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A REVIEW CROP RESIDUES MANAGEMENT OPTION FOR SUSTAINABLE SOIL HEALTH IN RICE-WHEAT SYSTEM

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ABSTRACT

The rice-wheat system is India's most dominant agricultural system, but its long-term viability is in jeopardy owing to deteriorating soil health and climate change concerns. The irrigated Rice-wheat system's high yields have resulted in massive amounts of agricultural leftovers. Rice straw burning is widespread in north-west India, resulting in nutrient losses and severe air pollution, both of which are harmful to human health. To prevent straw burning, agricultural residue management technologies could help farmers achieve sustainable productivity, decrease fertilizer and water inputs, and mitigate climate change risk. Crop leftovers contain large amounts of plant nutrients, and their proper use will improve nutrient management in the rice wheat system. Long-term residue recycling studies have shown increases in soil's physical, chemical, and biological health. Another viable crop residue management option is to use a portion of the surplus residue to produce biochar as a soil amendment to improve soil health, increase nutrient use efficiency, and reduce air pollution, as well as other options such as mushroom cultivation to convert inedible crop residues into valuable food, surface mulch to conserve soil moisture and prevent weeds, biofuel and composting. Soil organic carbon and other nutrients are significantly increased as a result of residue decomposition. The authors of this paper examined residue potential and alternatives for effective crop residue management in the rice wheat cropping system.

KEYWORDS: *Crop Residues, Human Health, Plant Nutrients, Rice-Wheat, Sustainable Soil Health.*

1. INTRODUCTION

Crop residues are plant components that have been left in the field after harvesting and threshing. Crop residue recycling has the benefit of turning excess agricultural waste into a valuable product that may be used to satisfy the nutritional requirements of following crops. Crop leftovers provide organic C to soil microbes while also providing nutrients to plants. Crop residue retention on the soil surface decreases run-off, soil erosion, and soil evaporation, as well as land preparation expenses. Crop residues are produced in India in quantities ranging from 500 to 550 million tonnes (Mt) each year. The Rice Wheat Cropping System (RWS) is one of India's most commonly used cropping systems, with 90 percent of the country's land located in the Indo-Gangetic Plains (IGP). In the northwestern portions of the IGPs, more than 75 percent of the rice land is harvested mechanically since the advent of combine harvesters(1–3)(4)(5).

Wheat straw is removed by the majority of farmers for animal feed. Rice straw, on the other hand, is a significant problem to handle since it is regarded as a poor feed for animals due to its high silica concentration(6). A swath of loose rice leftovers is left behind by the combine harvester, interfering with the seed drill's operations while planting wheat. Farmers burn agricultural waste to prevent these issues (90-140 Mt annually). From the perspective of the farmers, burning rice straw may be the most appropriate way of disposal. It is not only a cost-effective technique, but it also works as a pest control method(4)(7)(8). Rice straw burning is projected to generate 0.05 percent of India's total greenhouse gas (GHG) emissions, which not only results in the loss of vast amounts of biomass, such as organic carbon and plant nutrients, but also has a negative impact on soil characteristics as well as soil flora and fauna. As a result, strategies for managing this important resource must be developed. Crop residue potential, management choices, and soil characteristics related with residue management, among other things, are addressed in this article(9–11)(5).

1.1. Potential of Crop Residues:

According to the Ministry of New and Renewable Energy of the Government of India (2009), about 500 Mt of agricultural leftovers are produced each year. Uttar Pradesh produces the most agricultural wastes (60 Mt), followed by Punjab (51 Mt), and Maharashtra (40 Mt) (46 Mt). Cereals produce the most residue (352 Mt), followed by fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (13 Mt) (12 Mt). Cereal crops (rice, wheat, maize, millets) account for 70% of crop residues, with rice accounting for 34% of total residues and wheat accounting for 22% (Figure 1).

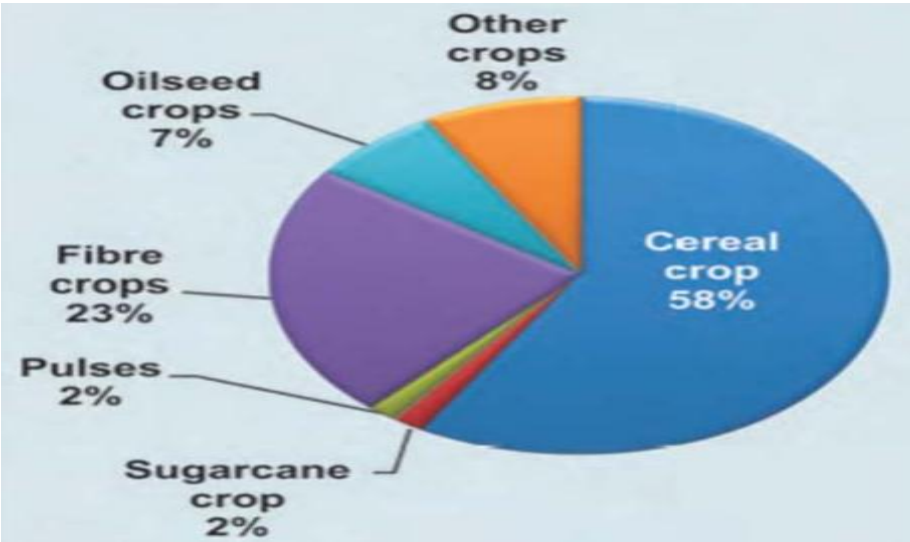

Figure 1: Represents the share of unutilized residues in total residues generated by different crops in India(12)**.**

In India, rice wheat accounts for almost a quarter of all crop residual output. The residue is mostly used as industrial/domestic fuel, animal feed, packing, bedding, in situ incorporation and manuring, thatching, and open burning in the field. On contrast, nearly all of the residue produced by combine harvesting is left in the field, eventually being burned(13)(14)(15).

1.2. Burning crop residues:

India, as an agriculturally dominant country, produces more than 500 million tons of crop residues each year, with a large portion of these unused crop residues being burned in the fields to clear the left-over straw and stubbles after harvest, which obstruct tillage and seeding operations for the following crop. Burning agricultural leftovers in the fields is caused by an increase in the usage of combines in harvesting, a lack of manpower, and the high expense of removing residue from the field. Burning agricultural wastes results in significant losses of nitrogen (up to 80%), phosphorus (up to 25%), potassium (up to 21%), and sulfur (up to 4-60%). This technique not only pollutes the air and depletes soil microbial mass, but it also kills pests and diseases. Burning residues depletes soil organic matter, posing a visible danger to the rice wheat system's long-term viability(16,17)(18).

1.3. Management options for crop residues:

The rice wheat farming method in India produces massive amounts of crop leftovers. On North West India, the majority of rice and wheat is harvested using a combine harvester, leaving leftovers in the field(19). Cereal crop leftovers are mostly utilized as livestock fodder. Rice straw and husk are utilized as a source of household heat or in rice parboiling boilers. Rice straw management, rather than wheat straw management, is a significant issue due to the short turnaround time between rice harvest and wheat planting, as well as a lack of appropriate recycling technology and a greater silica content than other crops. Livestock feed, mushroom culture, incorporation, surface retention and mulching, biochar, and baling and removing the straw are some of the agricultural waste management alternatives accessible to farmers. Depending on the circumstances, farmers use a variety of straw management techniques(20)(21)(21).

1.4. Livestock feed made from crop residues:

Crop leftovers are traditionally used as animal feed in India, either as is or supplemented with additives. Crop leftovers, on the other hand, are unpleasant and have a poor digestibility, therefore they cannot be used as a single diet for animals. Because of its high silica concentration, rice straw is considered poor animal feed. It varies from other straws in that it has a greater silica concentration (12-16 vs. 3-5%) and a lower lignin level (6-7 vs. 10-12 percent). Different techniques may be used to improve the nutritional value of rice straw. To increase the nutritional value of crop leftovers, physical, chemical, and biological treatments have been employed to weaken and break down lignocellulose linkages. Around 75% of wheat straw is used as animal feed, chopped into tiny bits using a special cutting machine, but this takes extra work and expense. 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. The leftovers must be processed and enriched with urea and molasses, as well as supplemented with green fodders (leguminous/non-leguminous) to meet the nutritional needs of the animals(18)(15).

1.5. Composting Crop Residues:

Crop leftovers are utilized as animal bedding and then piled in dung pits to make compost. Each kilogram of straw absorbs approximately 2-3 kg of urine in the animal shed, enriching it with nitrogen. When rice crop leftovers from a hectare of land are composted, they provide approximately 3 tons of manure that is as nutrient-dense as farmyard manure (FYM). Rice straw compost may be reinforced with P utilizing an indigenous low-grade rock phosphate source, resulting in a value-added compost with 1.5 percent nitrogen, 2.3 percent phosphorus, and 2.5 percent potassium.

1.6. Mushroom Cultivation with Crop Residues:

The use of residues in mushroom cultivation offers a beneficial conversion of inedible agricultural wastes into valuable food, which contains two to three times the protein of ordinary vegetables and an amino acid composition comparable to that of milk or meat, despite their high moisture content. Wheat and rice straws, two of the four most frequently cultivated fungi, are ideal substrates for growing Agaricus bisporus (white button mushroom) and Volvariella volvacea (straw mushroom). Straw for Agaricus culture is typically combined with horse manure and hay, resulting in a very high substrate conversion efficiency into fungal bodies. 1.7. Biofuel from Crop Residues:

Biofuel is unquestionably a crucial approach for reducing reliance on fossil fuels. The conversion of ligno-cellulosic biomass to alcohol is important because ethanol may be utilized as a fuel extender and octane enhancer in gasoline or as a standalone fuel in internal combustion engines. Theoretical ethanol production estimates range from 382 to 471 l t-1 of dry matter from various feedstocks (corn grain, rice straw, wheat straw, bagasse, and saw dust). However, in India, the technology for producing ethanol from agricultural waste is still developing. In the conversion of agricultural wastes to alcohol, there are a few limiting processes that need to be addressed.

1.8. Biochar from Crop Residues:

Biochar and agricultural residues have received a lot of attention in the last year as a potential approach for preserving soil health. Biochar is a fine-grained charcoal with a high carbon content that is produced by gradual pyrolysis (heating without oxygen) of biomass. It has the potential to play a significant role in long-term carbon storage in soil. When applied to soil, biochar made from plant biomass includes a unique refractory form of carbon that is resistant to microbial destruction and therefore may be utilized as a carbon sequester. Furthermore, biochar has been proven to decrease greenhouse gas (GHG) emissions from agricultural areas while also improving water quality due to its high pollutant absorption capacity. Biochar characteristics, on the other hand, are often affected by biomass sources and pyrolysis conditions.

1.9. Incorporation of Crop Residue:

Unlike crop waste removal or burning, straw inclusion improves soil organic matter and N, P, and K content. Ploughing is the most effective technique for incorporating residues. Depending on the cultivation technique, crop wastes may be absorbed partly or fully into the soil. Due to low temperatures and the short time between rice harvest and wheat planting, incorporating rice leftovers before wheat planting is more challenging than incorporating wheat straw before rice planting. Crop residue integration in the field is advantageous in terms of recycling nutrients, but also causes temporary immobilization of nutrients (e.g., nitrogen), necessitating the use of additional nitrogenous fertilizer to rectify the high C:N ratio at the time of residue incorporation. In the near term, this N shortage is produced by decomposer microbial immobilization of available soil and fertilizer nitrogen. This time frame is determined by the amount of time it takes for crop residue to decompose before the following crop is planted, as well as the quality of the residue and the soil conditions. The results of a six-year research indicate that in situ inclusion of rice straw in soil 10, 20, or 40 days before wheat planting had no negative impact on wheat grain production. Rice straw put into wheat had no impact on the rice harvest that followed(22)(23).

1.10. Crop residue as a surface mulch:

Residue retention on the soil surface seems to be a superior choice for soil conservation and preventing evaporative water losses. It also inhibits the germination of weed seeds and aids in the development of soil microbial communities, resulting in an increase in soil organic carbon, which is a direct indication of soil health. In the northwest IGP, zero-till wheat has been implemented in the rice wheat system, with favorable effects on wheat production, profitability, and resource efficiency. For this aim, a new advanced generation seed drill has been developed. According to reports, the Happy Seeder will encourage more people to practice conservation agriculture. If the residues are distributed evenly, the Happy seeder works well for direct drilling in standing as well as loose residues(24)(25).

When compared to no mulch, the 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.

1.11 Soil Health and Crop Residue Management:

Rice and wheat are both nutrient-intensive feeders, and excessive nutrient mining of soils is one of the main reasons of poor soil health in the rice-wheat system. Rice and wheat lose more nutrients than are supplied via fertilizers and recycled. Soil physical (structure, infiltration rate, plant available water capacity), chemical (nutrient cycling, cation exchange capacity, soil reaction), and biological (SOC sequestration, microbial biomass C, activity, and species diversity of soil biota) quality are all improved when residues are retained.

2. DISCUSSION

Soil physical characteristics such as soil moisture content, aggregate formation, bulk density, and porosity are all affected by crop residue management methods. Crop residues were incorporated and/or retained in the soils, which decreased bulk density and compaction. The annual application of 16 t ha-1 rice straw for three years reduced bulk density in the 0-5 cm layer on a sandy loam from 1.20 to 0.98 g cm-3. Because of the disintegration of aggregates and the development of a surface seal as a consequence of raindrop contact, the surface soil becomes more compacted, and the pore percentage of the surface soil decreases, resulting in reduced infiltration. This issue is solved via residue retention on the surface. In comparison to the no-residue condition, crop residue incorporation reduced BD and increased infiltration rate, WHC, microbial population, and soil fertility. The greatest production, nitrogen absorption, residual soil fertility, and soil microorganism status were achieved when residue was combined with NPK fertilizer.

The availability of nutrients such as N, P, and S is influenced by soil microbial biomass (SMB) and microbial activity, which are in turn influenced by the availability of organic substrates in the soil. The phyto-biomass contained in soil is positively linked with the population of soil flora and fauna. Crop residue-treated soil had 5-10 times more aerobic bacteria and 1.5-11 times more fungus than soil that had been burned or removed. In the zero till treatments of both rainfed and irrigated long term trials, soil microbial biomass (C and N) declined as the quantity of residue maintained on the soil surface decreased. The capacity of the soil to retain and cycle nutrients (C, N, P, and S) and organic matter is reflected in its microbial biomass, which plays an essential role in aggregate physical stability. Crop leftovers are also known to help asymbiotic bacteria fix nitrogen in the soil (Azotobacter chrococcum and A. agilis). The activity of soil enzymes responsible for converting inaccessible to available forms of nutrients rises as the microbial population of the soil grows.

The pH of the soil, which is heavily affected by agricultural residues absorbed in the soil, is a deciding element of soil fertility. Long-term straw application will enhance soil organic matter and nitrogen stocks, as well as macro- and micronutrient availability. The integration of residues of both crops in the rice wheat system improved the total P accessible P and K content in the soil over the removal of residues, according to an 11-year field research performed on loamy sand soil. The inclusion of crop residue over straw burnt enhanced inorganic and organic P, decreased P sorption, and boosted P release, according to a three-year research. Micronutrients (Zn, Fe, Cu, and Mn) taken up by rice and wheat crops may be recycled in the form of integrated residue to the tune of 50-80%. The availability of micronutrients like zinc and iron in rice is influenced by crop waste.

Decomposition is influenced by residue properties as well as soil and crop management variables. N immobilization may last 4-6 weeks under ideal temperature and moisture conditions. Residue management methods have an impact on soil microbial biomass (SMB). When leftovers are burned, many employees notice a decrease in microbial biomass. Microbial activity is higher when residues are incorporated rather than removed or burned.

3. CONCLUSION

The rice-wheat cropping system is the country's most intensive cropping system. It accounts for the majority of India's cultivable land. Its residue recycling has the ability to restore a significant quantity of plant nutrients to the soil. The stalling of yields as a result of decreasing soil organic carbon is a significant danger to this system. As a result, agriculturists have a significant problem in managing rice residues effectively and economically in order to increase carbon sequestration while preserving production sustainability. Every management approach has its own set of benefits and drawbacks. It is feasible under certain soil, climatic, and crop management circumstances, as long as they are compatible with existing equipment and are socially and economically acceptable. To prevent residues burning in rice wheat cropping systems, the technology with automated harvesters must be reviewed and upgraded for long-term residue usage. Conservation tillage technique tailored to a particular location and soil condition may be used. Diversification of the rice-wheat cropping system is also necessary, according to research. If rice wastes are correctly handled, soil physical, chemical, and biological characteristics will improve, and the rice-wheat cropping system's productivity will be maintained.

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