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Performance Evaluation of the BRRI Reaper and Chinese Reaper Compared to Manual Harvesting of Rice (*Oryza sativa* L.)

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Abstract

Introduction of appropriate machinery is one of the major factors for reducing time and labor requirements, production cost and also to help fit another crop in between successive two crops. In this study, performance of the Bangladesh Rice Research Institute (BRRI) developed self-propelled reaper and an imported Chinese reaper were evaluated for rice harvesting and were compared with manual harvesting. The experiment was conducted at BRRI Regional station in Rajshahi and Rangpur during *Boro* 2012-13. Average field capacity of the BRRI reaper was 0.250 ha/hr and that of Chinese reaper was 0.203 ha/hr. The average field capacity of manual harvesting was 0.004 ha/hr. Labour requirements for rice harvesting including bundle making were 248 man-hr/ha, 69 man-hr/ha and 68 man-hr/ha for manual, Chinese reaper and BRRI reaper, respectively. On an average, 72 and 03% labour was saved by the BRRI reaper over those of manual harvesting and Chinese reaper, respectively. Harvesting costs were saved by BRRI reaper and Chinese reaper about 68 and 61%, respectively over that of manual harvesting. Average fuel consumption of Chinese reaper and BRRI reaper were 0.727 and 0.826 l/hr, respectively. The walking speed of BRRI reaper (3.78 km/hr) was 62% higher than that of Chinese reaper (2.33 km/hr). The purchase price of imported reaper is almost double than that of BRRI reaper. The BRRI reaper was, therefore, considered as a better machine for harvesting rice in Bangladesh.

Keywords: BRRI Reaper, Imported Chinese reaper, Manual harvesting, Performance, Paddy fields

1. Introduction

Rice (*Oryza sativa* L.) is an important food crop for over half of the world's population (Li *et al.*, 2011; Juraimi *et al.*, 2013). About 850 to 900 man hours (hr) of labour is required for cultivating one hectare of rice **(**Singh *et al.,* 1991**)**. On the other hand, harvesting of crops are the most important agricultural operations which demand considerable amount of labour. Availability as well as cost of labour during harvesting is a serious problem. Working capacity (time required to harvest one hectare) is the highest in manual harvesting with an average of 111.10 hr/ha (Alizadeh *et al.*, 2013). Timely harvest of the crop is vital to achieve better quality and higher yield of the crops. The shortage of labour during harvesting season and vagaries of the weather cause great losses of yields. It is, therefore, essential to adopt the mechanical methods so that the timeliness in harvesting operation could be ensured and yield losses are minimized. This will also allow the land to be prepared for the subsequent crops.

Harvesting is traditionally done by sickle by both male and female farmers in Bangladesh (Pandey and Devnani, 1981). Which is laborious, costly and time consuming. The total labor requirements for harvesting of paddy are from 170-200 man-hr/ha using sickles which causes a peak labour demand during the harvesting season (Haque *et al*., 1989). It is also observed that the labour requirement per hectare of paddy for harvesting by the sickle was 240 man-hr/ha (Mondol *et al*., 1997; shakoor *et al.*, 2005). But, it is estimated that about one-third of total labour was saved by using reaper for harvesting operation. Meisner *et al.* (1997) showed that a reaper is 14 times more efficient than a daily laborer in cutting and placing cereals in the field. Veerangouda *et al.,* (2010) also reported that field capacity for a tractor operated combine harvester varied from 2.88 to 3.60 ha/hr. So, there is a great scope to introduce a self-propelled reaper or combine harvester in Bangladesh.

An imported reaper or combine harvester from abroad is a high cost and sophisticated 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 a 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. The objectives of this study were to assess the performance and operational costs of BRRI developed self-propelled reaper and imported Chinese reaper for rice harvesting and were compared with that of manual harvesting method.

2. Materials and Methods

The experiment was conducted at BRRI regional station at Rajshahi and Rangpur in 2012-13 *Boro* seasons. Boro rice was planted after harvesting Aman rice. The planting method of Boro rice in this region is mostly in row. The rice harvesting was performed both manually (with sickle) and mechanically (with reaper). The BRRI developed self-propelled reaper and imported Chinese reapers were used for harvesting. The cutting widths of both the machines were 1.2 m. The cutting height of the reapers could be adjusted from 0.15 to 0.60 m. The following factors were considered to evaluate the performance of both reapers:

2.1. Walking speed (forward speed)

For measuring forward speed of self-propelled reaper, while harvesting crop, the distance of the reaper travelled in 30 minutes was measured and the speed of travel was recorded in terms of km/hr.

2.2. Operating time and cutting area

The starting and finishing times of harvesting in each plot were noted. A total area of 0.232 ha (57.29 decimal) and 0.223 ha (55.16 decimal) of BRRI dhan-28 were harvested in 60 minutes by the Chinese reaper at Rajshahi and Rangpur, respectively. On the other hand, a total area of 0.271 ha (67.02 decimal) and 0.263 ha (65.02 decimal) of BRRI dhan-28 was harvested during same time by the BRRI reaper at Rajshahi and Rangpur, respectively.

2.3 Fuel consumption

Before starting the harvesting operation in the test plot, the fuel tank of the reaper was filled up to its full. The quantity of fuel required to fill the tank fully after harvesting the plot was measured to determine the quantity of fuel consumed for reaping the test plot.

2.4. Field capacity

Field capacity of a machine is the actual rate of land preparation/harvested or crop processing in a given time, based on total field time. In other words, effective field capacity of a machine is a function of the rated width of the machine. The percentage of rated width actually utilized the speed of travel and the amount of field time lost during the operation. In order to determine effective field capacity the rated width of the implement (cutting width), speed of travel and field efficiency were measured. Field capacity and field efficiency were calculated using the following formula (Hunt, 1973):

$$\text{Field capacity, } C = \frac{A}{T} \quad \text{.............................. (1)}$$

Where,

C = field capacity (ha/hr)

T = total time for the reaping operation (hr)

A = area of land reaped at specified time

2.5. Harvesting cost

The costs of harvesting with reaper are classified into two categories: fixed cost and variable cost. In order to compare harvesting costs in manual and reaper methods, all the costs of wages in manual and the fixed and variable costs in mechanical operations were calculated. Fixed cost included depreciation cost, interest, shelter and taxes and is a function of purchase value, useful life and interest rate. Annual interest was calculated on average investment on the machine over its full life. Depreciation was determined by straight-line method by the following equation:

$$\text{Depreciation, } D = \frac{P-S}{L} \quad \text{............................ (2)}$$

Where,

D= Mean yearly depreciation (Tk./year)

P= Purchase value (Tk.)

S= Salvage value (Tk.)

L = Useful life (year)

Useful life for power tiller was considered to be 10 years and this is assumed to hold for the reaper. The purchase price of BRRI developed self-propelled reaper was considered as Tk. 1, 20,000. On the other hand the market price of imported self-propelled Chinese reaper was Tk. 2, 20,000. The machine salvage value was considered to be 10% of purchase value. Interest is an actual cost in agricultural machinery and was determined by straight line method by the following equation:

$$\text{Interest, } I = \frac{P+S}{2} \times i \quad \text{.............................. (3)}$$

Where,

I= Mean interest (Tk. /yr)

P= Purchase value (Tk.)

S= Salvage value (Tk.)

i= interest rate (%)

The insurance and shelter costs were 3% of purchase value. Variable costs include fuel, lubricant, repair and operational costs and are directly related to the amount of work done by the machine. Repair cost for reaper power tiller was considered 3.5% of purchase value for every 100 hours of effective operation. Lubricant cost is 25% of fuel cost. The fuel cost (Diesel) in retail market was considered as Tk. 65 per litter.

The wages of labour in manual method of harvesting using sickle was also calculated and it was Tk. 350 per day (eight hours of working day). For agricultural machinery, the interest rate is considered to be15% of purchase value.

Fixed cost was calculated as:

Fixed cost, FC = Depreciation + Interest on investment + Tax, insurance and shelter

2.6. Break-even analysis

The break-even point, the area that a machine has to work per year in order to justify owning the machine, was determined by the following equation (Alizadeh *et al.*, 2007):

$$\text{Break-even point, } B = \frac{F}{Va - Vm} \quad \text{..........(4)}$$

Where,
B= Break –even point (ha/year)
F= Fixed costs of Machine (Tk./year)
V_a= Variable costs for manual method (Tk./ha)
V_m= Variable costs for machinery method (Tk./ha)

3. Results and Discussion

3.1. Reaper performance

The average value of some of the parameters that include total operating time, total cutting area, forward speed, effective field capacity and field efficiency are shown in Table 1. The average field capacity of imported Chinese reaper and BRRI developed self-propelled reaper was found to be 0.203 ha/hr (50.14 decimal/hr) and 0.250 ha/hr (61.75 decimal/hr), respectively. In manual harvesting with sickle, a laborer on an average, can harvest 40 m^2/hr, but this amount may differ with respect to crop condition, labour ability and climate condition. The required labour for harvesting one hectare of paddy field manually was 184 man-hr/ha compared to 4 man-hr/ha and 5 man-hr/ha for the reapers harvesting.

The average fuel consumption of the imported Chinese reaper and BRRI developed self-propelled reaper were found 0.727 l/hr and 0.826 l/hr, respectively (Table 1). The fuel consumption of BRRI developed self-propelled reaper was slightly higher than that of imported Chinese reaper because of higher horse power of BRRI reaper. The costs of imported Chinese reaper and BRRI developed self-propelled reaper were Tk.2, 20,000 and 1,20,000, respectively. It may be noted that the BRRI developed self-propelled reaper has been fabricated by locally available materials. As a result, its fabrication cost is low (almost half of the imported Chinese reaper).

During the field operation of the reaper, it was found that the walking speeds of imported Chinese reaper and BRRI developed self-propelled reaper were 2.33 and 3.78 km/hr, respectively (Table 1). Similar studies carried out by Alizadeh (2007) showed that forward speed of reaper for harvesting rice was 2.23-2.41 km/hr. Here, the walking speed of BRRI developed self-propelled reaper is higher than that of imported Chinese reaper. But this higher speed is not a problem for an operator to operate the reaper during field operation. On the other hand, the imported Chinese reaper has a drawback i.e. it creates a problem for an operator due to lower height of its handle from the ground level. During operation, the operator is to bend his body during harvesting paddy by the imported Chinese reaper. The operator has to exert an extra downward pressure on the handle during harvesting paddy due to imbalanced weight of the reaper. Those are the major ergonomer problems of the imported Chinese reaper which may create a health hazard in the long run. But BRRI developed self-propelled reaper has no such limitation due to adjustable balanced weight. As a result, the operator can harvest the paddy easily and continuously without any health hazard.

Table 1. Comparison of performance between BRRI reaper and Chinese reaper

Reaper	Place	Total operation time (min)	Effective width of cut (m)	Walking speed (km/hr)	Fuel consumption (l/hr)	Av. fuel consumption (l/hr)	Area covered (m^2)	Field capacity (ha/hr)	Av. field capacity (ha/hr)
Imported Chinese reaper	Rangpur	60.0	1.2	2.33	0.738	0.727	1840	0.184	0.203
	Rajshahi	60.0	1.2	2.33	0.716		2218	0.222	
BRRI reaper	Rangpur	60.0	1.2	3.78	0.836	0.826	2547	0.255	0.250
	Rajshahi	60.0	1.2	3.78	0.816		2443	0.244	

Table 2. Estimated total cost of BRRI reaper and manual harvesting

Machine harvesting cost			Manual harvesting cost	
Cost items	(Tk./Year)	(Tk./ha)	(Tk./ha)	(Tk./hr)
Fixed cost			Here, considered 4-5 labour required per bigha. That is average 33 nos. labour per hectare	
Depreciation	10800.00			
Interest	18000.00			
Taxes, Insurance and shelter	3600.00			
	32400.00			
Total cost	Tk.108/hr	396		
Variable cost				
Fuel		215		
Oil		54		
Labor		175		
Repair & Maintenance		52		
Total Variable cost (Tk./hr)	123 (Tk./hr)	496		
Labor required for making bundles, 8 no./ha		2800		
Total cost of harvesting (Tk./hr)	824 Tk./hr	3692	11550	43.75

Table 3. Estimated total cost of Chinese reaper and manual harvesting

Machine harvesting cost			Manual harvesting cost	
Cost items	(Tk./Year)	(Tk./ha)	(Tk./ha)	(Tk./hr)
Fixed cost			Here, considered 4-5 labour required per bigha. That is average 33 nos. labour per hector	
Depreciation	19800.00			
Interest	33000.00			
Taxes, Insurance and shelter	6600.00			
	59400.00			
Total cost	Tk.198/hr	852		
Variable cost				
Fuel		236		
Oil		59		
Labor		219		
Repair & Maintenance		332		
Total Variable cost (Tk./hr)	173 (Tk./hr)	846		
Labor required for making bundles, 8 no./ha		2800		
Total cost of harvesting (Tk./hr)	900 Tk./hr	4498	11550	43.75

3.2. Harvesting costs

The fixed and variable costs for harvesting paddy with both reapers and manually are shown in Tables 2 and 3. The working hour of self-propelled reaper was assumed to be 300 hr/year (Devani, 1985) and this is also recommended as per ISI standards. Costs of harvesting by the self-propelled reaper were estimated at its optimum conditions with field capacities of reapers as 0.250 ha/hr and 0.203 ha/hr by BRRI developed reaper and imported Chinese reaper, respectively. Labour required for rice harvesting was 248 man-hr/ha, 69 man-hr/ha and 68 man-hr/ha for manual harvesting, imported reaper and BRRI reaper, respectively including bundle making. The cost of manual harvesting was estimated considering the present wage level in Bangladesh, which was Tk. 350 per day for rice harvesting.

In this analysis, labour requirement for collecting and bundling of harvested crops in the field were also included as a part of machine operation. So, the total cost of harvesting by machine included labor cost for collecting and bundling of harvested crops. It was observed from the field study, in manual harvesting generally 4-5 number of labours are required for harvesting one bigha (33 decimals) rice. Thus, 33 numbers of labours were required per hectare. The working hour of each labour was 8 (eight) hours. Total cost of BRRI developed self-propelled reaper, imported self-propelled Chinese reaper and manual harvesting are shown in Tables 4 and 5. The total costs of harvesting operation by BRRI developed self-propelled and imported Chinese reapers were about 3692 and 4498 Tk/ha including bundling of harvested paddy, respectively, where as the manual cost was 11550 Tk/ha. The results indicate that about 68and 61% harvesting costs were saved by BRRI developed reaper and imported Chinese reaper, respectively over manual harvesting, whereas the labour saving was 72% (Tables 4 and 5). On the other hand, about 20 and 18% labour and harvesting costs were saved, respectively by BRRI developed reaper compared to imported Chinese reaper (Table 6).

Table 4. Comparative harvesting cost of BRRI reaper and manual harvesting

Harvesting cost (Tk./ha)		Harvesting time (hr/ha)		Percent cost saved over manual harvesting (%)	Percent labor saved over manual harvesting (%)
Reaper (including labor for binding and collecting)	Manual	Reaper (including labor for binding and collecting)	Manual		
3692	11550	68	248	68	72

Table 5. Comparative harvesting cost of Chinese reaper and manual harvesting

Harvesting cost (Tk./ha)		Harvesting time (hr/ha)		Percent cost saved over manual harvesting (%)	Percent labor saved over manual harvesting (%)
Reaper (including labor for binding and collecting)	Manual	Reaper (including labor for binding and collecting)	Manual		
4498	11550	69	248	61	72

Table 6. Comparative harvesting cost of BRRI reaper and Chinese reaper

BRRI reaper		Imported reaper		Cost saved (%)	Labour saved (%)
Harvesting cost (Tk./ha)	Time (hr/ha)	Harvesting cost (Tk./ha)	Time (hr/ha)		
3692	4	4498	5	18	20

3.3. Break-even analysis

The results of break-even analysis (comparison of manual and machine harvesting) are presented in Figures 1 and 2. Figure 1 shows that a farmer having only one hectare of land has to incur a harvesting cost of Tk. 32,400 by BRRI developed reaper. On the other hand, Figure 2 shows that a farmer having only one hectare of land has to incur a harvesting cost of Tk. 59,400 by imported reaper and Tk. 11,550 per hectare when harvested manually. However, with the increase in annual use of land from 1.0 ha up to 6.0 ha, the cost of machine harvesting decreased exponentially. At the yearly use level of 3.0 hectares, the harvesting cost of BRRI developed reaper and manual method were the same (Figure 1). Therefore, harvesting rice by BRRI developed reaper will be beneficial to the farmers when the annual use exceeds 3.0 hectares of land. Harvesting rice by imported reaper may be beneficial to the farmer when the annual use exceeds 5.0 hectares of land.

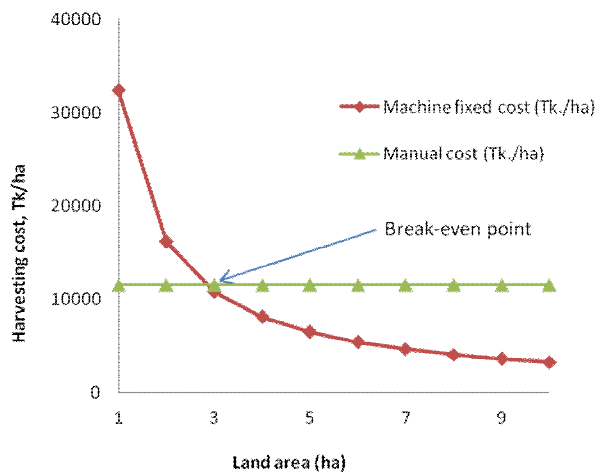

Figure 1. Harvesting cost of BRRI reaper compared to that of manual harvesting

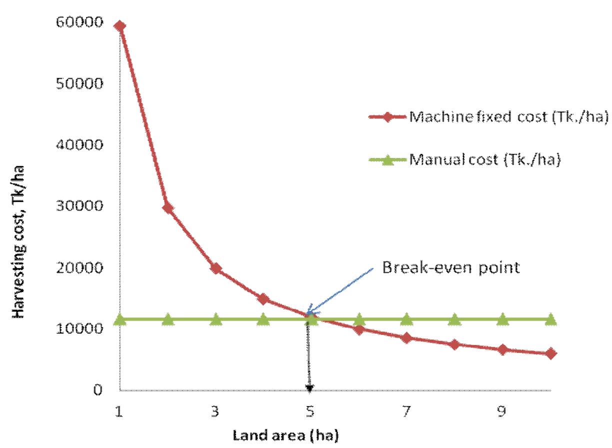

Figure 2. Harvesting cost of Chinese reaper compared to that of manual harvesting

4. Conclusions

The average field capacities of BRRI reaper and Chinese reaper were 0.250 ha/hr and 0.203 ha/hr, respectively compared to 0.004 ha/hr of manual harvesting. According to the test results, the average field capacity of BRRI reaper is greater than that of Chinese reaper. Labour required for harvesting was 248 man-hr/ha, 69 man-hr/ha and 68 man-hr/ha for manual, Chinese reaper and BRRI reaper, respectively including bundling. On an average, 72 and 03% time were saved by the BRRI reaper over manual harvesting and imported reaper, respectively. The cost of harvesting operation per hectare (including bundling) by manual labour was Tk. 11550 and by reaper harvesting was Tk. 3692 and 4498 by BRRI reaper and Chinese reaper, respectively; a reduction of about 68% in harvesting cost whereas the labour saving was 72%. On the other hand, about 20 and 18% labour and harvesting costs were saved, respectively by BRRI reaper compare to Chinese reaper. For economic justification of machine application, the yearly field capacity of machine must not be less than 3 ha and 5 ha for BRRI reaper and Chinese reaper, respectively for profitable use.

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