Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 21(1) January-April 2023]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 21(1) January-April 2023

CONTENTS

Assessing the feasibility and economics of tractor-drawn round straw balers for paddy and wheat crop harvesting

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ABSTRACT: Straw is undesirable plant part that is left in the field after harvesting. At present, the cost of straw gathering is increasing because of increased use of combine harvesters. High wages and scarcity of labour makes manual collection unfeasible. Farmers therefore often just burn it, which causes pollution, increased emission of green house gases and loss of opportunities to value addition.In terms of greenhouse gases.An economic, environmental evaluation and field testing of straw baler with different crops with capacity of 4.8 and 4.16 ha per day for paddy and wheat crop respectively. During field testing data on field capacity, field efficiency, straw recovery, fuel consumption, cost of operation and energy consumption were collected as 0.6 ha h^{-1}, 91%, 92%, 3.5l h^{-1}, ₹1672 per ha and 343.96 $MJha^{-1}$ for paddy and 0.52 hah^{-1}, 89%, 90%, 4 l h^{-1}, ₹2012 per ha and 458.63 MJ ha^{-1} for wheat respectively;whereas, the cost for manual gathering was ₹ 2332 and ₹2806 per ha for paddy and wheat straw respectively. The benefits of the machine are not only economical but also exclude the hazardous effects of burning of crop residues from environment.

Key words: Baling, carbon emission, environment, round straw baler

Paddy-wheat crop rotation is adopted in Northern and Central India. These are the two staple crops grown in the state and are an integral part of the crop rotation system. The crop rotation system is a traditional practice in which different crops are cultivated in a sequence to optimize soil fertility and productivity. In Madhya Pradesh, paddy and wheat are cultivated in rotation to enhance soil health, reduce disease and pest incidence, and increase overall crop yield.

According to recent data from the Directorate of Economics and Statistics, Government of Madhya Pradesh, the state has witnessed a significant increase in paddy and wheat production over the past few years. In the agricultural year 2019, Madhya Pradesh produced a record 24.20 million tonnes of paddy, marking a growth rate of 13.30% over the previous year. Similarly, the wheat production also witnessed a surge of 12.25% with a total of 20.16 million tonnes produced during the same period. The increase in production can be attributed to several factors such as government policies, advanced technologies, better irrigation facilities, and the crop rotation system.

Farmers often struggle to manage the large quantities of crop residues generated during harvesting within a short time frame to prepare for the next crop, such as wheat. In the state of Punjab, for instance, approximately 85-90% of the paddy straw is burnt in the fields by farmers, as reported by Mukerjee (2016). This is primarily due to factors such as the short sowing window for wheat crop, lower usability of straw as fodder, high costs of labor-intensive and time-consuming soil incorporation process, lower market demand, limited access to advanced technologies by marginal farmers, and cheaper rates of stubble supply by biomass power generation units, as pointed out by Kaur (2020).

In India, paddy and wheat are two of the most important crops and their crop residues are significant sources of biomass. The crop residues can be used for various purposes such as animal fodder, fuel and raw material for paper and board industry. However, the most common practice in India is to burn the crop residues, which leads to several negative impacts such as air pollution, greenhouse gas emissions, soil degradation, and loss of soil organic matter.

Crop residue is the non-edible plant parts that are left in the field after harvesting. India produces about 686 Mt crop residues annually out of which cereals contribute 368 Mt residues. About 234 Mt (34% of gross) of crop residues are estimated as surplus that is available in India for variable management options (Hiloidhari *et al.*, 2014).

Burning of crop residues results in emission of gases such as CH_4, CO, N_2O and NO; particulate matters, loss of plant nutrients and adversely affect the atmosphere, the environment and the soil health. The entire amount of C, approximately 80 to 90% of N, 25% of P, 20% of K and 50% of S present in the crop residues are lost in the form of various gaseous and particulate matters resulting in atmospheric pollution. It is also estimated that about 70% CO_2, 7% CO, 0.66% CH_4 and 2.1% N emitted as N_2O from crop residue burning, which impacts on environment heavily. It is estimated that one tonne rice residue on burning releases 13 kg particulate matter, 60 kg CO, 1460 kg CO_2, 3.5 kg NO_X, 0.2 kg SO_2. Burning of 23 million tonnes of rice residues in North-West India leads to a loss of about 9.2 million tonnes of C equivalent (CO_2-equivalent of about 34 million tonnes) per year and a loss of about 1.4×10^5 ton of N (equivalent to ₹200 crores) annually (ICAR, 2021).

Farmers in northwest India dispose of a large part of rice straw by burning in situ. There is a large variability in crop residues generation and their use depending on the cropping intensity, productivity and crops grown in different states of India. Residue generation is highest in Uttar Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). Madhya Pradesh contributes about 33.18 Mt (NPMCR, 2014). Burning rice straw may increase the soil surface layer temperature, causing a sharp drop in winter crop seedling emergence. The frequent straw burning may cause subsoil hard pan, which makes the drainage difficult, restricts seedlings emergence.

If crop residue is not incorporated in the soil then baling may provide an attractive, economical and environmentally safe option. According to Sharma *et al.* (2020), the average cost of crop residue burning to a farmer is ₹7370 ha^{-1}. The mechanized urea spraying system developed on baler was usedin a combine harvested field for spraying of urea solution on straw during baling operation. The system potentiallyimprove the nutritional quality of straws to cattle feed (Kumar *et al.*, 2021 & 2022).There are wide usages of the straw as fodder for dairy farming, soil mulching, bio manure making, paper industries for cardboard and hard-board manufacturing, biomass generation, thatching for rural homes, craft arts, fuel for domestic and industrial uses by making briquettes for burning in boiler, etc.Therefore, agricultural practices need to manage the crop residual on the harvested field without hazard to the soil, environment, soil fertility, and other factors.

Round straw balers offer several advantages for residue management, especially in comparison to manual collection or burning of crop residues. One of the main advantages of using a round straw baler is that it allows for efficient and cost-effective collection of large volumes of crop residues. This reduces the need for manual labor, which can be expensive and time-consuming. Additionally, the use of round straw balers can also reduce the amount of greenhouse gas emissions that result from burning crop residues, which helps to mitigate the negative impacts of climate change. Furthermore, the bales produced by the round straw balers can be used for various purposes such as animal fodder, composting, and energy production, which makes them a valuable resource for farmers. Overall, the use of round straw balers is an effective and sustainable approach to crop residue management, which can help to improve soil health, reduce environmental pollution, and increase the productivity and profitability of agricultural systems. This study was conducted with objectives to evaluate feasibility of straw baler application; to study of cost economics of baler;to evaluate the impacts of baler application on environment and society.

MATERIALS AND METHODS

The study was conducted with data gathering from secondary data sources and field tests for locally made and imported rice straw balers. Survey on status ofcrop residue gathering: manualand mechanical (baler), labor cost, straw price, use of ricestraw, type of using straw baler and local demand onstraw use.The experiments were conducted in JNKVV research farm, Jabalpur (Madhya Pradesh).

The university is located at 230^{0}13'15.32" N and 790^0 57'50.80" E and 390 m. above mean sea level. Soil type was clay loam which has sand 29.10%, silt 20.15% and clay 50.75%.Depending on actual condition at each site, testing area is 900 m^2 for one replication. Four replications were made during field test for each crop. For design of field layout 2×3 factorial randomized block design (RBD) was used. The control treatments were taken as gathering straw manually.

Apparatus used

Hot air oven used for drying straw and paddy samples The oven was in the range of 0-250 ^{0}C. The bulk density of straw was determined by standard oven method by putting a known weight of respective sample into an empty graduated jar (1000ml) and the volume occupied by the sample was noted (Mohsenin, 1980); graduated jar (500ml) and desiccators; digital weighing machine used to weight the sample of straw before and after drying; measuring fibre glass tape for measuring of area; scaling straw bale and fuel; steel measuring tape used for measuring cutting height of stubble and field test area (Verma *et al.*, 2019).

Straw baler specification

Tractor operated round balers are used for whole straw and no pre processing is needed. The round baler has four major units, first unit is for picking the windrow straw from the field and then moved through conveying unit (screw type) to compaction unit where the straw is compacted within aluminium ribbed rollers having standard PTO speed of 540 rpm equip in bale chamber to provide round shape of bale. Then, a knotter unit is provided to windup the bales tightly. The weight of bale varied depending upon the moisture content of straw. Table 1 depicted the specification of round straw baler.

Parameters monitored during the tests were crop taken for testing, harvesting method, average standing stubble height (mm),average moisture content (%),average loose straw length (mm),working width of baler (mm),average size of bale (height×diameter),average weight of bale (kg),field capacity (ha h^{-1}),time required (h/ha),field efficiency (%),fuel consumption(l h^{-1}),number of bale per h,average speed of operation(Km/h),density of bale(Kg/m³), straw recovery(%),cost of operation (₹/h), energy requirement (MJ ha^{-1}) were taken.Actual working capacity of baler was determined based on measured actual field area per unit time. In addition, actual speed of the machine working on the field was also determined. It is also basis for comparison of actual working and computed working capacity in the field. Fuel consumption was determined by measuring the level of fuel in a tank before and after operation.Straw yield was determined based on the corresponding straw recovery on the field and number and weight of each straw bale.

Energy consumption

The energy consumed in the form of direct energy, indirect energy, commercial energy and non-commercial energy was estimated taking into account all the inputs like machines, human labour, diesel, etc. (Verma, 2019).

Energy consumption (MJ ha^{-1}) = Fuel consumption (l h^{-1}) × Specific energy of fuel (MJ l^{-1}) × Working width (m) × Field capacity (ha h^{-1}) × 1 / Field efficiency (%)

RESULTS AND DISCUSSION

Straw yield

Straw yield is a measurement of the amount of straw produced per unit of land during a crop harvest. Straw yield can be affected by various factors such as the crop variety, soil type, climate, management practices, and the use of agricultural machinery. Typically, straw yield is reported in units of weight per area, such as kilograms per hectare or pounds per acre. Accurate measurement of straw yield is essential for crop management decisions and for

Table 1: Specification of round straw baler

S. No.	Specifications	Description
1	Make (Model)	Shaktiman(SRB-60)
2	Overall dimension (L x W x H), mm	2350 x 1780 x 1515
3	Weight of machine, kg	700
4	Ground clearance, mm	337
5	Tractor horse power& PTO speed (rpm) required	25 & 540
6	Bale chamber type	Chain driven pressure roller rotating on sealed bearing at ends
7	Working capacity, bale per h	50*
8	Pickup type	Fully floating, cylindrical drum with spring tines
9	Binding activation	Manual
10	Hitching system	Drawbar hitch
11	Effective picking and conveying width, mm	600

* Working capacity subject to change depending on the type & moisture content of material

(Source: www.shaktimanagro.com)

Table 2: Comparative performance parameters of straw baler after harvest of Paddy & Wheat crop

S. No.	Parameter	Value	
1	Crop	Paddy	Wheat
2	Harvesting method	Combine harvested	Combine harvested
3	Average standing stubble height, mm	250-300	220-260
4	Average moisture content, %	29-31	14-20
5	Average loose straw length, mm	460-500	480-550
6	Working width of baler, mm	1300	1300
7	Average speed of operation, ms^{-1}	0.83	0.83
8	Average size of bale (Height x Diameter), mm	(600 x 630)	(600 x 630)
9	Average weight of bale, Kg	22-26	11-14
10	Straw load ($tonneha^{-1}$)	1.6-1.8	0.8-1
11	Field capacity, hah^{-1}	0.60	0.52
12	Time required, hha^{-1}	1.63	1.92
13	Field efficiency, %	91	89
14	Fuel consumption, $l\ h^{-1}$	3.5	4.0
15	No of bale per h (ha)	37-38 (62-63)	30-34 (58-65)
16	Density of bale, kgm^{-3}	132	111
17	Straw recovery, %	92	90
18	Cost of operation, ₹h^{-1}	1025.69	1047.67
19	Energy requirement, $MJha^{-1}$	343.96	458.63

assessing the economic viability of residue management practices. Straw yield can be influenced by the type of crop, with some crops producing more straw than others. For example, wheat and rice crops are known to produce significant amounts of straw. By improving straw yield, farmers can not only maximize their crop productivity but also increase the availability of valuable residue for various applications, such as feed, fuel, and building materials. In this study straw yield depends on variety of crops, crop yield and cutting height of stubble. Straw yield was found to be 1.6 to 1.8 and 0.8-1.0 tonne per hectare having moisture content at range of 29-31% wb and 14-20% wb for paddy and wheat respectively.

Mechanical gathering of straw

Round type of straw baler make of Shaktiman Argo (Model SRB-60) (Figure 1) used during the test. Specification of machine can be depicted from Table 1. Performance evaluation of baler was tested at the field to determine the machine parameters shown in Table 2. Round straw balers used in testing had a capacity of 4.8 and 4.16 ha per day of 8 hours for paddy and wheat crop respectively, including gathering time and twine threading time. Fuel

Fig. 1: Operation of round straw baler in the field

Fig. 2: Manual gathering of straw

consumption for straw baling was 5.70 and 7.68 lha^{-1} for paddy and wheat respectively. Total cost of operating a baler was approximately with the cost of fuel and straw yield, the total cost for straw collection was ₹1025.69 per h and ₹1047.67 per h for paddy and wheat respectively which includesfuel cost, labour (tractor driver) cost, jute twine cost, etc. The cost of jute twine for baling is about ₹570 per ha and ₹480 per ha taking approximately 7 m per bale.Jute twine used for baler were available in local market or from the dealers.

Manual straw gathering

Manual gathering of straw is a traditional method of residue management that involves the physical collection of straw from the field after harvesting. This method has been used for centuries, but it is becoming less popular due to the high cost of labor and the increasing use of combine harvesters. Manual gathering of straw is a time-consuming and labor-intensive process, and it can be difficult to find enough workers to complete the task, especially in areas where labor is scarce.

After the harvest, the farmers gathered all the straw from the field and piled it up in the center, as depicted in Figure 2. According to the analysis, the cost of manually collecting straw from paddy and wheat crops was found to be ₹2331.70/ha and ₹2806/ha, respectively. These costs did not include the expenses incurred for transporting the straw using a tractor with trolley. The manual gathering of straw required 24 man-hours per hectare, and the cost of labor has been increasing due to the shortage of labor during the harvest season. The labour costs typically vary between ₹250-400 per working day, depending on the cropping season.

Energy consumption

The total energy consumption comprised of the fuel used for producing and maintaining machines, manual labor utilized for driving tractors and balers and handling the straw. The energy consumption networks of the collection machines varied from 351 to 588 MJ t^{-1}, with the primary contributions coming from direct and indirect energy obtained through the use of diesel. Findings are in line with the research conducted with Van *et al.*, 2016 in Vietnam.

CONCLUSION

The durable round straw baler demonstrated its effectiveness in handling straw for various purposes with varing level of moisture content (14-30% on wb). By employing the mechanical straw gathering method, the saving in cost and labour requirement achieved were 56% and 93% for paddy and 62% and 92% for wheat, respectively, when compared to manual gathering. The research findings revealed that the energy requirements for baling and the straw recovery rates were 343.96 MJ $ha^{-1}$and 92% for paddy and 458.63 MJ $ha^{-1}$and 90% for wheat, respectively. By adopting the appropriate business models, farmers could earn additional income by selling straw directly from the field. Baling crop residues instead of burning them has numerous positive effects on the environment and soil health. Firstly, it helps to reduce air pollution and greenhouse gas emissions, which can have a significant impact on local and global climate change. Secondly, baled straw can be used as animal feed, compost or bedding, which can provide additional income for farmers and improve soil fertility. Thirdly, baling helps to reduce soil erosion, which is a significant problem in many regions of the world. Baling crop residues preserves the natural nutrients of the soil, which would otherwise be lost through burning. Overall, adopting baling techniques is a sustainable and beneficial solution for managing crop residues.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, JNKVV, Jabalpur for their technical support and guidance during the research work. The facilities provided by the department were instruments in conducting the experiments and generating the results.

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Received: January 5, 2023
Accepted:April 21, 2023