Agronomic efficacy of nitrogen biobased fertilising products of co-digested pig manure

Field experiment silage maize 2019

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De doelstelling van het project KunstmestVrije Achterhoek (KVA) is het verduurzamen van de bemestingspraktijk door de bemesting van grasland en bouwland zo veel mogelijk in te vullen met regionaal beschikbare nutriënten. Het project is onderdeel is van het zesde Nederlandse actieprogramma in het kader van de Nitraatrichtlijn. Een van de doelstellingen betreft het bepalen van de agronomische effectiviteit van stikstof van stikstofhoudende bemestingsproducten gebaseerd op mest. Een tweede doelstelling het bepalen van enig risico op milieubezwaarlijkheid gelet op stikstof uitspoeling. Deze doelstellingen zijn door WUR-Wageningen Environmental Research uitgewerkt in een monitoringsprogramma met veldproeven op grasland en op maisland. Dit rapport geeft de resultaten van een veldproef met snijmais die in 2019 werd uitgevoerd op het proefbedrijf De Marke.

The aim of the project Biobased Fertilisers Achterhoek (in Dutch: Kunstmestvrije Achterhoek) is to make fertilisation practices more sustainable through use of locally available nutrients from renewable sources. The project is part of the Netherlands' sixth action programme serving the Nitrates Directive. One of the objectives is to determine the nitrogen fertiliser replacement value of biobased fertilising products made from animal manure. A second objective is to assess the risk of nitrogen leaching from these biobased fertilising products. These objectives have been implemented by WUR-Wageningen Environmental Research in a monitoring programme with field experiments on grassland and on arable land with silage maize. This document reports the results of a field experiment with silage maize in the year 2019. Field experiments on grassland and with silage maize on arable land will be continued in 2020.

Keywords: biobased fertiliser, mineral concentrate, ammonium sulphate, grassland, nitrogen fertilisers, yield, nitrogen uptake, nitrogen use efficiency, nitrogen fertiliser replacement value, environmental risk

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Photo cover: Silage maize

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Verification

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Approved reviewer who stated the appraisal,

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date: 15-09-2020

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date: 15-09-2020

Summary

The objective of the regional pilot Biobased Fertiliser Achterhoek (in Dutch: Kunstmestvrije Achterhoek (KVA) pilot) is to make fertilisation practice more sustainable by supplementing the fertilisation of nitrogen, potash and sulphur with regionally available nutrients as much as possible. The pilot is part of the Netherlands' sixth action programme serving the Nitrates Directive. One of the objectives is to determine the nitrogen fertilising replacement value of nitrogen of biobased fertilising products made from animal manure. A second objective is to assess the risk of leaching of nitrogen from these biobased fertilising products. These objectives have been elaborated in a monitoring programme by WUR-Wageningen Environmental Research (WUR-WENR). One part of the monitoring programme involve field experiments on grassland and with silage maize on arable land.

The monitoring programme started in 2019 with a field experiment on arable land with silage maize. This document constitutes a report of this field experiment. Two types of biobased fertilising products were tested. Both consist of a mineral concentrate made from co-digested pig-slurry enriched with nitrogen from condensated ammonia water. One type (BBFa+) had 6% concentrated ammonia water added, a second type (BBFb) had 1% concentrated ammonia water added. The field experiment on sandy soil served two objectives:

1. Agronomic effectivity: Determining the Nitrogen Fertiliser Replacement Value (NFRV) of the biobased fertilising products by means of field experiments;
2. Environmental risk assessment: Determine and compare the risk on nitrate leaching when using nitrogen biobased fertilising products as a substitute for mineral (synthetic, chemical) nitrogen fertilisers.

The climate in 2019 was dry with elevated temperatures which made sprinkler irrigation necessary.

The type of fertilising product had an effect on the number of plants at harvest; the application rate did not have an effect. Biobased fertilising product ammonium+ (BBFa+) had a significantly lower number of plants than other treatments. BBFa+ showed further higher values for the standard deviations than other treatments and thus had more variation. The lower number of plants is contributed to ammonium toxicity.

The dry matter yield was 15.8 ton/ha on average and varied from 7.3 to 19.3 ton dry matter/ha. Overall, there was some evidence that an increase in nitrogen application rate increased dry matter yields but variation between replications was of a similar magnitude as found in the differences between the treatments. Effects of fertilising product or application rate were therefore not significantly different between the treatments.

Nitrogen uptake of the whole plant averaged 179 kg N/ha and ranged from 92 to 225 kg N/ha. Without nitrogen application (0 kg N/ha), the nitrogen uptake was 134 kg N/ha which was significantly lower than the uptake from the treatments with nitrogen fertilisation. Also, the nitrogen uptake of the 50% application rate treatment (177 kg N/ha on average) was significantly lower than the nitrogen application rate of 125% (on average 196 kg N/ha). Other differences were not significant.

Nitrogen Use Efficiency (NUE) values varied from 21% to 54% (Table 7) NUE declines with an increase of the application rate of nitrogen (CAN). With treatments NUE values varied which is reflected in the large value of the LSD. Differences between NUE values of the fertilising products are therefore not significant.

The Nitrogen Fertiliser Replacement Value (NFRV) was calculated for each fertilising product per application rate with CAN as the reference fertiliser. Due to the large variation NUE values, differences between treatments and application rates were not significant.

At the start, soil mineral nitrogen of the total amount in the soil layer 0 – 90 cm was 54 kg N/ha. After the harvest, soil mineral nitrogen was significantly different between fertilising product treatments and application rates. However, there is no indication that the new biobased fertilising product increases the risk of nitrate leaching.

A simple nitrogen sheet balance showed that the soil contribution due to mineralisation of organic nitrogen to crop’s nutrition with nitrogen had a similar magnitude as the nitrogen application rates of the fertilising products. Next, this contribution tended to decline with an increase of the nitrogen application rate. These two findings effected the NUE of the treatments.

1 Introduction

The quality of groundwater and surface water in the Netherlands has improved over the past decades[1], but requires further still improvement[2] (the Netherlands' sixth action programme Nitrates Directive 91/676/EEC[3]). The Netherlands' sixth action programme lists a number of measures that contribute to this further improvement. These measures include several pilot projects, one of which is the regional pilot Biobased Fertiliser Achterhoek (the Netherlands' sixth action programme, 5.5.3.3, Annex 1).

The main goal of the regional pilot Biobased Fertiliser Achterhoek is to investigate the processing of animal manure at a practical level. Different manure processing technologies are reviewed, and promising technologies are implemented in practice. The project will focus on the quality aspects of these new nitrogen (N)-fertilising products based on animal manure, specifically on nutrient levels (N, potassium; K, and sulphur; S), the agronomic effectivity, the level of contaminants (heavy metals, organic micro-contaminants, pathogens and other contaminants (New Emerging Contaminants (NEC)). These fertilising products will be monitored on composition, agronomic effectivity, and environmental effects in pilots within the sixth action programme. The aim is to generate products that meet the requirements of the revised EU fertilising products regulation for free trade EC/2019/1009 (currently focused on liquid inorganic NKS fertilising products: PFC1c) and criteria that will be set for RENURE[4] fertilising products within the context of the Nitrates Directive. In the project, individual factions of the fertilising products, such as the thick fraction, the clean water fraction, and other fractions will also be monitored for their nutrient and contaminant levels. This is a joint study by the province of Gelderland, LTO Noord Projects, ForFarmers, 'Vruchtbare Kringloop Achterhoek en Liemers' and Wageningen University. There is regional cooperation with a large number of actors involved in the processing of manure at the practical level.

More specifically, the following objectives have been formulated in the regional Biobased Fertiliser Achterhoek pilot to find solutions for the manure problem:

- Inform, support, and facilitate local land users in their efforts to find circular solutions for manure and mineral-related issues at their companies. Here, knowledge from the various "manure projects" in the province is explicitly included;
- Identify the desired quality and composition of fertilising products from animal manure and sludge, becoming available for the market product by best available techniques for manure and sludge processing;
- Advise manure processors, sludge processors and water boards on the desired product (quality), so that a market-oriented offer is created;
- Create legal space for integral sustainable solutions for the use of minerals in the vegetable and arable production areas and in the animal sector with grassland and arable land for fodder crops. As a matter of policy, manure and products from manure and sludge must be positioned as valuable secondary raw materials for a circular agricultural practice.

LTO-Noord is the project leader of the regional pilot Biobased Fertilisers Achterhoek. Wageningen Environmental Research (WENR[5]) supports this project with a monitoring programme. WENR's monitoring programme is focused on a safe introduction of N fertilising products in the Achterhoek by

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[1] https://www.eea.europa.eu/themes/water/interactive/by-category/nitrate-directive

[2] Van Grinsven et al, 2016.

[3] EC Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates for agricultural sources.

[4] RENURE stands for "REcovered Nitrogen from manURE". RENURE is proposed by JRC in its study SAFEMANURE. RENURE is defined by JRC as any nitrogen containing substance fully or partially derived from livestock manure through processing that can be used in areas with water pollution by nitrogen following otherwise identical provisions applied to nitrogen containing chemical fertilisers as defined in the Nitrates Directive (91/676/EEC), while ensuring the achievement of the Nitrates Directive's objective and providing adequate agronomic benefits to enhance plant growth.

[5] WENR is one of the research institutes of Wageningen University & Research.

comparing the nitrogen fertiliser replacement value (NFRV; a measure for N use efficiency) to that of regular mineral (synthetic, chemical) N fertilisers and by studying the risk of nitrate leaching.

WENR advices on desired product quality and product composition of fertilising products, and monitors using an assessment of their agricultural effectiveness, and the risk of associated nitrate leaching. The monitoring programme consists of five points:

1. Assessment of risks associated with blending of fertilising products based on animal manure, sewage sludge, and mixtures thereof;
2. Field experiments to be conducted in 2019, 2020 and possibly in 2021
3. Demonstration field trials to be conducted in 2018, 2019 and 2020
4. Annual technical reports on risk assessment, field experiments and demonstration trials
5. Synthesis report of point 1 – 4.

For the positioning of the N fertilising products based on animal manure within legal frameworks on the use of animal manure and mineral fertilisers, it is important to gain insight into the NFRV of biobased fertilising products from processed animal manure and their risk on nitrate leaching.

The demonstration field trials[6], point 3 of the monitoring programme, started in 2018. The results gathered from the demonstration fields in 2018 and 2019 have been reported (Ehlert & Van der Lippe, 2020a, 2020b). 2020 is the last year to utilise demonstration fields, and is currently in progress[7].

1.1 Objectives

The field experiments started in 2019 with one field experiment on grassland and one field experiment with silage maize. These field experiments have two objectives:

1. Agronomic effectivity: Determine the NFRV of the biobased fertilising products by means of field experiments;
2. Environmental risk assessment: Determine and compare the risk of nitrate leaching when using N biobased fertilising products as a substitute for mineral (synthetic, chemical) N fertilisers.

1.2 Hypotheses

Crop available N in this study is defined as the quantity of N that is released from a fertilising product during crop growth within a growing season. This quantity is commonly assessed by comparison of N uptake by a crop with N from a test-product amended plots with N uptake by the crop amended with mineral N fertiliser, while correcting for the quantity of N taken up from plots without N fertilisation. A parameter that expresses this quantity is the NFRV[8].

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[6] Demonstration field trials were established on ten grassland plots of dairy farms. The plots were split in two blocks one receiving a biobased fertilising product while the other received a blend of mineral NKS fertilisers. The application rate of N, K and S was based on regular fertiliser recommendations for grassland in the Netherlands based on soil testing. Grass yields were estimated by measuring grass height around 15 days after fertilisation and 10 days before the actual harvest. The quantity mineral nitrogen was measured in three soil layers (0-30, 30-60 and 60-90 cm) before fertilisation started and after the harvest of the last (fifth) cut. Grassland use followed agricultural practices in the Achterhoek where cattle slurries are used for fertilising three of the five cuts of grass. Therefore, the biobased fertilising product and the blend were additional fertilisers in the nutrient management plan based on regular soil testing. The application rates of the nutrients of these fertilisers were exactly the same. The nutrients of animal manure were taken into account in the nutrient management plan. The experience in 2018 was that the agronomic performance of the biobased fertilising product equalled the blend of mineral fertilisers in both yield and residual soil nitrogen after the last harvest. Therefore, application rates of the test products from biobased fertiliser production were equal to those of the mineral fertilisers. In 2019, the agronomic performance of the biobased fertiliser was lower than of the blend of mineral fertiliser but also the quantity of residual nitrogen was lower compared with the blend. Both 2018 and 2019 were years with periods of severe drought in the Achterhoek.

[7] Date of observation August 2020,

[8] Also called Mineral Fertiliser Equivalent (Jensen, 2013).

The NFRV depends of the four agronomic fertiliser value determining factors[9]

- Type of fertilising product,
  - ⇨ The more crop available N is present, the higher the NFRV becomes.
- Application rate,
  - ⇨ The efficacy of N taken up from a fertilising product decreases with an increase of the application rate.
- Method of application and method of placement of a fertilising product,
  - ⇨ Application methods that do not mitigate ammonia volatilization and denitrification will have a lower NFRV
- Application timing of a fertilising product,
  - ⇨ A period of application well before crop growth, increases the risk of nutrient losses to the environment (volatilization, denitrification, and leaching) and will lower the NFRV.

The NFRV and residual nitrogen in the soil after the harvest of silage maize are objects of this study. Determination of the NFRV requires a reference fertiliser. In the Netherlands calcium ammonium nitrate (CAN[10]) is used as the reference for assessing NFRV. CAN is a prilled fertiliser. Prilled fertilisers require a broadcasting fertilisation technique (blanket application). As biobased N fertilising products are liquids (or suspensions) and often consist mostly of ammonium N these fertilising products are commonly injected rather than broadcasted. Because this difference in application techniques can affect NFRV, injection of the liquid fertiliser urea-ammonium nitrate solution (UAN) is used as a second reference.

The following hypotheses have been formulated:

1. The magnitude of NFRV depends on the reference N fertiliser that is used;
2. Biobased fertilising products have a similar magnitude of NRFV of the reference fertiliser;
3. Biobased fertilising products have a similar effect on residual nitrogen after the harvest of silage maize as a regular nitrogen fertiliser at similar application rates.

In this study, two types of biobased fertilising products have been tested. A type with a higher N/S ratio (Biobased fertilising product ammonium+ (BBFa+)) and a type with a lower N/S ratio (Biobased fertilising product (BBFb)). These types have significance for fertilisation of grassland respectively in spring for the first two cuts (BBFa+) with a higher demand for sulphur and the following cuts (BBFb) with no demand for sulphur and were tailored made for this use. Secondary raw materials mineral concentrate and condensed ammonium water served as compounds for these biobased fertilising products. As one of the biobased fertilising products was enriched with 6% condensed ammonium water, it was expected that the high ammonium concentration would reduce efficacy with a higher risk on ammonia volatilisation. This product, BBFa+, was therefore also tested in a diluted form (at a product/water ratio of 2:1 (v/v)). This diluted product has the notation DBBFa+ (Table 1). This led to a fourth hypothesis:

4. In combination with cattle slurry, dilution of the Biobased fertilising product ammonium+ with water increases NFRV.

Mineral (synthetic, chemical) N fertilisers are used as a reference in the research reported here.

The field experiment on grassland ended prematurely due to animal activities (badgers) and an inconsistency in composition of some fertilising products. The field experiment with silage maize enjoyed full and complete monitoring.
A new field experiment with silage maize has been conducted in 2020, as well as new field experiments on grassland. Also, a new field experiment with grassland is expected in 2021.

The project started in the same timeframe when Joint Research Centre (JRC) was carrying out its SAFEMANURE project. The aim of this project is the development of criteria for the safe use of processed N-containing fertilising products from manure in vulnerable zones (areas sensitive to nitrate

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[9] Also known as the 4R's: right fertiliser type, right application rate, right method of fertiliser application and right period of fertilisation.

[10] Calcium ammonium nitrate is a directly available nitrogen fertiliser. Other names are Nitro-limestone or nitrochalk. The fertiliser is a mixture of ammonium nitrate and lime.

leaching), established by the Nitrates Directive. In January 2020, a pre-final report of this study was discussed during a stakeholders workshop at JRC in Seville (ES). In May 2020, a final report[11] was presented for discussion within the Nitrates Expert Group[12].

The current project was triggered by the start of the SAFEMANURE project, but has another timeframe as field experiments next to 2019 are also foreseen in 2020 and 2021. The data and outcomes obtained in this project serve as touchstones for the still to be implemented RENURE criterions for N fertilising products based on processed animal manure.

This report presents the first-year results of the silage maize experiment. Materials and methods of the experiment are described in Chapter 2. Chapter 3 presents the main results (yield and N uptake of maize, nitrogen use efficiency; NUE, NFRV, residual soil mineral nitrogen; RSMN, and an indicative nitrogen balance. In Chapter 4, the results are evaluated and conclusions for this first experimental year with silage maize are reported.

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[11] The final report is not yet available in the public domain (date of this observation is August 2020).

[12] The expert group for the implementation of the Nitrates Directive provides an informal forum of discussion between DG Environment and the Member States on technical aspects linked to the implementation of the Nitrates Directive and nutrients policy.

2 Materials and methods

2.1 Design of the field experiment

This study explores the agronomic potential of biobased fertilising products as a nitrogen source for silage maize.

In the Netherlands, it is common to use animal manure as a standard fertilising product to fulfil large portions of the crop's nutrient needs. Full requirements of crops are met through additional fertilisation with mineral fertilisers. Quantities of N and phosphate have to meet application standards of the Fertiliser Act of the Netherlands (see section 2.4).

The field experiment followed an orthogonal design with fertilising product and application rate as factors, and included three repetitions. Treatments (Table 1) were randomised per replication. The design lead to a total of 57 plots.

Table 1 *Fertilising products and application rates (codes) of the field experiment with silage maize.*

Nr.	Fertilising product	Application Rate[a] (code)
1	Calcium ammonium nitrate (CAN)	1
2	Calcium ammonium nitrate (CAN)	2
3	Calcium ammonium nitrate (CAN)	3
4	Calcium ammonium nitrate (CAN)	4
5	Calcium ammonium nitrate (CAN)	5
6	Liquid urea ammonium nitrate (UAN[13])	2
7	Liquid urea ammonium nitrate (UAN)	3
8	Cattle slurry (CS[14])	2
9	Cattle slurry (CS)	3
10	Biobased fertilising product basic (BBFb)	2
11	Biobased fertilising product basic (BBFb)	3
12	Biobased fertilising product ammonium+ (BBFa+)	2
13	Biobased fertilising product ammonium+ (BBFa+)	3
14	Cattle slurry + biobased fertilising product basic (CS+BBFb)	2
15	Cattle slurry + biobased fertilising product basic (CS+BBFb)	3
16	Cattle slurry + biobased fertilising product ammonium+ (CS+BBFa+)	2
17	Cattle slurry + biobased fertilising product ammonium+ (CS+BBFa+)	3
18	Cattle slurry + diluted biobased fertilising product ammonium+ (CS+DBBFa+)	2
19	Cattle slurry + diluted biobased fertilising product ammonium+ (CS+DBBFa+)	3

[a]: application rates for codes 1, 2, 3, 4, and 5 are respectively: 0, 93, 140, 186, and 233 kg N/ha. The optimum application rate is 186 kg N/ha which is set at 100% ()code 4). other application rates were 0% (code 1). 50% (code 2). 75% (code 3) or 125% (code 5).

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[13] Liquid urea ammonium nitrate fertiliser (UAN) is a mixture of urea and ammonium nitrate. In the Netherlands, this fertiliser is called Urean.

[14] Cattle slurry from the experimental dairy farm De Marke (https:www.wur.nl/nl/locatie-De-Marke.htm).

2.2 Soil

The field experiment was conducted at the experimental farm De Marke on a sandy soil. The initial soil fertility status of the field experiment prior to fertilisation in spring is given in Table 2. For this, the soil top layer 0–25 cm was sampled (40 soil cores/field experiment). The determination of the soil fertility status served the derivation of fertilisation with nutrients.

Table 2 *Soil fertility status of the sandy soil of the field experiments.*

Parameter	Unit	Value	Method
Organic matter	%	2.5	NIRS[15]
C-inorganic	%	0.03	NIRS
Clay (< 2 µm)	%	1	NIRS
Silt (2-50 µm)	%	7	NIRS
Sand (>50 µm)	%	90	NIRS
CEC	mmol+/kg	29	NIRS
pH	-	5.7	NIRS
N-total	mg N/kg	1130	NIRS
P-capacity (P-Al-value)	mg P_2O_5/100 g	50	NIRS
P-plant available (P-$CaCl_2$)	mg P/kg	1.7	CCL3
K-capacity	mmol+/kg	2.3	NIRS
K-plant available	mg K/kg	40	CCL3
S-total	mg S/kg	190	NIRS
S-plant available	mg S/kg	4.0	CCL3[16]
Ca-total	mmol+ Ca/kg	21	NIRS
Ca-plant available	mg Ca/kg	1.1	NIRS
Mg-total	mmol+ Mg/kg		NIRS
Mg-plant available	mg Mg/kg		CCL3

Plant available N was measured in soil layers 0-30 cm. 30-60 and 60-90 cm with 1 M KCl (1:2.5 w/v) extraction on 17 April. 2019 prior to sowing. In these soil layers 23 kg N/ha. 4 kg N/ha and 3 kg N/ha was found.

2.3 Fertilising products

Fertilising products and combinations used in the experiment were calcium ammonium nitrate (CAN), liquid urea-ammonium nitrate (UAN), biobased fertiliser basic (BBFb), biobased fertiliser ammonium+(BBFa+), cattle slurry (CS), cattle slurry plus biobased fertiliser basic (CS+BBFb), cattle slurry plus biobased fertiliser ammonium plus (CS+BBFa+) and cattle slurry plus diluted ammonium plus (CS+DBBFa+).

CAN and UAN are commonly used mineral nitrogen fertilisers.

Biobased fertilising products were produced by the Green Mineral Mining Centre[17] of Groot Zevert Vergisting B.V. in Beltrum, the Netherlands. The Green Mineral Mining Centre launched the production of biobased fertilising products early in 2019. The plant uses innovative techniques for the production of biobased fertilisers and takes part in the EU H2020 project Systemic as a demonstration plant. The Systemic project gives a full description of the production process of biobased fertilisers[18].

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[15] Eurofins Agro, method NIRS (TSC®).
[16] Eurofins Agro, method CCL3(PAE®).
[17] https://www.groenemineralencentrale.nl/nl/english.
[18] https://systemicproject.eu/plants/demonstration-plants/groot-zevert-the-netherlands/.

The biobased fertilisers were produced from mineral concentrate obtained by processing co-digested pig slurry (digestate). This digestate is separated into a liquid and a solid fraction by use of a decanter. Next, the liquid fraction is processed into a mineral concentrate and a permeate (clean water) by a cascade of techniques, amongst which reverse osmosis. The mineral concentrate serves as a secondary resource for the production of biobased fertilising products. At the start of production, the Green Minerals Mining Centre used more sulphuric acid for the production of the mineral concentrate and the maintenance of the production line processing the liquid fraction than later in the year after mastering scaling issues. Therefore, there was a need to increase the N/S ratio of the biobased fertilising products to prevent a too high S application when using the BBF as nitrogen fertilising product. The increase of the N/S ration was effectuated by adding concentrated ammonium water. The biobased fertilising product ammonium+ (BBFa+) was a mixture of mineral concentrate with 6% condensed ammonium water. The biobased fertilising product basic (BBFb) was a mixture of mineral concentrate with 1% condensed ammonium water.

Table 3 gives an overview of the composition of the fertilising products (reference fertilisers and biobased fertilising products) that were used in the current field experiment with silage maize. An overview of the analyses of all samples that were analysed (this field experiment and the annulled field experiment on grassland) is given in the annex.

Table 3 *Composition of reference fertilisers CAN and UAN and biobased fertilising products (BBFb, BBFa+ and DBBFa+).*

Fertilising product	Dry matter, %	Organic matter, %DS	EC, mS	Bulk density, kg/L	pH	N-total, g N/kg	NH_4-N, g N/kg	NO_3-N, g N/kg	Urea-N[19], g N/kg	P, g P/kg	K, g K/kg	Mg, g Mg/kg	S, g S/kg	N/K	N/S	Lab
Calcium ammonium nitrate (CAN)	*	*	*	*	*	275	142.5	132.5	*	*	*	*	*	*	*	1
Liquid Urea-ammonium nitrate (UAN)	*	*	*	*	*	297.6	71.1	76.8	153	*	*	*	*	*	*	1
Cattle slurry (CS)	7.8	79.2	20.5	990	7.19	4.02	2.2	*	*	0.43	5.02	0.63	0.54	0.8	7.4	2
Biobased fertilising product. basic (BBFb)	4.2	32.4	80.6	1037	8.89	11.49	9.5	*	*	0.089	6.85	0.053	5.1	1.7	2.3	2
Biobased fertilising product. ammonium+ (BBFa+)	4.2	31.8	89.1	1051	9.13	15.90	11.9	*	*	0.060	7.09	0.035	5.34	2.2	3.0	2
Biobased fertilising product. ammonium+ diluted (DBBFa+)	3.4	32.3	74.1	1035	9.16	12.39	9.8	*	*	0.066	5.62	0.042	4.07	2.2	3.0	2

Lab 1: Lufa Nord West[20]. Germany.

Lab 2: Wageningen UR - Chemical Biological Soil Laboratory[21] (CBLB).

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[19] Biuret content was 0.22%.

[20] https://www.lufa-nord-west.com/.

[21] https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Facilities-Products/Environmental-Sciences-Laboratories/Chemical-Biological-Soil-Laboratory-CBLB.htm.

2.4 Application rates

Application rates of nutrients were based on fertiliser recommendations derived from soil testing. The recommendations of the Dutch Committee Fertilisation of Grassland and Fodder Crops (CBGV[22], 2019) were followed.

2.4.1 Nitrogen

The N application rate was based on the quantity of mineral nitrogen in the soil layers 0-30 cm and 30-60 cm, and the 1.0 M KCl (1:2.5 w/v) extraction. The optimum (recommended) N application rate was set at 190 kg N/ha. In the Netherlands, the Fertiliser Act sets application standards for all agricultural crops and maintains a 140 kg N/ha application standard for silage maize. This regulatory application standard is set as a starting point when designating the actual application rate. The application standard is set at 75%. The application rates 0%, 50%, 75%, 100% and 125% followed therefore by 0, 93, 140, 186 and 233 kg N/ha.

2.4.2 Other nutrients

The application rates of other nutrients were based on the results of the soil sample of the soil layer 0-25 cm. The recommended application rates are given in Table 4.

Table 4 *Recommended application rates for phosphate, potassium, sulphur and magnesium, and application rate after applying the Ceteris Paribus Principle with compensation for nutrients from all fertilising products.*

Nutrient	Unit	Application rate	Application rate with compensation
Phosphate	kg P_2O_5/ha	64	64
Potassium	kg K_2O/ha	260	260
Magnesium	kg MgO/ha	0	33
Sulphur	kg SO_3/ha	25	260

Biobased fertilising products and cattle slurry contain other nutrients in addition to N. These are taken into account by applying the *Ceteris Paribus* Principle[23]. Therefore, each treatment received the same quantity of phosphate, K, magnesium (Mg) and S. Phosphate was applied as Triple superphosphate, K was applied as potassium sulphate, and Mg as gypsum. Although the Mg status of the soil was adequate, with the application of biobased fertilising products and cattle slurry Mg is added as well. Therefore, Mg applications were equalised over treatments by the use of kieserite. The highest quantity Mg applied with a biobased fertilising product (BBF) determined the compensation application rate. When applying potassium sulphate and kieserite, S is also given. The S application rate was standardised to the treatment with the highest input. In other treatments, S was supplemented as calcium sulphate ($CaSO_4.2\ H_2O$).

The micronutrient status of the soil was adequate. Soil testing showed that there was no need for additional fertilisation with micronutrients.

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[22] https://www.bemestingsadvies.nl/nl/bemestingsadvies.htm.

[23] Ceteris Paribus Principle: all other things being unchanged or constant. For the field experiment: applications of all nutrients other than N are kept constant.

2.5 Fertilisation techniques

Fertilisation techniques differed per fertilising product. The equipment used is specifically designed for fertilisation of field experiments with small plots (e.g. 3 x 10 m).

Granular mineral fertilisers were applied with a spreader adapted for experiment field use (Photo 1).

Photo 1 *Equipment from WUR Unifarm for application of granular fertiliser CAN.*

The liquid mineral fertiliser UAN was applied with a field sprayer (Photo 2).

Photo 2 *Field sprayer from WUR Unifarm used for application of the liquid mineral nitrogen fertiliser UAN.*

The application of biobased fertilising products requires an injection technique and equipment that can handle application rates of 2-5 m^3/ha. For this purpose, an injector was designed and built (Photo 3).

Photo 3 *Injector was designed for biobased fertilising products. Injector was built by Slootsmid[24] at the request of Inagro[25] and is intended for specific use in field experiments. The design is aimed at mitigating/minimising ammonia losses.*

Cattle slurry is commonly applied with a field injector that can handle larger volumes than those used for the more concentrated biobased fertilising products. For this field experiment, the equipment from WUR Unifarm was used (Photo 4).

Photo 4 *Injector from WUR Unifarm designed for the application of animal slurries. Here adjusted for application of cattle slurry on grassland.*

For application on arable land and silage maize nozzles and injection slots are distanced at 50 and 75 cm respectively from each other.

Fertilisation was conducted on 9 and 10 May 2019.

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[24] https://www.slootsmid.nl/

[25] https://www.inagro.be/

2.6 Soil sampling: harvest and crop sampling

2.6.1 Soil sampling

The soil was sampled three times.

Sampling of the plough layer (0 – 25 cm) occurred on 17 April 2019, before the sowing of silage maize. A standard sampling protocol was followed: 40 soil cores were manually collected from the field experiment at a random distribution and pooled. This pooled soil sample was used for the determination of the application rates of P, K, Mg and S. At the same time, the soil layers 0 – 30 cm, 30 – 60 cm and 60 – 90 cm of the field experiment were sampled individually, using a motorised drill. In total, 12 soil cores were taken to assess the quantity of mineral N in the soil and to derive the N application rates.

Four days later (21 and 22 April 2019) the three soil layers of each individual plot (total of 57 plots with 12 soil cores per plot) were sampled in the same way to assess the quantity of mineral N in the soil at the start of the field experiment, before fertilisation and cultivation of silage maize. This practice was repeated at the end of the experiment (17 and 18 September 2019) to assess the amount of N remaining in the soil.

2.6.2 Crop

Silage maize (cultivar LG 31.211) was sown (14 May 2019) with a seeding density of 100,000 seeds/ha.

The number of plants per plot were counted before harvest. Next, 20 stems per plot were sampled for the determination of dry matter content and nutrient content (N, P and K). This was followed by the determination of the yield of the whole plant.

2.7 Analytical methods

2.7.1 Fertilising products

CAN and UAN fertilisers were analysed for N content and forms by Lufa Nord West, Germany. Lufa Nord West is an accredited laboratory and has a quality system based on the ISO-17025 standard. Methods used were total Nitrogen VDLUFA II, 3.5.2.7.: 1995; ammoniacal N, DIN EN ISO 11732 (e23): 2005-05; #6 and Nitrate N, DIN EN ISO 13395; 1996-12; #6; Carbamide N, VDLUFA II.1, 3.9.2, 1995 AND Biuret VDLUFA II.1, 3.9.2; 1995.

Other fertilising products were analysed by Wageningen UR - Chemical Biological Soil Laboratory (CBLB). CBLB has a quality system based on the ISO-17025 standard. CBLB follows internal methods bases on the following standards: dry matter NEN 7432:1998; organic matter, NEN 5754;2014 (loss on ignition); pH, NEN 5704. Nutrient contents (N, P, K, and Mg) were determined after destruction with sulphuric acid, hydrogen peroxide, and selenium. Sulphur content was determined after aqua regia destruction (microwave method). Electric conductivity is based on NEN-EN 13038:2011 and bulk density follows an internal standard.

2.7.2 Soil samples

Soil samples of the plough layer 0 – 25 cm were analysed by Eurofins Agro BV following its analysis package for grassland[26]. Eurofins Agro Testing Wageningen BV is an accredited[27] laboratory.

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[26] https://www.eurofins-agro.com/nl-nl/bemestingswijzer

[27] https://www.rva.nl/en/accredited-organisations/all-accredited-bodies nr. L122.

The mineral N content in the soil samples of individual soil layers was determined after an extraction with 1 M KCl (1:2.5 w/v) by Wageningen UR – CBLB. The method is an internal standard adapted from ISO/TS 14256-1:2003 en.

2.7.3 Crop samples

Samples of silage maize plants were shredded, dried overnight at 70°C, and ground. Next, samples were analysed for nutrient concentration by destruction with H_2SO_4-H_2O_2-Se, followed by photometric determination of N and P on a segmented flow analyser (SFA) and K on a flame-atomic emission spectroscope (F-AES). These analyses were conducted by CBLB.

2.8 Calculations

The nitrogen use efficiency (NUE) of the fertilising products was calculated according to Dobermann (2007):

$$NUE = 100 * (U_N - U_0) / F_N \quad (1)$$

With:
NUE = Nitrogen use efficiency or apparent recovery of nitrogen as percentage (%)
U_N = Uptake of nitrogen of fertiliser treatment (kg N/ha)
U_0 = Uptake of nitrogen of control treatment without nitrogen fertilisation (kg N/ha)
F_N = Application rate fertiliser treatment (kg N/ha).

The NUE depends on the congruence between plant N demand and the release of N from the fertilising product.

The nitrogen fertiliser replacement value (NFRV) of a biobased fertilising product can be calculated as follows:

$$NFRV = 100 * NUE_{\text{Biobased fertilising product}} / NUE_{\text{Calcium ammonium nitrate}} \quad (2)$$

With:
$NUE_{\text{Biobased fertilising product}}$ = Nitrogen use efficiency or apparent recovery of biobased fertilising product (%)
$NUE_{\text{Calcium ammonium nitrate}}$ = Nitrogen use efficiency or apparent recovery of calcium ammonium nitrate (%)

By this definition, the NFRV of calcium ammonium nitrate is 100%. This does not mean that this chemical fertiliser is 100% effective.

2.9 Statistical analyses

Liquid urea-ammonium nitrate (UAN), cattle slurry (CS), biobased fertilising product basic (BBFb), biobased fertilising product ammonium+ (BBFa+) were applied at levels 50% and 75%. The combinations with cattle slurry and biobased fertilising products and the diluted biobased fertilising ammonium+ product (DBBFa+) were applied at levels of 75% and 100%.

The response of maize to N fertilisation was analysed using linear regression with both experimental factors (fertiliser treatment and application rate) and their interaction as explanatory variables:

$$\text{Model} = \text{Block} + \text{Fertiliser} + \text{Application rate} + \text{Fertiliser} * \text{Application rate} \qquad (3)$$

With:
Model: parameter (Yield, N-uptake, NUE, soil stock N mineral) to be analysed statistically;
Block: repetition (=3).

Equation (3) was adapted for the stock of mineral nitrogen with the time of sampling.

Fertiliser: Fertiliser treatments control (no N fertilisation), calcium ammonium nitrate (CAN), liquid urea-ammonium nitrate (UAN), bio based fertiliser basic (BBFb), biobased fertiliser ammonium+ (BBFa+), cattle slurry (CS), cattle slurry plus biobased fertiliser basic (CS+BBFb), cattle slurry plus biobased fertiliser ammonium plus (CBBFa+) and cattle slurry plus diluted ammonium plus (CS+DBBFa+).

Application rate: 0, 93, 140, 186 and 233 kg N/ha.

Tests on pair wise differences of means were based on Least Significant Differences (LSDs) and probabilities of 95% ($\alpha = 0.05$, two sided) unless stated otherwise.

The nonlinear regression model for the nitrogen uptake for different application rates of CAN followed a quadratic model:

$$\text{Nitrogen uptake} = a * (\text{Application rate})^2 + b * \text{Application rate} + c \qquad (4)$$

With:
Nitrogen uptake in kg/ha
Application rate: 0, 93, 140, 186 and 233 kg N/ha
and a, b, and c estimates for the parameters.

Both NUE and NFRV were calculated per treatment and per replicate. NUE is reported with its LSD values. The variance in the N uptake at various N application rates of CAS was taken into account when calculating NFRV. This was based on nonlinear regression. Prediction of N uptake at a given application rate was used in the derivation NFRV. Pooled standard errors of these predictions are reported.

The statistical analyses were carried out with the general-purpose statistical package GenStat, nineteenth Edition (VSN. 2019).

3 Results

3.1 Weather conditions

The year 2019 was drier than average and characterised by relatively high temperatures during the months February, March, June, July, and August compared with the long-term monthly average (Table 5). The months April, May, June, July, and September had lower precipitation than the long-term monthly average (Table 6). During the growing season (March – September), 315 mm precipitation was registered, which is 158 mm less than the long-term average of 473 mm. The difference in total precipitation in 2019 compared to the long-term total was 193 mm for the whole year.

Table 5 *Monthly temperature in °C presented as monthly average, averages of decade I, II and III and monthly minimum and maximum values (data from Experimental Farm De Marke).*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly average	2.8	5.9	7.9	11.2	12.0	19.5	19.5	18.9	14.5	11.8	6.1	5.6
Long term monthly average	*2.7*	*3.5*	*6.3*	*9.6*	*13.9*	*16.2*	*18.4*	*17.9*	*14.8*	*10.7*	*6.3*	*3.3*
Decade I	4.9	4.5	8.1	9.5	8.7	18.3	16.3	19.2	14.2	11.3	7.0	4.4
Decade II	3.4	6.1	6.8	10.7	12.2	18.5	17.6	16.8	13.4	13.9	4.4	7.4
Decade III	0.2	7.7	8.8	13.3	14.6	21.9	24.2	20.6	15.8	10.3	6.0	5.0
Monthly minimum	-4.1	0.8	4.4	2.4	5.6	15.1	13.9	14.0	10.5	3.1	0.7	-0.4
Monthly maximum	8.3	9.2	11.5	18.0	18.9	28.7	30.7	24.7	19.2	17.1	13.1	11.1

Table 6 *Monthly precipitation for 2019 in mm, long-term averages, and days with rain categorised to quantities of precipitation (data from Experimental Farm De Marke).*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Monthly total	51.2	76.8	75.2	25.3	28.2	34.6	19.0	72.2	60.6	74.0	82.1	53.6	652.8
Long term monthly average	*70*	*58*	*67*	*42*	*62*	*68*	*78*	*78*	*78*	*83*	*82*	*80*	*846.0*
Decade I	14.0	73.4	16.6	1.7	15.6	10.6	5.2	20.6	8.0	42.2	18.7	5.4	232.0
Days with rain	8	10	6	2	9	7	3	5	6	9	8	8	81
Decade II	19.6	0.4	49.2	0.8	1.8	24.0	12.6	39.2	11.4	28.0	43.7	22.0	252.7
Days with rain	8	1	8	3	2	6	5	8	5	9	6	8	67
Decade III	17.6	3.0	9.4	22.8	10.8	0.0	1.2	12.4	41.2	3.8	19.7	26.2	168.1
Days with rain	8	3	1	5	4	0	2	2	7	5	5	6	48
Days with rain	22	14	15	10	15	13	10	15	18	23	19	22	196
0 mm	9	14	16	20	16	17	21	16	12	8	11	9	169
› 0 mm	22	14	15	10	15	13	10	15	18	23	19	22	196
› 1 mm	12	9	11	5	7	5	4	12	9	14	15	9	112
› 5 mm	2	5	7	2	2	2	1	7	3	4	4	4	43
› 10 mm	0	4	2	0	0	1	0	1	2	1	2	1	14

To combat drought. sprinkler irrigation was applied whenever there was a risk that soil moisture content decreased below 10%.

Before the start of the sprinkler irrigation, silage maize visually responded to N application. Maize plants in treatments with N fertilisation were greener compared to those in the control treatment (0 kg N/ha), which had also a reduced growth. After the start of sprinkler irrigation these visual differences disappeared.

3.2 Plant density

Silage maize was sown with a target of 100,000 seeds/ha. At harvest, the number of plants were counted (Figure 1). In general, the number of plants matched the 100,000 of seeds planted per ha across the different treatments. The type of fertilising product had an effect on the number of plants, but no effect was found for application rate. On average, plant numbers were significantly lower in plots fertilised with BBFa+ than in the other treatments.

BBFa+ plots also showed a larger variation than other treatments. Other treatments with BBFa+ (those that included application of cattle slurry) did not have a significantly lower number of plants.

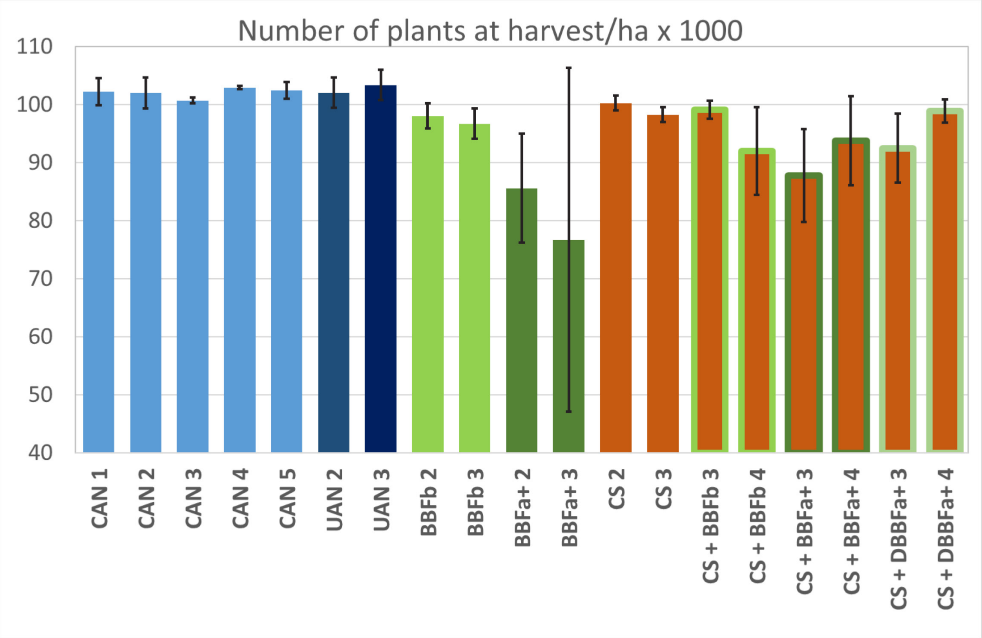

Figure 1 *Number of plants per ha at harvest (x 1000) for CAN, UAN, Cattle Slurry (CS), Biobased fertiliser basic (BBFb), Biobased fertiliser ammonia+ (BBFa+) and their combinations with Cattle Slurry (CS+BBFb, CS+BBFa+) and the combination with Cattle Slurry and the diluted BBFA+(CS+DBBFa+). Codes 1, 2, 3, 4 and 5 respectively represent the levels of application rates of nitrogen of 0%, 50%, 75%, 100% and 125%. Vertical bars represent standard deviations.*

3.3 Dry matter yield

Across treatments, the dry matter yield was 15.8 ton dry matter/ha on average. Large variation was found in treatments with BBFa+(Figure 2). Dry matter yields varied from 7.3 ton/ha for treatment BBFa+ at a rate of 75% to 19.3 ton/ha for treatment BBFa+ at a rate of 50%.

Overall, effects of fertilising product or application rate on maize yield were not significant. There was some evidence that an increase in the N application rate increased dry matter yields but variation between replications was of a similar magnitude as the differences between the averages of treatments.

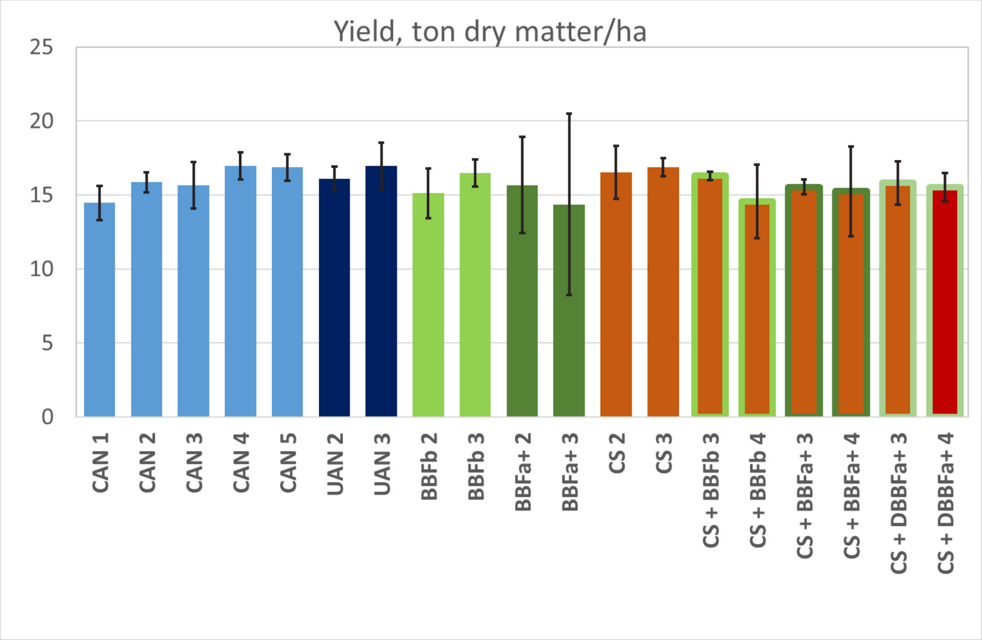

Figure 2 *Yield in ton dry matter/ha for CAN, UAN, Cattle Slurry (CS), Biobased fertiliser basic (BBFb), Biobased fertiliser ammonia+ (BBFa+) and their combinations with Cattle Slurry (CS+BBFb, CS+BBFa+) and the combination with Cattle Slurry and the diluted BBFA+(CS+DBBFa+). Codes 1, 2, 3, 4 and 5 respectively represent the levels of application rates of nitrogen of 0%, 50%, 75%, 100% and 125%. Vertical bars represent standard deviations.*

3.4 Nitrogen uptake and efficacy

3.4.1 Nitrogen uptake

Nitrogen uptake of the maize was 179.2 kg N/ha on average across all treatments and ranged from 91.6 kg N/ha to 225.3 kg N/ha (Figure 3). Without N application (0 kg N/ha) the maize N uptake was 133.5 kg N/ha, which was significantly lower than the uptake from the treatments with N fertilisation. Also, the N uptake of the 50% application rate treatment (177 kg N/ha on average) was significantly lower than the N application rate of 125% (for code 5 196 kg N/ha on average). Other differences between fertilising products were not significant. Effects of the fertilising products and of the interaction of fertilising products and application rates were not significant.

Variation in N uptake among different fertilising products and application rates was generally of a similar order of magnitude. However, BBFa+ treatments showed more variation (Figure 3).

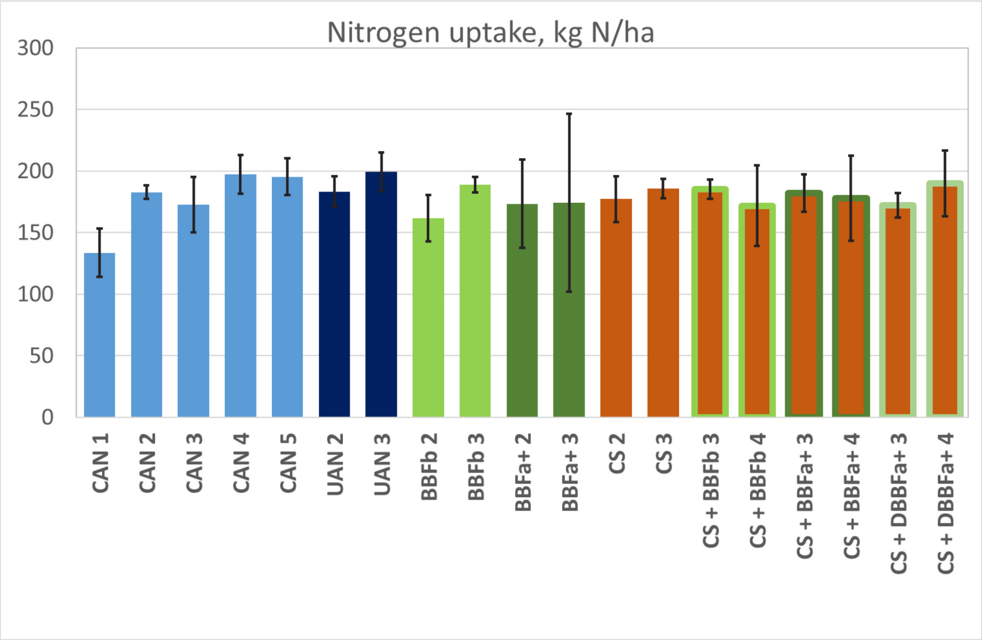

Figure 3 *Nitrogen uptake in kg N/ha for CAN, UAN, Cattle Slurry (CS), Biobased fertiliser basic (BBFb), Biobased fertiliser ammonia+ (BBFa+) and their combinations with Cattle Slurry (CS+BBFb, CS+BBFa+) and the combination with Cattle Slurry and the diluted BBFA+(CS+DBBFa+). Codes 1, 2, 3, 4 and 5 respectively represent the levels of application rates of nitrogen of 0%, 50%, 75%, 100% and 125%. Vertical bars represent standard deviation.*

3.4.2 Efficacy

In this report, efficacy of nitrogen is expressed as Nitrogen Use Efficiency (NUE) and Nitrogen Fertiliser Replacement Value (NFRV).

3.4.2.1 Nitrogen Use Efficiency (NUE)

NUE varied from 21% for application CS+BBFb at a 100% rate to 54% for application of CS at a 50% rate (Table 7). NUE declined significantly (α=0.05) with an increase of the N application rate. The results for CAN clearly show this decline: at 50% of the optimum application, NUE is 53% and at the application rate of 125%, it is 27%. The NUE at an application rate of 75% are lower than expected. Reasons for this deviation are not clear. Variation of NUE was relatively large within treatments, which is reflected in the large value of the LSD. Hence, no significant differences between the fertilising products were found.

Table 7 *Nitrogen use efficiency in percent (%) of CAN, UAN, CS, BBFb, BBFa+, CS+BBFb, CS+BBFa+ and CS+DBBFa+ per application rate (100%=140 kg N/ha).*

Fertilising product	Application rate 50%	75%	100%	125%	LSD (5%)
CAN	53	28	34	27	24
UAN	53	47	*	*	
CS	54	43	*	*	
BBFb	32	43	*	*	
BBFa+	48	33	*	*	
CS+BBFb	*	42	21	*	
CS+BBFa+	*	40	24	*	
CS+DBBFa+	*	32	31	*	

3.4.2.2 Nitrogen Fertiliser Replacement Value (NFRV)

NFRV was calculated according to equation [2] of paragraph 2.8. As NUE of CAN showed an inconsistent value for application rate 75%, a straightened nitrogen uptake as a function of the nitrogen application rate was used to balance variation according to equation [4] of paragraph 2[28]. Based on this straightened nitrogen uptake curve for CAS standard errors of means, (SE) were pooled based on SE of predicted nitrogen uptake of the reference fertiliser CAS and the SE of the fertilising product treatment (Table 8). NFRV was calculated for each fertilising product per application rate with CAN as the reference fertiliser.

Table 8 *Mean values with their standard error between brackets (SE[29]) for Nitrogen fertiliser replacement value (NFRV) in percent (%) UAN, CS, BBFb, BBFa+, CS+BBFb, CS+BBFa+ and CS+DBBFa+ per application rate (100%=140 kg N/ha) with CAN as reference nitrogen fertiliser.*

Fertilising product	Application rate		
	50%	75%	100%
CAN	100 (14)	100 (12)	100 (12)
UAN	126 (10)	128 (9)	*
CS	127 (10)	116 (9)	*
BBFb	74 (10)	115 (9)	*
BBFa+	112 (10)	88 (9)	*
CS+BBFb	*	113 (9)	64 (8)
CS+BBFa+	*	107 (9)	75 (8)
CS+DBBFa+	*	85 (9)	98 (8)

Based on SE a confidence interval can be calculated. As SE values are in the range of 8 – 14 and Student t value is 2.45, values for NFRV do not differ significantly from each other.

Visual differences in plant colour and height between treatments were initially observed. Without N, application plants' colour was more yellow, and growth was stunted. These differences disappeared when drought-induced sprinkler irrigation started. Sprinkler irrigation is assumed to cause a flush in soil N mineralisation (paragraph 3.5.2). This may have affected the nitrogen uptake of silage maize for all treatments and thus removed any differences in NUE and NFRV induced by the experimental factors.

3.5 Soil mineral nitrogen

3.5.1 Soil mineral nitrogen at start and after harvest

At the start of the field experiment the soil layers 0 – 30 cm, 30 – 60 cm and 60 – 90 cm had respectively 38, 13 and 3 kg/ha mineral N on average (Table 9). The total amount in the soil layer 0 – 90 cm was 54 kg N/ha. There were no significant differences in mineral soil N among the experimental plots.

After the harvest, soil mineral N was significantly different (α=0.05) between fertilising product treatments and application rates (Table 9).

Without N fertilisation (0 kg N/ha), the layer 0 – 30 cm and the layer 0 – 90 cm had a significantly lower quantity of mineral N after harvest in September than in April.

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[28] Estimates for the parameters and between brackets; their standard errors were:
Parameter a: -0.001077 (0.000768)
Parameter b: 0.510 (0.184)
Constant c: 135.15 (13.66)
Percentage variance accounted for was 61.1%

[29] Confidence interval can be estimated Mean value ± t x SE with t a Student-t with the value 2.45 (n = 6).

An application rate of 50% or 75% increased the quantity of soil mineral N measured in September for the UAN and BBFa+ treatments in the soil layer 0 – 90 cm compared to the quantity measured in April (Table 9). The differences were not significant for other fertilising products.

Application rates of 100% or 125% increased stocks of mineral soil N, both compared to the stock in spring and to the stocks after harvest for treatments with lower application rates. This is in line with the lower NUE values for higher application rates.

Fields fertilised with BBFa+ had a similar level of soil mineral N stock to fields fertilised with UAN at an application rate of 75%; both were significantly higher than CAN at the same application rate. BBFb, on the other hand, had significantly less soil mineral N than BBFa+, CAN or UAN.

Application rates of CS or BBFb had no significant effect on soil mineral N.

At an optimal application rate of 100%, the combinations of biobased fertilising products with CS had similar stocks of soil mineral N as CAN. There is therefore no evidence that the combined use exerts a higher risk on leaching of N.

3.5.2 Nitrogen balance sheet

Silage maize without N fertilisation (0 kg N/ha) had a nitrogen uptake of 134 kg N/ha (Figure 3). At the start of the field experiment, the soil layer 0 – 90 cm contained 54 kg N/ha and 28 kg N/ha after harvest. This points towards a contribution of soil organic N to maize N uptake of 133.5 – (54.1 – 27.7) = 107.1 kg N/ha. The difference between the stock of soil mineral N after harvest and the sum of the quantity present at the start, plus the N application rate minus the N uptake by silage maize is an indicator for the soil contribution (Table 10). This is a simple form of a partial soil N balance sheet and ignores losses through ammonia volatilisation and denitrification.

The apparent contributions from soil organic N were significantly higher for UAN and BBFa+ for other treatments. With an increase of the application rate, the soil contribution decreased.

The simple N balance sheet shows that the soil has contributed N to the nutrition of silage maize and to the stock of mineral N after harvest. The sprinkler irrigation to combat drought in combination with elevated temperatures is thought to have had an effect on soil organic N mineralisation. Before irrigation and without N fertilisation, the maize showed a more yellow colour and the growth was stunted. After irrigation, the yellow colour vanished, and the growth and development became similar to treatments with N application. The apparent contribution of soil organic N is of a similar magnitude as the N application rates, which may explain the absence of significant effects of application rate on NUE and NFRV.

Table 9 *Mean values for the quantity of mineral soil nitrogen in kg N/ha in soil layer 0 – 30 cm, 30 – 60 cm and 60 – 90cm before the start of the field experiment in April and after the harvest of silage maize in September for fertilising products CAN, UAN, CS, BBFb, BBFa+, CS+BBFb, CS+BBFa+ and CS+DBBFa+ per application rate (100%=140 kg N/ha).*

Product	Soil layer, cm	April 0%	50%	75%	100%	125%	Sept. 0%	50%	75%	100%	125%
CAN	0 - 30	39	41	39	34	42	14	40	46	66	96
	30 - 60	12	11	13	15	17	10	12	21	29	41
	60 - 90	3	2	3	3	3	4	3	3	5	6
	0 - 90	54	54	54	51	62	28	56	71	101	142
UAN	0 - 30	*	42	37	*	*	*	42	72	*	*
	30 - 60	*	20	12	*	*	*	22	26	*	*
	60 - 90	*	4	3	*	*	*	3	5	*	*
	0 - 90	*	65	52	*	*	*	67	103	*	*
CS	0 - 30	*	37	39	*	*	*	22	28	*	*
	30 - 60	*	11	12	*	*	*	10	17	*	*
	60 - 90	*	4	2	*	*	*	3	6	*	*
	0 - 90	*	51	53	*	*	*	35	51	*	*
BBFb	0 - 30	*	40	39	*	*	*	25	33	*	*
	30 - 60	*	13	14	*	*	*	12	13	*	*
	60 - 90	*	3	3	*	*	*	3	4	*	*
	0 - 90	*	56	57	*	*	*	40	50	*	*
BBFa+	0 - 30	*	34	38	*	*	*	30	69	*	*
	30 - 60	*	8	15	*	*	*	15	25	*	*
	60 - 90	*	3	2	*	*	*	3	8	*	*
	0 - 90	*	45	56	*	*	*	48	102	*	*
CS+BBFb	0 - 30	*	*	40	36	*	*	*	23	60	*
	30 - 60	*	*	12	11	*	*	*	12	28	*
	60 - 90	*	*	4	3	*	*	*	3	5	*
	0 - 90	*	*	56	50	*	*	*	38	92	*
CS+BBFa+	0 - 30	*	*	37	39	*	*	*	45	63	*
	30 - 60	*	*	11	12	*	*	*	16	30	*
	60 - 90	*	*	1	3	*	*	*	5	5	*
	0 - 90	*	*	51	54	*	*	*	65	99	*
CS+DBBFa+	0 - 30	*	*	35	36	*	*	*	29	56	*
	30 - 60	*	*	13	10	*	*	*	13	22	*
	60 - 90	*	*	2	2	*	*	*	3	3	*
	0 - 90	*	*	50	49	*	*	*	45	81	*
LSD (ɑ=0.05) Per sampling	0 - 30			8					22		
	30 - 60			6					7		
	60 - 90			1					2		
	0 - 90			12					27		
LSD (ɑ=0.05) between samplings	0 - 30					17					
	30 - 60					7					
	60 - 90					2					
	0 - 90					21					

Table 10 *Mean values of the soil contribution to crops nutrition in kg N/ha for CAN, UAN, CS, BBFb, BBFa+, CS+BBFb, CS+BBFa+ and CS+DBBFa+ per application rate (100%=140 kg N/ha) based on a simple nitrogen balance sheet.*

Fertilising product	Application rate, 0%	50%	75%	100%	125%
CAN	107	91	49	61	44
UAN	*	92	111	*	*
CS	*	80	63	*	*
BBFb	*	58	51	*	*
BBFa+	*	93	96	*	*
CS+BBFb	*	*	43	28	*
CS+BBFa+	*	*	75	39	*
CS+DBBFa+	*	*	46	42	*
LSD (α = 0.05)	36				

4 Evaluation and conclusions

In this study two types of biobased fertilising products were tested in a field experiment with silage maize. Both consisted of a mineral concentrate made from co-digested pig-slurry enriched with nitrogen from condensed ammonia water. One type (BBFa+) had 6% concentrated ammonia water added, a second type (BBFb) had 1% concentrated ammonia water added. The current field experiment served two objectives:

1. Agronomic effectivity: determining the NFRV of the biobased fertilising products by means of field experiments;
2. Environmental risk assessment: determine and compare the risk of nitrate leaching when using nitrogen biobased fertilising products as a substitute for mineral (synthetic, chemical) nitrogen fertilisers.

These objectives led to four hypotheses:

1. The magnitude of NFRV depends of the reference for a regular mineral N fertiliser;
2. Biobased fertilising products have a NRFV similar to that of the reference fertiliser;
3. Biobased fertilising products have a similar effect on residual nitrogen after the harvest of silage maize as a regular nitrogen fertiliser at similar application rates.
4. In combination with cattle slurry. dilution of the Biobased fertilising product ammonium+ with water increases NFRV.

The objectives and hypotheses were tested in a field experiment with silage maize on a sandy soil. The climate in 2019 was dry with elevated temperatures which made sprinkler irrigation necessary.

Number of plants at harvest

The type of fertilising product had an effect on the number of plants; the application rate did not have an effect.

Biobased fertilising product ammonium+ (BBFa+) had a significantly lower number of plants than other treatments. BFBBFa+ showed further higher values for the standard deviations than other treatments and thus had more variation. Other treatments with BBFa+, although a lower ranking did not have a significantly lower number of plants. The lower number of plants is attributed to the higher percentage of condensed ammonia water (6%) causing a high pH (Table 3) and this resulted in ammonium toxicity.

Yield

The dry matter yield was 15.8 ton/ha on average and varied from 7.3 to 19.2 ton dry matter/ha. Overall. there was some evidence that an increase in nitrogen application rate increased dry matter yields but variation between replications was of a same magnitude as found in the differences between the treatments. Effects of fertilising product or application rate were not significantly different between the treatments.

Nitrogen uptake

Nitrogen uptake of the whole plant was 179 kg N/ha on average and ranged from 92 to 225 kg N/ha. Without nitrogen application (0 kg N/ha) the nitrogen uptake was 134 kg N/ha which is significantly lower than the uptake from the treatments with nitrogen fertilisation. Also, the nitrogen uptake of the 50% application rate treatment (177 kg N/ha on average) was significantly lower than the nitrogen application rate of 125% (196 kg N/ha on average). Other differences were not significant. Effects of the fertilising products of the interaction of fertilising products and application rates were found not be significant. Variation in nitrogen uptake per fertilising product and per application rate was in general of a similar order of magnitude (Figure 2). BBFa+ treatments showed more variation (Figure 2).

NUE

Nitrogen Use Efficiency (NUE) values varied from 21% to 54% (Table 7). NUE declines with an increase of the application rate of nitrogen (CAN). With treatments, NUE values varied which is reflected in the large value of the LSD. Differences between NUE values of the fertilising products are therefore not significant.

NFRV

Nitrogen Fertiliser Replacement Value (NFRV) was calculated for each fertilising product per application rate with CAN as the reference fertiliser (Table 8). Due to the large variation in NUE values, differences between treatments and application rates were not significant.

Stock of soil mineral nitrogen

Mineral nitrogen, i.e. NH_4-N plus (NO_2 + NO_3)-N in the soil layers 0 – 30 cm, 30 – 60 cm and 60 – 90 cm was determined at the start of the field experiment in April before fertilisation and after the harvest in September (Table 9). At the start, the total amount in the soil layer 0 – 90 cm was 54 kg N/ha. After the harvest, the difference in soil mineral nitrogen was significant between fertilising product treatments and application rates (Table 9). Without nitrogen fertilisation (0 kg N/ha), the layer 0 – 30 cm and the layer 0 – 90 cm had a significantly lower quantity of post-harvest mineral nitrogen in September compared to the quantities measured in April.

An application rate of 50% or 75% did not change the quantity of soil mineral nitrogen measured in September in the soil layer 0 – 90 cm compared to the quantity measured in April (Table 9). Exemptions include UAN and BBFa+ which had significantly higher stocks of mineral soil nitrogen. Application rates of 100% or 125% boasted significantly higher stocks of mineral soil nitrogen both compared to the stock in spring as well as to the post-harvest stocks for treatments with lower application rates. This is in line with the lowering of NUE by increasing an application rate.

BBFa+ had a similar stock of soil mineral nitrogen as UAN at an application rate of 75%; both stocks were significantly higher than CAN at the same application rate. BBFb had significantly less soil mineral nitrogen than BBFa+, CAN or UAN.

Application rates of CS or BBFb had no significant effect on soil mineral nitrogen although it tended to increase with the higher application rate.

At an optimal application rate of 100%, the combinations of biobased fertilising products with CS had similar stocks of soil mineral nitrogen as CAS. There is therefore no evidence that the combined use exerts a higher risk on leaching of nitrogen.

Nitrogen balance sheet

A simple nitrogen balance sheet based on the stocks of mineral nitrogen at the start of the field experiment before fertilisation, nitrogen application rate, nitrogen uptake by silage maize and the post-harvest stock of mineral nitrogen showed effects of fertilising products and application rates but, above all, the effect of the nitrogen contribution from the soil due to drought combined with sprinkler irrigation. Fertiliser treatments followed the ranking:

UAN ~ BBFa+ > CS ~ CAN ~ CS+BBFa+ ~ BBFb ~ CS+DBBFa ~CS+BBFb

The contributions from soil for UAN and BBFa+ were significantly higher than for other treatments. The soil contribution decreased with an increase of the application rate.

In conclusion

In a field experiment on a sandy soil of the experimental farm De Marke, the effect of two biobased fertilising products on maize yield, N uptake and soil N cycling was tested. The year 2019 was a second year of drought in the Achterhoek, combined with elevated temperatures. The drought was severe and made sprinkler irrigation necessary. The consequence of sprinkler irrigation and elevated temperatures was that the mineralisation of soil organic N was thought to be stimulated. A simple nitrogen sheet balance showed that the soil contribution to crop’s nutrition with N had a similar magnitude as the N fertilising products application rates. Next, there was a tendency that this contribution declined with an increase of the nitrogen application rate. These two findings affected the NUE of the treatments which were not significantly different. Thus, differences in NFRV between treatments were not significant. Under these drought conditions with a significant contribution of nitrogen from the soil, the first hypothesis cannot be tested as there is an indication that there is an interaction between soil N from mineralisation and N application rate. Under the drought conditions and a significant contribution of nitrogen from the soil, the nitrogen contribution from a fertilising product is of less importance.

Stocks of post-harvest soil mineral nitrogen of silage maize were affected by fertilising product and application rate. The higher the application rate, the higher the stock of mineral nitrogen was. BBFa+ at a similar application rate increased this stock more than BBFb but did not differ from UAN. Combinations of CS with BBFb, BBFa+ and DBBFa+ at optimum application rates (100%) had similar stocks of soil mineral nitrogen as CAN. This field experiment shows that biobased nitrogen fertilising products have a similar risk on leaching of nitrogen as nitrogen of CAN at similar application rates.

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Annex 1 Composition of Biobased fertilising products BBFa+ and BBFb

Parameter	Unit	BBFa+			BBFb		
		Average	Standard deviation	Count	Average	Standard deviation	Count
Dry matter	%	4.67	0.52	5	5.13	0.67	6
Organic matter	%	36.3	6.16	5	38.4	7.1	6
EC	mS/cm	96	5	5	88	8	6
Bulk density	kg/L	1040	7	5	1037	2	6
pH	[-]	9.28	0.10	5	8.78	0.14	6
N-total	g N/kg	17.9	2.11	7	11.3	1.29	9
NH4-N	g N/kg	14.91	2.12	2	10.00	1.32	2
Nitrate-N	g N/kg	*	*	*	*	*	*
N-organic	g N/kg	*	*	*	*	*	*
P_2O_5	g P_2O_5/kg	0.048	0.014	5	0.16	0.15	6
K_2O	g K_2O/kg	8.45	0.08	5	9.28	1.02	6
Ca	g Ca/kg	0.02	*	1	0.07	*	1
Mg	g Mg/kg	0.03	0.007	5	0.04	0.01	6
Na	g Na/kg	3.93	0.008	2	5.17	0.006	6
SO_3	g SO_3/kg	16.0	1.6	5	15.2	3.08	6

Annex 2 Yield data and chemical composition of crop

Column	Parameter	Unit
1	Field	*
2	Fertilising product	*
3	Code application rate	*
4	Repetition	*
5	N application rate	kg N/ha
6	Plant count	plants/ha
7	Yield	ton fresh/ha
8	Yield	ton dry matter/ha
9	N-total	g N/kg
10	P-total	g P/kg
11	K-total	g K/kg
12	N-uptake	kg N/ha
13	P-uptake	kg P/ha
14	K-uptake	kg K/ha

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	BBFa+	3	1	125	103333	47.33	17.56	11.74	1.53	8.27	206.2	26.9	145.2
2	CAN	4	1	186	103333	48.00	17.86	11.83	1.54	7.96	211.3	27.5	142.1
3	CAN	5	1	232	104667	43.33	16.38	11.61	1.55	8.45	190.2	25.4	138.4
4	BBFb	3	1	131	94667	43.33	15.47	11.78	1.62	9.24	182.3	25.0	143.0
5	CS+DBBFa+	3	1	120	98000	48.00	17.09	10.66	1.53	9.75	182.1	26.2	166.5
6	CAN	3	1	139	100000	43.33	15.38	10.92	1.45	9.18	167.9	22.3	141.2
7	CS+BBFb	4	1	186	100000	46.67	15.07	11.22	1.45	11.12	169.2	21.8	167.6
8	CS+BBFb	3	1	124	101333	47.33	16.24	10.97	1.42	11.38	178.2	23.0	184.8
9	BBFa+	2	1	83	72000	38.00	13.00	11.53	1.66	9.47	149.8	21.5	123.1
10	CS+DBBFa+	4	1	181	99333	51.33	14.63	12.76	1.66	11.72	186.6	24.3	171.5
11	UAN	2	1	93	104000	48.00	15.17	11.51	1.45	10.89	174.6	22.0	165.2
12	CS	2	1	81	102000	47.33	14.63	10.90	1.45	10.49	159.5	21.2	153.5
13	BBFb	2	1	87	96000	45.33	13.19	10.86	1.50	9.32	143.3	19.7	123.0
14	CS+BBFa+	4	1	183	82000	40.67	11.79	12.04	1.65	10.80	142.0	19.4	127.4
15	CAN	2	1	93	106000	48.67	15.72	11.80	1.64	10.36	185.5	25.8	162.9
16	UAN	3	1	140	101333	48.00	15.41	12.03	1.61	9.98	185.4	24.9	153.7
17	CAN	1	1	0	104667	44.67	15.72	9.63	1.67	8.81	151.3	26.2	138.5
18	CS	3	1	121	100000	48.00	16.27	10.86	1.44	11.37	176.7	23.5	185.1
19	CS+BBFa+	3	1	122	76667	49.33	15.05	10.97	1.53	11.79	165.0	23.0	177.4
20	UAN	2	2	93	98000	41.33	16.33	10.91	1.34	8.47	178.2	21.8	138.2
21	CAN	1	2	0	98667	36.67	14.26	9.58	1.54	9.07	136.7	22.0	129.4
22	BBFb	2	2	87	101333	43.33	16.08	9.98	1.23	10.29	160.5	19.8	165.4
23	CAN	4	2	186	102667	44.67	16.04	11.23	1.46	8.99	180.1	23.4	144.1
24	CAN	3	2	139	101333	44.00	14.26	10.71	1.45	9.39	152.7	20.7	133.8
25	CS+DBBFa+	3	2	120	83333	46.00	16.15	10.63	1.44	10.94	171.6	23.3	176.6
26	BBFb	3	2	131	100667	47.33	17.18	11.08	1.64	8.83	190.5	28.2	151.7
27	CS	2	2	81	100000	47.33	16.76	10.46	1.52	10.67	175.3	25.4	178.8
28	CAN	5	2	232	101333	44.67	16.30	11.27	1.54	8.20	183.8	25.1	133.7
29	BBFa+	2	2	83	96667	42.00	14.74	10.56	1.55	9.02	155.7	22.8	133.0
30	CS+BBFa+	4	2	183	100000	45.33	16.55	10.90	1.44	12.34	180.4	23.8	204.2
31	CS+BBFa+	3	2	122	98000	44.67	16.04	11.68	1.57	10.35	187.3	25.1	166.0
32	CS+DBBFa+	4	2	181	101333	44.67	15.37	10.74	1.27	11.76	165.0	19.5	180.7
33	CS+BBFb	4	2	186	80667	40.00	11.88	11.85	1.72	10.22	140.8	20.4	121.4
34	CS+BBFb	3	2	124	97333	45.33	16.05	11.46	1.69	10.13	184.0	27.1	162.6
35	CAN	2	2	93	100667	46.00	16.61	11.24	1.66	8.79	186.7	27.5	145.9
36	BBFa+	3	2	125	31333	22.67	7.30	12.56	1.85	9.57	91.6	13.5	69.9
37	UAN	3	2	140	101333	46.67	16.85	11.65	1.73	10.01	196.2	29.1	168.7
38	CS	3	2	121	96667	48.00	17.52	10.83	1.62	10.11	189.7	28.5	177.2
39	UAN	2	3	93	104000	43.33	16.77	11.76	1.59	9.10	197.2	26.6	152.6
40	CAN	5	3	232	101333	48.00	17.90	11.86	1.48	9.00	212.4	26.6	161.1
41	CAN	3	3	139	100667	46.67	17.36	11.34	1.63	9.09	196.9	28.4	157.9
42	CS+BBFb	3	3	124	98667	48.00	16.61	11.68	1.66	9.83	193.9	27.6	163.3
43	CS+BBFa+	4	3	183	99333	53.33	17.39	12.13	1.72	10.38	210.9	29.8	180.5
44	CAN	4	3	186	102667	48.00	17.04	11.78	1.64	9.53	200.8	27.9	162.4
45	BBFb	3	3	131	94667	50.00	16.80	11.58	1.69	9.53	194.6	28.4	160.2
46	CAN	1	3	0	103333	40.00	13.44	8.38	1.81	8.58	112.6	24.3	115.3
47	UAN	3	3	140	107333	49.33	18.60	11.64	1.76	9.19	216.6	32.7	171.0
48	CS	3	3	121	98000	46.67	16.85	11.33	1.59	10.41	190.9	26.8	175.4
49	BBFa+	3	3	125	95333	46.00	18.22	12.37	1.82	9.51	225.3	33.2	173.2
50	BBFb	2	3	87	96667	41.33	16.12	11.25	1.75	9.51	181.3	28.2	153.3
51	CS+BBFb	4	3	186	95333	48.67	16.74	12.29	1.65	11.06	205.7	27.6	185.1
52	CS+DBBFa+	3	3	120	96000	42.00	14.20	11.44	1.76	8.79	162.4	24.9	124.7
53	CS+BBFa+	3	3	122	88667	44.00	15.53	12.51	1.68	9.35	194.2	26.1	145.3
54	CS+DBBFa+	4	3	181	96000	48.00	16.56	13.16	1.86	10.41	218.0	30.8	172.3
55	CAN	2	3	93	99333	44.67	15.28	11.55	1.61	9.71	176.4	24.7	148.3
56	CS	2	3	81	98667	46.00	18.22	10.80	2.34	9.78	196.8	42.7	178.2
57	BBFa+	2	3	83	88000	46.67	19.27	11.13	1.65	9.09	214.5	31.9	175.1

Annex 3 Mineral nitrogen in soil

Column	Parameter
1	Field
2	Fertilising product
3	Code application rate
4	Repetition
5	N application, kg N/ha
6	Layer 0 - 30 cm Spring
7	Layer 0 - 30 cm Fall
8	Layer 30 - 60 cm Spring
9	Layer 30 - 60 cm Fall
10	Layer 60 - 90 cm Spring
11	Layer 60 - 90 cm Fall
12	Layer 0 - 90 cm Spring
13	Layer 0 - 90 cm Fall

1	2	3	4	5	6	7	8	9	10	11	12	13
1	BBFa+	3	1	125	46.1	97.4	25.7	23.6	3.5	6.6	75.2	127.5
2	CAN	4	1	186	35.7	113.1	18.3	30.7	3.5	7.0	57.4	150.8
3	CAN	5	1	232	40.5	113.1	20.8	54.2	2.6	6.9	64.0	174.2
4	BBFb	3	1	131	35.7	48.7	14.3	13.1	2.2	3.5	52.2	65.2
5	CS+DBBFa+	3	1	120	38.9	32.5	14.4	15.6	1.8	3.5	55.1	51.7
6	CAN	3	1	139	29.0	58.8	8.1	13.7	2.2	3.6	39.4	76.1
7	CS+BBFb	4	1	186	42.3	60.2	9.1	26.1	2.2	3.6	53.7	89.9
8	CS+BBFb	3	1	124	36.7	22.9	11.2	13.3	3.1	2.7	51.1	38.9
9	BBFa+	2	1	83	31.8	40.0	8.2	16.0	2.2	1.8	42.3	57.8
10	CS+DBBFa+	4	1	181	41.8	67.3	11.5	28.2	2.2	2.7	55.5	98.2
11	UAN	2	1	93	38.9	56.4	11.9	18.7	3.6	3.6	54.4	78.7
12	CS	2	1	81	33.9	16.3	8.7	5.6	4.9	2.7	47.5	24.7
13	BBFb	2	1	87	39.1	37.0	12.0	11.1	2.2	1.3	53.3	49.5
14	CS+BBFa+	4	1	183	46.5	86.1	13.6	41.3	3.6	5.8	63.7	133.2
15	CAN	2	1	93	52.5	61.0	12.4	13.7	2.7	3.6	67.6	78.3
16	UAN	3	1	140	44.2	116.8	13.4	32.0	3.6	6.7	61.2	155.4
17	CAN	1	1	0	49.2	18.8	16.0	11.7	2.2	4.5	67.4	35.0
18	CS	3	1	121	46.9	22.6	13.1	10.9	3.1	3.6	63.0	37.1
19	CS+BBFa+	3	1	122	43.9	40.6	13.8	17.6	1.8	4.4	59.4	62.7
20	UAN	2	2	93	46.8	35.8	12.4	23.9	3.1	2.7	62.3	62.4
21	CAN	1	2	0	33.4	14.2	9.9	9.4	3.6	2.2	46.8	25.9
22	BBFb	2	2	87	46.8	20.7	13.6	14.4	3.6	3.1	63.9	38.3
23	CAN	4	2	186	34.3	52.3	13.6	35.2	4.0	4.0	51.9	91.5
24	CAN	3	2	139	42.0	43.3	15.2	29.2	2.7	2.7	59.9	75.1
25	CS+DBBFa+	3	2	120	29.3	26.0	12.3	11.9	2.2	1.8	43.9	39.8
26	BBFb	3	2	131	49.3	29.9	16.6	15.3	4.9	2.7	70.8	47.9
27	CS	2	2	81	41.2	32.7	14.7	16.8	4.5	2.7	60.4	52.3
28	CAN	5	2	232	46.9	111.9	12.8	36.3	4.5	4.9	64.2	153.2
29	BBFa+	2	2	83	34.3	26.7	9.8	14.5	3.1	2.7	47.2	43.9
30	CS+BBFa+	4	2	183	37.7	43.8	9.1	23.8	3.6	3.6	50.4	71.2
31	CS+BBFa+	3	2	122	34.7	69.8	8.2	16.0	3.1	4.9	46.0	90.7
32	CS+DBBFa+	4	2	181	33.2	32.4	9.0	15.0	2.7	3.6	44.9	51.0
33	CS+BBFb	4	2	186	32.1	80.6	10.8	33.1	3.1	5.8	46.0	119.5
34	CS+BBFb	3	2	124	44.9	24.9	16.5	10.0	2.7	3.1	64.1	38.0
35	CAN	2	2	93	34.1	33.7	12.1	11.3	2.2	3.1	48.5	48.1
36	BBFa+	3	2	125	37.3	67.6	10.0	34.8	1.8	13.0	49.1	115.3
37	UAN	3	2	140	32.8	50.4	9.1	24.3	1.8	4.0	43.7	78.7
38	CS	3	2	121	32.5	28.0	9.6	23.6	1.8	8.5	43.9	60.0
39	UAN	2	3	93	40.3	32.9	34.7	23.6	4.0	4.0	79.0	60.5
40	CAN	5	3	232	37.9	61.9	16.6	31.1	2.2	6.3	56.8	99.2
41	CAN	3	3	139	46.4	35.3	14.6	21.0	3.1	4.0	64.1	60.4
42	CS+BBFb	3	3	124	37.5	22.3	9.5	11.3	5.8	3.5	52.8	37.1
43	CS+BBFa+	4	3	183	33.6	60.6	13.3	25.7	2.2	4.9	49.1	91.2
44	CAN	4	3	186	30.6	33.9	11.7	22.5	2.2	4.0	44.5	60.4
45	BBFb	3	3	131	32.7	19.9	11.7	10.8	2.6	4.9	47.0	35.5
46	CAN	1	3	0	34.3	10.0	11.3	8.2	2.6	4.0	48.2	22.3
47	UAN	3	3	140	35.4	49.7	13.4	20.7	2.2	4.8	51.0	75.3
48	CS	3	3	121	38.3	32.9	12.2	17.0	1.8	5.8	52.3	55.6
49	BBFa+	3	3	125	30.6	41.1	9.6	17.9	2.2	4.9	42.5	63.9
50	BBFb	2	3	87	35.0	17.9	13.4	10.4	3.1	3.5	51.6	31.9
51	CS+BBFb	4	3	186	34.6	37.9	12.5	23.8	2.2	4.4	49.3	66.1
52	CS+DBBFa+	3	3	120	37.8	27.4	12.9	10.7	1.8	4.0	52.4	42.1
53	CS+BBFa+	3	3	122	33.9	24.7	11.2	13.0	1.8	5.3	46.9	43.0
54	CS+DBBFa+	4	3	181	33.0	69.0	10.4	21.7	1.8	4.0	45.2	94.7
55	CAN	2	3	93	37.4	24.8	7.9	12.2	1.8	3.6	47.0	40.6
56	CS	2	3	81	34.7	16.5	8.4	7.5	3.6	3.1	46.6	27.1
57	BBFa+	2	3	83	35.1	22.2	6.6	15.5	3.1	4.0	44.9	41.7

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