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Rebuilding America's Agricultural Future: A Microbial Approach to Glyphosate Remediation and Soil Regeneration

Restoring Quality, Safety and Security to America's Food Supply
Make America Healthy Again

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Executive Summary

Introduction

The deterioration of soil health poses a significant threat to U.S. agriculture, affecting food quality and safety, farm productivity, and long-term land viability. Decades of intensive farming practices, heavy reliance on chemical inputs, and loss of beneficial microbial communities have led to soil degradation, declining crop yields, contaminated soil, and reduced nutrient density in food. These factors are a major contributor to the chronic disease epidemic in America.

To address these challenges, microbial-based solutions offer a scientifically validated, field-tested approach to restoring soil function, improving crop productivity, and enhancing food quality and safety.

Ancient Organics Bioscience has developed RESILIENCE™ (formerly known as PaleoPower®), an organic soil amendment composed of beneficial microorganisms, designed to accelerate the breakdown of environmental toxins such as glyphosate and atrazine, restore soil microbial diversity, and enhance plant nutrient uptake. Field studies confirm that RESILIENCE reduces glyphosate levels in both soil and plants, improves soil fertility, boosts crop yields, and improves plant micronutrient density. RESILIENCE offers a practical solution to improve the quality and safety of America's food supply and combat the chronic disease epidemic.

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The Crisis of Soil Degradation and Nutrient Deficiency

Soil health is critical for producing nutrient-rich crops, yet modern agricultural practices have significantly depleted essential minerals in the soil and disrupted microbial ecosystems. Glyphosate-based herbicides such as RoundUp® have worsened this issue by disrupting soil microbiomes, binding essential nutrients, and reducing plant resilience.

The key challenges in soil degradation include:

- Loss of soil fertility due to depletion of organic matter and beneficial microbes.
- Reduced nutrient availability resulting from glyphosate chelation of essential micronutrients (e.g., zinc, manganese, and magnesium).
- Soil structure decline leading to poor water retention and increased erosion.
- Over-reliance on synthetic fertilizers to compensate for nutrient loss, further disrupting microbial ecosystems.

Glyphosate Accumulation and Its Long-Term Consequences

Glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA), persist in soil for extended periods, disrupting microbial diversity and limiting nutrient bioavailability. Studies confirm that glyphosate:

- Chelates essential minerals, making them inaccessible to plants.
- Inhibits beneficial soil bacteria, including nitrogen-fixing and phosphate-solubilizing microbes.
- Increases reliance on synthetic fertilizers to compensate for lost nutrient cycling capacity.
- Weakens soil structure, reducing water retention and plant resilience.

RESILIENCE™: A Microbial Approach to Soil Restoration

RESILIENCE is an organic microbial soil inoculant designed to degrade glyphosate and AMPA, restore microbial diversity, and enhance nutrient bioavailability. By introducing beneficial bacteria such as *Bacillus*, *Pseudomonas*, and *Paenibacillus*, RESILIENCE enhances soil function, plant health and crop performance through:

- **Accelerated Glyphosate Breakdown in Soil**: Field studies show up to 90% glyphosate degradation in treated soils within six (6) months.
- **Reduced Glyphosate Levels in Plants**: Analysis showed decreased glyphosate levels in plant tissue from crops grown on treated soils.
- **Improved Nutrient Availability and Increased Micronutrient Density**: Key minerals, including phosphorus, zinc, and boron, become more bioavailable for plant uptake, improving their micronutrient density.
- **Increased Microbial Diversity**: RESILIENCE repopulates soil with nitrogen-fixing and phosphate-solubilizing bacteria, restoring a healthy soil microbiome.
- **Enhanced Soil Structure and Water Retention**: Microbial activity improves soil aeration and organic matter decomposition, leading to stronger root systems and increased drought resistance.

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Scientific Validation & Field Study Results

Controlled field trials across a variety of crops (corn, silage, cotton, soy, and specialty crops) conducted in the US and Canada since 2019 confirm the effectiveness of RESILIENCE:

Corn and Silage Trials:

- Corn yield increased by 28.6% in RESILIENCE-treated fields.
- Silage yield improved by 9.6%, with a 9.3% increase in nutritional value.
- Soil microbial diversity increased by 42.3%, restoring beneficial bacteria for nutrient cycling.

Specialty Crops:

- Onion yields increased by 48%, carrots by 38%, and pumpkins by 36%.
- Improvements due to better nutrient absorption and enhanced soil microbial function.

Soil Nutrient Release & Uptake:

- 52% increase in molybdenum, 60% increase in boron, and 29% increase in zinc in treated soils.
- Significant uptake of key minerals in plant tissues, improving crop nutrient density.

A Practical Path Forward for Farmers and Policymakers

To accelerate adoption of microbial-based soil regeneration, scientific research, policy support, and farmer education are critical:

- Expanded Scientific Research & Field Trials: Multi-year studies to validate long-term soil health benefits.
- Policy Considerations & Incentives: Government support for microbial-based soil amendments as viable alternatives to synthetic chemical inputs.
- Farmer Adoption Strategies: Knowledge-sharing networks and on-farm demonstrations to encourage the adoption of microbial soil treatments.

Conclusion: Partnering for a Productive Agricultural Future

RESILIENCE provides a science-driven, field-tested approach to rebuilding soil health, reducing environmental toxins, increasing crop yields, and improving food nutrient density. By working together, farmers, researchers, and policymakers can implement microbial-based solutions that restore soil function, ensure long-term productivity, and improve food safety and quality.

Ancient Organics Bioscience, founded by Raul Cano PhD, a leading microbial ecologist and Professor Emeritus at California Polytechnic State University, San Luis Obispo, is at the forefront of microbial innovation to improve soil health, food quality and safety.

By adopting microbial solutions such as RESILIENCE, farmers can reduce chemical dependence, improve crop nutrition, and restore their land for future generations. We encourage government agencies, industry leaders, and farmers to partner with Ancient Organics Bioscience to scale these solutions. Let us work together to revitalize American agriculture, create a healthier food supply, and help combat the chronic disease epidemic in our nation.

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Introduction

The world faces a critical challenge: ensuring that our food supply remains nutrient-dense, chemical free, and abundant despite increasing pressures on soil health. By 2050, the global population is projected to reach nearly 10 billion, requiring a substantial increase in food production.[1]. However, decades of intensive agriculture—marked by excessive reliance on chemical inputs, soil depletion, and loss of essential microbial life—have significantly reduced the ability of our soils to support healthy, nutrient-rich crops. If left unaddressed, declining soil vitality will further compromise food quality, contribute to widespread micronutrient deficiencies, and threaten the resilience of agricultural systems, thus perpetuating the chronic disease epidemic in America. [2].

The Crisis of Soil Degradation and Food Insecurity

Modern farming practices have severely depleted soil fertility by stripping away essential minerals and disrupting the microbial ecosystems crucial for plant health [3]. The heavy reliance on synthetic fertilizers, pesticides, and herbicides—such as glyphosate—has diminished soil biodiversity and impaired the ability of plants to absorb vital nutrients like magnesium, zinc, and copper. Persistent exposure to these chemicals and micronutrient deficiencies in our food are increasingly affecting human health, contributing to weakened immune function, metabolic disorders, cognitive decline and diseases such as cancer and autism.

Additionally, the loss of organic matter and beneficial microbes has weakened soil structure, reducing its ability to retain water and support plant resilience. This degradation in soil quality has created a cycle of dependency on artificial chemical inputs that fail to restore the full spectrum of nutrients needed for both plant vitality and human well-being [4,5].

Furthermore, the widespread impacts of deforestation, habitat destruction, and monoculture farming have disrupted natural ecosystems that play a crucial role in maintaining productive farmland. The decline of essential soil microorganisms, pollinators, and other key species has reduced the natural support systems that help crops thrive, making agricultural systems more susceptible to pests, diseases, and climate-related stresses. [6].

The Decline of Natural Carbon Sinks

Healthy soil is the foundation of nutrient-rich food [7]. A biologically active, mineral-rich soil system enables plants to access and synthesize the full range of vitamins, amino acids, and trace elements essential for human health [8]. However, years of extractive farming have depleted these reserves, leading to widespread deficiencies in the food supply [9]. Without intervention, food crops will continue to lose nutritional value, exacerbating chronic diseases and global health concerns [10]. By revitalizing soil microbiomes and restoring lost minerals, we can enhance the nutritional density of crops, improve plant resilience, and reduce the need for chemical interventions [11,12]. Techniques such as microbial soil inoculation, remineralization, and regenerative farming practices offer a path toward rebuilding soil vitality and ensuring that future food sources contain the nutrients essential for human health [13,14].

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The Urgency of Soil Regeneration

Addressing soil degradation is not just about improving yields—it is about restoring the natural processes that produce healthy nutritionally superior food. Regenerative agricultural methods that emphasize microbial restoration, organic matter enrichment, and balanced mineral composition provide a sustainable approach to reversing the damage done by decades of chemical farming [15].

By prioritizing soil health at both the microbial and mineral levels, we can grow crops that are more resilient, free of environmental toxins and rich in the micronutrients that are increasingly absent in modern diets. Investing in soil-centered solutions will enhance food safety and security while also addressing the growing issue of nutrient depletion, which poses a significant threat to global health. [16-18].

Investment in innovative biotechnologies and nature-based solutions will not only ensure long-term agricultural productivity but also contribute to food safety and security, improved nutrition, and climate change mitigation [19]. By adopting a science-driven approach to sustainable agriculture, we can secure a resilient food system for future generations while restoring the health of our planet.

Glyphosate and Soil Regeneration: Addressing Soil Health and Food Quality

Glyphosate's Widespread Use in Agriculture

Glyphosate-based herbicides (GBHs), such as RoundUp®, are among the most widely used weed control solutions in modern agriculture [20]. Glyphosate functions by inhibiting the enzyme 5-enol-pyruvyl-shikimate-3-phosphate synthase (EPSPS), which is essential for plant and microbial metabolism [21]. While effective at managing weeds, the widespread use of glyphosate has raised concerns about its long-term impact on human health, soil health, nutrient availability, and food production [22].

Persistence and Chelation of Micronutrients

Glyphosate binds tightly to soil particles, with its persistence varying based on soil type, microbial activity, and environmental conditions [23]. Its half-life in soil ranges from a few weeks to more than six (6) months, depending on factors such as microbial degradation rates and soil composition. Repeated applications lead to the buildup and extended persistence of glyphosate in the soil. The continuing presence of glyphosate negatively impacts soil fertility by reducing the bioavailability of essential minerals, including iron (Fe), calcium (Ca), magnesium (Mg), manganese (Mn), copper (Cu), boron (B), and zinc (Zn) [24]. These micronutrients are crucial for plant growth, disease resistance, and the production of nutrient-dense foods [25]. Glyphosate, a known chelating agent, can lock these nutrients in forms that are unavailable to plants, potentially leading to deficiencies in crops and reducing overall food quality [26].

Long-Term Consequences of Glyphosate Accumulation

The persistence of glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA), in soil poses significant long-term risks to soil function, microbial diversity, plant health and food

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safety. Glyphosate can remain in soil for weeks to years, depending on frequency of use, environmental conditions, microbial degradation capacity, and soil composition, with AMPA often exhibiting even greater persistence due to its reduced biodegradability [27,28]. Over time, glyphosate and AMPA accumulation can disrupt soil nutrient cycling by chelating essential micronutrients such as manganese (Mn), zinc (Zn), and iron (Fe), making them less bioavailable to plants and inhibiting critical enzymatic functions necessary for growth and disease resistance [5,29]. Furthermore, glyphosate selectively inhibits beneficial microbial populations, such as nitrogen-fixing bacteria and phosphate-solubilizing organisms, while favoring pathogenic fungi and opportunistic microbes that thrive in disturbed ecosystems [30,31]. This imbalance in microbial communities weakens soil structure, reduces organic matter decomposition rates, and impairs soil fertility and water retention capacity. The long-term consequences of glyphosate accumulation therefore extend beyond immediate herbicidal effects, contributing to the progressive decline of soil health, reduced crop productivity, and an increased reliance on synthetic fertilizers to compensate for nutrient deficiencies [5,32]. Addressing glyphosate persistence through microbial remediation strategies is essential to restoring soil balance, enhancing nutrient cycling, and supporting sustainable agricultural practices.

A Microbial Approach to Glyphosate Remediation and Soil Health

The Power of Microbial Inoculants

Microbial soil inoculants offer a promising solution to counteract these effects and restore soil health [33]. By introducing beneficial bacteria that degrade glyphosate and AMPA, microbial formulations accelerate soil detoxification and enhance nutrient availability. Certain strains of *Bacillus, Pseudomonas,* and *Paenibacillus* have been shown to break down glyphosate into phosphate, carbon dioxide, and amino acids, reducing its persistence and restoring soil balance [34]. These microbes contribute to rebuilding soil structure, enhancing water retention, and improving organic matter decomposition, all of which are critical for producing healthy, nutrient-rich crops [18].

While glyphosate remediation is critical for reducing its persistence in agricultural soils, a more holistic approach is needed to not only break down residual herbicides but also restore soil vitality, improve crop productivity, and produce nutrient-dense foods. Simply eliminating glyphosate residues does not address the deeper issue of soil degradation, loss of beneficial microbes, and declining nutrient availability. A truly effective solution requires rebuilding soil ecosystems, enhancing microbial diversity, and improving the biological functions that support plant health. This is where microbial inoculants play a crucial role.

Microbial Inoculants Restore a Healthy Soil Microbiome

Microbial inoculants not only aid in the breakdown of residual herbicides but also foster a more resilient and self-sustaining soil microbiome [35,36]. When combined with regenerative agricultural practices, such as reduced tillage, organic amendments, and diversified crop rotations, microbial soil treatments can play a vital role in reversing soil degradation. Healthier soils lead to

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stronger plants, higher yields, and more nutrient-dense foods, ensuring that agricultural production supports both short-term productivity and long-term soil regeneration [7].

RESILIENCE™: A Microbial Solution to Degrade Glyphosate, Improve Soil Health and Enhance Food Quality and Safety.

How RESILIENCE Works

RESILIENCE, a specialized microbial formulation developed and manufactured by Ancient Organics Bioscience, combines glyphosate-degrading bacteria with soil-enhancing microbes to accelerate herbicide breakdown while simultaneously restoring nutrient cycling and soil fertility. These beneficial microbes work synergistically to decompose glyphosate and AMPA, unlock essential minerals bound in the soil, and improve plant access to key nutrients such as nitrogen, phosphorus, and micronutrients. By integrating RESILIENCE into soil management strategies, farmers can not only mitigate glyphosate contamination but also rebuild soil structure, enhance water retention, and increase crop resilience to environmental stress. The result is a healthier, more productive agricultural system that supports higher yields, reduces reliance on synthetic inputs, and delivers food with superior nutritional value and reduced environmental contaminants. Adopting this microbial-based approach ensures that farmland remains productive for future generations while addressing immediate concerns about herbicide persistence and its impacts on soil health and human health.

Key Benefits of RESILIENCE

Accelerates Glyphosate Breakdown

RESILIENCE is specifically formulated with glyphosate-degrading microbes that enhance the natural biodegradation process of glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA). These beneficial microorganisms, including *Bacillus, Pseudomonas,* and *Paenibacillus* species, produce specialized enzymes that break down glyphosate into phosphate, carbon dioxide, and amino acids, rendering it harmless while restoring soil fertility [37,38]. Controlled studies have demonstrated that soils treated with RESILIENCE show up to a 50% reduction in glyphosate residues within thirty (30) days, with degradation exceeding 90% within six (6) months, significantly outpacing natural attenuation [28]. This accelerated breakdown reduces long-term herbicide accumulation, mitigating its negative effects on soil microbiota and nutrient availability.

Increases Microbial Diversity and Nutrient Availability

By replenishing beneficial soil microbes, RESILIENCE restores microbial diversity that has been disrupted by prolonged glyphosate exposure and chemical farming practices. The microbial strains in RESILIENCE help repopulate nitrogen-fixing bacteria, phosphate-solubilizing organisms, and other beneficial microbes essential for soil fertility [30]. This restoration of microbial balance enhances nutrient cycling by making essential minerals such as nitrogen (N), phosphorus (P), potassium (K), and micronutrients like manganese (Mn) and zinc (Zn) more bioavailable to

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plants [29]. By breaking the dependency on synthetic fertilizers, RESILIENCE enables more sustainable and biologically driven soil management practices.

Enhances Soil Structure and Water Retention

Healthy soils rely on microbial activity to maintain structure, organic matter content, and water-holding capacity. RESILIENCE enhances soil aggregation by stimulating microbial polysaccharide production, which improves porosity and aeration while increasing water retention [39]. This effect is particularly beneficial in drought-prone regions, where enhanced soil structure prevents erosion and compaction, leading to improved plant root penetration and nutrient absorption. The beneficial microbes in RESILIENCE also contribute to organic matter decomposition, increasing soil organic carbon levels, which further enhances water infiltration and retention.

Improves Plant Resilience, Food Quality and Safety

By restoring soil health and improving nutrient bioavailability, RESILIENCE enhances plant growth, RESILIENCE, and productivity. Crops grown in RESILIENCE-treated soils demonstrate stronger root systems, greater drought tolerance, and improved resistance to pests and diseases due to the restoration of beneficial microbial communities that produce plant-growth-promoting compounds ([30,31]. Additionally, the enhanced nutrient uptake from improved soil conditions leads to higher micronutrient concentrations in edible plant tissues, resulting in more nutrient-dense food [29]. This is particularly critical in addressing widespread deficiencies in iron, zinc, and magnesium in modern diets, making RESILIENCE a valuable tool for both agricultural productivity and human health. RESILIENCE breaks down environmental toxins such as glyphosate, further improving the safety and quality of our food supply.

Scientific Validation

Glyphosate Bioremediation Studies

Bioremediation using microbial inoculants such as RESILIENCE offers a promising, nature-based solution to glyphosate accumulation by accelerating the degradation of glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA). The bacterial strains in RESILIENCE produce specialized enzymes that break down these compounds into phosphate, amino acids, carbon dioxide, and water, effectively detoxifying the soil while improving its fertility.

In multiple controlled studies RESILIENCE-treated soils showed up to a 50% reduction in glyphosate residues within thirty (30) days, up to 83% in ninety (90) days, and over 90% in one hundred eighty (180) days. This degradation process releases essential minerals that have been chelated by glyphosate, restoring soil fertility and enhancing plant nutrient uptake [40].

Evaluating RESILIENCE's Effectiveness Across Crops

Field trials conducted in diverse agricultural environments—including cotton and corn fields, vineyards, and controlled greenhouse systems—demonstrate that RESILIENCE effectively reduces glyphosate residues, restores microbial diversity, and improves soil fertility. These studies provide compelling evidence that microbial-based soil restoration can enhance crop productivity, reduce dependency on chemical inputs, and improve the nutritional quality of harvested

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produce. The following sections outline the key findings from these trials and illustrate the broad-spectrum effectiveness of RESILIENCE across different cropping systems.

Cotton and Corn: Enhancing Large-Scale Row Crop Systems

In large-scale row crop systems such as cotton and corn, where glyphosate-based herbicides are frequently applied, RESILIENCE significantly accelerated glyphosate degradation and improved soil health. A field study conducted in a cotton farm in Tanner, Alabama measured the persistence of glyphosate and its primary metabolite, aminomethylphosphonic acid (AMPA), over a 90-day period. In RESILIENCE-treated fields, glyphosate residues declined by 74.8%, compared to just 33.5% in untreated control fields, demonstrating that microbial inoculation nearly doubled the degradation rate of the herbicide. Figure 1 illustrates these results.

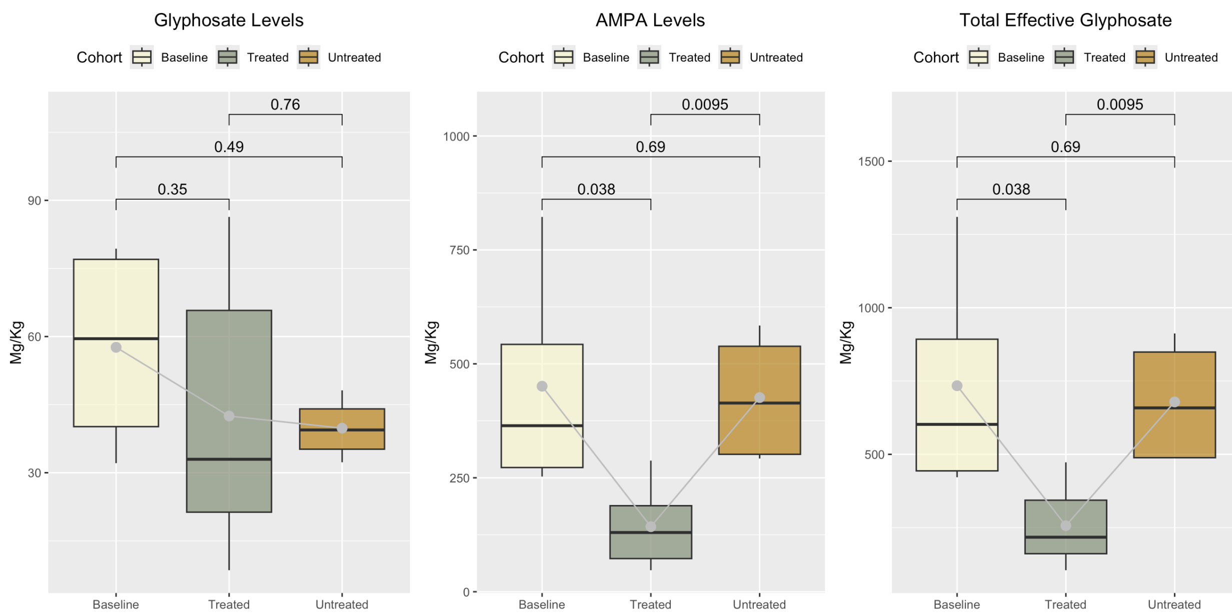

Figure 1. Glyphosate Degradation Dynamics in Treated Cotton Fields.

Boxplot of Glyphosate, AMPA, and TEG Concentrations Across the Baseline (Day 0), Untreated (natural attenuation), and Treated Cohorts. The plot was constructed in R using the ggplot2 and ggpubr packages. Statistical comparisons between cohorts were performed using t-tests, with significance indicated by p-values above the brackets. Grey circles represent the mean concentration for each cohort.

Concurrently, soil microbial diversity, measured using the Shannon diversity index, increased by 42.3%, indicating a significant restoration of beneficial bacteria that contribute to nutrient cycling and organic matter decomposition. Additionally, soil organic matter content increased by 15.7%, which improved water retention and soil structure, key factors in promoting sustainable plant growth and reducing reliance on synthetic fertilizers.

Figure 2 presents four key soil diversity metrics—Chao1 Diversity, Shannon Diversity, Phylogenetic Diversity, and Pielou's Evenness—demonstrating that RESILIENCE significantly enhances

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microbial richness, evenness, and phylogenetic complexity. Chao1 Diversity, a measure of species richness, was significantly higher in treated soils ($p = 0.003$), indicating a greater diversity of beneficial microbes essential for soil fertility. Shannon Diversity also increased ($p = 0.007$), confirming a shift toward a more balanced and functional microbial ecosystem.

The increase in phylogenetic diversity ($p = 0.016$) suggests greater functional stability, making the soil microbiome more resilient to environmental changes. Similarly, Pielou's Evenness ($p = 0.045$) improved, ensuring a more uniform distribution of microbial species, which prevents the overgrowth of opportunistic or pathogenic organisms.

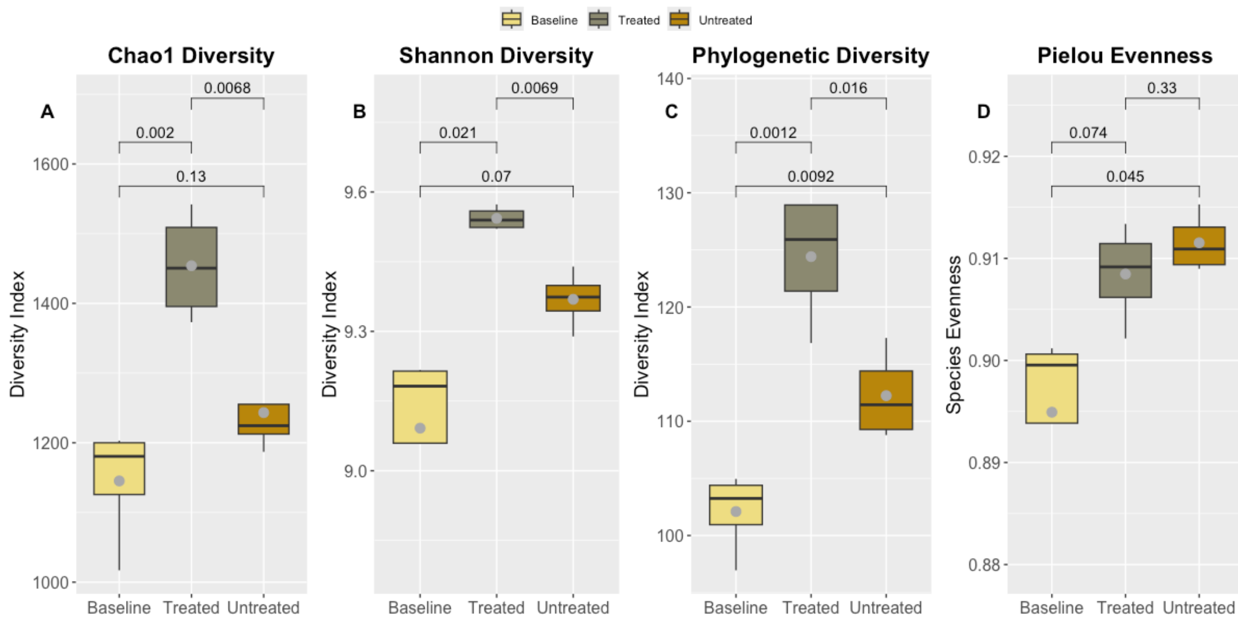

Figure 2: RESILIENCE Enhances Soil Microbial Diversity, Evenness, and Ecosystem Stability.

Boxplots of alpha diversity metrics for baseline (pre-harvest), treated (post-harvest), and untreated (post-harvest) cohorts. Statistical comparisons between cohorts were performed using t-tests, with p-values displayed above the comparisons. Grey circles represent the mean values for each cohort.

These results confirm that RESILIENCE restores microbial diversity, enhances soil RESILIENCE, and promotes biological nutrient cycling. By improving soil microbiome stability, RESILIENCE contributes to long-term soil health, increased crop productivity, and a more sustainable agricultural system.

Similarly, trials conducted in corn fields in Grand Mound, Iowa, further reinforced the efficacy of RESILIENCE in row crops. Over a 120-day observation period, glyphosate levels in treated soils decreased by 87.4%, whereas natural attenuation resulted in only 66.5% degradation.

The enhanced microbial degradation of glyphosate was accompanied by improved soil fertility indicators, including a 22.1% increase in nitrate-nitrogen (NO_3^-) availability, suggesting that RESILIENCE enhances nitrogen mineralization and uptake efficiency. Corn yields in treated plots were 28.6% higher than untreated controls, with improved biomass accumulation and stronger

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root development. Silage nutritional analysis also indicated increased levels of key micronutrients, highlighting the role of microbial inoculation in enhancing both productivity and nutritional density in large-scale row crops.

Implications for Soil Health and Food Security

These findings highlight the importance of microbial-based soil solutions in modern agriculture. Glyphosate residues in soil not only persist for extended periods but also disrupt nutrient availability, microbial balance, and overall soil function. By integrating biological degradation pathways, solutions like RESILIENCE provide a targeted approach to glyphosate mitigation, allowing farmers to restore soil integrity, reduce environmental toxins and improve crop nutrition.

Beyond herbicide degradation, the application of microbial soil inoculants plays a key role in enhancing nutrient cycling and improving soil structure. Glyphosate is known to chelate essential minerals, making them unavailable for plant uptake. RESILIENCE accelerates glyphosate breakdown, releasing these bound nutrients and promoting healthier root systems and stronger plant growth. This contributes to:

- Improved soil fertility, ensuring that crops receive adequate minerals for development.
- Higher nutrient density in crops, leading to better food quality and nutritional value.
- Stronger plant RESILIENCE, reducing susceptibility to disease and environmental stress.

Further large-scale field studies are necessary to refine application strategies and evaluate long-term benefits across different soil types and crop production systems. Additionally, research should continue to assess RESILIENCE's ability to break down other environmental toxins such as atrazine and its role in enhancing soil microbial diversity, optimizing nutrient availability, and supporting productive agricultural ecosystems.

The Impact of RESILIENCE on Soil Health and Crop Productivity

RESILIENCE offers a science-backed solution for restoring soil function and improving food quality and safety. Unlike chemical-based remediation, microbial inoculants both remove contaminants and enhance soil biology, unlocking nutrients, improving water retention, and supporting plant-microbe interactions for higher yields. Expanding research and field trials will help farmers adopt these scalable solutions to combat soil degradation and glyphosate contamination. Prioritizing soil health ensures long-term productivity, crop nutrition, food quality and safety, with RESILIENCE providing a practical path toward sustainable agriculture

RESILIENCE Restores Soil Health

Restoring soil function is essential for maintaining productive agricultural systems and ensuring high-quality food production. Over time, the accumulation of glyphosate and other agrochemicals can disrupt soil microbial communities, limit nutrient availability, and degrade overall soil structure. Addressing these challenges requires a targeted approach that not only mitigates chemical residues but also revitalizes soil biology.

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To evaluate the impact of microbial inoculants on soil health and crop nutrition, a controlled, multi-plot study was conducted using corn as the test crop. The study measured glyphosate degradation, along with key soil health indicators and nutrient uptake in plants, providing a comprehensive assessment of the intervention's effectiveness. The soil health metrics reveal substantial improvements in key soil parameters following treatment, as seen in the table below, demonstrating the effectiveness of the intervention in enhancing soil biological activity, nutrient availability, and overall soil fertility.

The application of RESILIENCE led to significant enhancements in soil fertility and microbial function, as reflected in key soil health indicators.

- Soil Organic Carbon (SOC): While total SOC was slightly lower in treated soils (118.00 ± 5.62 mg/kg vs. 148.00 ± 11.37 mg/kg), this suggests higher microbial activity and nutrient turnover, making organic carbon more bioavailable for plant uptake.
- Cation Exchange Capacity (CEC): Treated soils showed a 23.1% increase in CEC (8.78 vs. 7.13 meq/100g), indicating improved nutrient retention and availability, reducing leaching and enhancing soil fertility.
- Microbial Activity: Microbial Organic Carbon (MOC) tripled in treated soils (80.48 vs. 24.83 mg/kg), and CO_2 respiration increased by 167%, confirming greater microbial biomass and metabolic function, key drivers of nutrient cycling and organic matter decomposition.

These improvements highlight RESILIENCE's role in restoring soil function, increasing nutrient efficiency, and fostering a biologically active soil ecosystem essential for sustainable agriculture. These results are summarized in Table 1.

Table 1. Impact of RESILIENCE on Soil Health Metrics

Parameter	Treated (Mean ± SD)	Untreated (Mean ± SD)
Soil Organic Carbon (mg/kg)	118.00 ± 5.62	148.00 ± 11.37
Soil Health Score	13.26 ± 2.33	8.79 ± 0.80
Microbial Organic Carbon (mg/kg)	80.48 ± 23.54	24.83 ± 5.18
CO_2 Soil Respiration (mg/kg/day)	95.83 ± 30.34	35.88 ± 5.92
Cation Exchange Capacity (meq/100g)	8.78 ± 0.22	7.13 ± 0.55
NO_3-N (mg/kg)	38.15 ± 3.58	31.75 ± 4.43
NH_4-N (mg/kg)	0.6 ± 0.08	1.68 ± 0.41
Potassium (K, mg/kg)	368.75 ± 11.14	289.75 ± 34.11
Organic Matter (LOI, %)	1.90 ± 0.07	1.70 ± 0.07

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Impact of RESILIENCE on Corn and Specialty Crop Yields

These studies demonstrate the significant impact of RESILIENCE on crop yields, particularly in corn and silage, as well as a diverse range of specialty crops. Given that corn was the primary test crop, a detailed analysis of its response to microbial soil treatment provides insights into the underlying mechanisms that drive yield improvements across various crops.

Corn Yield and Agronomic Performance

Table 2 presents key agronomic metrics comparing RESILIENCE-treated and untreated corn fields. The data indicate a 28.6% increase in total corn yield, which is a substantial improvement in agricultural productivity. Additionally, corn ear density improved by 17.6%, reflecting stronger plant development due to better soil structure, microbial activity, and nutrient bioavailability.

Silage yields also exhibited notable gains, with a 9.6% increase in total biomass production, reinforcing the benefits of RESILIENCE in enhancing plant vigor and overall crop quality. Importantly, silage milk per acre increased by 9.3%, indicating improved nutritional density in the harvested feed. This suggests that RESILIENCE not only improves total yield but also enhances the nutrient composition of forage crops, which is crucial for livestock health and feed efficiency.

Table 2. Impact of RESILIENCE on the Agronomic Performance of Corn and Silage

Parameter	Treated (Mean ± SD)	Untreated (Mean ± SD)	% Change
Corn Yield (tons/acre)	7.20 ± 1.79	5.60 ± 0.68	+28.6%
Corn Ear Density	38.50 ± 1.87	32.75 ± 2.05	+17.6%
Grain Yield	246.40 ± 6.68	235.57 ± 7.03	+4.6%
Silage Yield (tons/acre)	36.26 ± 1.18	33.08 ± 1.51	+9.6%
Silage Milk/acre (lbs.)	121,703.00 ± 6,320.59	111,333.75 ± 3,652.58	+9.3%
Silage Milk/ton (lbs.)	3,426.00 ± 183.84	3,332.25 ± 67.36	+2.8%

Yield Improvements Across Diverse Crops

Beyond corn, the impact of RESILIENCE extended to specialty crops, as illustrated in Figure 3. The highest yield improvements were observed in onions (+48%), carrots (+38%), and pumpkins (+36%), highlighting the broad-spectrum effectiveness of microbial inoculation in enhancing soil fertility and plant productivity. The increased yields across diverse crop types suggest that RESILIENCE plays a key role in improving nutrient cycling, soil structure, and root development, all of which contribute to greater agricultural sustainability.

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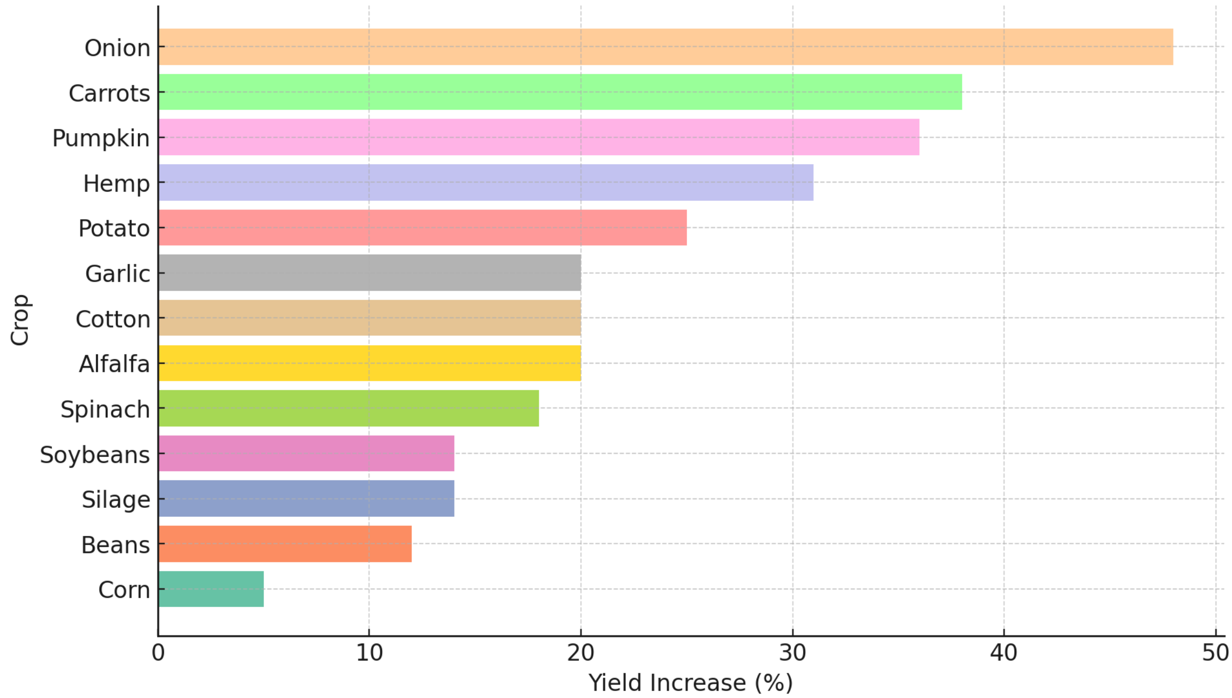

Figure 3. Yield Increase Across Various Crops with RESILIENCE Treatment

This bar chart illustrates the percentage increase in crop yield for various crops treated with RESILIENCE, compared to untreated controls. The data highlights significant yield improvements across row crops (corn, soybeans, cotton, silage), specialty crops (onion, garlic, spinach, pumpkin), and forage crops (alfalfa, hemp).

Microbial Mechanisms Behind Yield Increases

The yield gains observed across multiple crops are likely driven by enhanced microbial diversity and activity in the soil, which contribute to:

- Greater nutrient availability: Improved nitrogen fixation and phosphorus solubilization, reducing the need for synthetic fertilizers.
- Better soil structure: Increased organic matter decomposition leading to enhanced water retention and aeration, particularly beneficial for root crops such as onions and carrots.
- Enhanced plant resilience: A healthier soil microbiome strengthens crop resistance to drought, disease, and environmental stress, contributing to higher yield stability.

The results of these studies confirm that RESILIENCE significantly enhances soil health and crop performance, with consistent yield improvements in both staple and specialty crops. The substantial gains in corn yield, silage quality, and specialty crop productivity highlight the potential of microbial inoculants as a sustainable agricultural solution.

RESILIENCE Increases Nutrient Density in Crop Plants

The application of RESILIENCE significantly improved nutrient cycling and plant uptake, as demonstrated by the percent changes in micronutrient concentrations in soil and corn leaf tissues (Figure 4). These findings highlight the role of the soil microbiome in unlocking bound nutrients and making them more accessible to plants, leading to improved nutritional density in crops.

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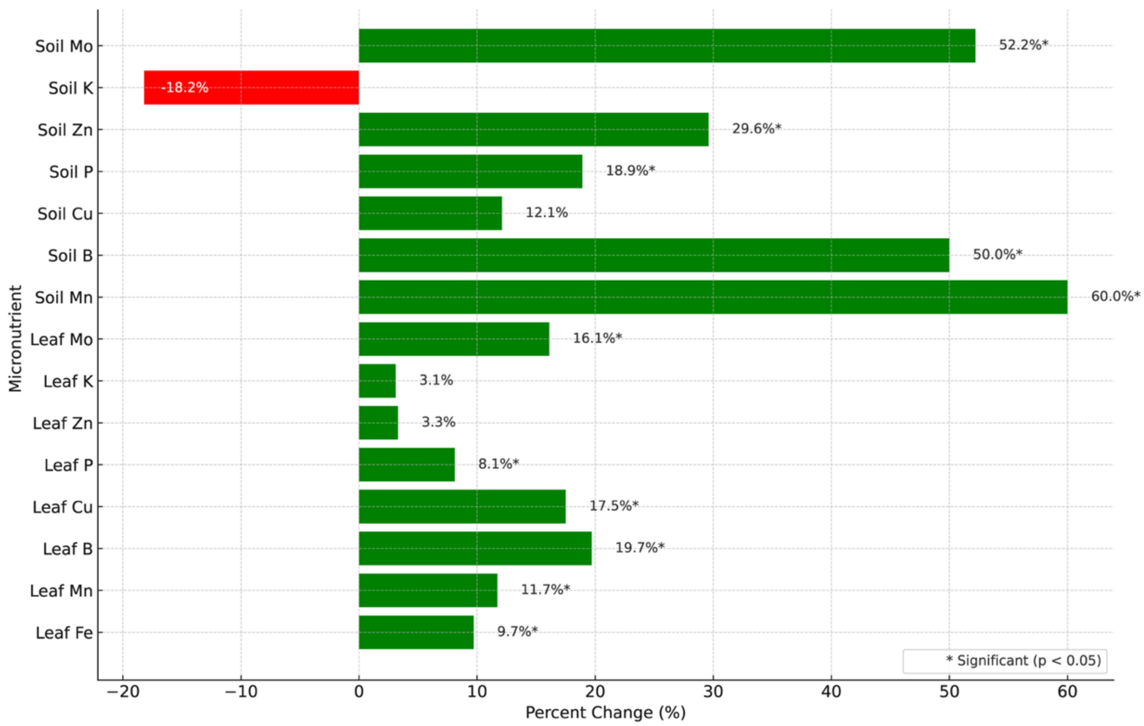

Figure 4: Nutrient Release and Uptake in Soil and Corn Leaves Following Microbial Treatment

The figure illustrates relative changes in micronutrient levels between treated and untreated groups. Green bars represent improved nutrient availability or plant uptake, while red bars indicate potential decreases, likely due to higher plant absorption. Statistically significant differences ($p < 0.05$) are marked with an asterisk (*).

The application of RESILIENCE significantly improved nutrient cycling and plant uptake, as demonstrated by the percent changes in micronutrient concentrations in soil and corn leaf tissues (Figure 4). These findings highlight the role of the soil microbiome in unlocking bound nutrients and making them more accessible to plants, leading to improved nutritional density in crops.

Soil Nutrient Release and Mobilization

Notable increases in soil nutrient availability occurred in molybdenum (Mo, +52.2%), boron (B, +60.0%), and zinc (Zn, +29.6%), all essential for enzyme activation, nitrogen metabolism, and plant development. These increases suggest that RESILIENCE stimulates microbial communities that enhance mineral solubilization and nutrient exchange within the soil. However, a slight reduction in soil potassium (K, -18.2%) was observed, likely due to higher uptake by plants, which is reflected in the leaf nutrient data.

Increased Nutrient Uptake in Corn Leaves

Enhanced soil microbial activity translated into higher micronutrient concentrations in corn leaf tissues, confirming greater plant uptake of essential elements. Boron (+19.7%), iron (+9.7%), and molybdenum (+3.1%) showed notable increases in leaf tissues, reinforcing the role of microbial activity in improving nutrient availability. The uptake of phosphorus (P, +18.9%) and zinc (Zn,

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+12.1%) further suggests that RESILIENCE enhances root absorption efficiency, reducing reliance on synthetic fertilizers.

Implications for Soil Health and Crop Nutrition

The increased nutrient bioavailability and higher uptake efficiency contribute to stronger plant growth, improved stress tolerance, and higher crop yields. By restoring microbial diversity and stimulating beneficial interactions between soil bacteria and plant roots, RESILIENCE supports a more sustainable and nutrient-dense agricultural system. These results reinforce the importance of microbial inoculants in modern farming, offering a natural solution to declining soil fertility and nutrient depletion.

Ancient Organics Bioscience: Pioneering Soil Regeneration Solutions

Our Commitment to Microbial Innovation

Ancient Organics Bioscience is dedicated to reducing chronic diseases and securing a safe and healthy food supply by restoring soil health and productivity, through scientifically validated microbial solutions. We rely upon cutting edge metagenomic, metabolomic, and microbiome research and leverage advances in microbial ecology, bioremediation, and plant-microbe interactions to develop highly effective soil restoration technologies.

Through years of laboratory research, controlled trials, and large-scale field applications, we have formulated RESILIENCE, a microbial inoculant to enhance soil biodiversity, degrade persistent agrochemicals such as glyphosate, and optimize nutrient cycling.

Unlike conventional agricultural inputs that rely on synthetic fertilizers and chemical amendments, our microbial-based technologies rebuild soil function from the ground up by:

- Enhancing microbial diversity, fostering a resilient soil ecosystem.
- Breaking down harmful chemical residues such as glyphosate and AMPA, reducing soil toxicity.
- Increasing nutrient bioavailability, allowing plants to uptake key micronutrients efficiently, thereby improving micronutrient density.
- Improving soil structure and water retention, making crops more resilient to drought and environmental stressors.

We believe that the future of sustainable agriculture depends on harnessing the natural synergy between microbes, soil, and plants. By focusing on biological soil regeneration, Ancient Organics Bioscience is leading the transition toward regenerative farming, ensuring long-term food safety, quality and security, environmental sustainability, and economic viability for farmers.

The Holobiont Approach: Soil, Plants, and Microbes as One Ecosystem

At the core of our soil restoration philosophy is the holobiont approach—a scientific framework that recognizes plants, soil microbes, and the surrounding environment as an interconnected system. In this model, soil health is inseparable from plant health, and microbial diversity is essential for sustainable crop production [41].

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Microbial communities in the soil regulate nutrient cycling, enhance disease resistance, and improve soil structure, creating a self-sustaining ecosystem that reduces reliance on external chemical inputs. By integrating RESILIENCE into regenerative agricultural practices such as reduced tillage, organic amendments, and crop rotation, we strengthen the natural interactions that drive soil fertility and plant resilience.

Key components of our holobiont-based approach include:

- Symbiotic microbial communities that support root colonization, pathogen suppression, and plant immunity.
- Enhanced mycorrhizal networks, improving nutrient exchange between plants and soil microbes.
- Microbial degradation of agrochemical residues, reducing the accumulation of persistent contaminants in farmland.
- A self-renewing soil system, where microbial succession maintains long-term soil fertility and ecosystem balance.

By adopting the holobiont perspective, Ancient Organics Bioscience is transforming soil restoration from a chemical-dependent practice into a biologically driven solution. Our commitment to microbial innovation ensures that agriculture can thrive, producing nutrient-dense crops while rebuilding the foundation of healthy soils for future generations.

A Practical Path Forward for Farmers and Policymakers

The challenges facing modern agriculture—soil degradation, declining crop nutrient density, and the persistent impact of agrochemicals like glyphosate—demand science-backed, sustainable solutions. Microbial-based soil regeneration presents a practical, scalable approach to restoring soil health, enhancing plant resilience, and ensuring food security while reducing reliance on synthetic inputs. By embracing biological interventions, farmers and policymakers can drive a transition toward regenerative agriculture, promoting long-term environmental and economic benefits.

The Role of Science-Backed Solutions in Agriculture

Microbial-based approaches represent the next frontier of sustainable agriculture, offering solutions rooted in soil microbiome science, ecosystem restoration, and precision agriculture. Research has demonstrated that healthy microbial communities play a crucial role in nutrient cycling, organic matter decomposition, and plant-microbe symbiosis [36,42]. Unlike conventional chemical inputs, which temporarily boost fertility but degrade soil function over time, microbial inoculants work with nature, rather than against it, rebuilding the foundation of biologically active, self-sustaining soil systems.

Key benefits of adopting microbial-based agricultural strategies include:

- Enhanced soil fertility through natural nitrogen fixation, phosphorus solubilization, and organic matter decomposition.
- Improved plant resilience against pests, pathogens, and environmental stressors, reducing the need for synthetic pesticides and fungicides.

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- Accelerated breakdown of residual agrochemicals, including glyphosate and AMPA, mitigating their long-term impact on soil productivity and presence in the food supply.
- Higher crop nutrient density, resulting in healthier food for consumers while maintaining or increasing agricultural yields.

For these solutions to reach widespread adoption, continued collaboration between scientists, policymakers, and agricultural stakeholders is essential. Regulatory frameworks and incentive programs must be designed to support the integration of microbial technologies into large-scale farming.

Next Steps: Scaling Microbial-Based Soil Regeneration

To ensure broad implementation and long-term success, microbial-based soil regeneration must be scaled through a combination of research, policy support, and farmer adoption strategies.

- Expanding Scientific Research & Field Trials
    - Large-scale, multi-year studies are needed to validate microbial formulations under diverse climatic and soil conditions.
    - Research should focus on long-term microbial stability, soil carbon sequestration, and economic benefits for farmers.
- Policy Considerations & Incentives for Adoption
    - Policymakers must recognize microbial soil amendments as a viable alternative to synthetic inputs and support regulatory pathways for approval.
    - Government grants, carbon credit incentives, and subsidies can encourage farmers to transition to biological soil restoration methods.
- Farmer Education & Implementation Strategies
    - On-farm demonstrations and knowledge-sharing networks can accelerate farmer adoption by showcasing real-world success stories.
    - Integration of microbial soil inoculants into existing precision agriculture models can optimize application rates and maximize return on investment.

By scaling microbial-based soil regeneration, we can fundamentally shift agricultural systems toward resilience, sustainability, productivity, and human health. The transition requires scientific rigor, supportive policies, and active engagement from the agricultural community, but the long-term economic, environmental, and health benefits far outweigh the costs. Microbial technologies provide a science-driven, field-tested solution for rebuilding soil health, ensuring that future generations inherit productive, biologically rich farmlands rather than degraded, chemically dependent soils. Our food with be healthier and safer.

Conclusion: Building a Productive Agricultural Future with RESILIENCE

The foundation of productive farming lies in healthy, biologically active soil. The evidence presented in this document confirms that RESILIENCE improves soil function, reduces levels of environmental toxins, enhances nutrient availability, and restores the microbial communities essential for long-term agricultural productivity. By addressing the accumulation of environmental toxins such as glyphosate and the increasing nutrient depletion and declining fertility of our

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soil, microbial-based solutions provide a practical, science-backed approach to improving land restoration, food production, food quality and safety.

Restoring Soil and Improving Food Quality and Safety for Generations to Come

Modern agricultural practices have significantly impacted soil structure, microbial diversity, and nutrient retention, leading to declining crop quality and increased reliance on chemical inputs. However, by integrating biological soil treatments, farmers can:

- Break down persistent residues of environmental toxins such as glyphosate, restoring natural soil balance and improving food safety.
- Replenish essential soil microbes, improving nutrient cycling and plant uptake.
- Increase crop yields and improve food nutrient density, ensuring a higher quality food supply.
- Enhance water retention and soil structure, reducing the need for excessive irrigation and artificial fertilizers.

A shift toward microbial-enhanced soil management ensures that farmland remains productive, resilient, and capable of meeting future agricultural demands. As soil health improves, so does food safety and quality, farm efficiency, and long-term land value.

Partnering for a Stronger Agricultural Future

Advancing soil restoration and productivity requires collaboration among farmers, researchers, and policymakers. To achieve widespread adoption of microbial-based solutions, it is critical to:

- Support further field trials and research to optimize microbial soil treatments across different crops and regions.
- Develop policies that recognize microbial solutions as an essential tool for enhancing soil fertility and improving crop quality.
- Educate farmers, agribusinesses, and food manufacturers on the benefits of biological soil restoration to reduce chemical dependence, improve land management, and produce safer and healthier foods.

Partnering with Ancient Organics Bioscience

Ancient Organics Bioscience is at the forefront of developing evidenced-based microbial solutions to restore soil health, improve crop productivity, and reduce reliance on chemical inputs. Healthier soil produces healthier plants which results in healthier foods

The company was founded in 2017 by Raul Cano, Ph.D., a world-renowned microbial ecologist and Professor Emeritus at California Polytechnic State University, San Luis Obispo, where he taught for 35 years. As a Fellow of the American Academy of Microbiology, Dr. Cano has made groundbreaking contributions to understanding microbial ecosystems and their applications in bioremediation, agriculture, and human health.

Dr. Cano's research directly influenced the development of the company's flagship product, RESILIENCE™, which relies on cutting edge metagenomic, metabolomic and microbiome modeling to provide a scientifically validated approach to soil restoration and nutrient management. His

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transition from academic research to practical innovation underscores his commitment to translating scientific discovery into real-world solutions.

Ancient Organics Bioscience continues to lead the way in developing evidenced-based microbial solutions for regenerative agriculture, ensuring that farmers, industry leaders, and policymakers have access to proven tools for improving soil function, increasing crop yields, and enhancing food quality and safety.

We invite government agencies, industry leaders, and farmers to work with us to rebuild the future of agriculture in America – a future built on healthy soil, reduced use of chemical inputs, higher-yielding crops, and improved food quality and safety.

Partner with us in our efforts to support production of nutrient dense foods free of contamination by environmental toxins - Make America Healthy Again!

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