



Effect of Rice Residue Management on Soil Properties

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Rice is one of the most important staple crops in Asia, and its cultivation generates enormous quantities of crop residues, particularly rice straw. Traditionally, rice residues have been either removed for fodder and fuel or burned in situ to facilitate timely sowing of the succeeding crop. However, residue burning has emerged as a serious environmental and agronomic concern due to its adverse effects on soil health, air quality, and nutrient cycling. Several studies have reported that inappropriate residue management leads to the depletion of soil organic carbon, deterioration of soil structure, and decline in biological activity. Conversely, scientific residue management practices such as residue incorporation, surface retention, mulching, and composting have shown significant potential to improve soil physical, chemical, and biological properties. Incorporation and retention of rice residues enhance soil organic matter, improve aggregation, increase nutrient availability, and stimulate microbial activity. This article reviews the effects of different rice residue management practices on soil properties, highlighting their role in sustaining soil fertility, improving crop productivity, and promoting long-term soil health under rice-based cropping systems.

Keywords: Rice residue; Straw management; Soil organic carbon; Soil fertility; Microbial activity; Sustainable agriculture

Introduction: Rice Residues and the Soil Health Challenge

Rice cultivation occupies a central position in Indian agriculture and plays a vital role in food security. Along with grain production, rice generates a large volume of residues, mainly straw and stubble, accounting for nearly 40–45% of the total biomass produced. In India, the annual generation of rice straw exceeds 150 million tonnes, posing a major management challenge, particularly in intensive rice–wheat and rice-based cropping systems. Farmers often resort to open-field burning of rice residues to quickly clear fields for the next crop. Although this practice saves time and labour, it results in severe nutrient losses and environmental pollution. Burning of one tonne of rice straw leads to substantial losses of nitrogen, phosphorus, potassium, sulphur, and organic carbon, thereby reducing soil fertility. Moreover, residue burning destroys beneficial soil microorganisms and adversely affects soil structure. In contrast, scientific rice residue management aims to recycle crop residues back into the soil system, thereby improving soil quality and sustaining productivity. Understanding the impact of residue management on soil properties is essential for developing environmentally sound and agronomically viable rice production systems.

Rice Residue Management Practices in Rice-Based Systems

Rice residue management includes a range of practices that differ in their impact on soil processes:

Residue Burning: Complete removal of residues through open-field burning.

Residue Removal: Straw collected for fodder, fuel, or industrial uses.

Residue Incorporation: Mixing residues into soil through tillage.

Surface Retention (Mulching): Retaining residues on the soil surface.

Composting and In-Situ Decomposition: Controlled biological decomposition of residues.

Among these, residue incorporation and surface retention are considered the most beneficial for improving soil health.

Effect of Rice Residue Management on Soil Physical Properties

Rice residue management significantly influences soil physical characteristics such as bulk density, aggregation, porosity, and water-holding capacity. Residue incorporation and mulching reduce soil bulk density by increasing organic matter content and promoting the formation of stable soil aggregates. The addition of rice straw improves soil structure by binding soil particles through organic binding agents released during decomposition. Studies have shown that long-term residue retention improves aggregate stability and reduces soil compaction. Surface retention of rice residues also protects soil from erosion and moderates soil temperature, which is particularly beneficial in tropical and subtropical regions. Improved soil porosity and infiltration rates under residue-managed systems enhance water-use efficiency and reduce runoff losses.

Effect on Soil Chemical Properties

Rice residues play a crucial role in nutrient cycling and soil chemical fertility. Incorporation of rice straw adds significant amounts of carbon and nutrients to the soil. Although rice straw has a wide C:N ratio, its gradual decomposition contributes to the build-up of soil organic carbon over time. Residue management practices have been shown to increase available nitrogen, phosphorus, potassium, and sulphur in soil due to nutrient mineralization and reduced losses. Potassium availability, in particular, increases substantially under residue retention, as rice straw contains high amounts of K that are easily released upon decomposition. Furthermore, residue incorporation improves soil cation exchange capacity (CEC) and buffering capacity, leading to better nutrient retention and reduced soil acidity fluctuations.

Effect on Soil Biological Properties

Soil biological health is highly sensitive to residue management practices. Burning of rice residues drastically reduces microbial biomass and enzymatic activity by exposing soil organisms to high temperatures. In contrast, residue retention and incorporation provide a continuous supply of organic substrates for soil microorganisms. Decomposing rice residues stimulate microbial populations, including bacteria, fungi, and actinomycetes, thereby enhancing soil biological activity. Increased microbial biomass carbon, dehydrogenase activity, and phosphatase activity have been reported under residue-managed systems. Residue retention also improves earthworm activity and rhizosphere processes, leading to enhanced nutrient mineralization and improved soil ecosystem functioning.

Environmental and Agronomic Benefits of Rice Residue Management

Scientific rice residue management offers multiple benefits beyond soil health improvement. It reduces greenhouse gas emissions associated with residue burning and improves air quality. Residue retention enhances carbon sequestration, contributing to climate change mitigation. From an agronomic perspective, improved soil properties under residue-managed systems result in better root growth, improved nutrient uptake, and enhanced crop productivity. Long-term studies have shown that residue incorporation and mulching sustain rice yields while reducing the dependence on external inputs.

Constraints in Adoption of Residue Management Practices

Despite its benefits, large-scale adoption of rice residue management faces several challenges. Slow decomposition of rice straw due to high silica content, short turnaround time between crops, and lack of suitable machinery discourage farmers from adopting residue retention practices. Additionally, improper management may lead to temporary nitrogen immobilization during early stages of decomposition. These constraints necessitate integrated

approaches involving residue decomposers, balanced fertilization, and appropriate mechanization.

Future Prospects and Sustainable Soil Management

Advances in residue management technologies such as Happy Seeder, Super SMS, and microbial decomposer formulations offer promising solutions for sustainable rice residue recycling. Integrating rice residue management with conservation agriculture and organic farming practices can significantly enhance soil health and system sustainability. Policy support, farmer awareness, and site-specific recommendations are essential to promote residue management as a core component of sustainable rice production systems.

Conclusion

Rice residue management plays a pivotal role in determining soil physical, chemical, and biological properties under rice-based cropping systems. While residue burning degrades soil quality and causes environmental harm, practices such as residue incorporation and surface retention improve soil organic carbon, nutrient availability, aggregation, and microbial activity. Although challenges exist in terms of decomposition and management logistics, the long-term benefits of scientific residue management far outweigh its limitations. Adopting sustainable rice residue management practices is essential for restoring soil health, improving productivity, and ensuring environmental sustainability in intensive rice-growing regions.

References

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