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METHODS FOR IMPROVING SOIL BIOLOGICAL PROPERTIES

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Annotation: This extended article deeply analyzes the importance and modern methods of improving soil biological properties. It comprehensively covers aspects such as the complex role of microorganisms in enhancing soil fertility, the biochemical cycling of organic matter, the ecological benefits of minimal tillage, and the agronomic effectiveness of crop rotation. The article also includes information on new approaches, including bio-stimulants and soil biomass monitoring.

Keywords: soil fertility, biological properties, microorganisms, organic matter, minimal tillage, crop rotation, compost, bio-fertilizers, soil degradation, bio-stimulants, soil biomass, phytoremediation, agroecology.

Introduction

Soil is a complex ecosystem of living organisms, and its health and fertility determine the sustainability of not only agriculture but also the entire ecological system. The biological properties of soil reflect its ability to provide nutrients for plants, retain water and air, and neutralize harmful substances. A single gram of healthy soil contains billions of bacteria, millions of fungi, thousands of protists, and other microfauna, which play an incomparable role in decomposing organic matter, converting nutrient elements, and forming soil structure.

Currently, due to intensive farming methods, excessive use of chemical substances, and improper soil management, soil degradation has become a serious global problem. This situation reduces the biological activity of the soil, decreases its fertility, and ultimately threatens food security. Therefore, understanding the biological properties of soil and improving them with effective methods is a priority task of modern agronomy.

Soil Biological Properties and Extended Methods for Their Improvement

There are many integrated approaches to improving the biological properties of soil. These not only increase yield but also have a positive impact on the environment.

1. Optimizing Soil Organic Matter Balance

Organic matter serves as an energy and nutrient source for soil microbes, and improves the soil's water-holding capacity, aeration, and nutrient retention. Synergistic Effect of Manure and Compost: Manure is not only a source of nutrients but also introduces numerous microorganisms into the soil. Compost, on the other hand, is a product rich in humic substances formed by the decomposition of various organic residues (plant residues, food waste, animal products) by microbes. The application of compost increases the cation exchange capacity of the soil, which ensures the retention of nutrient elements in the soil and prevents their leaching. It promotes the

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formation of soil aggregates, strengthening the soil structure. Green Manures (Siderates) and Their Biological Mechanisms: Siderate crops (e.g., legumes – vetch, alfalfa, clover) form a symbiotic relationship with nitrogen-fixing bacteria (Rhizobium) in their roots, converting atmospheric molecular nitrogen into a form usable by plants (ammonium). This naturally enriches the soil with nitrogen. The deep-penetrating root systems of siderates loosen the soil, bring nutrients from deeper layers to the surface, and provide new carbon sources for the soil biomass. Leaving Plant Residues in the Soil (Mulching): Leaving crop residues in the field after harvest reduces soil surface erosion, slows down water evaporation, and stabilizes soil temperature. These residues serve as a continuous nutrient source for microorganisms, gradually enriching the soil's organic matter and activating soil fauna (e.g., earthworms).

2. Supporting and Introducing Microorganisms

In increasing soil biological activity, it is crucial to directly introduce beneficial microorganisms or stimulate their natural development. Bio-fertilizers and Their Types: Bio-fertilizers contain nitrogen-fixing (e.g., Azotobacter, Azospirillum, Rhizobium), phosphate-solubilizing (Bacillus megaterium, Pseudomonas striata), potassium-mobilizing (Bacillus mucilaginosus) bacteria, and other beneficial microorganisms. They convert difficult-to-dissolve nutrient elements into an easily absorbable form for plants, thereby reducing the need for chemical fertilizers. Bio-stimulants: These preparations are natural substances that stimulate plant growth and development and increase their stress resistance. They may contain humic acids, fulvic acids, amino acids, seaweed extracts, and metabolites of beneficial microorganisms. Bio-stimulants indirectly stimulate microbial activity in the soil, improving nutrient movement. Microbial Inoculants: Special microbial preparations applied to seeds or soil before planting. They form colonies of beneficial microorganisms in the plant's root system, optimizing nutrient exchange.

3. Minimal Tillage (Conservation Tillage)

This technology aims to preserve the natural structure of the soil, thereby supporting soil life. No-Till Farming: A method of planting without any soil tillage. This helps preserve organic matter in the topsoil layer, prevents the disruption of soil aggregates, and creates a stable living environment for microorganisms. As a result, soil erosion is drastically reduced, water infiltration is improved, and carbon sequestration in the soil contributes to combating climate change. Minimum Tillage: Minimal soil disturbance (e.g., only in the planting row). This also helps preserve soil structure but allows for some loosening of the soil. Both methods reduce fuel consumption and labor costs.

4. Biological Benefits of Crop Rotation

Crop rotation is not just about pest and disease control, but also plays a significant role in improving soil biological health. Reducing Soil Fatigue: Continuously planting the same crop leads to a depletion of specific nutrients in the soil or an accumulation of metabolites harmful to plants. Crop rotation disrupts this process. Diversity of Root Systems: The roots of different crops penetrate to various depths in the soil. For example, deep-rooted crops (alfalfa) loosen the lower soil layers, while shallow-rooted crops enrich the top layer. This generally improves the soil and optimizes its water-air regime. Balance of Microbial Populations: Each crop type releases specific root exudates, which promote the development of particular groups of

microorganisms in the soil. Crop rotation increases the diversity of microorganisms in the soil, ensuring a healthy and stable soil ecosystem.

5. Water Management and Phytoremediation Efficient Irrigation Methods: Drip irrigation and micro-irrigation systems conserve water while maintaining optimal moisture levels in the soil. This ensures a stable moisture regime, which is crucial for the activity of soil microorganisms. In cases of water scarcity or excessive moisture, microbial activity decreases. Phytoremediation: Some plants have the ability to absorb heavy metals or other pollutants from the soil into their tissues or detoxify them. This method helps biologically purify the soil, which in turn increases the overall biological activity of the soil.

Conclusion

Improving soil biological properties is a strategically important task for the future of agriculture. This process requires a complex approach aimed at restoring and preserving soil health. Continuous input of organic matter, rational use of bio-fertilizers and bio-stimulants, widespread adoption of minimal tillage technologies, and crop rotation are methods that stimulate the activity of soil microorganisms and increase its fertility. As a result, yields increase, reliance on chemical substances decreases, the environment is protected, and sustainable soil resources are ensured for future generations. By treating the soil as a living organism and caring for it accordingly, we not only meet our current needs but also contribute to maintaining the ecological balance of our planet.

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