Study on Performance Evaluation of Self-propelled Reaper

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Abstract**—**Bangladesh is a nation of about 160 million people, living on about 55,000 sq miles (about the size of the state of Wisconsin in the USA) [1]. 45% of Bangladeshis are employed in the agriculture sector. Timely harvesting is very much important to get better yield. In this case mechanization plays a big role using reaper. Field experiment was carried out for the Performance evaluation of reaper on rice crops at "UttarMonohorpur, Gangachara" at Rangpur district for Aush season during harvesting of BR-48 in the second week of April in 2014 and at "Bishmuri,Chaderhat ,Nilfamary" for Aman season during harvesting of BR-52 in 13 November in 2014 [2]. Two different models were used for evaluating performance. For aush season Korean machine and for aman season Vietnam machine was used. Several measuring criteria's were considered during field experiment including operating speed, time of harvesting, fuel consumption, shattering loss, soil moisture, plant height & density, field efficiency, grain loss before & after harvesting, fixed costs, variable costs etc. .for machine 1field capacity was 0.1533 ha/hr, field efficiency 50% and break-even point 3.65 ha and fuel consumption 1.37L/hr .for machine 2field capacity was 0.232 ha/hr, field efficiency 64% and break-even point 3.81 ha and fuel consumption 0.74L/hr [3]. Machine harvesting during peak period minimize labor requirement. But due to higher purchase price and lack of popularity use of reaper is not available.

Keywords—theoretical field capacity, actual field capacity, field efficiency, break even analysis, operating speed.

INTRODUCTION

Bangladesh is an agro-based country where Rice (*Oryza sativa*) and wheat (*Triticumvulgare*) are the main cereal crops which contribute about 93.11% of the national food grain production (BBS, 2008). Some other minor crops are cultivated also [4]. Rice is cultivated in 113 countries and it is the staple food of more than 50 percent population of the world. About 90 percent rice area exists in Asia [5]. In Asia, more than 60% farmers have land holding size less than 2 ha. Therefore technology for small holding size plays a very important role in developing countries.

Farm mechanization for Crop production has become an important issue for agricultural production in the country. To feed her 150 million people from 8.2 million hectares of cultivable land is difficult. Every year almost 0.20 million people are adding to the total population whereas the estimated annual reduction of agricultural land is about 0.08 million hectares due to constructions of houses, offices, roads, mills, factories etc [6]. The country's food production has increased from 11.0 million tons in 1971 to about 30 million tons in 2007 [7]. Now, the country is self-sufficiency in cereal production. This is due to mechanized tillage and irrigation development and also partial mechanization in other agricultural operations as well as development in other crop production sectors.

But to meet up the food requirements of the ever growing population of the country in 2015, an additional 5 million tons of food grain need to be produced from the continuously decreasing agricultural lands. To increase food production and cropping intensity, the most important task will be the faster development of agricultural mechanization and other crop production sectors.

Mechanization is needed to raise productivity in rain fed upland and rain fed lowland and to increase cropping intensity in irrigated farms. Walking type vertical conveyer reaper, power tiller and tractor front mounted reaper save 50-60% labor and harvesting cost by 60-70% as compared to manual harvesting [8]. Use of pedal operated thresher, motorized hold on thresher reduce time, labor, cost of threshing to a great extent. Combine harvesting save 40-50% cost as compared to manual harvesting and threshing by power thresher [9].

An imported reaper or combine harvester from abroad is a high cost and sophisticated to implement. The marginal farmers of Bangladesh cannot afford to buy a combine harvester due to high initial cost. But in respect of field performance, operating and initial cost and maneuverability, the self-propelled reaper is better than a combine harvester. Now days, reapers

are used in Bangladesh for rice harvesting at very small scale and are mainly imported from China and Vietnam. Recently, the Workshop Machinery and Maintenance Division of Bangladesh Rice Research Institute (BRRI) developed a self-propelled reaper with a simple power transmission gearbox using locally available materials for harvesting rice and wheat. BRRI developed reaper is very simple and light, and easy to operate, time and cost effective and it reduce human drudgery as well as post-harvest losses. Both male and female farmers can operate it easily.

Due to lack of timely harvesting of paddy and wheat, a considerable amount of food grain is lost every year in the country. It is expected that the introduction of farm machinery through project will enhance agricultural mechanization program in Bangladesh [10]. Traditionally in Bangladesh, both paddy and wheat are harvested by manual labor using sickles. Due to the non-availability of labor or other reasons, crop harvesting is often delayed which exposes the crop to varieties of nature. Timely harvesting is utmost important, as delayed harvesting leads to a considerable loss of grains and straw owing to over maturity resulting in loss of grains by shattering.

MATRIALS AND METHOD

A. Field experiment

Field experiment was carried out for the performance evaluation of reaper on rice crops at "UttarMonohorpur, Gangachara" at Rangpur district for Aus season and at "Bishmuri,Chaderhat ,Nilfamary" for Aman season . The soil structure was identified for both as clay soil. The field experiment was carried out during Aus&Aman . Specific fuel consumption, field capacities (theoretical field capacity and effective field capacity), field efficiency, shattering losses, cost of operation etc were studied both for machine harvesting and manual harvesting. Cost comparisons were done for machine harvesting to manual harvesting.

A plot was selected to determine operational speed of the harvester, field capacity (ha/hr.), number of labor required for machine harvesting, fuel consumption and grain losses due to the reaper. The area of the plot was measured with tape. Also randomly three small areas were selected in the plot for determining shattering loss. The size of small area was (1m×1m) each. These plots were harvested manually and the total number of spikes was counted to estimate total yield. After harvesting, three plot of (1m×1m) were randomly selected and scattered spikes were collected from selected areas for both manual and reaper.

To calculate the operational speed of harvester, time was recorded that was taken to travel a certain distance. The distance was measured with a measuring tape and time was counted with a stop watch. Such operations were done in several times to calculate the average speed of operation. The actual field capacity was calculated by dividing the total area harvested by total time taken to harvest a certain plot. The theoretical field capacity was calculated by the formula. The materials or equipment's used for the field experiment listed in the following table.

TABLE-I List of equipment's used

Sl. No.	Equipment	Description of Use
1	Tape	Used for measuring length
2	Four Stick	Used for marking the area
3	Poly bag	For collecting grain
4	Tag	To identify the grain before and after harvest
5	Measuring cylinder	For measuring the fuel quantity.
6	Stop watch	To obtain the total time
7	Data sheet	Used to record the data

B. Test site and test plots

The study was carried out during Aush and Aman harvesting period in 2014 respectively. The study was conducted during the harvesting of BR-48 in second week of April in 2014 at Uttar Monohorpur, Gangachara, Rangpur and of BR-52 at 13 November in 2014 at Bishmuri, Chaderhat, Nilfamari.

C. Procedure of crop parameter determination

For determining the plant height in the test field, the height of plant from ground to the upper part of the panicle were measured .Then for determining the hill diameter in the test field, the area of hill were measured by measuring tape and then

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divided by 2π to get hill dia. With the help of tape the average plant to plant distance, hill to hill distance, and row to row distance were measured. All data were taken at three randomly selected plot and average data were taken. To obtain hill density row to row distance were multiply with total hill in one square meter.

D. Shattering loss

Shattering loss should be as minimum as possible during operation of reaper. Shattering loss was calculated from the following equation.

$$Shattering\ loss\ (\%) = \frac{Grain\ collected\ after\ harvesting}{Yield(14\%m.c)} \times 100$$

E. Harvesting

1) *Pre-harvest losses*

a) Carefully cut the paddy in all border lines between selected plots.
b) Carefully pick up all grains on the ground with in the sample plot. Care must be exercised not to lodge the crop.
c) Place the recovered grains in the poly bag and properly label the bag. Repeat the same for other plots.
d) Clean the grain.
e) Weight the clean grains and record it.
f) Take moisture contents reading and record it.

2*) Shattering losses*

a) Lay out the canvas on the cleared border. Make sure that the canvas in securely fastened to the ground
b) Harvest normally the paddy within the plot
c) Lay down the harvested crop in the canvas sheet
d) Collect carefully all the grains on the ground as a result of shaking during harvesting
e) Clean the collected grains
f) Weight the clean grains and record it
g) Take moisture reading and record it
h) Repeat the same procedure as in the other plots

F. Procedure of obtaining machine data

Forward speed was calculated to measure the theoretical field capacity of the reaper. Total time of field operation was recorded to measure the actual field capacity of the reaper with turning loss, operator personal loss, machine adjustable loss and troubleshooting loss during field operation. Numbers of grains were recorded from the pre-selected $1m^2$ areas before and after filed operation. The following formulas were used to measure theoretical field capacity, actual field capacity and field efficiency.

Forward speed was measured by dividing the distance by time required to travel that distance.

$$Forward\ speed,\ S = d/t$$ Where ***d***= distance travel (m), ***t***=time (sec)

Theoretical field capacity was measured based on the forward speed and the cutting width of reaper**.**

$$Theoretical\ field\ capacity, TFC\ = \frac{sw}{c}$$

Where, *s*= forward speed of travel, km/hr, *w*=total width covered, m, *c*=constant, 10

The actual field capacity is the actual average rate of coverage by the machine, based upon the total field time. The area covered divided by the total time is the actual field capacity. The actual field capacity was determined from measuring all the time elements involved while harvesting.

$$Actual\ field\ capacity, EFC = \frac{A}{T}$$

Where, A= actual area covered, ha, T= total time required, hr

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The field efficiency was determined by the ratio of effective field capacity to the theoretical field capacity.

$$Field\ efficiency\ (\%) = \frac{EFC}{TFC} \times 100\%$$

G. Cost calculation

1) Fixed Costs

The fixed cost is the cost which is involved irrespective of whether the machine is used or not. These costs include; Depreciation cost, interest on investment and taxes, shelter and insurance.

2) Depreciation

Depreciation is the reduction in value of a machine with the passage of time. Depreciation cost was calculated by straight line method.

$$The\ annual\ Depreciation, \qquad D = \frac{(P - S)}{L}$$

Where, P = purchase price (Taka), S = selling price (Taka), L = time between buying and selling, yr.

3) Interest on Investment

Interest on the investment in a farm machine is a legitimate cost, since money spent in buying a machine cannot be used for other productive enterprises. Interest on Investment was calculated by Straight Line Method.

$$Interest\ on\ Investment, \qquad I = \frac{(P + S)}{2} i$$

Where, P = Purchase price, Tk. S = Resale value, Tk. i = annual interest rate

4) Shelter, Tax and Insurance

$$Shelter, Tax\ and\ Insurance, \qquad STI = 2.5\%\ of\ P$$

5) Total Fixed Cost

$$Total\ Fixed\ Cost\ \left(\frac{Tk}{Yr}\right) = D + I + STI$$

$$Fixed\ Cost\ \frac{Tk}{ha} = \frac{Total\ Fixed\ Cost(\frac{Taka}{Year})}{Total\ Area\ Coverage(\frac{ha}{Year})}$$

6) Variable Costs

Fuel cost, oil cost, labor cost and repair and maintenance cost were determined by following formulae:

$$Fuel\ Cost(\frac{Tk}{ha}) = \frac{Fuel\ Consumed\ \left(\frac{litre}{day}\right) * Price\ (\frac{taka}{litre})}{Area\ Covered\ (\frac{ha}{day})}$$

$$Oil\ Cost, O\left(\frac{Tk}{ha}\right) = 15\%\ of\ Fuel\ Cost, F$$

$$Labor\ Cost, L\left(\frac{Tk}{ha}\right) = \frac{Some\ of\ Wages\ of\ Labours\ (\frac{taka}{day})}{Area\ Covered\ (\frac{ha}{day})}$$

$$Repair\ and\ Maintenance\ Cost, R\&M\left(\frac{tk}{year}\right) = 3.5\%\ of\ Purchase\ price, P$$

$$= \frac{Sum\ of\ R\&M\ Costs/\ total\ operating\ days}{Area\ Covered(\frac{ha}{day})}$$

$$Total\ Variable\ Cost\left(\frac{tk}{ha}\right) = (F + O + L + R\&M)\ tk/ha$$

$$Total\ Cost\ of\ Harvesting\left(\frac{tk}{ha}\right) = Fixed\ Cost\ \left(\frac{tk}{ha}\right) + Variable\ Cost(\frac{tk}{ha})$$

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H. Break-even analysis

The break-even point (BEP) is that point at which neither profit is made nor loss incurred. The total costs of the farm enterprise would be the same as the gross income. The following formula was used to estimate the BEP of the machine.

$$BEP = \frac{FC}{CR - VC}$$

Where, BEP = break-even point, ha yr^{-1}; FC = fixed cost, Tk yr^{-1}; VC = variable cost, Tk ha^{-1}; CR =custom hire rate, Tk ha^{-1}

TABLE-II Specification of reaper

Sl No.	Parameters	Machine 1	Machine 2
1	Model no	TR-1200B	CE
2	Reaper type	Self-propelled	Self-propelled
3	Engine model	Jamboo DE-300	GX-16072
4	Engine type	Diesel engine	Petrol engine
5	Dimension	(147×105×65)cm	(154×75×58) cm
6	Start mode	Exclusive cartridge starting	Exclusive cartridge starting
7	Weight(kg)	150	78
8	Cutting width	120cm	120 cm
9	Crop release	Right	Right
10	Number of cutting knife	28	16
11	Fuel type	Diesel	Petrol
12	Engine power(kw)	5.9	6.43

I. Parts identification of reaper

Fig. 1. Lug& Star Wheel

Fig. 2. Gear box

Fig. 3. Cutter bar

Fig. 4. Conveyor belt

Fig. 5. Header

Fig. 6. Spring guide

Fig. 7. Chain & sprocket

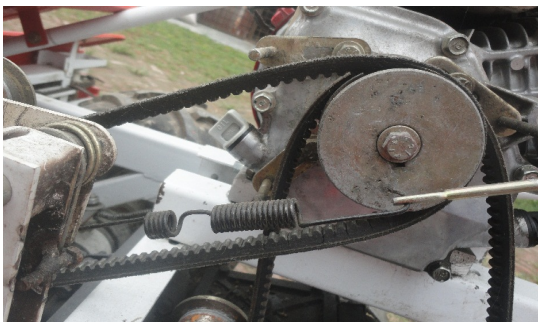

Fig. 8. Belt & pulley

Fig. 9. Fuel tank

Fig. 10. Reaper Lever

Fig. 11. Reaper starter

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J. Reaping process

The operational procedure of self-propelled reaper has shown in figure-13 and a complete reaper picture has shown in figure-14. The reaper has an automated system for moving and have handle in the back side for controlling its direction.

Fig. 12. Reaping process

Fig. 13. Complete reaper

RESULTS AND DISCUSSION

During field operation several agronomic data were taken. Theoretical field capacity, field efficiency, specific fuel consumption, Labor requirement was also calculated. Time of operation was calculated for both machines.

TABLE-III Agronomic data

Sl. No.	Parameter	For Aush	For Aman
1	Plant to plant distance, cm	30	30
2	Hill to hill distance, cm	23	24
3	Hill density, hill/m^2	14.49	13.88
4	Canopy height, cm	105	116
5	Hill diameter, cm	3.04	3.16
6	Number of hill per square meter	17	18
7	No of tiller per hill	13	11
8	Plant density, number/m^2	188	153
9	Soil moisture, %	19.8	21.5
10	Yield at 14% mc, kg/ha	3245.16	4560
11	Shattering loss, %	0.43	1.04

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In above table data taken were the average value by making trial for three plots. Adjustment of machine speed depends on mainly hill density and hill diameter. On the other hand cutter bar height depends on canopy height. Shattering loss was greater for Aman season than Aus season. It may be due to machine vibration or different variety.

TABLE-IV Field performance

Sl. No.	Parameter	Average value for machine 1	Average value for machine 2
1	Forward speed, km/hr	2.57	3.01
2	Theoretical field capacity, ha/hr	0.3084	0.36
3	Actual field capacity, ha/hr	0.1533	0.232
4	Field efficiency, %	50	64
5	Fuel consumption, L/ha	9.13	3.99
6	Labor requirement, man-hr/ha	6.81	4.84

The average value for theoretical field capacity and effective field capacity were taken for determining field efficiency. Field efficiency for machine 2 was more than machine 1 due to difference in land size, shape and operator's performance.

TABLE-V Time calculation

Sl. No.	Time	Machine 1(%)	Machine 2(%)
1	Straight time	50	78
2	Turning Time	34	18
3	Breakdown time	16	4

From table straight time for machine 2 was more than machine 1 but turning time is less than machine 1.Because the length of crop field used for machine 2 was more and that why turning was less. For clogging breakdown time was greater in machine 1.

TABLE-VI Cost calculation

Parameter	Machine 1	Machine 2	Manual harvesting cost, Tk/ha
Fixed cost, Tk/yr	52020	55080	
Fixed cost, Tk/ha	848.34	593.53	7450
Variable cost, Tk/ha	637.91	442.47	
Total cost(Tk/ha)	1486.25	1036	

The cost of two machines varies because of variation in purchase price, fuel cost and lubrication cost. But manual harvesting cost remains constant for both machines. The cost of harvesting for both machines is much lower than manual cost of harvesting.

Break-even analysis

The break-even point is the point where the profit and loss are equal. The above figure explains that the break-even point for using machine 1 is 7.64 hector and the associated cost less than 7450 taka per year. To get benefit from the reaper at least 7.86 hector need to cultivate otherwise it may face loss. More than 7.64 hectors will increase more profit. Similarly for machine 2 break even area is 7.86 ha. The value for break-even point for both machines was very close. That's why two curves superimposed.

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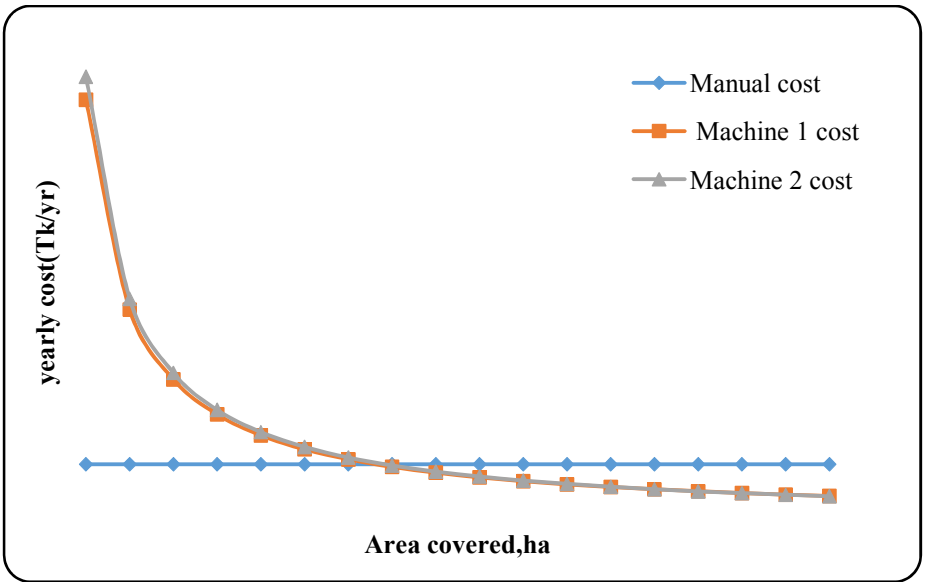

Fig. 14. Break-even analysis for two machines

CONCLUSION & RECOMMENDATION

A. Conclusions

The use of reaper is much more economic and efficient for harvesting of paddy in Bangladesh compared to conventional method. The study was carried out during Aush and Aman harvesting period in 2014. The study was conducted during the harvesting of BR-48 in second week of April in 2014 at Uttar Monohorpur, Gangachara, Rangpur and of BR-52 at 13 November in 2014 at Bishmuri, Chaderhat, Nilfamari. It was done by using two different machines. Field capacity for machine 1 and machine 2 were 0.1533 ha/hr and 0.232 ha/hr respectively. The field efficiency of machine 1 and machine 2 were 50% and 64% respectively.

B. Recommendation

From the study it was found that the use of reaper was more beneficial than manual harvesting for harvesting of rice. The present study is carried out only for rice cutting, but the same machine can be applied for cutting wheat. This field operation was carried out for small fragmented plot with three replications. But to get more satisfactory result it should conduct on large size plot with several replications. This was done mainly over the Rangpur region. Due to variation in soil condition the tested result may also vary. So it can also carry out for several regions. It can also applied for –

I. Testing machine by changing cutter bar height.
II. Testing machine by changing machine speed.

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