Agricultural Sciences, 2025, 16(11), 1199-1213
https://www.scirp.org/journal/as
ISSN Online: 2156-8561
ISSN Print: 2156-8553

Improvement and Field Performance Evaluation of the BARI Seeder

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How to cite this paper: Hoque, M.A., Hossain, M.A., Hossain, M.S. and Khan, M.S.I. (2025) Improvement and Field Performance Evaluation of the BARI Seeder. *Agricultural Sciences*, **16**, 1199-1213.
https://doi.org/10.4236/as.2025.1611069

Received: September 29, 2025
Accepted: November 10, 2025
Published: November 13, 2025

Abstract

Problem of late sowing of *Rabi* (Dry winter) crops can be solved using the power tiller operated BARI seeder (PTOS), which can save time, labour, fuel, and seeds over conventional tilling and seeding by power tiller. However, some problems were identified in the BARI seeder during on-farm operations. The heavy weight of the machine, non-uniform seed placement, missing seeds, and turning complications during operation were found to be the major drawbacks. The problems in the base plate, seed dropping funnel, hitching system, tine, furrow opener, and power transmission system were modified during 2017-2018. The improved seeder was made 15.5% lighter than the original BARI seeder. Seed to seed distances of maize were 4.50 cm and 4.83 cm for the former and the improved seeder, respectively. The spacing of 4.83 cm was closer to the recommended spacing of 5.0 cm. The seed distribution uniformity of the improved seeder was close to 97.33%. The seeding depth of the improved seeder was 3.90 cm, which was very close to the desirable planting depth of 4.0 cm. By the improved seeder (reduced full tillage) or PTOS, strip (ST), and zero tillage (ZT)), a single pass was required to complete land preparation and sowing of seeds in line, whereas the power tiller required 2 - 3 passes for land preparation. Field experiments were conducted in the farmers' fields of Rajshahi and Patuakhali districts in different soil and agro-ecological conditions for tilling and sowing of *Rabi* crops during 2018-2019. The treatments were: seeder (PTOS), strip till, zero till, and power tiller (PT). Significantly higher yields of lentil, mungbean, cowpea, and sunflower were found from PTOS, ST, and conventional tillage (CT), but no significant differences were found among the treatments for wheat. The payback period of the seeder was 2.93 years and that of the power tiller was 3.63 years. The benefit-cost ratio (BCR) of the improved

BARI seeder and power tiller were 1.54 and 1.08, respectively. The improved seeder saved time to prevent late sowing and also reduced labour to curtail crop production cost. In consideration of the above-mentioned advantages, the improved seeder is recommended for reduced tillage, strip tillage, and zero tillage practices in Bangladesh.

Keywords

Seeder, Improvement, Seed Distribution Uniformity, Payback Period, BCR

1. Introduction

Agricultural mechanization is the primary power of modern agriculture and a crucial input for agricultural crop production. It is the continued use of farm equipment to make activities such as land preparation, crop production, harvesting, processing, and transporting goods more efficient [1]. Many developed countries have been revolutionized by the use of farm mechanization, which has resulted in incredible production and productivity gains [2]. Mechanized agriculture involves tools, implements, and powered machinery as inputs to greatly increase farm worker productivity by mechanizing the work of agriculture [3]. The use of agricultural machinery at the field level has increased significantly, and massive potential exists for further increases. In Bangladesh, multiple cropping systems intensification has been enhanced by single-cylinder diesel engines for irrigation pumps and power tiller-based mechanization. Among mechanized on-farm operations, the power tiller is widely adopted for primary and secondary tillage [4]. The most popular farm machines in Bangladesh include power tillers, irrigation pumps, sprayers, rice-wheat threshers, maize shellers, and trailers, etc. The operation-wise farm mechanization in the country is about 97% for tillage and seedbed preparation, 5% for seeding/planting, 100% for plant protection, 20% for harvesting, 100% for maize shelling, and 89% for threshing of rice and wheat [5].

Rabi (dry-season, mid-November to mid-March) crops (Major crops: wheat, maize, potato, mustard, Boro rice, lentil, winter vegetables, etc.) are cultivated after harvesting of Aman rice in most areas in Bangladesh. However, the yield of the crop is very low due to late planting. Generally, the crop is planted after harvesting T. Aman in lands prepared by 3 - 4 tillage operations followed by hand broadcasting of seeds [6]. This process is time-consuming and costly and causes a delay in planting. As a result, yield loss of crops occurs in most cases. Farmers prepare the land by power tillers, which take more time, fuel, and labor, as well as increasing the cost of crop production. On the other hand, land preparation, sowing of seeds in line, and seed covering can be done in a single pass using the BARI seeder [7]. Farmers can plant crops by seeder just after harvesting Aman rice using residual soil moisture. The seeder saves time, fuel, and money for crop production. Some problems in the original BARI seeder were identified in field-level operation. Some of the problems were heavy weight, non-uniformity of seed dropping, less soil compaction, chain dropping, etc. Improvement of the existing BARI seeder was, thus, important for smooth operation of the machine. Therefore, efforts were made to improve the existing BARI seeder. This study was conducted to minimize the above problems and adapt the machine to minimum tillage cum seeder and CA planter and also to evaluate its performance in the farmers' fields for different grain crops in different soil and agro-ecological conditions.

2. Materials and Methods

2.1. Design and Fabrication

The BARI seeder was improved based on all the problems identified from field experiences and farmers' feedback. According to the improved design, a seeder was fabricated by a partner workshop (R. K. Metal, Faridpur) during 2017-2018. Some important manufacturing faults were identified and resolved. The weight of the base plates as well as the total weight of the seeder was reduced. Some parts of the rotavators (both arms, side arms, and power box) were redesigned and produced locally. The power transmission system was changed. A rubber guard was provided to reduce soil spreading. A special type of rotating blade was used for strip tillage [8]. Inverted T-type furrow openers and universal hitching systems were added [9]. Seed dropping funnels were made by plastic molding. The seed plate for mungbean (28 cell and 5 mm thickness) was redesigned and fabricated. The seed plate for soybean and cowpea was also (20 cell and 5 mm thickness) designed and fabricated at R.K. Metal, Faridpur. Different types of base plates and seed plates for different crops were also redesigned. The pictorial views of the seeder detached from the power tiller and the seeder hitched with the power tiller are shown in **Figure 1** and **Figure 2**, respectively.

Different parts of the existing BARI Seeder were modified to reduce weight as shown in **Table 1**. The rotavator and the seed box were modified for weight reduction. The former was made lighter by 16 kg (12.80%), and the latter by 7 kg (30.43%), compared to the original BARI seeder. Due to weight loss, the improved seeder was found to be easy to operate, especially when turning the machine. Thus, the user could operate the seeder for a longer duration and save considerable overall useful time.

Table 1. Modification of weights of different parts of the existing BARI seeder.

Parameter	Existing seeder	Improved seeder	Weight reduction
Weight of rotavator (kg)	141	125	16 (12.80%)
Weight of seed box (kg)	30	23	7 (30.43%)
Weight of base plate (g)	850	450	400 (88.89%)
Weight of each furrow opener (g)	845	641	204 (31.82%)
Total seeder weight (kg)	171	148	23 (15.54%)

Figure 1. Seeder alone detached from the power tiller.

Figure 2. Seeder hitched to a power tiller.

The improved seeder was tested in the laboratory of the FMPE (Farm Machinery and Postharvest Process Engineering) Division of BARI (Bangladesh Agricultural Research Institute), Gazipur, before multiplication of the seeder. Also, the performance of the existing seeder was evaluated simultaneously for comparison. The test was conducted during the period of July-August 2018. The following parameters were evaluated during the laboratory tests.

2.2. Testing and Performance Evaluation

2.2.1. Effective Field Capacity

Effective field capacity was determined by the following equation [10].

$$\text{EFC} = \frac{A}{T} \tag{1}$$

where, EFC = Effective field capacity (ha/h), A = Actual operational area (ha), T = Total operating time (h)

2.2.2. Theoretical Field Capacity

Theoretical field capacity is the rate of sowing seeds that would be obtained if the machine were performing its function 100% of the time at rated forward speed and always covering 100% of its sowing width. It was calculated by the following equation [10].

$$\mathrm{TFC} = \frac{SW}{10} \tag{2}$$

where TFC = theoretical field capacity, ha/h; S = rated forward speed, km/h; W = sowing width, m.

2.2.3. Field Efficiency

The field efficiency was determined by the following equation [10].

$$\mathrm{FE} = \frac{\mathrm{EFC}}{\mathrm{TFC}} \times 100 \tag{3}$$

2.2.4. Coefficient of Seed Distribution Uniformity

To calculate the coefficient of uniformity of seed distribution, a prepared land strip with measurements of 20 × 1.2 m was filled with a layer of fine soil of 50 mm thickness. Planting was performed on the strip at a speed of 2 km/h. An area of two rows with a length of one meter was randomly selected using a wooden frame in each replication. The planted seeds in this area were separated from the soil using a sieve. The coefficient of uniformity of seed distribution was computed using the following equation [11].

$$S_e = 100\left(1 - \frac{Y}{D}\right) \tag{4}$$

where, S_e = coefficient of seed distribution uniformity, %; Y = average numerical deviation of the number of plants per meter length of row from the average number of plants per meter run; and D = average number of plants per meter length of row.

2.2.5. Coefficient of Planting Depth Uniformity

To measure plant depth uniformity, planted seeds were irrigated gently and adequate time was provided for seedling emergence. Once emerged, seedlings were cut at the soil surface. A part of the stem that was inside the soil (from the soil surface to the seed remnants on the root) was taken out and its length was measured. This length was considered as a criterion to compare the seeding depth of the planter. Twenty samples were taken, and the coefficient of planting depth uniformity was calculated using Equation (5) [11].

$$S_d = 100\left(1 - \frac{Y_d}{D_d}\right) \tag{5}$$

where, S_d = coefficient of planting depth uniformity (%), Y_d = average numerical deviation of the depth of seeds planted from the pre-set planting depth (cm), and D_d = average depth of seeds planted (cm).

2.2.6. The Fuel Consumption

The fuel consumption was measured by the top fill method. The fuel tank of the power tiller engine was filled and refilled before and after the planting operation, respectively. The quantity of refilled fuel was measured by a measuring cylinder. The refilled quantity was the fuel consumption. The fuel consumption (L/hr/hp) was obtained by dividing the consumed fuel (L) by the time (hr) the engine was run and the rated horsepower (hp) of the engine.

2.3. Soil and Cropping Pattern

Field experiments were conducted in Tanore and Godagari Upazila of Rajshahi district and Dumiki and Kalapara Upazila of Patukhali district. The agro-ecological zones (AEZ) of Dumki and Kolapara of Patuakhali were AEZ: 13 (Ganges Tidal Floodplain), and the soil type was silty clay loam. Tanore and Godagari Upazila of Rajshahi district fall in AEZ 26 (High Barind Tract) with clay loam soil. The major cropping patterns in Patuakhali were T. Aman-mungbean-fallow and T. Aman-maize-fallow. In Tanore of Rajshahi, the major cropping patterns were T. Aman-wheat/lentil-fallow and T. Aman-potato-T. Aus, whereas in Godagari T. Aman-wheat-fallow and T. Aman-lentil-fallow were the main cropping patterns.

2.4. Field Experiments

Field experiments were conducted in Tanore upazila and Godagari upazila of Rajshahi district and Dumiki and Kalapara upazila of Patukhali district during *Rabi* 2018-2019. The existing common cropping patterns in all the project locations were T. Aman rice-based two crops. *Rabi* crops in the project locations were planted by BARI Seeder. Farmers' plots of about 0.1 ha were the unit experimental plots. The experiment was laid out in an RCBD design with four treatments and three replications. The treatments were: BARI improved seeder with single-pass full tillage (reduced tillage), strip tillage, zero tillage, and conventional tillage by power tiller followed by broadcasting seed sowing.

2.5. Data Analysis

Data for different parameters of the seeder were analyzed using a Microsoft Excel worksheet. Yield and yield-contributing parameters of crops under different tillage and sowing methods were analyzed using Statistix 10 software. Mean differences among the treatments were compared with Duncan's Multiple Range Test (DMRT) or least significant difference (LSD).

2.6. Economic Analysis

A simple economic analysis was done based on total crop production. Production cost included input cost. The input cost was calculated by considering the cost of land preparation, seed, fuel, fertilizers, herbicide, insecticide, irrigation, and hiring charges of labour. The gross return and net return were calculated on the basis of the local market price. The straight-line method was used for the calculation of depreciation. The annual cost of operation of BARI Seeder was computed as the sum of fixed costs and variable costs.

2.6.1. Fixed Cost

Fixed costs (FC) are expenses incurred regardless of whether the machine is operated or not. Fixed cost includes depreciation (D), interest on investment (I), and shelter, taxes, insurance (STI). In the calculation of fixed cost per year, the following equation was used as provided by [10].

$$FC_{yr} = D + I + S_L \tag{6}$$

where, FC = Total fixed cost (Tk/yr), D = depreciation (Tk/yr), I = interest on investment (bank interest rate on agricultural loans), (Tk/yr), S_L = shelter cost (Tk/yr).

Depreciation, $D = (P - S)/L$, where P = purchase price of machines, S = salvage value (10% of P), and L = machine life considered (5 years). Interest on Investment = $[(P + S)/L] * I$, where I = bank interest rate (14%).

$$FC_{ha} = \frac{FC_{yr}}{A_{ha}} \tag{7}$$

FC_{ha} = Field capacity per hectare, A_{ha} = Total seeded area in hectares

In the calculation of shelter (S) or housing of the seeder, 2.5% of the purchase price of the machine was considered, as given by [10].

2.6.2. Variable Cost

Variable costs (VC) are expenses incurred as a result of machine operation. Variable costs include labour cost, fuel, oil, repair and maintenance cost, and the required working hours for each field operation.

Total cost of operation (TOC) of a machine was calculated by [12].

Total cost of machine operation (Tk/ha)

$$TOC = FC + VC \tag{8}$$

Benefit-cost ratio (BCR) is the ratio of annual gross return to total costs. The method of benefit-cost analysis is simple in principle. The formula for calculating BCR (undiscounted) is shown below.

$$BCR = \frac{\text{Gross return}(\text{Tk/yr})}{\text{Cost of production}(\text{Tk/yr})} \tag{9}$$

The payback period is the length of time it takes to recover the invested capital or until the net benefits equal the investment cost. The payback period (PBP) of a machine was calculated by the following equation.

$$PBP = \frac{\text{Initial investment}(\text{Tk})}{\text{Net return}(\text{Tk/yr})} \tag{10}$$

3. Results and Discussions

3.1. Laboratory Performance

Laboratory performance of the existing seeder and improved seeder for maize seed spacing and depth uniformity is shown in Table 2. There were 10 observations, and each observation was replicated three times for both types of seeders. It was observed that seed-to-seed distance was increased by 0.33 cm with the improved seeder, which enhanced the uniformity of seed placement by 7.33% over the original BARI seeder and was much closer to the standard spacing of maize.

Thus, the seed spacing of maize was found satisfactory for the improved seeder. The average seeding depth with the improved seeder was 3.90 cm, which was much closer to the recommended depth (4.00 cm) for maize seed planting. The seeding depth uniformity increased by 18.58% over the original seeder. Therefore, the improved seeder was found more practical for sowing maize seeds than the original seeder.

3.2. Field Performance

Field performance of improved BARI seeder for *Rabi* crops in Rajshahi and Patuakhali is presented in **Table 3** and **Table 4**. Selected methods like seeder (PTOS), strip till (ST), zero till (ZT), and power tiller (PT) were tested in different soil conditions during 2017-2018 (**Table 3** and **Table 4**). The results of a comparative study between improved seeder and conventional power tiller in Rajshahi are shown in **Table 3**. These results are the average of Godagari and Tanore Upazila as they have the same soil condition (High Barind Tract with clay loam soil). The width of each of the tilling methods, PTOS, ST, and ZT was 120 cm, and for power tiller, it was 60 cm. The width of tilling of BARI Seeder was double that of conventional power tiller. However, the forward speed of the BARI seeder was less than that of the power tiller. The lower speed of the BARI seeder was compensated by the width of tilling [13].

Table 2. Performance of the original and improved seeder for the spacing and depth uniformity of maize seeds.

Parameters	Seed dropped in 1.0 running meter			
	Original seeder		Improved seeder	
	Spacing (cm)	Depth (cm)	Spacing (cm)	Depth (cm)
Standard value	5.00	4.00	5.00	4.00
Dropped seeds (Mean)	4.50	3.16	4.83	3.90
Standard deviation	0.52	0.49	0.36	0.07
Uniformity of seeding space or depth (%)	90.00	79.00	97.33	97.58

In Rajshahi, the tilling depths from the soil surface for PTOS, ST, ZT, and PT were 5.78, 5.79, 3.76, and 7.39 cm, respectively. The depth of the BARI seeder was lesser. The reason is that the BARI seeder is used for reduced tillage, *i.e.*, CA (conservation agriculture), but the power tiller is used as a conventional tillage machine. It was also observed that the effective field capacity of PTOS, ST, ZT, and PT were found to be 0.110, 0.109, 0.101, and 0.085 ha/h, respectively. The field efficiency of PTOS, ST, ZT, and PT were estimated as 77.91, 77.29, 75.62, and 77.77%, respectively. The fuel consumption for operation of the improved seeder for PTOS, ST, and ZT were similar except for the power tiller. The power tiller required at least three passes for complete land preparation, whereas the seeder required only one pass for both land preparation and seeding. The improved seeder saved about 62% and 63% fuel compared to the power tiller. Similar results were reported by Mottalib *et al.* [12] for sowing jute seeds in Khulna. By the BARI seeder, tilling (ST and ZT) could be done and seeds could be sown in line following coverage, but the power tiller was only used for land preparation.

Table 3. Field performance of different seed planting methods in Rajshahi.

Treatment	Required tilling passes	Forward speed (km/h)	Tilling width (cm)	Tilling depth (cm)	Fuel consumption (L/h)	Effective field capacity (ha/h)	Field efficiency (%)
Seeder (PTOS)	Single	1.25	120	5.78	1.26	0.110	77.91
Strip tillage	Single	1.24	120	5.79	1.25	0.109	77.29
Zero tillage	Single	1.27	120	3.76	1.24	0.101	75.62
Power tiller	Three	1.89	60	7.39	3.38	0.085	77.77

Field performance of the improved BARI seeder for sowing *Rabi* crops using different methods in Patuakhali (Kolapara and Dumki) is shown in **Table 4**. Similar performances of the seeder over the power tiller were found in Patuakhali and Rajshahi. However, in Patuakhali, greater depths of tilling and higher field capacities of the machines were observed. Two passes were required for land preparation by power tiller; it was three in Rajshahi. This is because the soil of Patuakhali was softer (silty clay loam), but heavier (clay) in Rajshahi [14].

Table 4. Field performance of different seed planting methods in Patuakhali.

Treatment	Required tilling passes	Forward speed (km/h)	Tilling width (cm)	Tilling depth (cm)	Fuel consumption (L/h)	Effective field capacity (ha/h)	Field efficiency (%)
Seeder (PTOS)	Single	1.36	120	6.18	1.20	0.112	78.81
Strip tillage	Single	1.28	120	5.96	1.18	0.110	76.68
Zero tillage	Single	1.37	120	4.12	1.15	0.108	77.54
Power tiller	Two	1.82	60	7.47	3.31	0.086	78.92

Table 5. Yield and yield-contributing characters of lentil at Godagari, Rajshahi.

Treatments	Plant population/m^2	Plant height (cm)	Pod/plant	Seed/pod	1000-grain wt. (g)	Yield (t/ha)
PTOS	112.33 a	38.30 a	61.57 a	1.53 a	21.90 a	1.57 a
ST	93.33 b	36.30 b	52.07 ab	1.07 c	20.59 bc	1.40 ab
ZT	81.67 b	35.40 b	44.20 b	1.13 bc	19.92 c	1.25 b
CT	113.33 a	38.05 a	53.10 ab	1.33 ab	21.30 ab	1.50 a
LSD	14.78	1.67	12.4	0.23	0.88	0.17
CV (%)	7.39	2.25	11.77	9.12	2.1	5.92

Yield and yield-contributing parameters of lentil at Godagari, Rajshahi during *Rabi* 2018-2019 are shown in **Table 5**. Significantly higher yields of lentil were found in PTOS and CT than in ST and ZT treatments. However, there was no significant difference in yields and yield parameters between PTOS and CT and also between ST and ZT. Plant population, plant heights, and pods per plant contributed to achieving the highest yields in full tillage treatments (PTOS and CT). This might be because lentil is a rain-fed crop and more moisture was conserved in the full tillage system than in ST and CT. Hence, plant population and plant growth were greater in the full tillage system, and these influenced higher yields. Considering sowing cost and yield, PTOS was found suitable for lentil sowing in Rajshahi. Similar results were presented by Hoque *et al.* [9].

Yield and yield-contributing parameters of wheat at Tanore, Rajshahi during *Rabi* 2018-2019 are given in **Table 6**. The higher grain and straw yields were found from ST, followed by PTOS, ZT, and CT methods, but there was no significant difference among the treatments. The number of spikes per square meter enhanced the higher grain yields. Other parameters among the treatments were found to be statistically similar, and this finding agreed with [7].

Table 6. Yield and yield-contributing characters of wheat at Tanore, Rajshahi.

Treatment	Plant/m^2	Plant height (cm)	Spike length (cm)	No. of grain/spike	1000-grain wt. (g)	Straw yield (t/ha)	Grain yield (t/ha)
PTOS	207.33	86.67	8.46a	38.67	44.00	5.13	3.26
ST	207.00	90.33	8.79a	39.67	45.00	5.28	3.43
ZT	206.00	89.33	7.79b	38.67	43.00	4.81	3.13
CT	203.67	85.67	8.47a	37.67	43.00	4.80	3.13
HSD	NS	NS	0.41	NS	NS	NS	NS
CV (%)	3.73	2.87	1.74	3.88	2.56	5.65	4.83

Table 7. Yield and yield-contributing characters of mungbean at Kalapara, Patuakhali.

Treatments	Plant/m^2	Plant height (cm)	Pod/plant	Pod length (cm)	Seed/pod	TGW (g)	Grain Yield (t/ha)
PTOS	23.00 ab	39.73 ab	30.37a	7.93 ab	9.60	43.33 a	1.95 a
ST	19.33 ab	34.10 b	21.70b	7.33 bc	8.57	42.33 ab	1.73 ab
ZT	17.00 b	33.93 b	19.57b	7.17 c	8.33	40.67 b	1.65 b
CT	25.00 a	43.67 a	30.07 a	8.07 a	9.47	42.33 ab	1.99 a
HSD	6.88	6.31	6.21	0.69	NS	2.06	0.30
CV (%)	11.54	5.89	8.64	3.22	6.15	1.73	5.79

Yield-contributing parameters of mungbean at Kalapara, Patuakhali during *Rabi* 2018-2019 season are shown in **Table 7**. Significantly higher seed yields were found from PTOS and CT over ST than ZT. Seed yields obtained from PTOS, CT, and ST were statistically alike. The highest pods per plant, pod length, 1000 seed weights, and seed yields were obtained from PTOS and the conventional method than ST and ZT. However, there was no significant difference in seed yield between ST and ZT. The reason might be that mungbean was cultivated in the Patukhali area under rain-fed conditions, and mungbean in ZT plots suffered from moisture stress as there was no rainfall during the growing period. Similar results were found for cowpea (**Table 8**) at Dumki, Patuakhali. The result indicated that PTOS and the conventional tillage method performed better for mungbean in both Kalapara and Dumki upazila in Patuakhali districts. Similar results were presented by Alam *et al.* [15].

Yield-contributing parameters of sunflower at Kolapara, Patuakhali are shown in **Table 9**. Significantly, the highest seed yields were found from PTOS and CT than ST and ZT. Head diameter and thousand seed weight influenced the seed yields. There were no significant differences in seed yields between PTOS and CT. The lowest yield was obtained from ZT plots. The reason might be that no irrigation was applied in sunflower plots and plants might suffer from moisture stress in ZT plots. These results agreed with Bell *et al.* [16].

Table 8. Yield and yield-contributing characters of cowpea at Dumki, Patuakhali.

Treatments	Plant population/m^2	Plant height (cm)	Pod length (cm)	Pod/plant	Seed/pod	TGW (g)	Grain yield (t/ha)
PTOS	15.33	242.33	16.77 ab	20.13	18.73 ab	115.00	1.32 ab
ST	16.33	245.00	17.63 a	20.10	19.47 a	115.00	1.34 a
ZT	15.00	244.00	15.77 ab	19.00	16.70 c	112.00	1.25 b
CT	17.00	247.00	15.33 b	19.00	17.00 bc	113.67	1.32 a
HSD	NS	NS	2.21	NS	1.94	NS	0.07
CV (%)	10.31	1.80	4.78	8.24	3.81	2.58	3.59

Table 9. Yield and yield-contributing characters of sunflower at Kolapara, Patuakhali.

Treatment	Plant/m^2	Plant height (cm)	Head diameter (cm)	Seed/head	1000-grain wt. (g)	Grain yield, (t/ha)
PTOS	6.75 a	125.05 a	60.18 a	471 a	88.78 a	2.08 a
ST	5.50 b	88.95 b	42.08 b	294 b	79.25 b	1.21 b
CT	7.00 a	134.78 a	58.80 a	480 a	86.50 a	2.27 a
LSD	0.64	18.04	40.35	40.35	3.9	0.21
CV (%)	5.81	8.97	5.23	5.62	2.66	6.47

The agroclimatic conditions of Rajshahi and Patuakhali are quite different. Rajshahi falls under AEZ (Agro-ecological zone) 26 (High Barind Tract) with terrace soil, high bulk density, and low organic matter. The seasonal characteristics are drought, low rainfall (annual 1200 mm), and a declining groundwater table. Farmers generally leave crop residues for moisture conservation in the dry season. So, farmers of Rajshahi liked strip tillage rather than full tillage to mitigate drought. On the other hand, Patuakhali falls under AEZ 13 (Ganges Tidal Floodplain); most of the top soils are acidic and subsoils are neutral to medium alkaline (Salinity: 8 - 10 dS/m), with wet soil, poor drainage, late planting, and unusual rainfall

[17]. Farmers generally removed crop residues for early drying of soil. So, farmers of Patuakhali liked full tillage to enhance drying of wet soil.

3.3. Economic Analysis

The economic analysis was done from the viewpoint of the machine owner as well as on a custom hire basis. Fixed cost and variable cost for seeder operation were estimated as Tk. 2460 per hectare and Tk. 1976 per hectare, whereas those for power tiller were Tk. 1886 per hectare and Tk. 3254 per hectare, respectively (Table 10). The economic life of the machine was assumed to be five years. The area under land preparation by both (seeder and power tiller) machine operations per year was 26 and 13 ha, respectively. These are the typical operational areas for local service providers in the study locations and in most areas of Bangladesh. In this point of view, with a seeder, one can till about double the land area compared to a power tiller. It is important to note that the width of the seeder cum tiller is 120 cm and for the power tiller it is 60 cm. The number of tilling tines of the seeder is 48, but for the power tiller the number is 18 - 24. Besides these, the average rotating speeds of the seeder and power tiller are 240 rpm and 480 rpm. Therefore, the area coverage of the seeder became double, and the tilth of soil was found to be better than that of the power tiller [12]. Again, the custom hiring charge for both the machines was estimated as Tk. 7000 per hectare based on the average field data. The average revenue received by the owner of the seeder is Tk. 66664 per year and for the power tiller owner Tk. 24180. Therefore, an LSP (local service provider) or a seeder machine owner can earn an additional Tk. 42484 per year compared to a power tiller owner. The payback period was analyzed to be 2.93 years for seeder machine operation and 3.63 years for power tiller operation. The result also shows that BCR of a seeder was found to be 1.54, which is a profitable venture for an entrepreneur compared to that (1.08) of a power tiller. Miah and Haque [18] found similar results for power tiller and PTOS.

Table 10. Economic analysis of BARI seeder and power tiller.

Items	Unit	Amount	
A. Fixed cost		Power tiller with improved BARI seeder	Power tiller without seeder
Purchase price (P)	Tk	190000	120000
Salvage value (10% of P)	Tk	19000	12000
Depreciation	Tk/yr	34200	21600
Payment for replacement	Tk/yr	29520	16318
Interest (14%) and shelter (2.5% of P)	Tk /yr	10578	7298
Total fixed cost	Tk/ha	2460	1886
B. Variable cost			
Fuel cost (Diesel)	Tk/ha	709	1393
Lubrication (15% of fuel costs)	Tk/ha	106	209

Continued

Repair and maintenance (3.5% of P)	Tk/ha	252	313
Labour/operator cost	Tk/ha	909	1339
Total variable cost	Tk /ha	1976	3254
Total annual operating cost (A + B)	Tk /ha	4436	5140
Annual use in the area	Ha/yr	26	13
Net return	Tk /yr	66664	24180
Benefit-cost ratio (BCR)	Ratio	1.54	1.08
Payback period	Yr	2.93	3.63

4. Conclusion

The original BARI seeder was improved by redesigning some parts of the seeder to reduce its weight and improve its performance. The improved seeder (148 kg) was lighter than the original seeder (171 kg) by 23 kg. The planting depth uniformity of the original seeder (79.0%) was lower than that of the improved seeder (97.58%), which is very close to the desirable planting depth uniformity (100.0%). The problems in the base plate, seed dropping funnel, hitching system, tine, furrow opener, and power transmission system were identified and modified. The seeder could be used as a conservation agriculture machine to perform reduced, strip, and zero tillage with some fitting arrangements. The improved seeder was found suitable for planting different types of crops such as wheat, lentil, mungbean, cowpea, sunflower, etc. Farmers of Rajshahi liked strip tillage, but in Patuakhali, the farmers liked full tillage for planting crops. The payback period of the seeder was 2.93 years, and that of the power tiller was 3.63 years. The BCR of the BARI seeder and power tiller were 1.54 and 1.08, respectively. Farmers liked the single pass reduced tillage-cum-seeding method for saving time and cost.

Acknowledgements

Authors are thankful to R. K. Metal for providing technical support for fabricating the seeder and providing training facilities. Special thanks are given to Krishi Gobeshona Foundation (KGF) for providing financial support, without which it would be difficult to conduct the research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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