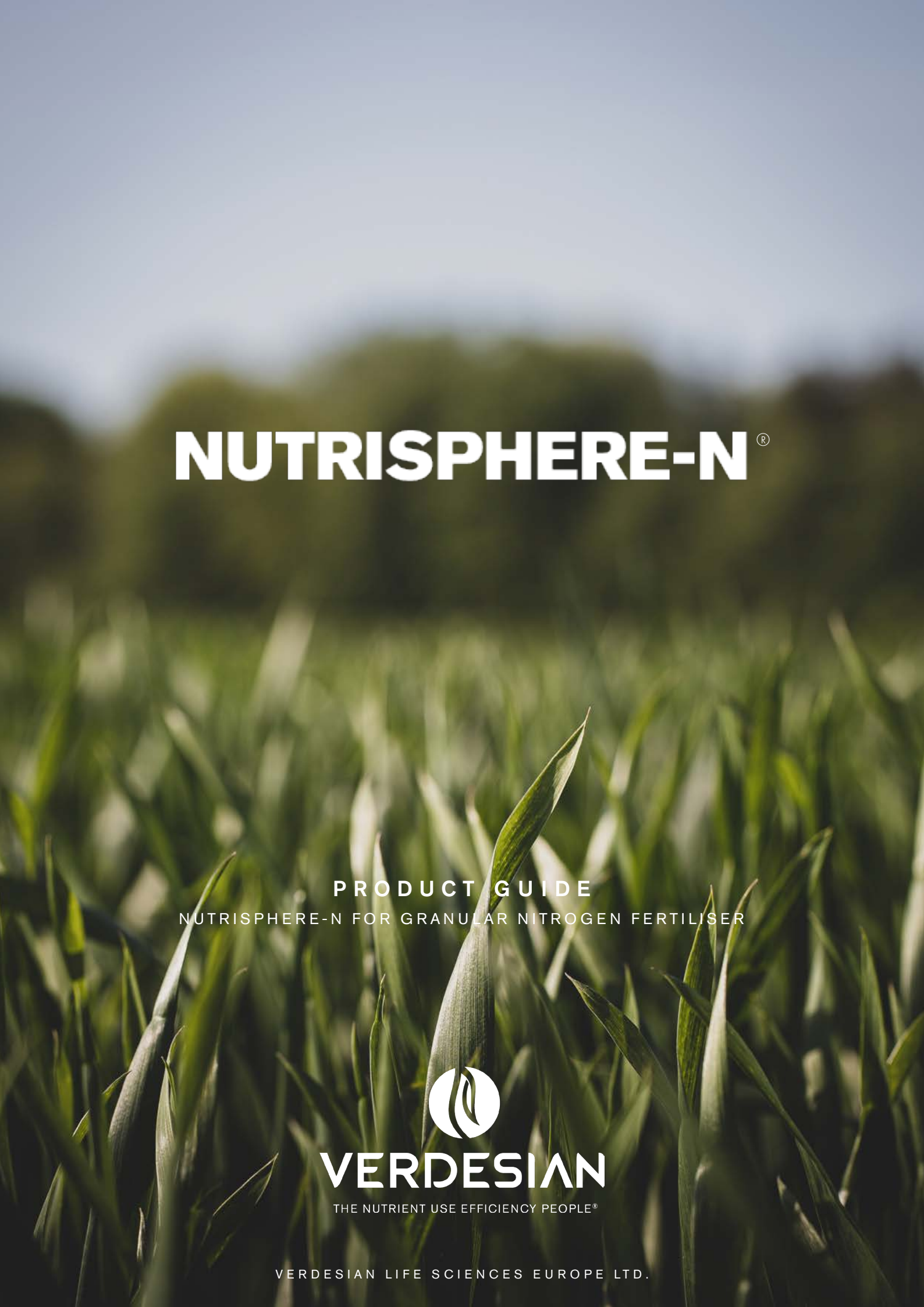


NUTRISPHERE-N®

PRODUCT GUIDE

NUTRISPHERE-N FOR GRANULAR NITROGEN FERTILISER

VERDESIAN

THE NUTRIENT USE EFFICIENCY PEOPLE®

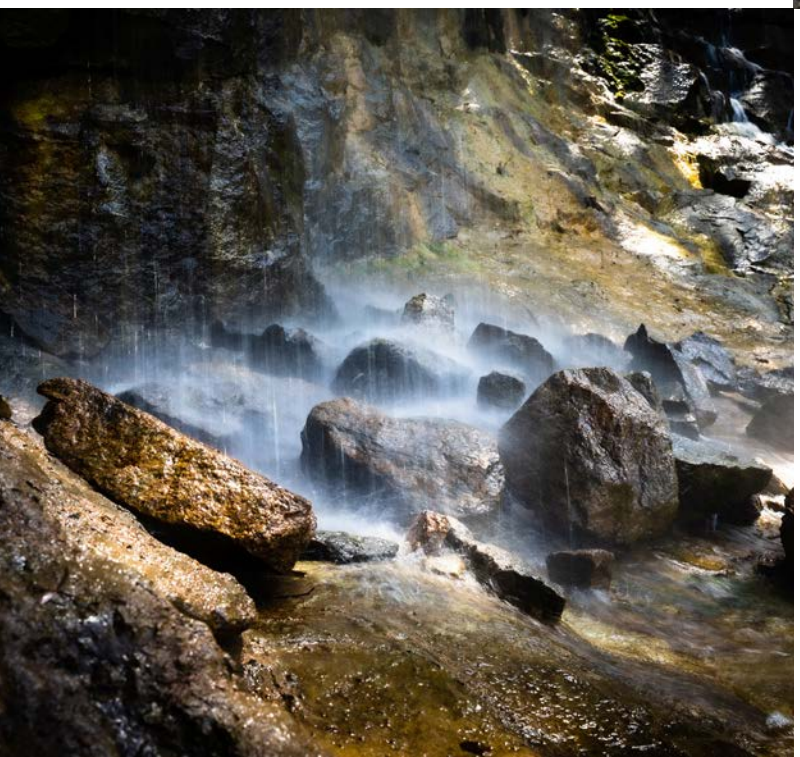
VERDESIAN LIFE SCIENCES EUROPE LTD.

Introduction

Stability

NutriSphere products and treated fertilisers demonstrate good stability when stored as recommended.

- NutriSphere-N® has a shelf life of 2 years.
- Granular urea treated with NutriSphere-N has a shelf life of 12 months and no deterioration during the storage period when blended with phosphate or sulphur based fertilisers.



Product Introduction

With governments preparing their clean air and clean water strategies there is a growing need for new technologies to help combat the environmental impact of ammonia release from urea-based fertilisers, the greenhouse gas nitrous oxide and nitrates as water pollutants. Verdesian Life Sciences Europe is able to provide a novel approach by introducing two products for urea granular and liquid-based fertilisers

Components

NutriSphere-N (and NutriSphere-NL for UAN) are 40% w/w aqueous solutions of maleic-itaconic acid copolymer. This dicarboxylic acid polymer is a large, highly water-soluble organic compound presented in the form of a single phase solution containing no immiscible particles. The itaconic acid is a fermentation product from maize and the maleic acid is commonly used in the food industry.

Use Rates

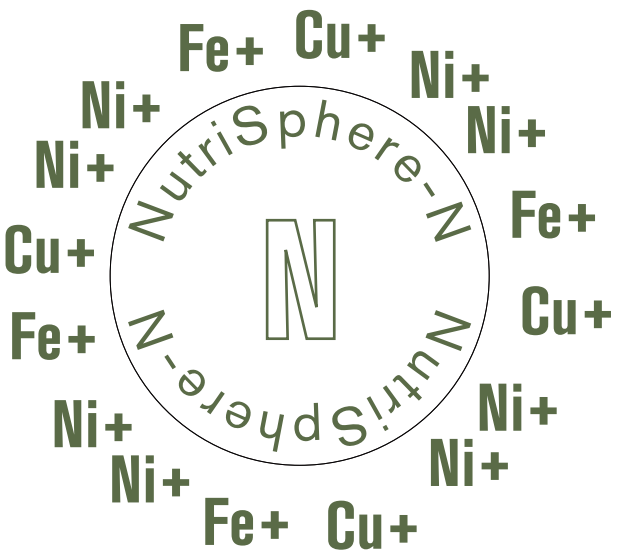
NutriSphere-N – rate: 2.1L/tonne granular urea, this provides the recommended 1030 ppm of active ingredient.

Methods of Application

NutriSphere-N is applied at the fertiliser blending stage by spraying onto granular urea on a conveyor belt or into a drum blender. NutriSphere -N is purchased premixed by the grower.

Due to degradation risk above 40°C the copolymer is not suitable to be introduced upstream at production sites for urea where manufacturing temperatures of above 60°C are common.

NutriSphere-N



NutriSphere-N influences the microzone around applied N.

Mode of Action

The strong negative charge of the maleic-itaconic acid (MIP) copolymer molecules have a cation exchange capacity (CEC)of 1,800 milliequivalents/100g polymer. This (CEC) attracts the three major cations Ni^{5+}, Cu^{3+} and Fe^{2+} which are integral to the biological process of converting urea to less stable forms, and effectively shields nitrogen on a molecular level.

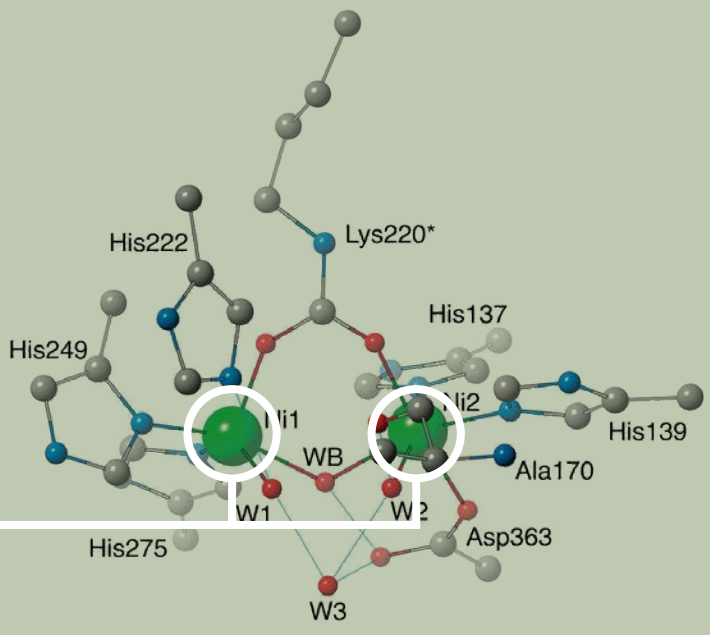
- Nickel fuels the urease enzyme that converts urea to ammonia lost to the atmosphere by volatilisation.
- Copper activates *Nitrosomonas sp.*, bacteria which oxidises ammonium-N into nitrite contributing to potential nitrogen loss by leaching.
- Iron stimulates soil bacteria *Nitrosomonas sp.*, which aid conversion of nitrites to nitrates potentially prone to nitrogen leaching.

NutriSphere-N has a low intrinsic pH 1-2. The activity of NutriSphere-N as an inhibitor of soil urease is therefore also due to its ability to create and maintain a low pH environment in the immediate vicinity of the fertiliser. This low pH environment along with chelation/sequestration of the cation nickel denies the bacteria the necessary process involved to produce a functional urease enzyme, meaning less active urease is available and less nitrogen lost through volatilisation as ammonia. NutriSphere-N enables more of the applied nitrogen to be held in the ammonium form (NH_4^+) available for plant uptake and reducing the potential environmental impact.

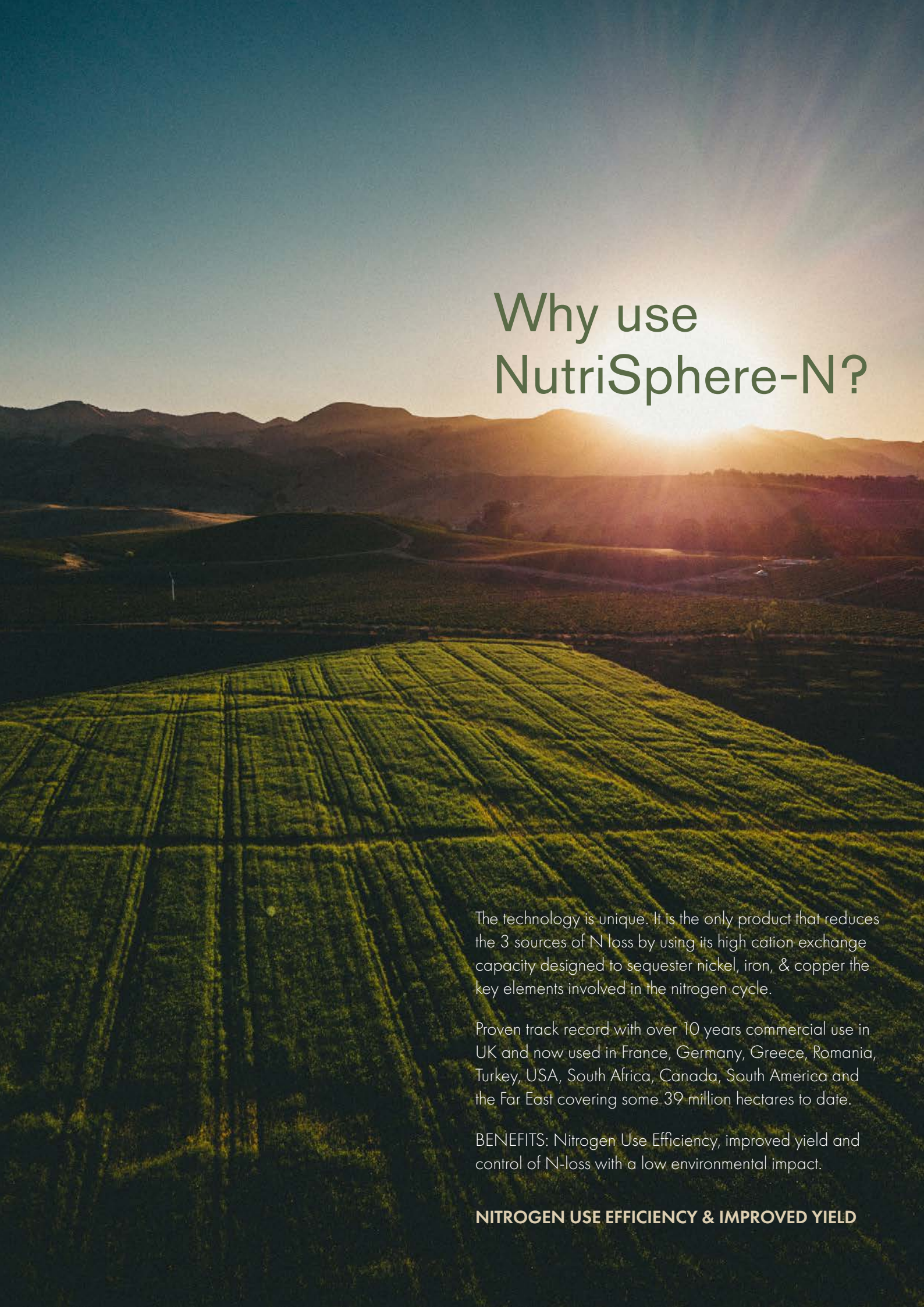
Unlike some other inhibitors, NutriSphere-N has no negative effect on soil ureolytic bacteria which cause the degradation of urea.

NUTRISPHERE-N TAKES THE NICKEL AWAY

This mode of action has been proven by the University of Bologna, peer reviewed and published 2018 in the Soil Science Society of America Journal.



Mazzei, L., V. Broll, and S. Ciurli. 2018. An Evaluation of Maleic-Itaconic Copolymers as Urease Inhibitors. Soil Sci. Soc. Am. J. 82:994-1003. doi:10.2136/sssaj2017.09.0323



Why use NutriSphere-N?

The technology is unique. It is the only product that reduces the 3 sources of N loss by using its high cation exchange capacity designed to sequester nickel, iron, & copper the key elements involved in the nitrogen cycle.

Proven track record with over 10 years commercial use in UK and now used in France, Germany, Greece, Romania, Turkey, USA, South Africa, Canada, South America and the Far East covering some 39 million hectares to date.

BENEFITS: Nitrogen Use Efficiency, improved yield and control of N-loss with a low environmental impact.

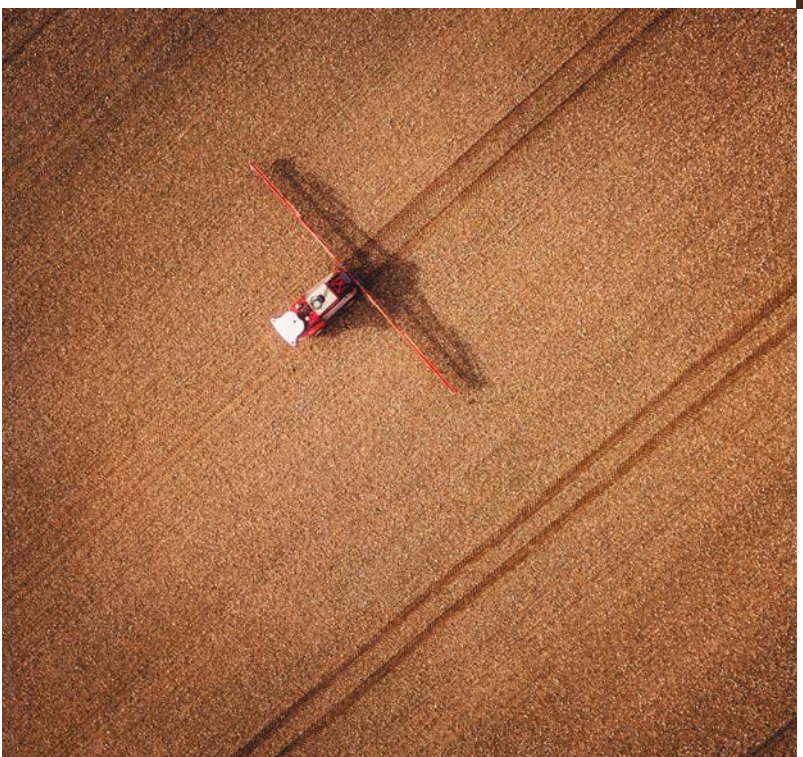
NITROGEN USE EFFICIENCY & IMPROVED YIELD

Product Trials and Results

Volatilisation Study Under Field Conditions 2021

A sponsored field volatilisation study in grassland monitoring ammonia release from NutriSphere-N treated urea granules was conducted in May 2021 by ADAS Gleadthorpe, UK.

STUDY - Ammonia emissions following the application of NutriSphere-N treated granular urea and urea.



Trial Outline

Total ammonia emissions (by plot) for the 21-day period were determined following the application of NutriSphere-N treated granular urea and urea applied at 100 kg N/ha on 4 May 2021.

Wind tunnels based on the design of Lockyer (Lockyer, D.R. 1984) were used to measure ammonia emissions following fertiliser application. This technique is typically used in field experiments for assessing fluxes from small plots for comparative experiments (Misselbrook et al., 2005; Miola et al., 2015).

There were four replicates of each treatment, arranged in a randomised block design.

Ammonia emissions after 7 and 14 days

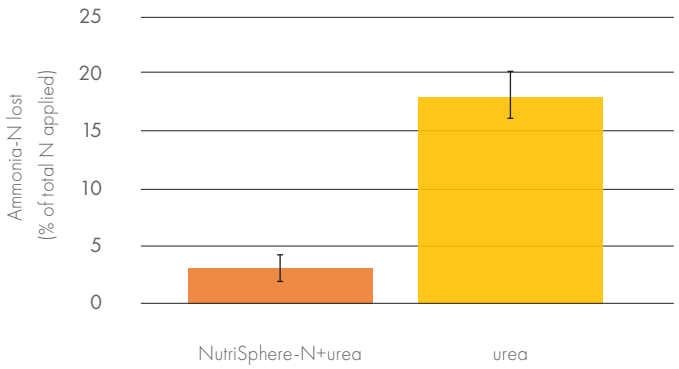
After 7 days mean ammonia emissions from the NutriSphere-N treated granular urea (mean: 2 kg ammonia-N/ha) were significantly lower than from urea (mean: 17 kg ammonia-N/ha), with emission factors of 2 and 17%, respectively ($p=0.005$). Similarly, after 14 days mean ammonia emissions from the NutriSphere-N treated granular urea (mean: 3 kg ammonia-N/ha) were significantly lower than from urea (mean: 18 kg ammonia-N/ha), with emission factors of 3 and 18%, respectively ($p<0.001$).

Ammonia emissions after 21 days

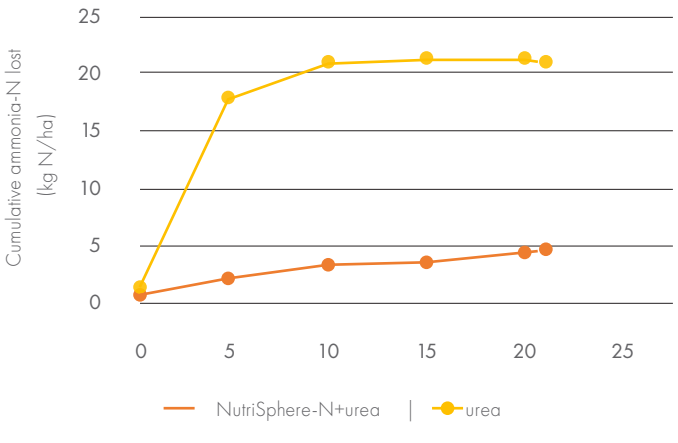
Ammonia emissions from the NutriSphere-N treated granular urea (mean: 4 kg ammonia-N/ha) were significantly lower than from the urea (mean: 18 kg ammonia-N/ha), ($p<0.001$) after 21 days. The emission factors (% of total N applied) were 4% for the NutriSphere-N treated granular urea and 18% for the urea, respectively.

Emissions Factor: Total ammonia-N lost (% of total N applied) 21 days after NutriSphere-N+urea and urea applications (100 kg N/ha) to grass.

Days since fertiliser applied



Days since fertiliser applied



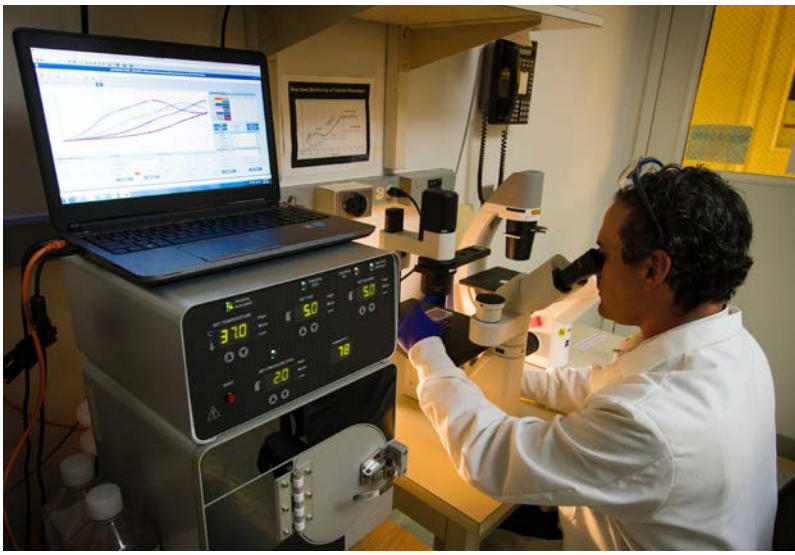
Cumulative emission curve (ammonia-N kg/ha) for the 21-day period following NutriSphere-N+urea and urea applications (100 kg N/ha).

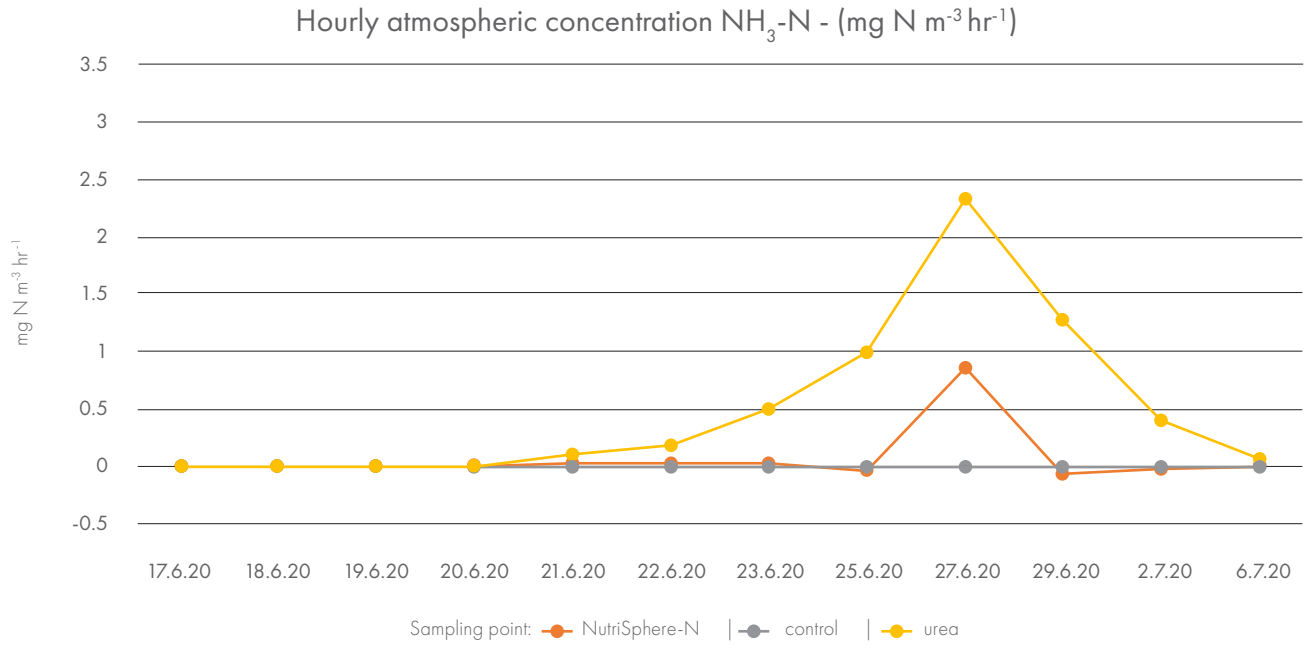
Product Trials and Results

Volatilisation Study Under Controlled Conditions 2020

A sponsored volatilisation trial performed in June 2020 by University College Dublin (UCD) showed 86% reduction in cumulative emissions of ammonia compared to untreated urea over 20 days. Results were statistically significant at 95% confidence level (p = 0.018).

The 84% reduction in ammonia release at 14 days, meets Reg. (EU) 2019/1009 criteria of 20 % reduction for urease inhibitors.





Meta Analysis Study

Urea vs. NutriSphere-N, 2015-2021, 58 trial results

France, Germany, Greece, Italy, UK, Turkey: relative yield difference urea+NN vs. urea (%)

Agronomic Trial Results

NutriSphere-N: A total of 70 field trials 2015-2021 across FR, PL, GR, DE TR & UK. Average yield 5.4% increase across 6 crops, including wheat, barley, oil seed rape, potato, maize and sugar beet.

There was no observable difference relating to soil pH and type for trials performed with a range of pH 5.1 – 8.1.

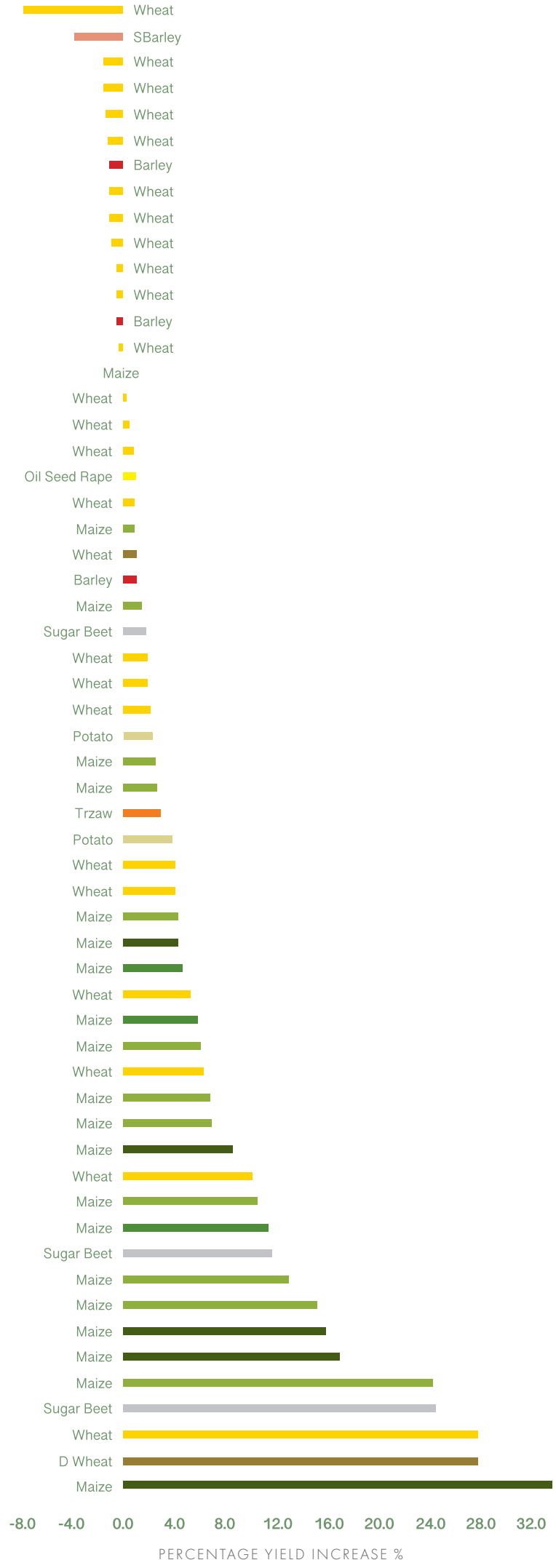
The trials demonstrated a total 87% positive yield result across all 70 trials.

AVERAGE YIELD INCREASE

+5.4%

KEY

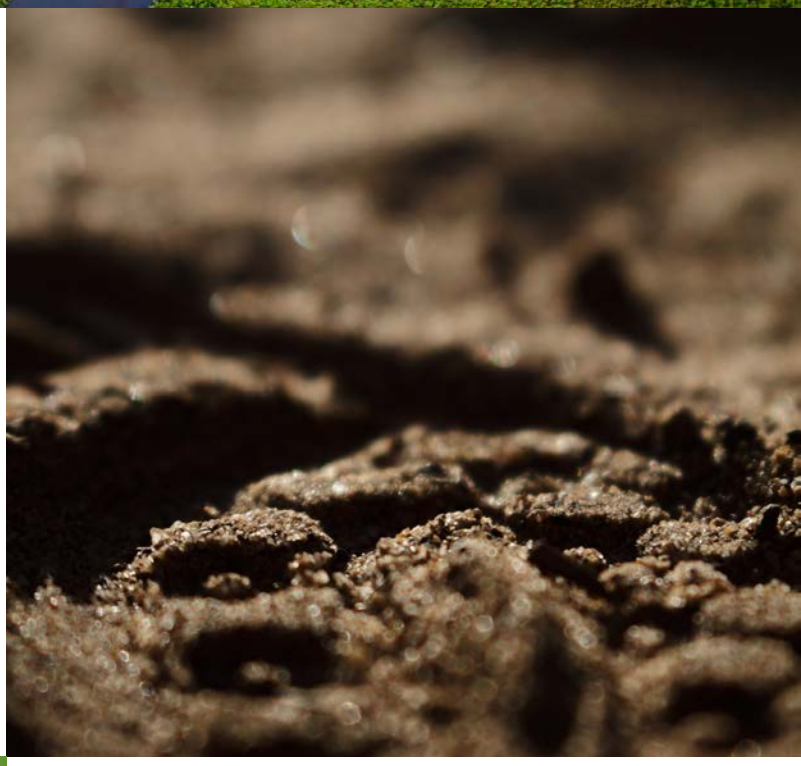
- Winter wheat (**29**)
- Durum wheat (**1**)
- Barley (**3**)
- Spring barley (**1**)
- Winter oilseed rape (**1**)
- Potato (**2**)
- Maize (**18**)
- Sugar beet (**3**)



The Environment

Ammonia Emission

Following fertiliser application, NutriSphere-N treated granular urea showed an average 80% reduction in volatilised ammonia compared to untreated urea after 21-days. At 14 days after application, NutriSphere-N treated granular urea showed an 85% reduction in total volatilised ammonia compared to the untreated urea.



Carbon Footprint

NutriSphere-N has a low carbon foot print value of 0.147 kg CO_2 per kg of product (kg CO_2-eq/kg 0.147).

This value represents the total amount of carbon dioxide released into the atmosphere per kg of NutriSphere-N when produced.

NutriSphere-N has a specific gravity of 1.12 g/ml, at standard application rate this equates to 2.35 kg of NutriSphere–N applied per tonne of urea fertiliser. Therefore, the additional carbon foot print to be taken into account is 0.346 kg of CO_2 per tonne of urea fertiliser treated.

Nitrous Oxide Emission

In an independent cotton trial conducted by the University of California, NutriSphere-NL with UAN reduced the total N_2O emissions by up to 61% at 56 and 112 kg nitrogen/ha and by 38 % with no nitrogen applied over a period of 226 days. An emissions factor of 0.2-0.36 was established.

Source: California Department of Food and Agriculture CDFA-Nitrous Oxide Emission Final Report 2015-0707-CDFA-N20-Final report Goorahoo(California State University, Fresno)

Soil Mineral Nitrogen

UAN treated with NutriSphere-NL applied in a fodder maize crop in Dorset significantly reduced the movement of soil mineral nitrogen (SMN) though the soil profile over a 5 month period post fertiliser application.

NutriSphere-NL maintained SMN in the upper soil levels and reduced SMN level by 34 % at a depth of 90 cm in the soil compared to a standard UAN treatment.

Source: Wessex water UK 2019

Nitrate Leaching

In a field tile drain trial in grain maize, UAN+NutriSphere-NL treatment compared to standard UAN application reduced the detectable nitrate levels in the outflow from the field tile drains by 42 % two days after application and 21 % after 290 days post application.

Source: Guthrie Centre Iowa, USA 2016

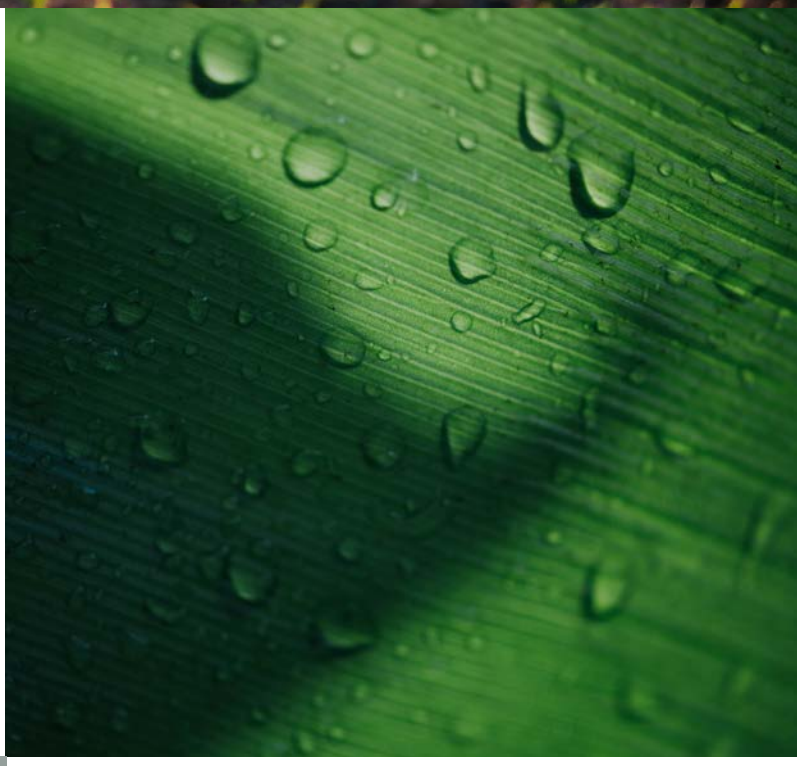
The Environment

Effects On Terrestrial Organisms

Chronic toxicity test on earthworms

Studies (ISO 11268-2/2015) performed at up to 10 times the agronomic dose determined that NutriSphere-N presents no long-term effect on the rate of mortality, reproduction or biomass inhibition of earthworms *(Eisenia fetida/ Eisenia Andrei)*.

The results showed that all rates actually increased the growth and number of larvae during the 12 month study period.



Effects On Soil Microorganisms

OECD 217 - Soil Microorganisms: Carbon transformation Test

Tests were performed with x1, x3, x10 the agronomic dose of NutriSphere-N. The results found the addition of NutriSphere-N to the soil surface determined no long-term influence on carbon transformation in soils.

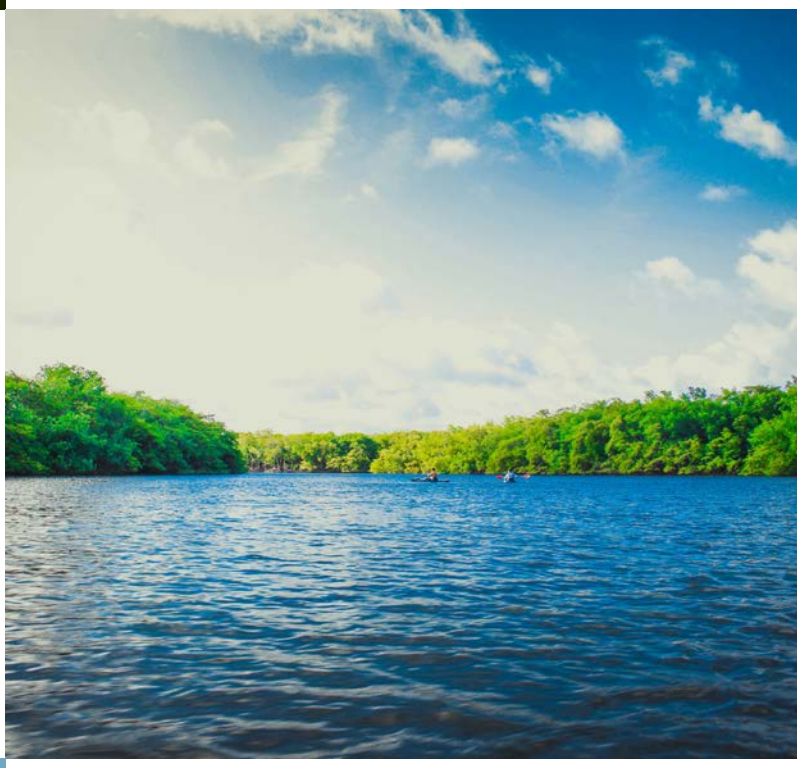
Effects on Mycorrhizal fungi Agricultural University of Athens

Results of a study performed with NutriSphere-N treated urea by Athens University reported a 73.49 % increase in Mycorrhizal colonization after 69 days compared with untreated urea.

Effects On Plants

Emergence and early growth of higher plants ISO 11269-2:2012

Results of a study performed with *Avena sativa* (Oats) and *Brassica napus* (Oil Seed Rape) at up to 10 times the agronomic dose found that NutriSphere-N had no adverse effects. The plants showed normal emergence (7 days), growth variation (20 days) and no phytotoxicity.



Effects On Aquatic Organisms

Acute & chronic studies (12 month) performed with NutriSphere-N at up to 10 times the agronomic dose determined there was no long-term effect on the mobility of Daphnia.

Water flea (Daphnia magna) mobility inhibition ISO 6341:2012

Acute & chronic studies (12 month) performed with NutriSphere-N at up to 10 times the agronomic dose determined there was no long-term effect on the growth of algae.

Algal growth inhibition (P. subcapitata) ISO 8692:2012

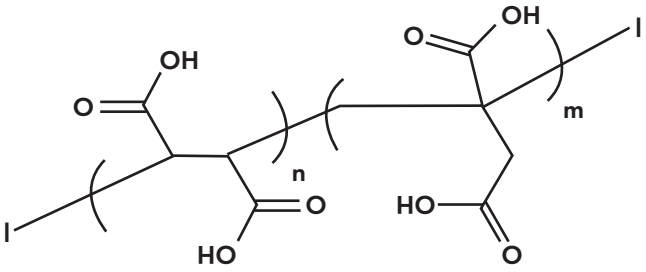
Acute study (96 hr) performed with NutriSphere-N at up to 10 times the agronomic dose determined there was no effect on fish mortality.

Acute toxicity to Freshwater fish (Danio rerio) ISO 7346-1:1996

ENVIRONMENTAL IMPACT

COPOLYMER STRUCTURE

The maleic-itaconic acid copolymer is part of the dicarboxylic acid copolymer family, which are large water-soluble organic compounds (comprising only carbon, oxygen and hydrogen in this case). When dissolved in water, they form a single phase and do not contain immiscible particles.

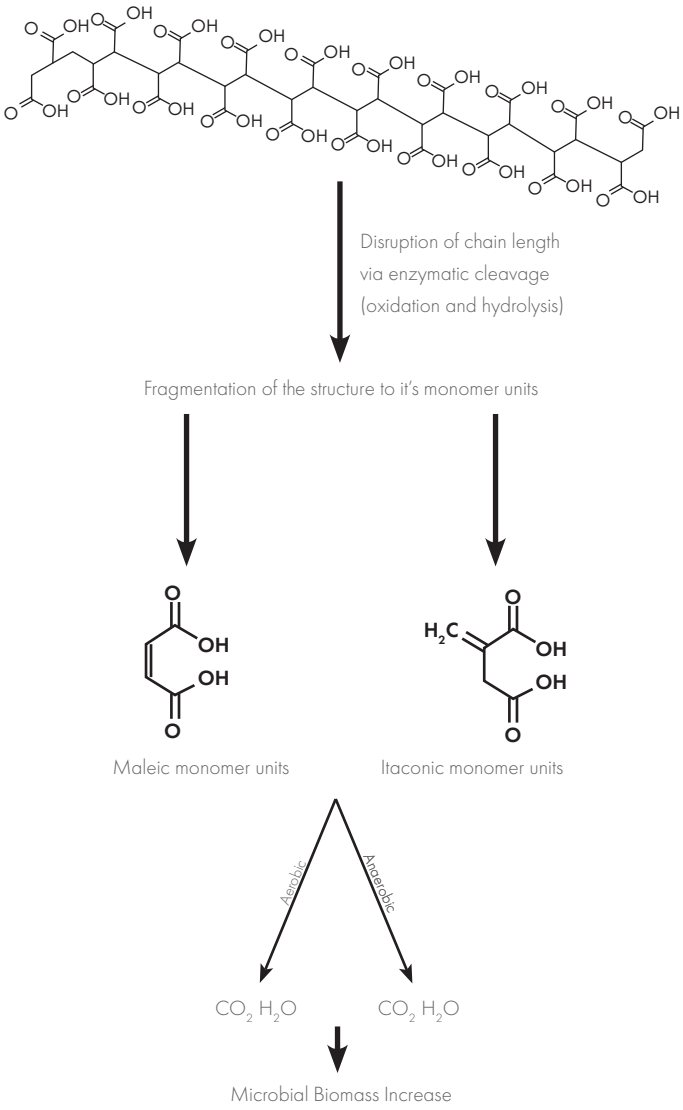


Maleic-itaconic acid copolymer:
Where n = maleic acid and m = itaconic acid.

DEGRADATION PATHWAY

The maleic-itaconic copolymer is present with a terminal itaconic moiety on a maleic monomer. Over time the structure fragments into its individual monomeric units. Both aerobic and anaerobic degradation processes lead to increased microbial biomass.

- Polymer biodegradation depends on physical and chemical properties with molecular weight and crystallinity being key, affecting the efficiency of biodegradation by microorganisms.
- Extracellular and intracellular depolymerase are responsible for polymer degradation. Exo-enzymes are generally involved in degradation of complex polymers into simple monomers and dimers which are then exploited by microorganisms as sources of energy and carbon.
- Polymer degradation (mineralization) forms new products during or at the end of the processes like H_2O and CO_2.



Summary

NutriSphere-N is a highly water-soluble organic compound primarily created from fermentation of maize.

The technology keeps the fertiliser where it is needed for longer, increasing nitrogen efficiency, yield and crop quality.

The technology is proven to reduce the three sources of N loss by using its high cation exchange capacity to deny certain bacteria key elements (Ni, Cu, Fe).

The technology has demonstrated a beneficial effect on soil biome.

NutriSphere-N is proven to provide farmers with a return on investment.

The technology helps reduce the environmental impact on air and water quality. NutriSphere-N breaks down in the soil to carbon, hydrogen and oxygen.

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