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Rice residue management alternatives in wheat under rice-wheat cropping system: A review

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Abstract

Residue management is becoming a more pressing concern for both environmental preservation and the sustainable growth of Indian agriculture, especially in the Indo-Gangetic Plains (IGP). Thirty percent of the 620 MT of agricultural residues produced annually in the nation are surplus, of which 234 MT are derived from rice and wheat. Of the entire agricultural residue burned, rice and wheat account for 62%, or about 16%. We currently lack a workable, organized strategy to deal with crop leftovers, or the rate of adoption is low. As a result, the majority of farmers burn rice wastes in the field, which not only degrades the environment but also significantly reduces nutrient levels. Intensive cultivation, combine harvesting, lack of conventional use for agricultural leftovers, and shortage of customers for rice straw are the main factors driving residue burning. It is imperative for farmers to have clear fields as soon as possible, regardless of the expense, to guarantee the timely seeding of wheat, the next crop, and to avoid any obstacles caused by loose straw during agricultural operations. Farmers are compelled to burn straw because it takes time to handle loose straw by mechanical means to ensure the next crop is sown in standing stubble smoothly. Farmers are compelled to burn straw because it takes time to handle loose straw by mechanical means to ensure the next crop is sown in standing stubble smoothly. Because it was done on a small scale, field burning of crop residue (FBCR) was not given much attention by policy makers in the previous 20 years. However, these days, FBCR is recognized as a serious agricultural pollutant that directly affects the environment, human health, and causes global warming because it produces greenhouse gases. This harmful practice depletes soil fertility and causes severe smog across Punjab, Haryana, Western Uttar Pradesh, and Delhi during harvest season. Rice and wheat are two of the main cropping systems in the IGP, and both create a lot of surplus wastes that is finally disposed of by burning it in the field, especially the leftover rice. The government and the legal system today do not tolerate FBCR. Strict regulations are already in place, punishing offenders with harsh fines and even jail time. Strict regulations are already in place, punishing offenders with harsh fines and even imprisonment. Despite being a major hassle for farmers, producers are nonetheless forced to continue this technique in the lack of a good and financially viable alternative. Crop residues must be managed both on the farm and after harvest. This can be done in a number of ways, including by modifying machinery, training farmers, adjusting the cropping method, and using rice straw for manufacturing and electricity production. An attempt has been made to cover the main topics of rice residue management in India's rice-wheat cropping system (RWCS) in this review.

Keywords: burning crop leftovers, environment, human health Plains of Indo-Gangetic, Management of residues, System of rice-wheat cropping

Introduction

A territory of 13.5 million hectares, mostly in the Indo-Gangetic plains, produces food for 400 million people, making rice-wheat cropping systems one of South Asia's main food supplies (Kumar *et al.*, 2018) ^[13]. Crop residues amount to 500-550 million tons (Mt) produced yearly in India. The Indo-Gangetic Plains (IGP) account for 90% of the country's rice cropping area (MoA, 2012) ^[16]. The Rice Wheat Cropping System (RWS) is one of the most extensively used cropping systems in India (Janaiah and Hossain, 2003) ^[11]. In the northwest of the IGPs, more than 75% of the rice land is harvested mechanically thanks to the advent of combine harvesters. According to estimates from the Indian government's Ministry of New and Renewable Energy (2009), 500 million tonnes of crop residue are produced each year. Uttar Pradesh produces the most crop trash (60 Mt), followed by Punjab (51 Mt) and Maharashtra (46 Mt). Cereals produce the most residues (352 Mt), followed by fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and

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sugar cane (12 Mt) among the other crops. 70% of crop leftovers come from cereal crops (corn, wheat, maize, and millet), whereas 34% come from rice crops alone, and wheat comes in second with 22%. The generated residue is primarily burned in the open for a variety of purposes, including animal feed, packing, bedding, in situ incorporation and manuring, thatching, and field placement. In contrast, combined harvesting leaves nearly all of the residue created in the field, where it is ultimately burned. Due to their considerable nutrient uptake, wheat and rice both severely reduce the amount of nutrients in the soil when they are planted in double crops. According to Dobermann and Fairhurst (2002) ^[1], 5-8 kg of nitrogen might be found in a tone of rice straw. Singh and Singh (2001) ^[7] state that a rice-wheat sequence that yields 7 t ha⁻¹ of rice and 4 t ha⁻¹ of wheat removes more than 300 kg N, 30 kg P, and 300 kg K ha⁻¹ from the soil. 10 t ha⁻¹ crops remove 730 kg of NPK from the soil, which is not always put back into the soil, according to another estimate by Gupta *et al.* (2002) ^[10]. This may lead to net negative balance and crop multi nutrient deficits because of soil mining for key nutrients. This is one of the causes of the yield loss in the rice-wheat system. Therefore, there is an urgent need to manage these crops' leftovers for the preservation of soil health and environmental stability Options for managing crop leftovers.

In India, the practice of planting rice with wheat yields copious amounts of crop wastes. The majority of wheat and rice in Northwest India are harvested using combination harvesters, which leave leftovers in the ground. The residues from cereal crops are mostly used as cow fodder. Both rice straw and rice husk used for parboiling are utilized as boiler fuel or as household fuel. Rice straw management is a significant issue as opposed to wheat straw management since there is minimal processing time between rice harvesting and wheat sowing, insufficient recycling technology, and a greater silica content than other crops. Among the various management choices are livestock feed, mushroom planting, incorporation, surface retention and mulching, biochar, baling, and straw removal to farmers in exchange for their efficient handling of crop leftovers. Farmers employ a variety of straw management techniques depending on the circumstances (Bisen and Rahangdale, 2017) ^[19].

Crop Water Productivity and Residue Management

Conserving water resources is the main issue facing modern farming. Retaining rice straw in the field after rainy rice harvest effectively preserves the remaining soil moisture for next crops, especially in arid regions (Chavan *et al.*, 2010) ^[32]. In addition to keeping the soil moist, mulching with rice straw also helps to control weed emergence, adjust soil temperature, and, most significantly, boost wheat production (Rahman *et al.*, 2005) ^[20]. 84% of the residues from rice- wheat systems are reportedly squandered (Singh and Panigrahy, 2011) ^[21]. Erenstein and Laxmi (2008) ^[31] and Ladha *et al.* (2009) ^[12] have reported that keeping rice straw in zero-till wheat under IGP boosts the wheat production, monetary return, and resource use efficiency. After harvesting, loose rice residue is evenly scattered using a happy seeder, which has been widely employed in conservation agriculture. In comparison to a condition when mulching is not done, the retention of rice residues reduces crop water use by 3-11% and enhances water use efficiency by 25% (Chakraborty *et al.*, 2010) ^[29]. Additionally, they observed that the improved soil moisture storage caused by rice straw results in a 40% improvement in wheat root length. Compared to residue burning, continual rice residue inclusion increased wheat output

by 34.89% throughout the course of the 13-year experiment because it improved soil health and resource use efficiency.

Management of Crop Residue and Soil Health

Both wheat and rice are heavy feeders of nutrients, and the over-mine of soil nutrients in the rice-wheat system is one of the main reasons for the poor health of the soil. The amount of nutrients that come from wheat and rice is more than the amount that fertilizers add and recycle. According to Singh and Bisen and Rahangdale (2017) ^[19], the preservation of residues improves the soil's physical, chemical, and biological qualities. The physical qualities include nutrient cycling, cation exchange capacity, soil reaction, and SOC sequestration, as well as microbial biomass C, soil biota activity, and species diversity. The implementation of sustainable agricultural residue management practices is one of the safer crop production choices (Raza *et al.*, 2019). ^[23] The careless burning of crop remnants has a major impact on the microbial community, plant micro- and macronutrients, organic matter content, and soil quality (Raza *et al.*, 2019, Nyanga *et al.*, 2020) ^[23, 24]. Around the world, a variety of crop residue management techniques, including conservation tillage, nutrient cycling, soil conversation methods, zero tillage and residue mulching, use in animal feed, and vermicompost preparation, are applied in real-world settings (Raza *et al.*, 2019). ^[23] By regulating the different biochemical characteristics of the soil, crop residue management can improve input consumption efficiency.

Physical Properties of Soil

Where there was the least degree of soil disturbance and more agricultural residue was retained on the soil surface or incorporated into the soil, the bulk density (BD) was frequently lower. BD is often lower in surface soils (0-15 cm) and increases in lower soil profiles (15-30 cm). When comparing different tillage techniques, zero tillage plots exhibited a lower bulk density

(1.59 mg m⁻³) than conventional tillage (1.61 mg m⁻³). In addition, surface soils with lower BD also show higher microbial activity levels. ZT+ residue retention (ZT+R) increased soil organic matter and reduced BD by increasing infiltration, aeration, and microbial populations Happy seeder can minimize soil disturbance while reducing the frequency of tillage operations Crop residue encourages increased soil aggregation through reduced BD, especially in RWCS, since it is lighter and decomposes more quickly than mineral matter. Conventional tillage procedures lead to increased soil compaction because they require more tillage operations.

Influence on the soil's physical health

Crop residue management techniques have an impact on the physical characteristics of soil, including bulk density, aggregate formation, soil moisture content, and soil porosity. Crop residue retention and/or incorporation has reduced soil compaction and bulk density (Bellakki *et al.*, 1998) ^[2]. For a period of three years, the bulk density in the 0-5 cm layer on a sandy loam was decreased from 1.20 to 0.98 g cm⁻³ by applying 16 t ha⁻¹ of rice straw annually. The reduced infiltration led to an increase in compaction and a decrease in the pore percentage of the surface soil because of the aggregates' disintegration and the raindrop effect's formation of the surface seal. The preservation of residue on the surface resolves this problem. Including agricultural residues Compared to no residue application, WHC, microbial population, and soil fertility, there was a drop in BD and an increase in infiltration rate. Maximum output, nutrient

absorption, enhanced residual soil fertility, and the condition of soil microorganisms were the outcomes of integrating wastes with NPK fertilizer. Research has demonstrated that the addition of residues from leguminous crops improves the physical characteristics of the soil, including its capacity to retain water and its permeability. By increasing the availability of nutrients in the crop root zone, the addition of leguminous crop residues also increases crop growth and production (Smitha *et al.*, 2019)^[27]. Heavy machinery and farm equipment, such as planters, reapers, zero-tillage implements, and combine harvesters, are frequently used in modern input-intensive agriculture. When these pieces of equipment are used carelessly, the soil can become compacted and its physical qualities, such as water-holding capacity, airflow, and infiltration rate, can be negatively impacted (Smitha *et al.*, 2019)^[27]. According to Carlesso *et al.* (2019)^[28], ryegrass and straw residues can be used as agricultural residue as well as mixed litter can greatly improve the soil's porosity and ability to hold water, which will ultimately raise the soil's efficiency. It has been shown that applying crop residues in conjunction with conservation tillage increases soil aggregate and increases carbon storage in rice-based cropping systems (wang *et al.*, 2019)^[35].

Impact on the soil's chemical health

The pH of the soil, which is heavily influenced by agricultural residues in the soil, is a determining factor in the fertility of the soil. Straw applied over an extended period of time will increase the availability of both macro- and micronutrients while also determining the amount of soil organic matter and N reserves. The introduction of residues from both crops into the rice-wheat system improved the total P accessible P and K content in the soil over residue removal, according to an 11-year study on loamy sand soil conducted by Beri *et al.* (1995). According to Gupta *et al.*'s (2007)^[10] three-year investigation, adding crop waste to burned straw reduced P sorption and increased P content of both organic and inorganic P release volume rises. Remaining residue can recycle between 50 and 80 percent of the Zn, Fe, Cu, and Mn micronutrients that rice and wheat crops need. The availability of micronutrients in rice, such as iron and zinc, is impacted by crop residues (Singh *et al.* 2005 and Gupta *et al.* 2007)^[25, 10]. Sustainable crop management can successfully improve the chemical properties of the soil, including pH, electrical conductivity, and cation exchange capacity (CEC), as well as the conversion of different nutrients from primary and secondary plants. The application of crop residue is found to have a substantial link with the soil carbon pool (both complete and labile pool). It is claimed that applying 75 kg of N ha⁻¹ in addition to 10 mg ha⁻¹ of wheat residue mulching will greatly boost the overall and volatile carbon stock in a system of irrigated maize cultivation (Chatterjee *et al.*, 2018)^[8]. Adoption of conservation tillage in a rice-maize cropping system with residue management may be beneficial in order to increase system production, K usage efficiency, and obvious K balance (Singh *et al.*, 2018)^[26]. Incorporating residue is advantageous for the requirement for external K supply and the recycling of up to 15% of useable K soil (Singh *et al.*, 2018). According to Smitha *et al.* (2019)^[26], using cluster bean crop residue prior to transplanting sacred basil (*Ocimum sanctum* Linn) greatly increased the availability and SOC of soil macronutrients.

Influence on the biological well-being of the soil

In particular, soil microbial biomass (SMB) and microbial activity, which in turn depend on the soil's supply of organic

substrates, are key factors in the availability of nutrients like N, P, and S. The population of soil fauna and flora has a positive correlation with the soil phyto- biomass current. According to Beri *et al.* (1995) and Sindu *et al.* (1995)^[39], soil treated with crop residues had 1.5-11 times more fungus than soil and 5-10 times more aerobic bacteria. Verhulst *et al.*'s 2009^[34] study^[40] revealed that in both rainfed and irrigated long-term trials, soil microbial biomass (C and N) declined in the zero-till treatments, and the amount of residue maintained on the soil surface reduced. The soil's microbial biomass is a representation of the soil's capacity to hold and cycle organic matter and nutrients (C, N, P, and S), which is crucial for the aggregate's physical stabilization. Additionally, crop leftovers have been shown to boost the asymbiotic bacteria in the soil that fix nitrogen (*Azotobacter chroococcum* and *A. agilis*). The increase in soil microbial population also boosts the activity of soil enzymes that convert inaccessible to useful nutrient types. It has been suggested that maintaining agricultural leftovers properly has a significant impact on controlling soil microbial biomass. Through the use of agricultural residue mulching, observed improved microbial activity in the top layer of soil, which may be related to changes in the plant-soil microclimate, more water availability, and fertilizers and regulation of soil temperature. According to Chatterjee *et al.* (2018)^[8], who saw similar outcomes, applying wheat crop residue greatly raised the amount of soil microbial biomass carbon (MBC). It has been shown that adding leguminous crop residues, like cluster beans, to the soil prior to planting the following crop increases soil microbial biomass and dehydrogenase activity (DHA) in comparison to the control treatment, which also uses crop residue. Additionally, it has been shown that retaining CA residue helps lower the population of soil nematodes in a wheat-soybean cropping system (Escalante *et al.*, 2020)^[18].

Effects on soil production and fertility

Cattle residue management done right is very advantageous for soil fertility maintenance and nutrient recycling. According to Rusinamhodzi *et al.* (2016)^[30], effective crop residue management enhances farm animals' general health as well as soil production and nutritional condition. Long-term crop residue utilization combined with conservation tillage has been suggested as a way to boost soil productivity, C-pool productivity, and earthworm population productivity (Frazao *et al.*, 2019). Crop residue is a valuable organic matter that is becoming more and more important in global agriculture. It improves soil characteristics, water conservation, C stock, and nutrient recycling. It also lessens residue burning patterns and the ensuing environmental hazards when it is retained (Fig. 2) (Liang *et al.*, 2016). Cereals account for 74% of the total crop residue production; sugar crops (10%), legumes (8%), tubers (5%) and oilseeds (3%) follow (Lal, 2005)^[14]. Crop residue contains a variety of mineral nutrients in addition to C, depending on the type of crop and the quality of the soil (Lal, 2005)^[14]. However, because crop residues are known to initially immobilize the available soil N due to their high C:N ratio, it is exceedingly difficult to determine how many nutrients would be available to crops at the time of crop residue integration (Garai *et al.*, 2020). Long-term, meanwhile, this practice is highly effective in producing high-quality organic matter and ensuring that nutrients are available for successive crops. and promotes increased food crop productivity (Yadvinder- Singh and Timsina, 2005)^[33]. The highest residues are seen in the cultivation of legumes, followed by grains. Legume residues are thought to be good quality residues rather than quantity since

they retain a considerable amount of soil C for an extended period of time.

Materials and methodology study area

The study was conducted at Lovely Professional University in Phagwara, Punjab, using sandy loam soils. Sand, silt, and clay contents in the research soils were 40.5%, 38.4%, and 33.2%, respectively. Before the study started, soil samples were taken at depths ranging from 0 to 15 cm throughout the entire experimental field. A composite sample was then made and analyzed later. The original pH of the soil was 7.79, with electrical conductivity (EC) of 0.28 dS m⁻¹, bulk density of 1.56 g cm⁻³, 0.37% soil organic carbon, oxidizable nitrogen (K_{mn}O₄) of 133.2 kg ha⁻¹, extractable phosphorus (P) of 13.94 kg ha⁻¹ NaHCO₃, and exchangeable potassium (K) of 270.4 kg ha⁻¹ (1.0 N NH₄OAc).

Experimental details and field management

The current study consist of 10 treatments details are: T1 - CTW drill sown after full residue removal, T2 - CTW rotavator sown after full residue incorporation, T3 - ZTW drill sown after full residue removal, T4 - ZTW drill sown in anchored stubbles, T5 - CTW super seeder sown in partial residue with pusa decomposer application (PD), T6 - CTW super seeder + partial residue + PD + 25 percent more N, T7 - CTW super seeder + partial residue + PD + Nano urea. T8 - CTW super seeder + partial full residue + PD, T9 - CTW super seeder + full residue + PD + 25 percent more N, T10 - CTW super seeder + full residue + PD + Nano urea were arranged with three replications using randomized complete block design (RCBD). The Happy Seeder is a tractor-mounted device that chops and lifts rice straw, plants wheat in the ground, and then spreads the straw mulch over the area that has been sowed. It is made up of a zero-till drill for planting the following crop and a straw management rotor for removing crop remnants from the previous one. The straw management rotor is equipped with flail-style straight blades that cut, strike, or shear standing stubbles or loose straw that comes in front of the sowing tyne.

This allows each tyne to be cleaned twice during a single rotor spin, ensuring proper seeding.

The failure to push the remnants as much as possible between the rows of seeds. The net plot size of individual plot are 11 m×5.5 m=60.5m². 1. Crop leftovers were burned by spreading loose straw on the field itself after the rice crop was harvested and before the field was irrigated before pre-sowing. Loose straw was physically gathered and removed from the field in order to treat residue removal. A chopper-cum-spreader machine was used to evenly spread and chop up loose straw across the field prior to planting the following wheat crop. Before the wheat crop was sown, pre-sowing irrigation was applied.

In zero-tillage plots with anchored stubbles, varying degrees of residue removal (none, partial) were maintained according to treatments, and drilling with a zero-till drill was used for seeding (T3, T4). The super Seeder machine, which sows seed directly in loose stubbles, was used to sow in zero tillage plots with partial residue retention (chopped or unchopped) with application of pusa decomposer and application of 25 percent more nano urea done in (T5, T6, T7). Conventional tillage after full residue incorporation done with rotavator in T1. Conventional tillage after the full residue removal with two harrowing and one time rotavator followed by planking done (T1, T2). Conventional tillage with partial residue by application of pusa decomposer before sowing and sowing with seed drill in T8. conventional tillage with application of pusa decomposer before sowing with

25 percent more nano urea and sowing done with super seeder in (T9, T10).

Conclusion

The country's most intensive farming system is the rice-wheat cropping system. It makes up a sizable chunk of all the cultivable land in India. Recycled leftovers have a remarkable potential to return a significant amount of plant nutrients to the soil. The system is particularly threatened by yield stagnation brought on by the soil's declining organic carbon content. Therefore, managing rice wastes effectively and efficiently is a major problem for farmers who want to maintain the sustainability of output while also increasing carbon sequestration. Every managerial decision has advantages and disadvantages. It is dependent upon a specific set of soil, environmental, and crop management parameters that are compatible with the machinery at hand as well as socially and suitable from an economic standpoint. To prevent residue burning in the rice-wheat cropping system, it is critical to assess and modernize mechanized harvester equipment for sustainable residue usage. It is possible to use appropriate conservation tillage techniques for the location and soil type. Changes in the physical, chemical, and biological characteristics of the soil can be justified and the productivity of the rice-wheat cropping system maintained provided rice residues are managed appropriately.

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