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Soileos
Bio-Active Crop Nutrition

How Soileos increases yield through activation of the microbiome

Soileos

Science Driven. Field Proven. Bio-Activated.

Increase microbial biomass with Soileos bio-available micronutrients

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Executive Summary

Soileos, a fertilizer innovation to solve micronutrient delivery problems.
Soileos is a soil-applied fertilizer that boosts yield, strengthens crop resilience, and supports soil health by delivering nutrients when plants need them most. Soileos is made using a patented process that upcycles cellulose derived from crop processing residues such as lentil, pea, or oat hulls into a sustainable delivery agent for nutrients. Unlike conventional products, Soileos' organic substrate means soil organic carbon levels are enhanced through its use. The net result is higher crop yields, improved nutrient density, and healthier soils with higher carbon.

Watch our *Mode of Action* video

This whitepaper contains the results of research on Soileos by Agriculture and Agri-Food Canada to illustrate the mode of action and the interaction with the soil microbiome with a focus on microbial activity.

Soileos triggers an increase in microbial biomass due to the biologically available source of carbon—cellulose—a core component of Soileos. Nutrients are delivered from Soileos to the crop using the symbiotic relationships between soil microbes and plants. The microbial community consumes the bioavailable carbon and begins to cycle, releasing the micronutrients back into the ecosystem in a bioavailable form ready for crop uptake. Research has also demonstrated that the use of Soileos results in minimal leaching, even at high application, proving that Soileos is environmentally safe.

Soileos provides a climate-smart solution for nutrient management in modern farming practices.

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Soileos & Lucent Bio

Lucent Bio, the parent company responsible for developing Soileos, is a Canadian Ag-Tech company and focused on creating sustainable science-based crop nutrition and fertilizer solutions.

Learn more at lucentbio.com

Why Soileos?

Soileos delivers crop nutrition that improves yield and supports long-term soil health. Designed for climate-smart agriculture, Soileos is helping farmers maintain profitability while improving soil resilience. Backed by years of research and development, Soileos is an industry-leading solution for climate- smart agriculture. We use patented cellulose-based fertilizer technology as a replacement for conventional micronutrient products such as oxysulphates or synthetic chelates like EDTA. Our proprietary technology provides crops with bioavailable nutrients resulting in higher yields, and improved soil health for the ultimate return.

Soileos

Increasing awareness of soil as an essential ecosystem is a fundamental shift in how we think about soil and in turn how we care for it. It is widely acknowledged that soil biomes are highly important for nutrient and carbon cycling.[1] There has been an urgent call to study the intercommunication between plants and microbes; specifically, identifying functional roles and interspecies interactions.[2] Recent scientific understanding of the extent to which soil biota and plants cofunction and the potential for nature-based microbiome priming to replace synthetic agricultural inputs have only started to be uncovered.[3] Some researchers call this void of information the “final frontier of ecology.”[4]

Soil microbiomes enhance plant growth through three processes: (1) hormone manipulations[5], (2) outcompeting and surviving pathogenic microbes,[6,7] and (3) increasing the bioavailability of nutrients in soil microbiomes.[8,9] This paper will focus on the third aspect and will explain how Soileos increases bioavailable nutrients in the soil microbiome. Topics covered will include soil microbiome, soil organic carbon, micronutrient absorption in plants, the limitations of oxy-sulphates and EDTA-based fertilizers, and the Soileos solution.

"Maintenance of soil health is central to agricultural sustainability and a key factor that reflects the productivity of agro-ecosystems" [23]

Micronutrient deficient soils are a global problem that directly impacts human health. Malnutrition due to the consumption of crops with low dietary value has ignited the pursuit of more sustainable solutions. According to the World Health Organization, more than two billion people around the world are at risk of zinc deficiency disorder.[10 11] Zinc deficiency is particularly acute in developing countries where populations rely mostly on cereals for staple food and have little access to meat.[12] In Canada and the USA, 10-12% of the population consumes inadequate amounts of zinc.[13]

Climate change is both, directly and indirectly, affecting interactions between the soil microbiome and plants by altering community structure, function, and prosperity.[14 15 16] Agricultural soils rely heavily on healthy microbiomes to achieve high productivity and crop quality.[17] Soil ecosystems are one of the largest reservoirs of biological diversity on Earth; they make up 60% of the Earth's biomass.[18]

In agro-ecosystems, zinc deficiency is the most geographically widespread micronutrient constraint limiting crop production. In western Canada, soil samples have shown that zinc is deficient in 30% of those taken in Alberta, 66% in Saskatchewan and 61% in Manitoba.[19] Zinc is a critical nutrient because it is essential for plant growth.[20] It plays a key role in DNA replication and regulation of gene expression and is vital for germination, chlorophyll production, pollen function, fertilization [21], and biomass production.[22]

Soil becomes zinc deficient when crop removal exceeds zinc availability and fertilization. Zinc may not be available for plant uptake due to soil characteristics such as high soil pH or low organic matter content. Zinc is also immobile in the soil, meaning it cannot travel to plant roots to be taken up unless it is dissolved and moves with the groundwater.

The Role of Microbes in Soil Health

Ecosystems rely on biogeochemical cycles. The soil itself is a complex and multifunctional domain that supports many processes, such as the cycling of major nutrients (i.e., carbon and nitrogen), and the decomposition of organic matter. Microbes are the most important contributors to soil processes. The collection of microorganisms that live in the soil is immense. Soil microbiomes are home to primary producers in an ecosystem, and they are determinants of successful environments (i.e., plant health) as they assist in the acquisition of nutrients.

Current global estimates suggest that soil contains greater than 4×10^{30} microbial cells.[25]

Living soil communities are made up of bacteria, fungi, algae, protozoa, and nematodes. In their complex world, some of these microbes are predatory, some break down nutrients, some act as antibiotics for plants, and some facilitate nutrient uptake in roots.

The soil biota that makes our environments livable has been greatly affected by anthropogenic processes. "It is well established that agricultural practices alter the composition and diversity of soil microbial communities."[24] Soil degradation exists in every inhabited region of the world. As the world's soils lose their nutrients, the soil biota dies, and these ecosystems become less productive. Because of this, many agricultural crops do not contain the nutrient densities they once did. From humans to microbes, nutrients are essential for the proper function of all living things.

Management strategies that increase soil biodiversity are important for soil health, plant health and vital to restoring these ecosystems back into rich and fertile farmland. Scientists have found that increasing the microbial biomass of soil increased aboveground plant productivity by 35%.[25 26]

Why Carbon Matters for Your Soil

Soil organic carbon is integral to increasing biodiversity belowground. Soil management strategies determine if carbon stays in the soil (is sequestered) or is released into the atmosphere. Increasing and sequestered carbon creates rich soil that improves crop yields. Organic carbon is an important source of energy for microbial activity which, in turn, creates fertile soil.

Researchers have found that soil microbes are responsible for 82% of the variation in soil carbon cycling.[27] Carbon cycling is just one ecosystem service that is provided by microbes in natural and cultivated environments. Plants use microbes to exchange their carbon for nutrients that are otherwise inaccessible to them.

As plants depend on microbes for nutrients, soil microorganisms may be limited by the availability of carbon that is transferred to them by plants.[28] In this way, the abundance of microbes can determine the health of the soil and the potential of soils to sequester carbon.[29] Soil carbon plays an indispensable part in enhancing agricultural productivity.

How Plants Really Take Up Nutrients

Plant absorption of micronutrients depends on physical, biological, and chemical conditions of the soil such as pH, organic matter, microbial activity, oxidization, and pre-existing minerals.[30] Micronutrients become available to plants through complex chemical and biological processes in the soil.

Research is evolving to develop a more complete understanding of the interactions between plants and microbes in the soil, and how this determines the availability of nutrients,[31 32] as well as, how plants may become tolerant to stressors such as drought, salinity, and heavy metals.[33]

Plants have developed mechanisms and symbiotic relationships with soil microbes to facilitate the nutrient acquisition. Microorganisms such as bacteria move in response to chemicals in the environment; this is known as a Chemotactic response. Capitalizing on this response, plants release certain chemicals known as root exudates (i.e., amino acids, carbohydrates, organic acids, and flavonoids) to influence microbial movement.[34] The root exudates provide energy in the form of carbon for the microbes, and the microbes increase nutrient availability for the plants. In this way, soil communities are influenced by the conditions imposed by plants[35] and microbes are indicators of nutrient availability within the soil.

The symbiotic relationship between plants and microbes occurs in a unique micro-ecosystem directly around plant roots known as the rhizosphere. These plant-microbe interactions and impact on nutrient availability, demonstrate the importance of fostering healthy, living soils.

In agricultural ecosystems, crops are harvested and removed from the ecosystem preventing nutrients from cycling back into the soil. Over time this leads to nutrient-deficient soils that need to be amended or fertilized to ensure continued land productivity. Supplementary nutrients are added to the system through either soil or foliar applications in ionic and chelated forms. Proper soil nutrient management is vital to producing high yields of nutritious foods year after year.

The Problem With Conventional Fertilizers

Oxy-sulphate, sulphate and EDTA (ethylene diamine tetraacetate) based agricultural fertilizers have been around since the 1930s. The use of these micronutrient forms is common in agricultural systems to alleviate micronutrient deficiencies.[36]

Oxy-sulphate fertilizers are inorganic, and even though they are more cost-effective than chelates such as EDTA, they have a low water solubility (especially in alkaline soils) and have a fine threshold between under- and over-application.[37]

Sulphate fertilizers are commonly used in oilseed crops and forage crops. However, once in the soil, they are very prone to leaching in wet and sandy soils.[38] Sulphate-based fertilizers may increase soil salinization over time which can stress soil microbes.

The Agronomic Red Flags

- Ineffective in high pH
- Harmful salts destroy life in soils
- Prone to leaching
- Fine threshold for over-application and toxicity

Chelates: What do they do?

A chelate ("key-late") grabs or binds inorganic ions or micronutrients (such as zinc) through multiple bonds usually with organic molecules (carbon containing compounds).

Chelation can improve nutrient availability by preventing conversion into insoluble solids in the soil, allowing the plant to uptake the delivered nutrient.

Synthetic EDTA-based fertilizers allow nutrients to be absorbed by plants; however, the synthetic components are released back into the soil. EDTA is a chelating agent that is water-soluble and can easily pick up heavy metals in the soil, thus enabling metals to enter and pollute water bodies. Unsustainable EDTA-based fertilizers amplify the modification of the Earth's biogeochemical cycles through mechanisms such as soil degradation, waterway eutrophication, and greenhouse gas emissions.[39 40 41]
Current micronutrient fertilizers that are sulphate, oxy-sulphate, and EDTA-based are expensive relative to their benefits, ineffective in alkaline soil, and can leach and contaminate agro-ecosystems.

The Soileos Solution

Soileos is a suite of climate positive, innovative fertilizers that solve the micronutrient delivery problems of today while improving the land for tomorrow. Soileos is a soil applied, innovative crop nutrition delivery system. It helps farmers reach their yield potential and increase their soil health. Soileos' on-time nutrient delivery and sustained bioavailability allow the crop to maximize its genetic potential. without polluting agro-ecosystems by resisting tie-up and leaching.

Soileos is made from repurposed cellulose derived from crop processing, such as pea, lentil or oat hulls. This natural fibre promotes nutrient cycling in the soil. It is the microbial decomposition of Soileos that releases nutrients for crop use. Unlike conventional products, Soileos' organic substrate improves microbial biomass in the soil and enhances soil organic carbon levels. This natural nutrient delivery mechanism results in healthy agricultural systems where farmers have higher crop yields with improved nutrient density, and healthier soils.

How Soileos Works In Your Field

Soileos is the fertilizer of the future. Patented technology binds micronutrients to cellulose and uses the soil's natural biological activity to release nutrients to the crops as required. When Soileos is applied and incorporated into the soil, the cellulose-bound nutrients are effectively delivered to the plants in an sustainable method. Nutrients delivered from Soileos to the crop lean on the symbiotic relationship of microbes and plants; micronutrients are slowly released from the cellulose of Soileos through microbial mineralization. This is why we call Soileos Bio-Active.

Watch our *Mode of Action* video

In collaboration with Agriculture and Agri-Food Canada (AAFC), completed research trials in 2020 to investigate the mode of action of Soileos and it's interaction with the soil microbiome with a focus on microbial activity.

When soils are fertilized with Soileos, the naturally present microbes begin to consume the organic carbon from the cellulose increasing their microbial biomass carbon. In this process, they also consume cellulose-bound micronutrients such as zinc. In studies conducted at AAFC, the microbial biomass increased more than 20% when using Soileos compared to the control (Figure 1).

Nutrients stay exactly where you need them.

Once the easily degraded carbon is consumed, the microbial population declines, and the micronutrients are released back into the soil in a bioavailable form for crop uptake. Unlike synthetic fertilizers, Soileos is a cellulose based fertilizer that fortifies the soil with natural carbon. Soil life in systems such as this can be over 80% more active than in conventional systems.[42]

The rate of microbial activity is dependent on conditions such as temperature, moisture, and pH. Warm, moist conditions facilitate a more active microbiome, whereas cool, dry conditions result in a less active microbiome. This means that the micronutrients from Soileos are not released from the cellulose until conditions are met that promote microbial activity. This allows nutrients delivered from Soileos to become available for plant uptake when the plants need them throughout the growing season.

FIGURE 1.
The interaction between Soileos and soil microbial community through assessment of microbial biomass carbon (MBC)

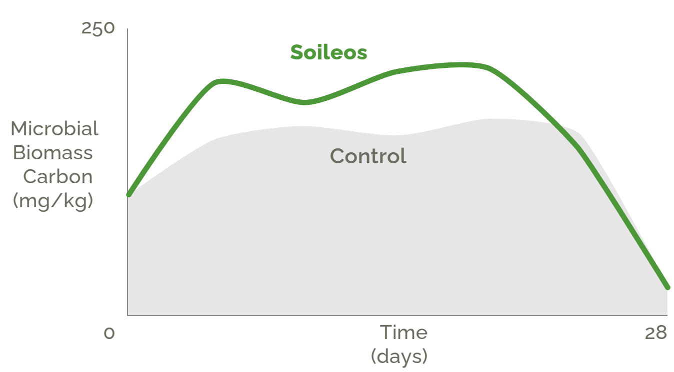
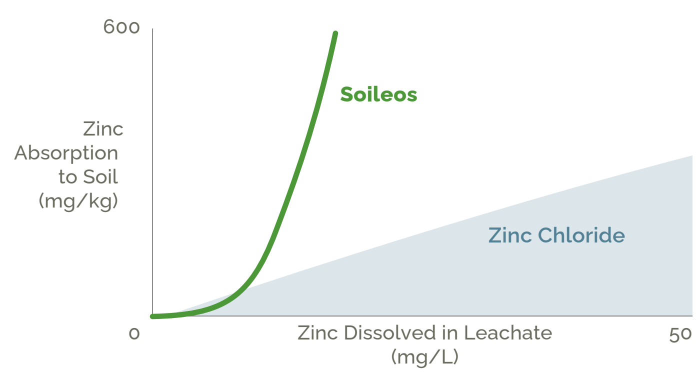


FIGURE 2.
Zinc absorption curves from soil treated with Soileos or zinc chloride



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Soileos is environmentally safe because the micronutrients are not subject to leaching in their cellulose-bound state. Zinc adsorption curves demonstrate that soil treated with Soileos Zinc resulted in minimal zinc leaching from the soil, even at high adsorbed zinc concentrations (Figure 2). In contrast, the concentration of zinc that leached from the soil treated with zinc chloride was significantly higher than that of Soileos Zinc and steadily increased with the amount of zinc adsorbed to the soil.

These curves demonstrate that Soileos micronutrients have a lower risk of leaching out of the soil profile, thereby mitigating the environmental pollution that is typically associated with the use of other fertilizers.

The Benefits of Soileos

The benefits of Soileos are numerous. Soileos provides a climate-smart solution for micronutrient management in modern farming practices with increased crop safety in comparison to sulphate-based fertilizers. Field trials show that Soileos increases crop yields and reduces risk of nutrient loss. In a study conducted by AAFC, cabbage fresh weight increased significantly with the increasing application rate of Soileos (Figure 3). In comparison, zinc chloride and zinc sulphate resulted in lower cabbage fresh weight with an increasing application rate. This highlights the risk of over-application of standard fertilizers which results in crop toxicities and yield reductions. Even at 10x the normal rate, Soileos showed no toxicity—proving its safety and flexibility.

Soileos has been tested across a range of crops including corn, wheat, canola, soybeans, tomato, and lettuce resulting in higher yields when crops were fertilized with Soileos (Table 1).

TABLE 1.
3 Years of Field Trial Results

CROP	AVERAGE YIELD INCREASE
Soybeans	10%
Canola	8%
Wheat	10%
Corn	12%

Agronomic biofortification is the deliberate use of fertilizers, like Soileos, to increase the nutritional content of crops; for instance, increasing the zinc concentration in grains to help address zinc deficiencies in the human diet.[43] However, zinc fertilizer recovery in agricultural soils is low (<1%), and over-application of zinc chelates often result in residual accumulation in the soil and subsequent leaching to the environment.[44] Soileos offers an alternative, bioactive zinc source and an efficient fertilization strategy to address zinc deficiency in crops and related health problems.

Fertilization with Soileos results in better plant uptake of zinc compared to standard zinc chloride and zinc sulphate fertilizers (Figure 4) and has resulted in higher zinc tissue concentrations of globally significant crops such as corn and wheat. In this regard, Soileos creates more nutritional food.

Designed to help farmers improve efficiency while supporting environmental stewardship, Soileos goes beyond net-zero. It is a climate-positive option for farmers who don't want to relinquish profitability for sustainability. Farmers who grow with Soileos have an environmentally safe bottom line.

FIGURE 3.
Cabbage fresh weight in response to increasing zinc application rates using Soileos, zinc chloride, and zinc sulfate in a potted greenhouse experiment

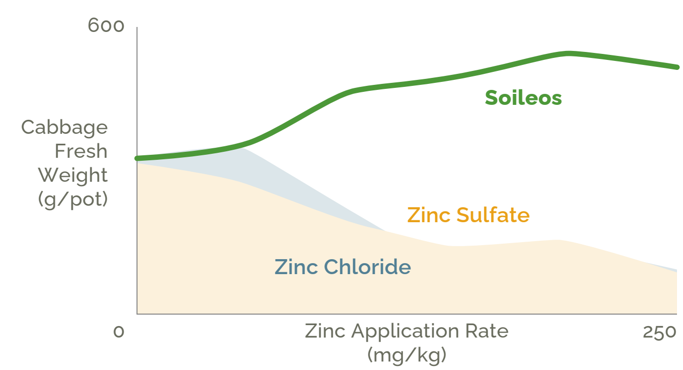
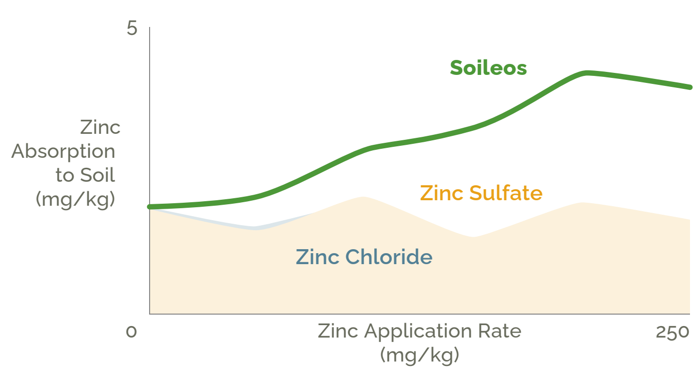


FIGURE 4.
Zinc uptake in cabbage in response to increasing zinc application rates using Soileos, zinc chloride, and zinc sulfate in a potted greenhouse experiment



Summary

Soileos is reinventing crop nutrition. delivering innovative fertilizer that solves today's micronutrient delivery problems while improving the land for tomorrow. By using upcycled agricultural co-products Soileos contributes to a circular economy and supports more sustainable food production. Soileos micronutrients are bioavailable to agricultural ecosystems thus enabling greater nutrient uptake and increased yields. Soileos supports life on land and safeguards soil to address global food security. A nutrient management strategy that includes Soileos is easy to implement, environmentally friendly, and healthy.

Higher yields and healthier soil for the ultimate return.

Compared to the classic sulphate and EDTA based fertilizer, Soileos offer some major benefits:

	SOILEOS	CHELATES	SULPHATES
Works in alkaline soils up to pH 10	+	–	– –
Easy to use	++	+	+/–
Increases crop yields	++	+	+/–
Increase nutrient density in crops	++	+/–	+/–
Bioavailable throughout plant life cycle	++	+/–	–
Improves phosphorus uptake efficiency	+	+	+
Activates microbiome	++	–	– –
No phototoxicity	++	+/–	–
No leaching	++	– –	– –
Climate-positive	+	– –	–
Cost per acre	+	– –	+

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