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Arpit Kumar
Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, West Bengal, India

Satish Manda
Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, West Bengal, India

Mukesh Jain
Department of Farm Machinery and Power Engineering, CCS Haryana Agricultural University, Hisar, Haryana, India

Correspondence
Arpit Kumar
Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, West Bengal, India

Performance evaluation of tractor PTO operated rotary mulcher

Arpit Kumar, Satish Manda and Mukesh Jain

Abstract
The performance of tractor Power Take off (PTO) operated rotary mulchers was evaluated in the combine harvested paddy field in Village Jhaloor, Dist. Barnala (Punjab). Both Haryana and Punjab have large lands of paddy field and most of the paddy crop is harvested by using combine harvesters. Combine harvesters after harvesting paddy crop leave behind straw in the form of standing stubbles. The loose straw left after harvesting by combine, lying in the windrows resulted in frequent choking in between furrow openers and frame of the drill. The straw present in field often builds up in front of tynes of drill and eventually blocks the tynes and frame, causing uneven seeding depth, rate and a patchy stand of plants.

Incorporation of the leftover straw into soil or chopping and spreading it on the soil surface to act as natural mulch is a better way of waste utilization which improves soil health and also reduces the difficulty faced during primary tillage. Thus performance of the rotary mulcher was evaluated in the field to check its applicability to overcome the problem faced by the farmers. The comparative analysis of the performance of different makes of rotary mulcher viz. Make ''A'' and Make ''B'' was also performed. The average field capacity, field efficiency, fuel consumption & percentage cut (height) observed in the field were 0.37 ha/h, 81.03 %, 14.678 l/ha& 82.56% for Make ''A'' and 0.352 ha/h, 79.54 %, 12.532 l/ha & 84.89 % for Make ''B'' respectively.

Keywords: Tractor PTO operated, rotary mulcher

Introduction
Paddy crop is cultivated on an area of about 1.1 million hectares (2015) in Haryana and approximately 3 million hectares (2015) in Punjab. Here most of the paddy crop is harvested by using combine harvesters. Combine harvesters after harvesting paddy crop leave behind straw in the form of standing stubbles of 30-45 cm height and loose straw of 35-60 cm length. The total yield of paddy straw in combine-harvested field is about 12.5 t/ha out of which the yield of standing stubbles and loose straw are about 7 t/ha and 5.5 t/ha, respectively which means a huge amount of residue is available for disposal every year.

This large amount of straw is wasted annually either by burning in the fields or due to poor utilization which otherwise could contribute to the income of farmers. There are several options for managing the paddy straw, which can be divided into two broad categories: Off-site use of straw and In-situ disposal of straw.

Off-site disposal of rice straw includes the use of straw for as a source of thermal power generation, card board/paper manufacturing, packaging material for horticultural crops, a substrate for microbial conversion of straw into alcohol or as animal feed. Paddy straw has higher silica content and is not preferred as animal feed. All of these account up to only 20% of the total straw management and the rest of the straw is managed by the other method i.e. in-situ disposal of paddy straw.

In-situ management of straw includes burning, incorporation into soil or chopping and spreading it on the soil surface to act as natural mulch. Burning of straw in the field itself is the easiest and the quickest way to manage the straw. Hence most of the farmers adopt the burning practices. Burning is not the satisfactory solution, as it not only creates environmental pollution but also results in the loss of organic matter and other nutrients available in straw. Bacterial and fungal populations are decreased immediately and substantially in top 2.5 cm soil upon burning. Burning also decreases the efficiency of some weedicides used for controlling weeds during wheat growth. It also causes a loss of about 79.38 kg/ha of nitrogen, 108.86 kg/ha of potassium and 183.71 kg/ha of phosphorus (*Beri and Sidhu, 1999*) [6]. One tonne of straw, on burning releases 3 kg particulate matter, 60 kg CO_2, 199 kg ash and 2 kg SO_2 (Gupta *et al*., 2004) [3].

If incorporation of straw in the field is to be done, the field needs 6-8 tilling operations (2-3 disking + 3 cultivator operations + 2-3 planking operations) or 6-8 operations of rotavator.

Incorporation of straw into soil improves the soil fertility, but it needs considerable energy, increases the cost of operation and delays the sowing of wheat crop.

The crop residues if left as it is in the field, creates problem during sowing of wheat crop. One of the major problems in sowing under no tillage is the hindrance in operation of No till machine due to the high amount of crop residues. Residue especially loose straw creates handling problem for no tillage drills but is a very valuable biological resource. The loose straw left after harvesting by combine, lying in the windrows resulted in frequent choking in between furrow openers and frame of the drill (Singh and Singh, 1995 and Bansal, 2002). The straw present in field often builds up in front of tynes of drill and eventually blocks the tynes and frame, causing uneven seeding depth, rate and a patchy stand of plants (Graham *et al*., 1986 and Blackwell, 2001).

To handle these problems while direct drilling in combine harvested field, a tractor PTO operated straw chopper cum spreader was developed in the department of Farm Power and Machinery (*Garg, 2003*) [1], whose performance was evaluated at different field conditions.

Tractor PTO operated mulcher chops green crop and left over stubbles of harvested crop into pieces and spreads on the ground in single operation. Machine consists of rotary shaft mounted with flail type "Inverted Gamma" blades. The chopped and evenly spread green crop or stubbles can easily be buried in the soil by the use of single operation of rotavator or disk harrow and gets decomposed after irrigation. The chopped crop or stubbles may also be left over on the field without mixing with the soil to act as good mulch.

Materials and Methods

Rotary-mulcher is a field equipment with 3-point linkage operated through tractor Power Take off (PTO) shaft. The machine chops the leftover paddy stubbles and straw remaining in the field into small pieces that can be used as the surface mulch & thereby assist in increasing the soil fertility and saving the use of fertilizers. Two different rotary-mulchers viz. Make ''A'' and Make ''B'' were evaluated for comparative field performance. The constructional details of the machines were measured by the Testing Engineers at the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Hisar which are as shown in Table 1.

Field test

To evaluate the comparative performance of the machines, tests were conducted in the combine harvested paddy fields in Village- Jhaloor, Dist. Barnala (Punjab) from October, 2017 to March, 2018. The type of soil was sandy loam and the variety of harvested paddy crop was PR-144. Tests were performed for 36-37 hours. Five number of tests were performed for better assessment of the required field parameters. Comparative performance evaluation of the machines included testing of the various parameters viz., stubble height before and after operation, % cut in stubble height, weight of the straw and stubbles per square meter before and after operation, field capacity, field efficiency, fuel consumption and the power consumption.

Table 1: Constructional details of Rotary-Mulcher

S.no	Particulars	Specifications	
1.	**Overall dimensions**	**Make ''A''**	**Make ''B''**
	Length	1120 mm	1020 mm
	Width	2250 mm	2180 mm
	Height from ground	990 mm	1070 mm
	Weight	610 Kg	560 Kg
2.	**Drive shaft/Propeller Shaft**	Telescopic shaft with universal joints	Telescopic shaft with universal joints
	Length	870-1070	1060-1250
	No. of splines	6 at both ends	6 at both ends
	Weight	17.26 Kg	20.3 Kg
3.	**Gear box**	Bevel & pinion	Bevel & pinion
	Gear ratio	1:3	1:3
4.	**Auxiliary drive shaft**		
	Length	890	1015
	Diameter	40	40
	No. of splines	6 at both ends	6 at both ends
5.	**Mast**		
	Type	M.S. Flat	M.S. Flat
	Size of sheet	640*205*8	660*230*10
	Shape	Pyramid shape	Pyramid shape
6.	**Chassis (M.S. Sheet)**		
	Size of sheet	2010*5	2040*980*5
	Size of supporting flat	840*540*10 (RHS) 840*820*10 (LHS)	840*540*10 (RHS) 840*820*10 (LHS)
7.	**Rotor shaft**		
	Length	1900	1960
	Dia.	164	520
	No. of flanges (brackets)	18	24
	Dia. of flanges	62*61	51*50
	Thickness of flange	14	19
	No. of blades on each flange	3	3
	Distance between two brackets	190	185
	Total no. of blades	54	72
	Dia. of rotor with blades	474	822
8.	**Rotor blade**		
	Type	Hatchet 'L' Type 36 & straight type 18	Hatchet 'L' Type 48 & straight type 24

		(Combined unit looks like inverted gamma)	(Combined unit looks like inverted gamma)
	Overall thickness	6.8 straight, 7.0 hatched	6 straight, 8 hatched
	Speed of rotor shaft	2860	2132
	Peripheral speed of rotor blades, m/sec	70.95	91.71

Results and Discussion

During the field evaluation of rotary-mulcher, the height of the straw stubbles and moisture content of the straw was 437 mm and 18 %, respectively. The average population density of the standing stubbles was found out to be 316.4 per square meter. The average temperature and relative humidity during the field test were 32^0C and 52 % respectively.

The field performance results are shown in Table 2 & Table 3. Forward speed of the tractor for the operation for Make ''A'' and Make ''B'' was 2.308, and 2.258 km/h respectively. The actual field capacity was 0.37 and 0.352 ha/h with the field efficiency of 81.032 and 79.536 % respectively. The field capacity and field efficiency was observed lesser in case of Make ''B'' model of rotary-mulcher. The average length of the spreaded straw was observed as 131.6 mm and 126.4 mm in case of Make ''A'' and Make ''B'' respectively. Percentage cut in stubble height was observed more in case of Make ''B'' i.e. 84.89 % than Make ''A'' i.e. 82.54 %. Average weight of the stubbles after shredding was observed as 1.065 kg/m^2 and 0.887 kg/m^2 in case of Make ''A'' and Make ''B'' respectively. The fuel consumption was observed more in case of Make ''A'' i.e. 5.012 l/h than 4.398 l/h in case of Make ''B''. It was because of Make ''A'' being heavier than the Make ''B'', thereby requiring higher power for operation. Power consumed by the machines was 24.52 kW and 23.36 kW in case of Make ''A'' and Make ''B'' respectively.

Table 2: Field crop conditions before and after operation

Particulars	Range of parameters	
	Make ''A''	Make ''B''
Temperature, ^{0}C	31.6	32.16
Pressure, m bar	992.2	985.6
Moisture content of straw, %	19.2	16.74
Paddy stubble population, No./m^2	301.8	331
Average length of straw, mm	131.6	126.4
Loose straw, kg/m^2	3.073	2.805
Avg. weight of stubbles before shredding, kg/m^2	1.772	1.666
Avg. weight of stubbles after shredding, kg/m^2	1.065	0.887
Avg. height of stubbles before shredding, mm	430.12	443.92
Avg. height of stubbles after shredding, mm	74.68	66.88
% cut of stubbles, %	82.54	84.89

Table 3: Field performance test

Particulars	Range of parameters	
	Make ''A''	Make ''B''
Forward speed, km/h	2.308	2.258
Avg. width of cut, m	1.97	1.92
Field efficiency, %	81.032	79.536
Field capacity, ha/h	0.37	0.352
Fuel consumption, l/h	5.012	4.398
Fuel consumption, l/ha	14.678	12.532
Power consumption, kW	24.52	23.36

Conclusions

In this study the performance of the rotary-mulcher was evaluated on the basis of the field tests. Based on the study it can be concluded that rotary-mulcher is useful machinery to the farmers for paddy straw management and quite a good alternative for the stubble burning as stubble burning is a horrific practice in Haryana & Punjab causing environmental pollution. Rotary-mulcher may result in discouraging the practice of stubble burning. During evaluation it was observed that the length of the spreaded straw was a major factor influencing the performance of the subsequent machinery used for field operations which can be resolved by improvising the machine specifications. The cut straw quality was found satisfactory to be used as the field manure by means of surface mulch. Make ''B'' was found more economic for the farmers as fuel consumption and power consumption was less than the Make ''A'' and more straw recovery was observed. Having more no. of blades and higher rotor blade peripheral speed, larger cut of the standing stubbles is observed in case of Make ''B'' as compared with Make ''A''. It was observed that by increasing the no. of blades and their peripheral speed, smaller size chopped straw was seen, thereby making it more suitable for better surface mulch preparation. It can be taken care of that the overall weight of the machine can be reduced so as to make it more fuel efficient and economic for farmers.

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