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Management of Paddy and Wheat Stubble (Parali)

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The paddy-wheat cropping system is extremely important for food security in India, but it faces challenges related to residue management after harvesting. Over the years, a significant shift has been observed in the in-situ management of paddy residues, impacting soil health and the sustainability of the production system. Recognizing paddy residues as a valuable resource, in-situ practices such as surface mulching and incorporating residues into the soil have been utilized to enhance productivity and environmental sustainability.

By examining nutrient cycling, microbial activity, and soil's physical and chemical properties, a balance between productivity and conservation has been highlighted. In-situ residue management significantly affects moisture retention, bulk density, porosity, aggregate stability, pH, cation exchange pH, cation exchange capacity, organic carbon, and nutrient content, which are crucial for sustainable agricultural practices.

Since 2018, the Government of India, through ICAR institutes, State Agricultural Universities (SAUs), and Krishi Vigyan Kendras (KVKs), has launched a Crop Residue Management Project to promote advanced machinery such as Happy Seeder, Super Seeder, and Zero-Till Seed Drill for in-situ residue management and conservation tillage. The results of this project have been highly encouraging, showing an increase in crop yield and cost-effectiveness, further reinforcing the importance of in-situ residue management for sustainable agriculture.

The objective of this study is to inform stakeholders, policymakers, and researchers, fostering collective efforts toward a harmonious

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coexistence between agricultural productivity and soil health in paddy and wheat farming.

Rice is a major crop in India, cultivated on more than 44 million hectares, with an annual production exceeding 130 million tons. Dwarf rice varieties accumulate a large amount of biomass, which, after harvest, poses a significant challenge as crop residue, creating issues in fields. Managing rice residues, particularly through in-situ (on-site) practices, has emerged as a crucial aspect in the pursuit of sustainable agriculture. It is estimated that the rice-based cropping system in India generates nearly 300 million tons of crop residues annually.

Historically, paddy and wheat residues, including straw and leftover biomass post-harvest, have been regarded as by-products, often disposed of through burning or other traditional methods. Although burning offers a quick solution to clear fields, it has led to severe environmental concerns such as air pollution, nutrient loss, and degradation of soil properties. To address these challenges, the approach towards in-situ residue management of rice has been evolving, presenting a strategic pathway to enhance both agricultural productivity and environmental sustainability.

In recent years, there has been a growing realization that rice and wheat residues, previously considered waste, actually hold untapped potential as a valuable resource for improving soil health. The shift towards in-situ residue management involves practices such as surface mulching (covering soil with crop residues) and residue incorporation into

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the soil. These methods maximize the positive impact on soil structure, nutrient content, and overall sustainability. However, understanding the subtle effects of these practices on soil health is essential to establish the right balance between agricultural productivity and environmental conservation.

Effect of Rice and Wheat Residue Management on Soil Health

Physical Properties of Soil

Moisture Content:

Incorporating rice and wheat residues into the soil improves its moisture content. This is because the residues reduce surface runoff and direct evaporation, enhancing the soil's water retention capacity and infiltration rate. A layer of straw on the soil surface effectively lowers the topsoil temperature, which capac ity and infiltration rate. A layer of straw on the soil surface effectively lowers the topsoil temperature, which influences evaporation and subsequently increases soil moisture levels. Higher moisture availability in the soil boosts its water-holding capacity, ensuring adequate moisture for better crop productivity.

Bulk Density:

Proper management of rice and wheat residues reduces soil bulk density, indicating improved porosity and aeration. This ultimately enhances soil structure. Different crop residues and their management strategies have varying effects on soil bulk density across different soil layers and growth periods.

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Porosity and Aggregate Stability :

The inclusion of chopped and crushed crop residues positively impacts soil porosity and aggregate stability. Organic matter from crop residues contributes to the formation of larger and more stable soil aggregates. This helps maintain soil structure and supports nutrient cycling.

Chemical Properties of Soil:

In-situ management of rice and wheat residues significantly influences various chemical properties of the soil. These changes improve soil health and contribute to increased crop productivity.

pH and Cation Exchange Capacity (CEC)

Crop residues play a crucial role in regulating soil pH, especially in soils with low buffering capacity. Incubation experiments have demonstrated that the corrective effects of decomposed crop straw products can significantly increase soil pH. However, certain practices, such as covering crop residues without tillage and rotary tillage, can lead to a decrease in soil pH. Additionally, crop residue management has a profound impact on cation exchange capacity (CEC). The accumulation of soil organic matter through crop residues generates a higher negative charge, leading to an increase in CEC. Studies have shown that a high level of crop residue accumulation significantly enhances CEC, highlighting the importance of residue management in influencing soil chemistry.

Organic Carbon and Soil Nutrient Content :

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Organic Carbon and Soil Nutrient Content :

Decomposed crop residues are integral components of the nutrient cycle, contributing to increased levels of organic carbon, nitrogen, available phosphorus, and potassium in the soil. Organic carbon, a critical indicator of soil stability, increases significantly with the return of crop residues, promoting the formation of larger aggregates. This process enhances soil properties and stability. Furthermore, the return of crop residues prevents nutrient loss and improves the availability of essential nutrients. Since crop residues contain approximately 40% organic carbon, they play a vital role in regulating soil characteristics and minimizing organic carbon loss.

Nitrogen :

The return of crop residues increases the availability of nitrogen in the soil, which is essential for the formation of proteins, amino acids, and nucleic acids.

However, the relatively high C/N ratio of crop residues can lead to nitrogen immobilization, necessitating the application of additional nitrogen fertilizers.

Phosphorus:

Long-term incorporation of crop straw into the soil increases the levels of available phosphorus in the soil, thereby improving phosphorus use efficiency over time.

Potassium:

Crop residues release ionic potassium, which leads to its accumulation in the soil. Various studies indicate that the use of different crop residues increases the amount of available

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potassium, highlighting its positive impact on soil fertility.

The inclusion of crop residues has been found to significantly increase organic carbon by 33.3–40.9%, underscoring its crucial role in nutrient recycling, soil fertility, and productivity enhancement. The dynamics of organic carbon are essential for understanding its profound effects on soil health and, consequently, on the overall biological health of the soil. Specifically, the careful management and incorporation of rice residues enhance the chemical properties of the soil, contributing to soil health maintenance and improved crop productivity.

Soil Biological Properties:

The in-situ incorporation of rice and wheat residues contributes to the biological proper ties of the soil. Given the critical role of soil microflora and macrofauna in maintaining soil biological health, this process is essential for long-term sustainability.

Thus, the biological characteristics of soil are more sensitive to changes in soil management compared to its chemical and physical properties.

Inclusion of Macro-Fauna and Residues:

The most important macro-fauna includes earthworms, which help improve soil health. It has been established that organic matter, such as crop residues, significantly increases the earthworm population. The incorporation of 5 tons of crop residues per hectare can increase the earthworm population by approximately 30%. An increase in macro-fauna helps boost the population of beneficial

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insects and predators. The conservation of crop residues and no-till farming create a habitat for soil macro-fauna, which includes organisms such as arthropods and rodents. However, not all crop residues have the same impact on the earthworm population. Crop residues with a high C:N ratio and high polyphenol concentration are less effective in enhancing microbial activity.

Roles of Soil Micro-Fauna and Microbial Communities:

Soil micro-fauna, which depends on soil organic carbon for metabolism, plays a crucial role in nutrient cycling and ecosystem stability. Changes in soil organic carbon content directly affect microbial populations, their structure, and functions. The incorporation of crop residues has been observed to rapidly enhance microbial activity, thereby improving the ecological environment of the soil. Microbial communities, which are essential for soil ecosystem processes and biogeochemical cycles, are positively influenced by the return of crop residues. Increased organic matter in the soil provides a favourable environment for the growth and reproduction of microorganisms.

In conclusion, the in-situ incorporation of rice and wheat residues significantly influences the biological characteristics of the soil, shaping the dynamics of macro- and micro-fauna as well as microbial communities. Understanding these processes not only enhances crop productivity but also ensures the long-term health and stability of the soil ecosystem.

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Efficient Machines for In-Situ Management of Rice and Wheat Residues

Happy Seeder:

The Happy Seeder has revolutionized the agricultural machinery sector, designed specifically for efficient wheat sowing. This innovative machine allows farmers to directly sow wheat seeds into the soil after harvesting rice, without the need for prior tilling. It effectively cuts and lifts previous crop residues while simultaneously planting the seeds, promoting "no-till farming", preserving soil moisture, and improving soil health. This sustainable approach not only enhances wheat cultivation but also reduces air pollution caused by traditional residue burning. The "Happy Seeder" stands out as a modern and eco-friendly solution for wheat sowing.

Super Seeder:

The Super Seeder is an advanced version of the Happy Seeder, equipped with an additional "rotavator" that performs shallow tillage while carrying out all other functions of the Happy Seeder. This machine enables farmers to directly sow wheat seeds into the soil while efficiently cutting, lifting, and removing previous crop residues. Although the "Super Seeder" is an improved version of the "Happy Seeder", its efficiency and benefits in wheat sowing have been particularly noted.

Zero Till Seed Drill :

The Zero Till Seed Drill is an innovative agricultural implement that revolutionizes wheat sowing practices. Unlike traditional methods that involve plowing and tilling before seed sowing, the Zero Till Seed Drill allows

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farmers to plant wheat directly into untilled soil, minimizing soil disturbance. This conservation tillage approach helps retain soil moisture, prevent erosion, and promote overall soil health. The machine ensures precise seed placement, maintaining uniform seed spacing and depth, which leads to consistent crop germination. The Zero Till Seed Drill is a sustainable solution that saves time and energy while enhancing wheat yield and contributing to environmental conservation.

Crop Residue Management Project :

To address the harmful practice of crop residue burning, the government has implemented a centrally sponsored scheme since 2018, titled. Promotion of Agricultural Mechanization for In-Situ Management of Crop Residues. This scheme is jointly executed by DAFW (Department of Agriculture & Farmers Welfare), ICAR (Indian Council of Agricultural Research), State Agriculture Departments, and leading extension institutions (Krishi Vigyan Kendras) across districts.

Wheat Yield and Farming Costs:

Agricultural machinery such as the "Happy Seeder, Super Seeder, and Zero till Seed Drill" was demonstrated in farmers' fields. These machines were used for wheat sowing, enabling in-situ management of paddy residues and significantly improving crop yield compared to traditional sowing methods. The use of the "Happy Seeder machine resulted in the highest recorded wheat yield of 51.74 kg/hectare" in demonstration plots.

The wheat yield under Super Seeder and Zero till Seed Drill was nearly the same, recorded

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at 50.91 kg/hectare and 50.89 kg/hectare, respectively.

Summary:

The use of in-situ crop residue management machines can transform so-called "waste" or residues into a "productive" asset, resulting in a productivity gain of 3.23 kg/day and a net profit of ₹104.3/day. Beyond food security and economic indicators, in-situ residue management contributes to soil sustainability and is an environmentally friendly practice.

Krishi Vigyan Kendras (Agricultural Science Centers) have increased the popularity of these machines by bringing them to farmers' fields, creating demand for them. State governments should promote both individual and community-based approaches to expand the use of these machines and ensure the proper and systematic management of crop residues.