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Development of a Motor-operated Maize Seeder for Marginal Farmers

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ABSTRACT

Maize is one of the most growing crops in Bangladesh. Sowing of maize seed is a time consuming, labor-oriented, and tedious operation. To overcome the problems in maize cultivation, a motor-operated maize seeder was designed and fabricated in the Department of Farm Power and Machinery, Bangladesh Agricultural University. A 24 volt DC motor worked as a power unit. The speed of the seeder was fixed with an accelerator governing by a motor controller unit. The power transmission system was chain and sprocket for the drive wheel, and the gear pinion system was used to operate the seed 12-cell plate type seed metering device at a revolution ratio of 1:1.3. The machine possesses an effective field capacity of 0.119 ha/h, field efficiency of 85.86%, average distance of dropping seed 21.29 cm, and an average missing rate of 2.78%, respectively. The fabrication cost of the seeder was USD 142.85, excluding the battery. The financial analysis of the seeder revealed that business by this machine is profitable as the BCR and IRR were found to be 1.54 and 230% with a payback period of 0.43 years if the bank interest rate is 12%. Results also revealed that the machine would be profitable if it can sow in more than 4.95 ha of land per year. The effectiveness of sowing and financial analysis predicts that the machine can be a better option for marginal farmers in sowing maize with less labor orientation and ease of operation securing production cost.

Introduction

Maize (*Zea mays* L.) is the third most important grain crop worldwide and one of the most cultivated crops in Bangladesh. Maize cultivation has been conducted in Bangladesh since 1975 but did not get popularity until 1992 due to low yield and lack of ensured market. With the introduction of hybrid varieties in 1993, yield increased from 1 ton to 7 ton/ha (Matin *et al.*, 2008). Nowadays, it is introduced relatively as the new crop of Bangladesh, especially in the northern region. The maize area has expanded from 334831 to 400469 hectares from the year 2015-2018 occupying the third position among cereals (BBS, 2019) in our country. There is still a deficiency of maize in Bangladesh, and its cultivation area is increasing every year. Bangladesh's government is providing credit at 4% interest for maize cultivation, which is further encouraging farmers. In our country, maize is cultivated mainly in the winter season as the crop fits well into a rice-based cropping pattern. Moreover, the gross return is higher in winter maize (US$ 509/ha) than summer (US$ 352/ha) (Kabir *et al.*, 2005). In manual planting, seeds sown per hill are more than the recommended amount, and a result of overpopulation of seeds and consequently reduces yield due to insect and pest and nutrient and sunlight competition. In the case of maize cultivation, farmers use labor-intensive line sowing, which is an advantage for the introduction of planters. (Ahmad *et al.*, 2014).

Researchers at home and abroad had gone through the development and evaluation of planter for maize establishment. (Singh, 1984; Lara-Lopez *et al.*, 1996; Roth *et al.*, 2001; Rolando *et al.*, 2011). Bangladesh Agricultural Research Institute (BARI) had been working on the development of power-operated maize seeder and designed a power tiller operated inclined plate planter (IPP) for multiple granular seeds and tested its performance and cost-effectiveness. Ahmmed *et al.*, (2004) reported that using a well-designed planter attachment to power tillers (two-wheel tractors) more area could be brought under maize, wheat, pulses, and oilseeds cultivation. Wohab (2003) developed a minimum tillage planter with an effective field capacity of 0.1 ha/h that could save 35% time and 27% cost when compared to traditional methods. Rabbani *et al.* (2016-b) designed and developed a manually operated maize seeder, which was found cost-effective. Hossain (2014) developed and evaluated the performance of a low-cost

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maize seeder. Still, now the seed sowing machine is being used in Bangladesh on a very small scale.

Under intensive cropping systems like in Bangladesh, timeliness of operations is one of the most important factors. During the use of manual seeders for maize, some problems were identified, such as the uneven rotation of the seeder drive wheel and fluctuation in the forward speed of the machine causes uneven rotation of the metering device, which results in non-uniformed seed spacing. When it is self-propelled, the seed metering device can rotate uniformly, and the seed will drop at a uniform distance. If the machine is self-propelled, the drudgery of the operator can be released, and efficiency will be higher. A stable forward speed can be maintained with the help of the power unit.

So, using a motorized seeder will help the farmers in many ways. Although it will be costly comparing to normal seeders, but it will meet the profit. The main objective of this research was to develop a motor-operated seeder and to test the field and financial performance of the seeder for maize seeding

Materials and Methods

The motor-operated seeder was fabricated and tested in the Department of Farm Power and Machinery workshop of Bangladesh Agricultural University during December 2016 to February 2017. Field performances were carried out at the testing bed of departmental workshop during *robi*, the major growing season according to tillage methodology recommended by Bangladesh Agriculture Research Institute. The experimental site was a medium high land containing sandy loam soil with low moisture content.

Components of the motor-operated seeder

The main components of the seeder are a seed hopper, plate type seed metering device, motor, motor controller, starting switch, battery, accelerator/speed regulator, seed tube, furrow opener, runner wheel, supporting wheel and a handle.

Seed hopper

It contained seed and seed metering device. The capacity of that hopper was designed for 1 kg of seed. The hopper was made by mild steel (MS) sheet. The length of the hopper was 20.2 cm, width 25.4 cm, and height 12.7 cm. An isometric view of the seed hopper is shown in Fig. 1.

Plate type seed metering device

The two plate type seed metering devices were used in that seeder, which is made of plastic. The metering device adjusted the seed rate and seed spacing. The diameter of the metering device was 12 cm, with 8 cells open for passing the seed (Fig. 2).

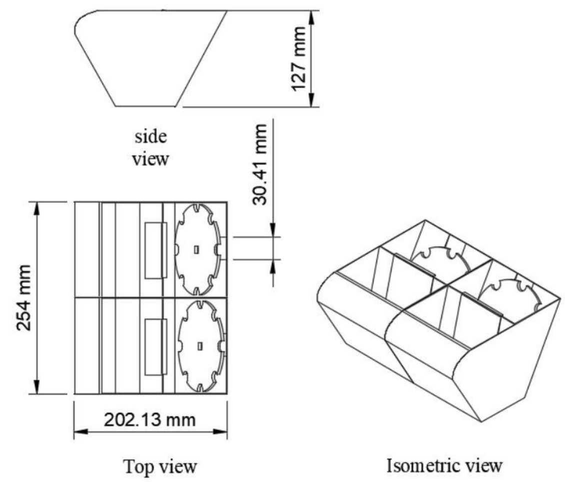

Figure 1. Design of the seed hopper

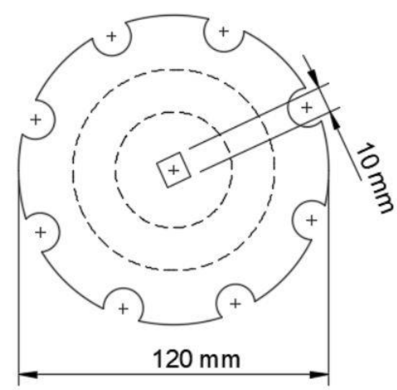

Figure 2. Schematic view of the metering device (8- cell opening)

Motor

A single-phase brushless type motor (Fig. 3) was used as the power unit. Specifications of motor used in the motor-operated seeder are shown in Table 1.

Motor controller

A motor controller was a device or group of devices that serves to govern in some predetermined manner the performance of a motor. A motor controller was connected to a power source such as a battery pack or power supply (Fig. 4).

Battery and accessories

Two rechargeable batteries (Sealed Lead Acid Battery) of 12-volt were used as a power source to power the seeder. The dimension of the battery was 14.9 ×9.8 ×10 cm. It required two hours to charge those batteries by charging kit or adaptor. A starting switch and a modified accelerator were attached with handle. Accelerator or speed regulator is a device that controls speed. This type of accelerator consists of a proximity sensor.

Seed tube and furrow opener

The seed tube was a simple plastic tube through which seeds were passed from the metering device to soil. The seed tube was 254 mm long, and the diameter of the tube was 25.4 mm. It was attached to the opening of the seedbox. A schematic view of the seed tube is shown in Fig. 5. The furrow opener was made of an MS square bar. The length of the furrow opener was 254 mm, with the cutting edge of 30 mm. The schematic view of the furrow opener is shown in Fig. 6.

Table 1. Specifications of the motor used in the seeder

Subject	Description
Product name	CZJB-g2C electric bike conversion kit
Manufacturer name	Changzhou Jiabo Machinery Manufacturing Co., Ltd.
Manufacturer country	China
Motor type	Brushless
Voltage	24 volt
Power	0.5 hp
Rated rpm	420
Weight	3.5 kg

Figure 3. The Motor

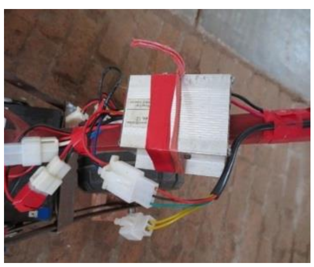

Figure 4. The motor controller

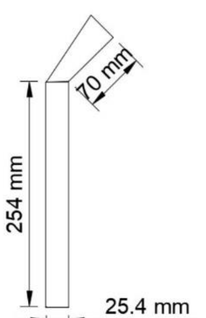

Figure 5. A schematic view of the seed tube

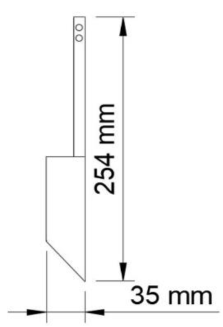

Figure 6. A schematic view of furrow opener

Runner wheel and supporting wheel

The motor-operated seeder had two runner wheels. The runner wheels were made of MS bar. The diameter of the runner wheel was 360 mm. The distance between runner wheels was 600 mm to maintain the spacing between rows. The gaps between of two wheels were changeable. Runner wheels were used to take the seeder in forward or backward direction. The diameter of the supporting wheel was 290 mm and thickness 90 mm. It was attached at a rare position of the machine with the help of four MS flat bar.

Power transmission system

A motor powered the maize seeder during the operation. The power is transmitted from the motor to the wheel shaft through chain and sprocket. From the wheel shaft, power is transmitted to the runner wheel through the direct coupling, and the power is provided to the seed metering device through the intermittent shaft using chain & sprocket and bevel gears. Bevel gears were adjusted with a 1:1.3 gear ratio. Thus the approximate revolution of the metering device was three-quarters of the drive wheel revolution. The flow diagram of the power transmission system is shown in Fig. 7.

Determination of the performance of the seeder

To determine machine performance and field performance of the motor-operated seeder, laboratory tests were conducted at the workshop of the Department of Farm Power and Machinery on an artificial bed made with sand (6.4 m × 2.43 m). The land was prepared by a power tiller before testing the seeder machine. Large course aggregates were separated and broke into small sized particles which was favourable for maize cultivation. Land preparation and other operations were done following the maize cultivation manual by Waddington (2018).

Performance parameters of the seeder

Self-weight, forward speed of the machine, theoretical and effective field capacity and field efficiency was considered as performance parameters of the seeder machine. Performance indicators were calculated by the following equations (Berger *et al.*, 1978).

$$\text{Forward speed (km/h)},\ \mathbf{S} = \frac{D}{t} \times 3.6 \qquad (1)$$

$$\text{Theoretical field capacity (ha/h), Cth} = \frac{SW}{10} \qquad (2)$$

$$\text{Effective field capacity,Ceff} = \frac{A}{T} \qquad (3)$$

$$\text{Field efficiency}(\%) = \frac{\text{Effective field capacity}\ (\frac{ha}{h})}{\text{Theoretical field capacity}\ (\frac{ha}{h})} \times 100\% \qquad (4)$$

Where S = Forward speed, km/h; D = Distance travel by the seeder, m, t = Time required to travel the distance (D), sec., C_{th} = Theoretical field capacity, ha/hr; S = Forward speed, km/h and W = Width of coverage by the seeder, m, C_{eff} = Effective field capacity, ha/h; A = Field coverage, ha and T = Actual time of operation, h.

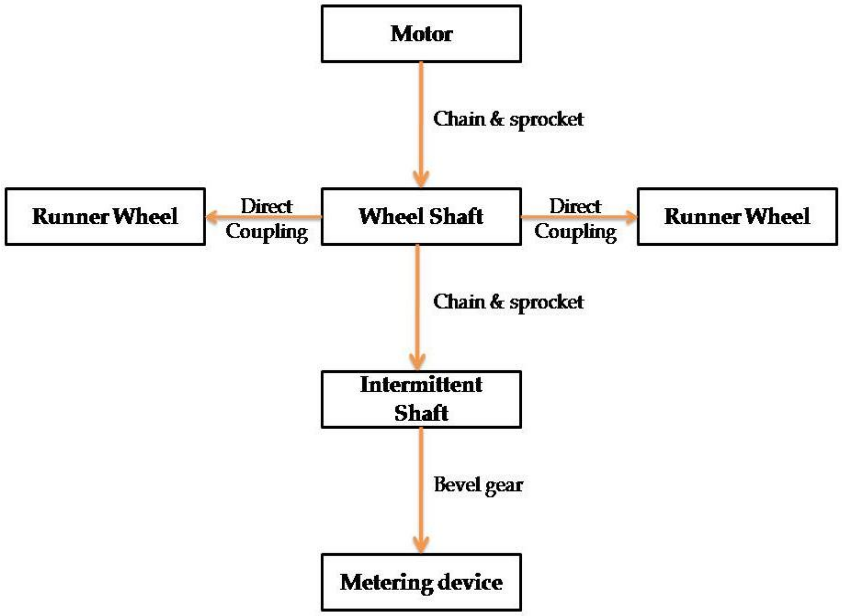

Figure 7. Flow diagram of the power transmission system

Seed spacing

The distance of dropped maize seed, maintained by the motor-operated seeder is measured very carefully. After each pass of the operation, the distance of dropped maize seed was observed and made average.

Missing rate

Percent missing rate was determined by the equation (5).

$$\% \text{ Missing rate} = \frac{N_1}{N_2} \times 100 \qquad (5)$$

Where N_1 = No. of maize seed to drop if no missing occurred and not more than one seed per cell for 10 revolutions of runner wheel and N_2= No. of maize seed actually dropped for 10 revolutions of runner wheel.

Seed rate (%)

The uniform seed rate in the plate type seed metering device was maintained by adjusting the gap of the seed meter. The seed rate for the motor-operated maize seeder machine was calculated by using the equation (6).

$$\text{Seed rate } \left(\frac{\text{number}}{\text{ha}}\right) = \frac{N \times 10^7}{w \times \pi \times d} \qquad (6)$$

Where N= No. of maize seed actually dropped for 10 revolutions of runner wheel, w= Width of the seeder, cm and d= Diameter of the runner wheel, cm.

Seeder Operational Cost

Operation cost consists of (a) fixed cost -Depreciation, interest, taxes and insurance, shelter etc.; (b) variable cost- labor, electricity, and repair and maintenance.

Fixed cost

Fixed cost comprises those costs, which have to bear regardless of the machine is used, namely depreciation, housing, interest on investment, and tax (if any). In this case of the seeder machine, the machine being a small one, the shelter cost is negligible and not applicable because there is no need for seperate shelter. Fixed costs are fixed in total, but decline per ha, as the annual use of the machine is increased (Barnard and Nix, 1979). In the calculation of fixed cost, a straight-line depreciation is assumed, and the following equation (7 and 8) was used (Barnard and Nix, 1979).

$$\text{Depreciation, } D = \frac{P-S}{L} \qquad (7)$$

$$\text{Interest on investment, } I = \frac{P+S}{2} \times i \qquad (8)$$

Where, D = Depreciation, USD/yr; P = Purchase price of machine or implement, USD; S = Salvage value, USD and and L = Life of machine or implement, yr. (assumed 5 yrs.), I= Interest on investment, USD/yr and i = Interest rate (assume 12%), percentage.

Variable costs

The variable cost is one, which changes when the level of output alters. Variable costs depend on hourly labor cost, fuel, oil, repair and maintenance cost, and the required working hours for each field operation. This cost of repair and maintenance was considered 0.035% of purchase price for 100 hours of the seeder's annual use (Hunt, 1995).

Operating cost

Operating costs are recurring costs that are necessary to operate and maintain a machine during its useful life (White *et al.*, 1989). Annual operating costs were divided into fixed costs and variable costs (USD/ha).

Rent out charge

The seeder rent-out cost for an entrepreneur was estimated by adding total operating costs and expected net profit. Net profit was determined as the daily wage of a marginal level farmer.

Benefit-Cost Ratio (BCR)

The benefit-cost ratio is the ratio of present worth benefit to present worth cost. The machinery can be said profitable if the BCR is greater than unity (Hunt, 1977).

$$BCR = \sum PWB / \sum PWC \quad (9)$$

Where, PWB= Present Worth Benefit and PWC= Present Worth Cost

Net present value (NPV)

The net present value (NPV) is a scientific method of present value calculation of inflows and outflows of an investment proposal, using a discount factor and subtracting the present value of outflows to get the net present value. The NPV is calculated by the following formula (Rahman *et al.*, 2015):

$$\text{Net present value (NPV)} = \sum PWB - \sum PWC \quad (10)$$

Internal Rate of Return

The internal rate of return (IRR) is the value of the discount factor when the NPV is zero. The seeder can be said profitable if the IRR value is greater than the Bank interest rate. The IRR can be computed with the help of this formula (Hunt, 1977):

IRR= Lower discount rate + {Difference between the discount rate × (Present worth of cash flow at lower discount rate/Absolute difference between the present worth of cash flow at the two discount rates)} (11)

Payback period

The payback period is the time within which the initial investment is returned as cash. The payback period can be calculated as the following formula (hunt, 1977):
Payback period= total initial investment (USD)/ Net benefit (USD/yr.) (12)

Economic use of seeder

Maize seeder can only be used in sowing operation, and the time of operation is only 50- 65 days in a year. The rest of the year, the machine remains idle, and there is no use of the seeder. So, for determining economic use, a break-even analysis was carried out to calculate the minimum operation area per year.

Results and Discussion

Development of power operated maize seeder

This machine has two rows in two seed hopper for applying seeds. It can be easily operated by one person (male/female). The complete seeder with a schematic diagram is presented in Fig. 8 and 9.

Figure 8. Motor-operated seeder

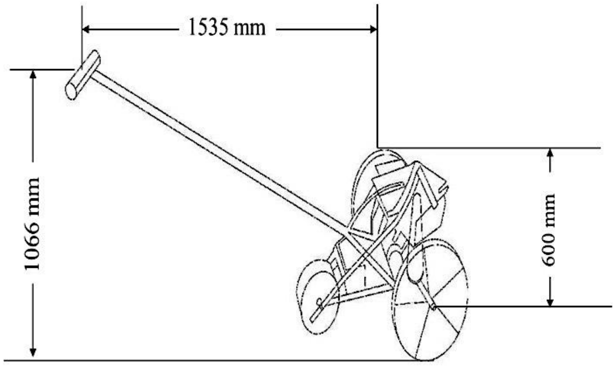

Figure 9. Schematic diagram of motor-operated seeder

Specification of power operated maize seeder

A manually operated seeder developed by Rabbani *et al.,* (2016-b) was selected, and a motor with other accessories was attached to it. The specifications of the power operated maize seeder are shown in Table 2.

Performance of the seeder in laboratory

The machine possessed an effective field capacity of 0.119 ha/hr at forward speed of 2.315 km/hr. the machine had a self weight of 30.7 kg which is too high for a small machine. However, with the heavy weight, the machine as operated with a motor, it was easy to operate, but operator faces difficulty in turning the machine. This causes a time loss during operation. The machine had a field efficiency of 85.86% which pretends the machine as an efficient machine for maize sowing operation. The machine performance of the seeder is described in Table 3.

Table 2. Specifications of the motor-operated maize seeder

Components	No of items	Dimension(cm)	Material
Motor (single phase, dc)	1	Diameter-9.5; Hp-1.5; 420 rpm	
Motor controller	1	7.5×5×3.6	Aluminum
Battery (Rechargeable)	2	14.9×9.8×10; Rating-12V/12 AH	
Seed hopper	2	9.2×25.5×12.7	Iron sheet
Seed metering device (plate)	2	Diameter-12 cm, 8-cell	Plastic
Seed tube	2	Height- 30.48; diameter- 254	Plastic
Runner wheel	2	Diameter- 36	Flat bar
Supporting wheel	1	Diameter-23, thickness- 9	Plastic
Battery cage	2	6×4.5×10	MS Flat bar
Chain & sprockets	2 sets	Set-1: 20 teeth and 9 teeth Set-2: Both 14 teeth	Mild steel

Table 3. Performance of motor-operated seeder

Performance parameters	Unit	Value
Self-weight	Kg	30.7
Area covered	Ha	0.00156
Operational time	S	47.3
Machine width	M	0.60
Forward speed	km/h	2.315
Theoretical field capacity	ha/h	0.138
Effective field capacity	ha/h	0.119
Field efficiency	%	85.86

Seed dropping capacity of the seeder

The test was conducted in two different rpm of the runner wheel, at low rpm 17.3 and medium rpm 28.5. Seed dropping capacity was found 4 and 3.04 kg/h for both rpm, respectively. As the metering device was rotated with the runner wheel at revolution ratio of 1:1.3, so, with the increase of the speed of runner wheel, rotating speed of metering plate increased but seed dropping rate decreased as the metering plate couldnot get proper time to pick seeds which leads to missing rate. So the machine should be operated at lower rpm of the runner wheel for full fill.

Missing rate (%)

The result of the missing rate of the seeder in the laboratory test is graphically presented in Fig. 10. It was observed that the missing rate is low due to the uniform machine speed, and the little variation occurs due to the setting of the metering device. The average missing rate was found at 2.78±0.96 %.

Seed spacing

The seed to seed distance of the applicator in the laboratory test was presented in Fig. 11. The experimental distance of dropped seed was 19.96 cm, whereas the recommended distance was 20 cm (Mondal *et al.,* 2014). From the figure, it was observed that the distance between seeds was varied due to the non-uniform size of the seed and changes in the speed of the machine at the time before turning. Sometimes, operator slow down or operate fast that causes flactuation in machine speed and causes drifting of seeds. Some of the seeds were trapped in between the seed hopper and the metering device due to its inclined face shape. The uniformity thus faces an anomaly, but the seed spacing range lies between 15-25 cm, with highest frequency of 18-21 cm.

Seed rate

The result of the seed rate/ ha of the seeder in the laboratory test is graphically presented in Fig.12. The seed rate that found experimentally was higher than the standard value (25-30 kg/ha) (Azad *et al*., 2019) as the machine has a constraint of multiple seed dropping and missing rate. It varied with the time required for revolutions of seed metering device, seed size, and shape.

Operating cost of the machine

Fabrication cost excluding two batteries was found USD 144.58. If this amount is considered as the machine purchase price and machine life is considered as 5 years with 12% bank interest rate, then fixed and variable cost items become as indicated in Table 4.

Rent out charge

Rent out charge is the total of operating cost, payment for replacement, and profit. The rent-out charge (gross income) was estimated at USD 18.07 per hectare if profit (net income) for the machine owner is considered as USD 6.41 per ha for renting.

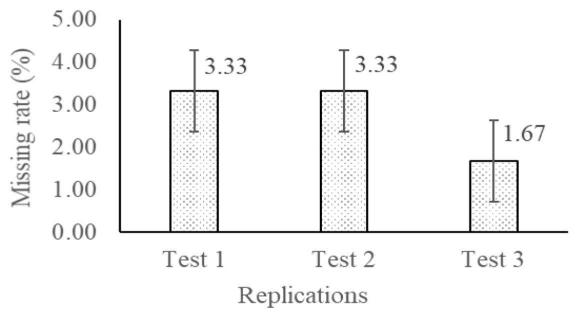

Figure 10. Missing rate (%) of seed

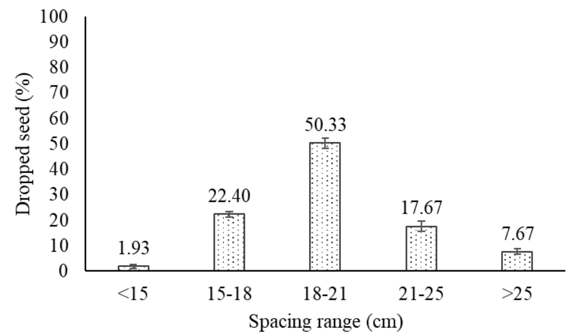

Figure 11. Distance between dropped seeds

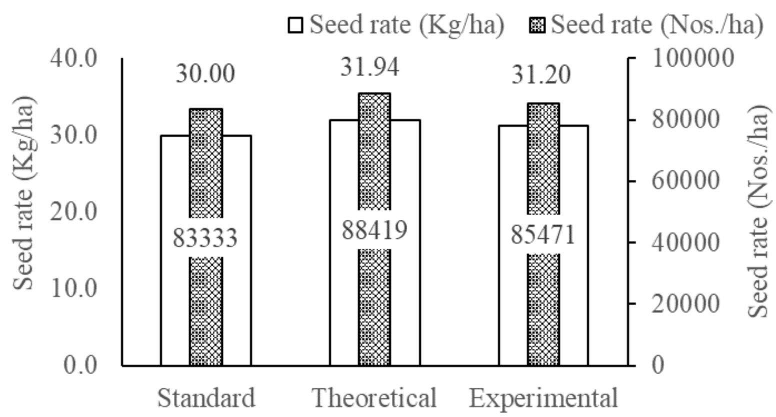

Figure 12. Seed rate compared to standard

Table 4. Cost parameters of the motor-operated seeder

Cost Items		Unit	Amount
Fixed cost items	Purchase price (P)	USD	144.58
	Salvage value (S) (10% of P)	USD	14.46
	Depreciation	USD/yr	26.02
	Interest on investment, I	USD/yr	9.54
Variable cost items	Electricity rate	USD/h	0.04
	Lubrication		0.005
	Repair and Maintenance cost (0.035% of P)	USD/h	0.05
	Cost of the operator	USD/h	1.20
Operational parameters	Average working hours per day		6
	Average working day per year		65
	Field capacity of seeder	ha/h	0.119
	Average working hours per year	ha/yr	46.41
Total fixed cost		USD/yr	35.57
Total variable cost		USD/yr	505.68
Total variable cost		USD/ha	10.90
Total operating cost		USD/ha	11.66

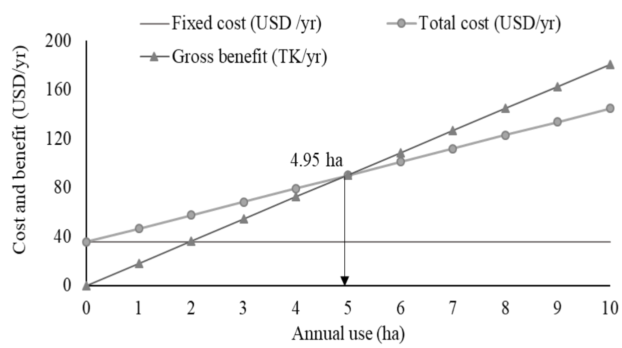

Figure 13. Economic use of motor-operated seeder

Financial analysis

The project appraisal method of financial analysis shows the acceptability of machines from the owners or service providers' point of view (Rahman *et al.*, 2015). From the analysis, at 12% discount factor, NPV of seeder was found USD 1065. The BCR was observed at 1.54. The BCR as higher than unity, the seeder service providing business was found profitable. The IRR was 230%, which is much higher than the bank interest rate which is the indicator of profitability. The payback period was found 0.43 years, i. e. 29 operation days. The payback period indicates that after operating this period, the owner can get back the payment for purchasing the machine. Considering these circumstances, the financial analysis substantiates the seeder as a highly profitable machine from the viewpoint of individual investors.

Economic use of the seeder

A break-even analysis was conducted to determine the economic use of the seeder in terms of operation area per year. Fig. 11 illustrates the break-even analysis for the motor-operated maize seeder. The break-even analysis shows that the minimum use to earn profit for the motor-operated seeder is 4.95 ha per year. The seeder must have a minimum operation of 4.95 hectares per year to meet profit.

Conclusion

The development of maize seeder was almost simple and easy to fabricate with locally available materials. The machine increases the sowing efficiency because of its efficiency, uniformity in sowing, and timeliness. It performs a sowing distance close to the standard value with the low missing rate. The fabrication cost of the motor-operated seeder was within the buying capacity of the marginal farmers of Bangladesh. The BCR was found higher than unity, and the IRR was greater than the bank interest rate. The payback period was found 0.43 years (29 operation days), and in this period, the machine will recover its manufacturing cost or buying cost. The analysis for annual use reveals that the machine will be beneficial if it can be used for more than 4.95 ha per year that will take only 29 operation days according to the field capacity. This time is much lower than the maximum use per year (65 days). So, the machine will bring profit for the rest operation days. The financial analysis indicates its business possibility as a machine and also in custom hire service. So, it can be concluded that the machine can be introduced to the farmers of Bangladesh as an effective and business potential machine.

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