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COMPARATIVE FIELD AND ECONOMIC EVALUATION OF BALER FOR BALING PADDY STRAW

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Abstract: A study was conducted to evaluate performance of paddy straw baler on loose paddy straw (system A), after stubble shaver operation (system B) and after stubble shaver along with rake operation (system C). The number of bales per ha and density of bales increased with increase in feed rate of paddy straw from 1.12 to 4.22 $t.h^{-1}$ and highest feed rate was observed when stubble shaver and rake were operated prior to baler (system C). The field capacities of system A, B and C were 0.35, 0.40 and 0.53 $ha.h^{-1}$ and the number of bales per ha varied from 126-149, 266-292, 298-332 respectively. The mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 $l.h^{-1}$ respectively. The mean percentage increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A were 1.06:1 and 0.85:1 respectively. The net savings per ha were Rs. 471.05 and 1537.59 with system B and C respectively.

Key words*: baler, density, feed rate, field capacity, paddy straw, rake, stubble shaver*

INTRODUCTION

Burning of paddy residue left in field leads to release of soot particles and smoke causing human health problems, emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide causing global warming, loss of plant nutrients such as N, P, K and S and useful micro organisms, adverse impacts on soil properties and wastage of valuable C and energy rich residues. If rice straw is not burnt or incorporated in the soil then baling may provide an attractive, economical and environmentally safe option. There are wide usages of the straw in paper mills for cardboard manufacturing, for packaging the materials, for mushroom cultivation, for burning in boilers, for animal feed in drought regions etc. So baling the straw and compacting it into small (120-135$kg.m^{-3}$), transportable size and shapes is also economical and safe for environment.

The baling facility in the field helps in saving the straw from weather calamities, makes handling and transportation easier, facilitates its easy and safe storage and maintains its quality. A baler is used to compress a cut and raked crop such as hay and straw into bales and bind them with twine. Rice occupied 2.808 million hectares with total production of 11.236 million tones during 2009-2010 in Punjab. The average grain yield of rice was 4.01 $t.ha^{-1}$ and average yield in terms of paddy was 6.033 t/ha [1]. The total yield of paddy straw in combine-harvested field is about 12.5 $t.ha^{-1}$ and the yield of standing stubbles and loose straw are about 7 $t.ha^{-1}$ and 5.5 $t.ha^{-1}$, respectively [4].

[3] mentioned that the two types of balers in popular use for baling straw and other fibrous materials are rectangular and round balers. They added that the bale density of the straw is affected by the type of material being baled, its moisture content at time of baling, and the resistance provided by convergence of the bale chamber. The bale density increased by increasing baler feeding rate and the moisture content of the materials being baled [2]. He also found that the optimum bale density was obtained by using the plunger-type field baler (36 x 46 cm bale chamber) at the feeding rates ranged from 4.2 to 6.0 $t.h^{-1}$ and the moisture content of rice straw bales ranged from 15 to 20%. [5] conducted the experiments on straw baler for its field performance and its economic evaluation in combine-harvested paddy field. The area of each experiment was 0.4 ha. The field capacity of the baler was 0.26 $ha.h^{-1}$ in combine-harvested paddy field and 0.36 $ha.h^{-1}$ in the field where stubble shaver was operated before baling. The size of bale varied from 80 x 45 x 45 cm to 90 x 45 x 45 cm, and accordingly the weight of bales varied from 18 to 28 kg. The number of bales formed was 205 in combine-harvested paddy field and 425 in stubble-shaved paddy field. Economics of the straw baler revealed that the cost of baling in stubble-shaved field was Rs. 2276.00/ha and the cost of transporting the bales was Rs. 4400.00/ha. The total cost of baling in stubble-shaved field including transportation of bales was Rs. 6676.00/ha. Very high transportation cost is the only reason due to which the machine is not gaining popularity. The total income from sale of straw was Rs. 5865/ha. [6] conducted economic investigation of field vegetable production introduced by using the production technology of tomato and they mentioned that costs of crop transport depend on the distance between the place of harvest and the processing company. Transport costs can be as high as production costs. The paddy straw burning issue can be resolved using baler machine and can earn profit to farmers also. Keeping the need in view, a technological approach was assessed to evaluate economic/comparative performance of baler for paddy straw in-situ condition and also after stubble shaver and rake machine operation in paddy straw field.

MATERIAL AND METHODS

The baling operation is a mechanical process, require three tractor-driven machines for cutting, lining, gathering and making bales. First stubble shaver is operated to harvest the stubbles from base level and then lining operation is perform by the rake machine after that gathering and bale formation is completed by the baler. The paddy straw moisture content varied from 15-25 % (wet basis) and straw load varied from 5.5-10.0 $t.ha^{-1}$ during field experiments. Tractor of 50 HP was used for present study. The stubble shaver, rake and baler machine used for baling purpose are described below:

Stubble Shaver Machine. The stubble shaver is used for cutting of standing paddy stubbles. It consists of two blades mounted on a vertical shaft and blades are covered with frame from four sides and top. The shaft is rotated by tractor PTO shaft through a gear box. It cuts standing paddy stubbles in the field (Fig. 1). It was operated in 2^{nd} low gear and between 1500-1700 engine rpm depending upon paddy straw load.

Figure 1. A view of stubble shaver machine

Figure 2. A view of rake machine

*Rotary Rake Machine.*The paddy stubbles cut by stubble shaver alongwith loose straw can be gathered in a narrow width using tractor operated rake. The rotary rake of 180 kg weight was used for the present study having raking width 2.6 m and spreading width 2.9 m (Fig. 2). The tractor requirement of rake machine is 35 HP. The function of rake is to collect the cut and loose paddy straw from field and makes a windrow of narrower section thereby provides dense straw input for baler machine. It was operated in 3rd low gear and between 1500-1700 engine rpm depending upon paddy straw load.

Table 1. Specifications of rectangular baler

S. No.	*Specifications*	*Dimensions*
1.	*Type*	*Rectangular*
2.	*Bale Size*	
	ss section b. Length	*x 46 cm b. 31 to 132 cm*
3.	*Flow-Action® Feeding System*	
	e	*Six feeder tines on a moving finger bar*
	ve	*Chain; sealed ball bearings*
4.	*Feed Opening*	*1826 cm²*
5.	*Plunger*	
	roke length b. Speed (540 rpm)	*2 cm b. 79 SPM*
6.	*Tying Mechanisms*	
	e b. Protection c. Capacity	*otter b. Shear bolt c. 04 Balls*
7.	*Dimensions*	
	ght (max.)b. Width c. Length	*a.146 cm b. 275 cm c. 610 cm*
8.	*Weight (approximate)*	*1399 kg*
9.	*Recommended Transport Speed*	*32 km/h*
10.	*Tractor Requirement**	*35 hp*
	**Tractor weight must be greater than baler weight;*	

Rectangular Baler Machine. The performance evaluation of rectangular baler was done in the present study. The baler specifications are given in Tab.1. In this baler there was provision for controlling degree of compaction and bale density. The metering device for varying the bale length is also given.

The main drive on the baler was hypoid geared in which crown wheel and pinions engage each other spirally. The advantage of this was that the contact area of the gear teeth was larger than with normal gear meshing and this contributes to durability and reliable power flow. In front of the transmission there was a large flywheel that absorbs the ram forces and ensures the smooth running characteristics of the baler. In present study baler was operated in 2nd low gear between 1500-1800 engine rpm depending upon paddy straw load.

Field Operations. The baler was operated in three field conditions of paddy straw. In first condition, the baler machine was directly operated in the combine harvested

paddy field without operation of any other machine. The baler machine was operated on paddy straw (standing + loose) after its sun drying for few days. In this condition, baler picks only loose paddy straw from the field. In the second condition, stubble shaver was operated in combine harvested paddy field for harvesting of standing stubbles. Thereafter the baler was operated in this field. In the third condition the stubble shaver was operated in combine harvested paddy field and then rake was operated in the same field. After the operation of stubble shaver and rake, baler was operated in the paddy straw field (Fig. 3). Under all of these three conditions parameters like number of bales, forward speed, operating width, field capacity, fuel consumption etc. were observed and recorded.

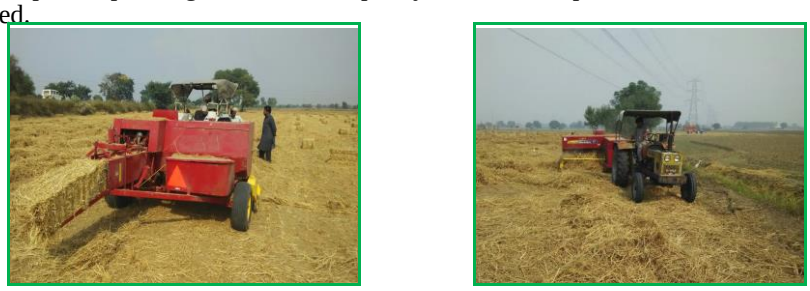

Figure 3. Views of baler machine in stubble shaver + rake operated field and only stubble shaver operated field.

RESULTS AND DISCUSSION

After operating baler for paddy straw in-situ condition and after stubble shaver and rake machine operation, field parameters for evaluating baler machine were recorded. The baler machine parameters like forward speed, feed rate, operating width, field capacity, number of bales per hectare, volume and weight of bale (for density calculation), fuel consumption were recorded and are shown in Table 3. The average length, width and height of bales varied between 87-92 cm, 46-52 cm and 30-36 cm and weight of bales varied between 18-30 kg during different field experiments. The field capacities of system A, B and C were 0.35, 0.40 and 0.53 $ha.h^{-1}$ respectively and the effect was significant at 5 % level of significance. The number of bales per ha varied from 126-149, 266-292, 298-332 respectively for system A, B and C respectively and the effect was significant at 5 % level of significance. Density of bales was highest for baler operation after stubble shaver and rake operation on paddy straw and the effect was significant at 5 % level of significance. The mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 $l.h^{-1}$ respectively under varying straw load conditions. The mean % increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. It is clear from Tab. 2 that the number of bales was more when baler was operated after the operation of stubble shaver and rake. The effect of feed rate on field capacity and fuel consumption of different systems and on number of bales and density of bales is shown in Fig. 4.

Table 2. Field evaluation of baler with three different systems

Particulars	*Baler (for loose paddy straw only) [A]*	*Stubble shaver + Baler [B]*	*Stubble shaver + Rake + Baler [C]*	*CD (5%)*
Mean forward speed, $km.h^{-1}$	*1.52*	*2.42*	*3.18*	-----

Mean feed rate of paddy straw, t.h^{-1}	*1.12*	*2.85*	*4.22*	*0.1281*
Mean Tractor Engine rpm	*1200*	*1200*	*1200*	-----
Mean operating width, m	*1.65*	*1.65*	*1.65*	-----
Field capacity of baler (mean), ha.h^{-1}	*0.33-0.37 (0.35)*	*0.39-0.42 (0.40)*	*0.52-0.55 (0.53)*	*0.03052*
Number of bales per ha (mean)	*126-149 (140)*	*266-292 (277)*	*298-332 (320)*	*30.4377*
Density of bale (mean), kg/m^3	*154.20-157.10 (155.77)*	*184.10-188.05 (185.72)*	*205.00-207.35 (205.97)*	*3.2504*
Fuel consumption (mean), l.h^{-1}	*4.50-5.50 (5.00)*	*9.00-11.75 (10.00)*	*10.75-13.25 (12.00)*	*2.3432*
Comparison between various systems	*Mean % increase in number of bales*	*Mean % increase in productivity of baler*	*Mean % increase in density of bales*	----
With system B in comparison to system A	*49.46 %*	*12.50 %*	*16.13 %*	-----
With system C in comparison to system A	*56.25 %*	*33.96 %*	*24.37 %*	----
With system C in comparison to system B	*13.44 %*	*24.53 %*	*9.83 %*	----

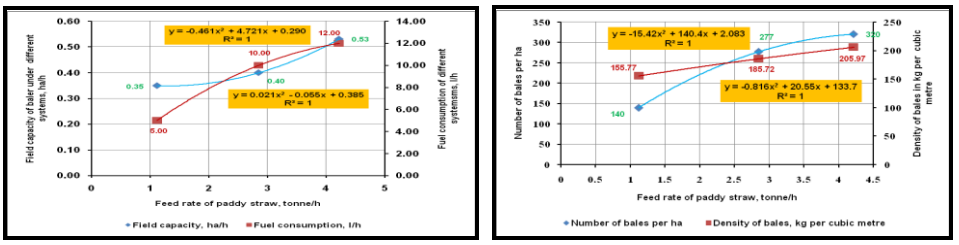

Figure 4. Effect of feed rate on field capacity of baler and fuel consumption of different systems and on number of bales and density of bales

The various regression equations between feed rate, field capacity of baler, fuel consumption, number and density of bales were obtained from these graphs and are as follows:

The equation for field capacity (ha.h^{-1}) of baler as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = 0.021x^2-0.055x+0.385 \quad (1)$$

The equation for fuel consumption of different systems (l.h^{-1}) as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -0.461x^2+4.721x+0.290 \quad (2)$$

The equation for number of bales per ha as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -15.42x^2+140.4x+2.083 \quad (3)$$

The equation for density of bales (kg.m^{-3}) as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -0.816x^2+20.55x+133.7 \quad (4)$$

It is clear from Fig. 4 that with increase in feed rate from 1.12-4.22 $t.h^{-1}$ numbers of bales increased from 140-320 and density of bales increased from 155.77-205.97 $kg.m^{-3}$ and effect of three different systems was found to be significant on feed rate.

Economic Evaluation of Baler Machine (with and without rake machine). There are different types of uses of baled paddy such as packaging purpose, power unit, compost etc. Few power units running on paddy straw are also established in Punjab, detail of which is given in Tab. 3. So there is a good scope for baler in future in context to all these uses. However for economics calculation of three systems i.e. with and without rake was calculated based on fixed costs, variable costs and average returns from sale of baled paddy straw and are shown in Tab. 4. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A was 1.06:1 and 0.85:1 respectively (Fig. 5). The system C was found to be most economical of three systems. The system A can be used by farmer alongwith happy seeder machine. As after collection of loose straw from combine harvested paddy field, happy seeder machine can be used for direct sowing of wheat in standing stubbles.

Table 3. Detail of Use of Paddy straw by different Power Generation Plants in Punjab

S. No.	*Thermal power plant which uses paddy straw*	*Capacity (Mega Watt (MW))*	*Rate of straw per tonne (rate cut by 10 % if moisture exceeds 10 %)*	*Paddy straw Area (ha) Covered in year 2013*	*Paddy straw quantity recovered (Tonne)*
1.	*M/s Malwa Power Ltd., village Gulabewala, Muktsar*	*6*	*1200*	*8800*	*55000*
2.	*M/s Punjab Biomass Power Pvt. Limited, Vill. Khokhar Khurd, Mansa,*	*10*	*1200*	*2,000*	*12,500*
3.	*M/s Punjab Biomass Power Pvt. Ltd. , Village Ghannaur, Patiala*	*12*	*1500*	*8000*	*50,000*

Table 4. Economic returns from baler with and without rake system

Particulars	*Tractor*	*Baler*	*Stubble shaver*	*Rake*
New Cost, P	*5,00000*	*5,00000 (After 50% subsidy)*	*40,000*	*1,00,000*
Salvage Value, S (10 % of P)	*50,000*	*50,000*	*4000*	*10000*
Life, L (Years)	*10 years*	*10 years*	*10 years*	*10 years*
Avg. Use/Year (h)	*1000*	*400*	*400*	*400*
Annual fixed charges				
Depreciation, Rs./yr = (P-S)/L	*45,000*	*45,000*	*3600*	*9000*
Rate of interest , i (%)	*12*	*12*	*12*	*12*
*Interest cost, Rs/yr = (P+S/2)*i*	*33,000*	*33,000*	*2640*	*6600*
Taxes, Insurance and shelter Rs./yr, 2% of P	*10,000*	*10,000*	*800*	*2000*
Total fixed cost, Rs/year	*88,000*	*88,000*	*7040*	*17,600*
Total fixed cost, Rs/h	*88*	*220*	*17.6*	*44*
Variable cost				
Repair & maintenance = 5% of P/Avg.	*25*	*62.5*	*5*	*12.5*

use /yr, Rs./h				
Mean Fuel consumption, l.h^{-1}	------	*5*	*4*	*3*
Fuel cost, Rs/h (Fuel cons. x rate@Rs.57per litre)	------	*260*	*208*	*156*
Cost of lubricants, (Rs./h) = 20 % of fuel cost		*52*	*42*	*32*
Labor cost, Rs//h	*20*	*30*	*20*	*20*
Total variable cost, Rs./h	------	*404.50*	*279.00*	*220.50*
Fixed +Variable, Rs./h	*133.00*	*624.50*	*296.60*	*264.50*
Total cost of using implement with tractor Rs./h	----	*757.50*	*429.60*	*397.50*
		System A	*System B*	*System C*
Cost of operation, Rs./h	----	*757.50*	*1187.10*	*1584.60*
Field capacity, ha.h^{-1}	----	*0.35*	*0.40*	*0.53*
Cost of opertation, Rs./ha (Fixed and variable)	----	*2164.28*	*2967.75*	*2989.81*
Mean number of bales/ha	----	*144.00*	*277.00*	*320.00*
Twine cost, Rs./ha (@Rs. 3.3 per bale)	----	*475.20*	*914.10*	*1056.00*
Transportation cost Rs./ha (@Rs.450/tonne for biomass plant in 30 km radius)	----	*1496.70*	*3116.25*	*4032.00*
Grand Total Cost of operation, Rs./ha	----	*4893.68*	*8185.20*	*9662.41*
Mean Straw recovered, t.ha^{-1}	----	*3.326*	*6.925*	*8.960*
Income from straw sale, Rs./ha (@Rs. 1250/tonne)	----	*4157.50*	*8656.25*	*11200*
Saving, Rs/ha (USD per ha)*		*-736.18 (USD --11.49)*	*+471.05 (USD 7.35)*	*+1537.59 (USD 23.99)*
B:C (Benefit:Cost) Ratio	----	*0.85:1*	*1.06:1*	*1.16:1*

**1 USD = 64.08 Indian rupee*

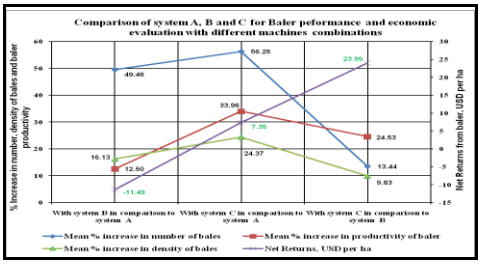

Figure 5. Effect of three different systems on performance of baler

CONCLUSIONS

The field capacities of system A, B and C were 0.35, 0.40 and 0.53 ha.h^{-1} and the number of bales per ha varied from 126-149, 266-292, 298-332 respectively for system A, B and C respectively and the mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 l.h^{-1} respectively. The mean percentage increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A were 1.06:1 and 0.85:1 respectively. The net savings per ha were Rs. 471.05 and 1537.59 with system B and C respectively. The number of bales per

ha and density of bales increased with increase in feed rate of paddy straw from 1.12 to 4.22 $t.h^{-1}$ The numbers of bales were more when baler was operated after stubble shaver and rake and the bales formed were denser as compared to bales formed without operating rake in field. The net returns from baler were more when operated after stubble shaver and rake as compared to other two systems.

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UPOREDNO POLJSKO I EKONOMSKO ISPITIVANJE BALERA ZA BALIRANJE SLAME PIRINČA

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Sažetak: Studija je izvedena radi ocene karakteristika balera slame pirinča. Broj i sabijenost bala se povećala sa povećanjem prinosa slame. Poljski kapacitet i broj bala varirali su u intervalima od 126-149, 266-292, 298-332, redom. Srednja potrošnja goriva za sisteme A, B i C bila je 5.0, 10.0 i 12.0 $l.h^{-1}$, redom. Maksimalan odnos troškova i prihoda bio je kod sistema C i iznosio 1.16:1.

Ključne reči*: baler, gustina, norma, poljski kapacitet, slama pirinča, grablje*

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