

Pro Farm Group

BIOst® Nematicide

Biologicals for Crop Protection

BOUNDLESS
IMPACT RESEARCH & ANALYTICS

Climate Impact Profile
September 2021

BIOst® Nematicide Climate Impact Profile

Biologicals for Crop Protection

Executive Summary

With the world's growing population expected to reach 10 billion by 2057, crop protection is increasingly important to securing the food supply. Many pesticides have proven to be hazardous to the environment, threatening biodiversity as well as the health of farmers working closely with these products. Pro Farm Group (PFG) uses naturally occurring microorganisms to develop effective bio-based products that align with their sustainability goal of producing environmentally responsible products that promote plant health, manage weeds, and fight pest and plant diseases in a broad range of crops.

Alignment with the SDGs



Zero Hunger



Good Health and Well-Being



Climate Action

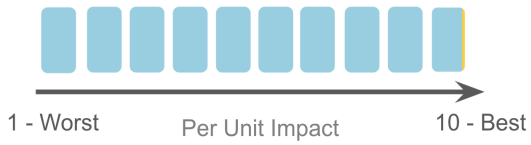


Life Below Water



Life on Land

Climate Impact Score: 9.9/10



BIOst® Nematicide is an innovative broad-spectrum seed treatment nematicide with activity on eggs and juveniles of early season nematodes and against soil-dwelling insect pests. Boundless performed an environmental assessment of PFG's seed treatment nematicide, BIOst® Nematicide, to quantitatively measure its environmental outcomes. Boundless also illustrated the relative benefits of PFG's technology compared to traditional insecticides commonly applied as seed treatments. Using its scientifically rigorous methodology, Boundless measured the impact and retained an independent insecticides expert to review the findings.

The assessment identified and analyzed the Greenhouse Gas (GHG) Footprint, Carbon Return on Investment (CROI), Proportion of Harmful Materials, Ecosystem Impact, Human Toxicity, Aquatic Toxicity, and Soil Toxicity of the BIOst® Nematicide. The life cycle inputs and impacts were evaluated considering raw material production, procurement, insecticide production, and transportation. Results were normalized relative to 1 million seeds treated and compared against neonicotinoids (imidacloprid, thiamethoxam, and clothianidin), diamides (flubendiamide, cyantraniliprole, and chlorantraniliprole), as well as abamectin and other biopesticides with similar functionality to BIOst® Nematicide.

Based on a formulaic comparison that measures relative performance across all metrics, BIOst® Nematicide scored a 9.9 out of 10 impact score on its overall performance. This Boundless Climate Impact Score is based on each million seeds impacted for the above-mentioned performance indicators and shows that BIOst® Nematicide has significant environmental advantages over its competitors.

Boundless assessed the CROI metric using industry-specific assumptions to compare alternatives on a dollar investment basis. The CROI metric measures the GHGs avoided when BIOst® Nematicide replaces its competitors. Analysis showed that for every $1 million invested in BIOst® Nematicide production capacity, 9,465 metric tons of carbon dioxide equivalent (CO_2e) savings could be realized by replacing neonicotinoids, 1,260 metric tons by replacing abamectin, and 5,319 metric tons by replacing diamides. It was also estimated that for every million acres of soybean and corn treated with BIOst® Nematicide instead of abamectin, 500 and 580 metric tons of CO_2e would be reduced, respectively. On average, under current conditions the GHG savings from replacing abamectin are equivalent to the carbon sequestered by over 600 acres of U.S. forest each year or removing 120 passenger cars from the road for a year. Boundless determined that switching to a 100% renewable electricity supply would reduce the BIOst® Nematicide GHG emissions by 47%. This would mean that per one million acres of soybean and corn treated with BIOst® Nematicide instead of abamectin, 550 and 620 metric tons of CO_2e can be avoided, respectively. Considering this improvement, PFG recently made the switch to a 100% renewable electricity supply in its PFG Michigan Manufacturing facility.

Environmental Highlights

Summarized below are the most relevant impact categories and codes that refer to the United Nations' Sustainable Development Goals (SDGs). The present section highlights the most important factors that explain how this technology impacts the environment and society.

Greenhouse Gas Emissions

The production of PFG's BIOst® Nematicide has a lower GHG Footprint (presented in this report as kilograms of CO_2e, based on a 100-year global warming potential [GWP], per million seeds treated) compared to more traditional insecticides commonly applied as seed treatment like neonicotinoids, abamectin, and diamides. The GHG Footprint per million kilograms of BIOst® Nematicide is 1.9 kg CO_2e, or 0.9 kg CO_2e per million seeds treated. Considering a 100% renewable electricity supply, the GHG emissions of BIOst® Nematicide are 1 kg CO_2e per kg of product, or 0.5 kg CO_2e per million seeds treated. Per $1 million investment in BIOst® Nematicide, 5,300 metric tons of CO_2e emissions can be saved on average when replacing neonicotinoids, abamectin, and diamides with BIOst® Nematicide. These GHG savings are on average equivalent to the carbon sequestered by 6,500 acres of U.S. forest in 1 year. Boundless determined that switching to 100% renewable electricity would produce savings from replacing neonicotinoids, abamectin, and diamides equivalent to the carbon sequestered by 6,700 acres of U.S. forest per year. Considering this improvement, PFG recently made the switch to 100% renewable electricity supply in its PFG Michigan Manufacturing facility. Note that using an alternative 20-year GWP assumption gives a GHG footprint of BIOst® Nematicide of 2.4 kg CO_2e per kilogram. Relevant Code: SDG 13. Climate Action

Good Health and Well-Being

The principles of Integrated Pest Management and Good Agricultural Practices dictate that the use of chemicals in the production of food should be reduced wherever possible and that farmers should follow all safety precautions on the product use label. Farmers are at a higher risk of exposure to pesticides, making it important that these substances are safe. Among the pesticides analyzed, abamectin presents the highest toxicity level to humans through ingestion, and the rest of the competitor pesticides analyzed present low or very low toxicity through ingestion, skin contact, or inhalation. There are no known or reported toxic hazards for humans with BIOst® Nematicide. Relevant code: SDG 3 Good Health and Well Being

Life on Land

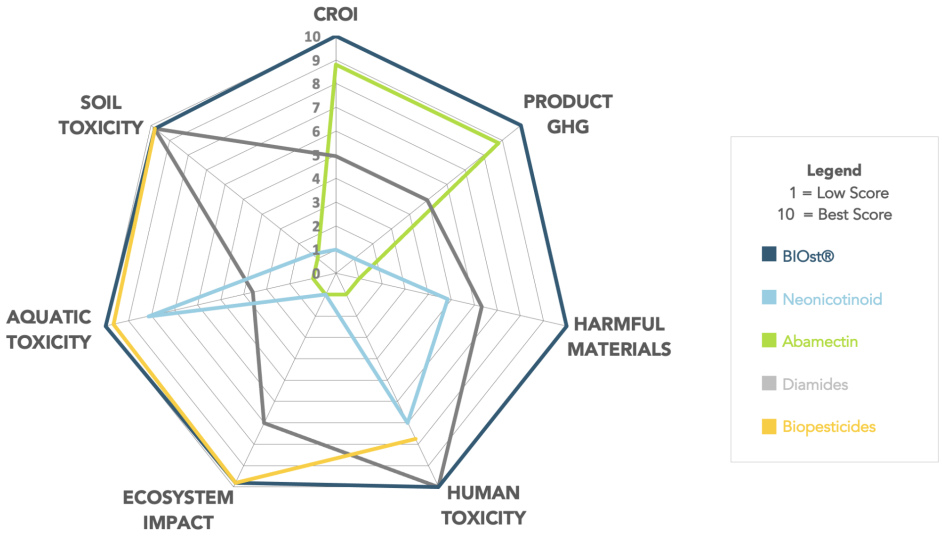
The application of pesticides can contaminate soil and may kill nontarget organisms such as pollinators and earthworms.[1] Pollinators, such as bees, provide indispensable ecological services that contribute to human well-being and environmental conservation. Bees directly contribute to food security and biodiversity through their role in pollinating crops and other wild plants that serve as food for humans and wildlife.[2] These insects are increasingly under threat from human activities, including pesticide use. With respect to soil health, earthworms are a good bioindicator, as their abundance is indicative of soil fertility. Small doses of neonicotinoids can easily kill bees and neonicotinoids present the highest risk to earthworms, but it is important to note that this hazard is mitigated by the application of these products as seed treatment. BIOst® Nematicide has not been found to pose a risk to bees or soil-dwelling organisms. Other indicators of the impacts an insecticide can pose to soil health include biodegradability and impact to soil microorganisms. PFG provided test results that demonstrate that BIOst® Nematicide is considered readily biodegradable and does not have a long-term influence on the nitrogen transformation activity of soil microorganisms. Relevant Code: SDG 2 Zero Hunger & SDG 15 Life on Land

Life Below Water

Pesticides can leak into water bodies and affect aquatic life, from small invertebrates to fish, impacting the entire food supply chain. Neonicotinoids, abamectin, and diamides are considered toxic to aquatic life, especially invertebrates. BIOst® Nematicide and the biopesticides considered in the assessment are not considered toxic for aquatic life. Relevant Code: SDG 14 Life Below Water

[1] Joko, Tri, Sutrisno Anggoro, Henna Rya Sunoko, and Savitri Rachmawati. 2017. "Pesticides Usage in the Soil Quality Degradation Potential in Wanasari Subdistrict, Brebes, Indonesia." Applied and Environmental Soil Science 2017. https://doi.org/10.1155/2017/5896191.
[2] Dangles, Olivier, and Jérôme Casas. 2018. "Ecosystem Services Provided by Insects for Achieving Sustainable Development Goals." Ecosystem Services 35. https://doi.org/10.1016/j.ecoser.2018.12.002.

Benchmarking and Conclusions



Boundless researched the material, energy, and performance characteristics for PFG's BIOst® Nematicide, based on detailed information provided by PFG that describes the material components and energy inputs. At the core of the methodology is a life cycle assessment (LCA) model for 1 million seeds treated with BIOst® Nematicide. Metric construction for industry alternatives relies on comparisons developed using scientific literature, industry reports, white papers, and assumptions provided by an independent industry expert.

The BIOst® Nematicide insecticide and nematicide GHG Footprint per million seeds treated with the product is significantly lower than those of neonicotinoids and diamides. For every $1 million invested in BIOst® Nematicide production capacity, 5,300 metric tons of CO_2e savings could be realized on average by replacing neonicotinoids, abamectin, and diamides. The electricity and steam required during the fermentation process to produce the nematicide make up 73% of the GHG Footprint for the BIOst® Nematicide per kilogram. With a 100% renewable electricity supply, the savings from replacing neonicotinoids, abamectin, and diamides would increase on average to 5,500 metric tons of CO_2e per $1 million investment in BIOst® Nematicide. This is on average equivalent to the carbon sequestered by 6,700 acres of U.S. forest in a year. Considering this improvement, PFG recently switched to a 100% renewable electricity supply for its PFG Michigan Manufacturing facility.

BIOst® Nematicide is not toxic to humans nor to the ecosystem, including bees, aquatic life, and earthworms. Neonicotinoids, a class of pesticides highly used worldwide, are very controversial for the risk they pose to bees, a fundamental pollinator in the ecosystem. Abamectin is highly toxic to humans when ingested and very toxic to fish, aquatic invertebrates, and earthworms. Diamides are not toxic for humans or earthworms but highly toxic for aquatic invertebrates.

Boundless concludes that BIOst® Nematicide demonstrates clear environmental and health improvements in the biopesticide industry, given its very low to nonexistent hazard to humans and the environment and its low GHG Footprint. Additionally, its Organic Material Review Institute (OMRI) certification indicates that BIOst® Nematicide is appropriate for organic operations.

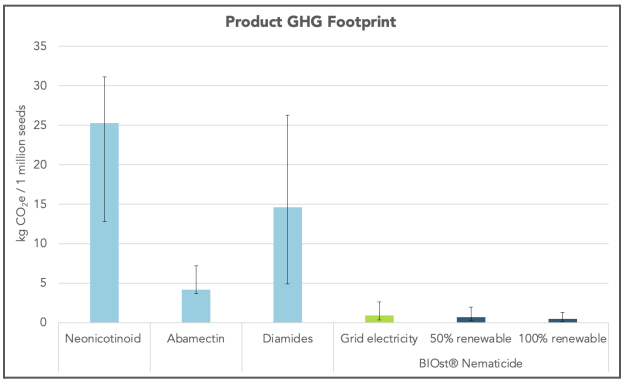
Boundless engaged an experienced agronomist who has held numerous positions in the field to review the BIOst® Nematicide assessment and validate the assumptions made in calculating the environmental metrics. The independent expert concluded that the inputs to the study are detailed and correct, that the assessment creatively compared BIOst® Nematicide to other competitors in its industry, and that BIOst® Nematicide can play an important role in agriculture and helping preserve the planet and conserve natural resources.

Environmental Key Performance Indicators (EKPIs)

Boundless evaluated the life cycle inputs and impacts per kilogram and per seed treated for the BIOst® Nematicide, considering raw materials, procurement, production processes, and transportation. Results are compared to neonicotinoids, diamides, abamectin, and biopesticides. More specifically, neonicotinoids include imidacloprid, thiamethoxam, and clothianidin; diamides include flubendiamide, cyantraniliprole, and chlorantraniliprole; and biopesticides consider parasitic bacteria-based pesticides with similar functionality to BIOst® Nematicide. The impact metrics are reported graphically using bar charts to illustrate a baseline result value, along with sensitivity bars reflecting a range of possible result values around deployment scenarios and key variables.

Product GHG Footprint

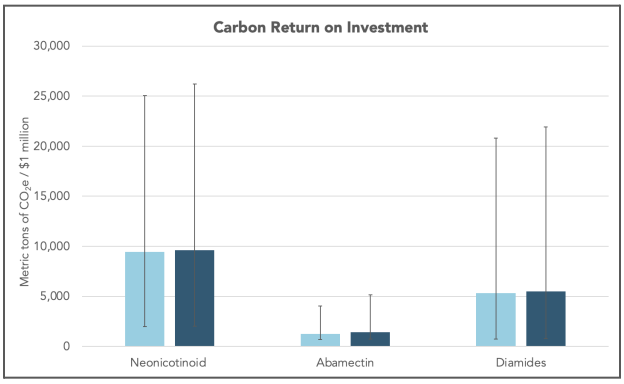
GHG emissions are reported in CO_2e per million seeds.



- GHG emissions for the BIOst® Nematicide, under current grid electricity supply, ranged from 1.6 to 2.3 kg CO_2e per kilogram of product. This translates to an average of 0.9 kg CO_2e per million seeds treated with the product.
- The estimated GHG footprint of BIOst® Nematicide is 96% lower than the GHG footprint of neonicotinoids, 78% lower than that of abamectin, and 94% lower than that of diamides.
- There is not enough available information to estimate the GHG footprint of other bioinsecticides, but it was found that the fermentation processes to produce these types of nematicides could range from 2 to 14 days.
- Using wind energy to supply either 50% or 100% of the facility electricity required to produce BIOst® Nematicide would reduce its GHG Footprint to 1.5 kg CO_2e or 1.0 kg CO_2e per kilogram of product, respectively, corresponding with reductions of 24% and 47%.

Carbon Return on Investment

The CROI presents the climate impact (positive or negative) of each million dollars in equity capital investment in PFG to replace traditional insecticides with BIOst® Nematicide.



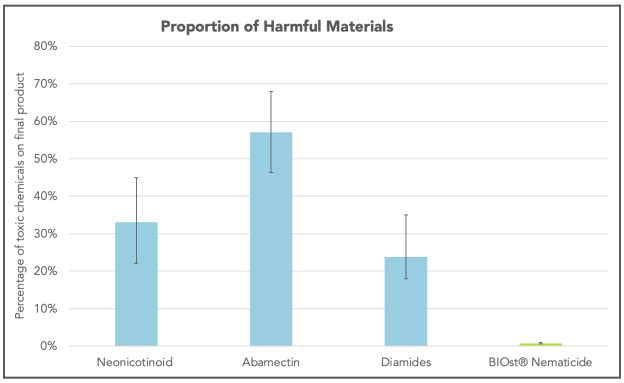
- Investing $1 million in BIOst® Nematicide to replace other neonicotinoids with similar functionality can save on average between 9,400 and 9,600 metric tons of CO_2e depending on the type of electricity supply used to manufacture BIOst® Nematicide.
- When replacing abamectin, BIOst® Nematicide can save between 695 and 4,026 metric tons of CO_2e, and when replacing diamides, savings can reach from 737 to 20,807 metric tons of CO_2e per million dollars invested.

EKPIs continued

Calculations of environmental metrics used to determine environmental impact.

Proportion of Harmful Materials

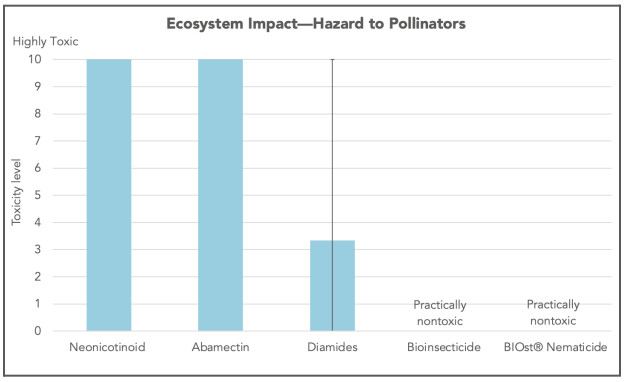
This EKPI represents the proportion of materials composing the insecticide that are considered toxic to some degree for humans or the environment.



- Less than 1% of the final weight of BIOst® Nematicide is composed of ingredients considered toxic chemicals.
- Neonicotinoid has between 22% and 45% toxic chemicals per weight; abamectin has between 46% and 68%; and diamide has between 18% and 35%.
- There is not enough publicly available information to obtain the proportion of toxic chemicals that compose biopesticides.

Ecosystem Impact

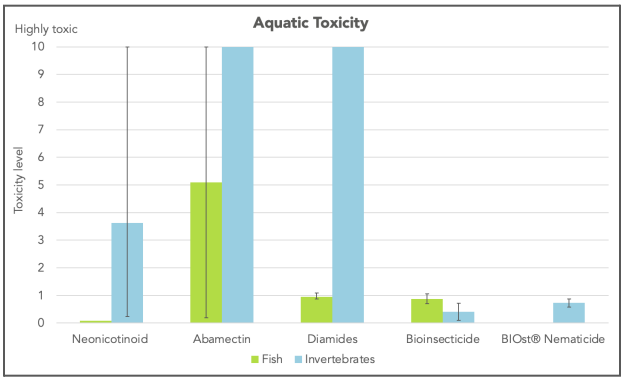
This EKPI represents the hazard to pollinators, including bees, resulting from the use of the insecticide. This metric is based on the lethal dose that results in 50% mortality to bees (LD50) and is calculated as 1/LD50.



- One of the main concerns with the use of pesticides is the possibility of harming bees, one of the pollinators responsible for the reproduction of plants that contribute to the food systems of animals, including humans, birds, and insects.
- BIOst® Nematicide has been shown to pose no risk to bees.
- Neonicotinoids and abamectin can be toxic to bees. Small doses of these types of insecticides can kill bees. It's important to note that this hazard is mitigated by the application of these products as a seed treatment.
- The high uncertainty of abamectin depends on the proportion and type of nematicide in which this chemical is present.

Aquatic Toxicity

This EKPI represents the hazard to fish and aquatic invertebrates from the use of the insecticide. This is based on the lethal dose that results in 50% mortality to fish (LD50) and the lethal concentration (LC50) that results in the immobilization of 50% of aquatic invertebrates.



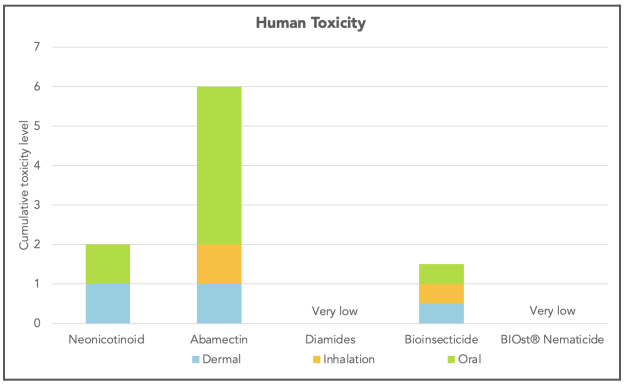
- BIOst® Nematicide and the biopesticides considered present very low toxicity levels for aquatic life.
- Neonicotinoids, abamectin, and diamides are considered toxic to aquatic life. The use of neonicotinoids, abamectin, and diamides can be considered a risk to aquatic invertebrates, which can affect the entire food supply chain.

EKPIs continued

Calculations of environmental metrics used to determine environmental impact.

Human Toxicity

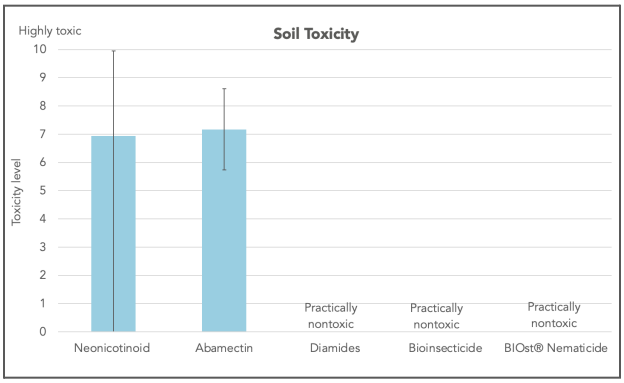
The measure of a nematicide's toxicity to humans based on dermal, inhalation, and oral routes of exposure, according to Environmental Protection Agency (EPA) acute toxicity categories.



- Abamectin is the most toxic of the nematicides assessed, with considerable toxicity level for all categories: low through dermal contact and inhalation, and very high toxicity by oral exposure.
- Neonicotinoids and some bioinsecticides present low toxicity through ingestion and dermal contact. Diamides can produce skin and eye irritation but do not present a toxicity hazard.
- There are no reported toxic hazards for humans with BIOst® Nematicide.

Soil Toxicity

This EKPI represents the hazard to soil-dwelling organisms from the use of the insecticide. This is based on the lethal concentration that results in 50% mortality to soil-dwelling nontarget organisms (LC50) with 10 representing the highest level of toxicity (< 1 mg/kg).



- In the absence of a more complex study, earthworms can be considered a good bioindicator for soil health, as their abundance can give valuable information on the fertility of soil.[3]
- BIOst® Nematicide, diamides, and the biopesticides considered have been shown to present practically no toxicity to earthworms.
- Abamectin poses moderate toxicity to earthworms, while neonicotinoids can present the highest risk to earthworms.
- Other indicators of the impacts an insecticide can pose to soil health are biodegradability and the impact to soil microorganisms. An insecticide is considered readily biodegradable if it has been demonstrated to biodegrade more than 60% under natural conditions within 28 days. Because soil microorganisms contribute to soil fertility,[4] an insecticide's impacts on microbial populations and activity are another important indicator of soil health. PFG provided the results of the test that demonstrate that BIOst® Nematicide is readily biodegradable and does not have a long-term influence on the nitrogen transformation activity of soil microorganisms.

[3] Lackmann, C., Velki, M., Bjedov, D., et al. 2021. "Commercial Preparations of Pesticides Exert Higher Toxicity and Cause Changes at Subcellular Level in Earthworm Eisenia andrei." Environmental Sciences Europe 33, no. 12. https://doi.org/10.1186/s12302-021-00455-5.
[4] C. Johns. 2017. "Living Soils: The Role of Microorganisms in Soil Health." https://www.futuredirections.org.au/publication/living-soils-role-microorganisms-soil-health/.

Technology

- BIOst® Nematicide is a microbial-based insecticide and nematicide seed treatment developed in partnership with Albaugh, a key North American distribution partner. In 2019, this product was applied to more than 10 million acres of cotton, corn, and soybeans in the United States.
- PFG's proprietary technology allows it to source and process microorganisms and plant extracts. This process has resulted in an extensive proprietary microorganism collection, microbial fermentation technology, screening technology, and a process to identify and characterize natural compounds with pesticidal activity. PFG has screened more than 18,000 microorganisms and 350 plant extracts.
- BIOst® Nematicide has demonstrated an ability to improve the control of soil-borne insect pests for the traditional chemical seed treatment. The use of BIOst® Nematicide to augment existing insecticidal activity for traditional seed treatments presents an Integrated Pest Management opportunity to use neonicotinoids and other insecticides at lower rates. This reduces the environmental and health impact on nontarget beneficial insects.
- Like all of PFG's commercial biocontrol products, BIOst® Nematicide is USDA National Organic Program compliant and OMRI certified.
- BIOst® Nematicide meets the EPA's reduced risk criteria for pesticides, meaning that it represents a minimal hazard to people using the product or consuming food and water treated with the product and a minimal hazard to the environment.

Operations

- The PFG R&D campus is located in Davis, California. PFG also has a large manufacturing facility in Bangor, Michigan.
- PFG signed a BIOst® Nematicide distribution partnership in 2016 with Albaugh, LLC, a leading provider of crop protection products and seed treatment technology.

Current Operations



BOUNDLESS
IMPACT RESEARCH & ANALYTICS

About Boundless Impact Research & Analytics

Boundless Impact Research & Analytics is a market intelligence and impact analytics firm that provides quantitative and evidence-based research and data for investors, companies, and funds. Driven by the latest research from independent industry and academic experts, Boundless Impact Research & Analytics offers analysis, market trends, and evidence of best practices in a growing number of emerging sectors that address significant environmental and health challenges. Our research into emerging technologies, impact assessment of companies, and thought leadership provide investors with the latest and most relevant information to drive their investment decisions.

Contact Us

Boundless Impact Research & Analytics
www.boundlessimpact.net
Michele Demers, CEO and Founder
mdemers@boundlessimpact.net

The information provided in this report by Boundless Impact Research & Analytics and accompanying material is for informational purposes only and is valid for one year after the date of the report. The information in this report should not be considered legal or financial advice, nor an offer to buy or sell or a solicitation of an offer to buy or sell any security, product, service, or investment. Boundless Impact Research & Analytics does not make any guarantee or other promise, representation, or warranty as to the accuracy or completeness of the statements of fact contained within, or any results that may be obtained from using our content. Neither this content, nor the investment examples cited, should be used to make any investment decision without first consulting one's own financial advisor and conducting one's own research and due diligence. To the maximum extent permitted by law, Boundless Impact Research & Analytics disclaims any and all liability in the event any information, commentary, analysis, opinions, advice, and/or recommendations prove to be inaccurate, incomplete, or unreliable, or result in any investment or other losses.