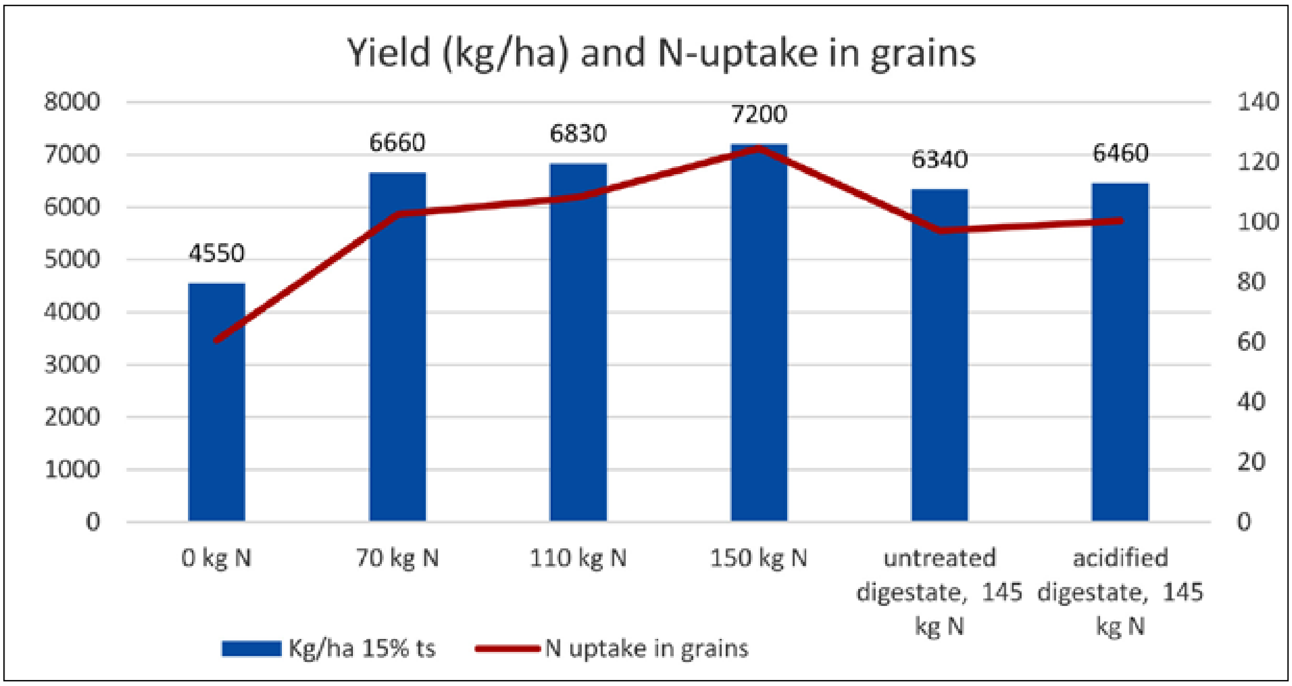

Diagram 2. *Yields and N-uptake in grains (kg/ha), averages of four repetitions.*

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Discussion

The amount of acid needed to acidify digestate was high, 5,47 l/m^3 to reach pH 6.0. In the project Baltic Slurry Acidification, many countries have had the same experience that digestate demands a higher acid amount than slurry. Less acid could have been used, to reach pH 6,4, but as it was unknown how fast digestate would buffer acid, pH 6 was chosen. As no pH was taken during spreading, we just know that the pH had increased to 6,5 when the digestate was analysed.

The results indicate that the field trial managed the extremely warm summer rather well. The control has an average yield of 4550 kg. The early irrigation with 15 mm might have compensated the lack of rain in the beginning of the summer as nitrogen has been available from both digestate and mineral fertilizer.

Based on harvest data, it can be concluded that the supplied plant nutrients had a clear impact on the yield. The mineral fertilizer was readably available compared to the digestate. That could be because half of nitrogen in NS 27-4 is nitrate nitrogen which binds loser to the soil particles. It can also be a question of concentration of nitrogen, as the concentration is higher where a fertilizer kernel melts compared to digestate that has contact with a bigger soil particle surface and therefore can bind the NH4-N harder.

In the present study, ammonia losses were not measured. However, it is well established that acidifying digestate to pH below 6.4 can decrease ammonia loss from the spread digestate (SEGES, 2015). In the present study, weather observations indicated conditions that favored ammonia losses. Yields and N- uptake in the grains one significantly different which indicates that untreated digestate might have had a higher ammonia loss than acidified digestate. As the differences is 120 kg/ha and 3.3 kg nitrogen uptake, it is not economically defensible this time to acidify digestate. The value of the harvest is 240 skr and the value of lost nitrogen is 33 skr but the cost of acid is ca 350 skr. As the mineral fertilized plots have received enough of sulfur, the sulfur value of acidified digestate does not reduce the cost of acid.

Conclusions

1. At acidification, 5.47 liters of concentrated sulfuric acid per ton of digestate were added which resulted in reduction of the pH-value from 8.4 to 6.0.
2. Weather conditions during spreading and the following days indicated conditions that favored ammonia losses.
3. Supplied plant nutrients, either as mineral fertilizer or digestate (untreated as well as acidified), had a clear impact on the yield.
4. Acidified digestate increased the yield by 120 kg/ha compared to untreated digestate.
5. Acidified digestate increased N-uptake in the grains by 3.3. kg compared to untreated digestate.
6. 105 kg NH4-N/ha was added as digestate which gave a yield in the same sense as 30 kg NS 27-4 extra during this dry year.

Reporting form: 2018, spring barley *(please, activate the link below)*
https://www.dropbox.com/s/0m5c51ll5dq1m5f/Sweden%20FT_RF_SCIENTIFIC_2018%25281%2529%20HS%20konsult%20AB-1.xlsx?dl=0

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References

Hannainstruments. 2017. http://www.hannainstruments.co.uk/hi-2002-02-edge-reg-ph-hybrid-meter.html (Brought 2017-04-10).

SEGES. 2015. Status, economy and consideration by acidification of slurry. Original report from SEGES in Danish. Translated to English and edited by Erik Sindhöj, RISE. Baltic Slurry Acidification. Interreg Baltic Sea Region.

www.smhi.se. Swedish Meteorological and Hydrological Institute. 2018-12-19.

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Material about Informational event

Event: Brunnby lantbrukardagar 2018 (Agricultural fair).

Description: Brunnby lantbrukardagar is an important agricultural exhibition in Mälardalen in Sweden (central Sweden) with participants from sector of agriculture (farmers, machinery companies, other agricultural companies, authorities, advisory services etc.).

Date: 4-5.07.2018.

Place: Brunnby Gård, Sweeden.

Number of participants: More than 5000 person visited the field days.

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www.balticslurry.eu

Summary of the project

Baltic Slurry Acidification is an agro-environmental project financed by Interreg Baltic Sea Region under the priority area Natural resources and specific objective Clear Waters. The aim of the project is to reduce nitrogen losses from livestock production by promoting the use of slurry acidification techniques in the Baltic Sea Region and thus to mitigate eutrophication of the Baltic Sea. Baltic Slurry Acidification project was implemented in the period March 2016 - February 2019.

Summary of the report

The aim of this Report is to reach a broad base of farmers and other end-users in every country and to raise their awareness, increase knowledge, build confidence relating to the effects of slurry acidification technologies (SATs).

Nine project partners from seven countries organized Field trials. The report starts from Methodology of field trials. This is necessary to understand for a reader how the project partners understood and implemented their activities.

The results from every country are presented in separate chapters. The country's report starts from a table with information about activities that were carried out in Field trial on different crops, using different slurry type.

Every e-version of partners' report includes interactive content and a table with a possibility to be directed to the Field trials case of interest; the report also includes raw data of Field trials (an excel reporting form in activated link) provided at the end of every report (text).

Every partner's report ends with data about informational events that were organized in order to share knowledge about SATs.

The format of the report was a mutual decision and was implemented in close co-operation with partners.