Current Journal of Applied Science and Technology

39(14): 31-40, 2020; Article no.CJAST.57380
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Comparison of Straw Chopper cum Incorporator with Existing Paddy Residue Management Technologies in Combine Harvested Paddy Field at North Western Region of India

Chelpuri Ramulu[1*], Raj Narayan Pateriya[1] and Mude Arjun Naik[1]

[1]Department of FMPE, GBPUA&T, Pantnagar, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author CR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author RNP managed the analyses of the study and guided during entire research work. Author MAN managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i1430694
Editor(s):
(1) Dr. A. A. Hanafi-Bojd, Tehran University of Medical Sciences, Iran.
Reviewers:
(1) Jasvarinder Chalotra, Punjab Agricultural University, India.
(2) Joaquim Odilon Pereira, Universidade Federal Rural do Semi-Árido, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/57380

Original Research Article

Received 20 March 2020
Accepted 29 May 2020
Published 08 June 2020

ABSTRACT

Burning of paddy residue is major problem which leads to adverse affect on our environment. Management of crop residues in conservation agriculture is vital for long-term sustainability of Indian agriculture. The straw chopper cum incorporator machine consists of chopping unit, incorporation unit, adjustable frame, pulleys and belts. The power is transmitted to the chopping unit and incorporation unit by tractor (55.95 kW) PTO with the help of gear box, belt, pulley and gear arrangement. The fuel consumption, field capacity and field efficiency of residue management machine were observed 12.5-14.0 l/h, 0.43-0.64 ha/h and 60.46% respectively. Cost economics of straw chopper cum incorporator machine was compared with existing technologies adopted by farmers i.e. straw chopper + 2 rotavator practice and 6 harrowing + rotavator + planker practice. The cost of operation of straw chopper cum incorporator machine was observed 4272.8 Rs.ha^{-1} lower than existing technologies. The break even point (BEP), pay back period and benefit cost (B:C) ratio of the Straw chopper cum incorporator machine were 45ha, 0.7 years and 1.17

**Corresponding author: E-mail: ramucae19@gmail.com;*

respectively. Therefore, it is concluded that the Straw chopper cum incorporator machine can be recommended to the farmers for paddy residue management of combine harvested paddy field.

Keywords: Straw chopper cum incorporator; burning; paddy residue; chopping; incorporation; cutting and conservation agriculture.

1. INTRODUCTION

The agricultural industry plays a major role in the overall economic growth of the world. Specifically, India is the second largest producer of rice and wheat in the world, two crops that usually produce large volume of residue. On an average, for every 4 t of wheat or rice, about 6 t of straw is produced which shows a huge amount of straw available for disposal every year. The total yield of paddy straw in combine harvested field is about 12.5 t/ha in which yield of standing stubbles and loose straw is about 7 t/ha and 5.5 t/ha, respectively [10]. Overall, India produces 686 MT gross crop residue biomass on annual basis, of which 234 MT (34% of gross) are estimated as surplus biomass. At state level, Uttar Pradesh produces the highest amount of crop residue amongst all the 29 states. Amongst all the crops, sugarcane produces the highest amount of surplus residue followed by rice. A total of 39 residues from 26 crops cultivated in India are considered for the study [4].

The sowing of wheat is recommended by the 30th November for obtaining higher yield. Thus, the total time available for timely sowing of wheat is about 15-20 days after combine harvesting paddy field. Farmers are unable to prepare the seedbed within this limited time, due to this reason farmers burns the paddy straw [3]. Burning of crop residues leads to release of soot particles and smoke causing environmental problems, emission of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide causing global warming, loss of plant nutrients such as N, P, K adverse impacts on soil properties and wastage of valuable organic carbon and energy rich residues. Open burning of paddy straw in fields releases pollutants into the atmosphere that contribute to enhance climate change issues [7]. Despite the known of its benefits, growers burn a significant portion of the crop residues on-farm so that the succeeding crop can be sown. Mechanized farming linked with lack of low-skilled farm labour and high initial cost of residue management machine further exacerbates the problem of on-farm burning of crop residues [9].

Possible alternatives to burning of crop residues with a chemical adjuvant, reducing the residue particle size by shredding and then incorporating the residue into the soil. Shredding of the trash would reduce the particle size, increasing surface area from which microbes could degrade the residue quickly. Results of shredding crop residue have generally hastened the degradation rate as indicated by increased carbon and nitrogen mineralization, altered the peak respiration time, or did not affect respiration. Soil incorporation with residues would also increase the residue surface that would come in contact with soil microbes and thus hasten decomposition [1].

Management of crop residues in conservation agriculture is vital for long-term sustainability of Indian agriculture. Burning of residues must be stopped and should be used positively for conservation agriculture (CA) for improving soil health and reducing environment pollution. Even in regions where crop residues are used for animal feed and other useful purposes, some amount of residues must be recycled to soil. Conservation agriculture benefits farmer because it reduces production costs and increases yield. Development of appropriate farm machinery is to facilitate the application of residues, and successful planting of a crop in the rotation under a layer of residues on soil surface [2].Incorporation of paddy (*Oryza sativa* L.) straw, compared with burning, affects soil nitrogen supply by increasing nitrogen and carbon inputs. Data indicated the decrement in fertilizer nitrogen utilization efficiency (FNUE) with a concomitant and more significant increase in the plant available nitrogen [11]. Incorporation of high and medium amounts of wheat straw had significant effects on increasing the soil N, P and K and the incorporation of crop residues significantly increased the grain production per unit area. Straw incorporation was the most effective practice for improving the soil properties and fertility, which can be recommended for crop residue management system to enhance both agricultural productivity and sustainability [12].

There is urgent need of new technologies which gives proper utility to soil by the paddy residue and popularizing this type of innovations because paddy straw has immense economic potential for the farmers popularizing the new innovations and new alternative techniques for paddy straw management [8]. The machinery available for crop residue management in are happy seeder, rotavator, zero seed drill, straw baler, paddy straw chopper and super straw management system on combine. The straw chopper cum incorporator can cut the stubbles and mix with other vegetable growth if any on the field. By keeping above views in mind the paddy residue management machine for combine harvested paddy field was developed and the cost economics was compared with existing paddy residue management technologies.

2. MATERIALS AND METHODS

2.1 Description about Straw Chopper cum Incorporator

Basically the straw chopper cum incorporator is the combination of straw chopper and rotavator with the adjustable frame. The developed frame has the superiority that is the horizontal and vertical clearance between straw chopper rotor shaft and rotavator shaft can be adjusted on either side. The purpose of this adjustment was made because the horizontal and vertical clearances that may affect the performance of our developed machine [5]. The straw chopper has inverted gamma type blades and rotavator with L- type blades will incorporate processed paddy residues. The straw chopper cum incorporator performs the job of straw chopping and incorporation in a single pass. Therefore, due to incorporation of paddy residue in soil would increases the decomposition rate of paddy residue and thus improves the soil health. Isometric view from rear side of straw chopper cum incorporator is shown in Figs. 1 and 2. Detail specification of the Straw chopper cum incorporator is presented in the Table 1.

2.2 Paddy Residue Management Practices

The main emphasis of economics comparison of that Straw chopper cum incorporator machine with existing technologies used by farmers is that to know whether this Straw chopper cum incorporator machine is economically viable or not. So the cost economics of this Straw chopper cum incorporator machine were compared with two available existing technologies for residue management. Those technologies were combination of straw chopper and rotavator. The second one is conventional residue management operations used by farmers prior to sowing of wheat i.e 6 harrowing + 2 planking. The specifications of the machinery used for cost economic comparison were shown in Tables 2, 3 and 4. These machineries were operated by using tractor of 33 kW. The cost economics comparison of straw chopper cum incorporator and existing technology were carried out by calculating the cost of operation of straw chopper cum incorporator with existing practices. The Fig. 3 Ilustrates residue management practices during field evaluation. The cost of operation was determined by standard procedure.

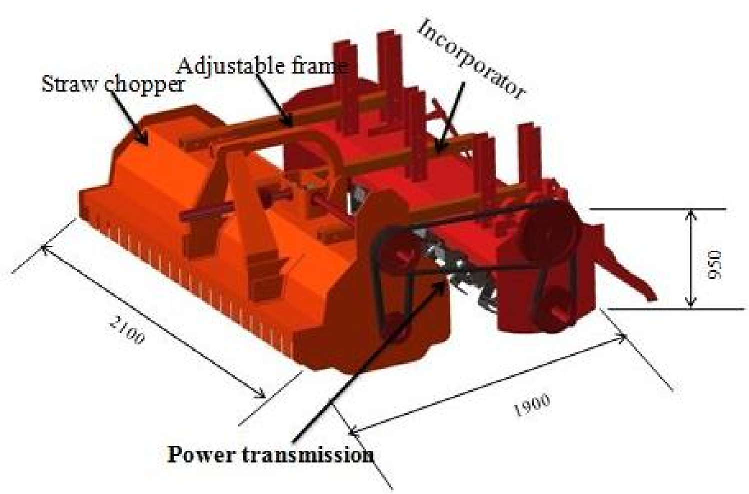

Fig. 1. Side view of the straw chopper cum incorporator
(All dimensions are in millimetre only)

Table 1. Specification of the straw chopper cum incorporator

S. no.	Particulars	Dimensions
1	Length X Width X Height	1900 X 2100 X 950 mm
2	Weight of the machine (W)	900 kg
3	Power requirement	56 kW
4	Number of working elements in chopper	22
5	Type of flails in chopper	Inverted gamma type
6	Speed of Flail shaft in chopper	900-1500 rpm
7	Shape of working elements in rotavator	L shape
8	Speed of rotavator shaft	180-210 rpm
9	Number of working elements in rotavator	48
10	Mode of Power Transmission	Belt, pulley and spur gears

Fig. 2. Isometric view of the straw chopper cum incorporator from rear side

Fig. 3. Field evaluation of existing paddy residue management technologies considered under this study

Table 2. Specifications of the straw chopper

S. no	Particulars	Specifications
1	Type of machine	PTO driven, mounted type
2	Power source, kW	Tractor of 34
3	Overall dimensions	
4	Length X Width XHeight, mm	900 X 1900 X 930
5	Number of flails	22
6	Flail spacing, cm	20
7	Shape of flail	Inverted gamma type
8	Transmission	
9	Diameter of drive pulley, mm	198
10	Type of pulley	B category, V-belt
11	Number of pulley	2
12	Type of make	MASCHIO
13	Price of machine, Rs.	161000

Table 3. Specifications of the rotavator

S. no.	Particulars	Specifications
1	Type of machine	PTO driven, mounted type
2	Power source, kW	Tractor of 34
3	Overall dimensions	
4	Length X Width XHeight, mm	2360 X 900 X 930
5	Number of flanges	8
6	Blades per one flange	6
7	Number of working components	48
8	Shape of blades	L- type
9	Transmission	
10	Type of power transmission	Gear drive
11	Number of gears	3
12	Type of make	DASMESH Rototiller
13	Price of machine, Rs.	80000

Table 4. Specifications of disc harrow

S.No.	Particulars	Specifications
1	Type of machine	Offset disc harrow, Trailed
2	Power source, Kw	Tractor of34
3	Overall dimensions	
4	Length X Width XHeight, mm	1700 X 1900 X 700
5	Number of gangs	2
6	Number of discs per gang	8
7	Number of working components	16
8	Diameter of disc, mm	600
9	Type of make	Jai Gurudev Industries, Rudrapur
10	Price of machine, Rs.	50000

2.3 Estimation of Cost of Operation

The cost of operation of Straw chopper cum incorporator machine was determined by straight line method by considering fixed and variable cost [6]. The sum of fixed and variable cost is operational cost.

$$\text{Cost of operation} = \frac{F.C+V.C}{H} \quad (1)$$

Where,

F.C = Total fixed cost
V.C = Total variable cost
H = Working hours

2.3.1 Fixed cost

2.3.1.1 Depreciation

Depreciation is the reduction in the value of a machine with time and use. It is the ratio of the total cost of the machine minus salvage cost by assuming life of 10 years multiply with the 250 annual working hours of designed prototype [6]. It is calculated under fixed cost.

$$D = \frac{C-S}{L*H} \quad (2)$$

where,

D = Depreciation, Rs.h^{-1}
C = Initial cost of machine, Rs.
S = Salvage value (10% of C in Rs.)
L = Expected life of machine (10 years)
H = Annual working hours (Assumed 200 h)

2.3.2 Interest cost

Interest cost is included in the fixed cost. It was calculated from capital investment taking 12% as interest. The interest cost is determined by following relationship:

$$\text{Interest cost (I)} = \frac{C+S}{2} \times \frac{i}{H} \quad (3)$$

I = Interest cost, Rs. h^{-1}
I = Rate of interest,%

2.3.3 Variable cost

2.3.3.1 Repair and maintenance

Repair and maintenance cost are difficult to determine as they greatly depending upon

Table 5. Cost of operation of a straw chopper cum incorporator machine

S. no.	Parameter	Tractor super 75	Straw chopper cum incorporator machine
Fixed cost (Rs/h)			
1	Initial cost (Rs.)	950000	250000
2	Solvage value (Rs.)	95000	25000
3	Expected life (yr)	10	10
4	Annual working hours (h)	1000	200
5	Depreciation (Rs.)	85.5	112.5
6	Interest (Rs.)	62.7	16.5
7	Repair and maintenance (Rs.)	9.5	1.25
8	Housing and insurance (Rs.)	0.95	0.25
9	Total	158.65	130.50
Variable cost (Rs./h)			
10	Fuel cost@68Rs.		850
11	Lubricant cost @20% of fuel cost		170
12	Labour cost @50Rs./h		400
13	Total	0	1420
14	Total cost of operation (Fixed+Variable) (Rs./h)	158.65	1550.5
15	Effective field capacity (ha/h)		0.4
16	Total cost of operation (Tractor+ Straw chopper cum incorporator machine) (Rs./ha)	4272.88	

Table 6. Cost of operation of a straw tractor + chopper + rotavator

S. no.	Parameter	Tractor 5310	Straw chopper	Rotavator
Fixed cost (Rs./h)				
1	Initial cost (Rs.)	800000	161000	80000
2	Solvage value (Rs.)	80000	16100	8000
3	Expected life (yr)	10	10	10
4	Annual working hours (h)	1000	200	200
5	Depreciation (Rs.)	72	72.45	36
6	Interest (Rs.)	52.8	10.63	5.28
7	Repair and maintenance (Rs.)	8	0.805	0.4
8	Housing and insurance (Rs.)	0.8	0.16	0.08
9	Total	133.6	84.04	41.76

S. no.	Parameter	Tractor 5310	Straw chopper	Rotavator
Variable cost (Rs./h)				
10	Fuel cost@68Rs.		272	558.28
11	Lubricant cost @20% of fuel cost		54.4	111.66
12	Labour cost @50Rs./h		400	400
13	Total	0	726.4	1069.936
14	Total cost of operation (Fixed+Variable) (Rs./h)	133.6	810.44	1111.70
15	Effective field capacity (ha./h)		0.49	0.71
16	Total cost of operation (Rs./ha)		1926.62	1753.94
17	Total cost of operation(2XRotavator + Chopper) (Rs./ha)	5434.49		

Table 7. Cost of operation of a tractor + 6XHarrowing + rotavator + planker

S. no.	Parameter	Tractor 5310	6 Harrowing	Rotavator	Planker
Fixed cost (Rs./h)					
1	Initial cost (Rs.)	800000	50000	80000	25000
2	Solvage value (Rs.)	80000	5000	8000	2500
3	Expected life (yr)	10	10	10	10
4	Annual working hours (h)	1000	200	200	200
5	Depreciation (Rs.)	72	22.5	36	11.25
6	Interest (Rs.)	52.8	3.3	5.28	1.65
7	Repair and maintenance (Rs.)	8	0.25	0.4	0.125
8	Housing and insurance (Rs.)	0.8	0.05	0.08	0.03
9	Total	133.6	26.10	41.76	13.05
Variable cost (Rs./h)					
10	Fuel cost@68Rs.		60.18	452.88	238
11	Lubricant cost @20% of fuel cost		12.04	90.58	47.60
12	Labour cost @50Rs./h		400	400	400
13	Total	0	472.216	943.456	685.6
14	Total cost of operation (Fixed+Variable) (Rs./h)	133.6	498.32	985.22	698.65
15	Effective field capacity (ha./h)		0.81	0.71	0.828
16	Total cost of operation (Rs./ha)		6X780.143=4680.86	1575.80	1005.13
17	Total(harrow+rotavator+Planker) (Rs./ha)	7261.79			

Table 8. Break even point, pay back period and B:C ratio

S. no.	Variables	Price
1	Total Fixed Cost(Rs./h)	130.5
2	Actual field capacity(ha/h)	0.4
3	Fixed cost (Rs.ha^{-1})	326.25
4	Variable Cost(Rs.ha^{-1})	3550
5	Assumed shredding Fees (Rs. ha^{-1})	5000
6	Working Hours (h)	200
7	Break-even Point(ha)	45 $\frac{130.5}{((5000-3550)/200)}$
8	Amount of investment(Rs.)	250000
9	Expected annual net revenue(Rs.)	355000 (3550x100)
10	Pay Back Period(yrs)	0.7 (250000/355000)
11	Gross returns (Rs.ha^{-1})	5000 (Assumed)
12	Cost of operation (Rs.ha^{-1})	4272.88
13	B:C ratio	1.17

operating conditions, location of service store, maintenance programs, local cost, etc. repair cost per hour of use will increases with age but tend to level off as the machine become older. Repair and maintenance cost was considered 10% for tractor and 5% for Straw chopper cum incorporator machine.

2.3.3.2 Labour cost

Labour cost is an important consideration in comparing ownership to custom hiring. The major cost involved in chopping cum incorporating was calculated from man-hrs. By considering daily wages that was about 400Rs day^{-1} and taking into account that two labours were required to operate the machine.

2.3.3.3 Fuel cost

Fuel costs can be estimated by considering data of average fuel consumption during operation in l/h. Fuel cost was calculated by considering diesel rates at the rate of 68Rs. per litre.

2.3.3.4 Lubricating cost

As literature suggest that total lubrication costs on field operation average about 15-35% of fuel costs. Therefore, it was considered as 30% of fuel cost.

2.3.3.5 Housing and insurance cost

Housing and insurance were calculated by considering 1% each of initial cost of tractor/ machine.

2.4 Break-Even Point (B.E.P)

The break-even point is equal to the annual fixed cost divided by difference between the custom rate per hour and the operating cost per hour. The break-even point was calculated by using following equation.

$$BEP=\frac{FC}{CF-C} \quad (4)$$

where,

BEP = Break even point, ha
FC = Annual fixed cost, Rs.year^{-1}
CF = Custom hiring fee, Rs.ha^{-1}
C = Operating cost, Rs.ha^{-1}

2.5 Payback Period

It is the number of year it would take for an investment to return its original cost through the annual cash revenues it generates, if the net cash revenues are constant each year. The payback period is calculated following equation.

$$P=\frac{I}{E} \quad (5)$$

where,

P = Pay back period, years
I = Amount of investment, Rs.
E = Expected annual net revenue, Rs.

2.6 Benefit Cost Ratio

It is the ratio of annual benefit to annual cost. The B.C ratio must be unity or more for a project investment to be considered worthwhile. This technique also ranks the project investments for selection. The ratio of unity indicates the coverage of costs without any surplus benefits. But usually the ratio has to be more than unity in order to provide some additional return over the costs for clear decision.

$$\text{B:C Ratio} = \frac{Grossreturns, Rsha^{-1}}{Costofoperation, Rsha^{-1}} \quad (6)$$

3. RESULTS AND DISCUSSION

The comparison of Straw chopper cum incorporator machine was carried out with conventional residue management machinery i.e. 6 X harrowing+ 1X rotavtor+1 X planking and 1 X straw chopper + 2 X rotavator. he cost economics parameters of straw chopper cum incorporator includes cost of operation, break even point, pay back period and benefit cost ratio. The results obtained are presented in Table 8. The cost of operation of Straw chopper cum incorporator machine was calculated Rs. 4272.88 ha^{-1}andpayback period was obtained0.7 years if the machine would operate for 100 working hours per annum. Benefit cost ratio will be 1.17 with break even point of45ha. Cost effective with comparison to existing residue management machinery systems. The cost of operation of conventional operation was found Rs.7261.79 ha^{-1}. The cost of straw mulcher and rotavator recorded Rs.5434.49 ha^{-1}. The reason for cost of operation of Straw chopper cum incorporator machine was comparatively lower than existing technologies because Straw chopper cum incorporator machine require only single pass to complete the operation and operating cost of Straw chopper cum incorporator machine was comparatively lower than the operating cost of considered existing residue management technologies.

4. CONCLUSIONS

It was concluded that the Straw chopper cum incorporator machine was cost effective and can be recommended for the commercial use of the farmer for the effective paddy residue management and thus the soil health and environmental condition can be improvised. The Straw chopper cum incorporator machine reduces the size of paddy residue uniformly and mixes with the soil for biological activity of the soil by incorporation in single pass.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Blanco-Canqui H, Lal R. Crop residue removal impacts on soil productivity and environmental quality. Crit Rev Plant Sci. 2009;28:139–163.
2. Ramulu Ch, Pateriya RN, Deepshika A. Machinery for residue management of different crops: A review.Journal of Pharmacognosy and Phytochemistry. 2018;7(6):2203-2207.
3. Garg IK. Design and development of rice straw Chopper-cum-Spreader. Journal of Research. 2004;41(1):130-138.
4. Hiloidhari M, Das D, Baruah DC. Bioenergy potential from crop residue biomass in India. Renew. Sustain. Energy. Rev. 2014;32:504–512.
5. Honglei J, Lichun W, Chunsheng L, Hongjie T, Chenglin M. Combined stalk–stubble breaking and mulching machine. Soil & Tillage Research. 2010;107:42-48.
6. Indian standard: Guidelines for estimating cost of farm machinery operation, IS: 9164-1979.
7. Kanokkanjana K, Garivait S. Alternative rice straw management practices to reduce field Open burning in Thailand. International Journal of Environmental Science and Development. 2013; 4(2):119-123.
8. Roy P, Kaur M. Status and problems of paddy straw management in West Bengal. Int'l Journal of Advances in Agricultural & Environmental Engg. 2015;2(1):44-48.
9. Sidhu HS, Singh M, Singh Y, Blackwell J, Singh V, Gupta N. Machinery Development for Crop Residue Management under Direct drilling; 2015.
10. Singh. Tillage and residue management practices in rice– wheat system in Indo-Gangetic Plains – a diagnostic survey. Technical Report, National Agricultural Technology Project. Indian Council of Agricultural Research, New Delhi and Punjab Agricultural University, Ludhiana, India; 2002.
11. Verma A, Singh A, Sidhu GS, Dixit A. Performance evaluation of tractor operated

paddy straw Mulcher. J KrishiVigyan. 2016:4(2):70-75.
12. Wei T, Zhang P, Wang K, Ding R, Yang B, Nie J. Effects of wheat straw incorporation on the availability of soil nutrients and enzyme activities in Semiarid Areas. PLoS ONE. 2015;10(4):1-15.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/57380