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Crop residue management for sustainable agriculture

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Abstract: India's agricultural sector faces challenges encompassing soil fertility, food grain production, environmental degradation, and food security amidst growing demands for limited cultivable land. About 17.6% of the population relies on arable land, highlighting strain on natural resources. Food grains, crucial for energy and sustenance, play a vital role.Crop harvesting advancements and mechanization lead to significant residue accumulation. Regrettably, residues are often burned, mistakenly believed to enhance soil fertility and pest control. However, research contradicts this notion, showing burning depletes organic carbon and vital soil nutrients. Emissions from residue burning, including CO_2, SO_2, CO, and smoke, harm the environment and human health. Annually, India produces 500 million tons of crop residues, valuable for animal feed, mulching, composting, and mushroom cultivation. Yet, around 93 million tons are burned due to labor shortages and residue mismanagement. This worsens as residues can host pests and diseases.

Introduction: India, a country where agriculture holds significant prominence, generates an annual surplus exceeding 500 million tons of crop residues. These residual materials serve various purposes, including being utilized as fodder for livestock, employed in home thatching, and serving as both domestic and industrial fuel sources. However, a substantial portion of these unused crop residues is subjected to combustion within fields, primarily undertaken to clear the remaining straw and stubble following harvest. This practice is primarily driven by factors such as the scarcity of labor, the prohibitive expense associated with removing residues from fields, and the increasing adoption of combine harvesters in crop harvesting. Unfortunately, the practice of burning crop residues in fields gives rise to a range of negative outcomes. It contributes to environmental pollution, poses risks to human well-being, emits greenhouse gases that contribute to global warming, and leads to the depletion of vital plant nutrients such as nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). Consequently, the effective management of crop residues takes on a paramount significance in addressing these challenges and mitigating their far-reaching implications.

Crop residues serve as a valuable source of organic carbon for soil microorganisms and play a crucial role in supplying essential plant nutrients. In India, a surplus of 140 million tons (Mt) of crop residues is produced annually, out of which 92 Mt is burned each year.The retention of crop residues on the soil surface has multiple beneficial effects, including the reduction of run-off and soil erosion, along with decreased soil evaporation and lower land preparation costs. India witnesses an annual production of 500-550 million tons (Mt) of crop residues. While farmers often remove wheat straw for animal feed, effectively managing rice straw poses a significant challenge due to its high silica content, rendering it less suitable for animal consumption. Mechanized combine harvesters tend to leave a layer of loose rice straw, which can interfere with the sowing of wheat using a seed drill. In order to address these issues, farmers resort to burning their crop residues, with an estimated annual range of 90-140 Mt.

Farmers often perceive burning as a cost-effective and practical approach to managing crop residues, as it not only facilitates disposal but also appears to aid in pest control. However, one of research studies has demonstrated that burning rice straw contributes to approximately 0.05% of total greenhouse gas emissions in India. This practice not only leads to the loss of substantial biomass, including organic carbon and plant nutrients but also exerts adverse effects on soil properties, both chemical and biological, as well as the physical attributes and the soil's flora and fauna.

– Burning of crop residue create following problems
– Loss of nutrients
– Impact on soil properties

– Emission of greenhouse gases (GHG)

– Challenges for management of crop residue

– Huge volume of crop residue. Collection and Storage.

– Time window between harvesting and sowing of two(next)crops.

– Utilization of crop residue.

– Cost-effective mechanization, awareness and availability of appropriate machinery.

Management of crop residues:

Balling and removing the straw : Excess agricultural straw presents several valuable possibilities, including its utilization as livestock feed, fuel, construction materials, bedding for livestock, and compost for mushroom cultivation an avenue that holds substantial promise for utilizing both forest and agricultural residues. This surplus straw can also be employed as bedding for vegetables like cucumbers and melons, as well as for mulching purposes in orchards and various other crops.

Soil mulch : Direct drilling in surface mulched residues is a practice that leaves remnants from a previous crop on the soil surface without incorporation. This surface retention shields fertile soil against wind and water erosion. While this method offers erosion protection, the substantial residue volume can lead to machinery issues, affecting subsequent crop seeding. Farmers often adopt this approach in no-till or conservation tillage systems. Surface residue retention can be optimal in various scenarios, effectively suppressing weed growth. Residues gradually decompose on the surface, boosting organic carbon and total nitrogen in the top 5-15 cm of soil, while safeguarding it from erosion. This practice enhances soil NO_3- concentration by 46%, nitrogen uptake by 29%, and yield by 37% compared to burning, while also maintaining soil temperature.Retained residues offer habitat for both harmful and beneficial organisms, and they provide a carbon substrate for heterotrophic nitrogen fixation, bolstering microbial activity, soil carbon, and nitrogen content. Additionally, it reduces nitrogen fertilizer needs for rice cultivation. Faster decomposition and nitrogen release are possible when residues are treated with urea during field preparation.

Crop residues incorporation : Crop residues can be incorporated into the soil partially or fully, depending on the cultivation methods. Straw incorporation has the potential to enhance crop yields, and ploughing is an effective means of achieving residue incorporation. However, incorporating rice residues before sowing wheat, compared to incorporating wheat straw before rice planting, can be challenging due to low temperatures and the short interval between rice harvest and wheat sowing. Unlike removing or burning crop residues, incorporation leads to increased soil organic matter (SOM) and higher soil nitrogen, phosphorus, and potassium levels. In certain studies, initial wheat yields were negatively impacted within the first one to three years of incorporating rice straw, primarily due to nitrogen immobilization in the presence of crop residues with a wide carbon-to-nitrogen (C/N) ratio. However, in subsequent years, straw incorporation did not adversely affect wheat yields. Conversely, incorporating rice straw resulted in significantly higher wheat yields (3.5 t/ha) compared to straw removal (2.91 t/ha).

Crop residues are rich in organic carbon and mineral nutrients, making them valuable sources of organic matter that can be reintroduced into the soil for nutrient recycling and to enhance soil physical, chemical, and biological properties. However, incorporating cereal straw has a notable drawback - the immobilization of inorganic nitrogen and subsequent adverse effects due to nitrogen deficiency. Incorporating rice straw into the soil post-harvest slows down decomposition and immobilizes soil inorganic nitrate, leading to a reduction in nitrogen uptake and yield of subsequent wheat crops by approximately 40%.

Recycling crop residues holds significant promise in replenishing essential plant nutrients within the soil. The risk of crop yield stagnation due to diminishing soil organic carbon poses a substantial threat to the agricultural system. Consequently, effective and efficient crop residue management becomes a critical challenge for agricultural practitioners, aimed at bolstering carbon sequestration and ensuring production sustainability.As mechanical harvesting gains prevalence in grain collection, substantial amounts of crop residues accumulate in fields, necessitating astute residue management practices. Options for residue management encompass mulching, soil incorporation, and surface retention, each carrying its own merits and drawbacks. The choice of strategy depends on factors such as location, soil characteristics, and prevailing conditions.Comprehensive research is essential to address the intricate issue of rice residue management. Surface retention emerges as a viable solution in certain cases for sustainable agriculture. In areas where subsequent crops contain rice residues, both stubbles and loose straw require meticulous handling, warranting intensive investigations across diverse crop-growing regions.Over the long term, incorporating crop residues into the soil serves to enhance soil's physical, chemical, and biological properties. Tailoring no-tillage technology to specific geographical and soil conditions offers a promising route. Ultimately, the eco-friendly practice of incorporating crop residues into the soil emerges as the most suitable option for promoting sustainable agricultural management.

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