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# Performance evaluation and economics of the reaper-cum-binder machine for the mechanized harvesting of wheat crop at Madhubani district of Bihar

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**Abstract**
India ranks second in terms of wheat production after China, the main reason being lesser productivity, which was 3173 kg/ha for India and 4995 kg/ha for China. Delays in harvesting may associate considerable or even severe losses due to over maturity or any unforeseen natural adversity. Early harvesting could open up opportunities for extra revenues through farming of short duration vegetable crops in the gap between two major crops i.e. paddy and wheat. The reaper cum binder is not that popular for the farmers of Bihar. The study was conducted on this machine for assessment of the performance as well as the economics of the operation, particularly in Bihar where wheat cropping system is still dominant. The reaper-cum-binder saved 11.11% per hectare of yield to the farmers. So, this machine is preferred well for custom hiring. The field efficiency of the reaper-cum-binder for the wheat crop was obtained as 70.44%. In harvesting by reaper-cum-binder for the wheat crop, total grain losses were found to be 92.11 kg/ha. The economics of machine over conventional methods of harvesting was calculated and it was found that the benefit-cost ratio for reaper-cum-binder for the wheat crop was 2.08. The breakeven hectares and breakeven hours of reaper-cum-binder for the wheat crop were calculated as 19.75 hectares and 51.94 hours respectively. The custom hiring rate estimated for the wheat crop, was also found to be beneficial for the farmers.

**Keywords:** Reaper-cum-binder, wheat harvest, custom hiring, field efficiency, field capacity

## Introduction
Harvesting becomes very time and labour consuming unit operation in agriculture under the traditional method with a sickle. The timeliness cost of harvesting is greatly significant. Delays in harvesting may associate considerable or even severe losses due to over maturity or any unforeseen natural adversity. Early harvesting could open up opportunities for extra revenues through farming of short duration vegetable crops in the gap between two major crops. Wheat is the world's leading cereal crop, cultivated near about 216.6 million hectares with a production of 674.88 million tonnes of grain with 3115 kg/ha productivity (2012-13). India (29.90 million ha) ranks first in area coverage followed by China (24.13 million ha), while in production China stands first (120.50 million tonnes) and India ranks second (94.8 million tonnes) (Anonymous 2016) [1].

For the high yielding varieties of short duration in case of multiple cropping systems, lesser time was available between the harvesting of one crop and sowing of the next crop. Migration of agricultural labours towards urbanized industries resulted in late harvesting, which caused heavy grain losses (Iqbal, Premalatha and Zahra, 1985) [2]. Also high labour demand would increase the labour wages and manual harvesting would also take greater time as compared to mechanized harvesting. There is a need for mechanization in order to complete farm operations on time and also to enhance land productivity to make agriculture sustainable and dependable for the farmers' income.

In India the small land holding is very common and that is the main hindrance in the adoption and use of big & high capacity machines. Under these constraints, the role of small-sized machines is more significant due to the better economy of operation and field efficiency. The reaper cum binder is not that popular for the farmers of Bihar. The study was conducted on this machine for assessment of the performance as well as the economics of the operation, particularly in Bihar where wheat cropping system is still dominant with the following objectives:

1. To evaluate the economic operation of the "reaper-cum-binder" machine vis-a-vis traditional method of manual harvesting of wheat by using a sickle.

2. To calculate the rate of custom hiring of reaper-cum-binder machine for the wheat crop in Madhubani district.
3. To calculate the expected profit by the use of this machine for the wheat crop.

## Material and Methods

This chapter deals with the brief description of the experimental site, details about the materials and machines used and the methods adopted for economics evaluation of operation for the reaper-cum-binder machine for the wheat crop under actual field conditions. The field trials of the machine were conducted at Mithila Farm Machine Bank in Madhubani district during April month in 2012.

### Experimental site

The experimental site was situated at Mithila Farm Machine Bank in Madhubani district at 26.37º N latitude and 86.08º E longitude, with 56 m altitude above mean sea level (MSL). The experiment was carried out with Reaper-cum-binder machine and harvesting of the crop was done under strip pattern. The experiment was aimed to evaluate the economics of operation of the machine and the best cutting pattern for maximum returns by reaper-cum-binder machine. There were at least five replications taken for the wheat crop under study.

### Climatic condition

The climatic factors of the experimental plot such as temperature, relative humidity and wind speed were recorded and are presented in table 1.

**Table 1:** Climatic parameters taken during operation

| Date | 13thApril2012 | 14th April 2012 | 15th April 2012 |
|---|---|---|---|
| Max. Temp.($^0$C) | 36.9 | 36.6 | 36.2 |
| Min. Temp. ($^0$C) | 22.3 | 22.3 | 20.0 |
| $RH_1$ (%) | 72 | 78 | 73 |
| $RH_2$ (%) | 41 | 38 | 37 |
| Wind speed (km/h r) | 4.3 | 3.4 | 4.9 |

(**Source:** Meteorological Department, RAU Pusa)

### Machine description

### Description of the reaper-cum-binder

The machine taken under study is based on the principle similar to that of a reaper with an additional arrangement for gathering and binding mechanism. The reaper-cum-binder has 1.22 m cutting width and vertical cut crop binding system. It consists of a cutter bar assembly and two iron forks for gathering the cut crop. There are belt and pulley arrangements along with control levers for power transmission. It cuts the crop approximately 8 cm from the ground to facilitate safe movement against the undulating surface. The driver's seat is shifted towards the left side so that it may not interfere with the sheaves dropped along the line of propagation. The machine needs special type of twines for binding the bundles. These are manufactured for the purpose and is made to meet the necessary strength required for binding sheaves. Generally, it comes in a bundle of weight 200-500 gm and is available under 100-200 string type. Special precaution is to be taken at the time of starting the engine that the flywheel is to be rotated in the anticlockwise direction to start the engine. It needs lubrication at 22 specified points regularly for better functioning.

### Steering mechanism

It is done by turning one of the two brake sleeves, left or right. For quick turns the inside wheel should be braked by pulling the upper brake lever in corresponding steering position. In case driver seat is attached, the corresponding foot pedal of the rear wheel should also be gently pushed, this supports the movement of the machine. The wheel brakes are given in the reverse order so that while turning, they come on the top from the driver's position.

### Description of gathering and binding mechanism

The machine binds the sheaves of the cut crops using twines. The crop sheaves are ejected in a straight line. The twines are waxed for smooth working. The claw of the crop gathering unit holds the crops cut with the help of blades. There is a binding-finger fixed between the claws, at the centre of the machine. As the volume of the crop increases, the finger gets pressed and it activates the binding mechanism. As the sheave is bonded, the twines get cut and the sheave is ejected. This process is repeated again. The knots are bound using the same mechanism somewhat similar as in the sewing machines.

### Power transmission systems in reaper-cum-binder

The power from the engine is transmitted to the wheels using chain sprocket mechanism using a crown gear. The crown gear of chain is fastened on the hub of the wheel. The prime mover drive unit is set on the reaper-cum-binder frame and fitted with connecting pins, which is fastened with four spring pins. The eccentric alignment of the drive for the fork moves it in a circular fashion, which leads to the gathering and binding movement. The machine simultaneously cuts the crop owing to the reciprocating movement and also binds the bundles. The cutting mechanism is very much similar to that of a reaper. The cutter bar assembly consists of the standard shoe guards with case-hardened edges and a reciprocating knife bar, with standard knife section, driven by the pitman results in the cutting process. The knife section is made up of high carbon steel riveted, which reciprocates in the slots of the stationary guards to cut the crop. Technical specifications of the reaper cum binder are presented in Table 2 given below.

**Table 2:** Technical specifications of the reaper-cum-binder

| Engine | Air cooled-single cylinder-diesel engine |
|---|---|
| Power | 10.2 h p |
| CC Capacity | 454 $cm^3$ |
| Injection pressure | 200 kg f/$cm^2$ |
| Bore | 85 cm |
| Stroke | 80 cm |
| RPM | Low ideal-115, High ideal-3000 |
| Alternator | 10 amps (magneto type) |
| Air cleaner | Oil bath type |
| Wheels | Pneumatic tyres |
| Inflation pressure | Front:25 psi Rear:30 psi |

| | | |
|---|---|---|
| Clutch | Hand operated-dry type-single plate-dia.180mm | |
| Brakes | Hand operated through cable transmission, special inner ring in oil bath | |
| Gear | Constant mesh gears with 4 forward and 1 reverse | |
| Speeds | 1st | 4.5 km/h r |
| | 2nd | 6 km/h r |
| | 3rd | 8 km/h r |
| | 4th | 10.8 km/h r |
| | Reverse | 4.6 km/h r |
| PTO shaft | Conical shaft 1125 rpm anticlockwise | |

The cutting and binding specifications for the reaper cum binder is given in table 3.

**Table 3:** Cutting and Binding specifications

| Particulars | Values |
|---|---|
| Binder height | 48 cm |
| Cutter bar width | 122 cm |
| No. of blades | 17 |
| No. of fingers | 16 |
| Blade holder | 6 |
| Maximum length | 360 cm |
| Maximum width | 185 cm |
| Weight | 400 kg |
| v-belt | B-154 |
| wheel driven chain | 5/8" × 1/4" |

**Crop details**

The formulas, terminologies and other details used for the evaluation procedure are presented below.

The crop parameters are presented in table 4 below.

**Table 4:** Crop parameters

| Crop | Wheat |
|---|---|
| Variety | UP-262 |
| Moisture content (%) | 12 |
| Plant height (cm) | 105 |

**Moisture content**

The crop from the field was brought into the lab and the plant was chopped to five samples. Each of these samples was dried in an oven. Their weight was again taken and the moisture content of the crop was calculated according to (Carneiro *et. al*. 2018) [3].

$$\text{Moisture content (dry basis)} = \frac{\text{Weight of sample - Weight of dried sample}}{\text{Weight of dried sample}} \times 100$$

**Grain/panicle**

The plants from the field were brought to the lab and the grains from the panicle were extracted and counted. Ten such replications were taken and the average was recorded. The data was used for the calculation of grain loss from the field.

**Weight /1000 grains (gm)**

There were five samples of 1000 grains, taken from the harvested crop and weighed. Their average was taken and recorded (Deivasigamani and Swaminathan, 2018) [4]. These values were used in the estimation of the weight of each grain and were taken to calculate grain loss in terms of the weight of grain lost per unit area.

**Plant population**

A M.S. (Mild Steel) rod frame of 1 m² in square shape was used for determining the plant population. Before starting the experiment, the sampler was thrown randomly in the field and the number of plants within the sampler was counted. Five such observations were taken for each replication and their average value was calculated.

**Number of effective panicles/m$^2$**

All the plants may not contribute to the effective yield. Hence the effective number of tillers were counted. The samples were taken using the A M.S. (Mild Steel) rod frame of 1 m2 made up of iron. The frame was thrown randomly in the field and data was recorded. Five such readings were recorded for each replication and their average was taken.

**Number of bundles/m$^2$**

There were five samples of bundles taken and their average area (length× width) were recorded for the determination of actual number of bundles/ ha.

**Grain loss**

Grain loss of various types in the field was determined by using the square sampler of 1 m$^2$ size. After the completion of harvesting, the sampler was thrown randomly over the harvested area and grains present within the sample was collected. A minimum of five observations was taken for evaluation of grain loss over an experimental area for each replication. Weight of shattered grains collected from the space occupied by the sampler divided by the sampler area enclosed. This gave the grain losses per unit area. The weight of the grain lost was calculated for 1 hectare using the formulae:

$$\text{Grain loss by weight /ha} = \frac{\frac{\text{grain lost}}{\text{m}^2} \times 1000 \times \text{wt. of 1000 grains in grams}}{10^6}$$

**Evaluation procedure**

Using the collected data and processing them, the value of field efficiency and field capacities were calculated. Further, it was used to study machine economics and its performance.

**Calculation of field capacity and efficiency**

Field efficiency of a machine is the percentage of the Actual field capacity of the machine with respect to the Theoretical

field capacity. It was calculated using the following formulae (Omrani, Shiekhdavoodi, and Shomeili, 2013) [5].

$$\text{Effective field capacity (ha/hr)} = \frac{\text{Actual area covered (ha)}}{\text{Actual time taken (hr)}}$$

Theoretical field capacity is the rate of field coverage for operation by a machine based on its rated speed and its width of operation. It was calculated as:

$$\text{Theoretical field capacity (ha/hr)} = \frac{\text{Width (m)} \times \text{Speed (m/hr)}}{10000}$$

The inputs needed to determine the field efficiency of the reaper-cum-binder were recorded and put in the formulae below to calculate its field efficiency:

$$\text{Field efficiency} = \frac{\text{Effective field capacity (ha/hr)}}{\text{Theorretical field capacity (ha/hr)}} \times 100\,\%$$

**Financial feasibility analysis**

Financial feasibility analysis was carried out to evaluate the feasibility of investment on reaper-cum-binder. The discounted and non-discounted cash flow techniques were employed as useful tools in evaluating the long-term financial feasibility analysis. Hence, for evaluating the investment and to find out the financial and economic viability of the investment on reaper-cum-binder, a few measures of feasibility evaluation techniques were employed (Alam et. al., 2018) [6]. The havesting of wheat by the reaper-cum-binder and by the manual harvesting process is shown in figure 1 and figure 2, respectively.

The following financial feasibility techniques were used in the study to evaluate the feasibility of investment for the reaper-cum-binder.

- Pay Back Period (PBP)
- Break-Even Point (BEP)
- Cost of use of machine
- Rate of custom hiring of machine

**Pay back period (PBP)**

It indicates the time required to recover the initial investment or the length of time required to repay the original investment made on the machine. In this study, the payback period was calculated by successively deducting the initial investment from the net return until the initial investment was fully recovered. Shorter the payback period, better would be the feasibility of investment on the reaper-cum-binder. The payback period formula used in the study is as follows,

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Averae annual net benefit}}$$

$$\text{Minimum annual payback (Rs.)} = \frac{\text{Cost of purchase of machine (Rs.)}}{\text{Life of machine (yrs)}}$$

**The break-even point (BEP)**

The break-even point is the annual use level at which the machine must be operated to make the investment profitable. The break-even point formula used in the study is as follows,

B (x) = Fixed cost + Variable cost

Where,
x = Break-even point (in tonnes per year)
B = Benefits (or the custom fee)

Using the break-even point measure for investment appraisal, the investment made on reaper-cum-binder can only be profitable, if the annual use level of the machine is at or above the break-even point.

$$\text{Break-even point (ha)} = \frac{\text{Annual payback (Rs.)}}{\text{Annual monetary save against manual harvesting (Rs./ha)}}$$

**Cost of use of machine**

This is the cost initially incurred during the operation. For the determination of cost of the use of the machine, the following concepts are used:

$$\text{Depreciation cost (Rs./hr)} = \frac{C - S}{L \times H}$$

$$\text{Interest (I) Rs./hr} = \frac{C + S}{2} \times \frac{i}{H}$$

Where,
C = Capital investment (Rs.)
S = Salvage value, 10% of capital
H = No. of working hours /year
L = Life of machine in years.
I = Interest rate /year (%)

**Rate of custom hiring of a machine**

The rate of custom hiring of a machine is calculated by the following methods:

**(For Reaper-cum-binder machine)**

**Annual fixed cost (A)**

1. Depreciation = (purchase price - trade-in value) ÷ life of the machine in years
2. Interest* = (purchase price + trade-in) × annual interest rate ÷ 2
3. Insurance & housing = purchase price x 2%

**Annual operating cost (B)**

1. Fuel & lubricants = (fuel consumption in L/hr x annual usage of machine in hr/yr x fuel cost/L x 1.15)
2. Repairs & Maintenance

**Annual machinery costs (C) = (A + B)**

1. Profit margin (return to management, admin. costs) (suggest 15% of machinery costs (C x 0.15) (D)
2. Operator labour (self or hired) - (suggest 15% over machine hr for travel, downtime) of machinery hr x 1.15 x wage/hr (E)

**Total costs (F) = (C+D+E)**

(G) Per hectare per hour = Custom rate F ÷ Total annual hectares or F ÷ Total annual hours

**Fig 1:** View of harvesting of wheat crop by Reaper-cum-binder

**Fig 2:** View of manually harvesting of wheat crop by Sickle

## Results and Discussion

This section deals with the results obtained during the field experiments of the reaper-cum-binder for the wheat crop in Uttara region (Madhubani), Bihar. The performance parameters like field capacity, field efficiency with different types of losses were calculated and compared. Further, the economics of the machine was also estimated and compared for better returns and performance.

### Field performance evaluation

The field trials of the machine were conducted at Mithila Farm Machine Bank, Uttara (Madhubani), Bihar. The machine was well prepared and checked before it was taken to the field. All the necessary arrangements were made to ensure the smooth functioning of the harvesting process. The labourers were made available according to the requirements, for the respective machine to ensure a better economic study of the machine under actual field conditions.

The crop was mature and the headland was manually cut around the field for the reaper-cum-binder trials. The machines started harvesting from the left side of the field and went anticlockwise along the sides of the field. The reaper-cum-binder was operated at 4.5 km/hr on 1st gear.

All the findings obtained from various replications carried out for the machine under wheat crop was processed and the results obtained are presented in table 5.

**Table 5:** Field performance of reaper-cum-binder for wheat crop

| Machine | Theoretical Field capacity(ha/h r) | Actual Field Capacity(ha/h r) | Field Efficiency (%) |
|---|---|---|---|
| Reaper-cum-binder | 0.54 | 0.3804 | 70.44 |

The trials were conducted for the wheat crop and data were processed for five replications. It was found that the actual field capacity of reaper-cum-binder was 0.3804 ha/hr. The theoretical field capacity of reaper-cum-binder was 0.54 ha/hr. The field efficiency was calculated for the reaper-cum-binder under study, which was found to be 70.44 %. The difference is due to the rated speed at which the machine can be operated. However, reaper-cum-binder has a speed of 4.5 km/hr on the 1st gear. The machine is provided with a driver's seat, which makes the operation possible even at a higher speed. Also, the presence of driver's seat facilitates better quality of work and reduces drudgery.

### Measurement for wheat crop

All the findings obtained from various replications carried out for the machine under wheat crop was processed and the following results were obtained.

**Table 6:** Evaluation of particular characteristics related to harvesting of the wheat crop

| Particulars | Average |
|---|---|
| No. of grains/panicle | 38 |
| Weight of 1000 grains | 34 gm |
| Length of panicle | 12 cm |
| No. of plants/$m^2$ | 295 |
| Weight/bundle (Machine) | 1.819 |
| Weight/bundle (left for farmer) | 13.43 kg |
| Weight/bundle (taken by labourers) | 29.88 kg |

The data presented in Table 6 given above was recorded for the evaluation of economics and losses of wheat crop harvesting by the machine and by the manual method. The trials of ten replications for each of the observations were taken for both, i.e. operation by the machine and by the manual labours. The average number of grains/panicles was 38 and the average weight of 1000 grains was found to be 34 gm.

### Comparison of the reaper-cum-binder with the manual method

**Table 7:** Economics of reaper-cum-binder and that of manual harvesting for wheat crop

| Particulars | Machine Harvesting | Manual Harvesting | |
|---|---|---|---|
| | | Farmer | Labour |
| Grain: Straw | 1:1.45 | 1:1.45 | 1:1.45 |
| Grain Yield (q/ha) | 17.16 | 14.72 | 2.752 |
| Straw yield (q/ha) | 24.882 | 21.344 | 3.99 |
| Operational cost (Rs./ha) | 3000 | 5152.60 | |
| Cost of lost grain (Rs./ha) | 956 | 699.04 | |
| Total cost (Rs./ha) | 3956 | 5851.64 | |
| Benefits over manual (Rs./ha) | 1895.64 | - | |

The trials were conducted for the wheat crop and data were processed for five replications and is shown in table 7. It was found that grain to straw ratio for both the method was the same as 1:1.45. The grain yield by the machine was found to be 17.16 q/ha, corresponding for the farmers and the labours were 14.72 q/ha and 2.752 q/ha respectively. The benefit over manual harvesting was found to be Rs. 1895.64/ha. Hence, the reaper-cum-binder was superior over manual harvesting.

**Measurement of custom hiring rate of reaper-cum-binder for wheat crop**

**Table 8:** Custom hiring rate of reaper-cum-binder

| Particulars | Cost (Rs. /ha) |
|---|---|
| Total cost of use | 923.646 |
| Profit margin | 256.30 |
| Twine cost | 1136.2 |
| Total | 2316.146 |

The custom hiring rate for the reaper-cum-binder was calculated as Rs. 2316.146/ha for the wheat crop. Thus, the above data recorded in table 8 for the actual custom hiring rate were benefited over the farm machine bank as Rs. 683.85/ha.

**Measurement of break-even point**

Break-even point has a great significance when it comes to calculate the profitable working span of the machine. The calculation of the break-even point enables us to find the hours of use as well as the numbers of hectares of land to be harvested after which the machine would start gaining profit.

**Comparison between the economics of manual harvesting and reaper-cum-binder with respect to their break-even point for wheat crop under study**

The calculation of economics has been done on the basis of break-even hours and break-even hectares of land as shown in table 9. The cost of the use of the machine includes fixed costs, variable costs, and the average cost of grains lost during the operations. The profit was calculated with respect to the cost of manual harvesting with a sickle.

**Table 9:** Break-even point values for the reaper-cum-binder

| Method of harvesting | Cost of use (Rs/ha) | Cost of Manual harvesting (Rs/ha) | Profit (Rs/ha) | Break-even (hectares) | Break-even (hours) |
|---|---|---|---|---|---|
| Manual harvesting | - | 5152.60 | - | - | - |
| Reaper-cum-binder | 1879.646 | - | 3272.954 | 19.75 | 51.94 |

As per data are shown in Table 9 given above, for the 1st year reaper-cum-binder should be operated in 19.75 ha for wheat crop and break-even time was calculated as 51.94 hrs for the wheat crop.

The perusal of recorded data for benefit-cost ratio although shows a marginal increase in benefit-cost ratio in case of reaper-cum-binder but the overall profitability of the machine during its commercial use would be very high. The reaper cum binder machine may be used up to 12 hours a day with 2 workers.

**Conclusions**

The study was conducted on this machine for assessment of the performance as well as the economics of the operation, particularly in Bihar where wheat cropping system is still dominant. The reaper-cum-binder saved 11.11 % per hectare of yield to the farmers. So, this machine is preferred well for custom hiring. The field efficiency of the reaper-cum-binder for the wheat crop was obtained as 70.44 %. In harvesting by reaper-cum-binder for the wheat crop, total grain losses were found to be 92.11 kg/ha. The economics of machine over conventional methods of harvesting was calculated and it was found that the benefit-cost ratio for reaper-cum-binder for the wheat crop was 2.08. The breakeven hectares and breakeven hours of reaper-cum-binder for the wheat crop were calculated as 19.75 hectares and 51.94 hours respectively. The custom hiring rate estimated for the wheat crop, was also found to be beneficial for the farmers.

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