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Conservation Agriculture: A Sustainable Solution to Stubble Burning

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Stubble burning is a major environmental and agricultural concern in intensive cropping systems, particularly in the rice–wheat production areas of India. The practice is mainly driven by the large quantity of crop residues left after mechanized harvesting and the limited time available for establishing the succeeding crop. Although burning provides a quick method of residue disposal, it results in the release of air pollutants and greenhouse gases and causes the loss of valuable nutrients and organic carbon. Conservation agriculture provides a sustainable alternative by promoting minimum soil disturbance, retention of crop residues on the soil surface and diversification of cropping systems. Practices such as residue retention, zero tillage and the use of happy seeder and related residue-management technologies allow farmers to establish the succeeding crop without burning or removing crop residues. These practices can also contribute to timely sowing, reduced fuel and cultivation costs, improved soil health, better moisture conservation and nutrient recycling. Conservation agriculture can transform crop residues from an environmental burden into a valuable resource, thereby contributing to cleaner air, healthier soils and more sustainable agricultural production.

Keywords: Conservation agriculture, stubble burning, crop residue management, happy seeder

Introduction

In north western parts of the country, where rice-wheat cropping system is practiced, farmers burn the remaining stubble after rice harvest to prepare their fields for sowing of subsequent wheat crop due to the narrow window between rice harvesting and wheat sowing (Keil *et al.*, 2021). Crop residue burning causes massive air pollution affecting millions of people across the Indo-Gangetic Plains and also result in subsequent loss of soil fertility (Prasad *et al.*, 1999). The problem of crop-residue burning is therefore not merely an issue of air pollution; it is also associated with inefficient nutrient recycling, soil degradation and the loss of a potentially valuable biomass resource. Conservation agriculture (CA) offers a promising approach to address this problem by changing the way crop residues are managed. Rather than viewing stubble as waste that must be removed or burned, CA treats crop residues as an important resource for maintaining soil health, conserving moisture and supporting sustainable crop production.

Stubble Burning and Its Environmental Consequences

Residue burning is widely practiced in the state of Punjab, where survey revealed that nearly three-quarters of stakeholders burn residues in the field, some adopt rotavator/no-till (NT) seed drill based management while a very few rely on traditional means (Kumar *et al.*, 2015; Kaur *et al.*, 2022). Farmers generally opt for residue burning as it helps overcome residue-induced immobilization of nitrogen (Vijayaprabhakar *et al.*, 2021), destroys weed seeds and provides better disease and insect pest management (Rasmussen & Rohde, 1988; Kaur *et al.*, 2022). However continuous residue burning in the Indian rice–wheat system contributes to

emissions of carbon monoxide, carbon dioxide, methane, nitrous oxide, nitrogen oxides and aerosols. It also results in nutrient and resource losses, adversely affecting soil health and productivity (Gupta *et al.*, 2004). The problem is particularly evident in rice–wheat systems because rice is harvested close to the time when wheat needs to be sown. Farmers therefore face considerable pressure to clear the field quickly. Conventional residue removal and intensive tillage require additional labour, machinery, fuel and time. Hence, residue burning becomes a short-term solution despite its long-term environmental effects. The large quantity of rice residues generated in the Indo-Gangetic Plains and the need for timely wheat sowing have consequently become major factor behind residue burning. Studies have shown that conservation-agriculture practices can help overcome these constraints by allowing wheat to be established directly in fields where rice residues have been retained (Kaur *et al.*, 2022).

Fig. 1: Stubble burning in farmer's field

Conservation Agriculture as an Alternative

Conservation Agriculture (CA) is an approach that aims to maintain agricultural productivity while improving and preserving natural resources. It is based on three basic principles: maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species (FAO, 2022). These principles are relevant to residue-burning problems because crop residues have become an integral component of the production system. Instead of removing or burning them, farmers can retain it on the soil surface and establish the succeeding crop through suitable technologies.

1. Residue Retention

Residue retention is one of the most important components of conservation agriculture for addressing stubble burning. Crop residues retained on the soil surface act as mulch, protecting the soil against erosion, reducing evaporation and contributing organic material as they decompose. Residue retention also facilitates nutrient recycling. In the long term, this can contribute to improved soil organic matter and biological activity (Kaur *et al.*, 2022).

2. Zero Tillage

Zero tillage (ZT) is another important conservation-agriculture practice. Under zero tillage, the succeeding crop is sown with minimal soil disturbance, thereby reducing the need for repeated ploughing and field preparation. In the Indian rice–wheat system, zero-tillage wheat can alleviate several constraints of the rice–wheat system, including delayed wheat establishment, high production costs and excessive water requirements (Erenstein & Laxmi, 2008). The importance of timely wheat establishment is particularly significant because delays in sowing can reduce yield potential. Thus, zero tillage provides a mechanism through

which farmers can avoid rice crop residue burning while simultaneously achieving timely wheat establishment.

3. Happy Seeder Technology

Among the technologies developed specifically to address rice-residue burning, the Happy Seeder is particularly important. The machine combines straw management along with seed drilling and allows wheat to be directly sown in the standing residues without burning (Sidhu *et al.*, 2007). Subsequent development of the Turbo Happy Seeder further improved the capacity to sow wheat under heavy rice-residue conditions (Sidhu *et al.*, 2015).

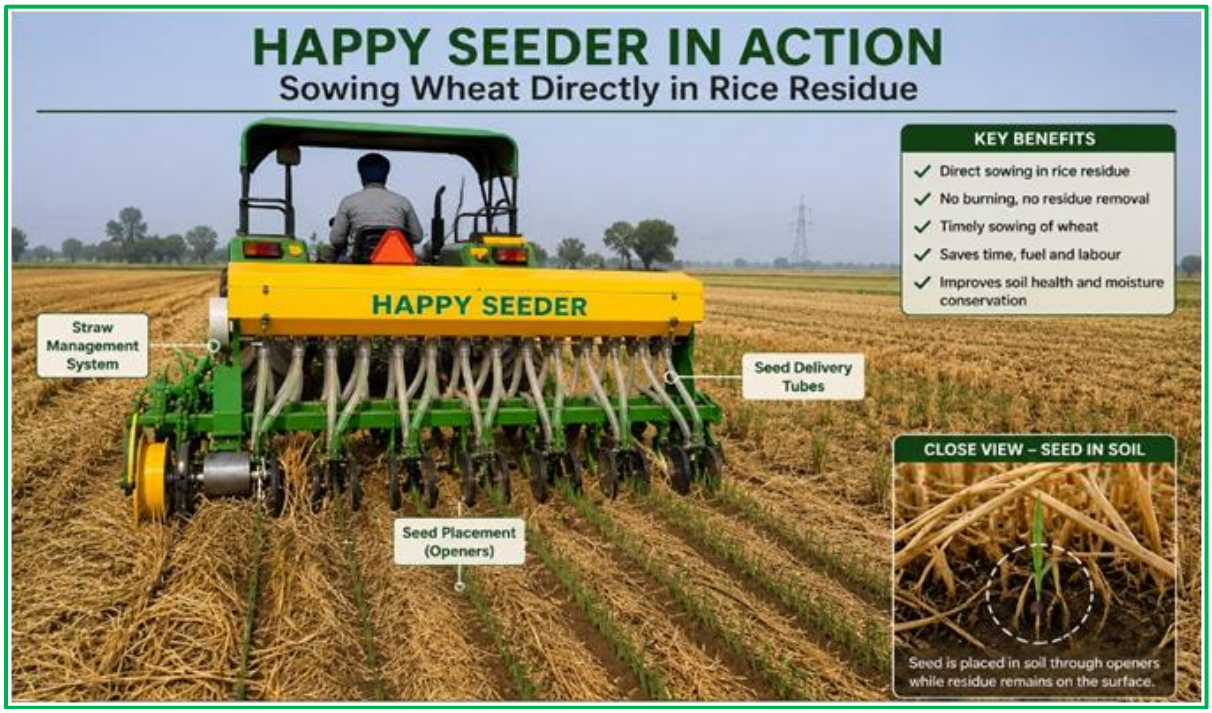

Fig. 2: Use of Happy Seeder for sowing wheat directly into rice residues

Soil Health Benefits

Conservation agriculture also contributes to improvement of soil health. Retaining crop residues increases the amount of organic material in the soil and provides a source of carbon for soil organisms. Surface residues can also protect soil aggregates from the direct impact of rainfall and reduce soil erosion. Minimum soil disturbance further helps maintain soil structure and reduces the physical disruption of soil habitats. Also, diversification with pulses, oilseeds and other locally suitable crops can improve the resilience and resource-use efficiency of cropping systems. The third principle species diversification is therefore important for moving beyond residue management toward a more sustainable production system (FAO, 2022). CA also enhances biodiversity and biological processes in the soil eco-system, contributing to improved water- and nutrient-use efficiency. Thus, residue retention is an important component of long-term soil-resource conservation.

Conclusion

Stubble burning is closely associated with the challenges faced by farmers in intensive rice–wheat systems, particularly the short period available between rice harvesting and wheat sowing. While burning offers a quick way to clear the field, it comes at considerable environmental and agricultural costs through air pollution, greenhouse-gas emissions and the loss of nutrients and organic matter. Conservation agriculture practices can reduce the dependence on burning while improving the efficiency with which soil, water and other farm resources are used. Technologies such as zero-till drills and the happy seeder demonstrate that crop residues can be retained in the field without compromising timely establishment of the succeeding crop. At the same time, retained residues can protect the soil, contribute organic matter and support nutrient recycling. By integrating these principles, conservation

agriculture can mitigate environmental concerns and improve the sustainability of farming system. With adequate institutional and policy support, it can become an important strategy for achieving improved soil health, efficient resource use and climate-resilient agriculture.

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