# A REVIEW MANAGEMENT OF CEREAL CROP RESIDUES FOR SUSTAINABLE RICE-WHEAT

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**ABSTRACT**

*The Indo-Gangetic Plains' rice-wheat (RW) farming pattern has contributed significantly to India's food security. However, owing to declining soil quality, increasing strain on natural resources, and looming climate change concerns, the long-term viability of this key agricultural system is in jeopardy. Conservation agriculture, which includes zero- or minimal-tillage and crop residue management (CRM) technologies to prevent straw burning, should help farmers achieve sustainable production while reducing fertilizer and water inputs and reducing climate change risk. The irrigated RW system's high yields have resulted in massive amounts of agricultural wastes (CRs). Rice straw burning is widespread in India's northwestern states, resulting in nutritional losses and severe air quality issues that endanger human health and safety. Mulch is an excellent alternative for managing rice residue throughout the wheat crop, particularly if no tillage is used. Mulch may boost production, water economy, and profitability while also lowering weed pressure. The leftover wheat crop residue may be put into the paddy fields with no negative impact on rice production. In anaerobic flooded soil, residue breakdown significantly increases methane emission compared to residue removal. Long-term residue recycling studies have shown increases in soil's physical, chemical, and biological health. Because CRs contain large amounts of plant nutrients, their continued use will improve fertilizer management in the RW system. Another viable CRM alternative is to utilize a part of excess residue to make biochar (and co-produce bio-energy) for use as a soil amendment to enhance soil health, boost nutrient usage efficiency, and reduce air pollution. The authors of this paper addressed existing problems and potential solutions for managing CRs in the RW cropping system.*

**KEYWORDS:** *Bioenergy, Crop Residues, Decomposition, Rice-Wheat System, Straw Mulch.*

## 1. INTRODUCTION

In India, the rice (Oryza sativa L.) - wheat (Triticum aestivum L.) (RW) cropping system was created by introducing rice into traditional wheat-growing regions and vice versa. RW emerged as the main production system spanning an area of 10 million hectares distributed over the Indo-Gangetic Plains (IGP) of India in the mid-1960s, thanks to Green Revolution technology. This area produces about one-third of India's total grains(1) The two NW states of Punjab and Haryana currently form a very productive RW zone in the IGP, producing approximately 69 percent of the country's total food production (about 84 percent wheat and 54 percent rice), and this area is known as the "food bowl of India." Several issues have arisen in the area as a result of the RW system's expansion during the past four decades, posing a danger to the system's long-term viability(2,3)(4).

Low levels of soil organic matter, the emergence of multiple nutrient deficiencies as a result of over-mining from soils, and poor management of crop residues (CRs), which leads to their burning, are just a few of the major factors contributing to the region's declining RW productivity. To feed India's anticipated population of 1.35 billion in 2025, agricultural output, particularly rice and wheat (India's main crops), will need to rise by around 25%. Furthermore, agricultural production in Punjab, Haryana, and western Uttar Pradesh may not be sustainable unless significant improvements in groundwater management and water use efficiency are made. Adopting conservation agricultural concepts in conjunction with improved bet crop management techniques will increase system productivity and total resource-use efficiency, leading in increased profitability and RW system sustainability(5–7)(8).

Every year, India produces about 500 million tons (Mt) of agricultural leftovers. Increased rice and wheat output has resulted in a significant rise in residue production. The production of CRs varies greatly, and their use is dependent on the crops grown, cropping intensity, and productivity in different parts of India. Cereal crops (rice, wheat, maize, millets) account for 70% of total CRs (352 Mt), with rice accounting for 34% and wheat accounting for 22%. Nearly one-fourth of India's total CRs are generated via the RW method. The excess CRs (i.e., total residues generated less the quantity utilized for different reasons) are usually burnt on-farm. India's excess CRs are projected to be between 84 and 141 Mt each year, with cereal crops accounting for 58 percent. Nearly 70 MT (44.5 Mt rice straws and 24.5 Mt wheat straws) of the 82 Mt of excess CRs are burnt each year(9–11)(12).

*1.1. Crop Residues as a Plant Nutrient Source:*

CRs are essential components for the stability of agricultural ecosystems because they are excellent suppliers of plant nutrients, the main source of organic matter (since C makes up approximately 40% of total dry biomass), and the primary source of organic matter supplied to the soil. At maturity, around 40% of the nitrogen, 30-35 percent of the phosphorus, 80-85 percent of the potassium, and 40-50 percent of the sulfur ingested by rice remains in the vegetative portions. Similarly, wheat residue retains approximately 25-30% of N and P absorption, 35-40% of S, and 70-75 percent of K uptake. On a dry weight basis, rice straw typically contains 5-8 kilogram N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg, and 40-70 kg Si per ton of straw. A ton of wheat residue includes 4-5 kg of nitrogen, 0.7-0.9 kg of phosphorus, and 9-11 kg of potassium. According to the study, rice straw contains 6.2 kilogram N, 1.1 kg P, and 18.9 kg K per ton, based on numerous observations(12)(13).

Potassium content is usually greater (up to 25 kg per ton) in rice straw of NW IGP than that from other areas of the India or other nations(14). The amount of nutrients in CRs is determined by soil conditions, crop management, variety, season, and other factors. In India, the quantity of NPK in rice and wheat residues produced (197 Mt) is about 4.1x 106 Mt. Given that 90% of rice straw and 30% of wheat straw are excess in Punjab, the yearly quantity of NPK recycled would be about 0.54 MT. A ton of rice and wheat residues contains approximately 9-11 kg S, 100 g Zn, 777 g Fe, and 745 g Mn in addition to NPK. Despite the dominance of chemical fertilizers in crop production, CRs continue to play a significant role in nutrient cycling. Under conventional fertilization methods, continuous removal and burning of CRs may result in net nutrient losses, resulting in greater nutrient cost input in the near term and a decrease in soil quality and productivity in the long run(15,16)(17).

*1.2. Crop Residue Management Options:*

The RW cropping method in NW India produces a large amount of CRs. On NW India, the majority of rice and wheat is harvested by combine, leaving leftovers in the field. While approximately 75% of wheat straw is gathered as animal fodder using a special cutting equipment, which involves extra work and expense, rice straw is considered poor animal feed owing to its high silica concentration. Rice straw varies from other straws in that it contains more silica (12-16 percent vs. 3-5 percent) and less lignin (6-7 vs. 10-12 percent). Rice straw stems are more digestible than leaves due to their lower silica concentration; thus, if the straw is to be given to animals, the rice crop should be cut as near to the ground as possible. Rice straw management, rather than wheat straw management, is a significant issue due to the short turnaround time between rice harvest and wheat planting and the absence of appropriate recycling technologies. Baling/removal for use as feed and bedding for animals, in situ absorption in the soil with tillage, and complete/partial retention on the surface as mulch utilizing zero or reduced tillage methods are among the CRM choices accessible to farmers (including burning). CRs may also be utilized for paper and ethanol manufacturing, bioconversion, and engineering uses once they have been bailed. Farmers are hesitant to spend in cleaning the field using a chopper since rice straw has little economic value and labor is scarce. This procedure necessitates a second surgery, which adds to the expense. Farmers in NW India have found that burning is the cheapest and simplest method to remove huge quantities of rice leftovers so that the wheat crop may be established quickly following rice. Currently, the famers burn more than 80% of the entire rice straw generated yearly in three to four weeks in October and November. When rice straw is burned, gaseous emissions include 70% $CO_2$, 7% CO, 0.66 percent $CH_4$, and 2.09 percent $N_2O$. Field burning of CRs contributes significantly to poor air quality (particulates, greenhouse gases) and has a negative effect on human and animal welfare, both medically and via traumatic road accidents in NW India owing to decreased visibility. Furthermore, burning CRs results in the loss of organic matter and valuable nutrients, including N and S. The yearly burning of rice residue in nearby fields corresponds with a surge in asthmatic patients in hospitals in NW India. Despite the fact that district judges in India's northwest have imposed a legal prohibition, farmers continue to burn CRs. In Punjab alone, about 20 Mt of rice and wheat residues are burned in situ annually, out of a total of 37 Mt, resulting in a loss of about 8 Mt of carbon equivalent to a $CO_2$ load of about 29 Mt per year and a loss of about 1 x 105 tons of nitrogen, as well as loss of S and destruction of beneficial soil microflora.

Removal of CRs for different off-farm uses (excluding composting and fodder) may have significant impacts on nutrient delivery, resulting in a short-term economic loss, but it will have a long-term detrimental impact on soil quality, water quality, and agricultural sustainability, as numerous studies have shown. In the long run, extra nutrient (NPK) fertilization will be required to restore harvested residue nutrients lost owing to residue removal(18).

*1.3. Decomposition and Release of Nitrogen from Crop Residues:*

In the sandy loam, total N release from buried residue by maximum tillering stage was approximately 6 kilogram N ha–1 (15 percent of original) and 12 kg N ha–1 (27 percent of initial) By the booting stage, the quantity of nitrogen produced from the buried residue on the sandy loam had risen to 12 kilogram ha-1, and by maturity, it had increased to 26-28 kg ha-1. Because N treatment after maximal tillering has a little impact on wheat grain production, the extra N released after booting may have no effect on grain output. During the wheat growing season, however, no N was released (rather, N was immobilized) from the leftovers on the soil surface, and the developing wheat crop received no N benefit. According to another research, the total quantity of nitrogen released by various rice straw decomposition treatments throughout the wheat crop's life span (150 days) varied from 6 to 9 kg N ha–1. With such tiny quantities of nitrogen released from integrated residue, substantial fertilizer N reductions are improbable. Furthermore, in the majority of experiments with incorporated residue, crops receive recommended or adequate amounts of fertilizer N, P, and K, implying that the increased yields of crops with incorporated rice residue were most likely unrelated to the contribution of macronutrients contained in the residue(19).

*1.4. Crop Residue Management on the Farm:*

Because of the shorter window between rice residue integration and wheat planting, and the sluggish rate of breakdown of rice straw due to high silica content and low temperature, recycling rice residue causes greater difficulties for succeeding wheat than wheat straw does for the next rice crop(20).

*1.5. Rice Straw Incorporation in Situ:*

While soil absorption of CRs is advantageous in terms of nutrient recycling, plowing under takes energy and time, results in temporary immobilization of nutrients (e.g., N), and the high C:N ratio must be adjusted by adding additional fertilizer N at the time of residue integration. In the near term, microbial immobilization of soil and fertilizer N causes N shortage in a crop produced shortly after residue assimilation. The amount of net N immobilization and net N supply from CRs to a future crop is determined by the decomposition time before planting the following crop, residue quality, and soil environmental conditions. In a long-term research, the inclusion of CRs shortly before planting the following crop reduced rice and wheat yields compared to the residue removal treatment(21)(14).

Rice straw may be effectively handled in situ by providing enough time (10-20 days) between its inclusion and wheat crop planting to prevent N shortage due to N immobilization. However, due to high integration costs and energy and time demands, only a few farmers have embraced in situ rice straw inclusion as an alternative to burning. Incorporating rice residue prior to wheat planting also causes a 2-3 week delay in sowing. In the rice-wheat system, three crop residue management techniques were used: residue removal, residue burning, and residue integration. The findings revealed that rice and wheat wastes may be safely integrated without causing any harm to the rice or wheat crops produced soon after inclusion. Rice residue application to wheat has a little impact on wheat yields in the first three years, but with the addition of straw in the fourth year, the effect becomes noticeable(22).

*1.6. Wheat Rice Straw Mulching:*

Mulching with rice straw in no-till wheat and incorporating combine-harvested or even manually harvested (as in the Middle and Lower IGP) wheat straw and stubble (1-2 t ha–1) in rice are emerging CRM alternatives in the IGP to prevent burning. CRs that are left on the soil surface help to save soil and water while also increasing crop production. In many semiarid settings, soil and water conservation is critical for agricultural production. In certain regions, up to 50% of a crop's total evapotranspiration may be lost due to evaporation from the soil surface. Mulching is the sole technique that decreases evapotranspiration by reducing evaporation, apart from altering the growth time of crops, as has been done for rice in the Indian Punjab. The aforementioned advantages are lost if all CRs are utilized as animal feed or eliminated for other reasons. As a consequence, it becomes more difficult to maintain soil production. Using suitable alternative practices, such as preserving partial residues, replenishing nutrients extracted in grain and CRs, producing forages that substitute for CRs, and implementing CA techniques, it is feasible to maintain crop output. Improvements in crop management that result in higher CR production may enable enough residues to be restored to fields and some to be removed without negatively impacting the soil ecosystem(23)(24).

In the NW IGP, zero-till wheat has been implemented on a large scale in the RW system, with good results in terms of wheat production, profitability, and resource efficiency. With tine-type openers, it has proven impossible to control CRs in no-till systems. Owing to the presence of loose straw in the seed drill furrow openers, the seed metering drive wheel loses traction, and the depth of seed placement is non-uniform due to frequent lifting of the implement under heavy trash circumstances, the depth of seed placement is non-uniform. Only when no-till is practiced consistently and the soil surface is covered by at least 30% of previous CR can the full advantages of no-till be achieved. Conservation agriculture will become more widely adopted in the area as a result of the usage of new-generation planters (Happy seeder). The Happy seeder works well for direct drilling in both standing and loose residues as long as the residues are evenly distributed. The weighted average wheat yield for HS seeded plots was substantially higher (3.24 percent) than the conventionally planted wheat, according to data from 154 on-farm experiments performed in various regions of Punjab between 2007 and 2010. When compared to no mulch, researchers found that rice straw mulch enhanced wheat grain production, reduced crop water consumption by 3-11 percent, and improved WUE by 25%. Mulch generated 40% larger root length densities in lower levels (>0.15 m) than no-mulch, owing to better soil moisture retention in deeper layers. Reduced tillage and in-situ absorption of rice crop residues (5 Mg ha–1), together with 150 kg N ha–1, were shown to be the most effective in achieving high wheat after rice yields in sandy loam soils of India's Indo-Gangetic plains. Wheat yields, on the other hand, were harmed by ZT owing to soil compaction, perhaps due to a lack of oxygen in the root zone, which hampered robust plant development.

## 2. DISCUSSION

Traditional agronomic methods are incapable of achieving the triple goals of:

1. Providing enough food to feed an ever-increasing population
2. Reducing the destruction of natural resources caused by agriculture
3. Ensuring the quality of the environment and ecosystem services.

CRs provide sustainable and environmentally friendly options for addressing agricultural fertilizer needs while also enhancing soil and environmental quality. Rice residue may be integrated into the soil with suitable equipment 10-20 days before planting of following wheat with no negative impact on the crop. Tillage to integrate rice residue, on the other hand, is expensive and time intensive, and it increases the danger of late wheat planting. Recent advancements in equipment (Happy Seeder) enable zero-till seeding of wheat using rice waste as surface mulch while preserving yield, reducing tillage costs and time, and eliminating the need for burning. It has been shown that using CR as a mulching material is advantageous since it lowers the maximum soil temperature and conserves water. Direct drilling wheat into rice residue with HS is a beneficial agronomic technique for wheat, as it helps to minimize soil organic matter loss while also increasing soil health. Owing to the decreased interaction with the soil, residues degrade slowly, and SOM breakdown is further slowed in wheat due to minimal tillage. Additional managerial skill requirements, fear of decreased crop yields and/or economic returns, unfavorable attitudes or views, and institutional limitations are all factors that prevent some farmers from adopting CRM systems. CRM makes nutrition management more difficult owing to increased residue levels and fewer choices for nutrient administration technique and timing. The difficulties of N fertilizer management in no-tillage with residue mulch systems point to the need for further study into better and more efficient fertilizer N use. In reality, a full bundle of activities (fertilizer, irrigation, weed control, pest management, and so forth) for CRM systems is required. It is necessary to investigate genetic variation in Si content in rice straw under various soil and water management conditions. To investigate various problems (genotypes with greater root biomass, equipment, insects, diseases, weeds, phytotoxicity, soil health, and economics) related with CRM, long-term research combining interdisciplinary methods are required. For fertilizer drilling, the HS has to be refined further, lowering its power requirements and increasing its capacity to operate in wet straw. Burning of CRs should be discouraged via reward and punishment in order to promote CR recycling on a wide scale. Subsidized machinery must be provided, as well as low-interest financing. During the awareness-raising phase, subsidies were a critical component in making the technology accessible.

## 3. CONCLUSION

Only if the management option is viable under a specific set of soil, climatic, and crop management circumstances, is compatible with existing equipment, and is socially and economically acceptable will the intended goals of adopting a certain CRM option be met. Future study should focus on the differences between above- and below-ground decomposition processes for a broader variety of CRs and nutrients, with a focus on both short- and long-term nutrient recycling. The impacts of CRM on pests and diseases in the RW cropping system have gotten little attention, and further study with various management methods is required. Because the flooded season may limit the survival of upland crop pathogens, there may be fewer mulch-related disease issues in the RW rotation than in a rotation of two distinct upland crops. Supporting on-farm adaption of CRM technology in both large and dispersed small fields, as well as providing targeted institutional and regulatory support, including suitable incentives, is needed in the IGP.

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