J. Sci. Technol. Environ. Inform. 08(02): 595-605 | Rabbani M. A. (2020)
EISSN: 2409-7632, Journal home: www.journalbinet.com
Crossref: https://doi.org/10.18801/jstei.080220.61

JSTEI ONLINE JOURNAL Journal of Science, Technology & Environment Informatics
Journal BiNET Scientific Publication

# Modification of Boom for a Lever Operated Knapsack Sprayer

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**Article Information**

***Key Words:***
*Boom design, Economic use, Fabrication cost, Modified knapsack sprayer, Optimum spraying height.*

Access by Smart Phone

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**ABSTRACT**

*Most of the developing countries apply pesticides using a lever operated knapsack (LOK) sprayer. In this method, operator swings the lance in front of his movement. Therefore, it is impossible to maintain a constant nozzle height that produced an uneven spraying. In addition, operator contaminated himself. To overcome this problem, a project was undertaken to design and develop a boom for LOK (Lever Operated Sprayer) sprayer. The development and experiment were done in Department of Farm Power and Machinery workshop at Bangladesh Agricultural University. The boom and frame were fabricated and its performance was tested as the research work. Forward speed of the operator while spraying was recorded as 2.015 km/hr. The effective field capacity of the boom sprayer was found as 0.145 ha/hr. This research observed that field efficiency was 71.86%. The fabrication cost of the boom sprayer was found to be 2310 tk. It was also found that the spraying service charge if estimated 700 Tk/ha, including a profit of 342 Tk/ha, the spraying operation using the machine to cover more than 2.53 ha per year will be profitable.*

**Citation:** Rabbani, M. A, Basir, M. S., Rifat, S. M. and Mona, N. (2020). Modification of Boom for A Lever Operated Knapsack Sprayer. Journal of Science, Technology and Environment Informatics, 08(02), 595-605. Crossref: https://doi.org/10.18801/jstei.080220.61



## I. Introduction

Bangladesh is an agricultural land where the largest employment sector involves in agriculture. Among the total area of 147570 Sq. km., total cultivable land is 8.50 million hectares. This cultivable area includes 2.44 million hectares for single crop, 3.82 million hectares as double-cropped and triple cropped area is about 1.63 million hectares. Now a day, net cropped area is 7.90 million hectares and total cropped area is 15.03 million hectares (BBS, 2014). Agricultural scenario of Bangladesh has changed intensely, especially after the end of Independent War. Crops productivity geared up due to technology involvement, mechanizations, increased chemical use, specialization and government strategies that favored maximizing production (ASR, 2006). These changes allowed fewer farmers with lessened labor engagement to produce the mainstream of the crops in Bangladesh. But with the increasing scenario of production, crop protection and management have become more challenging than that of the early ages. Crop protection always attempts to avoid or prevent crop losses or to reduce them to an economically acceptable level but losses due to pests is subjected to increase enormously. There are two foremost challenges in the road to development of the agricultural sector of Bangladesh, the production of sufficient food for the growing population and prevention of environmental degradation. There are many adverse and damaging impacts of pests and insects on agricultural production in environment and in market processing. One major constraint to upsurge food production is damage by pests, which includes insects, diseases, nematodes and rodents (Akoijam et al., 2014).

There are different pest control methods like Biological pest control, Cultural control, Trap cropping, pesticides, fumigation, sterilization. Among them, pesticide application is most widespread and oldest method worldwide. Pesticides are being used till now for protecting crops in most of the developing countries due to continuously increasing demands for quantity and quality of rice. These pesticides are mostly being applied using Lever Operated Knapsack (LOK) sprayers (Litsinger et al., 1980). Pesticides play significant role in conventional agriculture and horticulture but they have potential to pollute the environment and affect non-target organisms. Highly active chemicals can have a hazardous effect even applied in very small amounts in the wrong place. For example, pesticides can destroy aquatic life. Furthermore, offhand application of pesticides can also cause spray drift that may result in damage to neighboring crops and wildlife habitats as well as human being. Violence of prescribed rate is likely to restrict the effectiveness of that product. Furthermore, it increases the risk of damage that may lead to prosecutions (Sayed, 2011).

Applied pesticides are being wasted about 50-80% due to poor spray machinery and inapt methods of application (Khan et al., 1997). However, upholding a constant walking speed and maintenance of optimum distance between nozzle and plant tops can ensure uniform distribution of spray material. Fluctuation in walking speed or height of sprayer nozzle from plant tops results in uneven distribution of spray material. Spencer and Dent (1991), in their study said that walking speed of the operator regulates spray application quality in a big extent. Garman and Navasero (1984), Alam et al. (2000), and Piggin et al. (2001) reported that overlap or unsprayed areas can be occurred during swing operation of LOK's lance and the nozzle height was changed by 10% in each swing of lance and it is quite impossible to maintain a constant nozzle height during swing of the lance. Operator has also health hazards by swing of lance in front of his body. To reduce these problems, a boom for a lever operated knapsack sprayer was developed which has 75% field efficiency and was able to save 9.1% time for spraying (Rahman, 2010). The weight of the existing knapsack sprayer was considerably high due to the materials used and also the high operating and fabrication cost is also a concern. So, this research was conducted to fulfill the two objectives, such as to modify the boom and analyze the cost of fabrication and operation of the sprayer.

## II. Materials and Methods

### Design and development of the boom

The boom was fabricated and performance of the sprayer was tested in the workshop of Department of Farm Power and Machinery, Faculty of Agricultural Engineering and Technology, Bangladesh Agricultural University, Mymensingh.

### Design of the boom

Figure 01 represents the design of the boom with nozzles that was used in our study about design and fabrication of a boom for a lever operated knapsack sprayer.

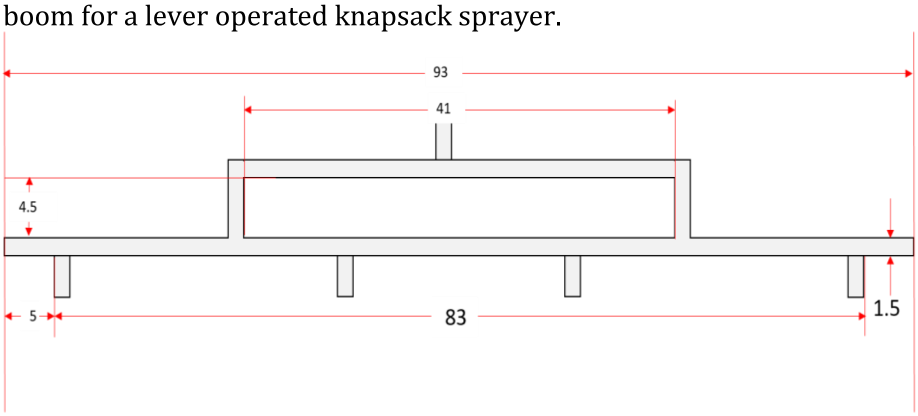


**Figure 01. Design of the boom to be fabricated (All measurements are in cm)**

EISSN: 2409-7632, Journal home: www.journalbinet.com
Crossref: https://doi.org/10.18801/jstei.080220.61

**Materials required to fabricate the boom**

Materials required to construct the machine were procured from the local market. Most of the parts of the machine were designed and fabricated in the workshop of the Department of Farm Power & Machinery, Bangladesh Agricultural University. The fabricated boom is shown in Figure 02. The major materials required to fabricate the boom are shown in the following Table 01.

**Table 01. Materials for making the boom**

| Item | Material | Amount (Nos.) |
|---|---|---|
| Nozzle | Plastic | 4 |
| Rod | M.S. | 2 |
| Bar | M.S. | 1 |
| Pipe | S.S. | 2 |
| Nut bolt | M.S. | 2 |
| Sprayer cylinder | plastic | 1 |

**Figure 02. Photographic view of fabricated boom**

**Travelling speed of the sprayer**

As it was is a manually operated sprayer so the speed was varied with the walking speed of the operator. The speed of the machine was determined by using equation (1)

$$S=\frac{d}{t} \quad (1)$$

Where S= Speed (km/h), d= Distance travelled (km) and t=Time (h)

**Field capacity of the sprayer**

Theoretical Field capacity was estimated by equation 2. (Kepner et al., 1978).

$$C_t=\frac{W\times S}{C} \quad (2)$$

Where, $C_t$ = Theoretical field capacity (ha/h), w = Spraying width of the boom (m), and C = Constant, 10.

Actual Field capacity of the sprayer was calculated using equation (3). It is the actual field capacity that indicates the actual area coverage in unit time.

$$C=\frac{A}{T} \quad (3)$$

Where, C=Field capacity (ha/h), A=Total area covered by the sprayer (ha) and T=Total time (h).

**Field efficiency**

It is the ratio of the effective field capacity to theoretical field capacity. Field efficiency of the sprayer was calculated using the following equation;

$$e = \frac{C}{C_t} \times 100 \quad (4)$$

Where e= Field efficiency (%), C= Actual field capacity and $C_t$= theoretical field capacity

**Laboratory test of sprayer**

**Weight of the sprayer**

Self-weight of the sprayer was measured by a digital weighing machine. Three measurement of weight was taken and an average was considered as self-weight of the machine.

**Measurement of spraying area in variable heights**

The boom was set at different height. At variable height the spraying area coverage data were recorded. For calculating optimum height, spraying area for 3-inch, 5-inch, 8-inch and 12 inches were measured. A white sheet was used for spraying on it. To identify the sprayed area blue color was mixed with water and sprayed on the paper by one walk. Then the colored area was calculated. The colored area represents the sprayed area and the white area represents the missing or void area. The working procedure is shown in Figure 03 and 04.

**Figure 03. Spraying on white paper**

**Figure 04. Spraying at 12 in. nozzle height**

**Measurement of missing area percentage**

After measuring colored space, the remaining white space was considered as missing area. Missing area was calculated by the following formula:

$$\text{Missing area } (\%) = \frac{\text{white area } (cm^2)}{\text{total area } (cm^2)} \times 100\% \quad (5)$$

The procedure of measurement of missing area is given in the Figure 05.

**Overlap percentage**

The overlap percentage is the measure of area under intersection of spraying. The comparative dark blue area was considered as overlap. Overlap area is indicated by deep blue colors in Figure 06. Overlap percentage (%) was calculated by equation 6.

$$\text{Overlap percentage } (\%) = \frac{\text{dark blue area } (cm^2)}{\text{total area } (cm^2)} \times 100\% \quad (6)$$

**Calculation of optimum height**

The missing and overlap percentage for different nozzle height was plotted in a graph and a straight line was found. Thus, the intersecting point of the line and optimum height (x axis) was identified. That intersecting point was considered as optimum height.

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**Measurement of spraying angle**

Spraying angle was found from the optimum height and sprayed width coverage by one nozzle. Equation (7) was followed for measuring spraying angle. Figure 07 represents the procedure to determine the spraying angle.

$$\theta = 2\tan^{-1}\left(\frac{\text{spray width}}{2\times \text{optimum height}}\right) \quad (7)$$

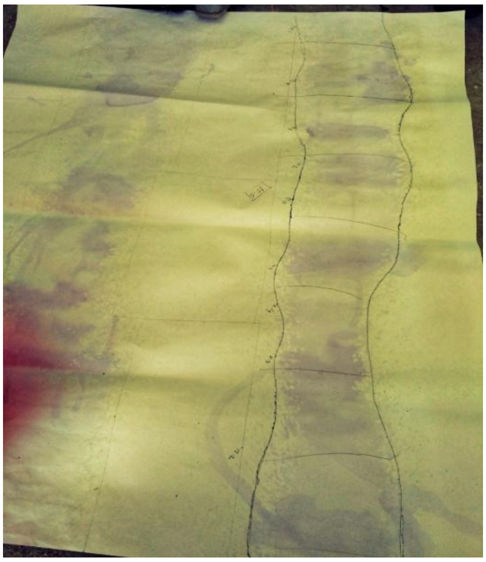

**Figure 05. Measuring procedure of missing area**

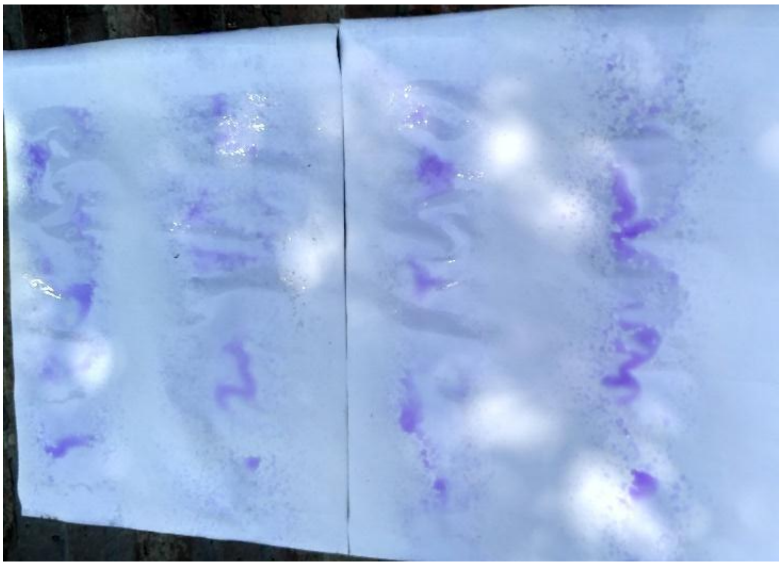

**Figure 06. Measurement of overlap percentage**

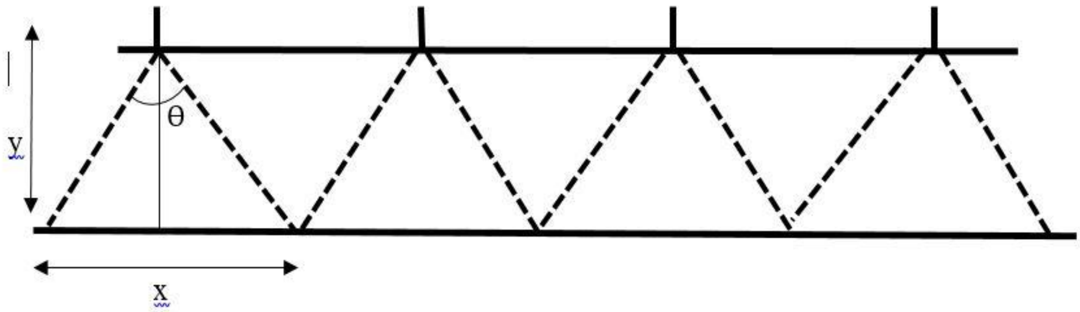


**Figure 07. Experiment set up for measuring angle**

Here x = spray width and y = optimum height.

**Cost analysis**

Cost analysis is very important for a new technology. Operational cost of the machine is the sum of fixed cost and variable cost of the machine. The total cost of the sprayer was determined by knowing the cost of the materials and fabricating cost of the boom. The operational cost (Tk /ha) was calculated by assuming some data.

**Fixed cost**

It is the total cost of depreciation, interest on investment, tax, insurance and shelter. For calculating, the depreciation of the machine straight-line method was used (Hunt, 1977).

**i) Annual depreciation:** Depreciation of the machine is calculated with the following equation;

$$D=\frac{P-S}{l} \quad (8)$$

Where D = Depreciation (Tk /yr.), P = Purchase price (Tk), S = Salvage value (Tk) and L = Life of machine (yrs.).

**ii) Interest on investment:** Interest on investment of the machine is calculated with the following equation:

$$I = \frac{P+S}{2} \times I \tag{9}$$

Where i = Rate of interest

**iii) Tax, insurance and shelter**
T = 2% of purchase price of the machine, Tk.

Total fixed cost per year, FC = T+I+D (10)

**Variable Cost**: Variable cost is depended on usage of the machine. It includes labor/ operators cost and repair and maintenance cost. Variable cost is calculated by the following equation:

**i)** Labor cost per hour L = Tk./ man-hr

**ii)** Repair and maintenance cost per year
R & M = 0.3 % of purchase price (11)
Total variable cost, VC = L+R & M (12)

**Spraying service charge**
Service charge was calculated from the sum of operating cost and estimated profit of the machine owner. Operating cost is the sum total of fixed and variable cost.

Service charge (Tk/ha)= Fixed cost + Variable cost + Estimated profit (13)

**Economic use of the sprayer**
Plotting the operating cost and rental charge per year in a graph, the break-even use of the sprayer was identified. The annual use obtained from the break-even analysis indicated in which extend the area covered by the sprayer per year will be profitable. Below that area, the sprayer will not be profitable for a single investor.

## III. Results and Discussion
Based on the objective, a manually operated boom sprayer consisting of 4 nozzles was fabricated in this research work. In this section the results and findings are presented and discussed accordingly.

**The fabricated boom sprayer**
**Specification of the boom sprayer**
The newly fabricated boom sprayer was consisting of a boom of 0.92 m with four plastic nozzles at a distance interval of 20.75 cm. Material of the boom was PVC pipe. The boom was connected below the cylinder with a frame made by MS rod. The length of the frame was 51 cm. The fabricated boom sprayer is shown in Figure 08.

**Figure 08. The LOK sprayer with the fabricated boom**

**Cost of fabrication**

Detailed cost of fabrication of the boom sprayer is demonstrated in Table 02.

**Table 02. Cost of the boom and sprayer**

| Materials | Unit | Amount | Rate (Tk.) | Cost (Tk) |
|---|---|---|---|---|
| MS rod (1 suti) | Kg | 0.4 | 70 | 28 |
| SS pipe (1.5 cm dia) | feet | 4 | 40 | 160 |
| MS flat bar (2 cm wide × 3 mm) | Kg | 0.6 | 70 | 42 |
| PVC pipe | Feet | 6 | 40 | 240 |
| Plastic nozzle | Nos. | 4 | 25 | 100 |
| MS nut bolts | Nos. | 2 | 10 | 20 |
| Making charge of frame to hold the boom | Nos. | 1 | 100 | 100 |
| Making charge of boom | Nos. | 1 | 500 | 300 |
| Total cost of the boom | | | | 890 |
| Cost of the LOK sprayer | | | | 1500 |
| Total cost of the sprayer with boom | | | | 2310 |

**Performance of the sprayer**

**Forward speed**

Forward speed of the operator while spraying was recorded as 2.015 km/hr. This speed is very much similar for a walking type machine like reaper, transplanter, and so on.

**Field capacity of the sprayer**

The performance of the sprayer was tested in the DFPM workshop premises. Spraying width was found 1.01m, forward speed as 2.01 km/hr. thus the theoretical field capacity becomes 0.203 km/hr. The average effective field capacity of the boom sprayer was found 0.145 ha/hr. Effective Field capacity of the sprayer is illustrated in Table 03.

**Table 03. Effective field capacity of the sprayer**

| Obs. No. | Length of the field (m) | Width of coverage (m) | Area of the row coverage (ha) | Time taken to cover the area (sec) | Effective field capacity (ha/hr.) | Average Effective field capacity (ha/hr.) |
|---|---|---|---|---|---|---|
| 1 | 5 | 5 | 0.00025 | 60 | 0.15 | |
| 2 | 5 | 5 | 0.00025 | 62 | 0.145 | 0.145 |
| 3 | 5 | 5 | 0.00025 | 64 | 0.140 | |

**Field efficiency**

Average field efficiency was found as 71.86%. The efficiency of the machine was found lower as the machine width was low. Field efficiency of the sprayer is demonstrated in Table 04.

**Table 04. Average field efficiency**

| Obs. No. | Spraying width(m) | Forward speed(km/hr) | Theoretical field capacity (ha/hr.) | Effective field capacity (ha/hr.) | Field efficiency (%) | Average field efficiency (%) |
|---|---|---|---|---|---|---|
| 1 | 1.01 | 2.01 | 0.210 | 0.150 | 71.41 | |
| 2 | 1.01 | 2.01 | 0.181 | 0.145 | 80.11 | 71.865 |
| 3 | 1.01 | 2.01 | 0.219 | 0.140 | 64.07 | |

**Laboratory test results**

**Missing percentage**

Missing percentage for 3 in, 8 in, 12 in and 18 in nozzle height was recorded as 74.5%, 59.3%, 2.1% and 0 %, respectively. From results it can be decided that in 3 inch and 8-inch nozzle height the percentage missing area is very high. On the other hand, in 12 inch and 18-inch nozzle height the percentage missing area is acceptable.

**Overlap percentage**

For 3 in, 8 in, 12 in and 18 in nozzle height, the overlap percentage was found 0 %, 0%, 16.30% and 38.96%, respectively. From the result it can be decided that in 12-inch height the overlap percentage is acceptable as some overlapping is better that missing in any area. But in 18-inch nozzle height the observed percentage of overlap area is high comparatively and it is not acceptable. In different nozzle height the percentage area of uniform spaying, missing and overlapping is shown in Figure 09.

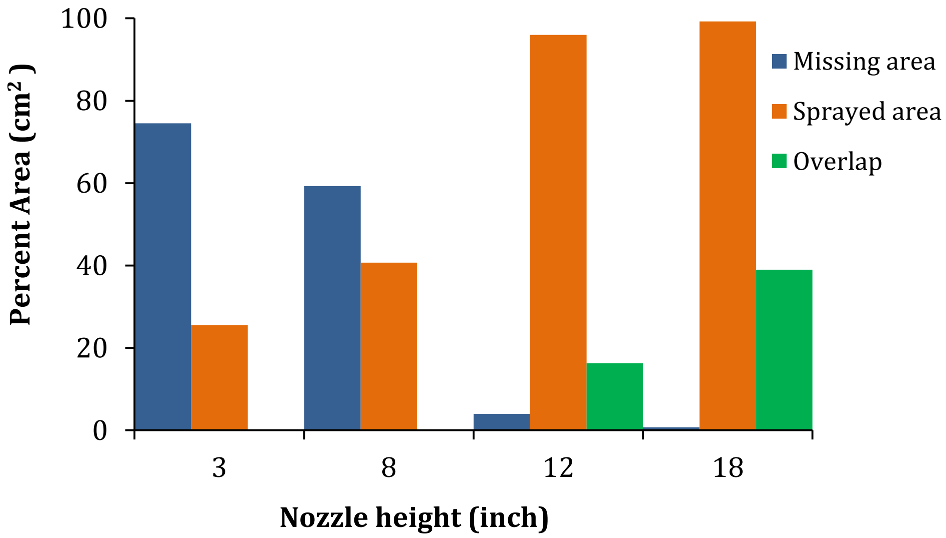


**Figure 09. Percent missing and overlap area in different nozzle height**

**Optimum nozzle height**

By plotting the data of missing and overlap percentage, a line was drawn and the optimum height of spraying with zero missing and zero overlap was found 13.20 inches from the crop height. Figure 10 illustrates the optimum spraying height for the sprayer.

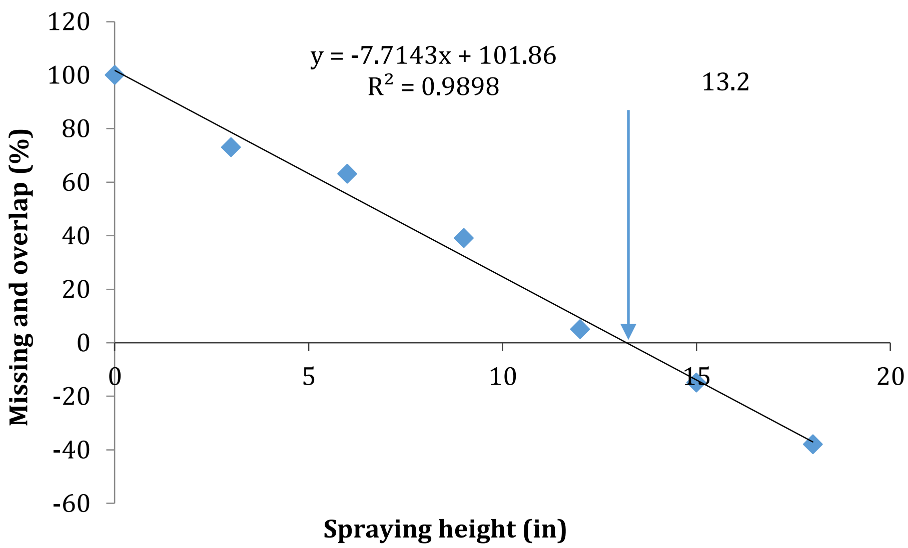


**Figure 10. Determination of optimum nozzle height**

**Spraying angle**

Considering the optimum height of spraying, spraying angle was found 44.7°.

**Economic use of the sprayer**

**Operating cost**

Operating cost of the sprayer is calculated in Table 05.

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**Table 05. Operating cost calculation**

| | | |
|---|---|---|
| Fixed cost calculating items | Purchase price (estimated), Tk | 2500 |
| | Salvage value, Tk | 250 |
| | Working life, yr. | 3 |
| | Interest on investment, Tk/yr. | 138 |
| | Interest rate, % | 10% |
| Variable cost calculating items | Repair and Maintenance cost, Tk/h | 0.88 |
| | Repair and Maintenance cost, Tk/yr. | 700 |
| | Cost of operator, Tk/h | 50 |
| | Average working hours per day | 4 |
| | Average working day per year | 200 |
| | Average working hours per year, h/yr. | 800 |
| | Field capacity, ha/h | 0.145 |
| | Average area coverage per year, ha/yr. | 116 |
| Calculations | | |
| Fixed cost | Depreciation, Tk/yr. | 750.00 |
| | Interest on investment, Tk/yr. | 138 |
| Total fixed cost, Tk/h | | 1.11 |
| Total fixed cost, Tk/ha | | 7.65 |
| Variable cost | Repair and Maintenance cost, Tk/h | 0.875 |
| | Cost of operator, Tk/h | 50 |
| Total variable cost, Tk/h | | 50.88 |
| Total variable cost, Tk/ha | | 350.86 |
| Total operating cost, Tk/ha | | 358.51 |

**Service providing charge**

To calculate the service charge, profit of the machine owner was estimated as 342.00 Tk/ha. Thus, the rental charge for the machine becomes 700.51 Tk/ha, in other words, it becomes 700.00 Tk/ha. Thus, an owner of the sprayer who also works as machine operator can earn 406.29 Tk/day.

**Break-even analysis**

Economic use of the sprayer is demonstrated in Figure 11. The break-even point of the sprayer per year was found 2.53 ha. It indicates that the machine will bring profit if the sprayer is operated to cover 2.53 hectare per year.

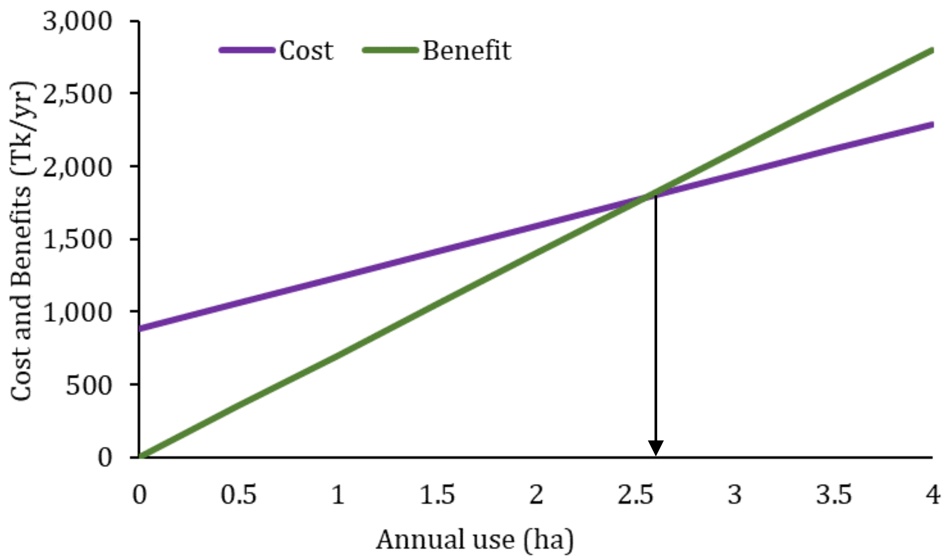


**Figure 11. Economic use of the sprayer**

## IV. Conclusion

The design and construction of the boom for LOK sprayer is simple and it is easy to construct, fix and adjust in local manufacturers. It can be adjusted at the back of the operator and thus eliminates the health hazard that was encountered in existing hand sprayers. Total fabrication cost of the boom was only 2500 Tk. which is affordable for the marginal farmers of Bangladesh. The machine can be effective to a large extend if spraying service is provided up to minimum 2.53 ha per year. The service provider can earn a wage of 406.29 Tk. Per day with the boom sprayer. The spraying efficiency can be improved by using this boom sprayer with increasing travelling speed. The fabricated boom has lower efficiency than previous one (Rahman, 2010), because of being smaller than the previous one in width. But from the financial point of view this sprayer is affordable for small scale farmers and easy to handle with an extra benefit of easy and affordable access with low manufacturing cost. Therefore, after evaluating the field performance, it can be concluded that the boom with a LOK sprayer will be effective in terms of both operation and financial profitability to the marginal farmers of Bangladesh.

## Acknowledgement

The Author is grateful to Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh for technical assistance and allowing the experiment to conduct in the departmental workshop.

**CONFLICT OF INTEREST**

There is no conflict of interest in this study.

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## HOW TO CITE THIS ARTICLE?

**Crossref:** https://doi.org/10.18801/jstei.080220.61

**MLA**

Rabbani, et al. "Modification of Boom for a Lever Operated Knapsack Sprayer". Journal of Science, Technology and Environment Informatics 08(02) (2020):595-605.

**APA**

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