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Performance evaluation of a manual and a motor-operated maize seeder

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Abstract

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A motor-operated maize seeder was designed and fabricated. The performance of the seeder was tested in laboratory and compared with a manual-operated seeder. Hybrid maize seed variety, Sunshine NK40 by Syngenta, was used for the performance test of the seeder during January to April/2017. The two seeders, manual-operated and motor-operated, provided an average seed spacing of 22.48 cm and 20.94 cm, respectively, while the standard seed spacing for maize is 20 cm. The seed spacing of the motor-operated seeder varied from the standard value because of the trapping of seed between the seed hopper and metering device. The missing rate of the manual seeder was 13.2% while the motor-operated seeder provided a missing rate of 5.9%. Due to constant forward speed, the motor-operated seeder resulted in 2.3 times lesser missing rate than the manual seeder. The seed rate of the manual- and motor-operated seeder was found to be 30 kg/ha and 25.7 kg/ha, respectively, although both the seeders were calibrated to maintain a constant seed rate of 25 kg/ha. The field capacity and field efficiency of the existing manual seeder was found 0.128 ha/h and 76.65%, respectively, whereas the field capacity and field efficiency of the motor-operated seeder was found 0.135ha/h and 74.76%, respectively. The motor-operated seeder has a limitation of time loss during turning and the required time loss resulted in low field capacity and field efficiency. Break-even analysis shows that at the yearly use of 0.23 hectares, the operation cost of manual seeder and hand application method were the same. Therefore, manual seeder will be beneficial to the farmers when the annual use exceeds 0.23 hectares of land. Compared to manually-operated seeder, the motor-operated seeder can reduce seed requirement by reducing missing rate and save labor and time of operation if the time loss during turning can be minimized.

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Introduction

Maize is one of the most cultivated crops in Bangladesh, and most cultivation operations are done manually. Manual planting of maize seed is the traditional system of sowing where seeds sown per hill are more than the prescribed amount. This often causes over-population of seeds and, consequently, reduces yield. This method also requires a lot of labor and time. In case of maize cultivation, farmers use labor-intensive line sowing, which indicates scope of introduction of planters (Ahmad *et al.*, 2014). Now-a-days, seeders are being introduced among farmers. The manually-operated seeder is preferable to them because of their affordable cost. Seeder ensures sowing seeds at suitable spacing and seed rate.

The manual seeder, operated by human force also is a time-consuming machine requiring extra labor and, thus, increases cost. In manual seeders, proper spacing cannot be maintained due to improper rotation of the metering device. A motor-operated light-weight seeder can reduce drudgery and also ensure proper spacing.

Mondal *et al.* (2004) developed a power-tiller-operated plate-planter for planting maize and wheat at BARI and observed a planting capacity of 0.2 to 0.25 ha/h with a row and plant spacing of 75 cm and 25 cm, respectively. Matin *et al.* (2008) tested a multi-crop power-tiller-operated inclined-plate planter for maize establishment in winter and summer seasons of 2005 in three districts of Bangladesh. The performance of the planter and profitability of using the planter was evaluated and compared with traditional practice. The average field capacity was 0.19 ha/h, saving total cost of production to 32.8% and labor costs of 79.2% over traditional practice. It was also observed that 18% yield increases in mechanical method using power tiller operated plate-planter compared to the traditional practice of maize planting. Hoque and Gathala (2018) improved the power-tiller-operated planter by modifying its tines for bed and strip planting with a simple maize conversion kit and attached it to the seeder for planting maize. After evaluation, it was observed that the desired seed spacing (20 cm) and uniformity (98%) could be achieved. This

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Performance test of power operated maize seeder

seeder was also tested for full tillage and strip tillage and compared with conventional planting method where modified PTOS machine-planted maize showed higher yield compared to the conventional practice (Hoque and Gathala, 2018). All the seeders discussed above were designed and developed for large farmer and need large investment. Thus, a small seeder is needed for the marginal farmers requiring less technical knowledge.

Metering mechanism is the heart of sowing machine, which has the function to distribute the seeds at a desired rate. In addition, calibration of a seeder is critical in getting the correct number of seeds per revolution of the runner wheel. The selection of seeder machine with a metering device is essential to suit for the crop and soil conditions. Bold seeds like ground nut or maize require seeders with an inclined cell plate or cup-feed type metering system (Rabbani *et al.*, 2016a). The main purpose of sowing operation is to put the seeds in rows at desired depth, maintain seed to seed spacing, cover seeds with soil and provide proper compaction over the seed. The timeliness, labor cost and sowing efficiency of the machine, and uniformity of sowing is also responsible for optimum yield (Rabbani *et al.*, 2016b).

There were some problems of a manually-operated seeder due to uneven rotation of the seeder drive wheel and fluctuation in forward speed of the machine. These cause uneven rotation of metering device and, consequently, the seed spacing remains non-uniform. When it is self-propelled, the seed metering device can rotate uniformly and the seed drops at distance apart. The fluctuation of forward speed can also be minimized as the machine is operated at a fixed forward speed by the power unit. Thus, concentrating on the aforementioned issues, this study was carried out to evaluate performance of a newly fabricated motor-operated seeder for maize seed and to compare the performance of the existing manual- and motor-operated seeders for maize.

Materials and Methods

This study was conducted at the workshop of Farm Power and Machinery Department of Bangladesh Agricultural University, Mymensingh during January to April/2017. The experimental site was a flat land containing sandy loam soil.

Manual and motor-operated seeders

The manually-operated seeder was fabricated and tested in FPMD workshop (Fig. 1). The machine was push-type with two metering devices for two seed hoppers. The power transmission system is a chain and sprocket system with the gear-pinion arrangement.



Fig. 1. Manual seeder

The two-row motor-operated seeder (Fig. 2) contains a single-phase DC motor of 0.75 hp, an aluminum motor controller, a switch, an accelerator (Fig. 3), two batteries with battery cages, two seed hoppers, two metering devices, two runner wheels, sweep-type bed former, a supporting wheel and two seed tubes. The specifications of a manual seeder and the motor-operated seeder are described in Table 1.



Fig. 2. Motor operated seeder



Fig. 3. Handle and switch of motor-operated seeder

Table 1. Specifications of a manual seeder and the motor-operated seeder

Name of the component	No. of items	Dimension (cm)	Material
Manual seeder			
Seed hopper	1	height 20.3, diameters 21.6 and 17	Plastic sheet
Plate type seed metering device	1	diameter 16.8, 8 cells	Plastic
Seed tube	1	height 30.48 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 diameter 2.54	MS bar
Nut & bolts	24		MS bar
Depth Control devices	2	length 33	MS bar
Motor-operated seeder			
Motor(single phase, dc, 24 volt)	1	9.5 Diameter	
Motor controller	1	length 7.5, width 5, height 3.6	Aluminum
Switch	1		Plastic
Accelerator	1		Rubber
Battery(12 volt)	2	length 14.9, width 9.8, height 10	
Seed hopper	2	height 12.7, length 9.2 and width 25.5	Iron sheet
Plate type seed metering device	2	16.8 diameter, 8 cells	Plastic
Seed tube	2	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
Supporting wheel	1	diameter 23, thickness 9	Plastic
Battery cage	2	length 6, width 4.5, height 10	MS Flat bar
Chain & sprockets	2 sets		Cast Iron

Test of seeders:

The performance of a manual and a motor-operated seeder was conducted based on seed spacing, missing rate, field capacity and efficiency of the machines for maize seeds. In the experiment, cell-type metering devices were used, and seed sowing was done in furrow. The manually-operated seeder was tested at the testing bed of the Farm Power and Machinery departmental (FPMD) workshop. The motor-operated seeder was fabricated at FPMD workshop and tested both in the laboratory and testing bed. A photograph of the seeded during calibration is shown in Fig. 4. The metering device used for maize seed sowing is shown in Fig. 5.



Fig. 4. Motor-operated seeder during calibration



Fig. 5. Seed metering device

Laboratory tests:

Parameters of laboratory tests like self-weight, seed rate, etc. were measured in the laboratory.

Self-weight of the seeder: The self-weight of a machine is related to the operational ease of the machine. The self-weight of the applicator was measured by a digital strain gauge scale balance.

Seed rate: By calibrating the seeder in laboratory, seed rate was determined. Uniformity of seed rate on the plate-type seed metering device was maintained by adjusting the gap of seed meter. The seed rate of different types of seed for seeder machine was calculated by (Asha, 2015).

Seed rate (kg/ha) =

$$\frac{\text{Seed obtained by 10 revolution of drive wheel (gm)}}{\text{Width of seeder (m)} \times \text{circumference of drive wheel (m)}} \dots\dots (1)$$

Field test: Field test was done in the testing bed containing sandy loam soil. The length and width of the testing bed was 13.41m and 2.13m, respectively.

Seed spacing: Distance of dropped seeds, maintained by the seeder, was measured carefully. After each pass of the seeding operation, one observer measured the spacing of dropped seeds in the field (Fig. 6). After observation, the average distance of dropped seeds was calculated.



Fig. 6. Distance between two dropped seeds

Performance test of power operated maize seeder

Missing rate: Missing rate of maize seed was determined by the following expression:

$$\text{Missing rate (\%)} = \frac{N_1}{N_2} \times 100 \dots\dots\dots (2)$$

Where N_1 is number of maize seed missing during pickup by metering device into seed tube and N_2 is number of maize seed dropped by the metering device if no missing occurred and there is no more than one seed per cell.

Field capacity: Theoretical and effective field capacity of the seeder was determined by equation (3) and (4), respectively (Kepner *et al.*, 1978). Theoretical field capacity is given by

$$C_{th} = \frac{Sw}{10} \dots\dots\dots (3)$$

Where, C_{th} is theoretical field capacity (ha/h), S is forward speed (km/h) and w is width of coverage (m). The effective field capacity is expressed by

$$C_{eff} = \frac{A}{T} \dots\dots\dots (4)$$

Where C_{eff} is effective field capacity (ha/h), A is field coverage (ha/h) and T is actual time of operation.

Field efficiency: Field efficiency of the machine was calculated by (Kepner *et al.*, 1978):

$$\text{Field efficiency, e (\%)} = \frac{\text{Effective field capacity} \left(\frac{\text{ha}}{\text{h}} \right)}{\text{Theoretical field capacity} \left(\frac{\text{ha}}{\text{h}} \right)} \times 100\% \dots\dots (5)$$

Seeder operational cost: Operation cost consists of (a) fixed cost like depreciation, interest, taxes and insurance, shelter etc. and (b) variable cost like labor, fuel, oil, repair and maintenance etc.

Fixed cost: Fixed cost is defined as one, which remains unchanged when level of output alters (i.e. it applies to a resource that is fixed in quantity). 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). Fixed costs are fixed in total, but decline per ha, as the annual use of the machine is increased (Barnard and Nix, 1979).

The straight-line method is the simplest for the calculation of depreciation and normally used in budgeting, since the concern is usually only with the average annual cost of machine (Barnard and Nix, 1979). Therefore, in calculation of fixed cost, a straight-line depreciation is assumed and the following equation (6) was used.

$$\text{Annual depreciation, D (tk)} = \frac{P - S}{L} \dots\dots\dots (6)$$

Where D = Depreciation (Tk/yr), P = Purchase price of machine or implement (Tk), S = Salvage value (Tk) and L = Life of machine (yr) (assumed 5 years for seeders).

The interest on investment in a seeder is included in fixed cost estimation. This charge is made since the invested money cannot be used for some other interest paying enterprises even if the investment money is not actually borrowed. The following equation was used for the calculation of interest on invest.

$$\text{Interest on investment, I} \left(\frac{\text{tk}}{\text{yr}} \right) = \frac{P + S}{2} \times i \dots\dots\dots (7)$$

Where, I = Interest on investment (Tk/yr) and i = Interest rate (assume 12%).

Insurance should be carried on farm machinery to allow for replacement in case of a disaster or accident. If insurance is not carried, the risk is assumed by the rest of the farm business. There is a tremendous variation in housing. Providing shelter, tools, and maintenance equipment for machinery will result in fewer repairs in the field and less deterioration of mechanical parts and appearance from weathering. To simplify calculating TIH (Tax, Insurance and Housing) costs, they can be lumped together as 2.5 percent of the purchase price.

Variable costs: The variable cost 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 operations. Repair and maintenance cost of seeder involved the price of replaceable parts after a regular interval and some incidental cost during operation. These were mainly bearings, power transmission chain, nuts and bolts of furrow opener and furrow closer. This cost was considered 0.08% of purchase price for 100 hours of the seeder annual use (Hunt, 1995). The cost of operator/labor was calculated as the labor rate in Tk/h.

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. All calculated fixed costs and variable costs were converted into Tk/ha and then summation of fixed and variable costs had given operating costs in Tk/ha.

Break-even use: It is the common phenomena of costing any agricultural machinery where the total cost per hectare decreases as annual use increases. This concept was used to determine the break-even use. Operation of seeder on the break-even usage, that is, the amount of land use for which the costs for seeding operation with seeder is the same as the costs of hand application. The break-even use (BEU) can be determined by the following equation.

$$\text{Break-even use, BEU (ha/yr)} = \frac{\text{Fixed cost (Tk/yr)}}{\text{Manual sowing cost (Tk/ha) - Variable cost of seeder (Tk/ha)}} \dots\dots\dots (8)$$

Results and Discussion

Self-weight: The manual seeder had a self-weight of 17 kg. The self-weight of the motor-operated seeder was 31.7 kg. This additional weight for the motor-operated seeder was due to batteries, DC motor and modification of chassis to hold them.

Table 2. Missing rate of motor-operated seeder

Obs. no.	Length of field (cm)	Standard distance to drop seed (cm)	Number of seeds dropped theoretically	Actual number of seeds dropped	Missing rate (%)	Average missing rate (%)
1	558	20	28	26	7.1	5.9
2	558	20	28	26	7.1	
3	558	20	28	27	3.5	

Table 3. Missing rate of manual seeder

Obs. no.	Length of field (cm)	Standard distance to drop seed (cm)	Number of seeds dropped theoretically	Actual number of seeds dropped	Missing rate (%)	Average missing rate (%)
1	558	20	28	24	14.3	13.1
2	558	20	28	25	10.7	
3	558	20	28	24	14.3	

Comparative missing rate: The average missing rate was 13.1% for the manual seeder and 5.9% for motor-operated seeder.

Seed spacing of maize for the motor-operated seeder:

The seed spacing for the three trials were found as 21.12 cm, 22.12 cm and 19.57 cm. Average seed spacing was 20.94 cm, which is very close to the standard value of 20 cm. Fig. 7 shows distance of dropped seeds (total 77) in 3 trials. The maximum seed dropped at a distance between 18 cm and 23 cm. About 9.21% seeds were dropped at less than 13 cm apart. This happened when the seed size was too small, and the metering device holds more than one seed. About 7.89% seeds were dropped at a distance greater than 33 cm and 13.15% at a distance of 29-33 cm, which increased the missing rate.

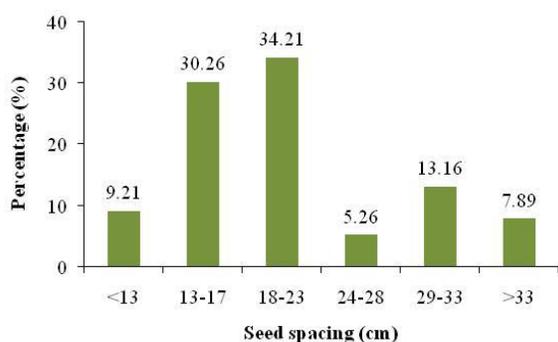


Fig. 7. Spacing of maize seed for the motor-operated seeder

Comparative seed spacing: Fig. 8 shows a comparison of the average seed spacing of maize sown by the manual seeder and motor-operated seeder. The average seed spacing for the manual seeder was 22.48 cm. The motor-operated seeder provided an average seed spacing of 20.94 cm.

Missing rate of the two seeders: The results of missing rate for maize sowing observed from the laboratory test of the motor-operated and manual-operated seeders are presented in Table 2 and Table 3, respectively.

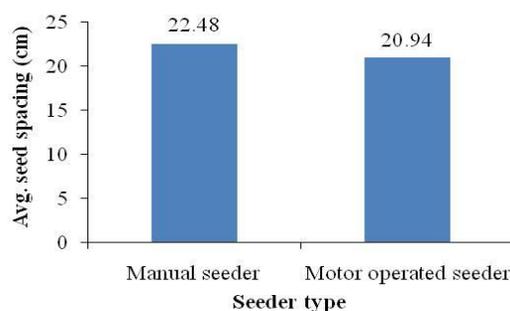


Fig. 8. Seed spacing of two seeders

Field capacity of the seeders: The field capacity of the manually-operated seeder was found 0.128 ha/h and that of motor-operated seeder was 0.135 ha/h. Fig. 9 demonstrates comparative field capacity of the two seeders. The average forward speed for the manual seeder was 2.3 km/h and that of the motor-operated seeder was 2.5 km/h.

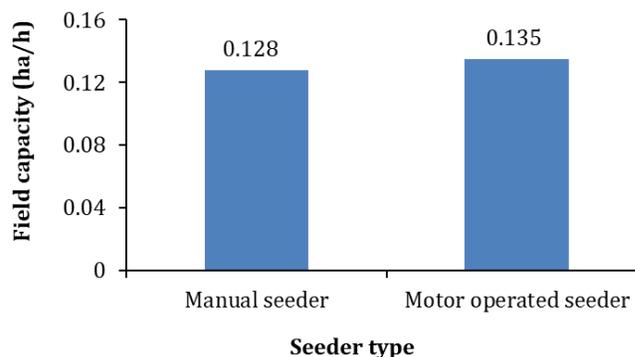


Fig. 9. Field capacity of two seeders

Field efficiency of the seeders: The manually-operated seeder performs at an efficiency of 76.65% but the motor-operated seeder performed at 74.76% efficiency (Fig. 10). The turning time of motor-operated seeder was relatively higher that caused reduction in its efficiency.

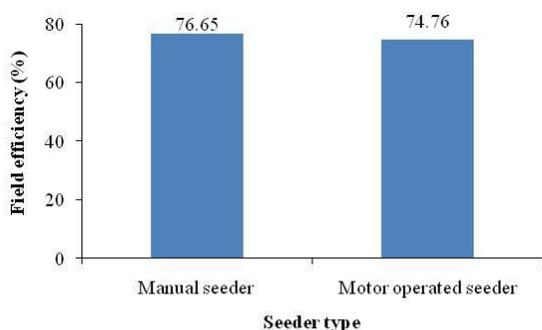


Fig. 10. Field efficiency of two seeders

Seed rate: The average seed rate of the manual seeder was 32 kg/ha while the motor-operated seeder has a seed rate of 25.78 kg/ha. Fig.11 illustrates seed rates of the two seeders and their comparison with the standard rate for maize. The standard seed rate for maize was obtained from BARI Handbook (2014). It is observed that the seed rate varies with the time required for revolutions and seed metering devices. Skidding was also a reason for variation in optimum seed rates. Besides, some of the

seeds were trapped between the seed hopper and the metering device due to the uneven size of the seeds.

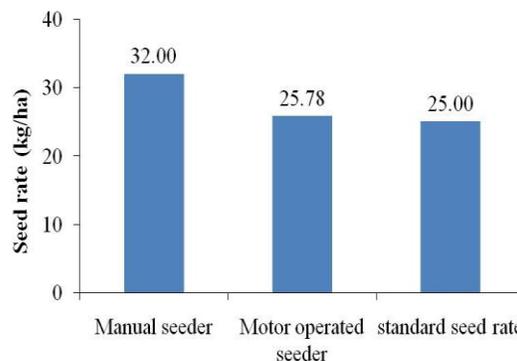


Fig. 11. Seed rate of two seeders with standard value

Operational cost of seeders: Cost of operation of two seeders was calculated based on their field capacity and fabrication price. Table 4 presents the cost parameters of two seeders along with manual sowing.

Table 4. Operational costs of motor-operated seeder, manual seeder and manual sowing

	Cost items	Motor-operated seeder	Manual seeder	Manual Sowing
Fixed cost items	Purchase price of Seeder (P) (Tk)	10,000	4,900	-
	Salvage value (S) (10% of P) (Tk)	1,000	490	-
	Working life (L) (yr)	5	5	-
	Interest on investment (Tk/yr)	550	270	-
	Sheltering (2.5% of P) (Tk/yr)	250	123	-
	Interest rate (%)	12%	12%	-
Variable cost items	power consumption cost (Tk/h)	3.00	0.00	-
	Repair and Maintenance (0.035% of P) (Tk/h)	3.50	1.72	-
	Repair and Maintenance cost (Tk/yr)	1,050	823	-
	Cost of labor (Tk/h)	0	0	50
	Cost of operator (Tk/h)	50	50	-
	Average working hours per day	5	8	-
Average working day per year	60	60	-	
Average working hours per year (h/yr)	300	480	-	
Field capacity (ha/h)	0.135	0.128	0.0084	
Average field coverage per year (ha/yr)	40.5	61.44	-	
Fixed cost	Depreciation (Tk/yr)	1,800.00	882.00	-
	Interest on investment (Tk/yr)	550	270	-
	Sheltering (Tk/yr)	250	123	-
Total fixed cost (Tk/yr)		2,600.00	1,274.00	-
Variable cost	Fuel (Tk/h)	3	0	-
	Lubricant (Tk/h)	0.45	0	-
	Repair and Maintenance cost (Tk/h)	3.5	1.715	-
	Cost of operator (Tk/h)	50	50	-
	Cost of labor (Tk/h)	0	0	50
Total variable cost (Tk/h)		56.95	51.72	-
Total variable cost (Tk/ha)		421.85	404.02	-
Operating cost (Tk/ha)		486.05	424.76	5952.38

The total costs of operation by power-operated seeder and manual seeder were 486.05 and 424.76 Tk/ha, respectively, whereas cost for hand operation was 5952.38 Tk/ha. The results indicate that 91.83% and 92.86% costs were saved by power-operated seeder and manual seeder, respectively over hand sowing. On the other hand, about 14% operating cost was increased after

adding the motor and other accessories to the manual-operated seeder. This is due to the high price of the motor, which acted as a prime mover for seeding operation in power-operated seeder.

Break-even analysis: The results of break-even analysis (comparison of hand sowing and both of the seeder

machines) are presented in Figure 12. It shows that a farmer having only any one of the two seeder machines has to incur a cost of Tk 2600 and Tk 1274 by power-operated seeder and manual seeder, respectively. However, with the increase in annual use of land the cost of hand sowing increased quite steeply compared to both of the seeders. At the yearly use of 0.23 hectares, the

operation costs of manual seeder and hand sowing were the same (Figure 12). Therefore, manual seeder will be beneficial to the farmers when the annual use exceeds 0.23 hectares of land. Similarly, power-operated seeder may be beneficial to the farmer when the annual use exceeds 0.47 hectares of land.

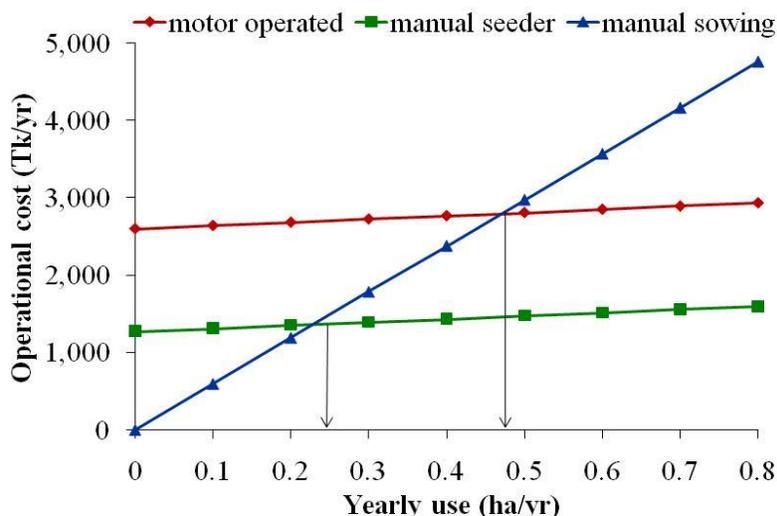


Fig. 12. Break-even use of seeders

Conclusion

The seed spacing of the motor-operated seeder varies from the standard value because of the trapping of seed between seed hopper and metering device. The missing rate of the motor-operated seeder was found 2.3 times lesser than that of manual seeder. The effective field capacity of the motor-operated seeder was satisfactory compared to the theoretical capacity of the machine. The dissimilarity in field capacity occurred for the manual seeder due to variation in walking speed were minimized in the motor-operated seeder as the motor RPM can be kept fixed in motor-operated seeder. The field capacity increased because of its uniformity and timeliness. The motor-operated seeder has a smaller field efficiency compared to the manual seeder since turning of the motor-operated seeder takes a considerably higher time than the manual seeder. So, the effective field capacity was much lower than that of the theoretical. The seed rate also varied for the manual seeder, but in case of the motor-operated seeder, it is closer to the standard value for maize sowing. The manually-operated seeder is time consuming and labor oriented. Sowing of maize by motor-operated seeder achieves the timeliness and uniformity of seeding and lessens labor requirement with more accuracy in sowing seeds. Therefore, it can be concluded that cultivation of maize by using motor-operated seeder is more effective than the manual seeder.

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