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Assessment of different tillage practices for sowing of wheat under manual harvested rice

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Abstract

This study evaluated four tillage practices for wheat sowing following manual rice harvesting in District Panipat, Haryana, within the Rice-Wheat Cropping System (RWCS) prevalent in the Indo-Gangetic Plains. The assessed practices included conventional broadcast sowing with rotary tillage (T1), zero tillage with a zero till seed drill (T2), zero tillage with a happy seeder (T3), and super seeder sowing (T4). Conducted over three years (2022-2024), the trials compared the agronomic performance and economic viability of these techniques. The results consistently showed that zero tillage with a zero-till seed drill (T2) provided the best economic returns and bene-fit-cost ratios, despite not always producing the highest yields. On average of over the years, the super seeder (T4) achieved the highest grain yield but incurred greater operational costs, reducing its profitability. The happy seeder (T3) exhibited intermediate performance, supporting its role as an alternative conservation tillage option. This study highlights the trade-offs between maximizing yield and optimizing economic efficiency, emphasizing the importance of residue management, especially considering anchored stubbles after manual rice harvesting. These findings advocate for adopting zero tillage with a zero till seed drill as a cost-effective and sustainable wheat establishment method in the RWCS, balancing productivity, profitability, and resource conservation.

Keywords: Zero Tillage, Conventional Tillage, Super Seeder, Happy Seeder

Introduction

The Rice-Wheat Cropping System (RWCS) is a predominant agricultural practice across approximately 10 million hectares in the Indo-Gangetic Plains of India, playing a vital role in ensuring regional food security and sustaining rural livelihoods (Dhanda *et al.*, 2022) ^[5] (Sharma *et al.*, 2022) ^[16]. Haryana, particularly District Panipat, is a core region where nearly 95% of the rice area during the Kharif season is followed by wheat cultivation in the Rabi season (Ashish, 2024; Ohlan, 2016) ^[2, 15]. In Panipat, net sown areas total around 100,000 hectares, with rice occupying 72,000 to 75,000 hectares and wheat covering 82,000 to 85,000 hectares annually. Despite its widespread adoption, the sustainability of RWCS faces significant challenges, including groundwater depletion, declining soil fertility, reduced factor productivity, increased pest and disease pressures, and shifting weed flora, all threatening the system's long-term viability (A. Kumar *et al.*, 2023; Yadav *et al.*, 2025) ^[11, 18]. Traditional wheat sowing following manual rice harvesting predominantly relies on conventional broadcast sowing combined with rotary tillage. This method involves intensive soil disturbance, leading to increased production costs, soil degradation, and inefficient residue management (Kahlon, 2019; R. Kumar *et al.*, 2015) ^[9, 12]. A particular challenge arises from anchored rice stubbles left after manual harvesting, which complicate residue handling and negatively affect subsequent wheat sowing operations and crop performance. In response to these challenges, resource-conserving technologies have been developed and promoted to sustain RWCS. Zero tillage (ZT), especially in Haryana, has emerged as a leading conservation tillage practice. Initially introduced to manage the herbicide-resistant weed *Phalaris minor*, ZT has demonstrated multiple agronomic and economic benefits, including reduced labor and fuel costs, conservation of soil moisture and organic matter, and improved soil health, leading to rapid farmer adoption (Ekboir, 2003; Mondal *et al.*, 2020) ^[6, 14]. Alongside ZT, specialized sowing equipment such as the zero-till seed drill, happy seeder, and super seeder have gained attention for their ability to manage crop residues effectively, particularly in fields burdened with heavy residue loads and anchored stubbles typical of manual rice harvesting.

The transition from conventional tillage to conservation tillage methods reflects ongoing efforts to optimize wheat sowing under the constraints posed by manual rice harvesting. While broadcast sowing with rotary tillage remains prevalent, the super seeder is increasingly replacing it due to its operational advantages in residue management, despite higher operational costs. Zero tillage methods using zero-till seed drills and happy seeders offer promising alternatives that balance productivity, cost-effectiveness, and residue management (Hendrik *et al.*, 2025; Ma *et al.*, 2025) [8, 13].

Despite the recognized benefits of conservation tillage, comprehensive evaluation of these technologies under local agroecological and management conditions is essential. Adoption decisions by farmers are influenced not only by yield potential but also by input costs, operational feasibility, and residue management challenges. Therefore, assessing the agronomic performance, economic viability, and practical suitability of different tillage practices is critical to promote sustainable intensification within the RWCS.

This study, conducted over three years (2022-2024) in District Panipat, Haryana, aims to evaluate and compare four tillage practices for wheat sowing following manual rice harvesting: conventional broadcast sowing with rotary tillage, zero tillage with a zero-till seed drill, zero tillage with a happy seeder, and super seeder sowing. By analyzing yield outcomes, cost structures, benefit-cost ratios, and residue management considerations—especially the operational challenges posed by anchored stubbles—this research seeks to provide evidence-based recommendations. The goal is to optimize wheat production and profitability while supporting farmers and policymakers in adopting cost-effective and sustainable tillage technologies tailored to the RWCS in the Indo-Gangetic Plains.

Materials and Methods

Study Area

The study was conducted in District Panipat, Haryana, located between latitudes 29°09'50" N and 30°15'15" N and longitudes 76°10'10" E to 77°17'05" E. The region lies in the Indo-Gangetic Plains characterized by flat terrain with slight slopes running from the northeast towards the south and southwest. Soils in the area are alluvial, ranging from sandy loam to clay loam, with plain topography and river basins. The district benefits from assured irrigation facilities through canals and tube wells. The climate is subtropical with monsoonal rainfall concentrated in July, August, and September. Temperature extremes occur with maximum temperatures reaching up to 46°C during May and June, while winters are cold, with January temperatures occasionally dropping to freezing and frost occurrence. Humidity varies seasonally, with minimum levels below 20% during April and May and high humidity during the monsoon period. Major crops include rice, wheat, and sugarcane. Although the land is productive, overexploitation of natural resources is a concern.

Experimental Design and Treatments

On-farm trials were conducted over three consecutive wheat growing seasons from 2022 to 2024. Three treatments were evaluated in 2022 but then after four tillage practices for wheat establishment following manual rice harvesting. Each

year, ten farmers were selected to participate in the trials. The treatments included:

- **T1:** Conventional broadcast sowing of wheat with rotary tillage
- **T2:** Zero tillage sown wheat using a zero-till seed drill
- **T3:** Zero tillage sown wheat using a happy seeder (included from 2023 onwards)
- **T4:** Super seeder sowing

Each treatment was implemented in farmers' fields under local management practices. The trials accounted for residue management challenges, particularly the presence of anchored rice stubbles typical of manual harvesting.

Data Collection

Data were collected on wheat grain yield (quintals per hectare), cost of cultivation (Rs/ha), gross returns (Rs/ha), net returns (Rs/ha), and benefit-cost (B:C) ratio for each treatment annually. Agronomic observations included residue management and operational feasibility of the tillage methods.

Statistical Analysis

The data collected were analyzed by averaging the treatments across 10 different locations to compare the performance of different tillage practices across years. Combined analysis over multiple years was performed to assess consistency and trends in agronomic and economic outcomes.

Results

The assessment of various tillage practices for sowing wheat following manually harvested rice, conducted by KVK Panipat over the period from 2022 to 2024, offers a detailed evaluation of both the agronomic performance and economic viability of the different methods under the prevailing local conditions. In the initial 2022 on-farm trials, three tillage systems were compared: conventional broadcast sowing with rotary tillage (T1), zero tillage sown wheat using a zero-till seed drill (T2), and super seeder sown wheat (T4). The zero tillage method (T2) demonstrated superior agronomic performance, with an average yield of 46.2 quintals per hectare (q/ha), representing a 6.21% increase compared to the conventional broadcast method (T1), which yielded 43.5 q/ha. The super seeder method (T4) also showed yield improvement relative to T1, producing 45.1 q/ha, which is a 3.68% increase. From an economic standpoint, T2 was the most advantageous, incurring the lowest production cost of Rs. 22,030 per hectare, generating the highest net returns of Rs. 77,063 per hectare, and the most favorable benefit-cost ratio (B:C) of 4.50. In contrast, although T4 improved yield compared to T1, it involved the highest cost (Rs 29,370/ha), which translated into a lower B:C ratio of 3.30, indicating lower economic efficiency (Table 1).

Building on these findings, the 2023 on-farm trials expanded the scope of evaluation by including zero tillage with a happy seeder (T3) alongside the previously assessed treatment. The super seeder method (T4) achieved the highest yield at 54.8 q/ha, marking a substantial 9.16% increase over the conventional broadcast method (T1), which yielded 50.2 q/ha. Zero tillage with a zero-till seed drill (T2) followed closely with 53.3 q/ha (6.18% increase), and zero tillage with a happy seeder (T3) recorded 52.9 q/ha

(5.38% increase). Despite T4's superior yield, economic analysis revealed that T2 provided the highest net returns of Rs 95,720 per hectare and the most favorable B:C ratio of 4.61. The super seeder method, while less profitable in economic terms (net returns Rs 93,545/ha and B:C ratio 3.93), remained the most preferred among farmers, likely because of its operational efficiency and residue management benefits (Table 2).

The 2024 on-farm trials reaffirmed the trends observed in the previous year by reassessing the same four treatments. Yield improvements were recorded across all methods, with T2 achieving 58.4 q/ha (3.9% increase over T1), T3 yielding 58.1 q/ha (3.4% increase), and T4 producing 57.8 q/ha (2.9% increase), whereas T1 yielded 56.2 q/ha. Economic evaluation once again underscored the superiority of T2, which recorded the highest net returns of Rs. 111,072 per hectare and a B:C ratio of 4.79. Conversely, T4, despite its relatively high yield, incurred the highest cost (Rs 32,423/ha) and consequently yielded lower net returns (Rs 106,572/ha) than T2 (Table 3).

A combined analysis of the 2023 and 2024 data further elucidated the comparative performance of tillage practices. The super seeder method (T4) consistently produced the highest average yield of 56.3 q/ha, representing a 6.03% increase over the conventional broadcast method (T1), which averaged 53.2 q/ha. However, zero tillage-sown wheat with a zero till seed drill (T2) maintained economic dominance, achieving the highest average net returns of Rs 103,396 per hectare and the most favorable B:C ratio of 4.70, followed by T3 and T4. The conventional broadcast method (T1) consistently recorded the lowest economic returns and B:C ratio of all the treatments (Table 4).

Overall, the trials conducted over this three-year period revealed a consistent pattern highlighting the trade-off between maximizing wheat yield and optimizing economic returns under manual rice harvesting conditions. While the super seeder method offers the highest yield potential and is preferred by farmers, likely because of its operational advantages and improved residue management, zero tillage sown wheat with a zero till seed drill provides a more cost-effective and economically advantageous option. These findings underscore the importance of balancing agronomic productivity with economic sustainability in selecting tillage practices for wheat sowing in the rice-wheat cropping system prevalent in the Indo-Gangetic Plains. The presence of anchored stubbles in paddy further emphasizes the need to consider residue management challenges when adopting suitable tillage technologies to ensure both yield optimization and economic viability.

Discussion

The assessment of different tillage practices for sowing wheat following manually harvested rice, as conducted by KVK Panipat from 2022 to 2024, emphasizes the agronomic and economic implications of adopting various tillage

systems under the rice-wheat cropping system prevalent in the Indo-Gangetic Plains.

The findings consistently demonstrate that zero tillage (ZT)-sown wheat using a zero-till seed drill (T2) offers a superior balance between yield performance and economic returns compared with conventional broadcast sowing with rotary tillage (T1) and other conservation tillage methods, such as the super seeder (T4) and happy seeder (T3). Over the three-year period, T2 recorded the highest net returns and benefit-cost ratios, despite not always producing the absolute highest yields, highlighting the economic efficiency of this method (Tables 1-4). These findings are in corroboration with (Chourasiya *et al.*, 2022) [4]. This suggests that zero tillage with a zero-till seed drill reduces input costs substantially, primarily due to savings in field preparation and labor, which translates into improved profitability for farmers (Chourasiya *et al.*, 2022; Esaulko *et al.*, 2019; Singh *et al.*, 2016) [7, 17].

The super seeder method (T4), while consistently producing the highest grain yields across all years (Tables 2-4), incurred the highest operational costs, which diminished its net profitability and benefit-cost ratio relative to T2. This trade-off between yield maximization and economic viability is critical in resource-constrained farming systems, where input costs significantly influence adoption decisions (Bishnoi *et al.*, 2024) [3]. Nevertheless, the super seeder's higher farmer acceptability, as noted in the trials, likely stems from its operational advantages, such as better residue management and ease of sowing in fields with anchored stubbles (Tables 3). This operational benefit is an important consideration given the challenges of managing crop residues in manual rice harvesting systems, where long-anchored stubbles remain in the field.

The inclusion of the happy seeder (T3) in the 2023 and 2024 trials provided additional insights into conservation tillage options. Although T3's yield and economic returns were slightly lower than those of T2, it performed better than the conventional method, reinforcing the potential of zero tillage technologies in improving wheat productivity and profitability. The performance of the happy seeder also indicates its suitability as an alternative conservation tillage tool, especially in fields where residue management is a constraint (Kaur & Grover, 2016) [10]. The incremental yield increases observed over the years across all treatments reflect improvements in agronomic management and possibly favorable climatic conditions during the study period. However, the persistent economic superiority of T2 over T4, despite the latter's yield advantage, underscores the importance of cost-effective technologies in sustaining the Rice-Wheat cropping system. This is particularly relevant in the context of the sustainability concerns highlighted in the introduction, such as groundwater overdraft, declining soil fertility, and pest pressures, where resource-conserving technologies, such as zero tillage, can contribute to mitigating these challenges (Alheeti, 2021) [1].

Table 1: Assessment of different tillage practices for sowing of wheat under manual harvested rice in the year 2022

Treatments	Average Yield(q/ha)	Increase over check (%)	Cost of CultivationRs/ha	GrossReturnsRs/ha	NeturnsRs/ha	B:C Ratio
T1- Broadcast sowing of Wheat with rotary tillage	43.5	-	27715	93653	65938	3.38
T2- Zero Till sown wheat with Zero till seed drill	46.2	6.21	22030	99093	77063	4.50
T4- Super seeder sown wheat	45.1	3.68	29370	96877	67507	3.30

Table 2: Assessment of different tillage practices for sowing of wheat under manually harvested rice in the year 2023

Treatment	Average Yield(q/ha)	Increase over check (%)	Cost of Cultivation Rs/ha	Gross Returns Rs/ha	Net Returns Rs/ha	B:C Ratio
T1- Broadcast sowing of Wheat with rotary tillage	50.2	-	30163	115675	85512	3.83
T2- Zero Till sown wheat with Zero till seed drill	53.3	6.18	26543	122263	95720	4.61
T3- Zero Till sown wheat with happy seeder	52.9	5.38	28373	121413	93040	4.28
T4- Super seeder sown wheat	54.8	9.16	31905	125450	93545	3.93

Table 3: Assessment of different tillage practices for sowing of wheat under manually harvested rice in the year 2024

Treatment	Average Yield(q/ha)	Increase over check (%)	Cost of Cultivation Rs/ha	Gross Returns Rs/ha	Net Returns Rs/ha	B:C Ratio
T1- Broadcast sowing of Wheat with rotary tillage	56.2	-	32513	135355	102842	4.16
T2- Zero Till sown wheat with Zero till seed drill	58.4	3.9	29288	140360	111072	4.79
T3- Zero Till sown wheat with happy seeder	58.1	3.4	29810	139678	109868	4.69
T4- Super seeder sown wheat	57.8	2.9	32423	138995	106572	4.29

Table 4: Comparison of different tillage practices for sowing of wheat under manually harvested rice over a period of two years (2022-2024)

Treatment	Average Yield(q/ha)	Increase over check (%)	Cost of Cultivation Rs/ha	Gross Returns Rs/ha	Net Returns Rs/ha	B:C Ratio
T1- Broadcast sowing of Wheat with rotary tillage	53.2		31338	125515	94177	4.00
T2- Zero Till sown wheat with Zero till seed drill	55.9	5.04	27916	131312	103396	4.70
T3- Zero Till sown wheat with happy seeder	55.5	4.39	29092	130546	101454	4.49
T4- Super seeder sown wheat	56.3	6.03	32164	132223	100059	4.11

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