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Utilization of crop residue

as an asset *vis-à-vis* crop nutrients and soil health

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Rice-Wheat cropping system is essential for food security of India which faces challenges of post-harvest residue management. Over the years, the paradigm shift has been utilized for in-situ rice residue management with its impact on soil health and sustainability of the production system. Recognizing rice residue as a valuable resource, in-situ practices like surface mulching and incorporation into soil are explored for enhanced productivity and environmental sustainability. Investigating nutrient cycling, microbial dynamics, and physicochemical properties, the delicate balance between productivity and preservation is highlighted. In situ management significantly influences moisture content, bulk density, porosity, aggregate stability, pH, cation exchange capacity, organic carbon, and nutrient content, which are crucial for sustainable agricultural practices. The Government of India through ICAR institutes, SAUs, KVK system introduced crop residue management project to popularize the proficient machines like happy seeder, super seeder, and zero till seed drill for in-situ residue management and conservation tillage for improving soil health 2018 onwards. The outcomes of the project have been very encouraging including enhanced crop yields and cost-effectiveness, reinforcing the importance of in-situ residue management for sustainable agriculture. This exploration aims to inform stakeholders, policymakers, and researchers, fostering a collective effort towards harmonious coexistence between agricultural productivity and soil health in rice cultivation.

Keywords: Burning, Crop nutrients, Crop residue, Mechanization, Soil health

RICE is the predominant crop of India with over 44 million ha area and more than 130 million tonnes annual production. The dwarf varieties of rice are characterized by the accumulation of substantial amounts of biomass, which after harvest as crop residue presents a challenge that extends beyond the fields. The management of rice residue has emerged as a critical facet in the quest for sustainable agriculture, particularly in the context of *in-situ* practices. According to estimates about 300 million tonnes of crop residue is produced annually in rice-wheat cropping system in India.

Rice residue, comprised of straw and remnants left after harvesting, has historically been viewed as a by-product, often disposed of through burning or other conventional methods. The conventional approach, while providing a quick solution for field clearing, has raised environmental concerns, contributing to air pollution, nutrient loss, and alterations in soil parameters. In response to these challenges, the paradigm is shifting towards the *in-situ* management of rice residue as a strategic avenue for promoting both agricultural productivity and environmental sustainability.

In recent years, there has been a growing recognition that rice residue, far from being a waste material, holds untapped potential as a valuable resource for the enhancement of soil health. The shift towards *in situ* management entails practices like surface mulching or incorporating residue into the soil, aiming to maximize the positive impacts on soil structure, nutrient content, and overall sustainability. However, understanding the nuanced effects of these practices on soil health is essential to strike the delicate balance between agricultural productivity and environmental preservation.

Impact of *in situ* rice residue management on soil health

Soil's physical properties

Moisture content: Incorporation of rice residues in soil helps in improving soil moisture content due to reduced surface runoff and direct evaporation from surface, enhances soil saturated water conductivity and improves water infiltration in the soil profile. The straw coverage on the soil surface can effectively reduce topsoil temperatures affecting the evaporation and thus enhance soil moisture content. The higher moisture availability in soil add to water holding of soil and availability of moisture for better crop productivity.

Bulk density: The bulk density of soil becomes low with enhanced management of rice residues which signifies an improvement in porosity and soil aeration and ultimately in soil structure. The different crops residue and their management have differential effect on soil bulk density across soil profiles and growth periods.

Porosity and aggregate stability: Positive effect of chopped and crushed crop residue incorporation in soil have been reported on soil porosity and aggregate stability. The organic matter addition through crop residues contributes to formation of larger and more stable soil aggregates. It helps in maintaining soil structure and nutrient cycling.

Soil's chemical properties

The *in situ* management of rice residues significantly influences various soil chemical properties, contributing to improved soil health and enhanced crop productivity.

pH and cation exchange capacity (CEC): Crop residues play a crucial role in regulating soil pH, particularly in soils with low buffering capacity. Incubation experiments have demonstrated that the ameliorating effects of crop straw decayed products can lead to a substantial increase in soil pH. However, certain practices, such as straw coverage with no-till and rotary tillage, may result in a reduction in soil pH. Additionally, crop residue management has a pronounced impact on cation exchange capacity (CEC). Accumulation of soil organic matter in crop residues generates more negative charges, leading to increased CEC. Studies have shown that higher crop residue retention levels correspond to significantly higher CEC, emphasizing the importance of residue management in influencing soil chemistry.

Organic carbon and soil nutrient content: Decaying crop residues are integral components of the nutrient cycle, contributing to increased levels of organic carbon, nitrogen, available phosphorus, and potassium in the soil. Organic carbon content, a vital indicator of soil stability, sees a notable rise with crop residue returning, fostering the formation of large aggregates. This process enhances soil properties and stability. Furthermore, the return of crop residues prevents nutrient loss and improves the availability of essential nutrients. Crop residues, comprising approximately 40% organic carbon, become a key factor in regulating soil properties and minimizing organic carbon loss.

Nitrogen: Crop residue returning increases the soil's available nitrogen, crucial for protein, amino acid, and nucleic acid formation. However, the relatively high C/N ratio of crop residues may lead to nitrogen immobilization, necessitating additional nitrogen fertilizer application.

Phosphorus: Long-term crop straw incorporation elevates soil available phosphorus levels, contributing to enhanced phosphorus use efficiency over time.

Potassium: Crop residues facilitate the release of ionic potassium, leading to its accumulation in the soil. Various studies demonstrate an increase in available potassium content with the application of different crop residues, indicating its positive impact on soil fertility.

The incorporation of crop residues has been found to significantly increase organic carbon by 33.3-40.9%, emphasizing its crucial role in recycling soil nutrients and enhancing soil fertility and productivity. The dynamics of organic carbon are pivotal for understanding its profound impacts on soil health and, consequently, on the overall biological health of the soil.

Precisely, careful management and incorporation of rice residues *in situ* enhances the chemical properties and contributes to sustaining soil health and enhancing crop productivity.

Soil's biological properties

Contribution of *in situ* rice residue incorporation adds to soil biological properties and thus vital for sustainability in view of the critical role of soil micro flora and fauna for maintaining the soil biological health. As such the soil biological properties have high degree of sensitivity for changes in soil management as compared to chemical and physical properties.

Macro-fauna and residue incorporation: The most important macro-fauna is earthworms which help in improving the soil health. It has been established that bio-matter alike of crop residue enhances earthworm populations substantially. An addition of 5 tonnes of crop residue in a hectare increases the earthworm population by about 30%. The increase in macro-fauna helps increasing population of friendly insects and predators against insects-pests and weeds. Retention of crop residue along with no tillage build up habitat for soil macro-fauna, including arthropods and rodents. However, not all crop residue yields similar impacts on earthworm's population. The crop residue containing high C:N ratio and polyphenol concentration are less effective in augmenting microbial activity.

Role of soil micro-fauna and microbial communities: Soil micro-fauna, dependent on soil organic carbon for metabolism, are crucial for nutrient cycling and ecosystem sustainability. Changes in soil organic carbon content directly impact microbial populations, compositions, and functions. The addition of crop residues has been observed to rapidly enhance microbial activity, improving the soil's ecological environment. Microbial communities, integral to soil ecosystem processes and biogeochemical cycles, are influenced positively by crop residue returning. The increased organic matter content in the soil provides an optimal environment for the growth and proliferation of microorganisms.

In conclusion, the incorporation of rice residues *in situ* significantly influences soil biological properties, shaping the dynamics of both macro- and micro-fauna, and microbial communities. Understanding these intricate relationships is essential for implementing agricultural practices that not only enhance crop productivity but also promote the long-term health and sustainability of the soil ecosystem.

Proficient machines for *in situ* management of rice residue

Happy seeder: Happy Seeder has revolutionised farm machinery segment designed for efficient wheat sowing. This innovative machine allows farmers to sow wheat seeds directly into the soil in field vacated after rice harvest. This machine effectively cuts and lifts the previous crop residues and simultaneously allow sowing of seeds, promotes no-till farming practices, conserves soil moisture and improves soil health. This sustainable approach not only enhances wheat cultivation but also addresses environmental concerns by reducing air pollution associated with traditional residue burning. Happy Seeder stands as a promising solution for modern and eco-friendly wheat sowing in agriculture.

Wheat sowing by Happy seeder

Super seeder: Super seeder is an improvement over happy seeder wherein rotavator is added which accomplish all the shallow tilling and all other activities of happy seeder for wheat sowing. This machine also allows farmers to sow wheat seeds directly into the soil effectively cutting and lifting the previous crop residues simultaneously. The Super Seeder, although an improvement over happy seeder but its efficiency and

Wheat sowing by Super seeder

advantages are yet to be established in the field. Farmers are still preferring Happy seeder for its higher yield advantage in wheat.

Zero till seed drill: The Zero till seed drill is an innovative agricultural tool that revolutionizes wheat sowing practices. Unlike traditional methods that involve plowing and tilling the soil before seeding, the Zero till seed drill allows farmers to sow wheat directly into untilled soil, minimizing soil disturbance. This conservation tillage approach helps retain soil moisture, prevents erosion, and promotes overall soil health. The machine features precision seed placement, ensuring optimal spacing and depth for uniform crop emergence. The Zero till seed drill is a sustainable solution, saving time and energy while contributing to enhanced wheat yields and environmental conservation.

Wheat sowing by Zero till seed drill

Crop residue management project

The Government has taken proactive measures to combat the detrimental practice of residue burning through the implementation of a centrally sponsored scheme "Promotion of Agricultural Mechanization for *in-situ* Management of Crop Residue", since 2018. The scheme has been collaboratively implemented by DAFW, ICAR, State Agriculture Departments and 60 frontline extension institutions (KVKs) spread in the districts of Punjab, Haryana, Delhi and Uttar Pradesh.

Wheat yield and cost of cultivation

Agricultural machines (Happy seeder, super seeder, and Zero till seed drill) were demonstrated on the farmers' fields. These machines were utilized for sowing of wheat consequently managed rice residue *in situ* and also contributed significantly to increase the crop yields compared to conventional methods of sowing. The use of happy seeder machine yielded the highest grain yield of 51.74 q/ha of wheat in demonstration plots. The grain yield of wheat under super seeder and Zero till seed drill were almost equivalent at 50.91 q/ha and 50.89 q/ha, respectively. While the conventional methods of sowing

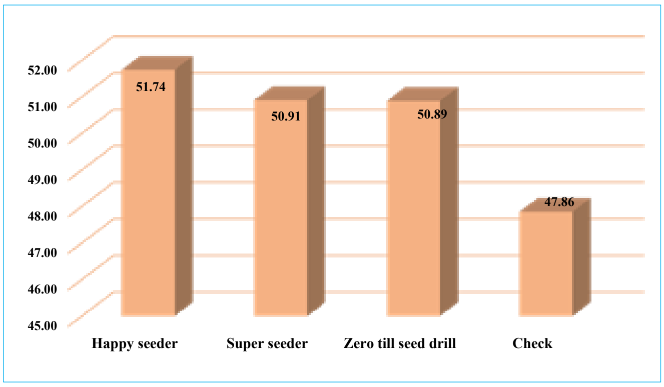

Fig. 1. Effect of different CRM machines on wheat yield (q/ha)

of wheat, due to its limitations, yielded the lowest of 47.86 q/ha, it incurred the maximum cost of cultivation of ₹41787/ha closely by ₹41201/ha by super seeder. Use of happy seeder incurred total cost of ₹35537/ha in wheat cultivation slightly higher than the lowest of ₹34926/ha under Zero till seed drill.

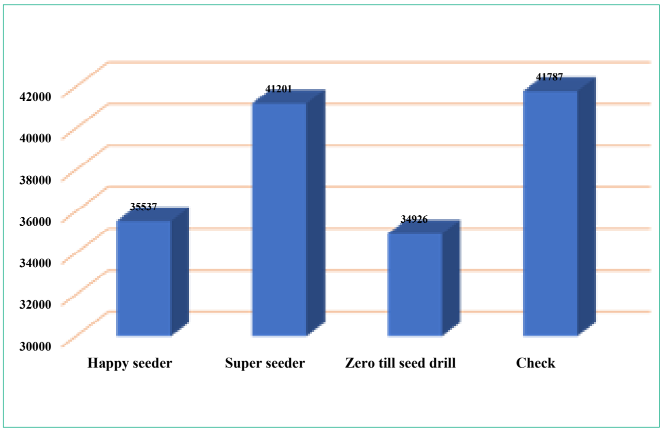

Fig. 2. Cost of cultivation (₹/ha) of wheat under different CRM machines

Monetary advantages

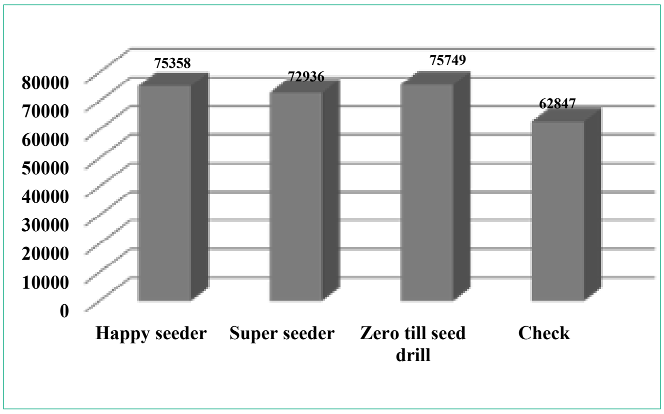

Fig. 3. Net income in wheat under different CRM machines (₹/ha)

The highest monetary advantage and efficiency *i.e.* net income and benefit:cost ratio of ₹75749/ha and 3.39, respectively were recorded with Zero till seed drill followed by the Happy seeder (₹75358/ha and 3.17) and Super seeder (₹72936/ha and 2.99). The conventional method gave significantly lower returns (₹62847/ha and 2.66).

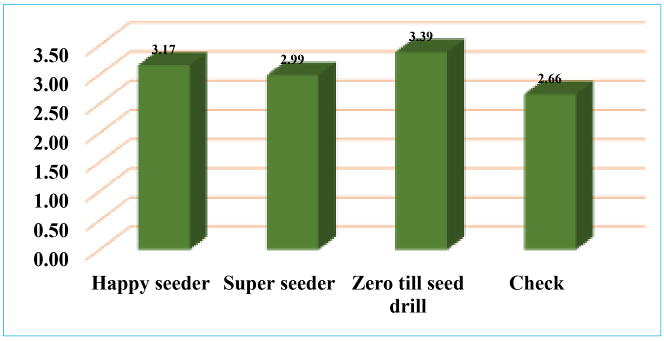

Fig. 4. BC ratio in wheat under different CRM machines

Information, Education and Communication (IEC) for last mile connectivity and awareness

District level frontline extension agencies of Haryana and Delhi organised 1218 campaigns during 2018-2023, at village, block and district level with the participation of 99,735 farmers. Besides, 331 training programmes were also conducted in which 13,746 farmers were trained for residue management practices. Rice growing farmers were given five-day trainings in collaboration with the state department of agriculture. The campaigns also included detailed information about schemes and incentives to farmers on crop residue management machinery and custom hiring centres. In Haryana and Delhi, students of 416 schools and 102 colleges were mobilized through essay competitions, paintings, debates, etc. and about 39,580 students were informed about benefits of *in situ* crop residue management. Total 103 farmers' fairs were organised in Haryana and Delhi with the participation of 65,511 farmers from nearby villages. Live demonstrations of machineries used for crop residue management after harvesting of rice were made in these farmers' fairs.

SUMMARY

Use of *in situ* crop residue management machines could turn 'so called' waste or residue into a much 'productive' asset contributing towards 3.23 kg/day in the productivity and ₹104.3 /day in net return. Beyond the food security and economic indicators, the *in-situ* residue management also contributes towards soil sustainability and is an environment friendly activity. The frontline extension institutes in target states of Punjab, Haryana, Delhi NCR and Uttar Pradesh proactively undertook these machines to farmers' fields for their popularization and infuse 'pull' effect for creating demand of these machineries. The State Governments should incentivised both individuals and community approach for upscaling machineries. The community frontline extension approach with active participation of public leadership, social and civil society organizations, children, students, teachers and spiritual leaders helped in better mobilization of society and all stakeholders responsible for an 'inclusive' ecosystem for the success of any movement of this nature.

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