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Case studies: Adoption of machinery-based

interventions for crop residue management in Uttar Pradesh

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The mechanisation of agriculture has revolutionised crop residue management in Uttar Pradesh. Technologies like Happy Seeder, Super Seeder, surface seeding, zero tillage and Drum Seeder have benefitted in minimising residue burning, enhancing soil fertility and reducing greenhouse gas emissions. Higher yields, lower cost of cultivation and improved resource efficiency have been documented from various trials conducted at farmers' fields. Case studies showed yield improvement varying from 7.01–23.90% and cost savings up to ₹30,005/ha. Zero tillage adoption grew from 238 ha in 2005–06 to 5,832 ha in 2019–20. Direct seeding of rice (DSR) saved 72.88% labour costs and 33% irrigation water. These sustainable practices promote eco-friendly and climate-resilient farming.

Keywords: Labour, Mechanisation, Super Seeder, Yields

DUE to migration of agricultural labours from rural to urban areas, it became very difficult to carry out labour intensive farm operations particularly for harvesting, threshing and winnowing. The mechanisation was needed to fill the gap of labours shortage (30–40%, Down to Earth). The use of combine harvester in 1990s for harvesting, threshing and winnowing eases the operation on one hand and raises a new problem of residue burning on other.

Rice residue creates challenges for field preparation for wheat sowing after rice harvest. The time required for removing left over rice residue further shortens the already limited window between paddy harvesting and wheat sowing, leading to delayed sowing and poor germination due to reduce soil moisture. About 30% rice residue is left behind with the use of combine harvester. Burning of crop residue quickly got popularised among farmers of northern region. In 2024, India's rice and wheat crop is estimated to have produced approximately 126.6 million tonnes of rice straw and 500 million tonnes of wheat straw, respectively. The emissions from burning of crop residues deteriorate air quality and adversely impact human health, exacerbating various diseases. It is estimated that burning one tonne of paddy straw releases 3 kg of particulate matter (PM), 60 kg of carbon monoxide (CO), 1,460 kg of carbon dioxide (CO_2), 199 kg of ash and 2 kg of sulphur dioxide (SO_2).

Effective crop residue management involves handling and utilising plant materials such as stalks, leaves, husks and roots left after harvests. Sustainable management techniques such as mulching, composting, soil incorporation and conservation tillage help to enhance soil health and microbial activity.

These improve soil moisture retention, promotes better soil structure, reduce soil erosion and suppress weed growth. Additionally, they increase soil organic carbon by stimulating microbial activity and in turn nutrient cycling. Adopting sustainable residue management contributes climate resilience by reducing greenhouse gas emissions and minimising air pollution by residue burning. Suitable techniques not only enhance soil fertility and crop production but also support environmentally sound, natural resource-based efficient agricultural systems. Furthermore, machinery interventions such as Happy Seeders, Super Seeders, Drum Seeders, etc. play a crucial role in the successful implementation of crop residue management strategies.

Income enhancement with the use of Happy Seeder in wheat

Happy Seeder is a mechanised direct drill that enables sowing without prior removal or disposal of crop residue. It plays a crucial role in reducing stubble burning, enhancing soil health and improving crop yields. It is a tractor-mounted implement, which simultaneously sows seeds and applies fertilisers. Farmers in district Azamgarh (U.P.) adopted Happy Seeder for wheat sowing in 2018, replacing conventional method of broadcasting with Rotavator or cultivator. They cultivated wheat in 9.0 acres with the help of Happy

Before and after of paddy crop in Mulcher and Happy Seeder use technology (KVK Bulandshahar)

Seeder and reduced the sowing cost up to 50% in comparison to conventional method. The machine eliminated the need for paddy residue burning by cutting stubble into small pieces and incorporating it into the soil, thereby improving soil organic matter. It increased soil organic matter content, improved water savings by reducing the need for 2–3 irrigations/crop and lowered chemical fertiliser usage. Tillers, which are lateral shoots in cereals capable of developing into grain-bearing stems, play a crucial role in determining final grain yield. An increase in tiller number enhanced yield potential while also reducing lodging incidence. Fertiliser use efficiency improved due to precise placement, which enhanced soil fertility through residue decomposition, resulting in savings of up to ₹2,753/acre. Additionally, paddy straw acted as natural mulch, suppressing weed germination and saving ₹650/acre on weed management. Reduced irrigation frequency, due to zero-tillage and minimised soil pulverisation, led to further savings of ₹3,771/acre on irrigation. The Happy Seeder intervention also contributed to a significant increase in wheat yield from 4.2 t/ha to 5.0 t/ha. Moreover, it saved ₹8,201/acre in field preparation and sowing costs, bringing the total economic benefit to farmers of ₹30,005 /acre. These results highlighted the technology's effectiveness in improving sustainability and profitability in wheat cultivation.

Surface seeding technology

Surface seeding technology involves directly wheat seeding into standing rice stubble, allowing them to germinate naturally. This approach, whether mechanised or manual, is cost-effective and enhances soil fertility by improving water retention, reducing erosion and promoting sustainable agriculture, particularly in waterlogged fields. In 2023, farmers in Uttar Pradesh adopted surface seeding technology using the shrub master for wheat cultivation. Their success encouraged over 50 additional farmers in the district to implement the technique. However, during the first 21 days, germination was either very low or not visible. Fields with minimal crop residue experienced higher weed infestation and lower plant population. Notably, wheat crops grown using surface seeding were unaffected by terminal heat stress and lodging. Additionally, a higher number of grains/spike were observed in these fields. Compared to conventional practices, surface seeding resulted in a 13.8% increase in yield, with a benefit:cost ratio of 3.59, demonstrating its economic advantage.

Mulcher and Happy Seeder technology

Effective crop residue management is crucial for sustainable farming. The Mulcher, a mechanised implement, finely shreds crop residues, enhancing soil moisture, fertility and organic matter while preventing weed growth and soil erosion. When combined with the Happy Seeder, this technology enables efficient residue incorporation and direct seeding, reducing the need for pre-sowing irrigation. Shri Rohit Verma, a 27-year-old farmer from Bareilly

Surface Seeder (KVK Kanpur Dehat)

district with a 10-acre landholding, previously use to burn rice stubble after harvesting. However, after receiving training from the Krishi Vigyan Kendra (KVK), he adopted the Mulcher and Happy Seeder technology to sow wheat on 2 acres. This method allowed timely sowing, reduced labour costs, saved one irrigation cycle and minimised weed infestation. Immediately after harvesting rice with a combine harvester, he chopped the standing residue using a Mulcher and directly sowed wheat with the Happy Seeder, utilising the available soil moisture. This approach significantly improved soil health, increased tiller production and reduced crop lodging compared to traditional broadcasting method. As a result, wheat yield increased by 7% and the benefit:cost ratio improved to 2.25. By transitioning to this sustainable practice, Shri Rohit Verma not only enhanced productivity but also contributed to eco-friendly farming by eliminating stubble burning.

Zero-till sowing

Zero-tillage wheat cultivation after rice has emerged as one of the most successful resource-conserving technologies in the North Indian Plains. This method offers multiple advantages, including timely wheat sowing, effective control of problematic weeds like *Phalaris minor*, reduced cultivation costs and significant water savings. Wheat cultivation in the Jaunpur district covers an area of 2,12,670 ha, with approximately 48,320 ha under low-lying conditions. Traditionally in low-lying area, they ploughed harvested paddy fields four to five times before sowing wheat, leading to excessive moisture depletion and delay in wheat sowing. The adoption of zero-till sowing of wheat began in 2005–06 with 238 hectares and expanded significantly, reaching 5,832 ha by 2019–20. Farmers in the region adopted a balanced fertiliser dose of N:P:K:S (120:60:40:20 kg/ha) as recommended by Krishi Vigyan Kendra (KVK) experts. With this improved practice, the wheat yield, initially at 34.51 q/ha, increased by 23.90%, reaching 42.76 q/ha. Additionally, farmers saved approximately ₹2,350/ha in cultivation costs. The economic analysis showed a gross income of ₹74,188/ha, net returns of ₹49,588/ha and a benefit-cost ratio (BCR) of 3.01, highlighting the profitability of zero-tillage technology. This case underscores the economic and agronomic benefits of zero-tillage in wheat, making it a sustainable and efficient alternative for farmers in the rice-wheat system.

Drum Seeder technology for paddy transplanting

A Drum Seeder is a device that sows pre-germinated seeds uniformly in rows, either manually or mechanically operated. With reduced labour requirements, it ensures uniform spacing, seed savings and improved productivity in paddy cultivation. Farmers in Prayagraj faced challenges due to labour scarcity during peak seasons and the high cost of transplanting. To address this issue, with the guidance of KVK experts, farmers adopted mechanised paddy cultivation, including accurate field levelling, Drum Seeder based direct sowing under wet conditions and weeding with a conoweeder.

One such farmer, Shri Shiv Sagar Kushwaha from Prayagraj, successfully maintained crop spacing, geometry and establishment under delayed monsoon conditions using a Drum Seeder for pre-germinated paddy seeds. This equipment has proven to be a boon for small and marginal farmers due to its affordability, ease of handling, adaptability and local fabrication feasibility. The Drum Seeder ensures proper plant-to-plant and row-to-row spacing, facilitating intercultural operations with a conoweeder. The technology has led to significant resource savings, including a 33% reduction in total labour requirements, 20% in seed usage and 25% in water consumption. Particularly in areas affected by delayed monsoons, water stress and labour shortages, this equipment have been invaluable. Over the past three years, Shri Shiv Sagar Kushwaha has consistently earned ₹ 20,000–₹ 25,000 more per hectare compared to manual transplanting, with no yield reduction observed. Given its low cost of approximately ₹ 5,000, it is an affordable solution for marginal farmers.

Similarly, Shri Manoj Kumar Patel from Raebareli adopted the direct seeding of rice (DSR) technology using a Drum Seeder. He sowed germinated paddy seeds with a basal dose of recommended NPK (150:60:40 kg/ha) and 20 kg of zinc per hectare, following KVK recommendations and necessary crop management practices. The results demonstrated that net returns were higher in DSR (₹ 57,075) compared to transplanted rice (₹ 46,120), with a benefit-cost ratio (B:C) of 2.38 in DSR versus 1.82 in transplanted rice (TPR). This translated to a 19.19% higher net return in DSR due to a 26.71% lower cost of cultivation. Additionally, farmers observed a 72.88% reduction in labour costs and a 33% reduction in irrigation water usage in DSR compared to traditional transplanting, making DSR a more economically efficient method for paddy cultivation.

The adoption of Drum Seeder technology in paddy cultivation has

On farm use of Drum Seeder

Table 1. Machinery in crop residue management

Machine name	Area and number of farmers covered	Sowing cost reduction	Residue management mechanism	Water saving	Yield increase by	Total economic benefit
Happy Seeder (Azamgarh)	9.0 acres	50% reduction	Cuts and incorporates paddy residue into soil	Saved 2–3 irrigations	4.2 t/ha → 5.0 t/ha (↑19%)	₹ 30,005/acre
Surface Seeding (Shrub Master)	Multiple farmers; >50 adopters	Low sowing cost (not quantified)	Seeds wheat on surface over paddy stubble	Higher water retention in soil	13.8%	High B:C ratio 3.59 (economic advantage)
Mulcher + Happy Seeder (Bareilly)	2 acres	Reduced labour and sowing cost (not quantified)	Mulcher chops stubble; Happy Seeder sows in residue	Saved one irrigation	7%	Improved B:C ratio to 2.25
Zero-Till Drill (Jaunpur)	Expanded from 238 ha → 5,832 ha	Reduced cultivation cost by ₹ 2,350/ha	No-till retention of residue improves moisture	Significant water saving (no ploughing)	23.9%	Net return ₹ 49,588/ha; BCR 3.01
Drum Seeder (Prayagraj and Raebareli)	Not fixed; used by multiple farmers	Saves labour cost (33–72.88% reduction)	Residue retained; direct seeding under wet conditions	25%–33% water saving	No yield loss; economic gain	₹ 20,000–25,000 more/ha (Prayagraj); ₹ 57,075/ha in DSR
Super Seeder (Rampur and Gorakhpur)	>240 units in use; large area coverage	Reduced cultivation cost by ₹ 12,175/ha	Cuts, mixes and incorporates paddy straw while sowing	Moisture conserved; fewer irrigations	7.5%	Additional net return ₹ 7,735/ha

demonstrated significant economic and resource-saving benefits, making it an ideal solution for small and marginal farmers facing labour shortages and rising input costs. By enabling direct seeding and reducing dependency on traditional transplanting methods, these technologies facilitate the retention of crop residues in the field, thereby enhancing soil organic matter and moisture retention.

Super Seeder (direct sowing) technology

The Super Seeder is a tractor-mounted implement designed to simultaneously sow wheat in rows and efficiently manage paddy crop residues. It combines a Rotavator and a zero-till drill, allowing for effective incorporation of paddy straw while ensuring precise seed placement. The Rotavator cuts standing stubbles, loosens straw and incorporates them into the soil, enhancing organic matter and improving soil structure. During this process, it also prepares the seedbed, enabling the zero-till drill to place seeds at the optimal depth in a single pass. By eliminating the need for stubble burning, the Super Seeder promotes soil fertility, conserves moisture and supports sustainable farming practices. This advanced technology not only reduces environmental pollution but also improves soil health and long-term productivity, making it a valuable tool for modern agriculture.

Farmers in Rampur have been using the Super Seeder for wheat cultivation over the past two years. Adoption of this technology has resulted in a reduction of ₹ 12,175/ha in cultivation costs while achieving a 7.5% increase in yield. This yield improvement is attributed to the timely sowing facilitated by the Super Seeder.

Similarly, farmers in Gorakhpur have integrated the Super Seeder for nitrogen management in wheat cultivation under partial residue conditions. The recommended practice involves applying 45 kg of urea per acre as a broadcast before sowing and 50 kg of DAP per acre through the Super Seeder at the time of sowing, with the remaining nitrogen applied in three splits for optimal yield. As a result, farmers achieved an additional net return of ₹ 7,735/ha compared to conventional practices.

Encouraged by these positive outcomes, farmers in the region have shown great interest in the technology. During 2022–23, a total of 113 Super Seeders were purchased, bringing the total number of units in use to over 240. This widespread adoption highlights the effectiveness of the Super Seeder in improving wheat productivity and profitability while promoting sustainable agriculture.

SUMMARY

Mechanised farming, through implements like Happy Seeder, Super Seeder, Zero Till Drill and Drum Seeder, has revolutionised crop residue management in northern India. These technologies have significantly reduced environmental degradation, enhanced soil fertility and lowered cultivation costs while improving farm efficiency and net income for farmers. Beyond economic benefits, mechanisation has strengthened farmer resilience, enabling diversification into additional income-generating activities. By eliminating the practice of stubble burning, these advancements contribute to reducing air pollution and greenhouse gas emissions, fostering a cleaner and more sustainable environment. In the long run, adopting such technologies will drive sustainable agriculture, ensuring higher farmer incomes and improved environmental health for future generations.

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