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Transformation Technology in Crop Residue Management: A Sustainable Solution to Stubble Burning

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Alka[1], Dr. Arunima Paliwal[2], Dr. Gargi Goswami[3], Shivam Singh[4]

[1]Ph.D. Scholar (Agronomy), College of Hill Agriculture, Veer Chandra Singh Garhwali University of Horticulture and Forestry (VCSGUUHF), Chirbatiya, Uttarakhand, India

[2]Assistant Professor (Agronomy), College of Hill Agriculture, VCSGUUHF, Chirbatiya, Uttarakhand, India

[3]Assistant Professor (Agronomy), College of Horticulture, VCSGUUHF, Bharsar, Pauri Garhwal, Uttarakhand–246123, India

[4]M.Sc. Ag. (Horticulture – Vegetable Science), SAAST, Chhatrapati Sahu Ji Maharaj University, Kanpur, Uttar Pradesh, India

Crop residue, especially rice stubble, has historically posed an agronomic and environmental challenge in intensive agricultural systems. In regions such as the Indo-Gangetic Plains of India, rice harvesting is immediately followed by wheat sowing, leaving farmers with a narrow time window for field preparation. Consequently, open stubble burning has become a widespread practice due to its speed and low cost. However, this releases large quantities of particulate matter and greenhouse gases, degrades air quality, harms human health, and destroys valuable soil nutrients.

Recent innovations emphasize sustainable residue management through microbial decomposers, biochar production, and in-situ mechanization tools such as the Happy Seeder and Super Straw Management (SMS)/Super Seeder. These technologies reduce environmental damage, improve soil health, and maintain productivity without compromising rapid field turnaround.

The Problem of Stubble Burning

Farmers often have only 15–21 days between rice harvest and wheat sowing, leading to preference for rapid residue removal methods (Näher and Ziulu,

2025). Although burning is quick and inexpensive, it causes:

- Loss of essential nutrients (especially nitrogen and potassium)
- Disruption of beneficial soil microbiota
- Increased emissions of CO_2, CH_4, $PM_{2.5}$ and PM_{10}

These effects contribute to seasonal air-pollution crises in northern India and aggravate climate change and public health risks. Hence, governments, research institutions, NGOs and farmers are exploring transformative crop residue management strategies.

Microbial Decomposers: Accelerating Natural Residue Breakdown

Concept and Mechanism

Microbial decomposers consist of specialized fungi and bacteria that accelerate lignocellulosic residue degradation. Products such as Pusa Decomposer secrete enzymes (ligninase, cellulase and pectinase) that convert tough crop residues into simpler organic compounds.

Developed by ICAR, Pusa Decomposer contains fungal strains such as *Trichoderma* spp., enabling conversion of rice straw into organic matter within 20–25 days, making it compatible with wheat sowing schedules (Asian J. Soil Sci. Plant Nutr., 2025).

Benefits for Sustainable Agriculture

- **Soil Enrichment:** Enhances organic matter and microbial activity; reported yield increases of 12–15%.
- **Reduced Chemical Dependence:** Improved nutrient cycling lowers fertilizer requirement.
- **Environmental Protection:** Prevents burning-related emissions and improves air quality.

Adoption challenges include limited awareness, logistical constraints, and availability, highlighting the need for extension services and coordinated field support.

Biochar: Turning Residue into a Valuable Soil Amendment

What Is Biochar?

Biochar is a carbon-rich product obtained through pyrolysis of biomass under limited oxygen. Unlike burning, pyrolysis converts residues into stable carbon that persists in soil for decades, acting as a carbon sink.

Environmental and Agronomic Advantages

1. **Carbon Sequestration:** Mitigates climate change by locking carbon in soils.
2. **Soil Health Improvement:** Enhances structure, water retention and cation exchange capacity.
3. **Reduced Fertilizer Losses:** Improves nutrient retention and use efficiency.
4. **Versatility:** Can be combined with compost or manure for greater soil benefits.

Biochar vs. Burning

While burning causes nutrient loss and degradation, biochar retains carbon and nutrients within the farming system, promoting circular agriculture. However, widespread adoption faces constraints related to equipment cost and logistics. Community pyrolysis units and subsidies could accelerate uptake.

In-Situ Mechanization: Happy Seeder, SMS and Super Seeder

Happy Seeder: Revolutionizing Direct Sowing

The Happy Seeder allows direct wheat sowing into standing rice residue. It cuts stubble, opens seed

furrows and deposits straw as mulch, eliminating the need for burning.

Key benefits include:

- Reduced soil disturbance and erosion
- Improved moisture retention and microclimate
- Up to 78% reduction in greenhouse gas emissions
- Long-term economic gains through lower labor and input costs

Government subsidies (up to 80%) have promoted adoption in Punjab, Haryana and Uttar Pradesh.

Super Straw Management (SMS) and Super Seeder

SMS attachments on combine harvesters evenly chop and spread residues, facilitating subsequent sowing. The Super Seeder integrates residue cutting and crop sowing in a single operation. Field trials show maintained or improved yields due to better seed placement and mulch benefits.

Integrated Benefits of Transformation Technologies

The combined use of microbial decomposers, biochar and mechanization provides:

- **Environmental Gains:** Reduced pollution, enhanced carbon storage and healthier soils
- **Economic Benefits:** Lower fuel and labor costs, improved yields and value-added residue products
- **Social Outcomes:** Cleaner air, improved public health and farmer livelihoods
- **Policy Alignment:** Strong synergy with government incentives and climate-smart agriculture goals

Challenges and Future Directions

Major constraints include:

- High machinery costs for smallholders
- Need for farmer training and awareness
- Limited infrastructure for biochar and microbial inputs
- Requirement for consistent policy support

Future research should prioritize region-specific microbial formulations, low-cost biochar technologies and multifunctional machinery.

Conclusion

Transformation technologies provide sustainable alternatives to stubble burning. Microbial decomposers enable rapid residue breakdown, biochar enhances soil fertility while sequestering carbon, and mechanization tools facilitate residue-retained sowing. Together, these approaches improve soil health, reduce emissions and build resilient cropping systems. Strategic investment in innovation, infrastructure and education, supported by enabling policies, can make crop residue management a cornerstone of sustainable agriculture in India and beyond.

References

1. Asian Journal of Soil Science and Plant Nutrition. (2025). Microbial and biological methods for crop residue management.
2. Down To Earth. (2025). Here is a solution for crop residue burning problem.
3. Drishti IAS. (2025). Issues associated with stubble burning and alternatives.

4. International Journal of Research in Agronomy. (2024). Role of microbial decomposers in sustainable stubble management.
5. Näher, D., & Ziulu, V. (2025). Does adoption of zero tillage reduce crop residue burning? *arXiv*.
6. Tata Trusts. (n.d.). Ending burning of crop stubble through Happy Seeder technology.
7. Times of India. (2025). Administration gears up to make Ludhiana stubble burning-free.
8. Times of India. (2025). Crop residues act as food for fields.