Introducing **Limus®**

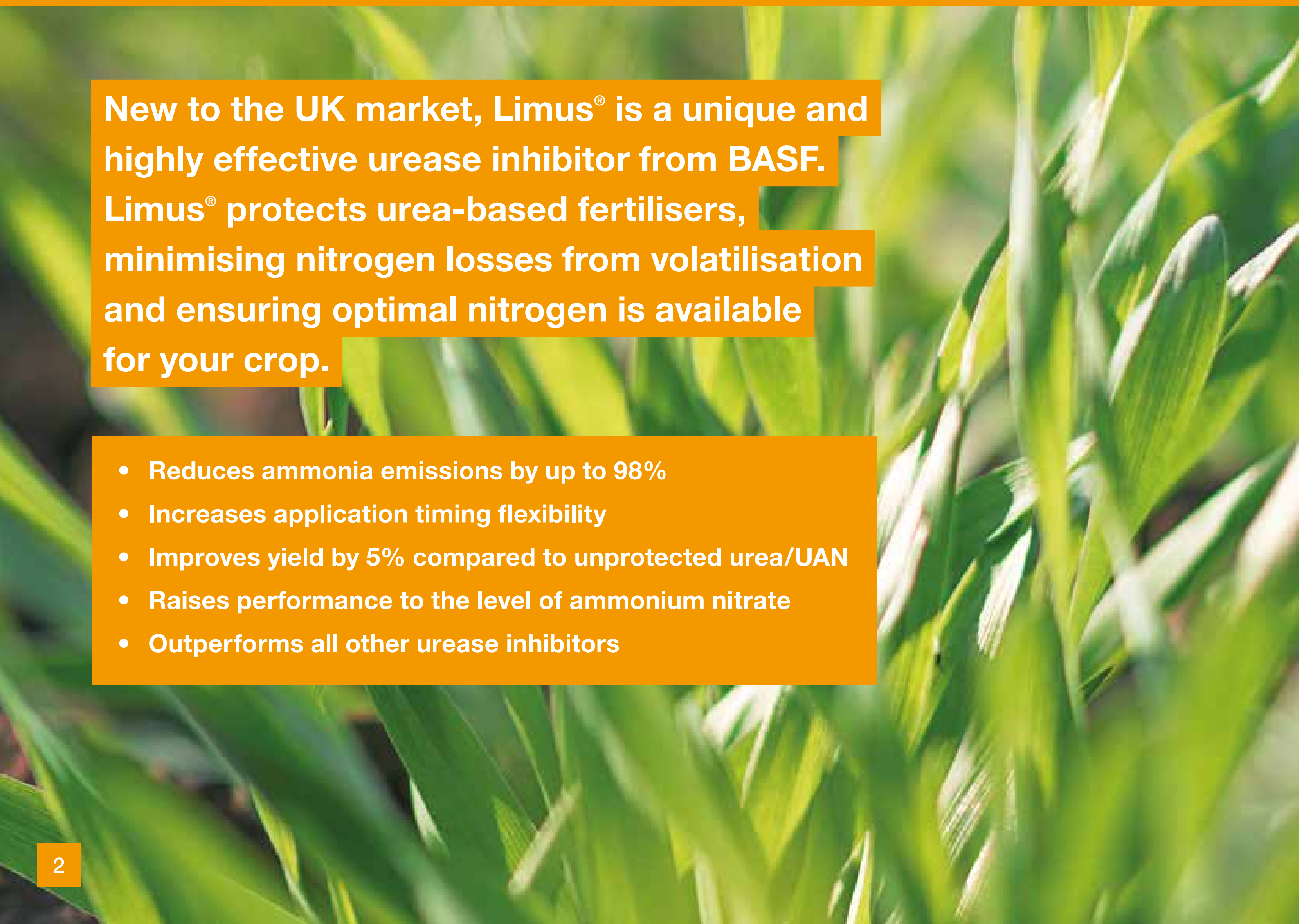
If you want to stop profits escaping, start by choosing Limus®

Why is your nitrogen up here?

When it can be down here.

BASF
We create chemistry

Contents



New to the UK market, Limus® is a unique and highly effective urease inhibitor from BASF. Limus® protects urea-based fertilisers, minimising nitrogen losses from volatilisation and ensuring optimal nitrogen is available for your crop.

- **Reduces ammonia emissions by up to 98%**
- **Increases application timing flexibility**
- **Improves yield by 5% compared to unprotected urea/UAN**
- **Raises performance to the level of ammonium nitrate**
- **Outperforms all other urease inhibitors**

Nitrogen losses

Only 50% of applied nitrogen is taken up by crops. Nitrogen losses can occur in the form of ammonia, nitrate leaching and the release of nitrous oxide into the atmosphere. While nitrogen losses generally result in an economic cost on farm, they also have a negative impact on the environment.

Smog

Ammonia losses

Significant ammonia losses can occur after the application of urea-based fertilisers. Ammonia is an air pollutant. A key component of smog, it binds with other pollutants and particles in the atmosphere, leading to negative impacts on human health. It is carried long distances by wind and brought down with rainfall, acting as a nitrogen fertiliser far from where it was intended and damaging sensitive natural habitats.

Increase in nitrate

Nitrate leaching

Nitrate is highly mobile in the soil. After heavy rainfall or low plant uptake, nitrate can leach out of the soil profile and accumulate in groundwater, which can be toxic if threshold limits are exceeded. Nitrate in surface water bodies stimulates water plant and algae growth. As algae and/or water plants decay, the resulting oxygen depletion may, under extreme conditions, lead to mortality in fish populations.

Climate change

Nitrous oxide losses

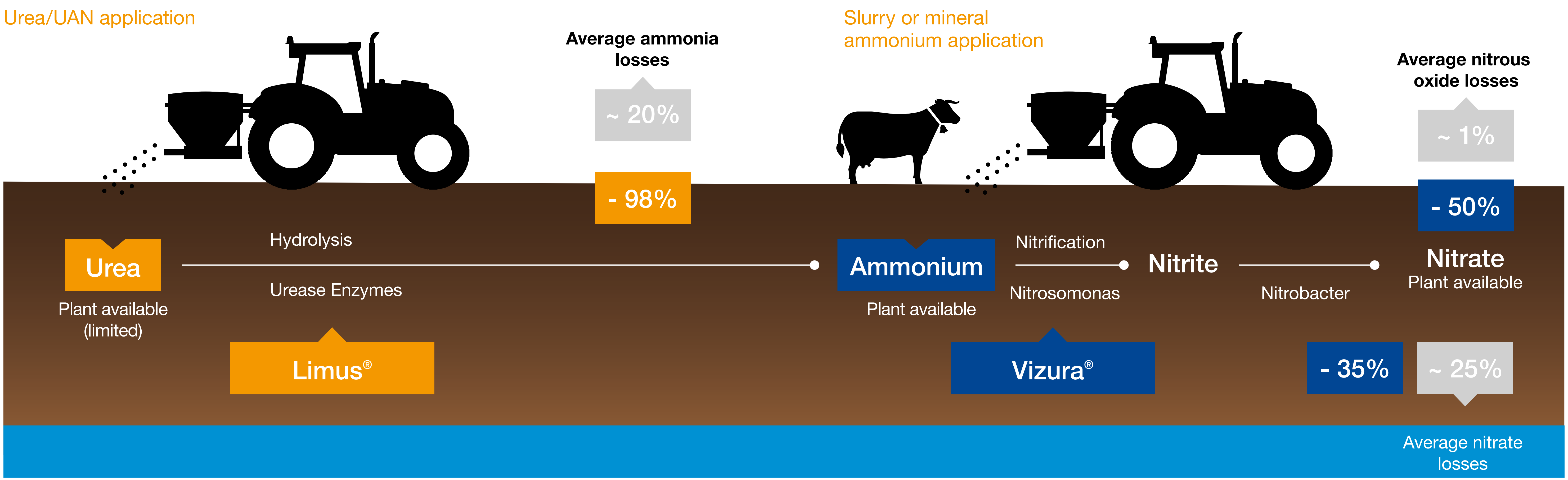
Nitrous oxide occurs during nitrification (conversion of ammonium into nitrite and nitrate through soil bacteria). Next to carbon dioxide and methane, nitrous oxide is one of the most dangerous greenhouse gases. Its global warming potential is 298 times that of carbon dioxide. Even small nitrous oxide losses may represent a cost factor to growers as well as a negative environmental impact.

Nitrogen losses

Nitrogen losses from ammonia, nitrate and nitrous oxide all occur at different stages of the nitrogen cycle. All nitrogen fertilisers are subject to some degree of loss, no matter the source, and innovative technologies can help minimise these losses.

Urease inhibitors

Nitrification inhibitors



How do nitrogen losses occur?

Hydrolysis: Urea fertiliser has limited availability to plants. It must first go through a process called hydrolysis, where urease enzymes convert it to plant available ammonium. During this process, some of the ammonium can be lost as ammonia through volatilisation.

Ammonia: Ammonia losses from urea based fertilisers can be up to 80% of the total applied nitrogen, depending on the urea fertiliser type, climate and soil pH value. In the UK, the DEFRA funded NT26 project concluded that around 20% of applied nitrogen from granular urea is lost as ammonia. For UAN these average losses are around 14%.

Nitrification: Ammonium, either from hydrolysis or following application of ammonium nitrate or slurry, is plant available and can be taken up and metabolised easier than nitrate. However, ammonium is rapidly converted into nitrate during a process called nitrification. Nitrosomonas bacteria in the soil change the ammonium to nitrite, which then gets converted into nitrate by nitrobacter.

Nitrate: Nitrate is negatively charged so no longer binds to the soil. Water can then transport it down the soil profile out of reach of the roots. Typically, nitrate leaching is worse in the winter when the soils are at water holding capacity. On light soils, leaching can occur in the spring following a heavy rainfall event.

Nitrous oxide: Nitrous oxide can also be given off during this process. Although typically only 1% of applied nitrogen is converted to nitrous oxide, it is a powerful greenhouse gas, 298 times more potent than carbon dioxide. Therefore contributes significantly to agricultural greenhouse gas emissions.

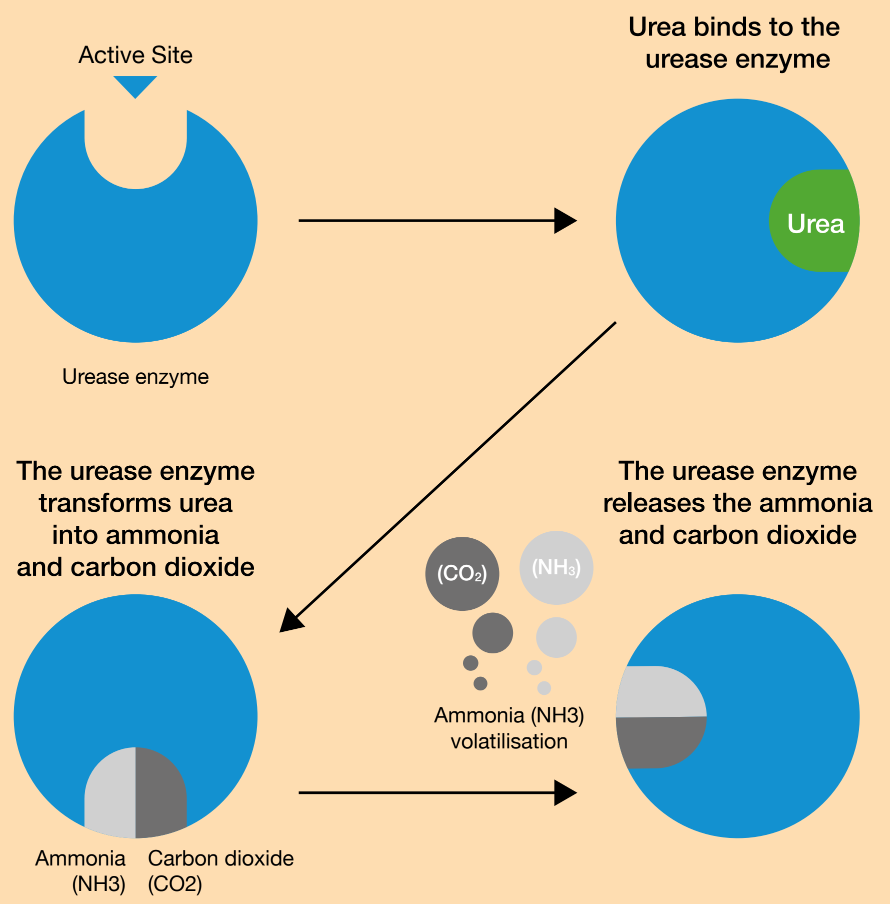
How can technologies reduce nitrogen losses?

Urease inhibitors: Urease inhibitors slow down the hydrolysis process, minimising losses from ammonia. Limus® reduces ammonia losses by up to 98%, making more nitrogen available to crops.

Nitrification inhibitors: Nitrification inhibitors inhibit the Nitrosomonas bacteria, preventing the conversion of ammonium to nitrite. The use of a nitrification inhibitor like Vizura®, reduces nitrous oxide emissions by around 50% and leaching by around 35%.

Only 50% of applied nitrogen is taken up by crops.

Ammonia volatisation

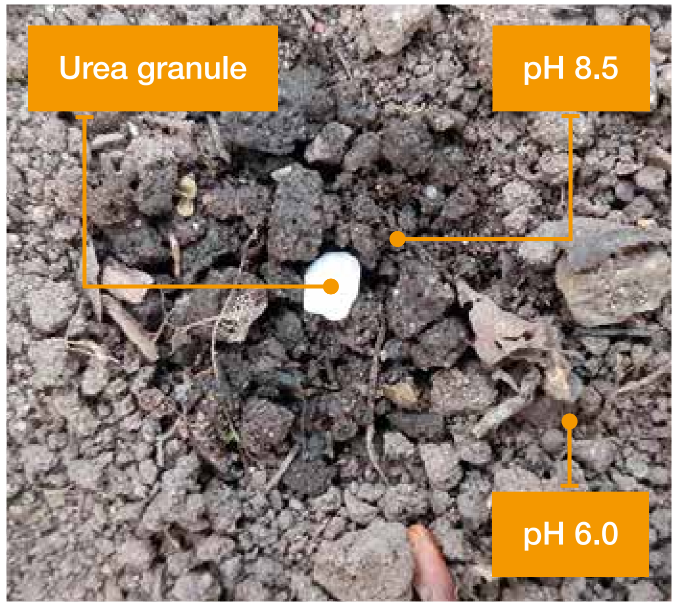


Urease enzymes

Urease enzymes are produced by plants and microbes in the soil. They have an active site that can bind urea. Once urease and urea are bound, the urease enzyme transforms urea into ammonia and carbon dioxide. If the urea has not been washed into the soil, this results in ammonia volatilisation. When ammonia and carbon dioxide leave the active site, the site is free to once again convert (hydrolyse) another urea molecule and the process can start over again.

Volatilisation

Urea granules are hygroscopic meaning they absorb moisture from the air and can begin to move into the soil even in the absence of rainfall. Once moisture is present, the urea is no longer stable. It's at this point the urease enzymes start the hydrolysis process, converting urea into ammonium. As ammonium is alkaline, this conversion process temporarily raises the pH of the soil around the urea granule. If the pH spike is not buffered by rainfall, it results in ammonia volatilisation.



Ammonia loss is a localised reaction

Urease inhibitors

How to reduce ammonia losses

There are three main ways nitrogen losses from ammonia volatilisation can be minimised:

1. Rainfall or irrigation (> 10 mm): Sufficient rainfall or irrigation will help wash the urea into the soil and buffer the pH spike, hence minimising volatilisation. However, considering the last couple of dry springs, ensuring a sufficient rain event shortly after application can be a challenge, whilst irrigation isn't feasible for the majority of UK crops.

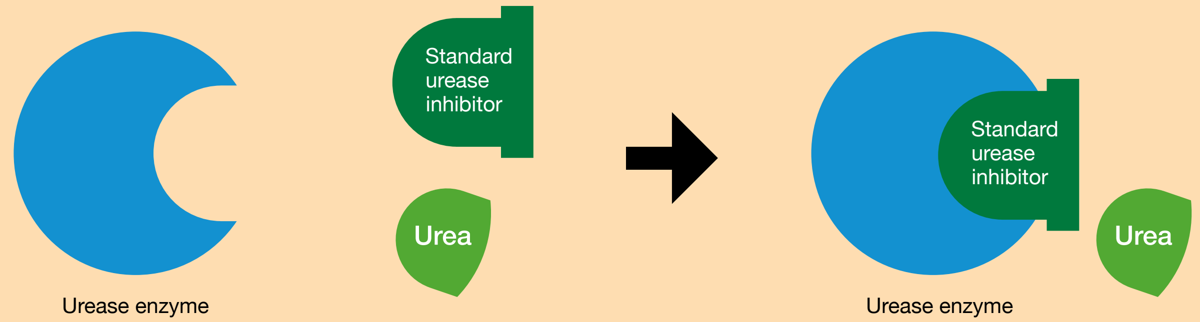
2. Incorporation (tilling > 10 cm) into the soil: Incorporation also helps minimise volatilisation. However, for winter crops, where sowing and fertilising are conducted in different seasons, tilling is not practicable.

3. Urease inhibitors: A reliable and pragmatic way to consistently reduce ammonia losses is to use urea-containing fertilisers with a urease inhibitor.

How urease inhibitors work

Urease inhibitors (eg. NBPT) temporarily inhibit urease enzymes from converting urea into ammonia - until the urea has been sufficiently washed into the soil. They do this by binding to the urease enzyme, preventing urea from binding to the active site, delaying the hydrolysis process and hence minimising volatilisation.

NBPT blocks the urease enzyme, slows down urea hydrolysis and hence ammonia volatisation.



Different urease enzymes require different urease inhibitors

The challenge with standard urease inhibitors

Soils differ in their urease enzyme composition and urease activity. A broad range of organisms in soil (bacteria, fungi and plants) all produce slightly different urease enzymes. These different urease enzymes require different urease inhibitors, meaning some will remain active despite the use of a standard urease inhibitor.

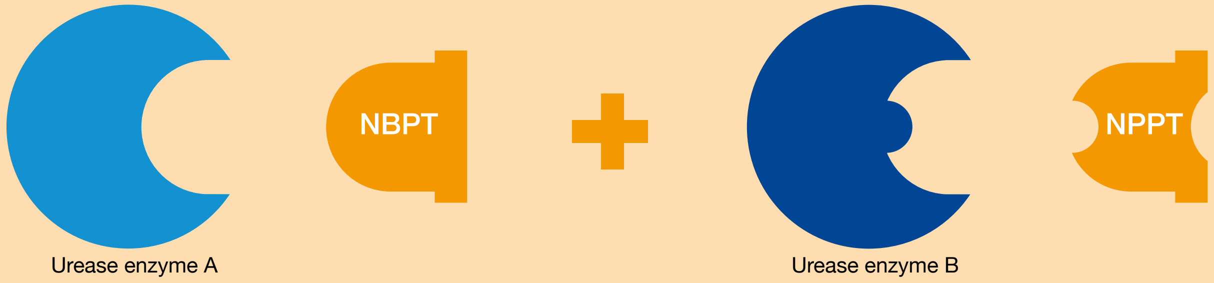
Introducing Limus®

Limus® is a highly effective and unique, dual-active urease inhibitor from BASF, available as both protected urea and as a tank mix additive for UAN

The most effective urease inhibitor

Limus® is the only urease inhibitor available with two active ingredients (NBPT and NPPT), enabling it to bind to a wider variety of urease enzymes, compared to a standard urease inhibitor, thus more effectively protecting the urea from ammonia volatilisation.

This dual-active combination, along with a multi-patented, innovative formulation makes Limus® the most effective urease inhibitor available.



Why Limus®?

Tried and trusted globally since its market introduction in 2015, Limus® brings a wide range of benefits to growers.

Reduces ammonia emissions by up to 98%	Increases application timing flexibility	Improves yield by 5% compared to unprotected urea/UAN	Raises performance to the level of ammonium nitrate	Outperforms all other urease inhibitors

For information on Limus® suppliers, please visit **agricentre.basf.co.uk/limus**

Limus® for granular urea

BASF has partnered with a number of urea importers who will apply Limus®, a liquid formulation, to their urea granules. Look out for 'Contains Limus®' when purchasing.

Limus® for liquid urea

Limus® Clear is for use with liquid urea containing fertilisers. It is available as a standalone product to be tank mixed with the fertiliser on farm shortly prior to use.

Limus® reduces ammonia emissions by up to 98%

Nitrogen use efficiency

Reducing ammonia losses allows the applied urea nitrogen to work more efficiently and enhance nitrogen nutrition. This often leads to higher yields or nitrogen fertiliser savings, as well as an improved environmental footprint. Limus® is the most effective solution for the reduction of ammonia losses and for increasing nitrogen uptake by plants from urea containing fertilisers.

Reduction of ammonia emissions

We have extensively tested the efficacy of Limus® in both laboratory conditions and in the field, and time and time again it has proven its strength as a highly effective urease inhibitor, reducing ammonia emissions by up to 98%.

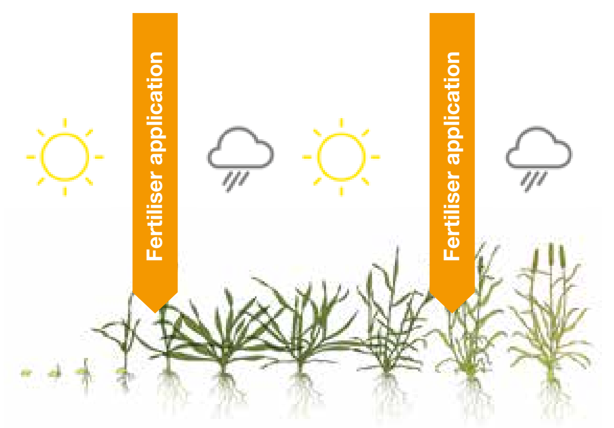
In the field, closed chamber devices with acid treated foam are used to measure ammonia emissions. Across 93 BASF trials, up to 98% reduction was achieved with an average reduction of 70%. Whilst in the laboratory, we have assessed its performance on a range of different soil types. Reductions of up to 98% were also achieved with an average reduction of 83%.

Closed chamber devices with acid treated foam

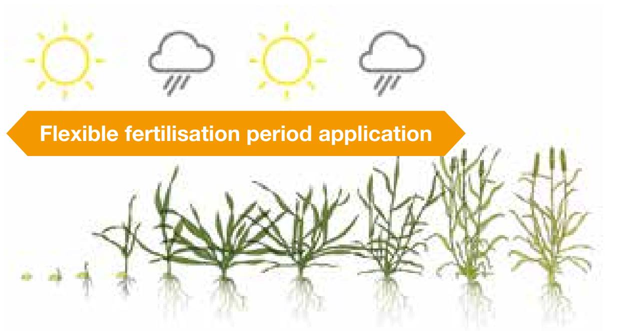
Limus® increases application flexibility

Urea based fertilisers should be applied shortly before rainfall in order to reduce ammonia losses from volatilisation. Traditionally, higher rates are used, or additional applications are made, to compensate for the losses that can often occur in our unpredictable maritime climate. Limus® protected urea fertilisers can be applied independent of weather conditions as they effectively prevent these losses. This not only simplifies fertilisation programmes considerably, it also allows for greater flexibility and a more efficient use of resources.

Application of urea without Limus®



Application of urea with Limus®



Limus® improves yield by 5% compared to unprotected urea/UAN

ADAS trials

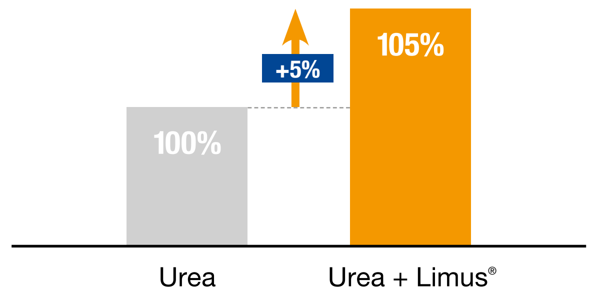
In a comprehensive set of replicated trials carried out by ADAS, we looked at the performance of Limus® protected urea versus unprotected granular urea, ammonium nitrate and a competing urease inhibitor. Six different sites were identified across the country that offered a range of different soil types and field conditions.

ADAS results

Across the six replicated trials, the results mirrored our extensive global data set. At a rate of 260kg/ha N, Limus® protected granular urea outperformed unprotected urea by an average of 5%, increasing yields by 0.5t/ha.

Yield differences varied, most likely reflecting the extent of ammonia emissions at each site. Limus® safeguards your investment from such losses, ensuring optimal nitrogen is available for your crop.

Relative yield increase (%) of Limus® vs. unprotected urea



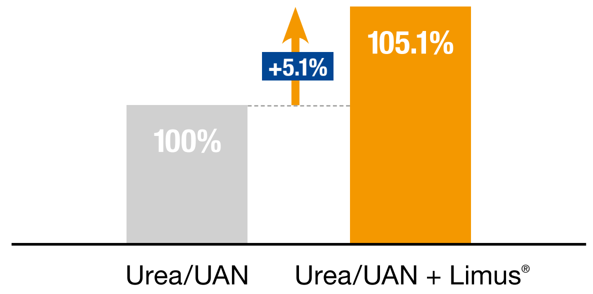
Source: ADAS/BASF, UK, winter wheat, n=6, 260kg/ha N in 3 application splits

BASF results

We have been extensively testing the yield performance of Limus® in the field for a number of years, across a range of crops.

Across 107 BASF trials, Limus® protected urea/UAN improved yield by an average of 5%, demonstrating that the reduction in losses achieved with Limus® ensured greater availability of nitrogen for uptake, resulting in higher yields.

Relative yield increase (%) of Limus® vs. unprotected urea/UAN



Source: BASF, range of crops, n=107

Limus® raises performance to the level of ammonium nitrate

NT26 project

As part of the wide-ranging DEFRA funded NT26 project, the performance of the urease inhibitor, NBPT (one of the active ingredients in Limus®) was evaluated as an alternative to ammonium nitrate (AN). The project concluded that granular urea plus NBPT matched AN for performance in winter cereals, according to average figures taken from 10 locations.

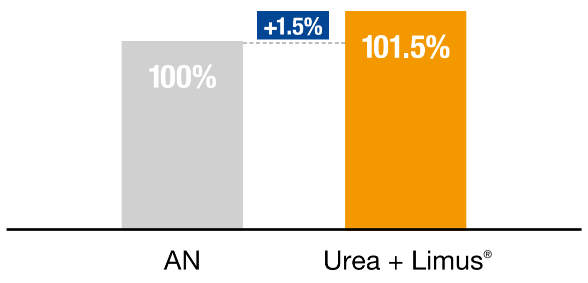
ADAS results

The six ADAS trials reinforced the findings from the NT26 project, showing a similar yield performance of Limus® protected granular urea to that of ammonium nitrate.

Limus® raises the performance of urea to the same level as ammonium nitrate by minimising the nitrogen losses from ammonia.

In these trials, at the rate of 260kg/ha N rate, Limus® protected granular urea actually outperformed ammonium nitrate by an average of 1.5%, increasing yields by 0.14t/ha.

Relative yield increase (%) of Limus® vs. AN



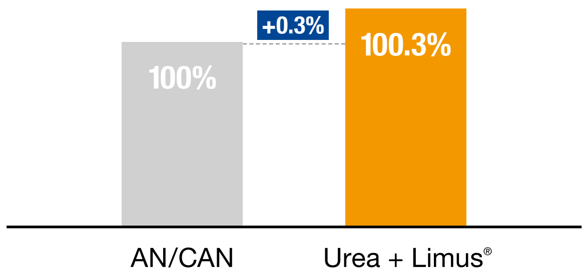
Source: ADAS/BASF, UK, winter wheat, n=6, 260kg/ha N in 3 application splits

BASF results

Across 74 BASF trials, Limus® raised the yield performance of granular urea to the level of ammonium nitrate and calcium ammonium nitrate.

These equivalent yields highlight that provided ammonia losses are minimised, urea is as reliable a source of nitrogen as ammonium nitrate.

Relative yield increase (%) of Limus® vs. AN/CAN



Source: BASF, range of crops, n=74

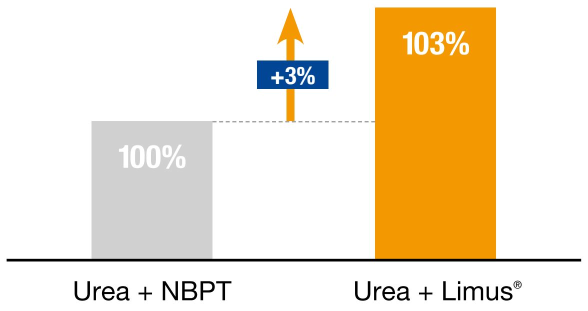
Limus® outperforms all other urease inhibitors

Efficacy

As the only urease inhibitor with two active ingredients, Limus® more effectively minimises ammonia losses, ensuring greater availability for crops and higher yields.

ADAS results

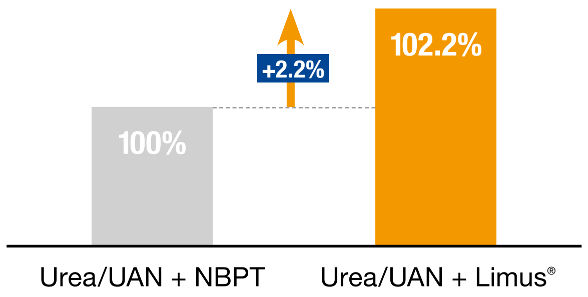
Relative yield increase (%) of Limus® vs. NBPT



Source: ADAS/BASF, UK, winter wheat, n=6, 260kg/ha N in 3 application splits

BASF results

Relative yield increase (%) of Limus® vs. NBPT

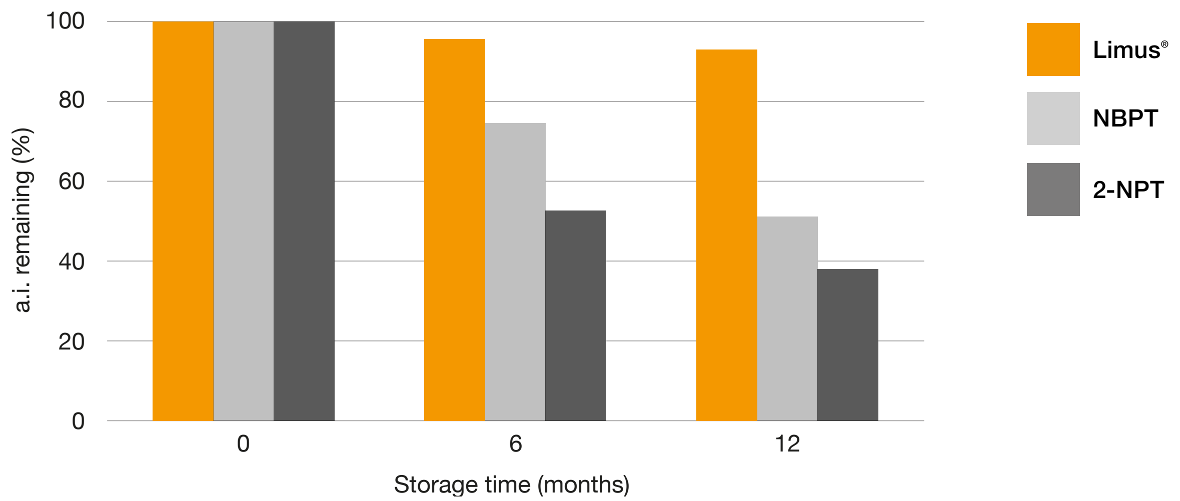


Source: BASF, range of crops, n=107

Storage stability

The stability of urease inhibitors when added to urea can be limited. Limus® contains our BASF patented polymer technology, providing longer a.i. stability versus generic NBPT and 2-NPT formulations. Even at 20°C Limus® is stable for more than 12 months, giving confidence that even if purchased a year in advance, Limus® will still work effectively.

Storage stability on urea 20°C, closed bag



Source: BASF

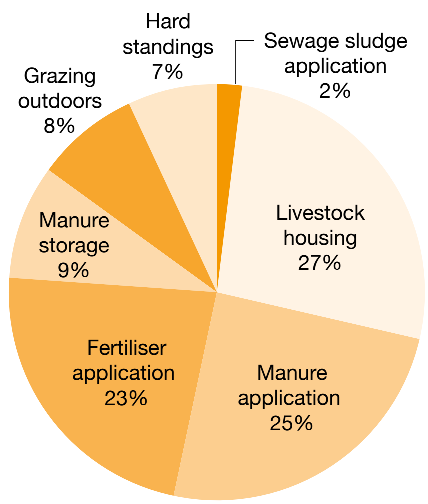
Ammonia and legislation

Ammonia emissions and agriculture

The agricultural sector accounts for 88% of UK ammonia emissions. 23% of agriculture's emissions are largely from the application of urea based fertilisers.

The UK government is committed to reducing these ammonia emissions from agriculture - along with pollutants from other sources - and in both its 2018 and 2019 Clean Air Strategy document, it advised that legislation might be introduced to support this reduction.

UK agricultural ammonia emissions by management category (2016)



Source: National Atmospheric Emissions Inventory 2018

Legislation

The path to UK legislation began in 1999 with the Gothenburg Protocol, designed to reduce acidification, eutrophication and ground level ozone emissions, including ammonia. The protocol was then revised in 2012 to include national emission reduction commitments for 2020 and beyond. This was implemented into EU legislation in 2016 as part of the National Emission Ceilings Directive, where countries including the UK and Ireland, committed to significant reductions.

The UK government has since reaffirmed it's commitment to these targets in recent strategy documents. It also introduced a Code of Good Agricultural Practice to serve as a guidance document to support reductions, which includes a recommendation to use urease inhibitors.

The government is currently seeking consultation on approaches to reduce ammonia emissions. Legislation focusing on urea-based fertilisers is expected, with the use of urease inhibitors one of the main approaches currently being evaluated.

Legislation roadmap

Gothenburg Protocol, 2012

- Abate acidification
- Eutrophication
- Ground level ozone

EU legislation, 2016

- National Emission Ceilings Directive
- Ammonia vs 2005
  - 2020: -8% (UK)
  - 2030: -16% (UK)

Clean Air Strategy 2018 (UK)

- Proposes the use of urease inhibitors with urea-based fertiliser, unless injected, by 2020
- Will provide a national code of Good Agricultural Practice to reduce ammonia emissions

Code of Good Agricultural Practice for reducing ammonia emissions (UK)

- Guidance document for reducing ammonia emissions
- Supports the use of urease inhibitors with urea based fertilisers

New Agricultural Bill (UK)

- Financial assistance for delivering clean air and water
- Includes reduction of ammonia emissions

Clean Air Strategy 2019 (UK)

- "A requirement to reduce emissions from urea-based fertilisers"
- Consulting in 2019 to bring through legislation in the shortest possible timeframe

The UK government is legally obliged to reduce ammonia emissions by 8% by 2020 and by 16% by 2030, compared to 2005 levels

For more information on Limus®, please visit **agricentre.basf.co.uk/limus**

For an optimised supply of nitrogen to your crops, please ask your supplier about Limus® products.

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