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In-situ Rice (*Oryza sativa*) Stubble Management in Preparing Paddy Land for the Next Crop in Brahmaputra Valley

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Abstract

The experiment was conducted during October, 2019 at Neul Gaon, Jorhat, Assam, India to evaluate the performance of a tractor-operated paddy straw chopper and its effect on straw incorporation into the soil. The chopper, operated using a 55 hp Eicher 855FE tractor, was tested in two gear settings (L_2 and L_3). The chopper's effective working width was 2.1 meters, with an effective field capacity of 0.67 hectares per hour. The chopped straw was analyzed for its length, with the L_3 gear producing smaller pieces (89.1% in the 0-20 cm range). The study further investigated the weight reduction of chopped straw after incorporation into the soil using two implements: a rotavator and a tyne tiller, both tilling to a depth of 8 cm. The incorporation was assessed two weeks after straw placement, revealing an average weight reduction of 37.36% for the tyne tiller and 36.20% for the rotavator. These findings suggest that the tractor-operated paddy straw chopper, when used in combination with post-chopping incorporation techniques, effectively reduces straw size, thereby promoting quicker decomposition. The smaller straw particles enhance microbial activity, contributing to improved soil quality and faster organic matter breakdown. This approach offers a sustainable solution for straw management in rice farming, helping reduce field residue, improve soil conditions, and support the overall sustainability of rice cultivation systems.

Keywords: Stubble, chopped straw, rotavator, chopper, *in-situ* incorporation

1. Introduction

Rice straw is commonly removed post-harvest for uses such as livestock bedding, feed, cooking fuel, and packaging (Dobermann, 2002; Singh et al., 2008). Effective crop residue management is vital for long-term soil fertility, as incorporation influences microbial processes, affecting nutrient availability and crop yields (Devevre et al., 2000). In mechanized farming systems, straw is often baled and used as cattle feed during lean periods. Rice straw contains 0.6% N, 0.1% P, 0.1% S, 1.5% K, 5% Si, and 40% C (Ponnamperuma et al., 1984). Annually, 0.7 billion tons of organic residues contribute approximately 3 mt N, 0.7 mt P, and 7 mt K-around 25% of the total chemical fertilizer use (Huang et al., 2011). Most of the K and about one-third of N, P, and S are retained in the straw (Ponnamperuma, 1984). When incorporated into soil, straw supplies macronutrients to the following crop (Amarasiri, 1977), and is also a valuable source of sulfur (Dobermann et al., 2002).

Burying straw accelerates decomposition compared to surface placement (Kumar and Goh, 2000), while surface retention helps conserve moisture and maintain soil structure (Sharrat, 1996). Other crop residues like maize stover can also be used for soil cover in conservation tillage systems (Hellin et al., 2013). Chopping efficiency of straw is influenced more by chopper speed than by moisture content or forward speed, with better chopping achieved at higher speeds (Singh et al., 2011). Proper management of paddy residues is crucial for timely and efficient establishment of the succeeding crop, whether by conventional tillage, direct drilling, or inter-row sowing (Mandal et al., 2004). Improperly managed stubbles can impede land preparation, cause machinery entanglements, and promote anaerobic decomposition that harms subsequent crop performance (Mahmood et al., 2016; Xu et al., 2022). Energy requirements for incorporating whole straw are higher compared to chopped straw (Shinde et al., 2022).

Burning of crop residue is a global environmental concern as agriculture significantly contributes to greenhouse gas (GHG) emissions (Crippa et al., 2021). Stubble burning releases harmful gases like CO_2 and methane, adversely impacting air quality and human health (Muhammad et al., 2020).

In Punjab, northwest India, agriculture employs over one-third of the 29.9 million population, with 83% of land used for cereal cultivation, mainly rice and wheat (Gulati et al., 2021). T he rice-wheat system, while vital, is linked to groundwater depletion and widespread stubble burning (Agarwala et al., 2022). Transitioning to no-burn crop residue management (CRM) is critical (Keil et al., 2021), but farmers face socio-economic, technical, and institutional barriers (Udakwar et al., 2023). Burning residues deteriorates air quality and poses health risks, especially during winter due to atmospheric inversion (Lan et al., 2022; Santiago-De La Rosa et al., 2018).

In northwest India, where cereal crops generate around 352 million tons of stubble annually-34% from rice and 22% from wheat (Singh et al., 2017)-residue burning is most prevalent. The narrow window between rice harvest (October–November) and wheat sowing (November) pushes farmers to burn residues for quicker turnaround (Keli et al., 2020; Abdurrahman et al., 2020). Given the severe environmental impacts, the Government of Punjab, supported by the central government, has launched several subsidy programs to promote no-burn agriculture (Anonymous, 2018). This study aims to evaluate the effectiveness of a tractor-operated paddy straw chopper in reducing straw size and enhancing incorporation for better crop establishment.

2. Materials and Methods

Experiment was conducted in farmer's field during October, 2019 at Neul Gaon (26°04´N, 94°57´E and 90 m above MSL), Jorhat, Assam, India. The soil of the experimental site wassilty loam type, pH 6.72 and averagesoilorganiccarbon content was 1.08. The average maximum temperature in the month of October was 29.55°C and average minimum temperature was 20.49°C. Total monthly rainfall was 17.4 mm and in 4 numbers of rainy days, rainfall was more than 2.5 mm. The minimum relative humidity fluctuated between 56 to 84% and maximum humidityvaried between 94 to 100%. Mean total duration of bright sunshine hours remained at 5.4 hrs day^{-1} during the month of study. In between the days of straw chopping and straw incorporation the total rainfall was 8.8 mm, maximum humidity ranged from 94 to 100% and average bright sunshine hours was 3.8 hrs day^{-1} respectively.

The tractor operated paddy straw chopper consisted of a rotary shaft mounted with blades called flails for chopping paddy straw. The working width of the machine is 2100 mm. Diameter of the rotary shaft is 200 mm. Total 33 pair of flail blades are mounted on the rotary shaft. The shape of the flail blades was Inverted "Y" type. The power from the tractor PTO to the machine gear box is supplied through universal shaft. Power to the rotary shaft is supplied through belt and pulley from the shaft passing through the gear box. The gear box has a gear ratio of 6:9 and the diameter of the drive pulley is 225 mm. Brief specification of the tractor operated paddy straw chopper is given in Table 1.

Table 1: Specifications of tractor operated paddy straw chopper

Sl. No.	Parameters	Specification
1.	Type of machine	PTO driven, Mounted type
2.	Power source	Tractor (45 hp or above)
3.	Overall dimensions	
	Length, mm	2100
	Width, mm	1120
	Height,mm	1100
4.	Diameter of the rotary shaft, mm	200
5.	Number of blades	33 pair, L Type
6.	Flail spacing, mm	200
7.	Shape of flail	Inverted "Y"
8.	Depth adjustment settings	3
9.	Transmission	
	Gear ratio	6 : 9
	Diameter of drive pulley, mm	225
	Type of pulley	C-section, V-belt
10.	Number of pulleys	2

Eicher 855FE Tractor of 55hp was used for operating paddy straw chopper during the experiment. Traditional Paddy variety Bus was harvested on 4th–6th October 2019 manually by using sickle. Left over straw was chopped with paddy straw chopper. Height of the crop and left-over straw conditions after manual harvesting is shown in Table 2. Three demarcated plots of similar soil condition of 0.267ha were taken to validate the collected data.

Two levels of lower gears (L_2 and L_3)were selected to operate the straw chopper. Size of cut straw on the basis of length

Table 2: Paddy field conditions where manual harvesting is followed

Parameter	Observation
Height of standing crop (m)	0.97–1.13
Moisture content of straw, % (wb)	65–73
Height of standing stubble, m	0.5–0.65
Straw load (standing stubble+ loose straw), t ha^{-1}	12.30

is evaluated for each operation. A 0.5×0.5 m^2 quadrate was placed randomly in three points of each plot of size 0.267 ha and the stubbles were collected before the operation of straw chopper and after the operation of the chopper.Average moisture content of rice straw is determined using Contech moisture metre. The stubbles were cleared of weeds and soil particles and allowed to dry in a hot air oven at 55±1°C till constant weight. The dry weight of the stubbles was recorded and expressed as g $square^{-1}$ metre.

3. Results and Discussion

The tractor-operated paddy straw chopper demonstrated an effective working width of 2.1 meters. The effective field capacity of the chopper was recorded at 0.67 ha·hr^{-1} at an average forward speed of 3.3 km·hr^{-1} when operating in gear L_2, and 3 km·hr^{-1} in gear L_3. Recent advancements in paddy straw management have focused on improving chopping efficiency and soil incorporation. A tractor-mounted straw chopper-cum-spreader developed by Punjab Agricultural

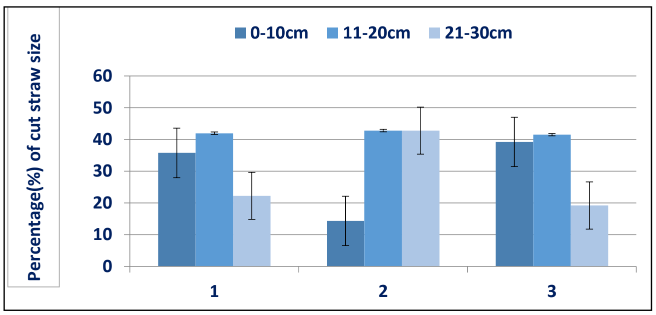

Figure 1: Percentage of different cut straw size in L_2 gear

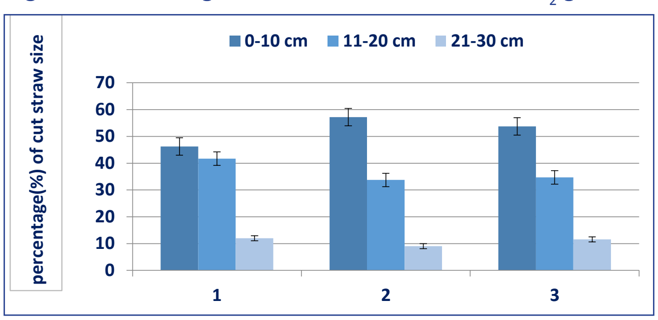

Figure 2: Percentage of different cut straw size in L_3 gear

University was evaluated, with optimal performance observed at 1450 rpm chopping speed and 2.0 km h^{-1} forward speed (Singh et al., 2024). The cut straw was categorized based on its length distribution, with the percentage of cut straw segments in various length ranges being significantly different in each gear setting. In a study by (Dash, 2022) found machine combining straw chopping with pulse sowing showed reduced straw size at higher chopping speeds, though with increased use of fuel. In L_2 gear, the cut straw length distribution showed 71.9% of the straw cut within the 0–20 cm range, whereas in L_3 gear, the percentage increased to 89.1% for the same segment. This indicated that the higher gear setting resulted in a finer chop of the straw. Additionally, each straw

Figure 3: Laceration of cut straw with distinct view of fibre

was subjected to a minimum of two cuts due to the action of the flails, as evidenced by the observed straw laceration shown in Figure 3. A review by Kaur et al. (2022) emphasized the importance of efficient residue management through various mechanized approaches. Straw moisture was found to significantly affect chopping efficiency and spread uniformity (Nalla et al., 2023).

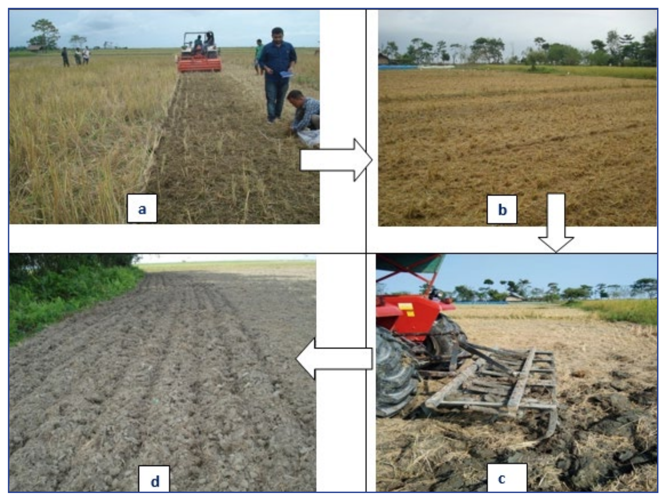

Figure 4: (a) Stubble remains with the operation of the straw chopper (b) View of straw chopped field (c) straw incorporation by tyne tiller (d) finished field after 2 weeks

The length-wise distribution of chopped straw for both L_2 and L_3 gears was measured and categorized into three segments: 0–10 cm, 11–20 cm, and 21–30 cm. In gear L_2, the average distribution of chopped straw across these segments was 29%, 42%, and 28%, respectively. In L_3 gear, the highest proportion of chopped straw (42%) fell within the 0–10 cm range, followed by 33% in the 11–20 cm range. This further confirmed that the chopper in L_3 gear produced finer straw pieces. The data suggested that gear L_3 was more effective at producing shorter straw segments compared to gear L_2 as shown in Figure 1 and Figure 2.

After one week of operation, the chopped straw was incorporated into the soil using two implements: a rotavator and a tyne tiller as shown in Figure 4. The incorporation depth was maintained at 8 cm. Two weeks post-incorporation, the weight of the remaining straw in each plot was measured. The results showed a significant reduction in the weight of straw in both treatments. The average reduction in straw weight due to incorporation was found to be 37.36% for the tyne tiller and 36.20% for the rotavator (Table 3). This reduction indicates the effective integration of chopped straw into the soil, facilitating quicker decomposition and nutrient cycling. Muzamil et al. (2024) reported that a tractor-operated collector-cum-chopper enabled efficient in situ straw chopping and soil incorporation. Furthermore, optimized tillage operations enhanced straw incorporation and improved soil health in rice–wheat rotations (Miresa et al., 2024). These studies support mechanized straw handling as a key component of sustainable agriculture.

In conclusion, the tractor-operated paddy straw chopper efficiently reduced the straw size, with L_3 gear providing the most effective chopping for finer straw. The subsequent incorporation of chopped straw into the soil, using either a rotavator or a tyne tiller, demonstrated effective straw management, with substantial reduction in the weight of remaining straw after two weeks. These findings support the use of such equipment for sustainable paddy straw management and soil improvement practices.

Table 3: Percentage reduction in weight of the chopped straw after 2 weeks

Sample no	Straw weight in an area of 0.25 m^2		Av. Straw weight after chopped (in 0.25 m^2)	Straw remaining after 2 weeks		Reduction in straw weight in % after 2 weeks (extent of incorporation)	
	L_2	L_3		Cultivator	Rotavator	Cultivator	Rotavator
1	294 g	352 g	323 g	201 g	198 g	37.77	38.70
2	391 g	227 g	309 g	214 g	226 g	30.74	26.86
3	155 g	586 g	370.5	209 g	211 g	43.58	43.05
Averagereduction in straw weight						37.36%	36.20%

4. Conclusion

The tractor-operated paddy straw chopper effectively reduced straw size, with the L_3 gear producing finer straw compared to L_2. Subsequent incorporation of the chopped straw using a rotavator or tyne tiller resulted in significant reduction in the weight of remaining straw after two weeks, with an average reduction of 37.36% for the tyne tiller and 36.20% for the rotavator.

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