

# Investigation on Selective Mechanization for Wet Season Rice Cultivation in Bangladesh

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## Abstract

**Purpose:** This study aimed to evaluate the profitability of four selective mechanization systems in rice cultivation. **Methods:** Field experiments were conducted in the farmers' field during the wet season (June to November) of 2015 in Bangladesh. Mechanization systems were applied to evaluate four different selective levels (treatment) in eleven consequent operations. Seedlings were raised in a traditional seedbed and trays for manual and mechanical transplanting, respectively. Land preparation, irrigation, fertilizer, pesticide, carrying, and threshing and cleaning operations were performed using the same method in all the experimental plots. The mechanical options in the transplanting, weeding, and harvesting operations were changed. The mechanization systems were  $S_1$  = hand transplanting + hand weeding + harvesting by sickle,  $S_2$  = mechanical transplanting + Bangladesh Rice Research Institute (BRRI) weeder + reaper,  $S_3$  = mechanical transplanting + BRRI power weeder + reaper, and  $S_4$  = mechanical transplanting + herbicide + reaper. This experiment was performed in a randomized complete block design with four replications. Power tiller, rice transplanter, BRRI weeder, BRRI power weeder, self-propelled reaper, BRRI open drum thresher, and BRRI winnower were used in the respective operations. Accordingly, the techno-economic performances of the different technologies were calculated and compared with those of the traditional system. **Results:** The mechanically transplanted plot produced 6-10% more yield than the hand transplanted plot because of the use of tender-aged seedlings. Mechanical transplanting reduced 61% labor and 18% cost compared to manual transplanting. The BRRI weeder, BRRI power weeder, and herbicide application reduced 74, 91, and 98% labor, respectively. The latter also saved 72, 63, and 82% cost, respectively, compared to hand weeding. Herbicide application reduced the substantial amount of labor and cost in the weeding operation. Mechanical harvesting also saved 96% labor and 72% cost compared to the traditional method of harvesting using sickle. Selective mechanization saved 15-17% input cost compared to the traditional method of rice cultivation. **Conclusions:** Mechanical transplanting with the safe use of herbicide and harvesting by reaper is the most cost- and labor-saving operation. The method might be the recommended set of selective mechanization for enhancing productivity.

**Keywords:** Cost, Harvesting, Herbicide, Threshing, Labor

## Introduction

Rice (*Oryza sativa* L.) is the major food crop covering 77% (10.71 Mha) of the total cropped areas (BBS, 2011). Rice ensures a country's sense of food security. Rice production involves numerous operations. Among which, transplanting,

weeding, harvesting, threshing, and winnowing are identified to affect yield and cost characteristics. Transplanting, weeding, harvesting, threshing, and cleaning are the most labor-intensive operations involved in rice cultivation. In fact, on-season labor shortage is a major problem in some paddy-growing areas of Bangladesh. The high labor demand during peak periods adversely affects the timeliness of operation, thereby reducing the crop yield. The peak farm operation because of the shift of agricultural labor to the

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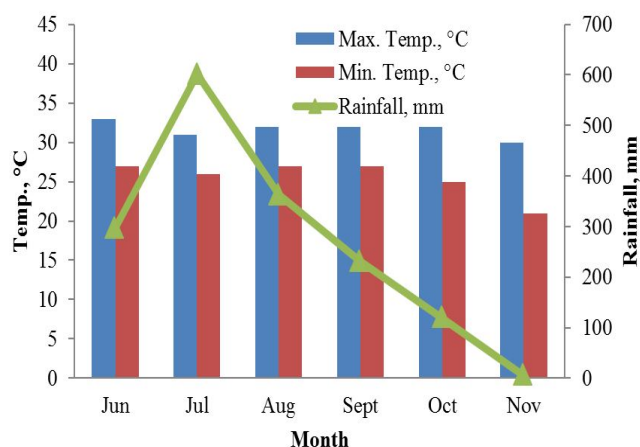
industrial sector. The agricultural labor force follows a decreasing trend (48.3% in 2002-2003 and 45.1% in 2013). Meanwhile, an increasing trend is observed in the non-agricultural sector (51.7% in 2002-03 and 54.9% in 2013) because of shifting from the low productivity to the high productivity sector (BBS, 2015). On the contrary, the drudgery and dignity of farm operations discourage labor to work in on-farm activity. The labor force increasingly becomes costly and scarce during the peak period of farm operations. The traditional method of rice cultivation is incapable, whereas the adoption of mechanization is a way to meet such conditions, albeit with a burden of a large investment (i.e., machine purchase cost). Mechanization in crop production is very important because it aids in the timeliness of operations, eliminates/reduces human drudgery, and improves productivity. Aurangzeb et al. (2007) stated that mechanization boosts up overall productivity and production with the lowest production cost. Mechanization also improves the working condition and performance of jobs that would, otherwise, be difficult or impossible to accomplish using the hand method. The overall cost reduction is also a highly desirable matter, although the net profit may slightly reduce in some situations because farmers prefer to mechanize to avoid problems of timeliness in operation and labor management. Therefore, emphasis should be given to mechanize farming operations and reduce the labor requirement in rice cultivation. The burning question is: Up to which degree is the mechanization suitable? The possible solution may be to adopt mechanization at a selective level considering its appropriateness based on labor requirement, operational capacity, economic feasibility, and outturn facilities. Therefore, a comparison of the different selective mechanization systems for rice cultivation would be required to decide when to adopt mechanization and when to drop it. Selective mechanization based on traditional devices is hypothesized to provide one cost-effective option. Studies on the farm machinery performance were done individually in rice cultivation and post-harvest operations. However, a combined study must be conducted on the major operations executed both in the mechanical and manual manners in the rice field to obtain a complete picture of the difference brought by mechanization in rice cultivation.

Keeping this in view, this study aims to evaluate the effect of adopting mechanical means in eleven selective operations (i.e., land preparation, seedling raising, transplanting, irrigation, weeding, fertilizer application, pesticide application, harvesting, carrying, threshing, and winnowing) and compare the results over the traditional methods. In other words, the study objective is to evaluate the profitability of selective mechanization in rice cultivation.

## Materials and Methods

### Experimental location

This experiment was conducted in the farmers' field ( $25^{\circ}32' - 25^{\circ}46' \text{ N}$  and  $89^{\circ}18' - 89^{\circ}30' \text{ E}$  with 12 m altitude from the mean sea level) located in Purbapara, Pirgacha, Rangpur, Bangladesh. The soil composition of the study area was alluvial soil (80% of the total area) of the Teesta River basin that belongs to the non-calcareous gray floodplain (non-saline) category (UNDP-FAO, 1988). The soil pH ranges from 5.4 to 6.5 with limitations, such as droughtiness in the dry season, rapid to moderate permeability, and low water holding capacity. The climate of the experimental region is tropical wet and dry. The annual rainfall averages to 2931 mm, while the annual temperature ranges from 11 to  $32^{\circ}\text{C}$  (Figure 1).



**Figure 1.** Temperature and rainfall distribution of the experimental period.

## Experimental design

Four mechanization systems were designed for the experiments (Table 1). Eleven operations (i.e., land preparation, seedling establishment, transplanting, irrigation, weeding, fertilizer application, pesticide application, harvesting, carrying, threshing, and winnowing) were considered to evaluate the composite mechanization system. The land preparation, irrigation, fertilizer, pesticide, carrying, threshing, and cleaning operations were conducted in all the experimental plots using the same method. The seedlings were raised in a traditional seedbed and trays for manual and mechanical transplanting, respectively. The mechanical options in the transplanting, weeding, and harvesting operations were changed. The experimental land was prepared using a power tiller. Two methods were used in transplanting, namely, hand transplanting (HT) using traditional seedling ( $S_1$ ) and mechanical transplanting (MT) using special seedling ( $S_2$ ,  $S_3$ , and  $S_4$ ). Four weed control methods were used (i.e., hand weeding (HW), BRRI weeder (BW), BRRI power weeder (BPW), and herbicide control (HC)). In addition, two harvesting methods were used (i.e., manual harvesting by using a sickle in  $S_1$  and mechanical harvesting using a self-propelled reaper in  $S_2$ ,  $S_3$ , and  $S_4$ ). The irrigation water was supplied by a privately owned shallow tubewell. The fertilizer and the pesticide were

applied by hand broadcasting and knapsack sprayer, respectively. The harvested crops were carried from the field to the farm yard on the head and shoulders of those carrying the crops. Furthermore, the crops were threshed using a BRRI open drum thresher (ODT) and cleaned using a BRRI winnower. The experiment was laid out in a randomized block design with four replications. Each of the replication represented a block in the experiment.

The land was well prepared to a puddle condition according to the layout on July 20, 2015. All weeds and stubbles were decomposed. The entire amount of phosphorus, potassium, sulfur, and zinc fertilizer in the forms of triple super phosphate, muriate of potash, gypsum, and zinc sulfate at the rates of 52, 82, 58, and 7.5 kg ha<sup>-1</sup>, respectively, were broadcasted and incorporated into the soil at the final land preparation. Cow dung was used at a rate of 10 t ha<sup>-1</sup> at the time of the final land preparation. Urea at a rate of 180 kg ha<sup>-1</sup> was top dressed in three installments (i.e., at 15 (60 kg ha<sup>-1</sup>), 45 (70 kg ha<sup>-1</sup>), and 55 (50 kg ha<sup>-1</sup>)) a day after transplanting. The standing water was drained out before transplanting. The high-yielding rice variety, BRRI dhan52, was used in all the plots in the experiment. In  $S_1$ , 38-day-old seedlings were manually transplanted by maintaining a spacing of 20 cm × 20 cm on July 23, 2015. However, haphazard transplanting was found in the field in the actual condition. Two or three seedlings

Table 1. Four different mechanization systems in this experiment

Sl no.	Operations	Mechanization system			
		$S_1$	$S_2$	$S_3$	$S_4$
1	Land preparation	PT	PT	PT	PT
2	Seedling establishment	Traditional	Tray method	Tray method	Tray method
3	Transplanting	HT	MT	MT	MT
4	Weeding	HW	BW	BPW	HC
5	Irrigation	STW	STW	STW	STW
6	Fertilizer application	HB	HB	HB	HB
7	Pesticide application	Sprayer	Sprayer	Sprayer	Sprayer
8	Harvesting	Sickle	Reaper	Reaper	Reaper
9	Carrying	HS	HS	HS	HS
10	Threshing	ODT	ODT	ODT	ODT
11	Cleaning	Winnower	Winnower	Winnower	Winnower

PT = power tiller; HT = hand transplanting; MT = mechanical transplanting; HW = hand weeding; BW = BRRI weeder; BPW = BRRI power weeder; HC = herbicide control; STW = shallow tubewell; HB = hand broadcasting; HS = head and shoulder; ODT = open drum thresher.

were transplanted in each hill. In  $S_2$ ,  $S_3$ , and  $S_4$ , 13-day-old seedlings were transplanted using a mechanical rice transplanter on July 23, 2015. A seedling mat was rolled and fed to the transplanter before starting the transplanting process. All the required adjustments, such as hill spacing, number of plant per hill, and planting depth, were also done based on the machine operator's manual. In the mechanical transplanter, a line-to-line distance was fixed at 30 cm. The plant-to-plant spacing can also be varied and set at 17 cm using the machine's space setting panel. The seedling tray required for mechanical transplanting was 165 per hectare. The experimental plots were irrigated as and when needed. Excess water was drained out of the plots before 15 days of harvest to enhance crop maturity. Severe pests infested the plants during the wet season. However, the pests were controlled by a single application of Virtaco40 WG (Clorantanipole + Thiomythoxam at  $300 \text{ g ha}^{-1}$ ), Differ (300 EC-Difeconazole + Propiconazole at  $750 \text{ ml ha}^{-1}$ ), and Nativo75 WG (Trifloxystrobin + Tebuconazole at  $300 \text{ g ha}^{-1}$ ) at the vegetative growth stage. The crops were kept under constant observation from planting to harvesting. Weeding was manually done by hand twice at 18 and 55 days after transplanting (DAT). Machine weeding was performed once at 20 DAT. No other weeding operation was done up to harvest, after which. Different weed species that grew in the experimental plot were identified during weeding. These weeds were counted species-wise. Rifiit (Pretilachlor) at  $100 \text{ ml ha}^{-1}$  was applied at 5 DAT in moist soil by hand broadcasting mixing with urea fertilizer in the plots. A bamboo frame measuring  $0.50 \times 0.50 \text{ m}$  was randomly thrown in the three places of each plot. Moreover, the number of weeds was counted to determine the weeding efficiency. To determine damaged plants, to ensure quality of the work done (Tewari et al., 1993), a bamboo frame of  $0.50 \times 0.50 \text{ m}$  was thrown randomly in three places of each plot and the number of damaged plants in the frame were counted. The data on the weed density were then collected from each plot at the vegetative growth stage of the rice plants using a  $0.5 \text{ m} \times 0.5 \text{ m}$  quadrat following the method described by Cruz et al. (1986). Two sample areas measuring approximately  $10 \text{ m}^2$  were randomly selected in each plot and harvested to

obtain the grain yield. The wet grain weight was adjusted to a 14% (wb) moisture content. The manually transplanted plots matured earlier as the seedling age was 36 days and harvested on November 17, 2015. The transplanted seedlings of 13 days matured later and harvested on November 23, 2015. The data on the working speed, total time, labor requirement, and material inputs were recorded to estimate the production cost. The machine rental charge was also included in the cost estimation. The mechanical weeder was an exception because it had no fuel cost. The land value and the interest on investment were considered to calculate the total production cost. The price of the produce was collected from the local market to compute the total production cost, gross return, gross margin, and benefit-cost ratio. In addition, a statistical analysis was conducted using CropStat 7.2 software. The least significant difference was used to compare the means.

## Results and Discussions

### Machine performance

Table 2 presents the performance parameters of the farm machines used in the study. As reported by Munna (2013), the field capacity of the DP480 model rice transplanter was lower than that of the Kukje model because of the smaller plot sizes. According to Islam et al. (2015a), the field capacity of the BRRI weeder was higher because of less weed infestation and soft soil. Weeding was performed on a contractual basis rather than by daily labor, thereby leading to a faster work. The field capacity of BRRI power weeder was slightly higher than that of the other model as mentioned in Alizadeh et al. (2011) because the soil in the study location was softer than that in Iran. Meanwhile, according to Zami et al. (2014), the field capacity and the fuel consumption of the Vietnamese self-propelled reaper were similar to those of the BRRI self-propelled reaper. Alam et al. (2007) mentioned that the threshing capacity of the open drum thresher was close to  $359 \text{ kg h}^{-1}$ , and the threshing loss was lower compared to 2.16 for the BRRI open drum thresher. The cleaning efficiency

**Table 2.** General performance characteristics of the farm machines

Machine	Forward speed, km h <sup>-1</sup>	Field capacity, ha h <sup>-1</sup>	Field efficiency, %	Fuel consumption, L h <sup>-1</sup>
Transplanter	1.80	0.14	57.09	0.71
BW	2.64	0.06	-	-
BPW	2.44	0.11	51.86	0.65
Reaper	3.67	0.24	53.90	0.84
ODT	Threshing capacity, kg ha <sup>-1</sup>	Loss, %		0.60
	Cleaning	Spilled	Total	
	353	1.30	0.34	
Winnowing	Capacity, kg ha <sup>-1</sup>	Cleaning efficiency, %	Grain loss, %	Electricity consumption, kW h <sup>-1</sup>
	359	99.81	1.77	0.37

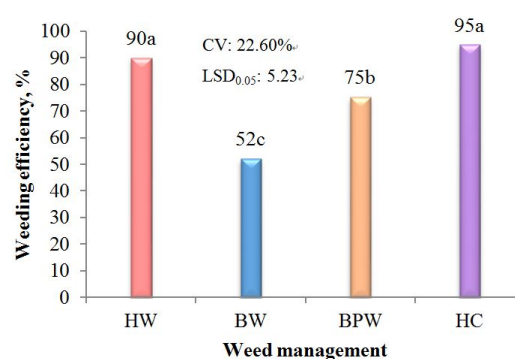
of the BRRI winnower was found satisfactory in a single-pass operation because of the improved design. The grain loss was noticeable, and the winnowing capacity was lower compared to 550-600 kg h<sup>-1</sup> because of the lack of operator's skill.

## Weeding efficiency

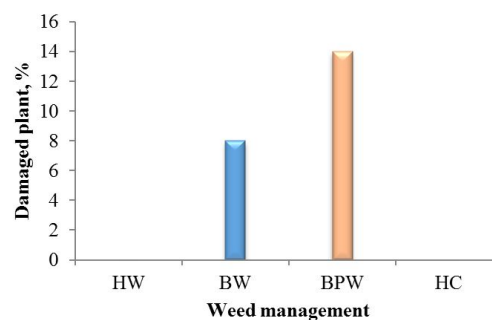
Figure 2 shows the weeding efficiency of the different weed management methods. Apparently, HW and HC successfully controlled the weeds. However, the weeds were seen to regrow in the HW field just after a few days because they were temporarily suppressed and not permanently uprooted. The weed regrowth necessitated second hand weeding. On the contrary, the herbicide successfully controlled the weeds. The efficacy of the herbicide depends on the application time and dose. Among the mechanical weed management options, the BPW showed the highest weed control efficiency. The reason behind the higher efficiency of the BPW compared to that of the BW was the active rotor mechanism of the power weeder that provided a tremendous shuffling force resulting in a much better displacement action against the weeds not only on the surface, but also from the root level. The weeding efficiency of the BPW observed in the present study was similar to that found by Islam et al. (2015a).

## Tiller damage

The damaged tiller ratio reflects the quantity of crops damaged during the weed control operation through



**Figure 2.** Weeding efficiency of the different weed managements.



**Figure 3.** Tiller damage during the weeding operation.

mechanical means. The ratio also depends on the uniformity of the plant-to-plant spacing in the experimental fields. Exact plant spacing is a prerequisite of mechanized weeding, which depends on skilled labor. The plots belonging to the BW and the BPW were transplanted using a rice transplanter. Therefore, the plant spacing was mostly uniform and did not enhance the tiller damage so much. However, the inclination of the plants over the inter-plant spaces caused an obstruction in the movement of the weeder and resulted in consequent crop damage. Figure

3 presents a comparison of the damaged plants in the experimental plots across the treatments. Between the two treatments, the BPW incurred the highest tiller damage (14%) because of high forward speed and blade rotation. The low tiller damage percentage was obtained in the BW (8%), which was operated at a slower speed than the BPW. The data also revealed that between the two weeding methods, the damaged tiller percentage in the BPW was as much as doubled than that in the BW. The

tiller damage in the BW was close to the findings of Islam et al. (2015a), but was higher in the BPW because of the lack of operator's skill and a faster machine speed.

### Grain yield

The mechanically and manually transplanted field showed an insignificant effect on the grain yield (Figure 4). Regular field monitoring was conducted to observe the crop condition. The field was nicely green in the whole period of the experiment, thereby ensuring normal crop growth. Severe and control measures were taken by applying insecticide and pesticide when insect pests and diseases were observed. No lodging of any plants was observed, and the yield was not reduced because of lodging.

### Labor requirement in rice production

Table 3 presents the labor requirement from seedling establishment to winnowing under selective mechanization in rice cultivation.

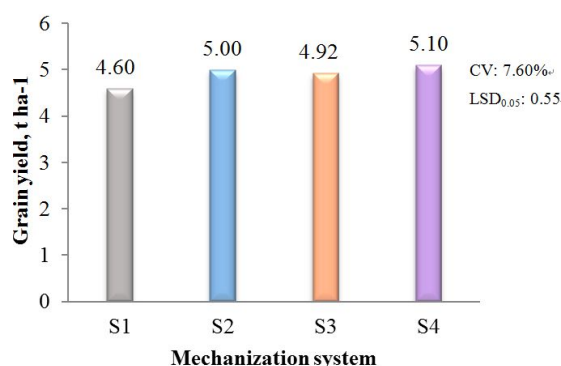


Figure 4. Effect of selective mechanization on the grain yield.

Table 3. Labor requirement in different operations in the selective mechanization systems

Operation	Mechanization system			
	S <sub>1</sub>	S <sub>2</sub>	S <sub>3</sub>	S <sub>4</sub>
Land preparation	16	16	16	16
	(2%)	(4%)	(5%)	(5%)
Seedling establishment	31	62	62	59
	(5%)	(17%)	(18%)	(17%)
Transplanting	150	9	9	9
	(23%)	(2%)	(3%)	(3%)
Weeding	98	26	9	2
	(15%)	(7%)	(3%)	(1%)
Fertilizer and pesticide application	9	9	9	9
	(1%)	(2%)	(3%)	(3%)
Harvesting	103	4	4	4
	(16%)	(1%)	(1%)	(1%)
Carrying	144	144	144	144
	(22%)	(39%)	(41%)	(43%)
Threshing	62	62	62	62
	(10%)	(17%)	(18%)	(18%)
Winnowing	33	33	33	33
	(5%)	(9%)	(9%)	(10%)
Total	646a (100%)	365b (100%)	348c (100%)	338c (100%)

N.B.: CV (%) = 31.30; LSD<sub>0.05</sub> = 14.30.



### Transplanting

The labor requirement in the seedling tray preparation for the mechanical transplanter was 49% higher than that in the traditional method of seedbed preparation because of the higher time required in soil sieving and tray irrigation. In contrast, manual transplanting required 17 times more labor than mechanical transplanting. The present findings coincided with the result mentioned by Islam et al. (2015b). Compared to manual transplanting, mechanical transplanting required 61% less time from seedling establishment to transplanting in the wet season. Islam et al. (2015b) also reported that the labor requirement in seedling raising in the dry season was 71-77 man-h ha<sup>-1</sup>, which was higher than the present findings of 61 man-h ha<sup>-1</sup> because of the lower age of seedlings and the less nursery time required in the wet season compared to that in the dry season.

### Weeding

The weed management method had a substantial effect on the labor requirement. The HW involved the highest labor, whereas the HC required less. Hand weeding reflected the most labor-intensive operation in rice production. The BW, BPW, and HC saved 74, 91, and 98% of the labor requirement in the weeding operation compared to the HW (i.e., 98%). The present results supported the findings reported by Islam et al. (2015a).

### Harvesting

A large variation of the labor requirement was observed in harvesting rice manually and using a reaper. The Vietnamese reaper saved 96% of labor over the traditional method. Alam et al. (2014) mentioned that manual harvesting took the highest labor.

### Total labor requirement

The mechanization system significantly affected the labor requirement in rice production. The highest labor requirement was observed in S<sub>1</sub> when traditional practice was maintained. Among the different mechanical interventions of rice cultivation, the lowest labor requirement was observed in S<sub>4</sub> because of the use of herbicide for weed control. The results indicated that 43, 46, and 48% of labor was saved in S<sub>2</sub>, S<sub>3</sub>, and S<sub>4</sub>, respectively, compared to S<sub>1</sub>. This finding showed that selective mechanization in any form drastically reduced the labor requirement compared to the traditional methods of crop cultivation.

### Economic analysis

Table 4 presents the production costs in different treatments along with the respective operations.

### Transplanting cost

The seedling establishment cost in mechanical transplanting was 38% higher than that in the traditional seed bed

**Table 4.** Operation-wise input cost in mechanized cultivation

Operation	S <sub>1</sub> Tk ha <sup>-1</sup>	S <sub>2</sub> Tk ha <sup>-1</sup>	S <sub>3</sub> Tk ha <sup>-1</sup>	S <sub>4</sub> Tk ha <sup>-1</sup>
Seedling establishment	2,899	4,703	4,703	4,703
Land preparation	7,753	7,753	7,753	7,753
Transplanting	7,510	3,809	3,809	3,809
Irrigation	3,000	3,000	3,000	3,000
Weeding	4,920	1,355	1,830	890
Fertilizer and pesticide application	13,579	13,579	13,579	13,579
Harvesting	5,158	1,446	1,446	1,446
Carrying	7,283	7,283	7,283	7,283
Threshing	4,115	4,115	4,115	4,115
Winnowing	1,890	1,890	1,890	1,890
Total	58,107a	48,935b	49,410b	48,469b

N.B.: CV (%) = 9.2; LSD<sub>0.05</sub>=3,673.

preparation because of the higher labor requirement in seedling raising and nursery management. On the contrary, the cost of manual transplanting was 49% higher than that in mechanical transplanting because of the labor-intensive operation. Mechanical transplanting, including seedling establishment, saved 18% cost compared to the hand transplanting method because of the less operational time required by the mechanical transplanter.

### Weeding cost

Hand weeding required the highest weeding cost, followed by the BPW, BW, and HC. The BW, BPW, and HC saved 72, 63, and 82% cost, respectively, compared to hand weeding.

### Harvesting cost

The manual harvesting cost was much higher because of the higher labor involvement and the increased wage rate in the peak season. Harvesting by reaper saved 72% of cost compared to the manual harvesting method, which showed lower than 89% (Rahman, 2004).

### Input cost

Operations, such as land preparation, fertilizer, irrigation, pesticide, carrying, threshing, and winnowing, took the same expense across the treatments. A significant variation was observed in the seedling establishment, transplanting, weeding, and harvesting operations because of the difference in the methods and the machinery used. A cost analysis showed that the input cost was significantly higher in  $S_1$ , followed by  $S_3$ , because of the higher labor requirement and labor wage, among others. The lowest cost was obtained in  $S_4$ , followed by  $S_2$ , because of the use of the appropriate technology. Irrespective of the combination of technology, selective mechanization saved 15-17% of the input cost compared to the use of the traditional technology.

### Labor and material cost

Table 5 shows the labor and material cost in different treatments. The traditional practices took a significantly higher labor cost than the other three mechanized methods. The labor cost in selective mechanization drastically reduced to 45% because of the use of different farm machineries and technologies. The material cost in the mechanized

**Table 5.** Labor and material input cost in selective mechanization

Parameter	$S_1$ Tk ha <sup>-1</sup>	$S_2$ Tk ha <sup>-1</sup>	$S_3$ Tk ha <sup>-1</sup>	$S_4$ Tk ha <sup>-1</sup>	CV, %	LSD <sub>0.05</sub>
Labor cost	32,907a (57%)	18,791b (38%)	17,955b (36%)	17,511b (36%)	31.4	2305
Material cost	25,200b (43%)	30,144a (62%)	31,455a (64%)	30,958a (64%)	8.90	1900
Total	58,107a (100%)	48,935b (100%)	49,410b (100%)	48,469b (100%)	9.20	3673

N.B.: The figure in the parentheses indicates the percentage. The values are the means of four replicates.

**Table 6.** Effect of the mechanization level on the gross, net returns, and benefit cost ratio

Mechanization system	Production cost Tk ha <sup>-1</sup>	Return from grain Tk ha <sup>-1</sup>	Return from straw Tk ha <sup>-1</sup>	Gross return Tk ha <sup>-1</sup>	Net return Tk ha <sup>-1</sup>	Benefit cost ratio
	A	B	C	D = B + C	E = D - A	F = D / A
$S_1$	80,060	71,848	10,746	82,594	2535	1.03
$S_2$	70,659	78,077	11,678	89,755	19,097	1.27
$S_3$	71,145	76,945	11,509	88,454	17,309	1.24
$S_4$	70,181	79,721	11,924	91,645	21,463	1.31

N.B.: The values are the means of four replicates.



method was 22% higher compared to the traditional method because of the rental charge for the machine and the corresponding fuel cost.

### *Effect of different treatments on the production cost and return*

Table 6 shows the total crop production cost along with the gross and the net return in different treatments. The input cost, rental charge of the land, and interest on investment were included in the total production cost. The gross return was calculated based on the local market price of paddy and straw. The total production cost was the highest in  $S_1$  because of the higher labor involvement compared to the other treatments. In contrast, the gross return was the highest in  $S_4$  because of the higher yield. However, the use of herbicide was affected by rain and was subjected to environmental issues. Herbicides should be used at the right time with the proper dose to minimize the environmental hazard and residual effect. Farmers should be trained on the safe use of herbicide before applying it on their crop field. With the exclusion of  $S_4$ ,  $S_2$  imposed the second highest BCR among all the four treatments because of the lower input cost alongside a moderate good yield.

## Conclusions

The traditional way of transplanting, weeding, and harvesting are labor-intensive, time-consuming, and expensive operations in crop cultivation. Mechanical intervention in all stages saves labor and cost and ensures a faster operation. Mechanical transplanting with herbicide application and harvesting by a reaper is also proven to be the most cost- and labor-saving set of selective mechanization with a significant effect on grain yield compared to the traditional method of rice cultivation. However, an environmental concern is raised on the use of herbicide. On the contrary, the BRRI weeder with mechanical transplanting and harvesting by reaper was the second most labor- and cost-saving set of selective mechanization. An environmentally safer ensuring consistency

in performance is also found in the usage of this method. Mechanical transplanting with the safe use of herbicide and harvesting by reaper could be recommended to farmers under the above mentioned considerations.

## Recommendations

This experiment should be repeated in dry season rice cultivation.

## Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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