Optinyte™ technology

# Global Environmental Guide

Reduce environmental impact and optimize crop agronomics.

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## Nitrogen is a Critical Crop Input

Nitrogen fertilizer is one of the most important agricultural inputs for maximizing yield and plant health. It is also one of the most costly inputs for farmers. Furthermore, applied nitrogen that is not stabilized in the root zone or utilized by the crop can be lost into the environment. Nitrogen leaching can decrease ground and surface water quality. Denitrification can lead to atmospheric pollution. Finally, nitrogen that is not utilized by the crop is a wasted investment. The need for maximizing crop productivity to feed a growing global population must be balanced with environmental sustainability and the farmer's return on investment.

Nitrogen stabilizers with Optinyte™ technology (N-Serve™, Instinct™ HL, N-Lock™, N-Lock MAX™, eNtrench™ and Vindicate™ nitrogen stabilizer brands), make nitrogen fertilizers work more efficiently for the planet and farmers. Optinyte technology is scientifically proven to minimize negative environmental side effects of nitrogen loss by keeping nitrogen in the root zone, providing better crop utilization of nitrogen, and helping to maximize crop yield.

*Optinyte™ technology is scientifically proven to minimize negative environmental side effects of nitrogen loss by* ***keeping nitrogen in the root zone****, providing better crop utilization of nitrogen, and helping to maximize crop yield.*

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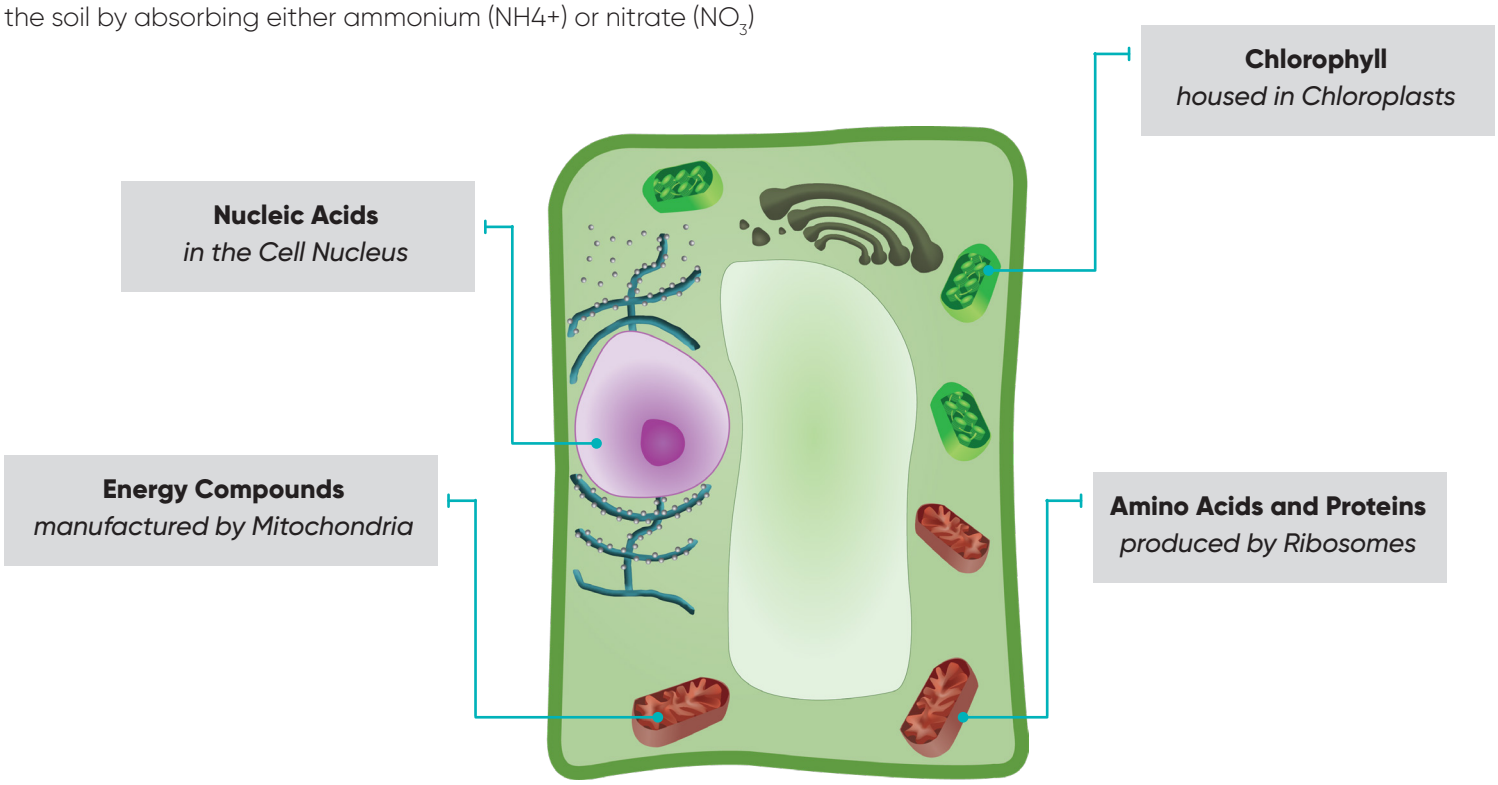
# Understanding Nitrogen

## Why is Nitrogen Important?

Nitrogen is a major macronutrient. In most crops it is the primary nutrient affecting yield and plant health. Nitrogen is essential in the structure of amino acids, nucleic acids, proteins, enzymes, metabolic reactions, and chlorophyll (the component that contributes to plants green color). While it exists in many different chemical forms, plants use nitrogen in the soil by absorbing either ammonium (NH4+) or nitrate ($NO_3$) ions into their roots. Nitrogen fertilizers are applied in either of these forms. The supply and the loss rate of nitrogen from the crop root zone greatly affects crop production. Nitrogen losses are especially significant during early growth stages of the crop when root systems are not well developed.

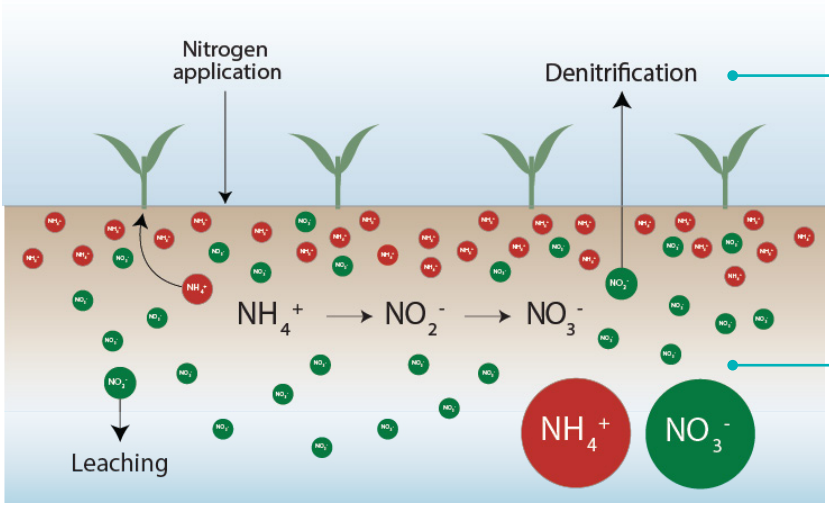



*The **supply** and the **loss rate** of nitrogen from the crop root zone greatly affects crop production.*

# How is Nitrogen Lost?

After nitrogen fertilizer application, naturally occuring soil bacteria quickly convert ammonium into nitrate in a two-step process called nitrification. This process is impacted by many factors including soil temperature, soil moisture, and soil pH. However, once converted to nitrates, nitrogen is subject to loss. Nitrate is prone to leaching with precipitation or irrigation. It can also be lost through denitrification or volatilization. Nitrogen losses commonly approach 25% of the applied nitrogen and can reach as high as 50-60% in some situations (Cassman, 2002). These losses are significant since the global market for nitrogen fertilizer is estimated at 113 million MT (IFA, 2014). It means that costly nitrogen fertilizer inputs are lost to the environment and not utilized by the crops.

## What Happens in the Soil



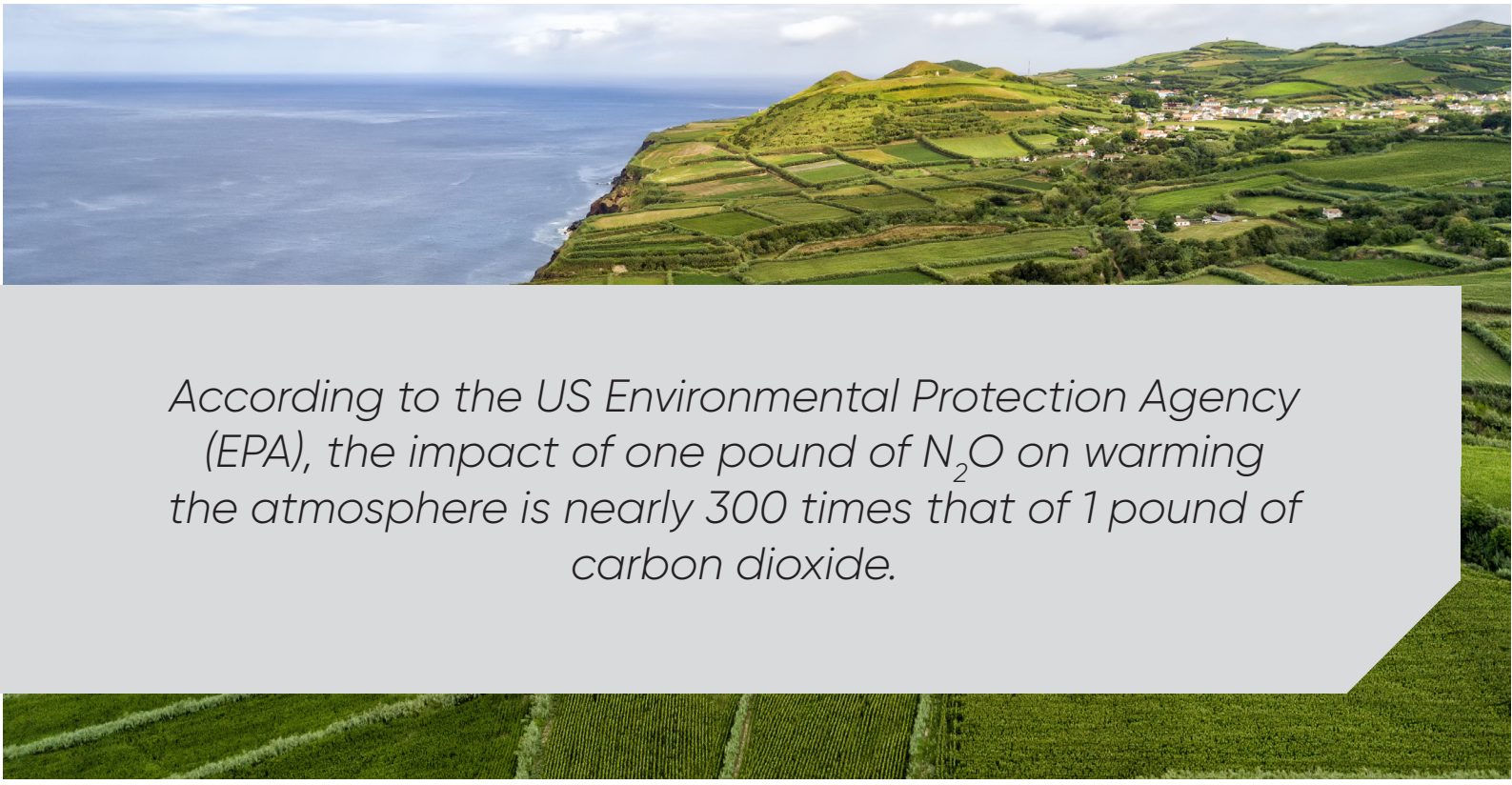

***Denitrification*** *is the loss of nitrogen to the atmosphere that occurs when soils are flooded causing anaerobic conditions. Under these conditions, nitrate ($NO_3$-) is removed from the root zone and is ultimately converted by bacteria to nitrous oxide ($N_2O$), a greenhouse gas considered an environmental pollutant.*

***Leaching*** *is the loss of nitrate to the soil below the plant root zone due to rain and irrigation. Nitrate is negatively charged and repelled by negatively charged soil surfaces. Nitrate can also move readily in water percolating downward through the soil profile, especially in coarser soils. On the other hand, ammonium is a form of nitrogen that is positively charged and attracted to soil surfaces, which greatly slows downward movement in soil water and as a result remains in the root zone for a longer period of time.*

# What are the Environmental Impacts?

Nitrogen lost through denitrification or volatilization is a greenhouse gas contributing to global warming and considered an environmental pollutant. According to the US Environmental Protection Agency (EPA), the impact of 1 pound of $N_2O$ on warming the atmosphere is nearly 300 times that of one pound of carbon dioxide. The EPA estimates emissions of nitrous oxide gases from the soil to be as much as 16% of the global budget of nitrous oxides in the troposphere. Kyoto Protocol is an international treaty that commits industrialized states to reduce their greenhouse gas emissions by a set goal. Nitrous oxide is one of six greenhouse gases targeted by the agreement.

Eutrophication occurs when water is contaminated with minerals and nutrients that are typically limited in the environment. Nitrates and phosphorous, like those found in agricultural fertilizers, are the most important contaminants driving eutrophication. This excess of nutrients accelerates plant and algal growth supporting large blooms that die off in mass when the nutrients have been used up. The microbial decomposition of dead algal blooms consumes dissolved oxygen faster than it can be replaced resulting in areas of low dissolved oxygen or hypoxic zones. In some cases, dissolved oxygen can retreat to a level that does not support sea life. The Great Barrier Reef (GBR) is the world's largest coral reef ecosystem. The health of the GBR is under pressure from sediments, pesticides and nutrients (especially nitrogen) discharged from nearby waterways. The Australian sugarcane industry is a significant contributor to the amount of nitrogen entering the GBR. Recent estimates in the Reef Water Quality Protection Plan (2013) suggests the industry contributes approximately 56% of the inorganic nitrogen load. Similarly, in recent years, there has been growing concern about the seasonal hypoxic zone in the ecologically and economically important Gulf of Mexico. This hypoxic zone is attributed to the discharge of nitrates from farms along the Mississippi river. In China, rapid growth has increased the pressure placed on the environment through nitrogen contamination. Nitrogen-containing pollutants from agriculture, transport and industry have increased more than 50% in the last 30 years (Qiu, 2013). One study found that as much as 50% of the nitrogen fertilizer applied to agricultural fields ends up in the environment either leached into ground water or volatilized into the atmosphere (June 2009).



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# Global Regulations

## Regulations Aimed at Nitrate Contamination

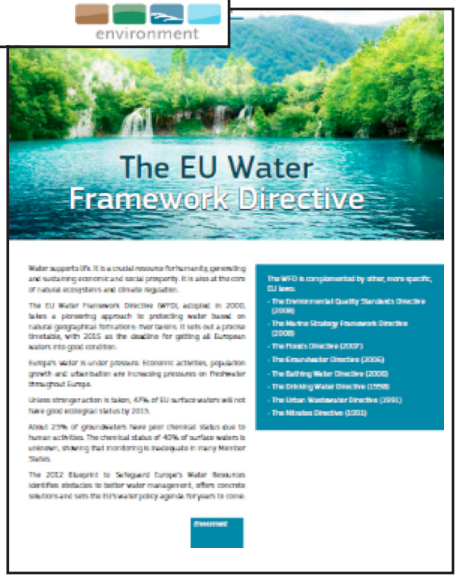
Across the globe, regulatory restrictions are being instituted to protect ground and surface waters from nitrate contamination. The Nitrates Directive (1991) from the European Union is a good example of legislative instruments intended to protect water quality by promoting the use of good farming practices. Under this directive, all Member States have an obligation to identify zones within their territories that are vulnerable to nitrates (NVZ), and establish codes of good farming practices for growers to adopt. The best management agricultural practices promoted to farmers vary by Member States, but they all have components that focus on the management of nitrogen fertilizer on farms.

Typically these practices include:

- Limits on the total amount of nitrogen applied to specific crops
- Limits to the amount of fertilizers that can be applied at one time
- Permissible periods of time when fertilizer may be applied
- Maintenance of accurate and complete fertilizer records
- Failure to comply with these guidelines can result in loss of subsidies

As Member States continue to assess their compliance with the Nitrates Directive, further measures that will impact crop production activities can be anticipated to be introduced.


*The EU Nitrates Directive*




*The EU Water Framework Directive*

# Optinyte™ technology

## What is Optinyte™ Technology?

Optinyte™ technology is the brand name used for products that contain Nitrapyrin as the nitrogen stabilizer and Corteva agriscience formulation technology. This proprietary and highly effective nitrogen stabilizer is the technology in well-known products including N-Serve™, Instinct™, N-Lock™, eNtrench™ and Vindicate™ for example. Products containing Optinyte technology can be used with pre-plant, at-plant and in-crop applications of nitrogen fertilizer and used with liquid manure, bio-slurry, and granular fertilizers such as urea and NPK, ammonium nitrate or liquid forms of nitrogen fertilizer, such as 28% or 32% UAN. Products with Optinyte technology have shown agronomic, economic and environmental benefits when utilized in a wide range of crops including: corn (maize), wheat, canola (oilseed rape), cotton, rice, sugarcane, tree nuts and vegetables. Formulations containing Optinyte technology are currently approved for use in over 25 countries with future plans to expand to additional countries.

*N-Lock™ with Optinyte™ technology is a proven nitrogen management tool that provides farmers with the rules of the Nitrates Directive. Optinyte technology has been shown to maximize the yield potential of their crop while reducing nitrogen leaching and reducing greenhouse gas emissions.*

### Brands Currently Registred for Sale

**Canada**
**eNtrench** HL
Optinyte™ technology
NITROGEN STABILIZER
**N-Serve®**
Optinyte™ technology
NITROGEN STABILIZER

**United States**
**Instinct®**
Optinyte™ technology
NITROGEN STABILIZER
**Vindicate™**
Optinyte™ technology
NITROGEN STABILIZER
**N-Serve®**
Optinyte™ technology
NITROGEN STABILIZER

**Europe**
**N-Lock** MAX
Optinyte™ technology
NITROGEN STABILIZER

**Africa**
**N-Lock** MAX
Optinyte™ technology
NITROGEN STABILIZER

**China**
**Entrench™**
Optinyte™ technology
NITROGEN STABILIZER

**Australia**
**eNtrench** HL
Optinyte™ technology
NITROGEN STABILIZER

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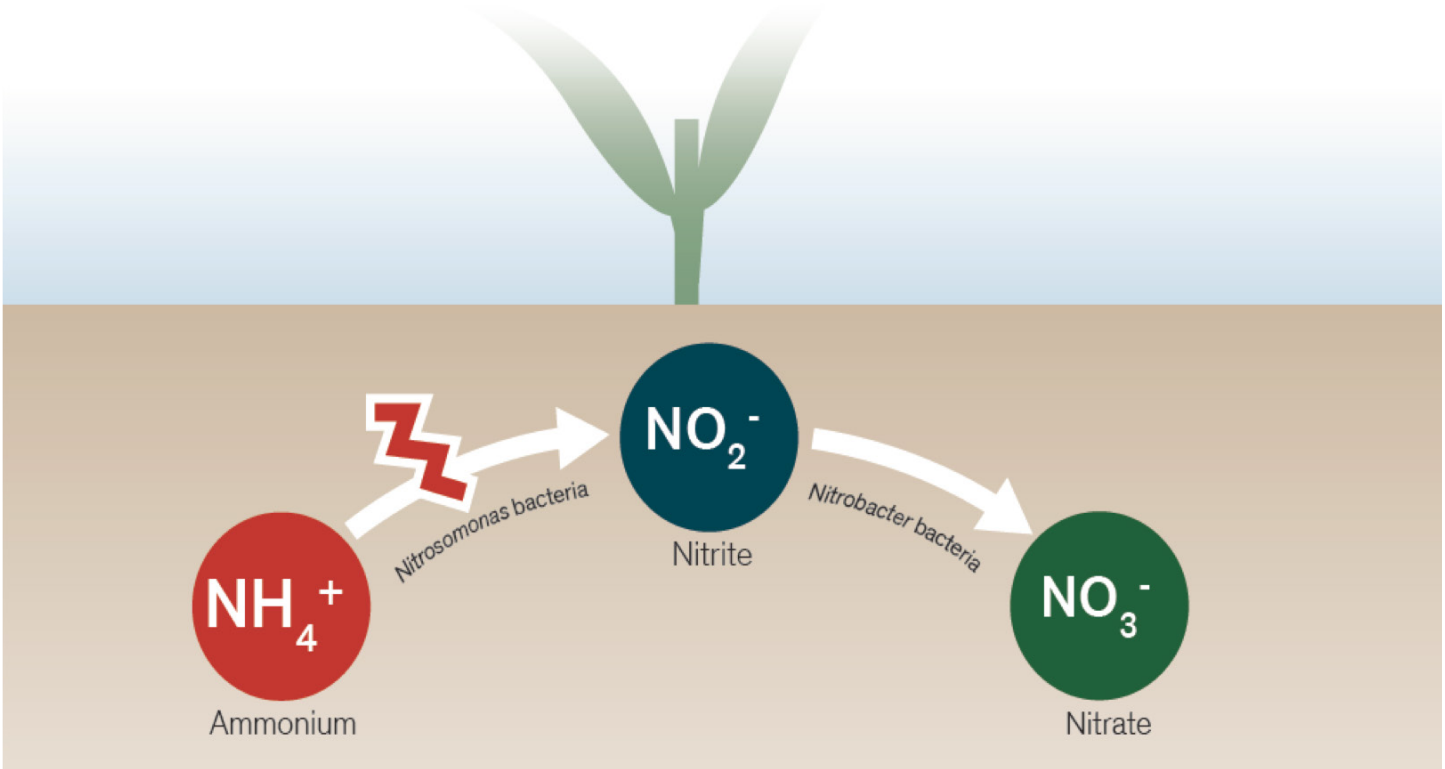
# How does Optinyte™ Technology Work?

Nitrogen stabilizers with Optinyte™ technology slow the nitrification process in soils by inhibiting ammonia monooxygenase, an enzyme found in *Nitrosomonas* bacteria that catalyzes and an important step in the conversion of ammonium into nitrate. As a result, the growth rate of *Nitrosomonas* bacteria and the associated ammonium metabolism is reduced. Thus the soil nitrogen is stabilized; it remains in the protected ammonium form in the root zone for a longer period of time allowing for better crop utilization as opposed to being lost into groundwater through leaching or the atmosphere through denitrification.

## How Optinyte™ Technology Inhibits Nitrification



# What are the Environmental Benefits?

Corteva agriscience nitrogen stabilizers, with Optinyte™ technology, are proven to protect nitrogen fertilizer which benefits both the environment and the crop. The environmental and agronomic benefits of Optinyte technology are documented in many peer-reviewed scientific publications and supported by more than 40 years of on-farm use. A foundational study published in 2004 (Wolt) summarized the benefits of Optinyte technology, through a meta-analysis. The study was based on published data from 186 field trials primarily conducted in US corn (maize) but also included data from other crops and geographies. Conclusions from this meta-analysis were that, on average, use of Optinyte technology resulted in a 51% reduction of nitrous oxide ($N_2O$) emissions and a 16% decrease in soil nitrogen leaching. The stabilization of nitrogen resulted in a 7% increase in crop yield. These results were confirmed in a second meta-analysis published in 2015 (Qiao). In this study, the authors collected data from peer-reviewed studies published between 1984 and 2013 covering many geographies and crops including barley, corn (maize), pasture grass, rice, vegetables, and wheat. In addition to confirming the environmental benefits, the Qiao meta-analysis demonstrated using a nitrification inhibitor increased farmer revenue by approximately 8.95% even after accounting for the cost of using the nitrification inhibitor. Qiao concluded, "Our findings showed that nitrification inhibitors could create a win-win scenario that reduces the negative impact of nitrogen leaching and greenhouse gas production, while increasing the agricultural output."

**Environmental Benefits**

- Stabilized nitrogen reduces leaching or loss from denitrification
- Less nitrate loss in waterways
- Reduces emissions of greenhouse gases into the atmosphere

**Crop Benefits**

- Nitrogen remains available in the root zone longer for crop uptake
- Increased yield in corn (maize), cereals and many other crops
- Improves crop quality and plant health

Furthermore, as an example of its ongoing commitment to sustainable chemistry, Dow AgroSciences reported life-cycle assessments (LCA) for Optinyte™ in Australian wheat farming and corn farming in the United States. These LCAs were holistic approaches to examining impacts over the complete life cycle of the product. In addition, the Optinyte LCA for corn farming was peer reviewed following ISO standards 14010 and 14044. The LCA results showed that potential benefits of using Optinyte far exceed the potential burdens created by its supply. Specifically the LCAs reported an 11-32% average reduction in life-cycle greenhouse gas emissions based on county and national data, with and without irrigation and drying. In addition, both assessments indicated that a reduction of marine eutrophication potential was a likely result of employing Optinyte technology in these systems.

## Nitrification Inhibitors: A Win-Win Scenario

**Reduces negative impact of nitrogen leaching and greenhouse gas production.**

**Increases agricultural outputs.**

**7%**
INCREASE IN CROP YIELD

**28%**
INCREASE IN SOIL NITROGEN RETENTION

**16%**
DECREASE IN NITROGEN LEACHING

**51%**
DECREASE IN GREENHOUSE GAS EMISSIONS

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# Optinyte Benefits are Recognized Worldwide

Scientists and advocacy groups continue to urge governments to enact regulations for better nitrogen management. Optinyte™ technology can enable more efficient use of nitrogen fertilizer, stabilizing it in the root zone where it can be utilized by the crop during important growth periods and reducing its movement to ground water and the atmosphere.

In 2016, Dow AgroSciences was awarded the prestigious U.S. Environmental Protection Agency (EPA) Presidential Green Chemistry Challenge Award for Instinct® nitrogen stabilizer with Optinyte™ technology. This is the fifth time Dow AgroSciences has been recognized with the EPA Green Chemistry Award, more than any other agricultural company. This illustrates the company's focus and commitment to advance products that address pressing challenges in a sustainable way.

Optinyte technology is one tool that is being recommended and utilized to minimize the potential environmental contamination from nitrogen fertilizers. For example, in 2013, the Iowa Department of Agriculture implemented a Water Quality Initiative encouraging growers to use nitrogen stabilizers with Optinyte Technology to reduce nitrogen losses.

The Iowa Nutrient Reduction Strategy is a science and technology-based approach to assess and reduce nutrients delivered to Iowa waterways and the Gulf of Mexico. The scientific assessment to evaluate and model the effects of nitrogen fertilizer use practices was developed through the efforts of 23 individuals representing five agencies or organizations, including scientists from Iowa State University, Iowa Department of Agriculture and Land Stewardship, Department of Natural Resources, United States Department of Agriculture Research Service and Natural Resources Conservation Service. The only nitrogen fertilizer practice that had both yield and environmental benefits was use of a nitrification inhibitor product with Optinyte technology.

In 2017, Dow AgroSciences was given the Iowa Water Quality Initiative Award. With this award, Dow AgroSciences was recognized for its focus on the importance of environmental stewardship and fertilizer efficiency. By providing technologies such as N-Serve® and Instinct® nitrogen stabilizers with Optinyte technology, farmers can achieve strong yield in a way that helps protect the environment. Instinct and N-Serve keep more nitrogen available in the root zone for crops to use, which reduces the escape of nitrates into groundwater and greenhouse gases into the atmosphere.

In addition, the US EPA cites that nitrification inhibitors (e.g., Optinyte technology) as the most effective tool for reducing the emissions of the greenhouse gas nitrous oxide from agricultural cropland and more effective than lower nitrogen rates, split applications or minimum tillage (United States EPA - 430-R-06-005).

*"Dow AgroSciences is honored to receive the State Secretary's Ag Leader Award and proud to support the state of Iowa's efforts to implement a science-based program to improve water quality," says Eric Scherder, PhD, field scientist, Dow AgroSciences. "We look forward to continuing our support of a voluntary approach to nutrient stewardship that provides growers with tools that support environmentally beneficial farming practices while maximizing yield opportunity."*

GREEN CHEMISTRY
A U.S. EPA Program

Presidential Green Chemistry Challenge:
**2016 Greener Reaction Conditions Award**

Instinct® Technology - Making Nitrogen Fertilizers Work More Effectively for Farmers and the Planet

- *Reduces fertilizer nitrate leaching to ground and surface waters and atmospheric nitrous oxide emissions. Nutrient pollution is one of America's most widespread, costly and challenging environmental problems.*
- *Retains applied nitrogen longer in the plants' root zone, optimizing crop utilization and yield, and reducing nutrient run-off.*

In 2014 this technology: added about 50 million bu. of additional corn, equating to over $205 million in additional production revenue for U.S. corn growers; and reduced carbon dioxide emissions by about 664,000 metric tons.

## 2014: Study Shows Alignment to Best Management Practices of Nitrates Directive of 1991

A collaborative study between Dow AgroSciences and the University of Bologna evaluated Optinyte™ technology in a European environment for the management of livestock manure used as a crop fertilizer (data not published). They compared the degree of nitrification and nitrogen leaching observed in soils treated with mixtures of Optinyte and cattle manure, pig manure or inorganic fertilizers. The study demonstrated the potential of Optinyte to reduce nitrification and nitrate leaching irrespective of the source of nitrogen providing both environmental and economic advantages. Optinyte technology clearly aligned to the Best Management practices mandated by the Nitrates Directive of 1991.

## 2016: Hungarian New Product Award

Optinyte technology was awarded the Hungarian New Product Award.

2014 2015 2016 2017

## 2017: Impact on the Great Barrier Reef

The Australian and Queensland governments announced a significant investment to support on-farm trials to evaluate nitrogen fertilizer technologies within sugar cane growing regions that flow to the Great Barrier Reef. Improving nitrogen use efficiency is a high priority to deliver significant reductions in nitrogen lost to waterways and the Great Barrier Reef lagoon. Nitrogen stabilizers with Optinyte™ technology are part of the next generation of fertilizer management tools that can increase farmer profit margins through improving yields, while at the same time benefiting the Great Barrier Reef by reducing fertilizer run-off and thereby improving water quality.

## The Future of N-Lock

Over its 40-year life, Optinyte has been tested extensively around the world by private companies, independent research institutions and universities. Positive results have been widely published in peer scientific journals; over 200 studies have been published to date.

Corteva agriscience continues to conduct and support research with nitrogen stabilizers that contain Optinyte™ technology as use expands into new countries and new crops. Research is focused on characterizing the agronomic, economic, and environmental benefits of nitrogen stabilization.

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