PROCEEDINGS OF VII. INTERNATIONAL AGRICULTURAL, BIOLOGICAL, LIFE SCIENCE CONFERENCE AGBIOL 2025

07-10 SEPTEMBER 2025

ISTANBUL, TÜRKİYE

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Organized by
Trakya University
Istanbul Beykent University
International Researchers Association

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WELCOME NOTES

You are welcome to our VII. AGBIOL Conference that is organized by Trakya University, Beykent University and International Researchers Association. The aim of our conference is to present scientific subjects of a broad interest to the scientific community, by providing an opportunity to present their work as oral or poster presentations that can be of great value for global science arena. Our goal was to bring three communities, namely science, research and private investment together in a friendly environment of Edirne, Turkey in order to share their interests and ideas and to get benefit from the interaction with each other.

In September 2018, we organized the first AGBIOL Conference with more than 700 scientists and researchers from all over the world with over 800 scientific papers. Due to COVID-19 situation, II. AGBIOL 2020 has organized fully on-line event which was one of the biggest online conferences in recent years in the world with 499 papers and 1133 authors with 333 oral and 166 e-poster presentations from 55 countries. Due to COVID-19 situation, AGBIOL 2021 was organized online again. AGBIOL 2022 conference was organized with a worldwide participation from 44 countries over 522 papers contributed by over 1300 authors. AGBIOL 2023 was organized with a record and worldwide participation from 33 countries 833 papers contributed by over 2000 authors with 522 oral and 311 poster presentations. AGBIOL 2024 consisted of 835 papers contributed by about 2000 authors with worldwide recodr participation again from 55 countries with 522 oral and 311 poster presentations.

There is a worldwide record participation from 60 countries 988 papers contributed over 2300 authors with 400 oral and 588 poster presentations in AGBIOL 2025.

The AGBIOL 2025 is normal participation as well as with online participation in Beykent University in Istanbul, Turkey on 07-10 September, 2025. The program included oral talks by invited prominent scientists and oral and e poster presentations by participants in selected topics from the submitted abstracts focusing on Agriculture, Biology and Life Sciences topics.

With care for our nature and environment, we aim the green congress, meaning that as little as possible papers will be used. Abstract book is published in electronic book and is distributed to the participants by e mail for online participants. All the e-posters are prepared in electronic form and then submit to via the conference e mail and exhibited in electronical poster boards as well as in online e poster hall in our web page during the conference.

The participants with paid conference fee accessed all the normal and virtual presentation talks in each session, as well as to visit the virtual poster hall via preliminary provided. The abstracts were published in the Conference Abstract and Proceedings Book. Participants might send us their full papers, which based on their preferences are published either in our Conference Abstract and Proceedings Book or in selected International Indexed Scientific Journals.

Conference Topics:

Agriculture, Forestry, Life Sciences, Agricultural Engineering, Aquaculture and Biosystems, Animal Science, Biomedical science, Biochemistry and Molecular Biology, Biology, Bioengineering, Biomaterials, Biomechanics, Biophysics, Bioscience, Biotechnology, Botany, Chemistry, Chemical Engineering, Earth Sciences, Environmental Science, Food Science, Genetics and Human Genetics, Medical Science, Machinery, Pharmaceutical Sciences, Physics, Soil Science.

We would like to thank all of you for joining this conference and we would like to give also special thanks to TUBITAK and collaborators for giving us a big support to organize this event.

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CONTENTS

TOXIC DIALOGUES: HERBICIDES, MICROBIAL VOICES, AND THE ECOSYSTEM'S RESPONSE

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ABSTRACT

Herbicides, long heralded as precise tools in agricultural management, leave behind echoes that reverberate through the most intimate layers of ecological networks. This study explores how herbicidal interventions—especially those involving compounds like glyphosate—silently alter microbial communities that anchor essential ecosystem functions. These non-target effects begin at the microscopic scale, where shifts in soil microbiome composition interrupt vital processes such as nutrient cycling, rhizosphere signaling, and plant–soil feedback mechanisms.

Framed through a microbiome-centric lens, we present a synthesis of recent studies alongside conceptual models illustrating how herbicide residues serve not only as chemical stressors, but as agents that restructure the metabolic dialogues among microbes and their hosts. Alterations in microbial diversity and function affect plant vitality, reduce resilience to biotic and abiotic stresses, and cascade upward to influence animal performance, herbivory dynamics, and pollination success. As herbicides disrupt these finely tuned interdependencies, we observe potential tipping points that may reshape ecosystem trajectories and even influence microbial and host evolution.

More than collateral damage, microbial responses to herbicidal exposure represent a silent rebellion—one with the power to mediate or magnify ecological instability. We advocate for integrative strategies that acknowledge microbiome health as a central criterion in agrochemical risk assessments. Understanding these subterranean symphonies is essential for mitigating the long-term consequences of anthropogenic disturbance and for crafting sustainable, microbe-conscious stewardship of ecosystems.

Keywords: microbiome, herbicides, soil microbial networks, environmental resilience, agrochemical impact, microbe-mediated risk

INTRODUCTION

Herbicides have revolutionized modern agriculture by enabling targeted and efficient weed control, contributing significantly to crop productivity and food security. Among these, **glyphosate** stands as one of the most extensively used broad-spectrum herbicides worldwide due to its effectiveness and non-selective inhibition of the *5-enolpyruvylshikimate-3-phosphate synthase* (EPSPS) enzyme in the shikimate pathway (Duke and Powles, 2008). However, while glyphosate's primary mode of action is aimed at plants, this same biochemical pathway is present in many soil microorganisms, raising growing concerns about its unintended effects on non-target species (van Bruggen et al., 2018).

Soil microbial communities, particularly those inhabiting the **rhizosphere**, play a pivotal role in maintaining ecosystem functions. These communities mediate **nutrient cycling, organic matter decomposition**, and intricate **plant–microbe interactions** that influence plant growth, health, and resistance to environmental stressors (Berg et al., 2020). Disturbances to microbial composition and diversity—whether through direct toxicity or altered plant exudation patterns—can ripple through the entire ecosystem. Emerging evidence suggests that herbicide residues can suppress **mycorrhizal colonization**, shift **bacterial community structures**, and increase plant susceptibility to **soil-borne pathogens** (Zaller et al., 2014; Newman et al., 2016; Johal and Huber, 2009).

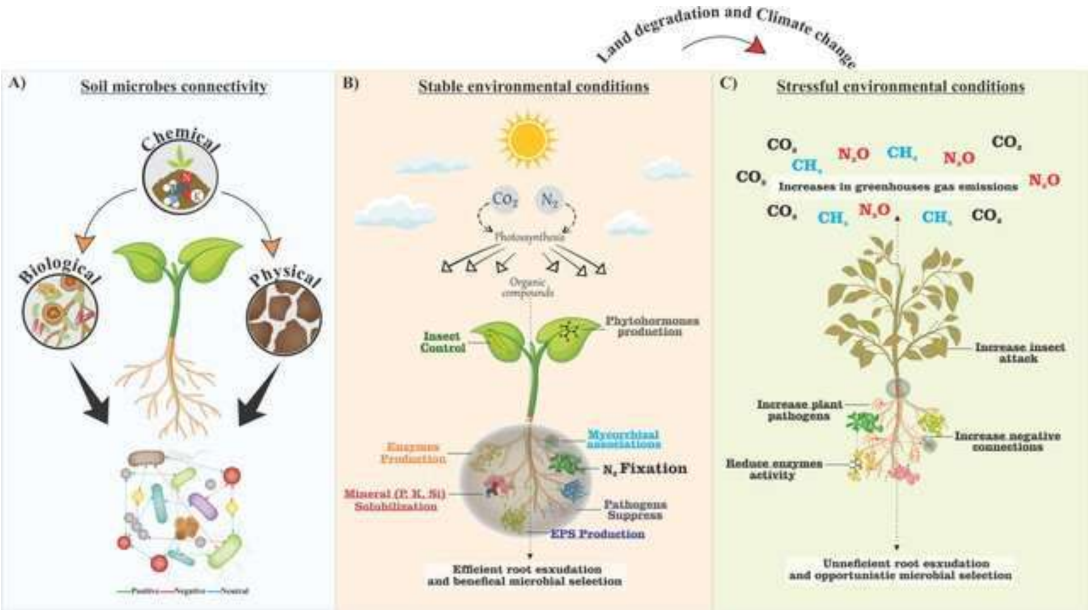

Figure 1. The intricate connections between soil biodiversity and plants. a These interactions are influenced, including chemical, physical, and biological variability. b In a stable ecosystem with no or low human disturbances, plants can effectively recruit their microbial communities, primarily facilitated through rhizosphere exudation and selection processes. This plant-soil biodiversity interactions catalyze multiple ecosystem processes such as enhanced enzyme activity, solubilization, nitrogen fixation, and disease suppressiveness. However, land degradation and ongoing climate changes disrupt these interactions, leading to an increased negative correlation among taxa. c As a result, plants become more vulnerable to harmful and opportunistic agents like insects and pathogens (from Pedrinho et al., 2024).

Importantly, these microbial alterations are not merely short-term or incidental. Herbicides may induce long-term **restructuring of microbial networks,** with implications for microbial evolution, functional redundancy, and overall soil resilience (Timmis et al., 2019). Furthermore, **chronic exposure** to glyphosate and similar compounds may drive microbial **adaptation or resistance,** potentially reducing the soil's capacity to buffer abiotic stressors such as drought or nutrient depletion (Schlatter et al., 2017).

Given the central role of the microbiome in **agroecosystem stability**, there is an urgent need to reconsider how herbicides are evaluated in terms of ecological risk. Traditional assessments focusing solely on crop yield or visible phytotoxicity fall short of capturing the subtle but profound consequences on **microbial health.** Integrating a **microbiome-centric perspective** into agrochemical regulation offers a more holistic understanding of ecosystem sustainability and resilience (Mitter et al., 2019).

This paper synthesizes recent findings on the impact of herbicides—especially glyphosate—on soil microbial communities. It aims to elucidate the biochemical, ecological, and evolutionary consequences of microbial disruption, and to advocate for frameworks that prioritize **microbial integrity** as a cornerstone of sustainable agriculture.

HERBICIDES AND THEIR LEGACY

Herbicides have revolutionized modern agriculture by enabling efficient weed control, reducing labor costs, and increasing crop yields. Since the introduction of synthetic herbicides like 2,4-D in the 1940s, over 270 active ingredients have been commercialized, shaping global farming practices and food systems (Mesnage et al, 2021; U.S. EPA, 2004). However, their legacy is complex—marked by ecological disruption, resistance evolution, and persistent residues in soil and water. Herbicides have played a central role in modern agricultural intensification, with compounds like **glyphosate, atrazine**, and **2,4-D** becoming dominant tools in weed control (Duke and Powles, 2008). Glyphosate, in particular, has been praised for its broad-spectrum action and post-emergent use. However, its primary target—the *shikimate pathway*, absent in animals but present in most plants and microbes—raises significant concerns about **non-target effects** on microbial communities (van Bruggen et al., 2018). While herbicides were initially believed to degrade rapidly in soil, increasing evidence shows that **residues persist** and interact with complex biotic and abiotic soil components, affecting ecosystem function far beyond weed suppression (Silva et al., 2019). Herbicides such as glyphosate, atrazine, and dicamba have become staples in conventional farming due to their broad-spectrum activity and compatibility with genetically modified (GM) crops (Parven et al., 2024). Systemic and pre-emergence herbicides offer targeted control, reducing the need for repeated applications and mechanical weeding.

Despite their utility, herbicides pose significant risks, as s**oil degradation** (long-term use alters microbial communities, reduces biodiversity, and impairs nutrient cycling), w**ater contamination** (runoff and leaching introduce herbicide residues into aquatic ecosystems, affecting non-target organisms like amphibians, fish, and invertebrates) and r**esistance development** (overuse has led to herbicide-resistant weed populations, complicating management and increasing chemical dependency (Mesnage and Antoniou, 2017).

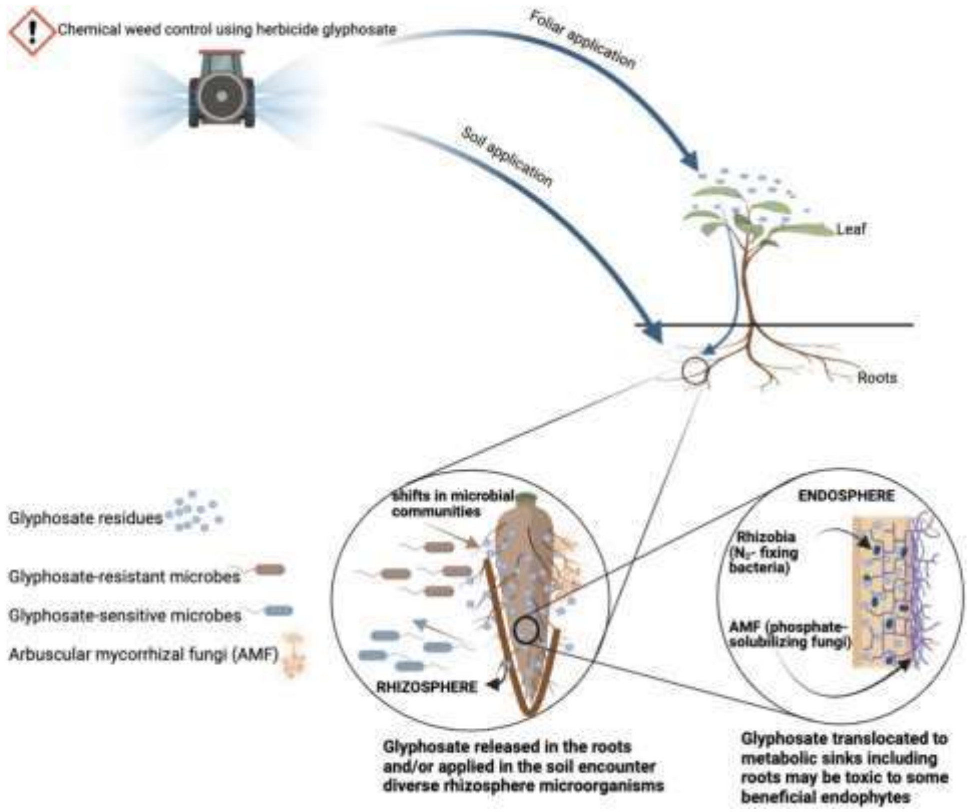

Figure 2. Possible interference of glyphosate with microbial communities in the rhizosphere and endosphere (from Sibalekile et al., 2025).

THE RHIZOSPHERE MICROBIOME: KEYSTONE OF SOIL HEALTH

The **rhizosphere microbiome**—microorganisms that inhabit the narrow zone surrounding plant roots—plays a foundational role in **nutrient cycling, stress response, and plant immunity** (Berg et al., 2020).

The specific functions of soil microbes can be divided into seven major groups (Berendsen et al., 2012; Cheng et al., 2022; Kumar et al., 2022):

- Decomposition: Microbes—bacteria and fungi—break down organic matter such as crop residues, insect carcasses, animal manure, and other organic materials in the soil. Microbes secrete enzymes that help break down complex organic compounds into simpler forms, releasing nutrients that plants can use. Microbes contribute to humification as they break down organic compounds. Humification produces stable, mature organic compounds that increase the organic matter content of the soil. This offers additional benefits to crops, such as increased water-holding capacity, nutrient retention, and carbon sequestration.
- Nutrient cycling: Microbes are involved in the circulation of essential nutrients in the soil. They can "unlock" nutrients that are locked up in forms inaccessible to the plant and therefore promote the availability of nutrients for plant absorption. Nitrogen fixation (mineralization) is one example of how many beneficial soil microbes convert organic nutrients into inorganic forms that can be absorbed by plants. Soil microbes also unlock nutrients from inorganic "bound" forms.
- Soil structure and aggregation: Certain bacteria and fungi produce sticky substances such as polysaccharides that bind soil particles together, forming aggregates. Soil

aggregates improve soil structure, porosity, and water-holding capacity, allowing for better root penetration and aeration.

- Disease suppression: Certain beneficial bacteria and fungi called biocontrol agents can suppress soil-borne pathogens and pests. Biocontrol agents suppress pathogens and pests through a variety of processes, including: producing antimicrobial compounds, consuming or parasitizing pests and pathogens, or outcompete pathogens for soil niches. The term "disease-suppressing soils" is often used to refer to fields that experience little or no impact from soil-borne diseases, even when the diseases are widespread throughout the surrounding region or minimal crop protection products are used. Microbial biocontrol agents are known to play a key role in the ability of disease-suppressing soils to mitigate the impacts of pathogens.
- Phytohormone Production: Some soil microbes can produce plant hormones in the soil, many of which are called "plant growth regulators" or PGRs. Hormones such as auxin, cytokinin, and gibberellin are known to support plant growth, yield, and stress tolerance when applied as foliar products. However, their routine application can be very expensive. Microbial hormone producers in the soil can also offer these benefits and have been found to support crop resistance to stressors such as drought and activate plant defense systems to ward off pathogens.
- Symbiotic relationships: Many plants form beneficial symbiotic relationships with soil microbes. Mycorrhizal fungi form associations with plant roots, extending their reach for water and nutrients in exchange for microbial “food” in the form of carbon produced by the plant through photosynthesis. Mutually beneficial bacteria, known as endophytes, live within plant tissues and promote plant growth by performing beneficial processes such as nitrogen fixation and carbon uptake through root exudates. This symbiotic relationship improves plant nutrient uptake, overall plant and soil health, and the efficiency of agricultural systems. However, common agricultural practices can disrupt these relationships, leading to a decline in beneficial microbes and increased dependence on agricultural inputs.
- Salinity regulation: Some microbes have adapted to survive in saline environments and possess mechanisms to tolerate high salt concentrations. They can actively colonize and thrive in saline soils where other organisms struggle. Salt exclusion is when certain microbes have mechanisms to exclude salts from their cells or actively limit their uptake. By excluding salts, microbes can ensure proper cellular function and growth in high salinity conditions. Salt metabolism is when certain microbes possess enzymes that can metabolize or break down specific types of salts. They can convert salts into less harmful forms or compounds that other organisms can use.

In short, balancing microbiome disruptions with practices that support plant-microbe symbiosis, such as cover crops and conservative tillage, is key to optimizing soil health processes and harnessing the benefits of soil microbes.

These microbial consortia are sensitive to external chemical inputs and serve as early indicators of soil disturbance (Kurenbach et al., 2021; Yang et al., 2023; El-Helow et al., 2024). Herbicides can alter:

- **Microbial richness and evenness**
- **Community composition** (e.g., shifts from *Proteobacteria* to *Actinobacteria*)
- **Enzyme activity**, such as dehydrogenase and phosphatase
- **Plant–microbe communication**, such as root exudate signaling

Soil microbial consortia—interactive communities of bacteria, fungi, archaea, and protists—are highly sensitive to herbicide exposure. Although herbicides are designed to target weeds, their biochemical specificity often extends to non-target organisms, leading to unintended disruptions in soil microbial dynamics. Also, herbicides can disrupt microbial communities by following mechanisms (Kurenbach et al., 2021; Yang et al., 2023; El-Helow et al., 2024):

- **Enzyme inhibition:** Common herbicides like glyphosate inhibit the shikimate pathway, which is present in bacteria and fungi. This hampers the synthesis of vital aromatic amino acids such as tryptophan, tyrosine, and phenylalanine, affecting microbial growth and metabolism.
- **Loss of microbial diversity:** Herbicide exposure can shift community composition by reducing beneficial groups like nitrogen-fixing bacteria, phosphate-solubilizers, and symbiotic fungi. This undermines key soil functions like nutrient cycling and plant-microbe interactions.
- **Metabolic shifts and functional decline:** While some microbes adapt to herbicides, this often comes with altered metabolic activity or reduced efficiency in organic matter decomposition and other soil biochemical processes.
- **Antibiotic resistance proliferation:** Studies show that prolonged herbicide use can increase the abundance of antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs), potentially facilitating the spread of resistant pathogens through horizontal gene transfer.

ADAPTIVE RESPONSES AND MICROBIAL RESISTANCE

Repeated herbicide exposure can drive **microbial adaptation**, including d**egradation capability evolution** (e.g., *Pseudomonas* acquiring glyphosate degradation genes), s**hift toward resistant or resilient taxa or horizontal gene transfer** of resistance traits. While such adaptations may improve degradation efficiency, they may also alter **microbial network interactions**, affecting ecological balance (Rousidou et al., 2013). Microbial shifts may feed back into **plant susceptibility**, nutrient cycles, and carbon dynamics, especially under climate stress.

Microbes adapt to herbicides through several strategies, such as e**fflux pump activation**, m**embrane modifications** (like changes in membrane permeability help microbes limit herbicide uptake and increase resistance to antibiotics), s**tress response pathways** (e.g. herbicide exposure triggers oxidative stress, DNA damage, and SOS responses, which can lead to mutagenesis and horizontal gene transfer) and c**ross-resistance evolution** (mutations that confer herbicide tolerance may also increase resistance to antibiotics, especially when stress pathways overlap) (Liao et al., 2021; Hill, 2017). These adaptive responses have cascading effects s**oil microbiome disruption, antimicrobial resistance and food chain contamination, like r**esidual herbicides and resistant microbes can enter crops and livestock, posing risks to human health (Daram et al., 2021; Paul and Mandal, 2019).

HERBICIDE EFFECTS ON ECOSYSTEM-LEVEL PROCESSES

While the rhizosphere is a well-studied hotspot of microbial activity, recent research reveals that microbial alterations extend far beyond root zones, influencing **macroecological processes** such as nutrient cycling, carbon sequestration, biodiversity patterns, and ecosystem resilience. These changes are not confined to local soil patches—they ripple across landscapes and biomes, shaping ecological trajectories at multiple scales (Wang and Zou, 2024; Mohanram and Kumar, 2019). Microbial communities in bulk soil, litter layers, and aquatic interfaces respond dynamically to environmental perturbations, including herbicide exposure, land-use change, and climate variability. These shifts can a**lter biogeochemical cycles**, m**odulate greenhouse gas emissions** and i**Influence plant community assembly (**Pantigoso et al, 2022; Ruuskanen et al., 2022).

Microbial alterations often involve **cross-kingdom interactions**, such as fungal networks facilitating bacterial dispersal or protists regulating microbial grazing. These interactions contribute to s**oil organic matter formation**, t**rophic cascades** and to h**abitat connectivity**.

Beyond the rhizosphere, microbial alterations influence **macroecological processes, such as carbon sequestration** via changes in microbial respiration, n**itrogen and phosphorus cycling and soil aggregation and erosion resistance. S**everal studies report that herbicide-induced microbial imbalance can decrease **soil organic matter**, reduce **greenhouse gas buffering capacity**, and lower **crop resilience to drought and pests** (Ghimire et al., 2020). These indirect impacts challenge the long-held belief in herbicide neutrality toward ecosystem services.

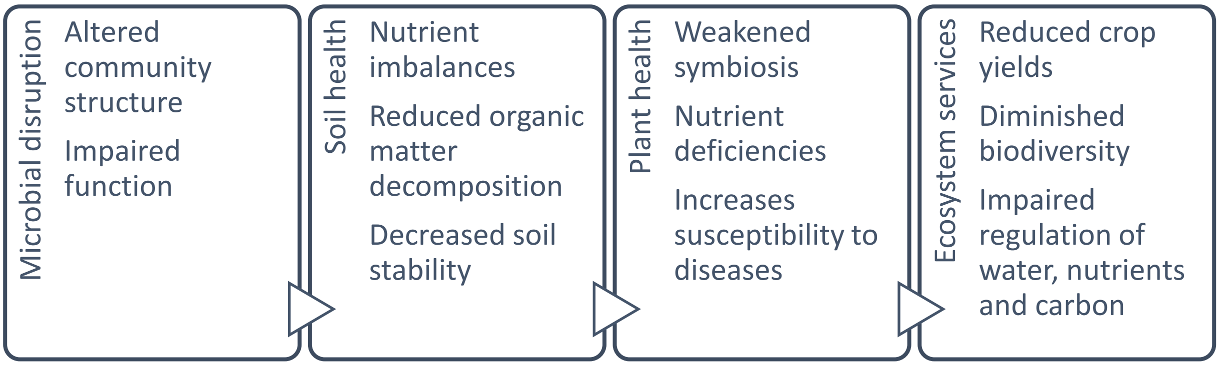

Figure 3. Ecosystem model showing cascading impacts of microbial disruption—soil health, plant health, insect interactions, and ecosystem services.

Herbicides have long been regarded as indispensable tools in modern agriculture—cost-effective, targeted, and efficient. Yet, their ecological footprint reaches far beyond weed suppression. Current herbicide risk assessment frameworks primarily focus on chemical persistence, toxicity to plants and animals, and residue levels in food and water. What remains largely overlooked is the impact of herbicides on the **soil microbiome**, a critical engine of nutrient cycling, plant health, and ecosystem stability (Sweeney et al., 2025; Kodikara et al., 2022).

Soil microbes—especially those in the rhizosphere—play foundational roles in maintaining agroecological functions. However, these organisms are almost entirely absent from conventional toxicological testing. Risk assessments typically rely on short-term, single-organism studies that fail to reflect the complexity and dynamism of microbial communities, which are deeply intertwined with numerous ecosystem services (Zhao et al., 2025; Wend et al., 2024).

An additional blind spot lies in **microbial genetic mobility**, where herbicide-induced stress can activate antibiotic resistance genes (ARGs) and mobile genetic elements (MGEs). This not only jeopardizes soil health but also raises concerns about public safety via the potential horizontal transfer of resistance traits to pathogenic microbes (EFSA, 2023; Liao et al., 2021).

Table 1. Gaps in Herbicide Risk Assessment.

Assessment Domain	Current Gaps
Soil Health	Focused mainly on chemical residues and physical structure
Non-target Effects	Limited consideration of microbial collateral damage
Temporal Dynamics	Assessed via static endpoints (e.g., residue half-life)
Bioindicator Integration	Rarely utilizes microbial indicators
Interaction Effects	Ignores chemical synergy or antagonism with microbial networks
Resistance Development	Focused on weed resistance only
Ecosystem Services Impact	Underrepresents microbial contributions to services
Standardized Protocols	Lacks harmonized microbial toxicity assays

CONCLUSIONS

Herbicides, while instrumental in modern agriculture, pose complex ecological challenges that extend far beyond weed control. Their influence on soil microbial consortia—especially in the rhizosphere—triggers cascading effects that alter nutrient cycles, suppress beneficial taxa, and potentially promote antibiotic resistance. These microbial disruptions reshape plant–soil interactions, reduce ecosystem resilience, and compromise vital services such as pollination, pest regulation, and carbon sequestration.

Conventional herbicide risk assessments often overlook these microbiome-mediated effects, focusing narrowly on chemical residues and plant toxicity endpoints. Integrating microbiome-centric metrics into regulatory frameworks—such as microbial diversity indices, functional group profiling, and gene transfer monitoring—offers a path toward more holistic ecological stewardship.

A microbiologically informed approach to weed management can help sustain soil health, foster agroecosystem stability, and safeguard public and environmental well-being. The microbial voice, long silent in regulatory discourse, must now become a guiding force in rethinking agricultural sustainability.

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