Sustainable use of calcium nitrate fertilizer under variable precipitation, soil properties and crop management

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Abstract

Application of nitrogen fertilizers in agriculture contributes substantially to global greenhouse gas emissions and nitrogen leaching. Accordingly, there is a need to increase knowledge about sustainable farming practices to reduce nitrogen losses to the environment without curtailing crop harvest. The effect of contrasting fertilizer types (calcium nitrate, ammonium-based fertilizers, and urea) on crop yield, nitrous oxide emissions and nitrate leaching, were elucidated in this study through a literature review and analysis of existing data. Separate datasets were developed for crop yield and nitrous oxide emissions under different precipitation, soil properties and crop management. Grain yield was analyzed for winter and spring cereals and from two sub datasets. The primary sub dataset consisted of yield data derived from the application of one fertilizer type along the crop cycle; the secondary sub dataset contained observations from the application of two different fertilizer types throughout the cropping season. The database for nitrous oxide fluxes included cereals, carrots, melon, and ryegrass. Nitrate leaching was assessed by a descriptive analysis of research carried out for Swedish conditions. Information from 338 observations in the primary sub dataset suggested there was a positive relationship between precipitation and spring cereals yield, whereas the opposite trend was observed for winter cereals. Split nitrogen applications between autumn and spring, or single doses in spring resulted in the most effective fertilizer application times to increase winter wheat grain yield. Across the dataset, the highest increase in grain yield (102%) with respect to non-fertilized treatments was obtained on fine-textured soils. Grain nitrogen recovery from the secondary sub dataset significantly predicted winter wheat grain harvest. Slope estimates implied that one unit increase in grain nitrogen recovery represents a yield raise of 1.15%. Nitrous oxide emissions were attributable to climate, soil pH, nitrogen dose and crop type. Higher gaseous losses were obtained in humid climates than in semi-arid conditions. Regression analysis estimated a reduction in nitrous oxide losses of 20% with the increase of one unit of soil pH within the range 4.1 to 8.3. A positive relationship between nitrogen dose and gaseous fluxes indicated an increase in nitrous oxide emissions by 0.5% for each kilo of added nitrogen in a hectare. Overall, fertilizer type did not show a significant effect on any of the assessed response variables. Nitrate leaching was found to be higher in the post-harvest period than during the cropping season in Sweden. Based upon the results of this review, calcium nitrate fertilizer would result in the same cereal yield and nitrous oxide fluxes as ammonium-based fertilizers and urea. However, an adequate dose of calcium nitrate would potentially reduce nitrous oxide emissions in acid soils. This review is proposed to be considered as an indicator as data variability hampers the ability to make predictions unambiguously.

Keywords: nitrogen, calcium nitrate, ammonium-based fertilizers, urea, nitrate leaching, nitrous oxide emissions, crop yield.

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1. Introduction

In 2018 approximately 108 Mt of nitrogen (N) were globally used in agriculture from synthetic fertilizers (FAO, 2018). Global greenhouse gas (GHG) emissions from the supply chain of those inorganic N fertilizers were estimated at 1129.1 Mt CO_2e. This datum accounts for fluxes associated with manufacturing, transport, and utilization in agriculture. Specifically, GHG emissions from fertilizer application, mainly in the form of nitrous oxide (N_2O) and carbon dioxide (CO_2), contributed with 59% of the total emissions (666.17 Mt CO_2e) (Menegat *et al.*, 2022). Nitrous oxide is a greenhouse gas with a global warming potential 300 times larger than CO_2 in a horizon of 100 years. Hence, it is considered one of the major contributors to stratospheric ozone depletion (Nishimura *et al.*, 2022). The increased N fertilizer adoption since the invention of the Haber-Bosch process has incremented N_2O emissions from arable land (Plaza-Bonilla *et al.*, 2017). In soil, direct nitrous oxide fluxes are produced as byproducts of nitrification and intermediate products of denitrification. These processes are regulated by soil properties such as moisture, organic carbon, temperature, oxygen concentration, pH as well as nitrate (NO_3^-) and ammonium (NH_4^+) availability (Rochette *et al.*, 2018).

Indirect N_2O fluxes from agroecosystems derive from mechanisms such as leaching of nitrate (Rütting *et al.*, 2018; Menegat *et al.*, 2022). In this pathway, NO_3^- leached from soil, is denitrified in the groundwater, or water bodies receiving drainage (IPCC, 2006). Wang *et al.* (2019) reported soil N leakage as the predominant pathway to increase NO_3^- concentrations in groundwater, and cause water eutrophication. Same authors stated total N input might be used to calculate leakage proportion through the fertilizer-induced emission factor (EF). Global estimates in 2001 showed that nitrate leaching EF was 19% from the total N applied (Lin *et al.*, 2001). Other studies performed by the Intergovernmental Panel on Climate Change (IPCC) suggested nitrate lost by leaching corresponded to 30% of applied fertilizer (IPCC, 2006). However, most nitrate leaching studies have examined the effect of a single fertilizer at a specific region, meaning comparative trials across a range of fertilizer formulations are needed. In terms of crop N recovery, this proportion has been reported to be less than 40% of the N applied as fertilizer in main globally grown crops such as cereals (Kant, 2018). The remaining N share is immobilized by microorganisms, fixed to soil particles, and dissipated through different mechanisms including, besides the aforesaid, volatilization and runoff. Hence, feasible farming practices are essential to increase N recovery and thus minimize losses in agricultural systems (Rütting *et al.*, 2018).

Tackling GHG releases associated with manufacturing of synthetic N fertilizers, various environmentally friendly initiatives have emerged worldwide. NitroCapt is a clean tech company with headquarters in Uppsala (Sweden) aiming at producing climate-neutral N fertilizers by the development of the chemical process SUNIFIX®. This breakthrough fixes nitrogen from the air to produce nitric acid, which is further neutralized to manufacture a nitrate salt such as calcium nitrate. Therefore, there is a need to increase knowledge about sustainable management of N fertilization in agriculture, emphasizing calcium nitrate. Research is required for different precipitation, soil types, and crop conditions to curtail environmental pollution without costing neither crop yield nor profit depletion.

2. Objectives and research questions

The objectives of the master thesis were:

I. To conduct a literature review and analysis of existing data on the effect of calcium nitrate, urea and ammonium-based fertilizers on crop yield, nitrate leaching and nitrous oxide emissions under variable soil properties and precipitation.

II. To define a sustainable management for calcium nitrate fertilization under different soil texture, pH, and crop management.

Based upon the objectives of the thesis, the following research questions were formulated:

I. How does precipitation affect crop yield, nitrate leaching and nitrous oxide emissions from ammonium-based, urea and calcium nitrate fertilizers?

II. How are crop yield, nitrate leaching, and nitrous oxide emissions influenced by soil properties and fertilizer type?

3. Background

3.1 Nitrogen in soil and crop systems

Nitrogen is present in the topsoil mainly in the form of organic compounds which represent more than 90% of the total soil N. The remaining 10% are in inorganic form as nitrate or ammonium (Esala, 1991). The inorganic soil N pool is a function of organic matter mineralization processes, which are determined by carbon to nitrogen (C:N) ratios. Net mineralization takes place when the C:N < 20:1, otherwise N immobilization by microorganisms will predominate, as N will be limited for their metabolic mechanisms (Gworek *et al*., 2021). Inorganic N is one of the drivers of crop growth. Among the forms of N, NO_3^- is highly mobile in soil and therefore more easily transported to the root zone for crop uptake (Kant, 2018). Ammonium is fixed to soil particles and consequently less mobile than nitrate. Inside plant tissues, NO_3^- is reduced to NH_4^+ by nitrate reductase to be incorporated into organic compounds. Thus, NH_4^+ uptake and utilization are less costly from an energetic point of view. However, NH_4^+ absorption leads to excretion of hydrogen ions (H^+) by plant roots, decreasing the pH of the rhizosphere and contributing to soil acidification in the long term (Masud *et al*., 2014; Hachiya & Sakakibara, 2017).

Cereals such as wheat usually take up 50-90% of the N before anthesis, depending on environmental conditions and variety (Esala, 1991). Hence, N fertilization is one of the key factors in grain yield, protein content and quality of wheat. Good baking quality requires a protein content of 12-13% with enough gluten forming proteins (Esala, 1991). Esala and Larpes (1984) reported that grain protein proportions increase linearly with N rates up to 200 kg/ha under Finnish conditions. Yet in Finland, maximum N doses for wheat are 130-140 kg N/ha. Broadcasted application of fertilizers during the growing season could also be a determining factor for increasing protein amounts. Top dressing applications aim at guaranteeing crop N uptake at stages such as grain filling. Concerning application time, Pushman and Bingham *et al.* (1976) claimed that especially late applications of urea spray (after anthesis) lowered wheat protein quality for baking. This is possibly because of a delayed N supplied in the crop cycle, or ammonia (NH_3) toxicity in plant tissues. Conversely, Lyu *et al.* (2022) demonstrated that foliar applications of NO_3^- and urea at or after anthesis of winter wheat promoted N remobilization (from vegetative organs to grain), improving grain protein quality.

Weather conditions may significantly affect N fertilization efficiency in cereals and consequently induce undesirable environmental impacts. In spring, inorganic soil N content might be low because of poor mineralization during winter, and possibly large leaching losses (Esala, 1991). Malhi (2001) reported that N_2O losses derived from nitrification and denitrification continue over late fall and early winter. Yet great variations in soil properties as well as farming practices make weather-associated N losses difficult to predict (Gworek *et al.*, 2021).

3.2 Nitrogen losses in agroecosystems

Nitrous oxide is a long-lived greenhouse gas, 300 times more efficient than CO_2 at trapping heat (Tian *et al.,* 2020). The main sources of N_2O emissions are fossil fuel combustion, N fertilizers application in agriculture, and natural processes occurring in aquatic and terrestrial ecosystems (Signor & Pellegrino, 2013). From fertilization, FAO (2017) claimed that in soil, an increase in available nitrogen boost nitrification and denitrification processes, with a consequent increment of direct N_2O emissions. Indirect N_2O production is associated with N losses in the form of NO_3^- leaching as well as NH_3 volatilization and re-deposition. The IPCC (2006) assumed that direct N_2O fluxes correspond to 1% of the total N added in the soil system as synthetic fertilizer, annual manure, and crop residues. Indirect emissions from nitrate leaching are estimated to be 0.75% of the N that is leaked. In humid climates, the IPCC (2006) approximated the leaching factor at 30% of applied N from soils with low water holding capacities. Nitrogen losses by ammonia volatilization are assumed at 10% of N supplied as synthetic fertilizers, and N_2O production from this loss is estimated at 1% of volatilized N. Nitrous oxide emissions from soil either by nitrification or denitrification are influenced by temperature, soil moisture, oxygen availability, soil organic carbon (SOC), soil pH and inorganic N concentration (Signor & Pellegrino, 2013). As direct N_2O emissions account for 57% of global GHG fluxes from fertilizer deployment, the following sections will focus on nitrification and denitrification mechanisms within the N cycle in soil.

In the soil system, nitrification consists of two aerobic steps. Ammonia is first oxidized to nitrite (NO_2^-) by ammonia oxidizing bacteria/archaea, followed by NO_2^- oxidation to NO_3^- by nitrite oxidizing bacteria (Norton & Stark, 2011). Denitrification is the anaerobic reduction of NO_3^- to N_2, generating NO_2^-, nitric oxide (NO) and N_2O as intermediate products. This microbial mechanism is mediated by facultative anaerobic bacteria. However, N_2O is not only produced by denitrification but also in the nitrification process (Figure 1; Wrage *et al.*, 2001).

The nitrite produced by nitrification might be reduced by ammonia-oxidizing bacteria to N_2O and N_2 via NO. This reduction is performed when oxygen is limited and accounts for up to 100% of N_2O fluxes from NH_4^+ in soil (Wrage-Mönnig *et al*., 2018). As O_2 concentration in soil decreases, N_2O emissions might be attributable to both nitrification and denitrification processes. Only under complete anoxic conditions, N_2O emissions can be derived exclusively from denitrification (Zhu *et al*., 2013). Nitrous oxide fluxes from nitrification appears to be favored by high build-up of NO_2^-. Thus, urea, manure and ammonium-based fertilizers are likely to contribute to nitrite accumulation and subsequent N_2O emissions (Wunderlin *et al*., 2012). Additionally, from nitrification, a small proportion of N_2O is produced by a non-biological process, namely hydroxylamine (NH_2OH) oxidation. Hydroxylamine is an intermediate compound in the ammonia oxidation that in acid and neutral soils reacts with iron (Fe) and manganese (Mn) ions to produce N_2O. In calcareous soils ($pH > 7.8$), the reaction between NH_2OH and calcium carbonate ($CaCO_3$) predominates with N_2 being the main product (Bremner *et al*., 1980).

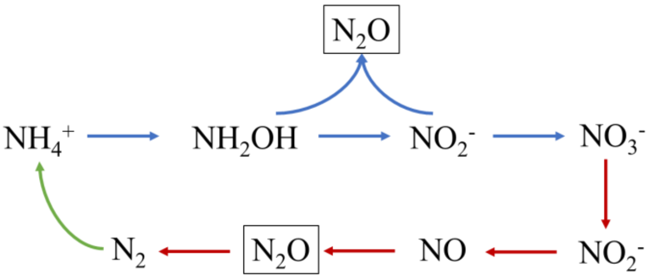

Figure 1. *Nitrous oxide emissions from nitrification (blue arrows) and denitrification (red arrows) in soil. The green arrow represents nitrogen fixation. Modified from* Wrage-Mönnig *et al*., 2018.

Nitrous oxide fluxes are reported to be influenced by soil texture and structure as well as by agricultural practices. Nitrous oxide emissions are larger in clayey soils than in sandy soils (Brentrup *et al*., 2000; Wrage *et al*., 2001). This is likely owing to the small proportion of macropores in clay textures that will increment anaerobic microsites and hence N_2O production (Signor & Pellegrini, 2013). Disrupted soil structure by reduced soil porosity also increases N_2O losses by limiting oxygen diffusion. Thereby, soil compaction, resulting from traffic of heavy machinery, intensive land use, animal trampling or inappropriate soil management, can have a major impact on undesired N_2O fluxes (Pulido-Moncada *et al.*, 2022).

Ammonia losses, unlike N_2O emissions, tend to be greater in coarse than in fine soil textures due to the low sorption capacity of coarse-textured soils. High evaporation also tends to increase volatilization losses by transporting NH_3 upwards, raising its concentration in the soil surface (Malhi *et al*., 2001). Urea fertilizers are hydrolyzed into NH_3 and CO_2 in a reaction catalyzed by the urease enzyme. Produced NH_3 is partly volatilized, reducing urea efficiency (Volk, 1966). Losses might be even higher in residue-covered soil as urease activity could be enhanced by litter. Nitrate-based fertilizers are less prone to volatilization, but NO_3^- is rapidly transported downward below the root zone, causing losses by leaching (Malhi *et al*., 2001).

Leaching of N is mainly in the form of NO_3^-. These losses from soil contribute to eutrophication, i.e., nutrient enrichment of watercourses, and groundwater contamination (Wallman & Delin, 2022). High soil NO_3^- concentrations in humid climates represent a risk for leakage. Specifically, in humid temperate regions, most of the NO_3^- is lost in autumn and winter when no or poor crop growth takes place. Norberg & Aronsson (2019) claim that in the Scandinavia region, nitrate leaching occurs predominantly after crop harvest, comprising the period from October to April. According to Blombäck *et al.* (2011) N leaching from Swedish arable land average at 19 kg/ha/year, with the highest records in southern Sweden.

The major factors regulating N leaching are rainfall intensity, soil texture and the availability of N in leachable forms (Myrbeck, 2014). Leaching of N is significantly higher in coarse-textured soils than in fine soil textures due to low sorption capacities and large percolation rates of the formers (Malhi *et al*., 2001). Owing to this great percolation in coarse soil textures, high precipitation rates exacerbate N losses. Soil mineral N accretion during autumn and winter is critical to increase the leakage of N (Mitchell *et al.*, 2001). In such a way, some studies suggested cover crops to be sown in post-harvest periods to minimize nutrient losses (Neumann *et al*., 2012; Norberg & Aronsson, 2019). Concerning agricultural practices, fertilization regimes and tillage equally affect N leaching. Split N doses to match crop demand and prevent exceeding the economic N optimum have been reported to effectively curtail N leakage (Delin *et al*., 2014). Inorganic N produced from mineralization comprises a greater proportion of the soil leached N than the N applied in fertilizer forms (Myrbeck, 2014). Mineralization has been indicated to increase with tillage operations as disrupted aggregates make organic matter more accessible to microorganisms (Six *et al.*, 2004). Reduced tillage has therefore been proposed as a potential measure to mitigate N leaching. Crop residues might have considerable effects on soil mineral buildup as well. Incorporation of cereal straw, usually characterized by high C:N ratio, has been approached to diminish N leaks due to N immobilization in microbial biomass during autumn (Jensen, 1997).

4. Materials and methods

4.1 Data collection

A literature review and analysis of existing data were conducted to evaluate the effect of calcium nitrate fertilizer under different precipitation, crop management, soil texture and pH on the response variables: cereal yield, nitrate leaching and nitrous oxide emissions. Crop management was represented by crop type, fertilizer application time and nitrogen dose. Urea and ammonium-based fertilizers were included as benchmarks. Datasets were built from scientific papers and reports that compared the influence of calcium nitrate and at least one other fertilizer on the response variables within the same field trial. Greenhouse trials were excluded from the review. Research papers were searched for on the academic databases *Web of Science*, *Google scholar* and *Scopus* using the key words: calcium nitrate (CN), $Ca(NO_3)_2$, urea (U), ammonium sulfate (AS), calcium ammonium nitrate (CAN), ammonium nitrate (AN), field, cereals, grain yield, nitrate leaching, N_2O, and nitrous oxide emissions. European countries were initially defined as affiliations for all response variables. However, trials comparing calcium nitrate and at least one other fertilizer within the same trial were scant in these locations. Consequently, research from other geographies in the Northern hemisphere with similar climate and soils properties as Europe was approached. For nitrous oxide emissions, other crops than cereals were also enclosed to increase the number of observations. Regarding nitrate leaching, research comparing calcium nitrate with other fertilizers within the same paper was in general scarce. Thus, Swedish fertilization trials were reviewed and described. No dataset for statistical analysis was possible to develop for this variable.

Cereal yield and N_2O emissions databases were developed including literature reference, year of the trial, location of the measurement (country and region), cumulative precipitation in the growing season, crop type, soil texture, soil pH, fertilizer type, N application dose, timing and method of fertilizer application, and the response variables. Other soil parameters such as SOC, soil type and soil N content were included when mentioned in the papers. Yet, these variables were not considered for analysis as the information was incomplete. All regions were classified according to its climate. Climate categorization was defined from the aridity index, calculated as indicated in equation 1 (Zomer *et al*., 2022).

$$Aridity\ index = \frac{Mean\ annual\ precipitation\ (mm)}{Mean\ annual\ reference\ evapotranspiration\ (mm)} \qquad \text{(Equation 1)}$$

Most mean annual precipitation measures were collected from the literature references, whereas missing values were replaced by precipitation data from the regions' closest weather station. When monthly precipitation was given in bar plots, WebPlotDigitizer was utilized to extract data (Rohatgi, 2022). Reference evapotranspiration was assigned to the different sites following the guidelines given by Zomer *et al*. (2022). Climate classes were based on the classification presented in Table 1. Aridity index calculation in this study delivered only humid, sub-humid and semi-arid as the climate categories in the datasets. Similarly, soil texture was sorted into three textural classes: coarse (including sand, loamy sand, sandy loam, loam, silt loam, and silt), medium (sandy clay loam, clay loam, and silty clay loam) and fine (sandy clay, silty clay, and clay) (Bouwman *et al*., 2002).

Table 1. *Climate categories based on aridity index calculations (Mengistu et al.,* 2020*). Categories included in this study are marked in bold.*

Aridity index (AI)	**Climate class**
AI < 0.03	Hyper-arid
0.03 < AI < 0.20	Arid
0.20 < AI < 0.50	**Semi-arid**
0.50 < AI < 0.75	**Sub-humid**
AI > 0.75	**Humid**

4.1.1 Cereal yield dataset

Two datasets were built for grain cereal yield. In the primary set (Appendix 1), data was obtained from research applying the same fertilizer type throughout the crop cycle. The secondary set (Appendix 2) included data from trials where two different fertilizer types were applied during the cropping season. The primary dataset comprised in total 338 observations from 15 different literature references. Two crop categories, winter cereals and spring cereals, were defined to facilitate analysis. Hence, of the total, 105 data corresponded to winter wheat yields, whereas 233 measurements were included in the group spring cereals (barley and wheat). Five countries in Europe (Finland, Italy, Portugal, Sweden, and UK) and the USA from North America were included in the database. All regions in Finland and Sweden were classified into the humid climate class together with some regions in the UK; sub-humid climates were represented by Italy as well as some sites in the UK, while included locations in the USA and Portugal had semi-arid conditions. Compared fertilizer types were calcium nitrate, urea, and ammonium-based fertilizers (ammonium sulfate and ammonium nitrate).

The secondary dataset, with two different fertilizer types applied along the crop cycle, had a total of 85 data from investigations carried out in Finland and Sweden. In Finland, Esala (1991) was the only source of data. Calcium ammonium nitrate was applied as the starter fertilizer in spring wheat, while calcium nitrate, urea or CAN were used as supplementary fertilization at the beginning of either tillering or ear emergence. In Sweden, the *Sverigeförsöken* database was the main source for winter wheat yields. Compared fertilizer types corresponded to urea and calcium nitrate broadcasted at two growth stages: late tillering and late stem elongation. Ammonium sulfate was the starter fertilizer for all the trials and was applied at early growth. As not all trials reported soil texture, clay content was used as classifier for texture classes. Grain protein content and grain N uptake were also included in the dataset from the *Sverigeförsöken* trials. Based upon N uptake, grain N recovery (the proportion of applied fertilizer that was successfully recovered by grain) was calculated as indicated in equation 2.

$$Grain\ N\ recovery\ (\%) = \frac{Grain\ N\ uptake\ fertilizer\ \left(\frac{kg}{ha}\right) - Grain\ N\ uptake\ control\ \left(\frac{kg}{ha}\right)}{Total\ N\ applied\ \left(\frac{kg}{ha}\right)} * 100 \qquad \text{(Equation 2)}$$

Where:

Grain N uptake fertilizer = N taken up by grain from fertilized treatments (kg/ha)
Grain N uptake control = N taken up by grain from unfertilized control treatments (kg/ha)
Total N applied = N dose applied from fertilizers (kg/ha)

In both datasets, the fertilization effect was analyzed as the increase in grain yield with respect to control treatments (no fertilization) (equation 3).

$$Yield\ increase\ (\%) = \frac{Yield\ fertilizer\ \left(\frac{kg}{ha}\right) - Yield\ control\ \left(\frac{kg}{ha}\right)}{Yield\ control\ \left(\frac{kg}{ha}\right)} * 100 \qquad \text{(Equation 3)}$$

Where:

Yield fertilizer = grain yield obtained from fertilized treatments (kg/ha)
Yield control = grain yield obtained from unfertilized control treatments (kg/ha)

4.1.2 Nitrous oxide dataset

Nitrous oxide emissions data (Appendix 3) was collected from trials in which the same fertilizer type was applied throughout the cropping season to different crop types: cereals (winter wheat, winter barley and maize) in Spain, France, Japan and the USA, vegetables (carrot) in Japan, fruits (melon) in Spain, and grass (ryegrass) in Ireland and the UK. The resulting database consisted of 133 data from 8 research articles. Compared fertilizer types corresponded to ammonium nitrate, calcium nitrate and urea. As some of the trials did not include control treatments, direct emissions from fertilizers were not estimated. Humid climate was represented by France, Ireland, Japan, the USA, and the UK. Sub-humid climate accounted for Spain and the USA, while semi-arid climate included Spain. Data corresponding to winter wheat and barley in Spain and France were obtained from Plaza-Bonilla *et al.* (2017) who performed a 9-year soil-crop simulation to predict N_2O fluxes under Mediterranean conditions. Even though the model had been previously calibrated and validated with experimental data, uncertainties were still a matter of concern.

4.2 Data analysis

A linear mixed effects (LME) model was deployed for data analysis to describe the response variables (grain cereal yield and nitrous oxide emissions) as a function of fertilizer type, crop management, soil, and climate properties. Region was defined as a random effect, while climate, precipitation, fertilizer type, nitrogen dose, fertilizer application time, crop type and soil attributes were modeled as fixed effects. This kind of model is powerful and useful to account for correlations between one dependent continuous variable and several independent continuous and categorical predictors per observation unit (Oberg & Mahoney, 2007). Analysis of variance tables were computed for each model to identify predictors with significant effects on the response variables. Estimated marginal means (emmeans) and estimated marginal means of linear trends (emtrends) functions were used to estimate the difference in means and slopes, respectively for significant predictors. For comparisons, a pairwise post-hoc test was used. All analysis for N_2O fluxes were conducted on natural log transformed data to meet the assumptions of a linear regression. The statistics were performed at 5% significance level in the software R (R Core Team, 2019). Categorical predictors corresponded to climate, fertilizer application time, crop type, fertilizer type, and soil texture. Continuous variables were nitrous oxide emissions, cereal yield, soil pH, nitrogen dose and cumulative precipitation during the growing season. Descriptive analyses were performed for the single trial in Finland with two fertilizer types applied along the cropping season, as well as for nitrate leaching research in Sweden.

5. Results and Discussion

5. 1 Crop yield

5.1.1 Effect of precipitation, soil properties and one fertilizer type in the cropping season

The effect of one single fertilizer type applied along the crop cycle (primary dataset) was analyzed as the increase in grain yield with respect to non-fertilized treatments (equation 3). On average, fertilization increased cereal yield by 68% in comparison with unfertilized control treatments. Dataset comprised all textural classes (fine, medium and coarse), with soil pH ranging between 5.7 and 8.1. Nitrogen application doses varied between 50 and 200 kg/ha for winter cereal trials. Doses were supplied as single or split applications. About 46% of the winter wheat observations came from single N doses applied in spring, 16% from a single dosage supplied in fall, and 38% derived from N doses split between fall and spring. Autumn doses ranged between 67 and 112 kg N/ha and were administered at sowing or near it. Spring applications varied from 56 to 168 kg N/ha and were applied either at late tillering or at stem elongation stages. Split N doses ranged between 50 and 200 kg N/ha, with first applications in autumn at sowing and the second ones in spring, at tillering and/or stem elongation. For spring cereals, total N doses ranged from 44 to 150 kg/ha, and most data originated from applications at sowing. For both crop types, broadcast was the predominating application method of fertilizer. To a smaller extent, cover dressing and injection by irrigation systems were also registered for winter cereals. For spring cereals, combine-drilled, incorporation, and side dressing were also represented as practiced methods in the included data.

Grain yield was modeled as a function of climate, fertilizer type, cumulative precipitation in the growing season, and cereal type. No individual significant factor effects were observed (Table 2), but the interaction between precipitation and cereal type significantly predicted the response variable (p-value < 0.05). Figure 2 illustrates grain yield data variability as a function of monthly average precipitation in the growing season for spring and winter cereals. The estimated slope from the model indicates that one millimeter of precipitation was equivalent to 0.125% yield increase in spring cereals, while the same amount of rainfall would significantly reduce yield by 0.161% in winter cereals. Some studies have demonstrated that winter cereal yields are negatively correlated with precipitation in various areas (Kristensen *et al.*, 2010; Himanen *et al.*, 2013). In Nordic regions, increased precipitation in autumn complicates winter wheat sowing, germination and causes nutrient leaching from soil, especially nitrogen and phosphorus. Wet autumns also promote strong winter weed populations that compete with crops for resources. Additional damage relates to moist conditions in May and June that raise Septoria leaf spot incidence, decreasing photosynthetically active leaf area (Wiréhn, 2018). The positive correlation between spring grain yields and increasing precipitation has also been reported in some studies (Gan *et al.*, 2014; Morgounov *et al.*, 2018). Cammarano *et al.* (2019) ascribed this positive relationship to the uptake and assimilation of nutrients promoted by raised rainfall between sowing and anthesis of spring barley. Morgounov *et al.* (2018) stated June as a critical month in spring wheat, where an increased precipitation alleviates heat shock at the stem elongation stage.

Table 2. *Statistical effect of climate, cumulative precipitation in the growing season, fertilizer type and cereal type predictors on grain yield.*

Factor	**P-value**
Precipitation growing season	0.4135
Cereal type	0.4447
Fertilizer type	0.5601
Climate	0.1520
Precipitation growing season x Cereal type	**0.0001**
Precipitation growing season x Fertilizer type	0.6109
Cereal type x Fertilizer type	0.5007
Precipitation growing season x Cereal type x Fertilizer type	0.7549

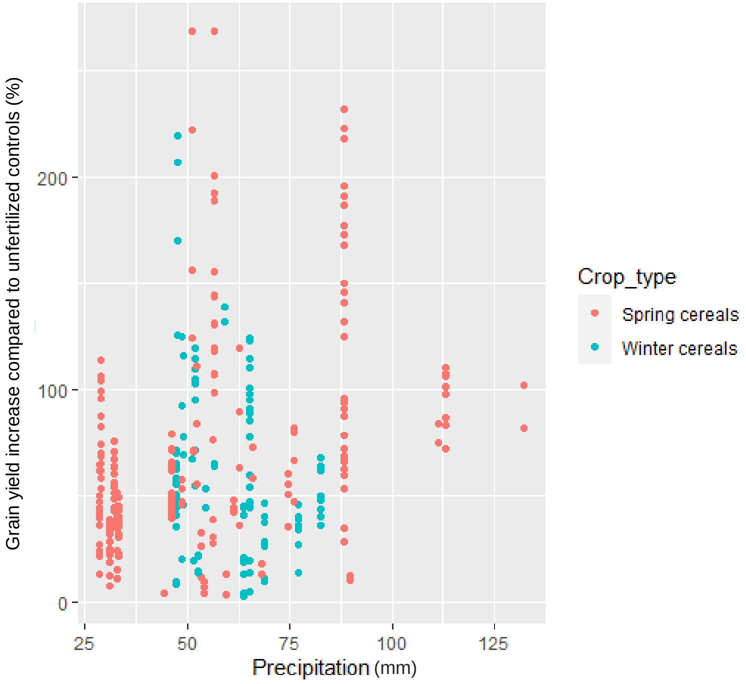

Figure 2. *Grain yield data variability for spring and winter cereals as a function of monthly average precipitation in the growing season.*

The grain yield attributable to fertilizer type was not significant. Hence, under these circumstances, fertilization with calcium nitrate would result in the same yield as ammonium-based fertilizers or urea. This is in agreement with Mahler *et al.* (1994) and Carranca *et al.* (1999) who did not find a significant influence of different fertilizer types on cereal grain yield.

As both nitrate and ammonium-based fertilizers are liable to N losses when applied in autumn (Malhi & Nyborg, 1986), fertilizer application time (autumn, spring or both) was modeled independently for winter cereals. Results indicated that grain yield was indeed significantly affected by the time of supplying (p-value < 0.05) (Table 3). Single applications in fall showed the lowest yield among all timings, whereas splits between autumn and spring, and single supplies in spring were not distinct (Figure 3). This is noteworthy to highlight that the above differences might have been ascribed to lower N doses in autumn (ranging from 67 to 112 kg N/ha) than those supplied as split applications (50-200 kg N/ha) or exclusively in spring (56-168 kg N/ha). The findings in this study, however, coincided with Malhi *et al.* (2001) who in a review observed that the efficiency of N administered in autumn is lower than of N applied in spring. Furthermore, Aulakh and Rennie (1984) reported a higher proportion of N immobilization from autumn-applied N than from spring-distributed N doses. This in turn means larger crop N recovery and yield from spring applications than from fall supplies. Based on the aforementioned and the results of this study, N applications at late tillering or stem elongation in spring would potentially boost winter wheat grain yields in humid conditions.

Overall, climate was not a significant predictor of cereal yield. However, in semi-arid climates, splitting N doses between fall and spring would positively impact the first growth stages. Fertilizer application time did not affect grain yield of spring cereals. These results agree with Melhi *et al*. (2001) who claimed that at spring applications, neither timing nor fertilizer type are exceptionally relevant as weather promotes fast spring cereals growth and nutrient uptake.

Table 3. *Statistical effect of fertilizer application time and cumulative precipitation on grain yield of winter cereals.*

Factor	P-value
Fertilizer application time	**< 0.0001**
Precipitation growing season	0.0049
Fertilizer application time x Precipitation growing season	0.5246

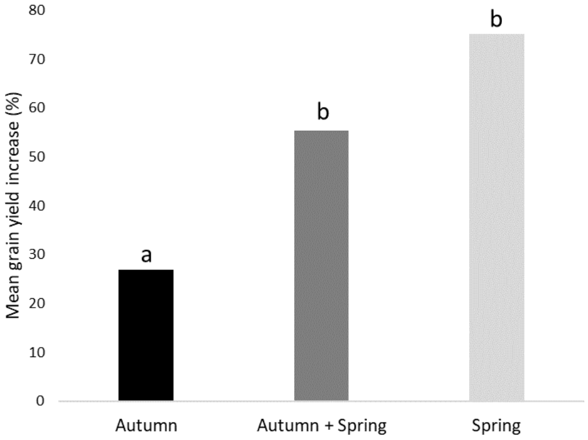

Figure 3. *Mean grain yield increase with respect to unfertilized treatments by fertilizer application time. Different letters indicate significant differences.*

Since the mechanisms of N losses are soil properties dependent (Wallman & Delin, 2022), the relationship between grain yield, soil properties (textural class and soil pH) and fertilizer type was analyzed across the whole database. Computed ANOVA pointed out that only textural class had a significant effect on cereal yield (Table 4). Means from the model in Figure 4 illustrate that fertilization in fine-textured soils increased grain yield by 102% in comparison to no fertilizer addition. Coarse soil textures differed significantly from fine but not from medium textural classes. Tremblay *et al*. (2012) found in a meta-analysis conducted in the USA, that corn yield response to added N was significantly greater in fine textured soils than in coarse ones. This is attributable to the large yield potential of fine textures represented by great water holding capacity, organic matter content and cation exchange capacity.

Table 4. *Statistical effect of soil properties, fertilizer type and climate predictors on grain yield.*

Factor	P-value
Textural class	**< 0.0001**
Fertilizer type	0.6010
Soil pH	0.0882
Climate	0.1751
Textural class x Fertilizer type	0.5491
Soil pH x Fertilizer type	0.9386

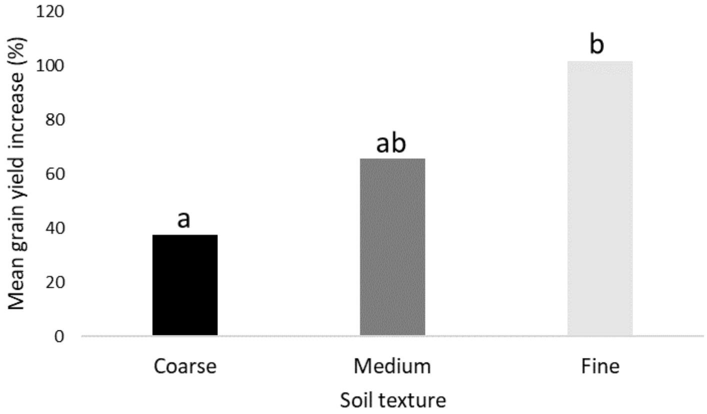

Figure 4. *Mean grain yield increase with respect to unfertilized treatments by soil textural class. Different letters indicate significant differences.*

The application method for fertilizer was not statistically analyzed since broadcasted application was the predominant method across the database, and analysis would have been skewed. Nevertheless, it has been identified that the distribution practice of N fertilizers in the field might affect crop N uptake, yield and N losses. Esala (1991) claims that broadcast applications aim at guaranteeing crop N uptake at stages such as grain filling in cereals. However, Malhi *et al.*, (2001) suggests that when fertilizers are evenly broadcast to the soil surface, N is prone to losses by volatilization and run-off. Fertilizer incorporation usually implies spreading of granules onto the topsoil and subsequently mixing them with soil by tillage. When using this method, the microbial contact with the fertilizer increases per unit area of soil and thereby increases N immobilization or transformation. However, the net occurrence of any of these latter mechanisms depends on the soil C:N ratio. Malhi *et al.* (1996) found that when fertilizers were incorporated, soil N recovery was larger than sideband and below seed row methods. Carter and Rennie (1984) also reported great microbial immobilization of supplied N under incorporation. In-soil banded applications consist of placing N fertilizers as bands in parallel to crop rows in soil (Malhi *et al.*, 2001). This practice is reported to improve the efficiency of fertilizer supply as both immobilization and volatilization losses are likely to be reduced (Fenn and Miyamoto, 1981). Literature reviews have indicated that nitrification is also strongly slowed down when N fertilizers are in bands compared to broadcast and incorporation practices (Malhi *et al.*, 2001; Yadvinder-Singh *et al.*, 1994). In humid climates, Van Kessel *et al*. (2013) indicated that fertilizer placement in bands at 5 cm depth would decrease nitrous oxide fluxes. Minimized N losses due to banding will result in high crop N recovery and hence large yields.

5.1.1.1 Effect of two different fertilizer types in the cropping season

This section focuses on grain yields obtained from the application of two different fertilizer types throughout the cropping season (secondary dataset). A descriptive analysis was performed for spring wheat trials in Finland, while experiments in Sweden were assessed by the LME model in R software.

Essala (1991) carried out a field experiment in Jokioinen and Mietoinen (Finland) from 1986 to 1989. The aim of the trial was to evaluate the effect of split nitrogen doses on spring wheat grain yield, and grain protein content. Treatments corresponded to three fertilizer types and two times of application; no control was included in the analysis. Total N dose was 140 kg N/ha. All treatments received a basal application of 100 kg N/ha of CAN applied by combine-drilled. The remaining 40 kg of N were granules broadcasted either as CAN, CN or U at the beginning of tillering or beginning of ear emergence. A foliar sprayed urea treatment was also included. One single dressing of 140 kg N/ha as CAN at sowing was used as comparison. Trials were established on clay soils with a pH of 6.4. Spring wheat was sown in May and harvested between the end of August and beginning of September at each location. Fertilization at tillering was applied one month after planting, while for ear emergence fertilizer was supplied about 1.5 after sowing. Four-year mean precipitation in the growing season was 348 and 364 mm in Jokioinen and Mietoinen, respectively.

Results were presented as averages for two experimental sites and four years. Neither fertilizer type nor application time showed any statistically significant effect on grain yield (Table 5). By contrast, both fertilizer type and timing were significant predictors of protein content. Foliar sprayed urea resulted in the lowest protein amount among all fertilizer types. Similar outcomes were demonstrated by Lamattina *et al*. (1985) as both granular and sprayed urea decreased protein proportions in comparison with granular calcium nitrate. Reduced protein content by foliar urea is suggested to be caused by NH_3 volatilization not only from foliage but also from urea that ended up in soil surface. Another plausible explanation might be associated with phytotoxicity of NH_3, supported by scorching of the leaves observed after sprayed urea by Vasilas *et al*. (1980).

Fertilizer application at the beginning of ear emergence significantly increased protein content by 0.2% than an early supply at tillering. A grain yield of 3480 kg/ha was obtained with a single application of 140 kg N/ha as CAN fertilizer at sowing. This was significantly higher than yields from split applications. Protein content (14.5%) however, was statistically lower than when splitting the N dose.

Table 5. *Grain yield and protein content of spring wheat in the period 1986-1989 at two experimental sites in Finland (Modified from Esala 1991).*

Fertilizer source	**Application time**	**Yield (kg/ha)**	**Protein content (%)**
CAN$^+$	Tillering	3340	14.6
CAN	Ear emergence	3320	14.8
CN	Tillering	3370	14.8
CN	Ear emergence	3320	15.1
U granular	Tillering	3340	14.5
U granular	Ear emergence	3310	14.8
U foliar	Tillering	3340	14.4
U foliar	Ear emergence	3350	14.3
Fertilizer type mean values			
CAN		3330	14.7
CN		3345	14.9
U granular		3325	14.7
U foliar		3345	14.4
Application time mean values			
Tillering		3348	14.6
Ear emergence		3325	14.8
Statistically significance of differences			
Fertilizer		ns	***
Application time		ns	*
Fertilizer x Application time		ns	ns

$^+$Dose of 40 kg N/ha. All treatments receiving 100 kg N/ha as CAN applied at sowing along with seed. *Significance difference at 95% confidence level ($\boldsymbol{\alpha}$=0.05). ***Significance difference at 99.9% ($\boldsymbol{\alpha}$=0.001). ns= not significant.

In Sweden, winter wheat trials were carried out from 2016 to 2018 by Swedish agricultural societies (*Sverigeförsöken, series L3-2300*). Field experiments were set up each year at six different locations within the municipalities Grästorp, Lund, Simrishamn, Ängelholm, Eslöv, Västerås, Mjölby, Hallstahammar and Linköping. Total N dose corresponded to 160 kg/ha. All trials received a standard application of 20 kg N/ha as ammonium sulfate between March 27th and April 17th. Treatments consisted of calcium nitrate, urea or ammonium nitrate supplied at tillering (100 kg N/ha) and stem elongation (40 kg N/ha). All fertilizers were broadcasted. Grain yield, grain N uptake and grain protein content were the response variables. Grain N recovery was estimated as indicated in equation 2, and an average value of 52% was obtained from the dataset.

Grain yield increase with respect to unfertilized controls was modeled as a function of fertilizer type, cumulative precipitation in the growing season and grain N recovery. Outcomes showed only grain N recovery significantly predicted yield increment (p-value < 0.05; Table 6). Slope estimates that a 1% increase in grain N recovery will represent a grain yield rise of 1.15%. Fertilizer type effect was not significant in this dataset either. Among all trials, the experiment carried out in Eslöv (2017) showed significant differences in grain yield associated with fertilizer type. In this respect, calcium nitrate exhibited the highest grain yield with 8970 kg/ha compared to 8580 kg/ha and 8200 kg/ha for ammonium nitrate and urea, respectively. This represents a 105, 96 and 88% yield increase for each fertilizer type compared with unfertilized treatments. Yet, factors that might have contributed to differences between fertilizer types in this individual trial are uncertain.

Table 6. *Statistical effect of fertilizer type, grain N recovery and cumulative precipitation in the growing season predictors on grain yield.*

Factor	**P-value**
Fertilizer type	0.7164
Grain N recovery	**0.0026**
Precipitation growing season	0.1166
Fertilizer type x Grain N recovery	0.9799
Fertilizer type x Precipitation growing season	0.9971
Grain N recovery x Precipitation growing season	0.9037
Fertilizer type x Grain N recovery x Precipitation growing season	0.9638

A separate model was run to evaluate whether grain protein content was influenced by fertilizer type. Unlike the results for Finnish spring wheat trials, fertilizer type did not have any significant effect on the protein content for this dataset (p-value > 0.05; Data not shown).

Additionally, no clear trends were observed between soil properties, fertilizer type and grain yield from this data collection (Table 7).

Table 7. *Statistical effect of soil properties and fertilizer type predictors on grain yield.*

Factor	**P-value**
Soil pH	0.2166
Clay content	0.4523
Fertilizer type	0.7569
Soil pH x Clay content	0.2733
Soil pH x Fertilizer type	0.9953
Clay content x Fertilizer type	0.9069
Soil pH x Clay content x Fertilizer type	0.9610

5.2 Nitrous oxide emissions

Nitrous oxide emissions data was collected from medium and coarse soil textures, with pH ranging from 4.1 to 8.3. The dose and application time of fertilizer (AN, CN and U) was site and crop dependent. In winter cereals in France and Spain, N fertilizer was broadcasted at stem elongation (Plaza-Bonilla *et al.*, 2017). In Japan, N was incorporated immediately before sowing regardless of the crop (Nishimura *et al.*, 2021; 2022). Fertilizer injection was carried out in the USA (Duxbury & McConnaughey, 1986; Waterhouse *et al.*, 2017) and Spain (Abalos *et al.*, 2014) for maize and melon, respectively. Split N applications were applied to ryegrass for one year in the UK (Clayton *et al.*, 1997) and Ireland (Rahman & Forrestal, 2021). Nitrogen doses ranged between 50 and 360 kg N/ha/year. The minimum supply was registered for winter barley in a semi-arid region in Spain, whereas the maximum dosage was applied in ryegrass under humid climate in the UK. Nitrous oxide emissions ranged from 0.07 to 5.21 kg/ha/year across the database.

When N_2O fluxes were modeled as a function of fertilizer type, climate, and cumulative precipitation in the growing season, only climate was a significant predictor of the emissions (p-value < 0.05; Table 8). Mean cumulative annual N_2O release was significantly higher in humid climates than in semi-arid conditions (Figure 5). This agrees with Plaza-Bonilla who found larger N_2O production under humid climates (2.51 kg N_2O/ha/year) than in semi-arid ones (0.26 kg N_2O/ha/year). These authors also reported that N_2O fluxes range between 0.26 and 0.65 kg/ha/year in semi-arid climates of the Mediterranean region. A similar range (0.32 - 0.68 kg N_2O/ha/year) was indicated by Kessavalou *et al*. (1998) in the semi-arid plains of the USA. These outcomes might respond to the interannual rainfall variability and evapotranspiration within each type of climate that impact soil properties such as moisture. A positive correlation has been described between soil moisture and N_2O fluxes (Giacomini *et al*., 2006). Perdomo *et al.* (2009) reported the highest soil emissions after rain or irrigation events as the water filled pore space (WFPS) usually increased. The larger the WFPS the greater N_2O fluxes from denitrification. This implies that denitrification is the main source of N_2O when WFPS is higher than 70%, whereas nitrification is the major origin when WFPS decreases below 60%. Other factors such as soil temperature also affect nitrification and denitrification rates. A clear correlation has been observed between soil temperature and N_2O emissions, as microbial activity rises at higher temperatures. Increasing soil temperature stimulates microbial respiration, meaning increasing anaerobic sites in which denitrification might occur (Liu *et al*., 2011).

A model was run to assess the influence of soil properties (textural class and pH) and fertilizer type on N_2O fluxes. Also, climate was included as a factor in the model since it might affect soil water balance. Regression analysis showed that emissions were significantly attributable to soil pH (p-value < 0.05; Table 9). A regression coefficient of -0.2236 suggested a reduction of 20% in N_2O releases with the increase of one unit of soil pH within the range 4.1-8.3. This is in context with literature reviews that indicate that low soil pH inhibits the functioning of the nitrous oxide reductase enzyme (that mediates the reduction of N_2O to N_2), hence enhancing N_2O releases (Hénault *et al.*, 2019; Nadeem *et al*., 2020). Thus, continued acidification of arable land from fertilizers use would intensify N_2O production, while a pH adjustment by for instance liming would decrease emissions (Signor & Pellegrino, 2013). Studies have reported that calcium nitrate fertilization raises soil pH, becoming a potential way to reduce pollution by N_2O. Gudmundsson *et al*. (2004) found a long-term increase in pH of 0.4 units when calcium nitrate was compared to unfertilized controls in an Icelandic gleysol. In dryland, Conyers *et al.* (2011) reported in a year 0.3 units increase in pH compared with control, as wheat was fertilized with calcium nitrate in Australia. Hénault *et al.* (2019) observed that when raising soil pH to neutrality (6.8), N_2O emissions are efficiently diminished.

It is important to highlight that the data included emissions from medium and coarse soil textures, while studies on fine texture soils were lacking. If comparable fertilizer trials in fine-textured soils had been found, possibly differences might have arisen between soil textures. Overall, research claims larger nitrous oxide fluxes in clayey soils than in sandy soils (Brentrup *et al*., 2000; Wrage *et al*., 2001; Signor & Pellegrini, 2013). This is likely owing to the small proportion of macropores in clay textures that will increment anaerobic microsites and hence N_2O production.

Table 8. *Statistical effect of climate, cumulative precipitation in the growing season and fertilizer type predictors on annual* N_2O *emissions.*

Factor	p-value
Fertilizer type	0.0719
Precipitation growing season	0.5622
Climate	**0.0143**
Fertilizer type x Precipitation growing season	0.9806

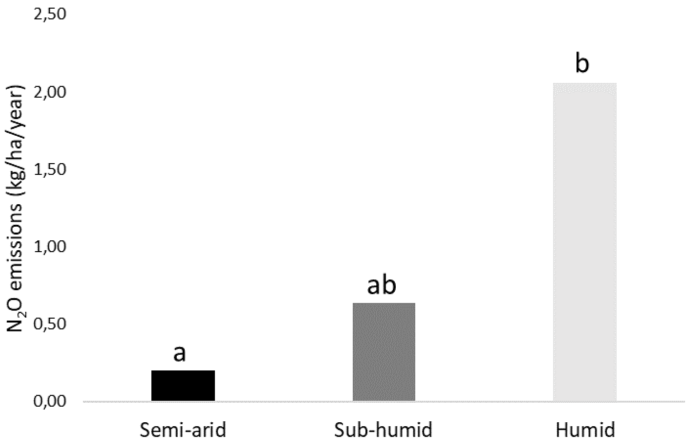

Figure 5. *Mean cumulative N_2O emissions in different climates. Different letters indicate significant differences.*

Table 9. *Statistical effect of soil properties, climate, and fertilizer type predictors on annual N_2O emissions.*

Factor	**P-value**
Textural class	0.2521
Fertilizer type	0.0699
Soil pH	**0.0158**
Climate	0.1204
Textural class x Fertilizer type	0.3542
Textural class x Soil pH	0.2980
Fertilizer type x Soil pH	0.4078
Textural class x Fertilizer type x Soil pH	0.8863

Nitrous oxide emissions are likely to increase with N application dose (Wrage-Mönnig *et al*., 2018). As this study indicated that N dose was crop-dependent, a model comprising application dosage, crop type and fertilizer type was analyzed. Nitrogen application dose and crop type resulted in factors significantly influencing the gaseous fluxes (Table 10). The regression coefficient for N dose estimated that N_2O emissions increased by approximately 0.5% for each kilo of N added/ha. Similar outputs were obtained by Maaz *et al*. (2021) who in a meta-analysis calculated an increment of 0.4% in N_2O fluxes with the increase of 1 kg N/ha. A positive relationship between N dose and N_2O emissions has also been described by Bouwman *et al*. (2002). Ciarlo *et al.* (2008) observed great nitrous oxide fluxes during the first two weeks after fertilizer application, implying higher emissions from larger N doses. Since an increase in available nitrogen boost nitrification and denitrification processes (FAO, 2017), split N applications are claimed to decrease N_2O release in comparison to single doses.

Concerning the crop types included, carrots had the highest N_2O emissions, while melon exhibited the lowest releases (Figure 6). Reduced fluxes from melon might have been associated with large N use efficiency owing to fertilizer injection (Abalos *et al*., 2014). Thus, results might be related to fertilizer application method rather than the crop itself. Fertigation, known as the application of soluble fertilizers via irrigation systems, is reported by Hasler *et al*. (2017) as a practice to use water and nutrients efficiently. Besides, the flexible application schedule permits precise nutrient administration at key crop growth stages. Under these circumstances, N losses are feasible to be reduced. Principally in harsh climates, where conditions are unsuitable for intensive crop production, irrigation and its combination with soluble fertilizers allow agricultural production to thrive. According to Sauer *et al.* (2010), 20% of the global arable land is under irrigation, representing roughly 40% of the harvest worldwide. Nevertheless, irrigation is an energy and carbon demanding practice. FAO (2017) predicted that 23% of the energy used on-farm for crop production in the USA was for pumping with irrigation purposes.

Table 10. *Statistical effect of crop type, fertilizer type and N dose predictors on annual N_2O emissions*

Factor	p-value
Fertilizer type	0.0665
N application dose	**0.0095**
Crop type	**0.0053**
Fertilizer type x N application dose	0.2418

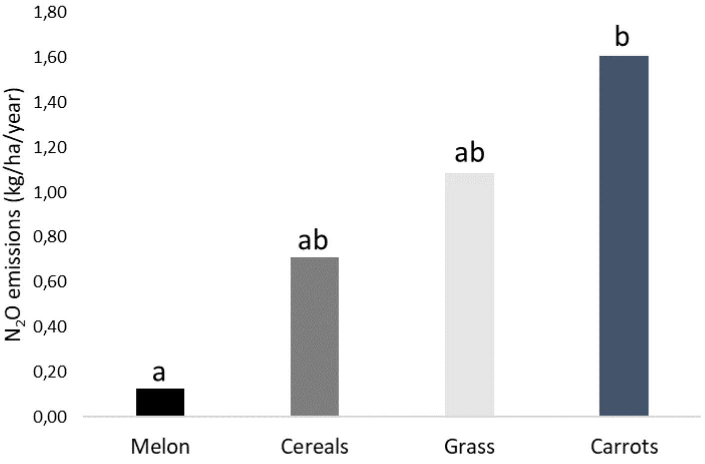

Figure 6. *Mean cumulative N_2O emissions by crop type. Different letters indicate significant differences.*

Overall, fertilizer type did not significantly influence N_2O production. Emissions averages for CN, AN and U were 0.560, 0.648 and 0.679 kg N_2O/ha/year, respectively. Abalos *et al.* (2014) state that for urea and ammonium-based fertilizers both nitrification and denitrification can be involved in N_2O production, weighing the denitrification emissions from nitrate-based fertilizers. Results from this analysis coincide with Bergstrom *et al*. (2001) who did not observe any differences in N_2O fluxes when comparing urea, ammonium sulfate and calcium nitrate applied to grass. Conversely, Bhandral *et al.* (2007) found N_2O were significantly attributed to fertilizer type when applied to a compacted coarse-textured soil in a New Zealander grassland. According to that study, 10 times more N_2O was emitted from potassium nitrate compared to ammonium sulfate and urea. Under uncompacted soil, differences were less marked, however, potassium nitrate still showed the highest gaseous fluxes. Even though these outcomes might have been allocated to the large N dose applied (600 kg N/ha), it is pertinent to highlight the importance of preserving soil structure and thereby aeration, minimizing the most soil compaction.

5.3 Nitrate leaching

In this section, diverse research on nitrate leaching carried out under Swedish conditions are compared descriptively, meaning no statistical analysis was performed.

Norberg and Aronsson (2019) carried out a trial from 2012 to 2018 to evaluate the effect of cover or catch crops on N leaching following a main spring cropping season. The main crop was spring barley for all years, except for 2013 that was cultivated with peas. Catch crops corresponded to oilseed radish and control plots with no cover crop were included for comparison. Spring crops were harvested around July to enable an early sowing of catch crops in August. In late autumn, cover crops were soil incorporated by tillage. The field trial was performed in southern Sweden at the Lönnstorp Research Station. Mean annual precipitation was 602 mm (1961-1990), and soil texture was silt loam, classified as coarse textural class (Bouwman *et al.*, 2002). The main crop was fertilized at sowing with 100 kg N/ha in the form of ammonium nitrate placed along with the seed. Drainage samples were collected from tile-drained plots and total N concentrations were determined from unfiltered samples. Soil mineral N was measured three times in each plot: after the main crop was harvested and before the catch crop was sown; before residues incorporation of catch crops in late fall, and before the main crop cultivation in spring. Raw data derived from this research was provided by Helena Aronsson in March 2023, which was deployed to analyze N dynamics in soil cropped with barley. Thus, results presented in this review focused on only the barley growing season and its post-harvest (2014 onwards) in control plots.

Figure 7 shows the seasonal variability of N leaching for spring barley during the growing (April-July) and post-harvest (August-March) periods in control plots. Monthly precipitation was also included as a reference. On average, 93% of N leaching occurred in the post-harvest season, while the remaining proportion was attributable to the barley growing period. In humid cool temperate regions, precipitation surpasses evapotranspiration, allowing the downward flow of water through the soil profile (Jelinski *et al.*, 2022). After soil reaches field capacity, water drains from macropores owing to gravitational forces (Zotarelli *et al.*, 2010), transporting soluble constituents, such as nitrate, below the root zone. Di and Cameron (2002) reported that N leaching predominates in the no-crop season of humid temperate regions because of residual soil N and low or null evapotranspiration and crop N uptake. Since the major share of N leaching takes place in the post-harvest season, Norberg and Aronsson (2019) demonstrated that oilseed radish minimized leakage of N by on average 59% when compared to control. This was derived from the N uptake and its subsequent incorporation in above-ground biomass of radish during autumn that decreased N availability for leaching.

Figure 8 illustrates both NO_3^- and NH_4^+ distribution in the soil profile of control plots at 0-30 and 30-60 cm depth at two different sampling times: before sowing of barley in spring and at harvest for the period 2015 to 2017. A clear trend for ammonium to stay predominantly in the topsoil (0-30 cm) was observed. A similar pattern was identified for NO_3^-, being spring 2017 the exception as the subsoil concentration was larger than on the shallow depths. Ammonium reductions from harvest to spring suggest continuous nitrification over autumn and winter, though N immobilization might also be a cause. This coincides with Yadvinder-Singh *et al.* (1994) who states that substantial nitrification takes place in winter, promoting NO_3^- leaching and some build-up in early spring. Malhi *et al.* (2001) estimated an average nitrification rate in Alberta (Canada) at 0.19 kg N/ha/day during late autumn and early winter when soils were at or close to freezing.

A general NO_3^- depletion from the beginning of the growing season until harvest at 30-60 cm depth was also marked, indicating an active crop N uptake. The increase of NH_4^+ concentration in the topsoil, also during the crop cycle, may reveal mineral N input from organic matter mineralization and fixation by free living diazotrophs. This confirms the claim by Wrage-Mönnig *et al.* (2018) that during crop seasons, root exudates stimulate microbial activity, hence triggering N transformations in the rhizosphere. Nitrogen produced from these reactions is then a matter of competition between plants and microorganisms. Therefore, plant N uptake decreases losses derivable not only from NO_3^- leaching but also from N_2O emissions (Wrage *et al.*, 2001).

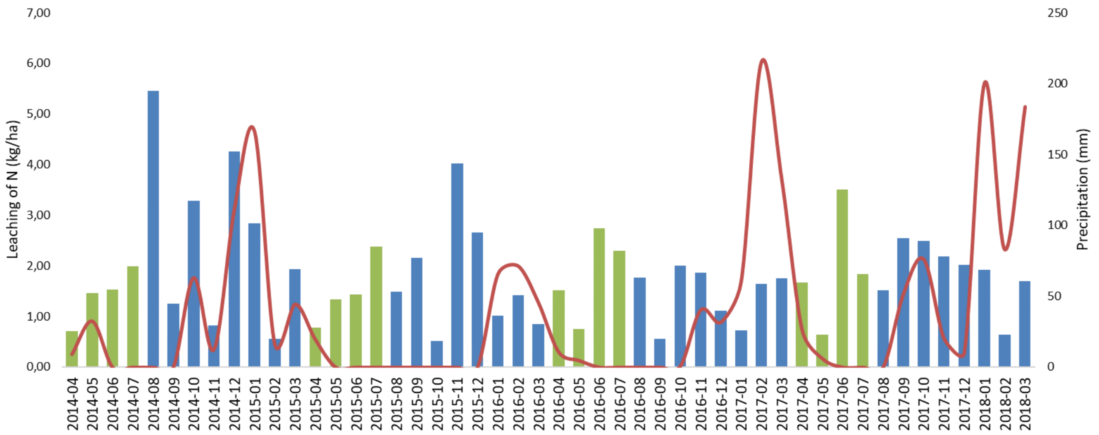

Figure 7. *Seasonal variation of nitrogen leaching and precipitation for barley growing season and its respective post-harvest period. Green bars represent rainfall in the crop cycle (April-July), whereas blue bars indicate post-harvest precipitation (August-March). Red line refers to nitrate leaching.* ***Source:*** *own elaboration based on data provided by Norberg and Aronsson (2019). Precipitation data was obtained from Malmö weather station (2014-2018 SMHI).*

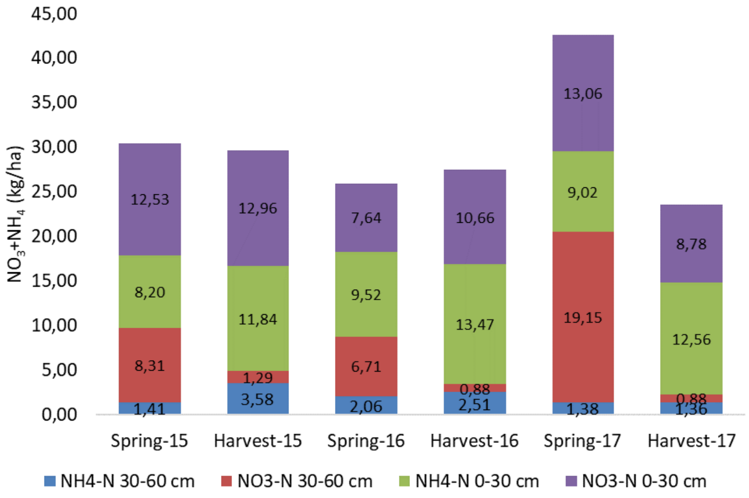

Figure 8. *Nitrate and ammonium distribution in the soil profile of control plots (no catch crops) at 0-30 and 30-60 cm depth, and at two different sampling times: before sowing of barley in spring and at its harvest for the period 2015 to 2017.* ***Source:*** *own elaboration based on data provided by Norberg and Aronsson (2019).*

Wallman and Delin (2022) conducted a tile-drained plot experiment at Lanna Research Station in southwestern Sweden. The aim was to estimate the effect of N source (mineral and organic) and application rate on total N leaching from cropping season and onwards. As the effect of organic N sources are out of the scope of this thesis, only treatments with synthetic fertilizers are referred to in this review. The soil texture was silty clay with pH ranging between 6.6 and 7.2. Nitrogen atmospheric deposition in the area was estimated at 6 kg N/ha/year. Three agronomic years were studied (April 1st, 2014 - March 31st, 2017) with annual precipitation of 640, 548 and 399 mm, respectively. Each agronomic year comprises a crop season from April to September, and a no-crop period between October and March. Crop rotation was winter wheat - spring barley - spring oats for the years 2014, 2015, and 2016 respectively. Treatments were as follows:

1. Control with no fertilizer addition
2. Normal mineral N rate (NM): 160 kg/ha for winter wheat, and 120 kg/ha for barley and oats
3. High mineral N rate (HM) with 50% more N than in the normal dose: 240 kg/ha for winter wheat, and 180 kg/ha for barley and oats

Normal mineral N rates were defined based on recommendations by the Swedish Board of Agriculture for each crop to reach the economic optimum. Nitrogen rates were split in two applications in April and May. All first N doses were supplied in the form of ammonium nitrate. The second doses were in the form of calcium nitrate for winter wheat, and ammonium nitrate for spring cereals. All fertilizers were (surface) broadcasted. Grain yield and N uptake were also included as response variables.

Results over the three agronomic years showed that HM treatment tended to have the largest N leaching among all treatments (Table 11). Alike Norberg and Aronsson (2019), Wallman and Delin (2022) indicated that the no-crop period dominated the leaching of nitrogen. In the agronomic years 2014-2015 and 2015-2016 around 80-85% of N leakage occurred in the post-harvest season, while this share represented 60% in 2016-2017. Nitrogen leaching did not differ statistically between normal mineral N rates and control treatments. Large N rates (HM) gave higher grain and N yields than control and recommended doses (NM). In spring barley, the normal N rate of 120 kg/ha resulted in 17 kg/ha/year of N leaching. Similar leaching rates were found by Bertilsson (1988) when testing different fertilizer types in spring cereals cultivated in a coarse-textured soil in Sweden. In this study ammonium sulfate, calcium ammonium nitrate and calcium nitrate were broadcasted two weeks after emergence at a dose of 120 kg N/ha. Leaking of N was 20 kg N/ha/year for AS, while leaching from CAN and CN registered the same loss (16 kg N/ha/year; Bertilsson, 1988).

Table 11. *Leaching of N, grain yield and N uptake derived from control, normal mineral N rate and high mineral N rate treatments.* ***Source:*** *Modified from Wallman and Delin (2021). Values with the same letter are not significantly different.*

Treatment	**Leaching of N (kg/ha/year)**	**Grain yield (kg/ha)**	**Grain N uptake (kg/ha)**
	2014-2015: **Winter wheat**		
Control	18.87 a	3500 a	43 a
NM: 160 kg N/ha	20.10 a	7700 bc	136 b
HM: 240 kg N/ha	25.11 b	8000 c	168 c

2015-2016: **Spring barley**			
Control	14.07 a	2500 a	28 a
NM: 120 kg N/ha	17.04 a	7000 b	88 b
HM: 180 kg N/ha	22.62 b	7900 c	120 c
2016-2017: **Oats**			
Control	4.70 a	2500 a	28 a
NM: 120 kg N/ha	4.33 a	6100 b	76 b
HM: 180 kg N/ha	6.25 a	6800 c	102 c

Aligned with tile-drained plot experiments, Bergström (1987) performed a field trial to evaluate the effect of calcium nitrate fertilization on N leaching from barley, grass ley and lucerne ley. The research was carried out from 1981 to 1984 in Kjettslinge, central Sweden. The soil texture was clay loam with soil pH of 6.3. Treatments consisted of barley with no fertilizer addition, barley with 120 kg N/ha, grass ley with an annual split N distribution (120 + 80 kg N/ha), and lucerne ley with no fertilization. Results indicated that most of the N contained in drainage water was in the form of NO_3^-, while NH_4^+only represented a small fraction (0.1 mg/l). Nitrate losses presented in Table 12 suggest that calcium nitrate fertilization increased NO_3^- leaching in barley compared to grass ley over time. This contrast is attributable to considerable amounts of inorganic N left in soil by barley crops and mineralization that takes place in autumn. As grasses are perennials, N uptake is continuous, reducing the risk for nitrate leaching in the short term (Gustafson, 1983). Considering NO_3^- concentrations were rather constant in drained water, variations of results owing to drainage volumes each year. Thus, a drainage volume of 305 mm in 1981 clearly increased leaching of N in comparison with the 42 mm of drainage obtained in 1983.

Table 12. *Leaching of N by treatments defined by Bergström (1987). Differences between treatments are not presented as they were not included in the research paper.*

	Nitrate leaching (kg/ha/year)			
Treatment	**1981**	**1982**	**1983**	**1984**
Barley 0 kg N/ha	22.5	7.4	1.0	2.8
Barley 120 kg N/ha	26.9	13.7	0.2	7.6
Grass ley (120 + 80 kg N/ha)	17.4	4.6	0.2	7.1
Lucerne ley 0 kg N/ha	8.2	5.6	0.0	2.4

Bergström and Brink (1986) carried out another experiment at Lanna Research Station to analyze the effect of increasing N rate on nitrate leaching from barley and oats. Nitrogen doses were 0, 50, 100, 150 and 200 kg N/ha in the form of calcium nitrate. Trials for the agrohydrological years 1978-1979 and 1979-1980, showed NO_3^- leakage raised with dose, confirming the findings by Wallman and Delin (2022) (Table 13). Differences in leaching between crops are suggested to be derived from greater residual nitrate left in soil at harvest of barley (12 kg/ha) than oats (7 kg/ha).

Table 13. *Leaching of N with increased N dose. Differences between treatments are not presented as they were not included in the research paper (Bergström & Brink, 1986).*

Year	**Crop**	**Precipitation (mm)**	**Nitrate leaching (kg/ha/year)**				
			0 kg N/ha	**50 kg N/ha**	**100 kg N/ha**	**150 kg N/ha**	**200 kg N/ha**
1978-1979	Barley	530	2.01	5.03	6.84	18.31	35.61
1979-1980	Oats	618	1.81	3.62	4.83	16.09	27.16

Subject to the above description of research performed in the humid climate of Sweden, the leaching factor is estimated at 13% from the N applied at recommended doses. This differs from that proposed by the IPCC (2006), which suggested a leaching factor of 30% from the total N applied in soils with low water holding capacity. The deviation derives from fine and medium soil textures with high available water capacities that characterize most Swedish soils.

6. Limitations of the datasets

Datasets in this study had unbalanced observations for categories such as climate and application method of fertilizer, contributing to the uncertainty of the outcomes. As fertilizer application method was predominated by broadcasting, more equilibrated data collection is suggested to evaluate the efficiency of contrasting application practices in future reviews. Nevertheless, it is also important to highlight that as N distribution methods in the field might vary with equipment and investment availability, site-specific field trials would be recommended to define the most suitable alternatives. Moreover, semi-arid conditions were underrepresented in the climate categories, meaning more information might be requested for robust comparisons. The nitrous oxide emissions database was analyzed based on total soil emissions instead of fertilizer-induced fluxes, as control data was overlooked in some research such as Plaza-Bonilla *et al.* (2017). The lack of data from control treatments in this paper relied on obtaining data from simulations rather than from field trials. Even though the deployed soil-crop model was calibrated and validated with experimental data, uncertainties are always present. As inputs from atmospheric deposition, N fixation, manure and plant residues are mostly unseen in research, the associated N_2O releases are also challenging to predict. Concerning crop type, few data was collected from crops other than cereals which could have biased the related results. More data would be needed in each crop category (for further analysis) to draw stronger conclusions. Based on the aforesaid, this review is proposed to be considered as indicative, since data variability associated with geography, crop management, soil properties and climate hamper making predictions unquestionably.

7. Recommendations

Over optimal rates of N seem to contribute to increase the risk of N leaching and nitrous oxide emissions. This underlines the importance of applying N rates according to recommendations. The Swedish Board of Agriculture (2023) suggested applying a rate of 165 kg N/ha to winter wheat to harvest roughly 7000 kg/ha of grain and the corresponding number for barley and oats is 115 kg N/ha. These N rates are proposed to reach an economic optimum and reduce nitrate leaching in Sweden. In other regions without specific recommendations, soil analysis-based rates are advised to close the gap between the crop nutrient requirement and soil nutrient supply (FAO, 2017).

Split N applications potentially reduce substrate availability for nitrate leaching and nitrous oxide emissions. In this study, split N distributions between autumn and spring, and supplies exclusively in spring indicated to give high winter wheat grain yields. Under these circumstances, spring N doses applied at late tillering or stem elongation would likely improve N fertilization efficiency in humid climates. For semi-arid conditions, N supplied in autumn and spring might be suggested to enhance winter wheat growth along the crop cycle. The band application method of fertilizers is reported to decrease N losses. However, field trials would be recommended to define the most appropriate distribution practice according to equipment availability and farm-specific operations. As estimated in this review and confirmed by literature, acid soil pH is conceivably to raise nitrous oxide emissions. Therefore, it is advised to maintain soil pH near neutrality to diminish those contamination fluxes.

Even though fertilizer type did not show a significant effect on crop yield or nitrous oxide emissions, calcium nitrate might be considered as a potential asset to reduce the gaseous fluxes from acid soils. Moreover, if the application of calcium nitrate is optimized and match crop nutrient requirements along the crop cycle, the risk of nitrate leaching can be minimized. Calcium nitrate foliar spray may also be contemplated within application alternatives. This aims to increase the efficiency of the complete fertilizer formulation since not only nitrate losses might be decreased but also the fixation of calcium onto negatively charged soil particles. As compacted soils are reported to contribute to hotspots for N_2O production from nitrate-based fertilizers, controlled-traffic farming (CTF) is proposed as a mitigation strategy. Anken and Holpp (2011) defined CTF as a system where all traffic is restricted to permanent uncropped lanes so that wheel load and pressure are reduced in the whole field. Since animal trampling is also a cause of soil compaction, rest grazing periods in meadows are highly recommended. As a general suggestion, maintaining appropriate levels of organic matter in soil would guarantee soil structure preservation and thereby aeration, reducing suitable conditions for N_2O production.

The 4Rs principle of precision agriculture: right source, right time, right place and right dose are pillars of N use efficiency. Site-specific nutrient management is proposed to account for spatial and temporal variation of the field, by obtaining inputs from sensing devices, geographic information systems, machines for variable application, among other technologies (Abit *et al.*, 2018). Remote sensing systems provide reflectance information of crops that allow the estimation of vegetation indices (Zhang *et al.*, 2020). The normalized difference vegetation index (NDVI) represents the greenness of the canopy thereby being widely used to monitor variation in chlorophyll content and N deficiencies. Li *et al*. (2016) reported that canopy reflectance sensor-based N fertilization in corn on average reduced fertilizer input by 11% (vs. fixed N rate) without decreasing grain yield. Losses of N in the form of N_2O, NH_3 and NO_3^- were also reduced by 10, 23 and 16%, respectively compared to farmer-decided N dosage. Yet, the best N management is not fixed, but it is dynamic and depends on main limiting factors on each individual production system.

8. Conclusions and future work

Fertilizer type did not show a significant effect neither on grain yield nor nitrous oxide emissions when comparing calcium nitrate with ammonium-based fertilizers and urea. Hence, calcium nitrate fertilizer would result in the same cereal yield and nitrous oxide emission as the other evaluated fertilizers. Research under Swedish conditions demonstrated that leaching of NO_3^- predominantly occurs after (cereal) harvest when evapotranspiration is diminished, high levels of residual N are left in soil, and rainfall is large. Precipitation in the growing season had a cereal type-dependent effect on grain yield, showing a positive trend for spring cereals and a negative relationship for winter cereals. Fine soil textures were found to enhance grain yield with fertilizer addition, while coarse-textured soils were pinpointed to reduce fertilization effect. Nitrous oxide fluxes were estimated to be larger in humid conditions than in semi-arid climates and raised with N dose and at low soil pH. In this respect, an adequate dose of calcium nitrate would potentially reduce emissions from acid soils as it is reported to increase soil pH. Crop type did influence gaseous releases; however, more robust data would be needed for further comparisons. Split N applications between autumn and spring or supplies exclusively in spring might significantly increment winter wheat grain yield with fertilization, which may mean in turn reduced environmental losses.

Based upon the results of this review, some guidelines are suggested for future work. Field trials are proposed to define the most sustainable management of calcium nitrate fertilization, aiming at reducing N losses and maximizing crop yield. Testing different fertilizer application methods in granular and liquid forms would provide evidence for decision-making. Precision agriculture techniques are recommended to be integrated to analyze their cost-benefit ratio. Comparing diverse fertilizer types, however, would not be advisable as this review indicated cereal yield and nitrous oxide emissions were not attributable to fertilizer types. For future applications, the obtainment of experimental data would allow calibration and validation processes for soil-crop simulations that could be useful to tune up calcium nitrate application and optimize profit.

9. Popular scientific summary

Considerable amounts of nitrogen fertilizers are applied to crops to meet the food demand of an increasing population. However, nitrogen supplied is not all taken up by plants. Instead, some portions are lost to the atmosphere and to water courses. Former losses are in a gaseous form named nitrous oxide, while the latter ones relate to nitrogen that is washed off from soil, in a pathway called leaching. These nitrogen losses cause contamination and contribute to climate change. Factors such as soil characteristics, rainfall, crop practices and nitrogen fertilizer type might influence nitrogen leaks from agriculture. Thus, to deal with these undesired losses, without reducing crop production, sustainable farming practices are needed. This thesis focuses on revising literature to compare the effect of different nitrogen fertilizer types (calcium nitrate, urea, and ammonium-based fertilizers) on winter and spring cereals production, nitrous oxide emissions and nitrogen leaching under variable soil, climate, and crop factors. From the literature review, data was collected with the purpose of creating data pools for cereal yield and nitrous oxide releases. Nitrogen leaching was described for Swedish conditions. Other crops than cereals: carrots, melon and grass were included in the nitrous oxide emissions dataset. After running statistical tests on the gathered data, results showed that rainfall increased spring cereals grain yield, while reducing winter wheat cereals production. Soil texture, that refers to the proportion of sand, silt, and clay in soil, affected in a significant way cereal yield across the data pool. Soils with high proportions of clay gave a larger grain production compared to soils where sand predominated. Nitrous oxide emissions were influenced by climate, soil pH, nitrogen application dose and crop class factors. Estimations from the statistical test indicated humid conditions increased nitrous oxide releases with respect to semi-arid climates. When soil pH is enlarged by 1-unit, nitrous oxide emissions are reduced by 20%. The opposite trend was observed for nitrogen application dose, as gaseous losses increase by 0.5% with 1 kilo of N added. Carrots showed the highest nitrous oxide emission among all crop types, however more data would be needed in each category to draw stronger conclusions. Fertilizer did not have any influence either on cereal yield or nitrous oxide fluxes. Leaching of nitrogen was found to be higher after main crops are harvested than during the cropping season in Sweden. Based on the above, calcium nitrate fertilizer would result in the same crop yield and nitrous oxide emissions as the other evaluated fertilizers. However, an adequate dose of calcium nitrate fertilizer would potentially reduce nitrous oxide releases from acid soils as it has been reported to increase soil pH. This thesis is proposed to be considered as a reference since data variability makes predictions difficult.

Keywords: nitrogen, calcium nitrate, ammonium-based fertilizers, urea, nitrate leaching, nitrous oxide emissions, crop yield.

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Appendix 1. Grain yield primary dataset

Reference	Country	Region	Year_sowing	Precipitation_ growing season (mm)	ET (mm)	Annual_ precipitation (mm)	Aridity_index	Climate	Crop_type	Crop	Soil_texture
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Reaseheath	1959	692,61	625	734	1,17	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Netherton	1960	688	625	872,5	1,40	Humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Clopton	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Clay
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	Levington	1960	472	875	625	0,71	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam

Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	St Weonards	1960	574,8	875	708,66	0,81	Humid	Winter cereals	Winter wheat	Clay loam
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Devine & Holmes, 1964	UK	Rainford	1961	588,26	625	789,94	1,26	Humid	Winter cereals	Winter wheat	Sandy
Gasser, 1962	UK	Woburn	1958	442	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser, 1962	UK	Woburn	1958	442	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser, 1962	UK	Woburn	1958	442	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser, 1962	UK	Woburn	1958	442	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Carranca et al. 1999	Portugal	Elvas	1991	291	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Carranca et al. 1999	Portugal	Elvas	1991	291	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Carranca et al. 1999	Portugal	Elvas	1992	307	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Carranca et al. 1999	Portugal	Elvas	1992	307	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Carranca et al. 1999	Portugal	Elvas	1993	309	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Carranca et al. 1999	Portugal	Elvas	1993	309	1625	500	0,31	Semi-arid	Winter cereals	Winter wheat	Sandy clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2010	578	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Galieni et al. 2016	Italy	SantAngelo	2011	362,2	1125	732	0,65	Sub-humid	Winter cereals	Durum wheat	Clay loam
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay

Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Tawton	1961	282	875	932,5	1,07	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Henley	1961	143,48	875	597	0,68	Sub-humid	Spring cereals	Spring barley	Clay loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Levington	1961	163,05	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam

Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Stratton Hall	1961	143	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Felixstowe	1961	165,83	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam

Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Cotton Hall	1961	160,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Claydon	1961	154,42	875	625	0,71	Sub-humid	Spring cereals	Spring barley	Loam
Devine & Holmes, 1963	UK	Methlick	1961	310	625	879	1,41	Humid	Spring cereals	Spring barley	Loamy sand
Devine & Holmes, 1963	UK	Methlick	1961	310	625	879	1,41	Humid	Spring cereals	Spring barley	Loamy sand
Devine & Holmes, 1963	UK	Dalton	1961	396,5	625	789,94	1,26	Humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	Dalton	1961	396,5	625	789,94	1,26	Humid	Spring cereals	Spring barley	Sandy loam
Devine & Holmes, 1963	UK	North Wyke	1961	280,92	875	947,42	1,08	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Wyke	1961	280,92	875	947,42	1,08	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Wyke	1961	280,92	875	947,42	1,08	Humid	Spring cereals	Spring barley	Clay
Devine & Holmes, 1963	UK	North Wyke	1961	280,92	875	947,42	1,08	Humid	Spring cereals	Spring barley	Clay
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam

McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Lower Fulford	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
McTAGGART & Smith, 1995	UK	Middlestot	1988	353	625	678,18	1,09	Humid	Spring cereals	Spring barley	Sandy clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1967	267	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1967	267	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1967	267	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1967	222	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam

WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
WIDDOWSON et al, 1964	UK	Rothamsted	1961	231	875	701	0,80	Humid	Spring cereals	Spring barley	Clay loam
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1972	339,3	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1975	183,7	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1975	183,7	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Jaakkola, 1978	Finland	Vantaa	1975	183,7	625	651	1,04	Humid	Spring cereals	Spring wheat	Sandy
Yngveson, 1993	Sweden	Tirupsgarden,	1991-1993	544,1	741,0	658,0	0,89	Humid	Winter cereals	Winter wheat	Loam
Yngveson, 1993	Sweden	Tirupsgarden,	1991-1993	544,1	741,0	658,0	0,89	Humid	Winter cereals	Winter wheat	Loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Yara, 2018	Sweden	Grastorp	2017	588	625,0	701	1,12	Humid	Winter cereals	Winter wheat	Silty clay loam
Gasser & Hamlyn 1968	UK	Rothamsted	1963	526,5	875	701	0,80	Humid	Winter cereals	Winter wheat	Clay loam
Gasser & Hamlyn 1968	UK	Rothamsted	1963	526,5	875	701	0,80	Humid	Winter cereals	Winter wheat	Clay loam
Gasser & Hamlyn 1968	UK	Rothamsted	1963	526,5	875	701	0,80	Humid	Winter cereals	Winter wheat	Clay loam
Gasser & Hamlyn 1968	UK	Rothamsted	1963	526,5	875	701	0,80	Humid	Winter cereals	Winter wheat	Clay loam
Gasser & Hamlyn 1968	UK	Woburn	1963	475,94	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser & Hamlyn 1968	UK	Woburn	1963	475,94	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser & Hamlyn 1968	UK	Woburn	1963	475,94	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Gasser & Hamlyn 1968	UK	Woburn	1963	475,94	875	629	0,72	Sub-humid	Winter cereals	Winter wheat	Sandy loam
Spratt & Gasser, 1970	UK	Rothamsted	1966	372,35	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1966	372,35	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1966	372,35	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam
Spratt & Gasser, 1970	UK	Rothamsted	1966	372,35	875	701	0,80	Humid	Spring cereals	Spring wheat	Clay loam

WiDDOWSON et al, 1967	UK	Bedfordshire	1963	307,4	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Clay
WiDDOWSON et al, 1967	UK	Bedfordshire	1963	307,4	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Clay
WiDDOWSON et al, 1967	UK	Bedfordshire	1963	307,4	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Clay
WiDDOWSON et al, 1967	UK	Bedfordshire	1963	307,4	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Clay
WiDDOWSON et al, 1967	UK	Suffolk	1963	324,25	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1963	324,25	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1963	324,25	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1963	324,25	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1963	457	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1963	457	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1963	457	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1963	457	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Bedfordshire	1964	312,5	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Sandy loam
WiDDOWSON et al, 1967	UK	Bedfordshire	1964	312,5	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Sandy loam
WiDDOWSON et al, 1967	UK	Bedfordshire	1964	312,5	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Sandy loam
WiDDOWSON et al, 1967	UK	Bedfordshire	1964	312,5	875	632,46	0,72	Sub-humid	Spring cereals	Spring barley	Sandy loam
WiDDOWSON et al, 1967	UK	Suffolk	1964	292,5	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1964	292,5	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1964	292,5	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Suffolk	1964	292,5	875	640,08	0,73	Sub-humid	Spring cereals	Spring barley	Loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1964	376	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1964	376	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1964	376	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
WiDDOWSON et al, 1967	UK	Hertfordshire	1964	376	875	670,56	0,77	Humid	Spring cereals	Spring barley	Sandy clay loam
SLU, 2000	Sweden	Eskilstuna	1999	622,3	625,0	584	0,93	Humid	Winter cereals	Winter wheat	Clay
SLU, 2000	Sweden	Eskilstuna	1999	622,3	625,0	584	0,93	Humid	Winter cereals	Winter wheat	Clay
SLU, 2000	Sweden	Vreta Kloster	1999	536,1	625,0	522	0,84	Humid	Winter cereals	Winter wheat	Clay
SLU, 2000	Sweden	Vreta Kloster	1999	536,1	625,0	522	0,84	Humid	Winter cereals	Winter wheat	Clay
SLU, 2000	Sweden	Odensbacken	1999	591	625,0	592	0,95	Humid	Winter cereals	Winter wheat	Loam
SLU, 2000	Sweden	Odensbacken	1999	591	625,0	592	0,95	Humid	Winter cereals	Winter wheat	Loam
Goos et al. 1999	USA	Arthur, ND	1992	272	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Arthur, ND	1992	272	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Kindred, ND	1992	269	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Kindred, ND	1992	269	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Page, ND	1992	238	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Loam
Goos et al. 1999	USA	Page, ND	1992	238	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Loam
Goos et al. 1999	USA	Kindred, ND	1993	389	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Kindred, ND	1993	389	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Silty clay
Goos et al. 1999	USA	Tower city, ND	1993	463	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Loam
Goos et al. 1999	USA	Tower city, ND	1993	463	1125	559	0,50	Semi-arid	Spring cereals	Spring wheat	Loam

Textural_ class	Soil pH	pH Class	Fertilizer	Dose (kg N/ha)	Dose_ distribution	Timing	Stage	Application_ method	Yield_ Control (kg/ha)	Yield_ Fertilizer (kg/ha)	Yield difference	Yield_ Increase (%)
Coarse	6,2	Acid	AS	67	Single	Fall	Emergence	Broadcasted	4356	5524	1168	27
Coarse	6,2	Acid	AN	67	Single	Fall	Emergence	Broadcasted	4356	6038	1682	39
Coarse	6,2	Acid	CN	67	Single	Fall	Emergence	Broadcasted	4356	4959	603	14
Coarse	6,2	Acid	AS	67	Split	Fall+Spring	Emergence+Tillering	Broadcasted	4356	5938	1582	36
Coarse	6,2	Acid	AN	67	Split	Fall+Spring	Emergence+Tillering	Broadcasted	4356	6050	1694	39
Coarse	6,2	Acid	CN	67	Split	Fall+Spring	Emergence+Tillering	Broadcasted	4356	5825	1469	34
Coarse	6,2	Acid	AS	67	Single	Spring	Tillering	Broadcasted	4356	6101	1745	40
Coarse	6,2	Acid	AN	67	Single	Spring	Tillering	Broadcasted	4356	6076	1720	39
Coarse	6,2	Acid	CN	67	Single	Spring	Tillering	Broadcasted	4356	6364	2008	46
Coarse	6,7	Neutral	AS	67	Single	Fall	Sowing	Broadcasted	2498	2737	239	10
Coarse	6,7	Neutral	AN	67	Single	Fall	Sowing	Broadcasted	2498	2774	276	11
Coarse	6,7	Neutral	AS	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2498	3502	1004	40
Coarse	6,7	Neutral	AN	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2498	3214	716	29
Coarse	6,7	Neutral	CN	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2498	3151	653	26
Coarse	6,7	Neutral	AS	67	Single	Spring	Tillering	Broadcasted	2498	3439	941	38
Coarse	6,7	Neutral	AN	67	Single	Spring	Tillering	Broadcasted	2498	3188	690	28
Coarse	6,7	Neutral	CN	67	Single	Spring	Tillering	Broadcasted	2498	3653	1155	46
Fine	8	Alkaline	AS	67	Single	Fall	Before sowing	Broadcasted	2460	3553	1093	44
Fine	8	Alkaline	AN	67	Single	Fall	Before sowing	Broadcasted	2460	3691	1231	50
Fine	8	Alkaline	CN	67	Single	Fall	Before sowing	Broadcasted	2460	3829	1369	56
Fine	8	Alkaline	AS	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	2460	3879	1419	58
Fine	8	Alkaline	AN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	2460	4017	1557	63
Fine	8	Alkaline	CN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	2460	4068	1608	65
Fine	8	Alkaline	AS	67	Single	Spring	Tillering	Broadcasted	2460	4005	1545	63
Fine	8	Alkaline	AN	67	Single	Spring	Tillering	Broadcasted	2460	4218	1758	71
Fine	8	Alkaline	CN	67	Single	Spring	Tillering	Broadcasted	2460	4193	1733	70
Coarse	6,5	Neutral	AS	67	Single	Fall	Before sowing	Broadcasted	1632	2209	577	35
Coarse	6,5	Neutral	AN	67	Single	Fall	Before sowing	Broadcasted	1632	1796	164	10
Coarse	6,5	Neutral	CN	67	Single	Fall	Before sowing	Broadcasted	1632	1770	138	8
Coarse	6,5	Neutral	AS	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	1632	2209	577	35
Coarse	6,5	Neutral	AN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	1632	2298	666	41
Coarse	6,5	Neutral	CN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	1632	2410	778	48
Coarse	6,5	Neutral	AS	67	Single	Spring	Tillering	Broadcasted	1632	2385	753	46
Coarse	6,5	Neutral	AN	67	Single	Spring	Tillering	Broadcasted	1632	2460	828	51
Coarse	6,5	Neutral	CN	67	Single	Spring	Tillering	Broadcasted	1632	2586	954	58
Medium	7,1	Neutral	AS	67	Single	Fall	Before sowing	Broadcasted	3440	3540	100	3
Medium	7,1	Neutral	AN	67	Single	Fall	Before sowing	Broadcasted	3440	3590	150	4
Medium	7,1	Neutral	AS	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	3440	3892	452	13
Medium	7,1	Neutral	AN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	3440	4080	640	19
Medium	7,1	Neutral	CN	67	Split	Fall+Spring	Before sowing+Tillering	Broadcasted	3440	4167	727	21

Medium	7,1	Neutral	AS	67	Single	Spring	Tillering	Broadcasted	3440	4845	1405	41
Medium	7,1	Neutral	AN	67	Single	Spring	Tillering	Broadcasted	3440	4997	1557	45
Medium	7,1	Neutral	CN	67	Single	Spring	Tillering	Broadcasted	3440	4959	1519	44
Coarse	6,3	Acid	AS	67	Single	Fall	Sowing	Broadcasted	2322	2648	326	14
Coarse	6,3	Acid	CN	67	Single	Fall	Sowing	Broadcasted	2322	2436	114	5
Coarse	6,3	Acid	AS	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2322	4306	1984	85
Coarse	6,3	Acid	AN	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2322	3703	1381	59
Coarse	6,3	Acid	CN	67	Split	Fall+Spring	Sowing+Tillering	Broadcasted	2322	4432	2110	91
Coarse	6,3	Acid	AS	67	Single	Spring	Tillering	Broadcasted	2322	4594	2272	98
Coarse	6,3	Acid	AN	67	Single	Spring	Tillering	Broadcasted	2322	4983	2661	115
Coarse	6,3	Acid	CN	67	Single	Spring	Tillering	Broadcasted	2322	4883	2561	110
Coarse	6,68	Neutral	AS	112	Single	Fall	Before sowing	Broadcasted	1221	2174	953	78
Coarse	6,68	Neutral	CN	112	Single	Fall	Before sowing	Broadcasted	1221	1782	561	46
Coarse	6,68	Neutral	AS	112	Single	Spring	Tillering	Broadcasted	1221	2640	1419	116
Coarse	6,68	Neutral	CN	112	Single	Spring	Tillering	Broadcasted	1221	2068	847	69
Medium	6,6	Neutral	U	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	3556	507	20
Medium	6,6	Neutral	CN	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	3556	507	20
Medium	7,3	Neutral	U	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	8237	1681	67
Medium	7,3	Neutral	CN	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	8237	1681	67
Medium	7	Neutral	U	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	3965	491	20
Medium	7	Neutral	CN	180	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Broadcasted	2500	3965	491	20
Medium	8,1	Alkaline	U	50	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	3400	900	36
Medium	8,1	Alkaline	CN	50	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	3600	1100	44
Medium	8,1	Alkaline	U	100	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	3500	1000	40
Medium	8,1	Alkaline	CN	100	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	3700	1200	48
Medium	8,1	Alkaline	U	150	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	4100	1600	64
Medium	8,1	Alkaline	CN	150	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	4200	1700	68
Medium	8,1	Alkaline	U	200	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	3750	1250	50
Medium	8,1	Alkaline	CN	200	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2500	4050	1550	62
Medium	8,1	Alkaline	U	50	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	3250	1150	55
Medium	8,1	Alkaline	CN	50	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4100	2000	95
Medium	8,1	Alkaline	U	100	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	3600	1500	71
Medium	8,1	Alkaline	CN	100	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4400	2300	110
Medium	8,1	Alkaline	U	150	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4500	2400	114
Medium	8,1	Alkaline	CN	150	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4600	2500	119
Medium	8,1	Alkaline	U	200	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4250	2150	102
Medium	8,1	Alkaline	CN	200	Split	Fall+Spring	Before sowing+Tillering+Stem elongation	Cover-dressing	2100	4300	2200	105
Fine	6,5	Neutral	AS	50	Single	Sowing	Sowing	Broadcasted	1444	3163	1719	119
Fine	6,5	Neutral	AN	50	Single	Sowing	Sowing	Broadcasted	1444	3327	1883	130
Fine	6,5	Neutral	CN	50	Single	Sowing	Sowing	Broadcasted	1444	3691	2247	156
Fine	6,5	Neutral	U	50	Single	Sowing	Sowing	Broadcasted	1444	3151	1707	118
Fine	6,5	Neutral	AS	101	Single	Sowing	Sowing	Broadcasted	1444	5323	3879	269
Fine	6,5	Neutral	AN	101	Single	Sowing	Sowing	Broadcasted	1444	4343	2899	201

Fine	6,5	Neutral	CN	101	Single	Sowing	Sowing	Broadcasted	1444	4167	2723	189
Fine	6,5	Neutral	U	101	Single	Sowing	Sowing	Broadcasted	1444	4218	2774	192
Fine	6,5	Neutral	AS	50	Single	Sowing	Sowing	with seed	1444	2863	1419	98
Fine	6,5	Neutral	AN	50	Single	Sowing	Sowing	with seed	1444	3151	1707	118
Fine	6,5	Neutral	CN	50	Single	Sowing	Sowing	with seed	1444	3000	1556	108
Fine	6,5	Neutral	U	50	Single	Sowing	Sowing	with seed	1444	3339	1895	131
Fine	6,5	Neutral	AS	101	Single	Sowing	Sowing	with seed	1444	3515	2071	143
Fine	6,5	Neutral	AN	101	Single	Sowing	Sowing	with seed	1444	3527	2083	144
Fine	6,5	Neutral	CN	101	Single	Sowing	Sowing	with seed	1444	2988	1544	107
Fine	6,5	Neutral	U	101	Single	Sowing	Sowing	with seed	1444	3339	1895	131
Medium	7,9	Alkaline	AS	50	Single	Sowing	Sowing	Broadcasted	1971	3351	1380	70
Medium	7,9	Alkaline	AN	50	Single	Sowing	Sowing	Broadcasted	1971	3691	1720	87
Medium	7,9	Alkaline	CN	50	Single	Sowing	Sowing	Broadcasted	1971	3428	1457	74
Medium	7,9	Alkaline	U	50	Single	Sowing	Sowing	Broadcasted	1971	3189	1218	62
Medium	7,9	Alkaline	AS	101	Single	Sowing	Sowing	Broadcasted	1971	4029	2058	104
Medium	7,9	Alkaline	AN	101	Single	Sowing	Sowing	Broadcasted	1971	4218	2247	114
Medium	7,9	Alkaline	CN	101	Single	Sowing	Sowing	Broadcasted	1971	3930	1959	99
Medium	7,9	Alkaline	U	101	Single	Sowing	Sowing	Broadcasted	1971	4017	2046	104
Medium	7,9	Alkaline	AS	50	Single	Sowing	Sowing	with seed	1971	3252	1281	65
Medium	7,9	Alkaline	AN	50	Single	Sowing	Sowing	with seed	1971	3327	1356	69
Medium	7,9	Alkaline	CN	50	Single	Sowing	Sowing	with seed	1971	3126	1155	59
Medium	7,9	Alkaline	U	50	Single	Sowing	Sowing	with seed	1971	3025	1054	53
Medium	7,9	Alkaline	AS	101	Single	Sowing	Sowing	with seed	1971	4068	2097	106
Medium	7,9	Alkaline	AN	101	Single	Sowing	Sowing	with seed	1971	3853	1882	95
Medium	7,9	Alkaline	CN	101	Single	Sowing	Sowing	with seed	1971	3928	1957	99
Medium	7,9	Alkaline	U	101	Single	Sowing	Sowing	with seed	1971	3602	1631	83
Coarse	7	Neutral	AS	50	Single	Sowing	Sowing	Broadcasted	2410	3490	1080	45
Coarse	7	Neutral	AN	50	Single	Sowing	Sowing	Broadcasted	2410	3351	941	39
Coarse	7	Neutral	CN	50	Single	Sowing	Sowing	Broadcasted	2410	3365	955	40
Coarse	7	Neutral	U	50	Single	Sowing	Sowing	Broadcasted	2410	3377	967	40
Coarse	7	Neutral	AS	101	Single	Sowing	Sowing	Broadcasted	2410	3640	1230	51
Coarse	7	Neutral	AN	101	Single	Sowing	Sowing	Broadcasted	2410	3452	1042	43
Coarse	7	Neutral	CN	101	Single	Sowing	Sowing	Broadcasted	2410	3365	955	40
Coarse	7	Neutral	U	101	Single	Sowing	Sowing	Broadcasted	2410	3477	1067	44
Coarse	7	Neutral	AS	50	Single	Sowing	Sowing	with seed	2410	3503	1093	45
Coarse	7	Neutral	AN	50	Single	Sowing	Sowing	with seed	2410	3365	955	40
Coarse	7	Neutral	CN	50	Single	Sowing	Sowing	with seed	2410	3252	842	35
Coarse	7	Neutral	U	50	Single	Sowing	Sowing	with seed	2410	2988	578	24
Coarse	7	Neutral	AS	101	Single	Sowing	Sowing	with seed	2410	3327	917	38
Coarse	7	Neutral	AN	101	Single	Sowing	Sowing	with seed	2410	3428	1018	42
Coarse	7	Neutral	CN	101	Single	Sowing	Sowing	with seed	2410	2786	376	16
Coarse	7	Neutral	U	101	Single	Sowing	Sowing	with seed	2410	2674	264	11
Coarse	7,9	Alkaline	AS	50	Single	Sowing	Sowing	Broadcasted	2495	3679	1184	47

Coarse	7,9	Alkaline	AN	50	Single	Sowing	Sowing	Broadcasted	2495	4104	1609	64
Coarse	7,9	Alkaline	CN	50	Single	Sowing	Sowing	Broadcasted	2495	4029	1534	61
Coarse	7,9	Alkaline	U	50	Single	Sowing	Sowing	Broadcasted	2495	3553	1058	42
Coarse	7,9	Alkaline	AS	101	Single	Sowing	Sowing	Broadcasted	2495	3402	907	36
Coarse	7,9	Alkaline	AN	101	Single	Sowing	Sowing	Broadcasted	2495	2824	329	13
Coarse	7,9	Alkaline	CN	101	Single	Sowing	Sowing	Broadcasted	2495	3076	581	23
Coarse	7,9	Alkaline	U	101	Single	Sowing	Sowing	Broadcasted	2495	3163	668	27
Coarse	7,9	Alkaline	AS	50	Single	Sowing	Sowing	with seed	2495	3741	1246	50
Coarse	7,9	Alkaline	AN	50	Single	Sowing	Sowing	with seed	2495	3477	982	39
Coarse	7,9	Alkaline	CN	50	Single	Sowing	Sowing	with seed	2495	3602	1107	44
Coarse	7,9	Alkaline	U	50	Single	Sowing	Sowing	with seed	2495	3602	1107	44
Coarse	7,9	Alkaline	AS	101	Single	Sowing	Sowing	with seed	2495	3063	568	23
Coarse	7,9	Alkaline	AN	101	Single	Sowing	Sowing	with seed	2495	3100	605	24
Coarse	7,9	Alkaline	CN	101	Single	Sowing	Sowing	with seed	2495	3038	543	22
Coarse	7,9	Alkaline	U	101	Single	Sowing	Sowing	with seed	2495	3503	1008	40
Coarse	7,3	Neutral	AS	50	Single	Sowing	Sowing	Broadcasted	2322	3377	1055	45
Coarse	7,3	Neutral	AN	50	Single	Sowing	Sowing	Broadcasted	2322	3038	716	31
Coarse	7,3	Neutral	CN	50	Single	Sowing	Sowing	Broadcasted	2322	3063	741	32
Coarse	7,3	Neutral	U	50	Single	Sowing	Sowing	Broadcasted	2322	3264	942	41
Coarse	7,3	Neutral	AS	101	Single	Sowing	Sowing	Broadcasted	2322	3138	816	35
Coarse	7,3	Neutral	AN	101	Single	Sowing	Sowing	Broadcasted	2322	3189	867	37
Coarse	7,3	Neutral	CN	101	Single	Sowing	Sowing	Broadcasted	2322	3051	729	31
Coarse	7,3	Neutral	U	101	Single	Sowing	Sowing	Broadcasted	2322	3377	1055	45
Coarse	7,3	Neutral	AS	50	Single	Sowing	Sowing	with seed	2322	3327	1005	43
Coarse	7,3	Neutral	AN	50	Single	Sowing	Sowing	with seed	2322	3365	1043	45
Coarse	7,3	Neutral	CN	50	Single	Sowing	Sowing	with seed	2322	3226	904	39
Coarse	7,3	Neutral	U	50	Single	Sowing	Sowing	with seed	2322	3264	942	41
Coarse	7,3	Neutral	AS	101	Single	Sowing	Sowing	with seed	2322	3464	1142	49
Coarse	7,3	Neutral	AN	101	Single	Sowing	Sowing	with seed	2322	3339	1017	44
Coarse	7,3	Neutral	CN	101	Single	Sowing	Sowing	with seed	2322	2849	527	23
Coarse	7,3	Neutral	U	101	Single	Sowing	Sowing	with seed	2322	2824	502	22
Coarse	7,8	Alkaline	AS	50	Single	Sowing	Sowing	Broadcasted	2586	3553	967	37
Coarse	7,8	Alkaline	AN	50	Single	Sowing	Sowing	Broadcasted	2586	3728	1142	44
Coarse	7,8	Alkaline	CN	50	Single	Sowing	Sowing	Broadcasted	2586	4155	1569	61
Coarse	7,8	Alkaline	U	50	Single	Sowing	Sowing	Broadcasted	2586	3841	1255	49
Coarse	7,8	Alkaline	AS	101	Single	Sowing	Sowing	Broadcasted	2586	4230	1644	64
Coarse	7,8	Alkaline	AN	101	Single	Sowing	Sowing	Broadcasted	2586	4418	1832	71
Coarse	7,8	Alkaline	CN	101	Single	Sowing	Sowing	Broadcasted	2586	4143	1557	60
Coarse	7,8	Alkaline	U	101	Single	Sowing	Sowing	Broadcasted	2586	4331	1745	67
Coarse	7,8	Alkaline	AS	50	Single	Sowing	Sowing	with seed	2586	3703	1117	43
Coarse	7,8	Alkaline	AN	50	Single	Sowing	Sowing	with seed	2586	3916	1330	51
Coarse	7,8	Alkaline	CN	50	Single	Sowing	Sowing	with seed	2586	3553	967	37
Coarse	7,8	Alkaline	U	50	Single	Sowing	Sowing	with seed	2586	3741	1155	45

Coarse	7,8	Alkaline	AS	101	Single	Sowing	Sowing	with seed	2586	4544	1958	76
Coarse	7,8	Alkaline	AN	101	Single	Sowing	Sowing	with seed	2586	4218	1632	63
Coarse	7,8	Alkaline	CN	101	Single	Sowing	Sowing	with seed	2586	3979	1393	54
Coarse	7,8	Alkaline	U	101	Single	Sowing	Sowing	with seed	2586	4042	1456	56
Coarse	7,9	Alkaline	AS	50	Single	Sowing	Sowing	Broadcasted	1845	2434	589	32
Coarse	7,9	Alkaline	AN	50	Single	Sowing	Sowing	Broadcasted	1845	2373	528	29
Coarse	7,9	Alkaline	CN	50	Single	Sowing	Sowing	Broadcasted	1845	2460	615	33
Coarse	7,9	Alkaline	U	50	Single	Sowing	Sowing	Broadcasted	1845	2298	453	25
Coarse	7,9	Alkaline	AS	101	Single	Sowing	Sowing	Broadcasted	1845	2535	690	37
Coarse	7,9	Alkaline	AN	101	Single	Sowing	Sowing	Broadcasted	1845	2523	678	37
Coarse	7,9	Alkaline	CN	101	Single	Sowing	Sowing	Broadcasted	1845	2310	465	25
Coarse	7,9	Alkaline	U	101	Single	Sowing	Sowing	Broadcasted	1845	2535	690	37
Coarse	7,9	Alkaline	AS	50	Single	Sowing	Sowing	with seed	1845	2561	716	39
Coarse	7,9	Alkaline	AN	50	Single	Sowing	Sowing	with seed	1845	1984	139	8
Coarse	7,9	Alkaline	CN	50	Single	Sowing	Sowing	with seed	1845	2260	415	22
Coarse	7,9	Alkaline	U	50	Single	Sowing	Sowing	with seed	1845	2284	439	24
Coarse	7,9	Alkaline	AS	101	Single	Sowing	Sowing	with seed	1845	2549	704	38
Coarse	7,9	Alkaline	AN	101	Single	Sowing	Sowing	with seed	1845	2498	653	35
Coarse	7,9	Alkaline	CN	101	Single	Sowing	Sowing	with seed	1845	2197	352	19
Coarse	7,9	Alkaline	U	101	Single	Sowing	Sowing	with seed	1845	2071	226	12
Coarse	5,7	Acid	CN	84	Single	Sowing	Sowing	with seed	2598	4432	1834	71
Coarse	5,7	Acid	U	84	Single	Sowing	Sowing	with seed	2598	4456	1858	72
Coarse	6,2	Acid	AS	73	Single	Sowing	Sowing	with seed	2486	4293	1807	73
Coarse	6,2	Acid	CN	73	Single	Sowing	Sowing	with seed	2486	3942	1456	59
Fine	5,7	Acid	AS	78	Single	Sowing	Sowing	with seed	1895	2636	741	39
Fine	5,7	Acid	AN	78	Single	Sowing	Sowing	with seed	1895	2423	528	28
Fine	5,7	Acid	CN	78	Single	Sowing	Sowing	with seed	1895	3339	1444	76
Fine	5,7	Acid	U	78	Single	Sowing	Sowing	with seed	1895	2473	578	31
Coarse	6,5	Neutral	CN	60	Single	Sowing	Sowing	Broadcasted	3200	4100	900	28
Coarse	6,5	Neutral	AS	60	Single	Sowing	Sowing	Broadcasted	3200	4300	1100	34
Coarse	6,5	Neutral	AN	60	Single	Sowing	Sowing	Broadcasted	3200	4100	900	28
Coarse	6,5	Neutral	CN	90	Single	Sowing	Sowing	Broadcasted	3200	5400	2200	69
Coarse	6,5	Neutral	AS	90	Single	Sowing	Sowing	Broadcasted	3200	5700	2500	78
Coarse	6,5	Neutral	AN	90	Single	Sowing	Sowing	Broadcasted	3200	5200	2000	63
Coarse	6,5	Neutral	CN	120	Single	Sowing	Sowing	Broadcasted	3200	5100	1900	59
Coarse	6,5	Neutral	AS	120	Single	Sowing	Sowing	Broadcasted	3200	6000	2800	88
Coarse	6,5	Neutral	AN	120	Single	Sowing	Sowing	Broadcasted	3200	5400	2200	69
Coarse	6,5	Neutral	CN	120	Split	gence	Sowing+Emergence	Broadcasted	3200	5200	2000	63
Coarse	6,5	Neutral	AS	120	Split	gence	Sowing+Emergence	Broadcasted	3200	5700	2500	78
Coarse	6,5	Neutral	AN	120	Split	gence	Sowing+Emergence	Broadcasted	3200	6000	2800	88
Coarse	6,5	Neutral	CN	120	Split	ng	Sowing+Tillering	Broadcasted	3200	4900	1700	53
Coarse	6,5	Neutral	AS	120	Split	ng	Sowing+Tillering	Broadcasted	3200	6100	2900	91
Coarse	6,5	Neutral	AN	120	Split	ng	Sowing+Tillering	Broadcasted	3200	5300	2100	66

Coarse	6,5	Neutral	CN	120	Single	Emergence	Emergence	Broadcasted	3200	6100	2900	91
Coarse	6,5	Neutral	AS	120	Single	Emergence	Emergence	Broadcasted	3200	6200	3000	94
Coarse	6,5	Neutral	AN	120	Single	Emergence	Emergence	Broadcasted	3200	5500	2300	72
Coarse	6,5	Neutral	CN	150	Single	Sowing	Sowing	Broadcasted	3200	4900	1700	53
Coarse	6,5	Neutral	AS	150	Single	Sowing	Sowing	Broadcasted	3200	7200	4000	125
Coarse	6,5	Neutral	AN	150	Single	Sowing	Sowing	Broadcasted	3200	5500	2300	72
Medium	6,7	Neutral	CN	60	Single	Sowing	Sowing	Broadcasted	2200	5100	2900	132
Medium	6,7	Neutral	AS	60	Single	Sowing	Sowing	Broadcasted	2200	3700	1500	68
Medium	6,7	Neutral	AN	60	Single	Sowing	Sowing	Broadcasted	2200	4300	2100	95
Medium	6,7	Neutral	CN	90	Single	Sowing	Sowing	Broadcasted	2200	6400	4200	191
Medium	6,7	Neutral	AS	90	Single	Sowing	Sowing	Broadcasted	2200	5400	3200	145
Medium	6,7	Neutral	AN	90	Single	Sowing	Sowing	Broadcasted	2200	5300	3100	141
Medium	6,7	Neutral	CN	120	Single	Sowing	Sowing	Broadcasted	2200	7100	4900	223
Medium	6,7	Neutral	AS	120	Single	Sowing	Sowing	Broadcasted	2200	6000	3800	173
Medium	6,7	Neutral	AN	120	Single	Sowing	Sowing	Broadcasted	2200	5500	3300	150
Medium	6,7	Neutral	CN	150	Single	Sowing	Sowing	Broadcasted	2200	7300	5100	232
Medium	6,7	Neutral	AS	150	Single	Sowing	Sowing	Broadcasted	2200	7000	4800	218
Medium	6,7	Neutral	AN	150	Single	Sowing	Sowing	Broadcasted	2200	6300	4100	186
Medium	6,7	Neutral	CN	120	Split	gence	Sowing+Emergence	Broadcasted	2200	6500	4300	195
Medium	6,7	Neutral	AS	120	Split	gence	Sowing+Emergence	Broadcasted	2200	6400	4200	191
Medium	6,7	Neutral	AN	120	Split	gence	Sowing+Emergence	Broadcasted	2200	6300	4100	186
Medium	6,7	Neutral	CN	120	Split	ng	Sowing+Tillering	Broadcasted	2200	5900	3700	168
Medium	6,7	Neutral	AS	120	Split	ng	Sowing+Tillering	Broadcasted	2200	6100	3900	177
Medium	6,7	Neutral	AN	120	Split	ng	Sowing+Tillering	Broadcasted	2200	5900	3700	168
Medium	6,7	Neutral	CN	120	Single	Emergence	Emergence	Broadcasted	2200	6400	4200	191
Medium	6,7	Neutral	AS	120	Single	Emergence	Emergence	Broadcasted	2200	6300	4100	186
Medium	7,9	Alkaline	AS	112	Single	Sowing	Sowing	Broadcasted	2640	2960	320	12
Medium	7,9	Alkaline	AN	112	Single	Sowing	Sowing	Broadcasted	2640	3330	690	26
Medium	7,9	Alkaline	CN	112	Single	Sowing	Sowing	Broadcasted	2640	3500	860	33
Medium	7,9	Alkaline	AN	112	Single	Sowing	Sowing	Broadcasted	1800	1880	80	4
Medium	6,5	Neutral	AS	44	Single	Sowing	Sowing	Broadcasted	3138	4444	1306	42
Medium	6,5	Neutral	CN	44	Single	Sowing	Sowing	Broadcasted	3138	4695	1557	50
Medium	6,5	Neutral	U	44	Single	Sowing	Sowing	Broadcasted	3138	4369	1231	39
Medium	6,5	Neutral	AS	44	Single	Sowing	Sowing	with seed	3138	4719	1581	50
Medium	6,5	Neutral	CN	44	Single	Sowing	Sowing	with seed	3138	4456	1318	42
Medium	6,5	Neutral	U	44	Single	Sowing	Sowing	with seed	3138	4569	1431	46
Medium	6,5	Neutral	AS	44	Single	Sowing	Sowing	Side-dressing	3138	4544	1406	45
Medium	6,5	Neutral	CN	44	Single	Sowing	Sowing	Side-dressing	3138	4506	1368	44
Medium	6,5	Neutral	U	44	Single	Sowing	Sowing	Side-dressing	3138	4632	1494	48
Medium	6,5	Neutral	AS	87	Single	Sowing	Sowing	Broadcasted	3138	5084	1946	62
Medium	6,5	Neutral	CN	87	Single	Sowing	Sowing	Broadcasted	3138	5611	2473	79
Medium	6,5	Neutral	U	87	Single	Sowing	Sowing	Broadcasted	3138	5185	2047	65
Medium	6,5	Neutral	AS	87	Single	Sowing	Sowing	with seed	3138	5398	2260	72

Medium	6,5	Neutral	CN	87	Single	Sowing	Sowing	with seed	3138	5146	2008	64
Medium	6,5	Neutral	U	87	Single	Sowing	Sowing	with seed	3138	4745	1607	51
Medium	6,5	Neutral	AS	87	Single	Sowing	Sowing	Side-dressing	3138	5373	2235	71
Medium	6,5	Neutral	CN	87	Single	Sowing	Sowing	Side-dressing	3138	5373	2235	71
Medium	6,5	Neutral	U	87	Single	Sowing	Sowing	Side-dressing	3138	5197	2059	66
Coarse	6,8	Neutral	U	75	Single	Sowing	Sowing	with seed	1650	2840	1190	72
Coarse	6,8	Neutral	AS	75	Single	Sowing	Sowing	with seed	1650	3080	1430	87
Coarse	6,8	Neutral	CN	75	Single	Sowing	Sowing	with seed	1650	3020	1370	83
Coarse	6,8	Neutral	U	150	Single	Sowing	Sowing	with seed	1650	3400	1750	106
Coarse	6,8	Neutral	AS	150	Single	Sowing	Sowing	with seed	1650	3470	1820	110
Coarse	6,8	Neutral	CN	150	Single	Sowing	Sowing	with seed	1650	3320	1670	101
Coarse	6,8	Neutral	U	150	Single	Sowing	Sowing	Broadcasted	1650	3320	1670	101
Coarse	6,8	Neutral	AS	150	Single	Sowing	Sowing	Broadcasted	1650	3420	1770	107
Coarse	6,8	Neutral	CN	150	Single	Sowing	Sowing	Broadcasted	1650	3260	1610	98
Coarse	6,8	Neutral	U	100	Single	Sowing	Sowing	with seed	1940	2760	820	42
Coarse	6,8	Neutral	AS	100	Single	Sowing	Sowing	with seed	1940	2870	930	48
Coarse	6,8	Neutral	CN	100	Single	Sowing	Sowing	with seed	1940	2800	860	44
Coarse	7	Neutral	U	120	Single	Spring	Tillering	Broadcasted	4870	7020	2150	44
Coarse	7	Neutral	CN	120	Single	Spring	Tillering	Broadcasted	4870	7480	2610	54
Medium	6,6	Neutral	CN	140	Single	Spring	Tillering	Broadcasted	3770	8460	4690	124
Medium	6,6	Neutral	AN	140	Single	Spring	Tillering	Broadcasted	3770	8390	4620	123
Medium	6,6	Neutral	AS	140	Single	Spring	Tillering	Broadcasted	3770	7360	3590	95
Medium	6,6	Neutral	U	140	Single	Spring	Tillering	Broadcasted	3770	7560	3790	101
Medium	6,6	Neutral	CN	140	Single	Spring	Tillering	Liquid in furrow	3770	7450	3680	98
Medium	6,6	Neutral	AN	140	Single	Spring	Tillering	Liquid in furrow	3770	7130	3360	89
Medium	6,6	Neutral	AS	140	Single	Spring	Tillering	Liquid in furrow	3770	5520	1750	46
Medium	6,6	Neutral	U	140	Single	Spring	Tillering	Liquid in furrow	3770	6690	2920	77
Medium	6,6	Neutral	CN	140	Single	Spring	Stem elongation	Liquid in furrow	3770	5540	1770	47
Medium	6,6	Neutral	AN	140	Single	Spring	Stem elongation	Liquid in furrow	3770	5820	2050	54
Medium	6,6	Neutral	AS	140	Single	Spring	Stem elongation	Liquid in furrow	3770	4490	720	19
Medium	6,6	Neutral	U	140	Single	Spring	Stem elongation	Liquid in furrow	3770	5440	1670	44
Medium	6,8	Neutral	AS	56	Single	Spring	Stem elongation	Broadcasted	5750	6565	815	14
Medium	6,8	Neutral	CN	56	Single	Spring	Stem elongation	Broadcasted	5750	6578	828	14
Medium	6,8	Neutral	AS	112	Single	Spring	Stem elongation	Broadcasted	5750	7030	1280	22
Medium	6,8	Neutral	CN	112	Single	Spring	Stem elongation	Broadcasted	5750	6980	1230	21
Coarse	6,3	Acid	AS	84	Single	Spring	Stem elongation	Broadcasted	2122	4795	2673	126
Coarse	6,3	Acid	CN	84	Single	Spring	Stem elongation	Broadcasted	2122	5737	3615	170
Coarse	6,3	Acid	AS	168	Single	Spring	Stem elongation	Broadcasted	2122	6779	4657	219
Coarse	6,3	Acid	CN	168	Single	Spring	Stem elongation	Broadcasted	2122	6516	4394	207
Medium	7,7	Alkaline	AS	56	Single	Before sowing	Before sowing	Broadcasted	2668	3620	952	36
Medium	7,7	Alkaline	CN	56	Single	Before sowing	Before sowing	Broadcasted	2668	4024	1356	51
Medium	7,7	Alkaline	AS	112	Single	Before sowing	Before sowing	Broadcasted	2668	4270	1602	60
Medium	7,7	Alkaline	CN	112	Single	Before sowing	Before sowing	Broadcasted	2668	4147	1479	55

Fine	8	Alkaline	AS	44	Single	Before sowing	Before sowing	Broadcasted	1029	2310	1281	124
Fine	8	Alkaline	CN	44	Single	Before sowing	Before sowing	Broadcasted	1029	2636	1607	156
Fine	8	Alkaline	AS	88	Single	Before sowing	Before sowing	Broadcasted	1029	3314	2285	222
Fine	8	Alkaline	CN	88	Single	Before sowing	Before sowing	Broadcasted	1029	3791	2762	268
Coarse	7,3	Neutral	AS	44	Single	Before sowing	Before sowing	Broadcasted	4469	4896	427	10
Coarse	7,3	Neutral	CN	44	Single	Before sowing	Before sowing	Broadcasted	4469	4783	314	7
Coarse	7,3	Neutral	AS	88	Single	Before sowing	Before sowing	Broadcasted	4469	4645	176	4
Coarse	7,3	Neutral	CN	88	Single	Before sowing	Before sowing	Broadcasted	4469	4645	176	4
Medium	7,9	Alkaline	AS	44	Single	Before sowing	Before sowing	Broadcasted	2335	3440	1105	47
Medium	7,9	Alkaline	CN	44	Single	Before sowing	Before sowing	Broadcasted	2335	3892	1557	67
Medium	7,9	Alkaline	AS	88	Single	Before sowing	Before sowing	Broadcasted	2335	4244	1909	82
Medium	7,9	Alkaline	CN	88	Single	Before sowing	Before sowing	Broadcasted	2335	4193	1858	80
Coarse	8	Alkaline	AS	56	Single	Before sowing	Before sowing	Broadcasted	2021	3138	1117	55
Coarse	8	Alkaline	CN	56	Single	Before sowing	Before sowing	Broadcasted	2021	3716	1695	84
Coarse	8	Alkaline	AS	112	Single	Before sowing	Before sowing	Broadcasted	2021	3716	1695	84
Coarse	8	Alkaline	CN	112	Single	Before sowing	Before sowing	Broadcasted	2021	4268	2247	111
Coarse	7,9	Alkaline	AS	56	Single	Before sowing	Before sowing	Broadcasted	3490	5147	1657	47
Coarse	7,9	Alkaline	CN	56	Single	Before sowing	Before sowing	Broadcasted	3490	5084	1594	46
Coarse	7,9	Alkaline	AS	112	Single	Before sowing	Before sowing	Broadcasted	3490	5499	2009	58
Coarse	7,9	Alkaline	CN	112	Single	Before sowing	Before sowing	Broadcasted	3490	5360	1870	54
Medium	7,2	Neutral	AS	56	Single	Before sowing	Before sowing	Broadcasted	2486	4055	1569	63
Medium	7,2	Neutral	CN	56	Single	Before sowing	Before sowing	Broadcasted	2486	3389	903	36
Medium	7,2	Neutral	AS	112	Single	Before sowing	Before sowing	Broadcasted	2486	5448	2962	119
Medium	7,2	Neutral	CN	112	Single	Before sowing	Before sowing	Broadcasted	2486	4720	2234	90
Fine	6,2	Acid	CN	120	Single	Spring	Tillering	Broadcasted	4390	7240	2850	65
Fine	6,2	Acid	AN	120	Single	Spring	Tillering	Broadcasted	4390	7190	2800	64
Fine	6,7	Neutral	CN	120	Single	Spring	Tillering	Broadcasted	2710	6090	3380	125
Fine	6,7	Neutral	AN	120	Single	Spring	Tillering	Broadcasted	2710	5220	2510	93
Coarse	6,6	Neutral	CN	120	Single	Spring	Tillering	Broadcasted	2340	5590	3250	139
Coarse	6,6	Neutral	AN	120	Single	Spring	Tillering	Broadcasted	2340	5420	3080	132
Fine	7,3	Neutral	CN	112	Single	Before sowing	Before sowing	Incorporated	3384	4000	616	18
Fine	7,3	Neutral	U	112	Single	Before sowing	Before sowing	Incorporated	3384	3830	446	13
Fine	7,3	Neutral	CN	112	Single	Before sowing	Before sowing	Incorporated	4310	4860	550	13
Fine	7,3	Neutral	U	112	Single	Before sowing	Before sowing	Incorporated	4310	4770	460	11
Coarse	7,5	Neutral	CN	112	Single	Before sowing	Before sowing	Incorporated	4030	4560	530	13
Coarse	7,5	Neutral	U	112	Single	Before sowing	Before sowing	Incorporated	4030	4160	130	3
Fine	7,4	Neutral	CN	112	Single	Before sowing	Before sowing	Incorporated	1470	2700	1230	84
Fine	7,4	Neutral	U	112	Single	Before sowing	Before sowing	Incorporated	1470	2570	1100	75
Coarse	7,7	Alkaline	CN	112	Single	Before sowing	Before sowing	Incorporated	1160	2110	950	82
Coarse	7,7	Alkaline	U	112	Single	Before sowing	Before sowing	Incorporated	1160	2340	1180	102

Appendix 2. Grain yield secondary dataset

Reference	Country	Region	Year	Precipitation_ growing.season (mm)	Crop	Sowing	SOC (%)	Clay_content/Texture	Soil.pH	pH Class	Fertilizer_1	Dose_1 (kg N/ha)
Lans, 2017	Sweden	Grastorp	2016	515,8	Winter wheat	6-oct	3,4	38	6,5	Neutral	AS	20
Lans, 2017	Sweden	Grastorp	2016	515,8	Winter wheat	6-oct	3,4	38	6,5	Neutral	AS	20
Lans, 2017	Sweden	Grastorp	2016	515,8	Winter wheat	6-oct	3,4	38	6,5	Neutral	AS	20
Persson, 2017	Sweden	Simrishamn	2016	521,2	Winter wheat	22-sep	3,4	17	7,3	Neutral	AS	20
Persson, 2017	Sweden	Simrishamn	2016	521,2	Winter wheat	22-sep	3,4	17	7,3	Neutral	AS	20
Persson, 2017	Sweden	Simrishamn	2016	521,2	Winter wheat	22-sep	3,4	17	7,3	Neutral	AS	20
Persson, 2017	Sweden	Angelholm	2016	743,7	Winter wheat	10-sep	3,6	29	6,3	Acid	AS	20
Persson, 2017	Sweden	Angelholm	2016	743,7	Winter wheat	10-sep	3,6	29	6,3	Acid	AS	20
Persson, 2017	Sweden	Angelholm	2016	743,7	Winter wheat	10-sep	3,6	29	6,3	Acid	AS	20
Hakansson, 2017	Sweden	Eslov	2016	674,5	Winter wheat	18-sep	2,6	19	6,7	Neutral	AS	20
Hakansson, 2017	Sweden	Eslov	2016	674,5	Winter wheat	18-sep	2,6	19	6,7	Neutral	AS	20
Hakansson, 2017	Sweden	Eslov	2016	674,5	Winter wheat	18-sep	2,6	19	6,7	Neutral	AS	20
Ericsson, 2017	Sweden	Vasteras	2016	305,6	Winter wheat	12-sep	2,2	29	6,8	Neutral	AS	20
Ericsson, 2017	Sweden	Vasteras	2016	305,6	Winter wheat	12-sep	2,2	29	6,8	Neutral	AS	20
Ericsson, 2017	Sweden	Vasteras	2016	305,6	Winter wheat	12-sep	2,2	29	6,8	Neutral	AS	20
Larsson, 2017	Sweden	Mjolby	2016	466,6	Winter wheat	15-sep	5,4	47	5,9	Acid	AS	20
Larsson, 2017	Sweden	Mjolby	2016	466,6	Winter wheat	15-sep	5,4	47	5,9	Acid	AS	20
Larsson, 2017	Sweden	Mjolby	2016	466,6	Winter wheat	15-sep	5,4	47	5,9	Acid	AS	20
Hakansson, 2016	Sweden	Lund	2015	666,7	Winter wheat	10-sep	2,8	20	6,3	Acid	AS	20
Hakansson, 2016	Sweden	Lund	2015	666,7	Winter wheat	10-sep	2,8	20	6,3	Acid	AS	20
Hakansson, 2016	Sweden	Lund	2015	666,7	Winter wheat	10-sep	2,8	20	6,3	Acid	AS	20
Persson, 2016	Sweden	Simrishamn	2015	472,5	Winter wheat	19-sep	3,1	16	8,4	Alkaline	AS	20
Persson, 2016	Sweden	Simrishamn	2015	472,5	Winter wheat	19-sep	3,1	16	8,4	Alkaline	AS	20
Persson, 2016	Sweden	Simrishamn	2015	472,5	Winter wheat	19-sep	3,1	16	8,4	Alkaline	AS	20
Hakansson, 2016	Sweden	Angelholm	2015	890	Winter wheat	29-sep	4,9	24	6,8	Neutral	AS	20
Hakansson, 2016	Sweden	Angelholm	2015	890	Winter wheat	29-sep	4,9	24	6,8	Neutral	AS	20
Hakansson, 2016	Sweden	Angelholm	2015	890	Winter wheat	29-sep	4,9	24	6,8	Neutral	AS	20
Ericsson, 2016	Sweden	Hallstahammar	2015	509,7	Winter wheat	3-oct	6	47	5,9	Acid	AS	20
Ericsson, 2016	Sweden	Hallstahammar	2015	509,7	Winter wheat	3-oct	6	47	5,9	Acid	AS	20
Ericsson, 2016	Sweden	Hallstahammar	2015	509,7	Winter wheat	3-oct	6	47	5,9	Acid	AS	20

Larsson, 2016	Sweden	Linkoping	2015	322,2	Winter wheat	25-sep	5,8	47	7,0	Neutral	AS	20
Larsson, 2016	Sweden	Linkoping	2015	322,2	Winter wheat	25-sep	5,8	47	7,0	Neutral	AS	20
Larsson, 2016	Sweden	Linkoping	2015	322,2	Winter wheat	25-sep	5,8	47	7,0	Neutral	AS	20
Lans, 2018	Sweden	Grastorp	2017	511	Winter wheat	1-oct	4,3	38	6,8	Neutral	AS	20
Lans, 2018	Sweden	Grastorp	2017	511	Winter wheat	1-oct	4,3	38	6,8	Neutral	AS	20
Lans, 2018	Sweden	Grastorp	2017	511	Winter wheat	1-oct	4,3	38	6,8	Neutral	AS	20
Persson, 2018	Sweden	Simrishamn	2017	354,4	Winter wheat	26-sep	3,8	19,4	6,3	Acid	AS	20
Persson, 2018	Sweden	Simrishamn	2017	354,4	Winter wheat	26-sep	3,8	19,4	6,3	Acid	AS	20
Persson, 2018	Sweden	Simrishamn	2017	354,4	Winter wheat	26-sep	3,8	19,4	6,3	Acid	AS	20
Hakansson, 2018	Sweden	Angelholm	2017	744	Winter wheat	30-sep	2,7	16	8	Alkaline	AS	20
Hakansson, 2018	Sweden	Angelholm	2017	744	Winter wheat	30-sep	2,7	16	8	Alkaline	AS	20
Hakansson, 2018	Sweden	Angelholm	2017	744	Winter wheat	30-sep	2,7	16	8	Alkaline	AS	20
Larsson, 2018	Sweden	Mjolby	2017	376,3	Winter wheat	20-sep	4,5	38	6,8	Neutral	AS	20
Larsson, 2018	Sweden	Mjolby	2017	376,3	Winter wheat	20-sep	4,5	38	6,8	Neutral	AS	20
Larsson, 2018	Sweden	Mjolby	2017	376,3	Winter wheat	20-sep	4,5	38	6,8	Neutral	AS	20
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	12-may	1,7	Clay loam	6,5	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	12-may	1,7	Clay loam	6,5	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	12-may	1,7	Clay loam	6,5	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	12-may	1,7	Clay loam	6,5	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1990	217	Spring wheat	14-may	1,7	Sandy clay	6,9	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1990	217	Spring wheat	14-may	1,7	Sandy clay	6,9	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1990	217	Spring wheat	14-may	1,7	Sandy clay	6,9	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1990	217	Spring wheat	14-may	1,7	Sandy clay	6,9	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100

ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Jokioinen	1989	248	Spring wheat	17-may	2,7	Clay loam	6,73	Neutral	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100
ESALA, 1992	Finland	Mietoinen	1989	240	Spring wheat	9-may	1,97	Sandy clay	6,2	Acid	CAN	100

Application_time1	Application_method1	Fertilizer_2	Dose_2 (kg N/ha)	Application_time2	Application_method2	Fertilizer_3	Dose_3 (kg N/ha)	Application_time3	Application_method3
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Stem elongation	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Stem elongation	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Stem elongation	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Stem elongation	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Stem elongation	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Stem elongation	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted

Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Stem elongation	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Stem elongation	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Stem elongation	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	AN	100	Tillering	Broadcasted	AN	40	Stem elongation	Broadcasted
Tillering	Broadcasted	U	100	Tillering	Broadcasted	U	40	Stem elongation	Broadcasted
Tillering	Broadcasted	CN	100	Tillering	Broadcasted	CN	40	Stem elongation	Broadcasted
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U	40	Beginning of tillering G21	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U	40	Beginning Ear emergence G50	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U	40	Beginning of tillering G21	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U	40	Beginning Ear emergence G50	Liquid top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning of tillering G21	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning Ear emergence G50	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A

Sowing	Combine-drilled	U granular	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning of tillering G21	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning Ear emergence G50	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning of tillering G21	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning Ear emergence G50	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning of tillering G21	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning of tillering G21	Foliar spray	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CAN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	CN	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U granular	40	Beginning Ear emergence G50	Granular top dressing	N/A	N/A	N/A	N/A
Sowing	Combine-drilled	U foliar	40	Beginning Ear emergence G50	Foliar spray	N/A	N/A	N/A	N/A

Total_N (kg/ha)	Yield_ Control (kg/ha)	Yield_ Fertilizer (kg/ha)	Yield difference	Yield_ increase (%)	Grain_Nuptake_ Control (kg/ha)	Grain_Nuptake_Fertilizer (kg/ha)	Grain_ Nuptake_ Difference	Grain_ Nrecovery (%)	Grain_proteincontent (%)
160	2510	7840	5330	212	35,5	130	94,5	59	9
160	2510	8520	6010	239	35,5	137	101,5	63	9
160	2510	7700	5190	207	35,5	123,5	88	55	9
160	5450	9620	4170	77	90,5	194,8	104,3	65	12
160	5450	9410	3960	73	90,5	186,7	96,2	60	11
160	5450	9620	4170	77	90,5	195,1	104,6	65	12
160	3300	7050	3750	114	49,5	140,1	90,6	57	11
160	3300	7370	4070	123	49,5	156,5	107	67	12
160	3300	7470	4170	126	49,5	161	111,5	70	12
160	4370	8580	4210	96	75,3	173,7	98,4	62	12
160	4370	8200	3830	88	75,3	158	82,7	52	11
160	4370	8970	4600	105	75,3	183,3	108	68	12
160	5320	8270	2950	55	80,5	161,5	81	51	11
160	5320	8050	2730	51	80,5	152,6	72,1	45	11
160	5320	8190	2870	54	80,5	167	86,5	54	12
160	5110	8850	3740	73	76,7	167,1	90,4	57	11
160	5110	8550	3440	67	76,7	163,9	87,2	55	11
160	5110	9050	3940	77	76,7	174,6	97,9	61	11
160	3520	6930	3410	97	56,7	144,2	87,5	55	12
160	3520	7360	3840	109	56,7	148,6	91,9	57	12
160	3520	7580	4060	115	56,7	159,9	103,2	65	12
160	3250	8930	5680	175	47,6	151,2	103,6	65	10
160	3250	8890	5640	174	47,6	150,7	103,1	64	10
160	3250	9200	5950	183	47,6	160,5	112,9	71	10
160	2160	6020	3860	179	36	138,3	102,3	64	13
160	2160	5800	3640	169	36	130	94	59	13
160	2160	6210	4050	188	36	145,9	109,9	69	13
160	4150	7660	3510	85	68	147,1	79,1	49	11
160	4150	7210	3060	74	68	138,9	70,9	44	11
160	4150	7680	3530	85	68	154,4	86,4	54	12

160	2790	5560	2770	99	42,2	112,5	70,3	44	12
160	2790	5110	2320	83	42,2	108,3	66,1	41	12
160	2790	6010	3220	115	42,2	128,6	86,4	54	12
160	3380	7390	4010	119	47,6	154,1	106,5	67	12
160	3380	6780	3400	101	47,6	135,9	88,3	55	11
160	3380	7540	4160	123	47,6	156	108,4	68	12
160	2810	4530	1720	61	38,5	66,4	27,9	17	8
160	2810	4720	1910	68	38,5	68,7	30,2	19	8
160	2810	4570	1760	63	38,5	66,6	28,1	18	8
160	1640	3140	1500	91	26,8	48,7	21,9	14	9
160	1640	3280	1640	100	26,8	51,1	24,3	15	9
160	1640	3160	1520	93	26,8	48,8	22	14	9
160	4930	7110	2180	44	86,1	151,5	65,4	41	12
160	4930	7140	2210	45	86,1	153,3	67,2	42	12
160	4930	7610	2680	54	86,1	178,4	92,3	58	13
140	1620	2310	690	43	34,4	62,4	28,0	20	18
140	1620	2450	830	51	34,4	65,9	31,5	23	18
140	1620	2450	830	51	34,4	68,3	33,9	24	19
140	1620	2380	760	47	34,4	66,1	31,7	23	19
140	2250	3570	1320	59	44,3	89,2	44,9	32	17
140	2250	3580	1330	59	44,3	87,3	43,0	31	16
140	2250	3590	1340	60	44,3	88,7	44,4	32	17
140	2250	3740	1490	66	44,3	90,9	46,6	33	16
140	1720	3940	2220	129	N/A	N/A	N/A	N/A	19
140	1720	3950	2230	130	N/A	N/A	N/A	N/A	19
140	1720	3910	2190	127	N/A	N/A	N/A	N/A	19
140	1720	4340	2620	152	N/A	N/A	N/A	N/A	19
140	1720	3970	2250	131	N/A	N/A	N/A	N/A	17
140	1720	4080	2360	137	N/A	N/A	N/A	N/A	19
140	1720	3850	2130	124	N/A	N/A	N/A	N/A	19
140	1720	4220	2500	145	N/A	N/A	N/A	N/A	19
140	1590	4130	2540	160	N/A	N/A	N/A	N/A	14
140	1590	3820	2230	140	N/A	N/A	N/A	N/A	14

140	1590	4340	2750	173	N/A	N/A	N/A	N/A	14
140	1590	4140	2550	160	N/A	N/A	N/A	N/A	13
140	1590	4150	2560	161	N/A	N/A	N/A	N/A	13
140	1590	3920	2330	147	N/A	N/A	N/A	N/A	14
140	1590	4360	2770	174	N/A	N/A	N/A	N/A	14
140	1590	4120	2530	159	N/A	N/A	N/A	N/A	14
140	1560	3980	2420	155	N/A	N/A	N/A	N/A	15
140	1560	4220	2660	171	N/A	N/A	N/A	N/A	15
140	1560	4120	2560	164	N/A	N/A	N/A	N/A	14
140	1560	4200	2640	169	N/A	N/A	N/A	N/A	14
140	1560	3840	2280	146	N/A	N/A	N/A	N/A	16
140	1560	4080	2520	162	N/A	N/A	N/A	N/A	16
140	1560	3940	2380	153	N/A	N/A	N/A	N/A	15
140	1560	4190	2630	169	N/A	N/A	N/A	N/A	14
140	1720	4240	2520	147	N/A	N/A	N/A	N/A	12
140	1720	4470	2750	160	N/A	N/A	N/A	N/A	12
140	1720	3760	2040	119	N/A	N/A	N/A	N/A	12
140	1720	3970	2250	131	N/A	N/A	N/A	N/A	12
140	1720	4080	2360	137	N/A	N/A	N/A	N/A	13
140	1720	4230	2510	146	N/A	N/A	N/A	N/A	13
140	1720	3800	2080	121	N/A	N/A	N/A	N/A	13
140	1720	3910	2190	127	N/A	N/A	N/A	N/A	12

Appendix 3. Nitrous oxide emissions dataset

Reference	Country	Region	Year	ET (mm)	Annual_precipitation (mm)	Aridity_index	Climate	Precipitation_growing season (mm)	Crop_type	Crop	Soil_texture	Textural_class	Soil.pH
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2005-2006	1250	336	0,27	Semi-arid	143,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2006-2007	1250	336	0,27	Semi-arid	166,81	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2007-2008	1250	336	0,27	Semi-arid	311,66	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2005-2006	800	450	0,56	Sub-humid	295,30	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2006-2007	800	450	0,56	Sub-humid	339,82	Cereals	Winter wheat	Loam	Coarse	8,3

Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2007-2008	800	450	0,56	Sub-humid	328,98	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2005-2006	905	685	0,76	Humid	324,20	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2006-2007	905	685	0,76	Humid	394,33	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2007-2008	905	685	0,76	Humid	402,00	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2011-2012	1250	336	0,27	Semi-arid	143,71	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8

Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2012-2013	1250	336	0,27	Semi-arid	274,42	Cereals	Winter wheat	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Senes	2013-2014	1250	336	0,27	Semi-arid	236,57	Cereals	Winter barley	Silty clay loam	Medium	8
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2011-2012	800	450	0,56	Sub-humid	246,52	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2012-2013	800	450	0,56	Sub-humid	286,20	Cereals	Winter wheat	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	Spain	Selvanera	2013-2014	800	450	0,56	Sub-humid	288,62	Cereals	Winter barley	Loam	Coarse	8,3
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2011-2012	905	685	0,76	Humid	341,29	Cereals	Winter wheat	Loam	Coarse	7

Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2012-2013	905	685	0,76	Humid	631,60	Cereals	Winter wheat	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Plaza Bonilla et al. 2016	France	Auzeville	2013-2014	905	685	0,76	Humid	583,22	Cereals	Winter barley	Loam	Coarse	7
Nishimura et al. 2022	Japan	Sapporo city	2018	875	967	1,11	Humid	481,10	Cereals	Winter wheat	Clay loam	Medium	5,5
Nishimura et al. 2022	Japan	Sapporo city	2018	875	967	1,11	Humid	481,10	Cereals	Winter wheat	Clay loam	Medium	5,5
Waterhouse et al. 2017	USA	California	2012	1625	992	0,61	Sub-humid	992,90	Cereals	Maize	Loam	Coarse	6,95
Waterhouse et al. 2017	USA	California	2012	1625	992	0,61	Sub-humid	992,90	Cereals	Maize	Loam	Coarse	6,95
Nishimura et al. 2021	Japan	Sapporo city	2016	875	938	1,07	Humid	688,37	Vegetables	Carrot	Clay loam	Medium	6,1
Nishimura et al. 2021	Japan	Sapporo city	2016	875	938	1,07	Humid	688,37	Vegetables	Carrot	Clay loam	Medium	6,1
Nishimura et al. 2021	Japan	Sapporo city	2017	875	938	1,07	Humid	627,48	Vegetables	Carrot	Clay loam	Medium	6,1
Nishimura et al. 2021	Japan	Sapporo city	2017	875	938	1,07	Humid	627,48	Vegetables	Carrot	Clay loam	Medium	6,1
Nishimura et al. 2021	Japan	Sapporo city	2017	875	938	1,07	Humid	627,48	Vegetables	Carrot	Clay loam	Medium	6,1
Abalos. 2014	Spain	Madrid	2011	1625	460	0,28	Semi-arid	373,30	Fruits	Melon	Clay loam	Medium	7,6
Abalos. 2014	Spain	Madrid	2011	1625	460	0,28	Semi-arid	373,30	Fruits	Melon	Clay loam	Medium	7,6
Abalos. 2014	Spain	Madrid	2011	1625	460	0,28	Semi-arid	373,30	Fruits	Melon	Clay loam	Medium	7,6
Abalos. 2014	Spain	Madrid	2011	1625	460	0,28	Semi-arid	373,30	Fruits	Melon	Clay loam	Medium	7,6
Rahman & Forrestal. 2021	Ireland	Wexford	2020-2021	625	1035	1,66	Humid	1176,00	Grass	Ryegrass	Sandy loam	Coarse	6,2
Rahman & Forrestal. 2021	Ireland	Wexford	2020-2021	625	1035	1,66	Humid	1176,00	Grass	Ryegrass	Sandy loam	Coarse	6,2
Clayton et al. 1997	UK	Penicuik	1992	625	639,3	1,02	Humid	559,17	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1992	625	639,3	1,02	Humid	559,17	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1992	625	639,3	1,02	Humid	559,17	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1992	625	639,3	1,02	Humid	559,17	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1993	625	639,3	1,02	Humid	605,37	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1993	625	639,3	1,02	Humid	605,37	Grass	Ryegrass	Clay loam	Medium	5,5

Clayton et al. 1997	UK	Penicuik	1993	625	639,3	1,02	Humid	605,37	Grass	Ryegrass	Clay loam	Medium	5,5
Clayton et al. 1997	UK	Penicuik	1993	625	639,3	1,02	Humid	605,37	Grass	Ryegrass	Clay loam	Medium	5,5
Duxbury & McConnaughey. 19	USA	Ithaca	1981	1125	972,57	0,86	Humid	201,80	Cereals	Maize	Silt loam	Coarse	6,9
Duxbury & McConnaughey. 19	USA	Ithaca	1981	1125	972,57	0,86	Humid	201,80	Cereals	Maize	Silt loam	Coarse	6,9

pH Class	Fertilizer	Total_N (kg/ha)	Dose_distribution	Timing	Application_ method	Emissions (kg/ha/year)
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,68
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,64
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,78
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,67
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,65
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,57
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,35
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,39
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,40
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,38
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,36
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,30
Alkaline	AN	50	Single	Stem elongation	Broadcasted	0,20
Alkaline	AN	50	Single	Stem elongation	Broadcasted	0,22
Alkaline	CN	50	Single	Stem elongation	Broadcasted	0,19
Alkaline	CN	50	Single	Stem elongation	Broadcasted	0,22
Alkaline	U	50	Single	Stem elongation	Broadcasted	0,20
Alkaline	U	50	Single	Stem elongation	Broadcasted	0,13
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,66
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,68
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,54
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,57
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,74
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,70
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,35
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,36
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,30
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,27
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,41
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,35

Alkaline	AN	90	Split	Stem elongation	Broadcasted	0,42
Alkaline	AN	90	Split	Stem elongation	Broadcasted	0,36
Alkaline	CN	90	Split	Stem elongation	Broadcasted	0,42
Alkaline	CN	90	Split	Stem elongation	Broadcasted	0,34
Alkaline	U	90	Split	Stem elongation	Broadcasted	0,44
Alkaline	U	90	Split	Stem elongation	Broadcasted	0,34
Neutral	AN	170	Split	Stem elongation	Broadcasted	2,04
Neutral	AN	170	Split	Stem elongation	Broadcasted	2,00
Neutral	CN	170	Split	Stem elongation	Broadcasted	1,82
Neutral	CN	170	Split	Stem elongation	Broadcasted	1,82
Neutral	U	170	Split	Stem elongation	Broadcasted	2,27
Neutral	U	170	Split	Stem elongation	Broadcasted	2,28
Neutral	AN	170	Split	Stem elongation	Broadcasted	2,81
Neutral	AN	170	Split	Stem elongation	Broadcasted	2,11
Neutral	CN	170	Split	Stem elongation	Broadcasted	2,98
Neutral	CN	170	Split	Stem elongation	Broadcasted	2,01
Neutral	U	170	Split	Stem elongation	Broadcasted	3,33
Neutral	U	170	Split	Stem elongation	Broadcasted	2,37
Neutral	AN	150	Split	Stem elongation	Broadcasted	2,50
Neutral	AN	150	Split	Stem elongation	Broadcasted	2,75
Neutral	CN	150	Split	Stem elongation	Broadcasted	2,86
Neutral	CN	150	Split	Stem elongation	Broadcasted	2,83
Neutral	U	150	Split	Stem elongation	Broadcasted	2,94
Neutral	U	150	Split	Stem elongation	Broadcasted	2,93
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,33
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,34
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,30
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,31
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,34
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,32
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,29
Alkaline	AN	60	Single	Stem elongation	Broadcasted	0,35
Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,30

Alkaline	CN	60	Single	Stem elongation	Broadcasted	0,34
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,33
Alkaline	U	60	Single	Stem elongation	Broadcasted	0,27
Alkaline	AN	50	Single	Stem elongation	Broadcasted	0,27
Alkaline	AN	50	Single	Stem elongation	Broadcasted	0,37
Alkaline	CN	50	Single	Stem elongation	Broadcasted	0,29
Alkaline	CN	50	Single	Stem elongation	Broadcasted	0,41
Alkaline	U	50	Single	Stem elongation	Broadcasted	0,25
Alkaline	U	50	Single	Stem elongation	Broadcasted	0,26
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,52
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,56
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,49
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,51
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,56
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,53
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,67
Alkaline	AN	110	Split	Stem elongation	Broadcasted	0,84
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,59
Alkaline	CN	110	Split	Stem elongation	Broadcasted	0,84
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,69
Alkaline	U	110	Split	Stem elongation	Broadcasted	0,78
Alkaline	AN	90	Split	Stem elongation	Broadcasted	0,69
Alkaline	AN	90	Split	Stem elongation	Broadcasted	1,14
Alkaline	CN	90	Split	Stem elongation	Broadcasted	0,66
Alkaline	CN	90	Split	Stem elongation	Broadcasted	0,15
Alkaline	U	90	Split	Stem elongation	Broadcasted	0,66
Alkaline	U	90	Split	Stem elongation	Broadcasted	0,94
Neutral	AN	170	Split	Stem elongation	Broadcasted	3,03
Neutral	AN	170	Split	Stem elongation	Broadcasted	4,00
Neutral	CN	170	Split	Stem elongation	Broadcasted	2,90
Neutral	CN	170	Split	Stem elongation	Broadcasted	3,86
Neutral	U	170	Split	Stem elongation	Broadcasted	3,25
Neutral	U	170	Split	Stem elongation	Broadcasted	4,22

Neutral	AN	170	Split	Stem elongation	Broadcasted	2,30
Neutral	AN	170	Split	Stem elongation	Broadcasted	3,32
Neutral	CN	170	Split	Stem elongation	Broadcasted	2,12
Neutral	CN	170	Split	Stem elongation	Broadcasted	3,14
Neutral	U	170	Split	Stem elongation	Broadcasted	2,47
Neutral	U	170	Split	Stem elongation	Broadcasted	3,48
Neutral	AN	150	Split	Stem elongation	Broadcasted	2,26
Neutral	AN	150	Split	Stem elongation	Broadcasted	3,22
Neutral	CN	150	Split	Stem elongation	Broadcasted	1,99
Neutral	CN	150	Split	Stem elongation	Broadcasted	3,00
Neutral	U	150	Split	Stem elongation	Broadcasted	2,37
Neutral	U	150	Split	Stem elongation	Broadcasted	3,38
Acid	U	190	Single	Sowing	Incorporated	0,85
Acid	CN	190	Single	Sowing	Incorporated	0,70
Neutral	AN	202	Single	Stem elongation	Liquid injected	0,95
Neutral	CN	202	Single	Stem elongation	Liquid injected	0,35
Acid	AS	120	Single	Before sowing	Incorporated	2,89
Acid	CN	120	Single	Before sowing	Incorporated	1,72
Acid	AS	120	Single	Before sowing	Incorporated	1,31
Acid	CN	120	Single	Before sowing	Incorporated	0,84
Acid	U	120	Single	Before sowing	Incorporated	1,07
Alkaline	CN	125	Split	Weekly distribution	Liquid injected	0,07
Alkaline	U	125	Split	Weekly distribution	Liquid injected	0,19
Alkaline	CN	125	Split	Daily distribution	Liquid injected	0,09
Alkaline	U	125	Split	Daily distribution	Liquid injected	0,19
Acid	AS	220	Split	Split	Broadcasted	1,07
Acid	CN	220	Split	Split	Broadcasted	2,54
Acid	AS	360	Split	Split	Broadcasted	0,69
Acid	U	360	Split	Split	Broadcasted	3,01
Acid	CN	360	Split	Split	Broadcasted	1,63
Acid	AN	360	Split	Split	Broadcasted	1,50
Acid	AS	360	Split	Split	Broadcasted	1,28
Acid	U	360	Split	Split	Broadcasted	5,21

Acid	CN	360	Split	Split	Broadcasted	4,00
Acid	AN	360	Split	Split	Broadcasted	4,23
Neutral	CN	120	Single	Stem elongation	Liquid injected	0,30
Neutral	U	120	Single	Stem elongation	Liquid injected	2,50

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