

Sustainable wheat (*Triticum aestivum*) production in Western Indo Gangetic Plains: impact of tillage and residue management

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Received: October 2024; Revised accepted: January 2025

ABSTRACT

Crop residue management has emerged as a major challenge in recent years. No-till wheat sowing, aims to either incorporate paddy residue or retain it in the field, is one of the best technological measures to address this challenge. Therefore, a farmer participatory on-farm trial was conducted during 2020–21 and 2021–22 at five locations in Rohtak to validate no-till wheat sowing for resource conservation, paddy residue management and its impact on wheat yield and profitability. The trial consisted of four different wheat establishment methods: conventional sowing, zero till drill sowing, happy seeder sowing and super seeder sowing. The no-till sowing resulted in 75–80% reduction in fuel consumption and 10–25% savings in water during first irrigation. Zero tillage and happy seeder methods showed 40–45% less weed flora incidence, especially of *Phalaris minor*. The grain yield was 5.3% higher under the super seeder than the conventional method, while zero till drill and happy seeder sowing were comparable to conventional sowing. However, the B: C ratio (3.5) was significantly higher under zero till drill sowing. Thus, the participatory on-farm trials demonstrates the potential benefits of no-till wheat sowing for sustainable crop production and better economics in western Indo-Gangetic plains.

Key words: Happy seeder, No-till, Residue incorporation, Residue retention, Super seeder and Zero drill

The rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system occupies 13.5 million hectares in the Indo-Gangetic Plains (IGP), predominantly in India (9.2 million hectares), contributing significantly to food security (Jat *et al.*, 2020). However, the sustainability of this system is threatened by soil, water, nutrient, and environmental issues, as both crops are exhaustive cereal crops (Singh *et al.*, 2020). The problem is further intensified when farmers burn the rice crop residue left in their fields after mechanized harvesting. Crop-residue is the biomass which is retained either below or on the soil surface after an economic product of a crop has been harvested (Reddy *et al.*, 2021). Rice straw constitutes 60% of burned crop residues, with an estimated 50 million tonnes burned in fields annually (Bhattacharya *et al.*, 2021). In northwest India, about 23 million tonnes of rice residue are burned by approximately 2 million farmers during October/November

(NAAS, 2017). In Haryana, the total paddy straw generated was 7.6 million tonnes in 2020 and 6.8 million tonnes in 2021 (PIB, 2021). Due to the lack of economical alternatives, around two-third to three-fourth of the residue is burned in the field. Moreover, the removal of paddy straw from the field is labor-intensive, and there is a very short window between the harvesting of paddy and the sowing of wheat, making burning the easiest method to dispose-off the residue for timely wheat sowing. The leftover rice residue also interferes with tillage and sowing operations for the successive wheat crop. In Haryana, a total of 4202 active burning events were recorded in 2020, which increased to 6987 in 2021, marking a 66.3% increase. However, in 2022, the number of active burning events reduced to 3661, a 47.6% decrease compared to 2021 (CREAMS-IARI, 2022).

Effectively managing paddy straw has the potential to safeguard agricultural sustainability and enhance the economic security of those dependent on rice farming (Sharma *et al.*, 2021). A common perception among farmers is that sowing wheat in leftover paddy stubble results in poor crop germination. Thus, finding alternative methods for managing rice straw with minimal environmental, soil and health impacts is a significant challenge. Potential solutions

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include sowing wheat in leftover paddy residue using no-till sowing machines like zero till drill, happy seeder and super seeder, either to incorporate or retain the residue on the soil surface. Zero-tillage wheat reduces the infestation of *Phalaris minor*, a significant challenge to maintaining sustainable wheat production in the rice-wheat cropping system. Weed count was significantly reduced by 13.1-times with happy seeder technology (Gupta *et al.*, 2021). Singh *et al.* (2024) also reported that CRM (Crop residue management) practices significantly reduce the usage of organic and inorganic fertilizer. Thus, no-till wheat sowing presents a promising approach to sustainable crop production by managing crop residues effectively. Considering these points, a farmers' participatory on-farm trial was conducted to assess no-till wheat sowing with different machineries at farmers' fields during 2020–2022.

MATERIALS AND METHODS

Farmers' participatory on-farm trials (OFTs) on wheat sowing with different machineries were conducted for two consecutive years during the *Rabi* seasons of 2020-21 and 2021-22 at farmers' fields in Rohtak district under CCS Haryana Agricultural University Krishi Vigyan Kendra, Rohtak (Haryana).

The district received an average annual rainfall of 432.8 mm and 844.2 mm during 2020-21 and 2021-22, respectively, with about 80% of this rainfall occurring during the monsoon season (June to September). The mean temperatures ranged from a minimum of 12.8°C to a maximum of 27.2°C during the wheat season (November to April). There was a significant increase (2 to 4°C) in minimum and maximum temperatures in March and April during 2021-22 (Table 1). The soil of the experimental fields was sandy loam in texture with low organic carbon (0.3-0.6%) and available nitrogen (250-280 kg/ha), medium in available phosphorous (9-13 kg/ha) and available potassium (180-220 kg/ha) with pH 7.8-8.4. The OFTs comprising four crop establishment methods: conventional wheat sowing (T1), zero till drill sowing in anchored stubble (T2), happy seeder machine sowing with residue retention (T3) and super seeder machine sowing with residue incorpora-

tion (T4) were conducted at five farmers' fields, considering each field as a separate replication.

Rice was harvested manually at 10–15 cm above ground in the zero till drill sowing treatments, while a combine harvester fitted with a straw management system (SMS) was used in happy seeder and super seeder sown wheat treatments. After harvesting the paddy, wheat variety 'HD 2967' was sown at the farmers' fields during the first fortnight of November using a seed rate of 100 kg/ha and a row-to-row spacing of 20 cm with different wheat establishment methods. All crop production and protection practices were adopted as per recommendations of CCS Haryana Agricultural University. In the conventional sowing method, field preparation involved two harrowings, followed by cultivation and leveling with a planker, and sowing was carried out using a seed-cum-fertilizer drill. Conversely, in the no-tillage system, wheat was directly sown using zero-till drill, happy seeder and super seeder. Fertilizer application across all establishment methods included nitrogen (150 kg/ha), phosphorus (60 kg/ha), potassium (30 kg/ha), and zinc (25 kg/ha), with 50% of nitrogen and the entire dose of phosphorus, potassium, and zinc applied at sowing, while the remaining nitrogen was top-dressed at the first irrigation. The crop received three irrigations: pre-sowing, at 22 days after sowing (DAS), and at 85 DAS. Supplemental rainfall occurred during the later growth stages at all experimental sites. Weed management was uniformly implemented across all treatments through

Table 2. Details of experimental site

Village	GPS Location	Soil type
Bainsi	29.024223N 76.411613E	Sandy loam
Bainsi	29.024054N 76.411655E	Sandy loam
Bainsi	29.024194N 76.412365E	Sandy loam
Sanghi	29.065277N 76.625833E	Sandy loam
Sanghi	29.033333N 76.616666E	Sandy loam

Table 1. Monthly meteorological observation during 2020–2022 (mean monthly temperatures and total monthly rainfall)

Parameters	July	August	September	October	November	December	January	February	March	April	May	June
2020-21												
Max. Temp (°C)	34.4	32.9	33	32.6	27.7	22.3	19.5	26.2	30.9	36.9	36.8	38.7
Min. Temp (°C)	27	26.1	24.1	19.3	14.1	9	6.6	11.1	16.4	18.9	22.5	25.9
Rainfall (mm)	82	60	8	4	16	25	36.4	33.8	0	6	92	69.6
2021-22												
Max. Temp (°C)	36	34.6	32.4	32.1	27.5	22.4	16.8	23.4	31.8	40.7	41.4	41.1
Min. Temp (°C)	26.8	26.3	24.9	19.3	11.7	8.3	8.4	10.6	17.1	21.7	25.6	26.9
Rainfall (mm)	262.4	127.0	251.5	7.6	0.0	7.4	83.4	32.4	0.0	2.0	41.3	29.2

the application of pendimethalin at 5.0 L/ha as a pre-emergence herbicide, followed by the post-emergence application of ACM-9 at 600 g/ha. Germination (%), saving of irrigation water (%) and visual weed incidence (%) observation at 30 DAS was reported on scale of 0 to 100.

Plant height (cm) at harvest and yield attributes were measured from five randomly selected plants. The number of effective tillers/meter row length was counted from five randomly selected one-meter rows. The crop was harvested at physiological maturity when the grains had approximately 12% moisture content, and grain yield was converted to q/ha.

All experimental data for various parameters were analyzed using SPSS software (version 26). The significant difference among treatments was tested using one-way ANOVA (F-test) and comparison of treatment means was tested using critical difference at 5% level of significance. The economics of different treatments was worked out in terms of net returns (₹/ha) and B:C, on the base of prevailing market prices for inputs and outputs.

RESULTS AND DISCUSSION

Germination and resource conservation

The no-till wheat sowing method has been identified as the most time and energy-efficient compared to conventional sowing methods. It allows for the wheat crop to be sown 10 to 15 days earlier, which results in timely sowing and an increase in yield. Among all the treatments, the highest germination percentage (95%) was observed with conventional and super seeder sowing methods, followed by zero drill sowing (Fig 1). However, the number of plants per meter row length was statistically lower with happy seeder sown wheat (Table 3). This might be due to both conventional and super seeder sowing methods ensure better seed placement, uniform seed-to-soil contact, and optimal seed depth, all of which contribute to a higher germination percentage. In contrast, happy seeder sowing leaves a significant amount of loose straw on the soil surface,

which can create a barrier, reducing seed-to-soil contact and hindering seedling emergence.

The zero till, happy seeder and super seeder sowing methods demonstrated a significant reduction in fuel consumption, being 75-80% lower compared to conventional methods. The lower fuel consumption in no-till sowing is due to less soil disruption and fewer machinery operations, resulting in more efficient field operations. Additionally, both the zero till drill and happy seeder methods led to substantial water savings. The first irrigation required about 25% less water with the zero till and happy seeder methods, while the super seeder method achieved a 10% water saving compared to the conventional method. This reduction in water usage is likely attributed to the presence of residue or stubbles in the fields, which help reduce evaporation and maintain soil moisture. These residues act as mulch, limiting water loss. Additionally, minimal soil disturbance helps preserve soil structure, enhancing its moisture retention capacity. As a result, the soil retains water more effectively, decreasing the need for extra irrigation.

Weed management

Tillage affects various factors, such as the vertical distribution of weed seeds in the soil, soil moisture, inter-day temperature fluctuations and light availability. These factors influence weed seed dormancy, emergence and mortality, thereby affecting weed density in the field. The major weed flora in wheat crops at farmers' fields includes *Phalaris minor*, *Polypogon monspeliensis*, *Rumex dentatus*, *Convolvulus arvensis*, *Chenopodium album*, *Medicago denticulata*, *Coronopus didymus* and *Melilotus alba*. After harvesting paddy, no tillage facilitates the timely sowing of wheat, creating more favourable ecological conditions for crop growth rather than for weeds. At 30 DAS, no-till wheat establishment methods showed a 15 to 45% reduction in weed flora incidence, especially *Phalaris minor*, compared to conventional sowing (Fig 1). This reduction is likely due to minimal soil disturbances, causing

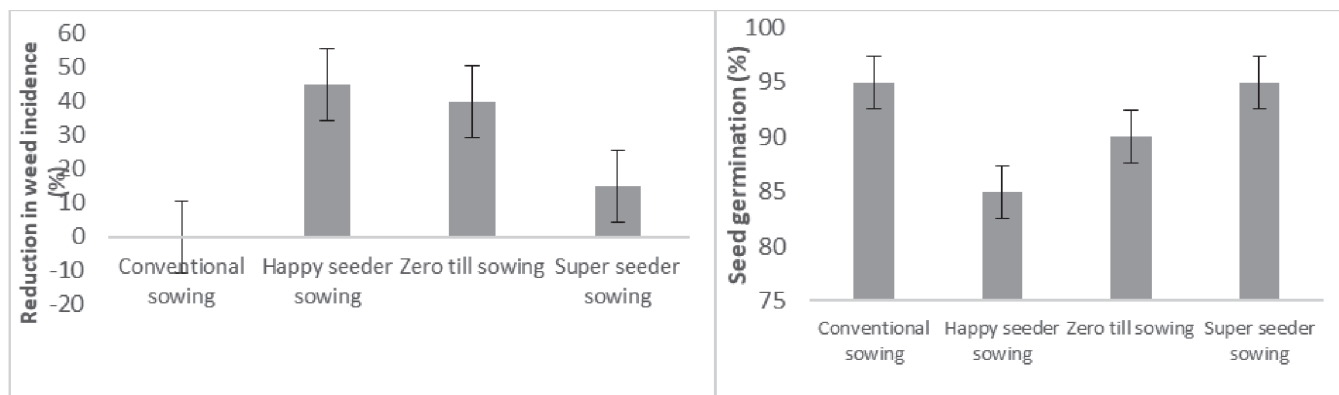


Fig. 1. Germination percentage and weed reduction (%) under different machineries

weed seeds present in the lower soil layer to fail to germinate due to mechanical impedance. Similarly, Kumar *et al.* (2013) reported that when rice residues are kept on the soil surface as mulch, the emergence of *P. minor*, *C. album* and *R. dentatus* was inhibited by 45%, 83% and 88%, respectively, at a 6 t/ha rice residue load compared to fields without residue mulch. Raj *et al.* (2022) also observed that CA-based zero-till rice-wheat-mungbean system with residue retention reduces weeds, boosting wheat yield and profitability in the NW Indo-Gangetic Plains.

Yield parameters and yield

In the current farmer field experiment, the super seeder sown wheat exhibited statistically greater plant height, a higher number of effective tillers, more spikelets per panicle, longer panicle length and a greater number of grains per panicle in both years (Table 3). The grain yield using the super seeder machine was reported to be 5.43 t/ha, which is 5.3% higher than the conventional sowing method and statistically higher than all other treatments. The zero till and happy seeder sowing methods yielded 5.16 and 5.20 t/ha, respectively, and were statistically similar to each other and to the conventional sowing method (Table 3).

An overall yield reduction was observed during 2021-22 *rabi* season, likely due to a significant increase in temperature during the grain filling and crop maturing period (Fig 2). The mean weekly temperature during 2021-22 was relatively 1 to 4°C higher (Table 1) than the previous year during crop maturity. This rise in temperature adversely affected grain size and number, leading to a reduction in wheat crop yield. The results are consistent with Song *et al.* (2015) who stated that significant reduction in the rate of grain filling in wheat cultivars at day/night temperature of 32/22°C when compared with that of 25/15°C. Singh *et al.* (2011) also reported that even a rise of 1°C in the mean temperature in month of March–April leads to reduction in the duration of wheat crop by seven days and yield by about 400 kg/ha. In present experiment, wheat sown with the happy seeder had a slightly higher yield than

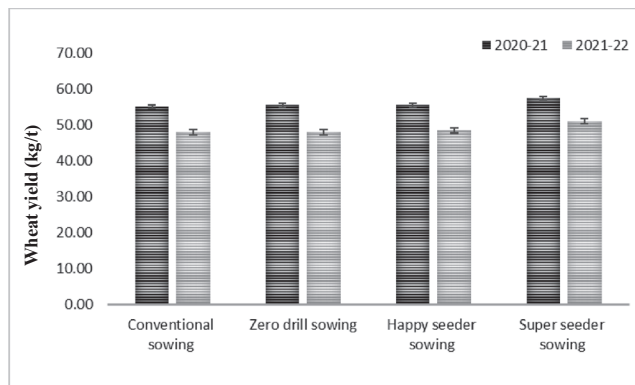


Fig. 2. Wheat yield under different sowing machineries during 2020–21 and 2021–22

zero till drill sowing and convention sowing method during 2021-22, likely because the crop residue used as mulch helped lessen the effects of terminal heat stress on grain number and size during the grain filling and maturation stages (Fig 2). However, this yield was statistically similar to both zero till drill and conventional sowing methods.

Super seeder sown wheat recorded the highest net return, while the highest benefit-cost (B: C) ratio was observed with zero till drill sown wheat due to its lower cost of cultivation (Table 3). The cost of cultivation for no-till sown wheat was significantly reduced, as the expenditure for field preparation was only one-fourth of that for the conventional sowing method. The results of the effect of sowing method on net returns are in line with the findings of Singh *et al.* (2024) who stated that adoption of CRM practices in wheat crop has reduced the cost of cultivation by 4 per cent and increased gross and net returns by 26.8 and 44.3 per cent, respectively.

Pest incidence

The increased stem borer infestation was observed in wheat might be due to the surface retention of paddy residues from the happy seeder sowing method which provides a favorable habitat for stem borers. These results are in line with Jasrotia *et al.* (2021) who reported that pink stem

Table 3. Crop growth and yield parameters of wheat sown with different machineries at harvest stage (pooled data)

Treatments	Plants/ m.r.l	Plant height (cm)	Effective tillers (No./m ²)	Spikelets/ panicle	Panicle length (cm)	Grains/ panicle	Grain yield (t/ha)	Benefit: cost ratio
Conventional sowing (T ₁)	42.6 ^c	108.8 ^b	510 ^a	18.0 ^a	9.4 ^a	59.6 ^a	5.16 ^a	2.8
Zero drill sowing (T ₂)	39.2 ^b	106.2 ^a	502 ^a	19.0 ^a	9.5 ^a	60.9 ^a	5.18 ^a	3.5
Happy seeder sowing (T ₃)	34.6 ^a	106.2 ^a	504 ^a	18.0 ^a	9.5 ^a	60.0 ^a	5.20 ^a	3.2
Super seeder sowing (T ₄)	42.8 ^c	110.2 ^b	531 ^b	21.0 ^b	10.14 ^b	64.6 ^b	5.43 ^b	3.3
SEm±	0.83	0.53	2.68	0.46	0.76	0.48	0.04	

m.r.l- meter row length

borer damage was significantly higher in the no tillage system. Similarly, the retention of straw on the surface, combined with heavy rain and high moisture, caused chlorosis (yellowing) in wheat during the early stages of growth under happy seeder sowing.

The study indicates that no-till wheat sowing is an effective way to manage crop residue and improve wheat profitability. Super seeder sowing showed better germination and higher yield than other methods. However, the benefit-cost ratio (3.5) was higher with zero till machine, making it the preferred choice for most farmers when manually harvesting. Conversely, for combine harvesting, farmers favored the super seeder over the happy seeder due to lower incidences of stem borer and reduced risk of yellowness in the wheat crop after heavy rain or high moisture, which were more common with the happy seeder due to surface straw retention. Therefore, no-till wheat sowing can be recommended to farmers for better crop residue management and sustainable wheat production.

However, further research on the efficiency of the super seeder machine and its long-term impact on soil health is recommended from a sustainability perspective.

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