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Design and development of a low cost planter for maize establishment

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ABSTRACT

Maize cultivation gets popularity now-a-days in Bangladesh because of multifarious use of maize as human food and especially in the poultry industries. Maize is cultivated manually which is time consuming, labor intensive and costly. A low cost manually operated push type maize planter was designed, developed and tested in the testing bed of the department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh which reduces these problems. The maize planter consists of two runner wheels, a seed hopper, an inclined plate type seed metering device, a seed tube, a pair of bed former and handle. Power is transmitted from the runner wheel to the metering device through bevel gear mechanism. UniGreen (NK-41) hybrid maize seeds were used to test the planter. The planter was calibrated in the lab to maintain the desired seed rate of 25-30 kg/ha. In the laboratory test, the effective field capacity, field efficiency, average distance of dropped seed, plant population and missing rate were found as 0.128 ha/hr, 76.5%, 22.5 cm, 8 plants/m², and 13.43% respectively for first maize planter. The operational cost of the first maize planter was achieved as 410 Tk/ha whereas in manual planting of maize it is 5250 Tk/ha, thus the planter may save about 92% cost for maize establishment. The pushing force of the maize planter was 90 N, which is quiet low to operate by a female person. The machine might be acceptable since it is easy to operate, simple in design and mechanism, light in weight, requires less labor and cost of planting after further trial in the farmer's field.

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I. Introduction

Maize (*Zea mays L.*) is the third most important grain crop in the world. It is introduced relatively as new crop of Bangladesh especially in the northern region. Every year 1.2 million tons of maize is utilized, of which only 42% is produced in the country and remaining Asian is imported from other countries (BBS, 2011). More than 90% of maize is used as poultry feed and the remaining in fish sector



and as human food products. The country has a great potentiality to improve and expand the maize production. Maize is a crop with versatile uses and it has an enormous market potential in Bangladesh. The country's poultry industry continues to grow and so there is also a growing demand for maize. Maize cultivation has been conducted in Bangladesh since 1975, but did not get popularity until 1992 due to low yield and no ensured market. With the introduction of hybrid varieties in 1993 yield increased from 1 tonne to 7 tonne/ha (Matin et al., 2008). Rapid expansion of poultry industry created a huge demand for maize in the preparation of poultry feed. Shelling of maize was also another barrier for maize cultivation. Roy et al. (2007) reported that power operated maize sheller could overcome the shortage of expensive labour during peak harvesting season. In the last ten years (2000-01 to 2009-10) the maize area has expanded from 2,834 to 50,202 hectares occupying the third position among cereals (BBS, 2011). There is still shortage of maize in Bangladesh and its cultivation area is increasing every year. The Bangladesh government is providing credit at 4% interest for maize cultivation which is further encouraging farmers.

The major factors responsible for low maize yield are the use of low yielding varieties and inadequate cultural management practices particularly in the area of fertilization, insect, diseases, weed control, and most importantly, planting operation. In Bangladesh, maize is normally cultivated manually and in manual planting, seeds sown per hill are more than the prescribed amount. This results to over population and consequently reduce yield due to insect build-up and nutrients and sunlight competition. This method of maize cultivation also requires a lot of labor and time. Farmers practice broadcast sowing of maize which costs less, but final income is also less due to increased plant population rate, higher seed cost, increase intercultural operational cost and lower grain yields. Few farmers practice labor intensive line sowing method with higher labour cost which also encourages the introduction of maize planters. Researchers in home and abroad (Singh et al., 1984; Lara-Lopez et al., 1996; Roth et al., 2001; Rolando et al., 2011) had gone through the development and evaluation of planter for maize establishment. 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 seed and tested its performance and profitability. 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 oil seeds cultivation. Wohab (2003) developed a minimum tillage planter with effective field capacity of 0.1 ha/hr that could save 35% time and 27% cost when compared to traditional methods. Seeding operation of maize in Bangladesh is at low level as farmers still use bare hands or hand tools to sow seed in the furrow beds and then cover the seed by hand. The maize planters available in the market are imported, designed to operate in large farms, expensive and not suited to local conditions. Therefore, the use of big maize planter under Bangladesh condition is not economically feasible. A low cost maize seeder is able to remove all this constraints and suitable for maize establishment in Bangladesh. Thus objectives of this study were to develop a low cost planter for maize planting and to evaluate the performance of the planter in Bangladesh context.

II. Materials and Methods

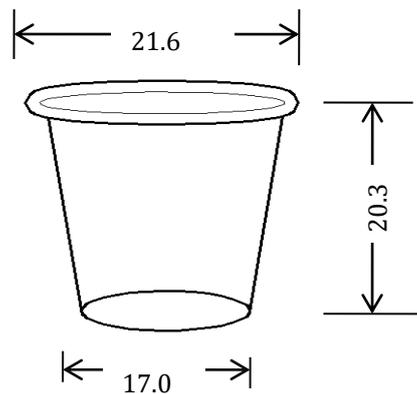
This study was conducted at the workshop of the department of the farm power and machinery, Bangladesh Agricultural University, Mymensingh in 2013 and field performance were carried out in the testing bed of departmental workshop during *robi*, the major growing season according to tillage methodology recommended by the BARI. The experimental site was a medium high land contains a sandy loamy soil with low moisture content.

Components of the Maize Seeder

Main components of the maize seeder were seed hopper, plate type seed metering device, seed tube, disc type bed former, runner wheel and handle. Details of the components are described below:

Seed hopper: It contains seed and the seed metering device. The amount of seed contained depends upon the size of the seed hopper. The capacity of this seed hopper is around 2 kg. The top and bottom

diameter of the hopper was 21.6 and 17 cm, respectively and the depth of the hopper was 20.3 cm. The seed hopper is made by plastic for low cost, light weight and longer life. The Isometric view of seed hopper is shown in Figure 01.



Dimensions are in cm
Figure 01. Isometric view of seed hopper

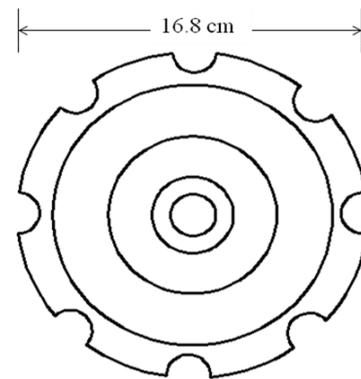


Figure 02. Orthographic view of a plate type seed metering device for the planter (8 teeth)

Plate type seed metering device: Metering device is the most important part of a maize seeder. The seed rate and seed spacing are adjusted by metering device. Maize seeds are relatively large and flat plate type seed metering device is well suited for planting maize seeds. The stationary ring surrounding the plate should fit well for best performance. Plates with round or oval holes were used for drilling and hill dropping seed. The diameter of the metering device is 16.8 cm with 8 cells open for passing the seed. The entire metering device is attached to a vertical shaft. A differential mechanism was used between the vertical shaft and a horizontal shaft, attached to the runner wheels. The orthographic view of a plate type seed metering device for the seeder (8 teeth) is shown in Figure 02.

Seed tube: It is a plastic tube through which seeds were passed from the metering device to the soil. The length of the seed tube was 30.48 cm and diameter was 2.54 cm. It is attached to the bottom of the seed hopper.

Disc type bed former: Bed former is used to form a ridge by gathering soil. The sweep type bed former of the maize planter makes a ridge by gathering soil from the two sides of the falling seed in the land and cover the seeds with soil. The bed formers were made of rigid mild steel sheet. The diameter of the bed formers was 25.4 cm. The bed formers were attached to an adjustable frame maintaining a disc angle of 45° and tilt angle of around 10° to 15° . There were holes on both sides of the frame by which the position of the bed formers were adjusted. This affects in the height and width of the ridge. The isometric view and photographic view of the disc type bed former is shown in Figure 03.

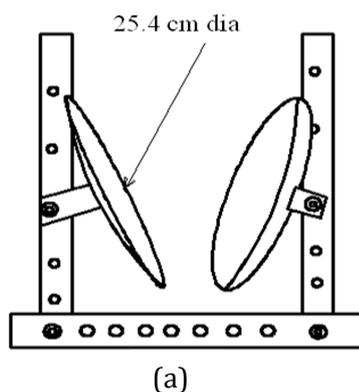
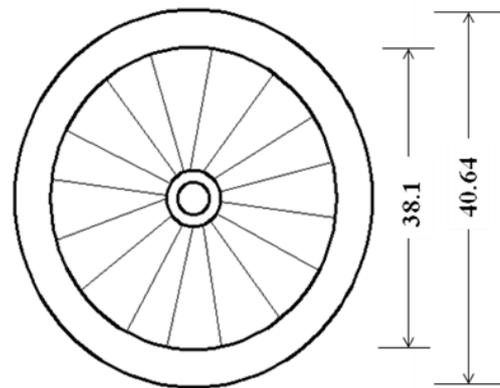


Figure 03. Disc type bed former (a) Isometric view, and (b) Photographic view

Runner wheel: There were two runner wheels in the maize planter. Runner wheels were used to take the planter in forward or backward. The diameter of the runner wheel was 40.64 cm. Distance between the runner wheels was fixed to 60 cm to maintain the spacing between the rows. The isometric view of runner wheel and photographic view of runner wheel are shown in Figure 04.



(All dimensions are in centimeter)

(a)

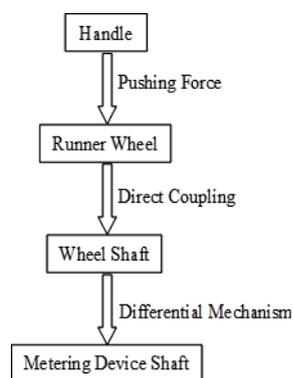


(b)

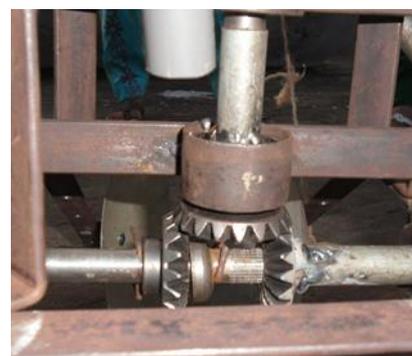
Figure 04. Runner wheel (a) Isometric view, and (b) Photographic view

Handle: By pushing the handle the seeder go forward. The handle was made of GI pipe. The length of the handle was 60.96 cm and diameter of the handle was 2.54 cm.

Power Transmission System: The maize seeder was operated manually to make it cost effective. Power was transmitted from the runner wheel to the seed metering device through bevel gears using a differential mechanism. Flow diagram of the power transmission system is presented in Figure 05(a), and the photographic view of the differential mechanism is illustrated in Figure 05(b).



(a)



(b)

Figure 05. Power transmission system (a) Flow diagram, and (b) Photographic view of the differential mechanism

Test of maize seeder: According to the design the maize seeder was fabricated in the departmental workshop. Finally, the seeder was tested both in the laboratory and testing bed (13.41 m length and 2.13 m width, sandy loam soil texture). The calibration of the maize seeder is shown in Fig. 06. The Field test of the maize seeder is shown in Figure 07.



Figure 06. Calibration of the maize seeder



Figure 07. Field test of the maize seeder

The following performance parameters were tested to evaluate the maize seeder:

Missing rate

Missing rate is determined by the following equation.

$$\text{Percent missing rate} = \frac{N_1}{N_2} \times 100$$

Where,

N_1 = No. of maize seed missing during pickup by metering device into seed tube

N_2 = No. of maize seed drop by the metering device if no missing occurred and not more than one seed per cell.

Field capacity

Turning time at the end of the field was added with actual operating time for effective field capacity determination. Theoretical and effective field capacity of the maize seeder was determined by the following two equations:

$$\text{Theoretical field capacity: } C_{th} = \frac{Sw}{10}$$

Where,

C_{th} = Theoretical field capacity, ha/hr

S = Forward speed, km/hr

w = Width of coverage, m

$$\text{Effective field capacity: } C_{eff} = \frac{A}{T}$$

Where,

C_{eff} = Effective field capacity, ha/hr

A = Field coverage, ha

T = Actual time of operation, hr

Distance of dropped maize seed

Distance of dropped maize seed is a vital measure to control the plant population. In between distances of the dropped maize seeds by the maize seeder were measured very carefully. The bed former beside the seed tube were detached before the operation. After the field trial, the average distance of dropped maize seed was calculated.

Cost analysis

Operational cost of the machine is the sum of fixed cost and variable cost of the machine. The total cost of the machine was determined by knowing the cost of the materials used to fabricate the applicator and fabricating cost of the machine. The cost of operation of the seeder was determined considering the fixed cost and variable cost parameter of the applicator. The operational cost (Tk/ha) was calculated using available market price. For total fixed cost calculation only depreciation and 10% interest on investment were considered. No tax, insurance or shelter costs were considered for Bangladesh context.

Variable cost is related to the operation of the applicator. In calculation of variable cost, labor cost and repair and maintenance cost were considered.

III. Results and Discussion

Development low cost maize planter

All the components of the planter were developed and fabricated in the workshop of the department of Farm Power and Machinery. The self-weight of the maize planter is about 14 kg. A photographic view of fabricated low cost maize planter is shown in Figure 08 and also the Isometric view of the designed maize planter is shown in Figure 09. The overall specification of the maize planter is presented in Table 01.



Figure 08. Photographic view of a designed low cost maize planter

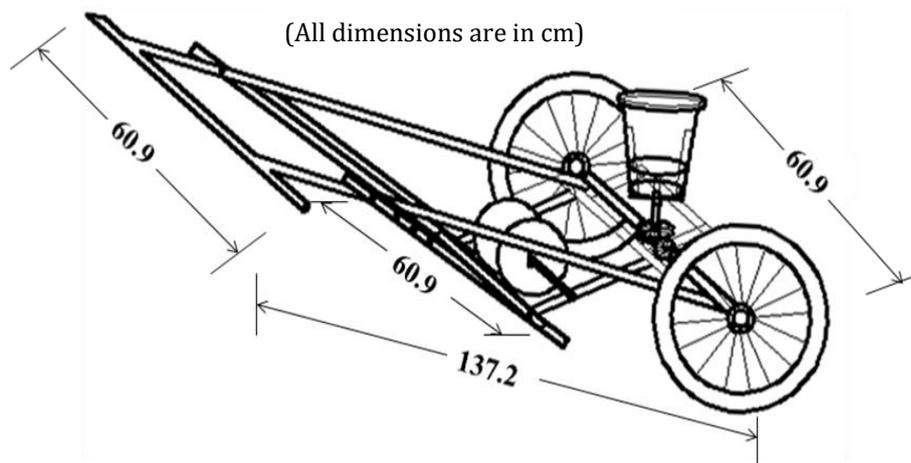


Figure 09. Isometric view of designed maize planter

Table 01 Specifications of a low cost maize planter

Name of the component	No. of items	Dimension (cm)	Materials
Seed hopper	1	20.3 height, 21.6 and 17 diameter	Plastic sheet
Plate type seed metering device	1	16.8 diameter, 8 cell	Plastic
Seed tube	1	30.48 height and diameter 2.54	Plastic
Sweep type bed former	2	diameter 25.4	MS bar
Runner wheel	2	Diameter 40.64	Rubber
Handle	1	length 60.9 and 2.54 diameter	MS bar
Nut & bolts	24		MS bar
Depth Control devices	2	length 33	MS bar

Performance test of low cost maize planter

Missing Rate of the maize planter

Missing rate of the maize planter is presented in Figure 10. It is observed that the missing rate varies due to the changes in speed of the machine. The average missing rate was 13.43%.

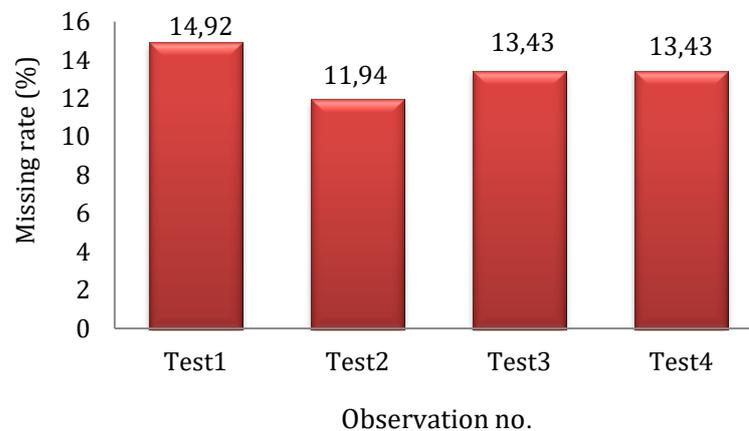


Figure 10. Graphical representation of test of Missing rate (%) for developed maize planter

Field Capacity for developed maize planter

Figure 11 shows the test result of field capacity. It is observed that the effective field capacity varies due to the change in time loss and for variable operational speed of the machine. The machine performance was reduced due to clogging of the bed former when the machine operates in soil of high moisture content. The effective field capacity was 0.101, 0.133, 0.155 and, 0.123 ha/hr for test 1, 2, 3 and, 4 respectively. The average field capacity was found as 0.128 ha/hr.

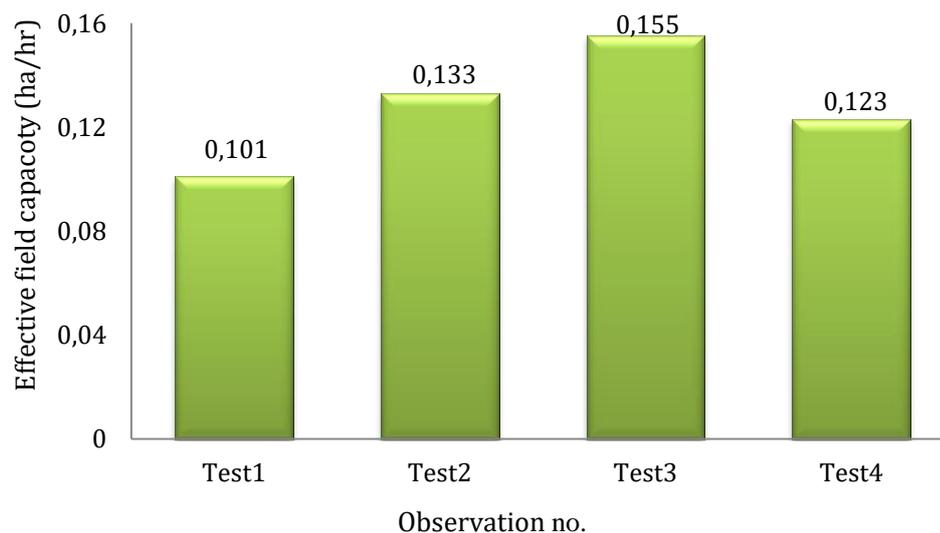


Figure 11. Graphical representation of test of Effective field capacity for developed maize seeder

Field efficiency for developed maize planter

Figure 12 shows the test result of field efficiency. It is observed that the field efficiency varies due to the changes in speed, loading of the seed and/or turning of the machine, and also the field condition. The field efficiency was 60.48 %, 79.64 %, 92.81 % and, 73.65 % for observation 1, 2, 3 and, 4 respectively for different pass with the average field efficiency of 76.65 %.

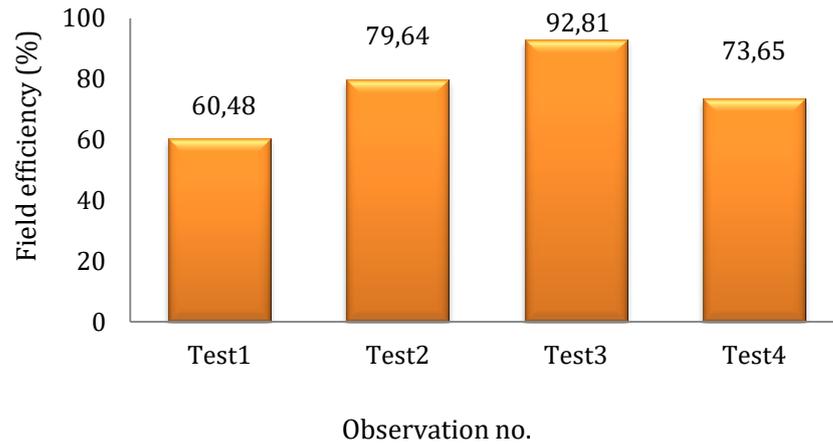


Figure12. Graphical representation of test of field efficiency for developed maize planter

Distance of dropped seed for developed maize planter

The metering device of the planter was calibrated to maintain the desired spacing. It was observed that the distance of dropped seed varies because the metering device was not functioning uniformly due to changes in operating speed of the machine. Some of the seeds were trapped in between the seed hopper and metering device due to its inclined face shape. The average distance of dropped seed was 23.15, 22.57, 22.26 and, 22.03 for test 1, 2, 3, and, 4 respectively whereas the recommended distance was 20 cm by [Mondal et al. \(2014\)](#). Distance of dropped seed in the test of maize seeder is presented in Figure 13.

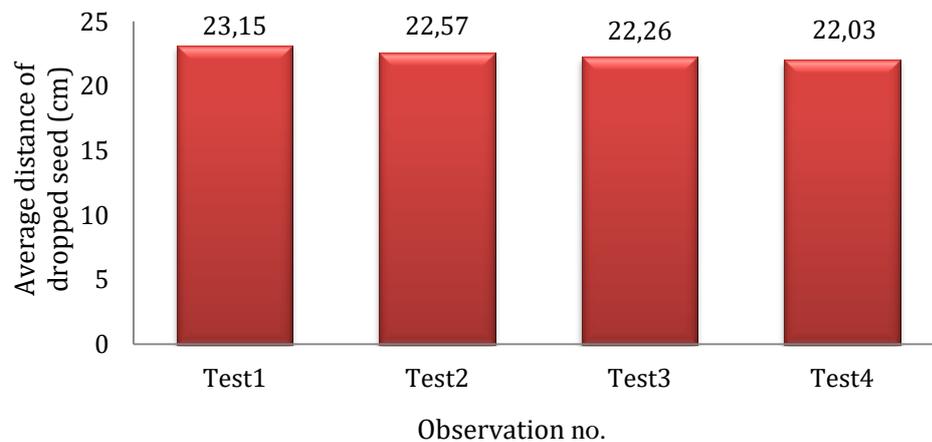


Figure 13. Average distance of dropped seed for maize planter

Test result of plant population

Figure 14 shows the result of plant population of maize. Standard plant population is based on the reference by the CIMMYT as 83000 plants/ha. It was observed that the number of plant was much higher for the manual planting which would have a downbeat affect on the overall yield of maize. Moreover, the plant population for the developed planter was also low than the recommended population. Therefore, the seeder was needed to modify to obtain the appropriate plant population.

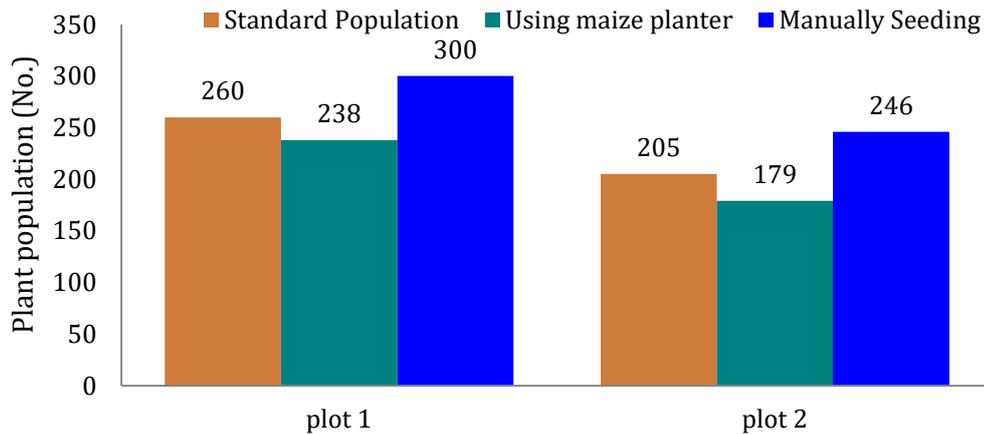


Figure 14. Laboratory test of plant population for developed maize planter

Force measurement

The pushing force was measured by spring balance. Table 02 shows amount of pushing force, draft and drawbar power of the low cost maize seeder. The maize planter required very less power to push. Only 10 kg pushing force was required to operate the planter and 0.044 kW drawbar power was developed by the maize planter.

Table 02: Determination of pushing force and draft

Pushing Force (kg)	Pushing angle (degree)	Draft force (N)	Drawbar power (kW)
10	35.87	79.49	0.044

Total cost of the maize planter

The fabrication cost of the designed maize seeder is presented in the Table 03 below. The manufacturing cost of the developed maize seeder was approximately Tk.1800. The annual cost of the developed maize seeder per hectare was Tk. 410 whereas the manual seeding cost is Tk. 5250/ha (Hossain et al., 2012). Thus, the maize seeder can save about 92% seeding cost for maize cultivation.

Table 03: Fabrication cost of the developed maize planter

Serial no.	Fabrication materials	Quantity, pcs	Lump-sum cost, (Tk.)
1	MS Flat bar	6 kg	240
2	Seed metering device	1	200
3	Seed tube	1	25
4	Seed hopper	1	85
5	Bed former	2	50
6	G.I pipe	4 kg	200
7	Bevel gear	2	175
8	Ball bearing	10	150
9	Wheels	2	500
10	Nuts and bolts	75	150
Total fabrication cost			Tk. 1775

IV. Conclusion

Development of maize planter was simple and very easy to fabricate with locally available materials as evidenced by this study. Its operation was easy and required very less power to push. Therefore, one female person can operate it. The fabrication cost of the maize planter was low. The cost of the developed maize seeder was approximately Tk.1800 which is within the buying capacity of the farmers of Bangladesh. The average missing rates of maize planter was 13.43%. The field capacity of developed maize planter was 0.128 ha/hr and field efficiency of maize seeder was 76.65%. So, the overall performance of low cost maize planter was satisfactory. Therefore, the low cost maize seeder may be accepted for demonstration and use. Calibration of the seed metering device should be done accurately to get right seed rate and seed spacing. The machine should operate at normal working speed (2- 3 km/hr), because too fast causing splitting the seed and slow walking decrease field capacity of the machine. The maize planter is needed to test in the farmer's field to judge its performances.

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