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Original Research Article

Conservation Agriculture: Crop Residue cutting Mechanisms for Direct Drilling in Crop Residual Condition

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A B S T R A C T

Conservation Agriculture involves practices such as minimum or zero mechanical disturbance, crop residues retention and permanent organic soil cover. The major problem in direct drilling under no-tillage condition is the high amount of residues of previous crop, which hinder operation of no-till machine. The crop residue cutting devices were developed and evaluated for rice crop residue cutting ability in the soil bin. The crop residue cutting mechanisms were operated on a wide range of straw densities from 3000 to 5000 kg/ha at forward speed of carriage 2.5 km/h and at rotational speed of straw cutting mechanisms of 150 to 250 rpm and speed ratios from 5.20 to 8.67 and evaluated their performance in the soil bin laboratory of Central Institute of Agricultural Engineering, Bhopal. The relative effect of the variables of speed ratio, pair of press wheels, straw density and type of disc blades on the responses of horizontal force (F_h), vertical force (F_v), power consumption and straw cutting percentage were studied. The horizontal force (F_h) requirement of toothed blade was observed to be higher by 19% than that for the plain blade disc at all speed ratios and straw density levels. On an average 34% higher vertical force (F_v) was found for straw cutting by toothed blade disc than that for the plain blade. The power requirement of plain blade with a pair of twin press wheel assembly was estimated to be 192.66, 280.23 and 356.33 W at 3000, 4000 and 5000 kg/ha straw density, respectively at 5.20 speed ratio, whereas it was found to be 262.82, 396.00 and 585.83 W for toothed blade disc for the same straw density and speed ratio. The quantity of straw cut with plain blade was 100% for all straw densities and speed ratio however, it was found to be 91.00, 90.33 and 92.00% for toothed blade at 3000, 4000 and 5000 kg/ha straw density level, respectively. The developed crop residue cutting mechanism performed better under no-till conditions and recommended for no-till sowing under heavy crop residue conditions.

Keywords

Conservation agriculture, No-till, Crop residue and straw cutting mechanism

Introduction

Conservation Agriculture (CA) technologies have the potential to contribute to increased productivity in a sustainable way. The term CA refers to a set of agricultural practices and is based on three fundamental principles namely, no-tillage, permanent soil cover and diversified crop rotations. Conservation Agriculture involves practices such as minimum or zero mechanical disturbance, crop residues retention, permanent organic soil cover, diversified crop rotations, precise placement of agro chemicals, in-field traffic control and application of animal manure and crop residues. The benefits of CA are lower farm traffic, reduction in use of mechanical power, labour inputs thus resulting in timely field operations, lower risk of crop failure and ultimately resulting in higher yields, lower costs and reduction in environmental pollution. Late sowing of wheat is a major problem in paddy-wheat cultivated areas, which results into decreased yield by 1 to 1.5 % per day when planted after November. Sowing of wheat with traditional method requires 7 to 8 days for field preparation that also delays sowing of wheat resulting in decreased yield (Tandon, 2007).

Rice - wheat is an important crop rotation and covers an area of 72 Mha in the world and 10 to 12 Mha in India. The total area under no-tillage in the world is 90 Mha and in India it is about 3.43 Mha (Saunders *et al.,* 2012; Tandon, 2007). Due to increase in demand for food production, the farmers have started growing more than one crop a year resulting in land degradation, unsound agricultural practices and increase in use of different inputs such as seed, fertilizer, chemicals and agricultural machinery. In North-Western India, combine harvesting of rice and wheat is now a common practice leaving large amount of crop residues in the fields. the conservation tillage systems, besides the high levels of crop residues do present a constraint for adopting conservation tillage, because the residues mechanically interfere with crop residues on the soil surface pose difficulty for uniform seedling establishment in seeding operations. Improved seeding equipment or residue removal may be necessary for successful direct drilling practices. The main operational problem in direct drilling of paddy straw residue is the accumulation and wrapping of loose straw on the tines and frame of no-till drills and traction problems with the ground wheel (Hegazy and Dhaliwal, 2011; Graham *et al.,* 1986).

Proper seed placement is very important component of the crop production system. No-till seeding requires drills capable of cutting through large quantities of crop residue, penetrating untilled soil, and depositing the seed 25 to 50 mm deep. Problem associated with seed placement under no-till and minimum tillage practices are density, toughness of crop residue and soil penetrating resistance. No till drills have indicated that under heavy crop residues, failures of the disc openers to cut through the residue resulted in the seed being placed either in the residue or on the soil surface. The seed was placed on this trash resulting in poor germination. Since, no-till and minimum tillage system have considerable potential for saving energy, time, man hours, machine hours, controlling wind and water erosion, reduction of soil moisture loss by evaporation, it is extremely important to investigate problems associated with seed placement under crop residue conditions (Kushwaha *et al.*, 1886; Baker and Saxton, 2007).

The combine harvested rice-wheat fields are generally left with long loose straw and stubbles in the field which create several operational problems in land preparation for the next crop. Nearly 75% of rice-wheat straw goes as waste besides causing environmental pollution due to straw burning in the field prior to tillage for subsequent sowings. Burning of rice stubbles is widely practiced in Punjab, India, due to a lack of suitable machinery for direct drilling of wheat seed into combine-harvested rice residues. Although direct drilling of seed into burnt stubbles is a rapid and cheap option, and it allows for a quick turnaround between crops, it is causing serious problems for human and animal health due to air pollution, and decline in soil fertility due to loss of nutrients and organic matter (Singh *et al.*, 2008). Considering the problems with direct drilling of wheat into combine-harvested rice fields the study was undertaken to develop and evaluate the performance of straw cutting mechanism for direct drilling in crop residual conditions in the soil bin.

Materials and Methods

The research work was carried out in Soil Dynamic Laboratory, Agricultural Mechanization Division, Central Institute of Agricultural Engineering, Bhopal (MP). The experiment of straw cutting mechanisms was conducted according to CRD design and Response Surface Methodology (RSM) was applied to the experimental data. The relative effect of the variables of speed ratio, pair of press wheels and straw density on the responses was studied. The responses studied were horizontal force (draft), vertical force, power requirement and straw cutting percentage.

The straw cutting mechanisms viz., plain blade disc with twin press assembly and toothed blade disc with twin press assembly were developed for studying their straw cutting ability in no-till crop residue conditions in the soil bin. Parametric software Pro-Engineer creo element was used to design the straw cutting mechanisms. Based on the design of plain disc, the whole disc of 460 mm in diameter and 4 mm thick was divided in to eight parts for fabrication of plain eight blades (Fig. 1). These plain blades were fixed on the flange of 350 mm diameter. The flange was made up of mild steel from 4.0 mm thick plate. The bevel angle of the blade was 12°. This plain blade has advantage of replacement of damage or blunt blade instead of complete replacement of whole disc. The toothed blade disc was also developed for evaluating its performance in the soil bin (Fig. 2). A pair of twin press wheel assembly was developed to hold and press the straw under tension during cutting of the straw. Press wheel assembly consists of twin press wheel, fork and ratchet returning spring. Straw cutting mechanisms along with cutting discs are shown in Figure 3 and 4.

The straw cutting mechanisms were operated on a wide range of straw densities from 3000 to 5000 kg/ha at carriage speed of 2.5 km/h and at speed ratios 5.20 to 8.67 with a pair of twin press wheels assembly at constant depth of 15 mm. The straw cutting mechanisms were fixed on the tool bar provided on the carriage. The carriage was brought and parked over the packed soil and operating depth was set. The tool bar was lowered to the desired depth of penetration from the zero mark. Preparation of straw for an experiment was tedious and time consuming. The rice straws were taken from the bale for maintaining the uniformity in the all experiments. Pieces of straw of length 400 mm were made and taken for the experiment and maintained the required range of density from 3000 to 5000 kg/ha (Mangaraj and Kulkarni, 2010).

The carriage motor was set at desired speed of 2.5 km/h. The data acquisition program was run with a data file. Data were collected with straw cutting mechanism running on the straw. Soil force and torque data automatically collected for the working distance of 5 m. Exported the data to MS excel for further analysis purpose. At the end of the run, the straw cutting mechanism was lifted up and the carriage returned. Collected uncut straw pieces from the soil bin for its measurement of uncut and cut straw percentage and the soil was prepared for the next run.

Simulation of soil conditions in the soil bin was the major factor in determining the performance of the straw cutting mechanisms. Various operations such as tilling, wetting of soil, leveling and packing were the part of soil preparation.

The soil preparation unit includes roto-tiller, deep working tines, sheep foot roller, soil leveler and water application system to obtain uniform moisture and penetration resistance throughout each experiment with repeatability measures.

The field condition of soil compaction level was closely simulated in the soil bin. One important parameter is soil compactness and this was measured in the field and in the soil bin with a cone penetro-logger. Data were collected from fields with a cone penetro-logger. Data for soil penetration resistance were collected at seeding time with stubble under no-till conditions on the field of the Central Institute of Agricultural Engineering, Bhopal. Cone index values were evaluated at 0 to 300 mm depth by taking an average of five readings of five different plots.

The core of the complete soil bin system was a computer controlled data acquisition and analysis unit. It was a supervisory control and data acquisition (SCADA) and programmable logic control (PLC) based system. The computer based data acquisition and control system provides on-line display and logging of experimental variables while simultaneously prepares reports in printable format which allows rapid evaluation of experimental results. The experimental design was applied after selection of the ranges. The experiments were randomized in order to minimize the effect of unexplained variability in the observed responses due to extraneous factors. The centre point in the design was repeated six times to calculate the reproducibility of the method. The developed straw cutting mechanism was fixed to the frame provided on front tool bar of the carriage across the bin width. The straw cutting mechanism was fitted on the frame through a sub frame which was entirely supported from the carriage through six appropriately oriented force transducers for measuring the horizontal force, vertical force and lateral force acting on the straw cutting mechanism (Singh *et al.*, 2008).

The power was given to the straw cutting mechanism from 3.75 kW motor through chain and sprocket arrangement and the torque sensor was coupled to the shaft of the motor. The proximity switch was fitted at the frame of torque sensor's foundation for counting the rpm of straw cutting mechanism. The effect of various parameters of straw cutting mechanism like pair of press wheels, straw density and speed ratio on horizontal force, vertical force, power required for straw cutting mechanism and straw cutting percentage was measured.

Results and Discussion

Horizontal force requirement for straw cutting mechanisms

From Table 1 it is seen that the requirement of horizontal force (F_h) by the straw cutting mechanism equipped with a toothed blade and twin press assembly was observed to be 13.52, 14.91 and 16.01 kgf at 3000, 4000 and 5000 kg/ha straw density, respectively at 5.20 speed ratio while it was found to be 12.16, 12.50 and 13.59 kgf for plain blade disc at the same straw density level and speed ratio. Similar trend was also observed at speed ratios of 6.94 and 8.67 (Table 1). The increase in F_h in toothed blade as compared to the plain blade may be attributed to the fact that the straw were trapped in tooth of the blade and carrying straws along with its periphery.

Whereas, the plain blade had the continuous contact of its cutting edge with the straw and helped for smooth cutting of straw and resulted into less requirement of F_h than the plain blade. The values of F_h obtained demonstrated that, F_h requirement of 10, 16 and 15% was observed higher for toothed blade disc than that for the plain blade disc at 3000, 4000 and 5000 kg/ha straw density, respectively. Choi and Erbach (1986) reported that an average horizontal force of 20.1 kgf is required for cornstalk residues shearing by rolling coulter at 38 mm depth.

The reported higher value of F_h was due to the higher depth of operation of 38 mm and rolling coulter. The Eq. 1 in terms of actual factors can be used to make predictions about the response of horizontal force (F_h) for given levels of each factor.

The regression Eq. 1 describing the effects of the variables on horizontal force for toothed and plain blade in terms of actual levels of variables given as,

$$\text{Horizontal force} = 2.94 + 0.29\,X_1 + 2.72\,X_2 + 0.0034\,X_3 + 0.26X_2^2 \qquad (1)$$

Where, X_1- speed ratio, X_2- pair of press wheels and X_3- straw density, are the variables

Vertical force on straw cutting mechanism

From Table 2 it is seen that the requirement of vertical force (F_v) by the straw cutting mechanism equipped with a toothed blade and twin press assembly was observed to be 33.17, 36.42 and 40.63 kgf at straw density of 3000, 4000 and 5000 kg/ha, respectively at 5.20 speed ratio, while it was found to be 12.16, 12.50 and 13.59 kgf for plain blade disc at the same straw density level and speed ratio (Table 2). Similar trend was also observed at speed ratios of 6.94 and 8.67 (Table 2). On an average 22% higher F_v was found for straw cutting by toothed blade disc than that for the plain blade at 5.20 speed ratio. This increase in vertical force (F_v) would have been due to the straw pushed into the soil by the toothed knives of toothed blade and therefore, the toothed blade demanded higher vertical force (F_v) for their penetration in the soil. The requirement of higher F_v it may due to the impact shearing of straw by the tooth.

The regression Eq. 2 describing the effects of the variables on vertical force for toothed and plain blade in terms of actual levels of variables given as,

$$\text{Vertical force} = 6.21 + 0.35\,X_1 + 8.70\,X_2 + 0.0023\,X_3 - 1.27X_2^2 \qquad (2)$$

Effect of variables on power requirement of straw cutting mechanisms

The estimation of power required by straw cutting mechanisms equipped with toothed blade disc and a pair of twin press wheel assembly was found to be 243.21, 383.93 and 544.79W. Whereas, it was found to be 192.66, 280.23 and 356.33 W for plain blade disc at 3000, 4000 and 5000 kg/ha straw density, respectively at 5.20 speed ratio (Table 3). Similar trend was also observed for power requirement at other speed ratios of 6.94 and 8.67. Agreement of Kushwaha *et al.,* (1986) for power consumption of powered coulters working at 55 mm depth and at 4000 kg/ha straw density was 173.2 for plain coulter. These values of power consumption are lower because of the lower speed ratio of 2.0 whereas, in the present study, the experiments were carried out at 5.2 to 8.67 speed ratio.

Fig.1 Plain blade disc for straw cutting

Fig.2 Toothed blade disc for straw cutting

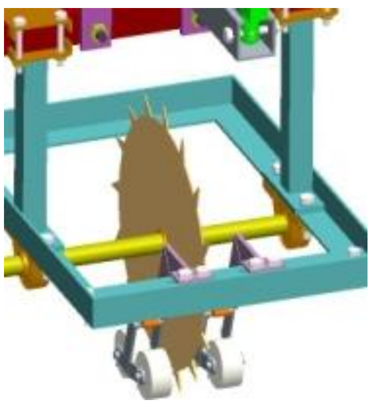

Fig.3 Straw cutting mechanism equipped with toothed blade

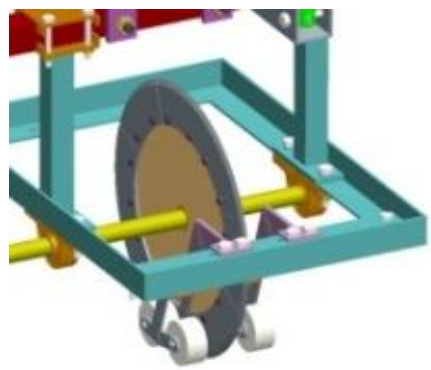

Fig.4 Straw cutting mechanism equipped with plain blade

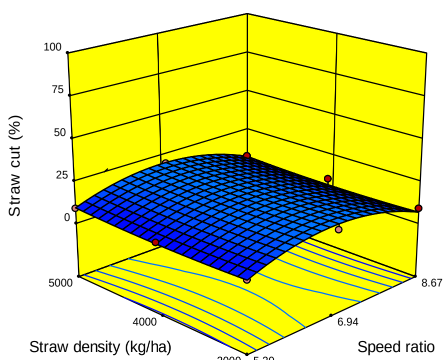

Fig.5 straw cutting percentage by straw cutting mechanism equipped with toothed blade disc

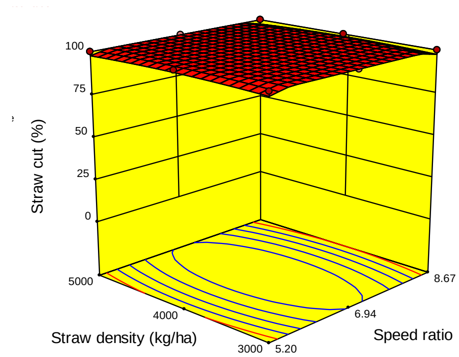

Fig.6 straw cutting percentage by straw cutting mechanism equipped with plain blade disc

Fig.7 Straw cutting mechanism equipped with plain blade and a pair of twin press wheels assembly

Table.1 Requirement of horizontal force (kgf) for toothed and plain blade disc straw cutting mechanism

Speed ratio	Toothed blade disc at straw density, kg/ha			Plain blade disc at straw density, kg/ha		
	3000	4000	5000	3000	4000	5000
5.20	13.52	14.91	16.01	12.16	12.50	13.59
6.94	14.09	15.37	16.63	12.58	13.68	13.81
8.67	14.85	15.90	16.89	13.24	14.51	14.18

Table.2 Requirement of vertical force (kgf) for toothed and plain blade disc straw cutting mechanism

Speed ratio	Toothed blade disc at straw density, kg/ha			Plain blade disc at straw density, kg/ha		
	3000	4000	5000	3000	4000	5000
5.20	33.17	36.42	40.63	27.58	29.91	32.82
6.94	33.74	36.93	41.19	28.37	30.94	32.79
8.67	34.69	38.23	41.51	28.85	31.76	35.05

Table.3 Power requirements (Watts) of straw cutting mechanisms equipped with toothed and plain blade disc

Speed ratio	Toothed blade disc at straw density, kg/ha			Plain blade disc at straw density, kg/ha		
	3000	4000	5000	3000	4000	5000
5.20	243.21	383.93	544.79	192.66	280.23	356.33
6.94	246.02	412.77	551.56	199.83	284.89	368.60
8.67	256.03	421.85	565.98	203.13	313.57	389.99

Table.4 Straw cutting percentages of straw cutting mechanisms equipped with toothed and plain blade disc

Speed ratio	Toothed blade disc at straw density, kg/ha			Plain blade disc at straw density, kg/ha		
	3000	4000	5000	3000	4000	5000
5.20	75.67	73.67	77.00	100.00	100.00	100.00
6.94	84.33	82.33	82.00	100.00	100.00	100.00
8.67	73.00	76.00	74.67	100.00	100.00	100.00

Straw cutting performance of the blades

From Table 4, it is depicted that the 100% straw cutting percentage was observed by plain blade disc at all the straw density levels of 3000, 4000 and 5000 kg/ha and at all the speed ratio of 5.20, 6.94 and 8.67. It may due to that a pair of twin press wheels assembly was sufficient for holding the straw which were fitted at both sides of straw cutting blade and the plain blade had smooth cutting edge resulted into 100% of straw cutting.

Kushwaha *et al.,* (1986) also reported that the plain coulter cut the straw nearly 100% at all the rotational speeds and straw densities. Whereas, the straw cutting performance of toothed blade was observed lower than that of plain blade and it was observed to be 84.33, 82.33 and 82.00% at 3000, 4000 and 5000 kg/ha straw density, respectively at 6.94 speed ratio. The regression Eq. 3 describing the effect of variables on percentage of straw cut in terms of actual levels of variables is given as,

$$\text{Straw cut} = 16.508 + 28.858\,X_2 - 0.008\,X_1^{\,2} + 6.506X_2^{\,2} - 4.39\times10^{-9}X_3^{\,2} \qquad (3)$$

Figure 5 and 6 shows the straw cutting work performed by the toothed blade and plain blade equipped with a pair of twin press wheels assembly. From Figure 7, it is seen that, after passing the plain blade the straws were cut and the cut straws were completely sectioned into two halves.

The amount of clogged straw by straw cutting mechanism equipped with plain blade and a pair of twin press wheels assembly was observed to be 7.58, 4.51 and 6.22 kg/ha at 3000, 4000 and 5000 kg/ha straw density, respectively at 5.20 speed ratio whereas, 21.46, 24.82 and 23.89 kg/ha was observed for toothed blade disc at the same straw density and speed ratio. Almost similar results were also obtained at 6.94 and 8.67 speed ratios.

A very less amount of clogged straw i.e. 4.01 kg/ha was observed in straw cutting mechanism of plain blade with a pair of twin press wheels assembly, it was due to that the pair of wheels press hold the laid straws properly at the time of straw cutting. A pair of twin press wheel assembly had higher contact area of press wheels with straw and soil surface, and hence almost all the straw were hold by the pressing wheels and resulted into less straw clogging. A very few amount of clogged straw was found and it may due to the 100% straw cutting. The regression Eq. 4 describing the effect of variables on straw clogged in terms of actual levels of variables is given as,

$$\begin{aligned}&\text{Straw clogged}\\&= -20.436 + 21.372X_1 - 54.16X_2 - 0.202X_1X_2 - 1.536X_1^{\,2} + 19.028X_2^{\,2}\\&+ 1.244\times10^{-8}X_3^{\,2}\end{aligned} \qquad (4)$$

The quantity of straw cut by straw cutting mechanism equipped with plain blade disc and a pair of twin press wheels assembly was 100% for all straw densities and speed ratios and it performed better under no-till conditions and recommended for no-till sowing under heavy crop residue conditions.

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References

Baker, C.J. and Saxton, K.E. 2007. No-tillage seeding in conservation agriculture, 2nd edition, published by FAO of United Nations.

Choi, H.C. and Erbach, D.C. 1986. Cornstalk residue shearing by rolling coulters. Transaction of the *ASAE*. Vol. 29(6):1530-1535.

Graham, J.P. Ellis, F.B. Christian, D.G. and Cannell, R.Q. 1986. Effects of straw residues on the establishment, growth and yield of autumn-sown cereals. *J. Agric Eng. Res*. 33:39-49.

Hegazy, R.A. and Dhaliwal, I.S. 2011. Evaluation of a Power Driven Residue Manager for No-till Drills. *Agricultural Engineering International: the CIGR Journal*. Manuscript No.1641 13(1).

Kushwaha, R.L. Vaishnav, A.S. and Zoerb, G.C. 1986. Performance of powered-disk coulters under no-till crop residue in the soil bin. *Canadian Agricultural Engineering Journal*, 28(2): 85-90.

Mangaraj, S. and KulkarnI, S.D, 2010. Field straw management- A techno economics perspectives. *Journal of the Institute of Engineering*, 8(1):153-159.

Saunders, C. Davis, L. and Pearce, D. 2012. Rice-wheat cropping systems in India and Australia, and development of the Happy Seeder. *Australian Centre for International Agricultural Research*, Australia, pp. 10-15.

Singh, K. P. Pardeshi, I. L. Kumar, M. Srinivas, K. and A. K. Srivastava, 2008. Optimisation of machine parameters of a pedal-operated paddy thresher using RSM. *Biosystem Engineering*, 100:591-600.

Tandon, S.K. 2007. Conservation Agriculture Practices to meet challenges of global warming. *Indian Council of Agricultural Research*, New Delhi.