Annals of Bangladesh Agriculture
Journal homepage: gau.edu.bd/aba

ORIGINAL ARTICLE

Design, fabrication, and evaluation of an innovative power sprayer for field crops in Bangladesh

Md Mostafizar Rahman[1*] and Khokan Mohanto[1]

[1,2]Department of Farm Machinery and Precision Engineering, Gazipur Agricultural University, Gazipur 1706.

ARTICLE INFO.

Keywords:
sprayer engine, wheel, nozzle, evaluation, eggplant.

Received : 4 July 2025
Revised : 13 November 2025
Accepted : 24 December 2025
Published : 05 January 2026

Citation:
Rahman, M. M. and K. Mohanto. 2026. Design, fabrication, and evaluation of an innovative power sprayer for field crops in Bangladesh. *Ann. Bangladesh Agric.* 29(2): 45-66

ABSTRACT

Pest and weed infestations pose significant challenges to crop production in Bangladesh, where most farmers rely on manually operated sprayers that are labor-intensive, inefficient, and ergonomically taxing. To address these issues, a power-operated sprayer was designed, fabricated, and evaluated. The developed sprayer integrated a gasoline engine with a mobile frame equipped with multiple nozzles, enabling high-pressure pesticide application with reduced human effort. Performance evaluation was conducted under both laboratory and field conditions. Key parameters, such as spraying angle, discharge uniformity, swath width, overlap, field capacity, and operational cost, were analyzed. Laboratory results demonstrated uniform nozzle discharge with low coefficient of variation (1.92%), consistent spray coverage, and optimal spraying angles across variable boom heights. Field trials on eggplant crops revealed a theoretical field capacity of 0.89 ha/h, an actual field capacity of 0.72 ha/h, and a field efficiency of 80.86%. The total operational cost was estimated at Tk. 299.97 per hectare with a break-even area of 55.19 ha. The power sprayer significantly reduced operator fatigue and enhanced application efficiency, making it a promising solution for sustainable pesticide application in Bangladesh and similar agro-ecological contexts.

*Corresponding Author: Department of Farm Machinery and Precision Engineering, Gazipur Agricultural University, Gazipur 1706. Email: mostafizar@gau.edu.bd

https://doi.org/10.3329/aba.v29i2.83149
ISSN 1025-482X (Print)/2521-5477 (Online)

Introduction

Effective pest, disease, and weed management are critical for ensuring global food security and maintaining agricultural productivity. In many agrarian economies, particularly developing nations like Bangladesh, the judicious application of agrochemicals plays a pivotal role in protecting field crops. These protective agents, including insecticides, herbicides, and fungicides, are often synthetic or naturally derived preparations designed to control pest populations or inhibit their reproduction (Ware and Whitacre, 2004; Matthews *et al.*, 2014). The efficient and precise application of these chemicals is achieved through specialized devices known as sprayers, which are essential tools in modern agriculture for achieving uniform distribution and minimizing chemical losses (Nuyttens *et al.,* 2009).

The agriculture and horticulture sectors have been significantly revolutionized by the emergence of agricultural sprayers machine which enable farmers to achieve better yield through effective management of biotic stresses, such as pests, weeds, and diseases (Nuyttens *et al.,* 2009; Matthews *et al.,* 2014). Sprayer machines are versatile tools used in numerous farming activities including weed and pest control, liquid fertilization, garden spraying, and even polishing of plant leaf. The advantages of these sprayers include ease of operation, maintenance, and handling; the ability to facilitate uniform chemical distribution; capability to deliver chemicals at the desired height; and an adjustable precision nozzle that allows for different spray patterns (such as light, heavy, or foggy spray), depending on crop and pest requirements (Matthews *et al.,* 2014; Ghafoor *et al.,* 2022).

Globally, different types of sprayers are available, including manually operated, mechanically operated, and automatically operated systems. In developing countries such as Bangladesh, manually operated knapsack lever-arm sprayers are particularly popular among farmers due to their perceived ease of operation and portability (Dasgupta *et al.,* 2007; Hossen, 2019). However, prolonged use of these sprayers often causes pain in the hands, shoulders, and waist of operators, thereby limiting their practical utility over large areas and reducing working efficiency while posing potential health risks (Yassin *et al.,* 2002; Atreya, 2007). Despite these ergonomic challenges, nearly 100% of pesticide applications in Bangladesh are carried out using various types of sprayers, including knapsack, foot pump, and power sprayers, with over two million units currently in use across the country (Rahman *et al.,* 2021). However, the use of conventional sprayers often results in issues such as uneven spray distribution, chemical wastage, and environmental contamination (Nuyttens *et al.,* 2009; Ghafoor *et al.,* 2022).

In contrast, more advanced mechanical and automatically operated sprayers are increasingly being adopted in developed and some developing countries for pest and weed control. Automated sprayers manage the entire system through a central control unit, requiring no direct manual intervention (Dhiraj *et al.,* 2016; Devi *et al.,* 2021). In comparison, mechanically operated sprayers still require a human operator to control the spraying mechanism (Raut *et al.,* 2013; Kshirsagar *et al.,* 2016; Zaffar and Khar, 2022). Despite the availability of these advanced technologies, most smallholder farmers in Bangladesh continue to show active interest in improved farming equipment that can reduce direct overhead costs particularly labor expenses and optimize capital investment.

The integration of wheels with lever-operated sprayers, known as wheel-mounted sprayers, has developed traction in some developing countries due to their comfort and ease of handling in the field compared to conventional knapsack sprayers (Mulatu, 2018; Rahman *et al.,* 2025). Similarly, engine-powered backpack sprayers have become popular in various countries for their higher efficiency in controlling crop pests and diseases, but their considerable weight often leads to significant operator fatigue, and reduce working efficiency particularly during prolonged operation or when traversing uneven terrain (Kumar, 2015; Zilpilwar *et al.,* 2021).

To address the limitations of lever-operated and engine-powered backpack sprayers commonly used in Bangladesh, this study proposes the integration of wheels with an engine-operated backpack sprayer effectively creating a power-operated wheeled sprayer. This innovative design aims to significantly enhance maneuverability and ease of operation in vegetable fields (Ghafoor *et al.,* 2022). The core hypothesis is that the proposed power sprayer will not only reduce operating time and improve application efficiency but also substantially alleviate the physical strain experienced by operators during pesticide and herbicide applications. This research aims to design, fabricate, and evaluate the performance of the power-operated wheeled sprayer under Bangladeshi field conditions, offering a sustainable solution for improved crop protection.

Materials and Methods

Sprayer main components

Gasoline engine and tank: The gasoline engine (Fig. 1) functions as the primary power source for the innovative power-operated sprayer. This engine drives an integrated high-pressure pump, which is responsible for generating the necessary fluid pressure to atomize the liquid and propel it through the nozzles. The sprayer system included a 20-liter tank directly connected to the pump intake, ensuring a continuous supply of spray solution.

Wheel system: The sprayer's mobility system was engineered to facilitate ease of movement across field terrains. It incorporated two distinct wheel types (Fig. 2). The primary drive wheels are standard bicycle-type wire wheels, measuring 609.6 mm × 49.53 mm. These were selected based on the sprayer's

Specification	
Engine Model	139F, 31cc, 4 Stroke
Fuel Type	Octane/Petrol
Fuel Consumption	0.35L/H
Tank Capacity	20 Litre
Size	45 x 41 68.5 cm
Weight	10 KG

Fig. 1. Gasoline engine operated sprayer.

overall design specifications, providing adequate traction and stability for propulsion. Additionally, a smaller support wheel, with dimensions of 243.84 mm × 39.12 mm, was strategically integrated to provide auxiliary balance and support for the sprayer's frame on the ground, enhancing maneuverability and reducing operational load on the operator.

Nozzle configuration: The sprayer system is equipped with a nozzle (Fig. 3) featuring a precise 1.5 mm diameter spray hole (orifice). This orifice size is a critical determinant of the nozzle's flow rate and atomization characteristics. The resultant water jet diameter, which defined the effective spray width, was observed to vary between 0.5 to 2

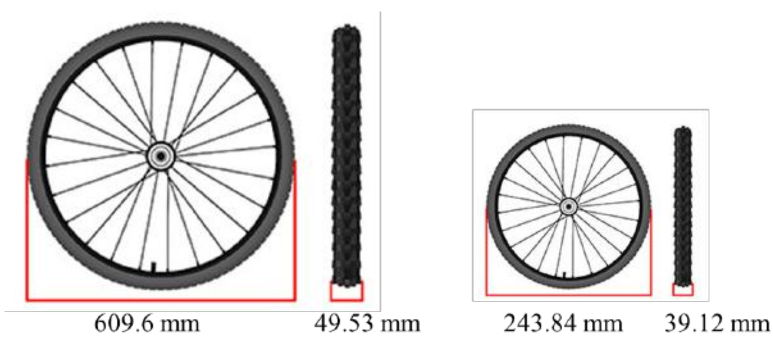


Fig. 2. Incorporated two distinct wheel types.

Fig. 3. Spray nozzle and its dimensions.

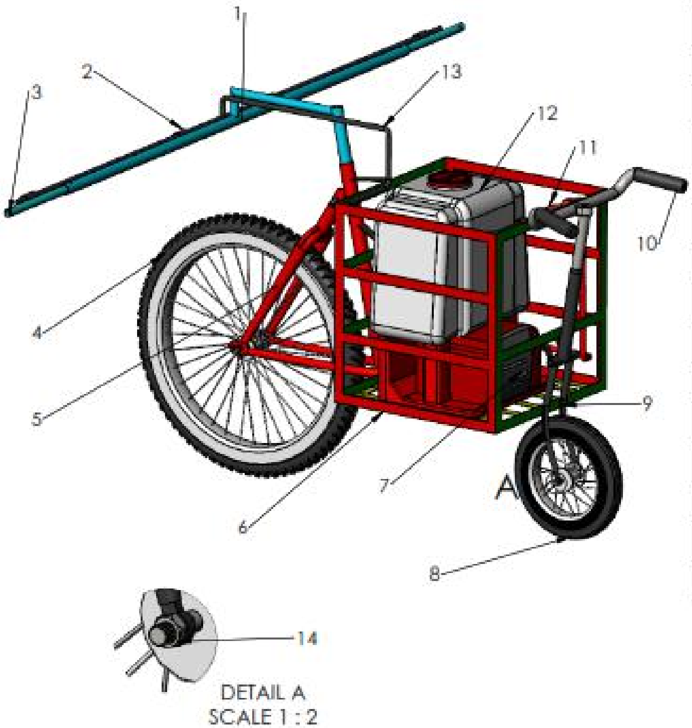
meters. This variability is directly dependent on the operating fluid pressure, a fundamental characteristic of hydraulic nozzles where higher pressures typically lead to a wider and finer spray pattern.

Other supporting components: Beyond the primary systems, the fabrication and assembly of the innovative power sprayer necessitated various auxiliary components to ensure structural integrity, fluid transfer, and functional completeness. These included standard bicycle components (e.g., for frame integration or specific linkages), bearings for smooth rotational movement (e.g., in the wheel axles), iron bars for structural framework and reinforcement, hoses for liquid conveyance, nuts and bolts for secure fastening, and specialized nozzle and pipe connectors for leak-proof fluid pathways. The project also relied on a range of standard workshop tools and equipment, encompassing both mechanical and, where applicable, basic electrical instruments for fabrication and testing procedures.

Design and fabrication of the innovative power sprayer

The innovative power sprayer was systematically designed utilizing SolidWorks CAD software (Fig. 4), allowing for precise component modelling, assembly visualization, and structural analysis prior to physical fabrication.

The core of the sprayer's structure is a two-wheeled frame constructed from mild steel bars. This frame's design drew inspiration from conventional bicycle frames, optimizing for lightweight yet robust support and maneuverability. All frame components were precisely cut, shaped, and joined



SL No.	Components Name
01	Sprayer Boom
02	Spray Nozzle
03	Sprayer Boom with Extension
04	Ground Wheel
05	Supporting Frame of Ground Wheel
06	Sprayer Box
07	Engine
08	Supporting Wheel
09	Frok of Supporting Wheel
10	Handlebar Grip
11	Pressure Relief Valve
12	Sprayer Tank
13	Hose Pipe
14	Nut and Bolt

Fig. 4. Design of power sprayer machine by SolidWork software.

through welding according to the SolidWorks schematics (Fig. 5), ensuring structural integrity.

All necessary components, including the bicycle wheels, the sprayer unit (tank and pump assembly), and various auxiliary parts (e.g., hoses, connectors, fasteners), were efficiently sourced from the local market in Bangladesh. This approach not only supported local commerce but also ensured the use of readily available and repairable materials.

During the assembly phase, the selected bicycle wheels were integrated onto the mild steel frame, forming the mobile base. Subsequently, the main sprayer unit was securely mounted onto this two-wheeled chassis. A critical aspect of the spraying mechanism involved the installation of four nozzles, precisely spaced at 0.9-meter intervals along a boom to ensure optimal spray pattern overlap and coverage. Finally, the gasoline engine sprayer (referring to the engine-pump unit) was affixed to the frame and hydraulically connected to the manifold supplying the four nozzles. Upon activation of the engine, the integrated pump generates the necessary pressure to atomize and propel the insecticides (or other liquid solutions) through these nozzles, enabling efficient field application.

Fig. 5. Fabricated power sprayer.

Evaluation of the innovative power sprayer

The performance of the newly developed power sprayer was rigorously evaluated through a dual-phase approach. Initial controlled assessments were conducted in the workshop of the Department of Agricultural Engineering (Fig. 6(a)), allowing for precise measurement of key operational characteristics under controlled conditions. Subsequently, the sprayer underwent practical field trials within the research plots during eggplant cultivation (Fig. 6(b)), providing real-world performance data.

During the workshop evaluation, the following parameters were systematically assessed: operational speed, uniformity of nozzle discharge, spraying angle, swath width, and overlap percentage, along with the measurement of the sprayer's coverage area. The field trials complemented these measurements by specifically evaluating the sprayer's effective field capacity and overall field efficiency under actual agricultural conditions.

Travelling speed of the sprayer: The operational speed of the sprayer was measured based on the operator walking speed, as the sprayer is pushed manually. The speed of the sprayer was calculated using the following equation (1).

$$\text{Speed of sprayer (S)}, \left(\frac{\text{km}}{\text{h}}\right) = \frac{\text{Distance travelled(d)}}{\text{Time(T)}} \quad (1)$$

Uniformity of nozzle discharge: To assess the consistency of chemical application, the discharge rate (ml/sec) from each nozzle

a) In Workshop b) In Field

Fig. 6. Performance evaluation of power sprayer machine in the workshop and field.

was measured over a 20 m travel distance. Liquid from each nozzle was collected in polyethylene bags, then quantified using a graduated scale. The time taken to cover the distance was simultaneously recorded to calculate individual discharge rates. This process was replicated three times. The coefficient of variation (CV%) was subsequently calculated to quantify discharge variability among nozzles. A CV% below 10% is considered an acceptable standard for spray uniformity (Gomez and Gomez, 1984), ensuring even distribution of agrochemicals.

Measurement of spraying angle: The spraying angle was measured from the optimal height, along with the spray width coverage from a single nozzle. Equation (2) was used to calculate the spraying angle, and Figure 7 illustrated the procedure used to determine the spraying angle.

$$\theta = 2\tan^{-1}\frac{Spray\ width}{(2 \times Optimum\ height)} \tag{2}$$

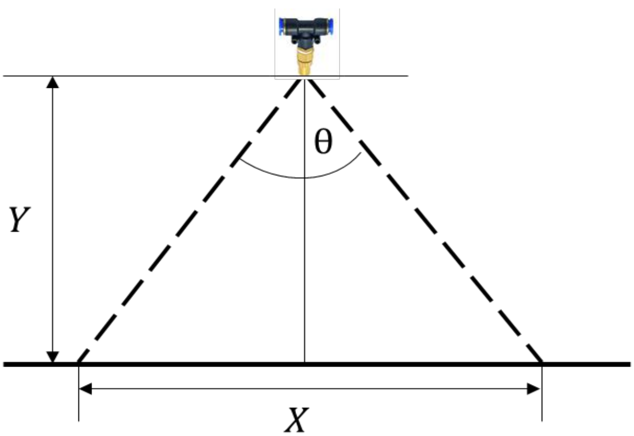


Fig. 7. Measurement of spraying angle.

Measurement of spraying area at variable heights: The sprayer was positioned at different heights to record data on spray area coverage. Coverage areas were measured at heights of 0.701m, 0.78m and 0.864m for testing. A white marker was used to outline the spray coverage on the floor from a single pass of the sprayer (Fig. 8), and the marked area, representing only the sprayed portion, was then calculated.

Swath width: The swath width was determined by measuring the area covered by spray droplets during a single pass of the nozzle.

Spray overlap: Overlap is the width covered by two adjacent nozzles relative to the width covered by a single nozzle and is calculated as a percentage (Fig. 9). Overlap primarily influences the spray pattern and coverage of the sprayer, which are also affected by the boom height and nozzle spacing.

Field capacity of the sprayer

Theoretical Field capacity was determined by the formula (4) (Kepner *et al.,* 1978).

$$F_T = \frac{W \times S}{C} \quad (3)$$

Where, = Theoretical field capacity (ha/h),

w = Spraying width (m),

S = Speed of Sprayer (km/h), and

C = Constant (10)

Fig. 8. Spraying coverage area measured on floor in the workshop.

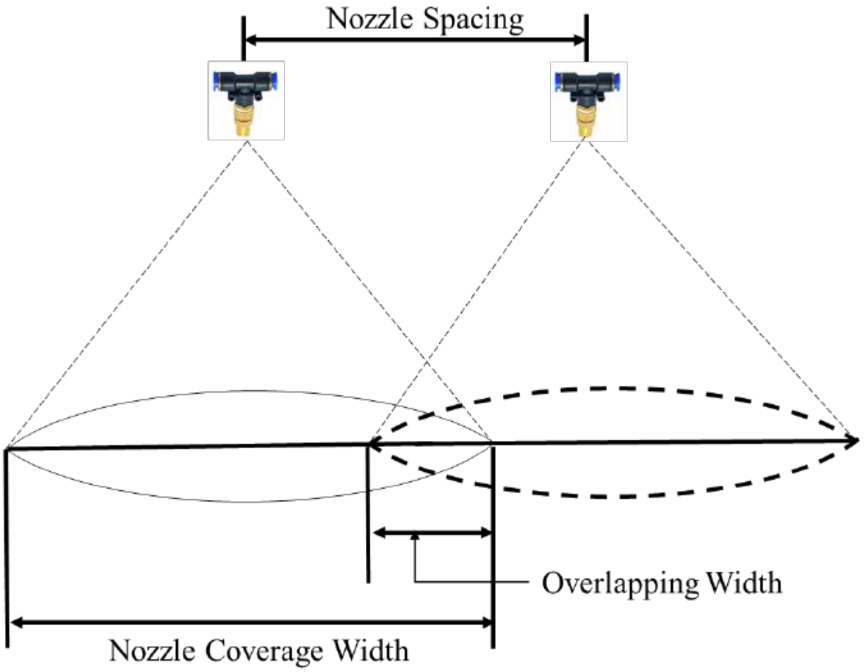


Fig. 9. Spray overlapping.

The effective field capacity of the sprayer was determined using the equation (5). This represents the real area coverage per unit of time.

$$F_E = \frac{A}{T} \quad (4)$$

Where,

F_E = Effective 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 determined using the following formula (6).

$$E_f = \frac{F_E}{F_T} \quad (5)$$

Where, = Field efficiency (%),

= Effective field capacity, and

= Theoretical field capacity

Operational cost analysis of power sprayer

The fixed costs and variable costs both were considered to calculate the total operational cost of the powered sprayer machine (in ha/h),

Fixed costs: Fixed cost is the sum of depreciation, interest on investment, and costs associated with taxes, insurance, and shelter.

i) Annual depreciation and interest cost (ADIC): Annual depreciation and interest costs was determined using the capital recovery factor (CRF) and the estimated purchase price of the sprayer machine.

$$ADIC = CRF \times \text{Cost of Sprayer Machine (Tk)} \quad (6)$$

Where,

$CRF = \frac{i\,(1+i)^n}{(1+i)^n - 1}$; i=interest rate and n=working life

ii) Tax, insurance, and shelter amount to 1.5% of the cost of the sprayer machine.

Variable costs: Variable costs depend on the repair and maintenance costs, operator costs, and lubrication costs.

i) Repair and maintenance costs were calculated at Tk. 3.0 per hour.

ii) Lubrication costs were assumed to be Tk. 3.9 per hour.

ii) Operator costs were calculated using the equivalent annual cost factor (EACF) and the operator's annual salary.

$$EACF = \left\{ \frac{(1+r)^n - (1+i)^n}{(1+r) - (1+i)} - \left(\frac{i}{(1+i)^n - 1} \right) \right\} \quad (7)$$

Where r is the rate of escalation (12-15%)

$$\text{Operator Cost} = EACF \times \text{Operator per year} \quad (8)$$

Finally, a Break-Even Analysis was estimated to know the Break-Even point, which provides how many land covered the sprayer machine needs to perform in order to cover its costs.

Results and Discussion

Evaluation of power sprayer machine in the laboratory scale

Forward operating speed: The forward operating speed of the innovative power sprayer was determined to be 2.64 km/h. This value was derived from controlled field measurements where the sprayer traversed a 10-meter distance within 13 to 14 seconds

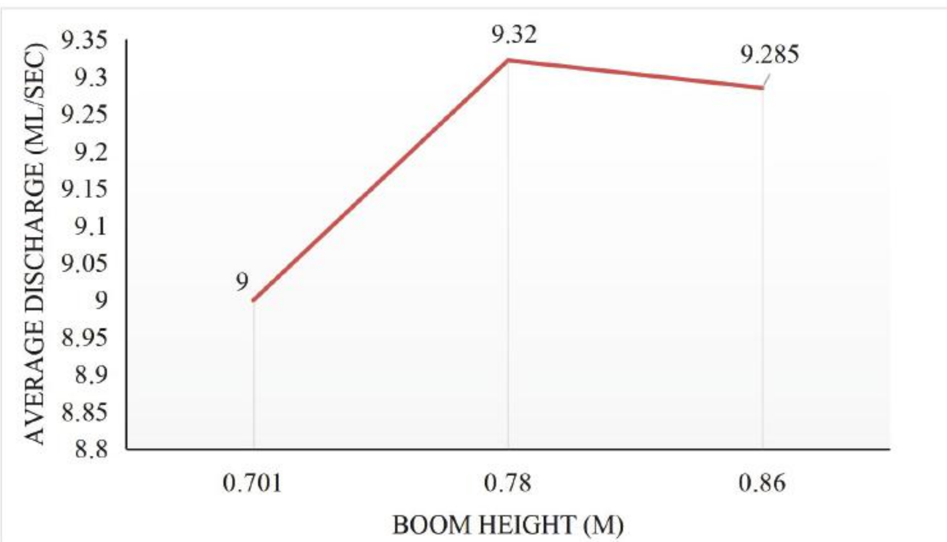


Fig. 10. Discharge variation with varying boom height.

(Table 1). This measured speed is significant because it falls within the typical operational range of pedestrian-controlled agricultural machinery, such as reapers and transplanters, commonly used in small-scale farming. According to Ghafoor *et al*. (2022), a self-propelled crop sprayer operating in similar field conditions exhibited comparable speeds, supporting ergonomic compatibility for human operators. Additionally, Matthews *et al.* (2014) emphasize that maintaining a walking-speed range between 2–3 km/h is ideal for operator comfort and efficient agrochemical application. This comparability indicates that the sprayer's speed is ergonomically appropriate for human operators, minimizing fatigue while ensuring efficient field coverage. It also suggests that the sprayer can be readily integrated into existing farming practices in regions like Bangladesh, where such walking-type machines are prevalent.

Table 1. Speed of powered sprayer machine

Distance (m)	Time (s)	Speed (m/s)	Average Speed (km/h)
10	14	0.71	2.64
10	13	0.77	
10	14	0.71	

Sprayer nozzle discharge and uniformity: Figure 10 illustrated the consistent discharge performance of the sprayer's nozzles. Average discharge rates were measured at 9.01 mL/s, 9.32 mL/s, and 9.29 mL/s across varying boom heights (0.701 m, 0.780 m, and 0.864 m) over a 10meter distance. The coefficient of variation (CV) for these discharge rates was an exceptionally low 1.92%. According to standard spray application guidelines, a CV of less than 10% is considered acceptable for uniform spray distribution to ensure precise agrochemical delivery (ASABE, 2006; Matthews *et al.,* 2014). This low CV signifies highly uniform pressure distribution across the nozzles, ensuring consistent chemical application regardless of minor boom height fluctuations. Such uniformity is vital for effective pest control, minimizing spray drift, and reducing environmental impact.

Spraying angle analysis: Figure 11 illustrated the direct influence of boom height on the sprayer's spraying angle. As the boom height increased from 0.701 m to 0.780 m, and then to 0.864 m, the average spraying angles across nozzles N1, N2, N3, and N4 consistently decreased, registering 86.02°, 82.26°, and 77.78°, respectively. This inverse relationship indicated that an increase in boom height tends to reduce the effective spray angle. This variation can be attributed to the geometric relationship between nozzle height and the spread of the spray pattern, as well as potential minor fluctuations in sprayer pressure. Both boom height and pressure are known to significantly affect the spray cone angle and ultimately the spray distribution pattern (Ozkan, 2000; Nuyttens *et al.,* 2007).

Sprayer coverage area at variable heights: Figure 12 presents the sprayer's coverage area as a function of boom height during laboratory evaluation. As the boom height was increased (0.701 m, 0.780 m, 0.864

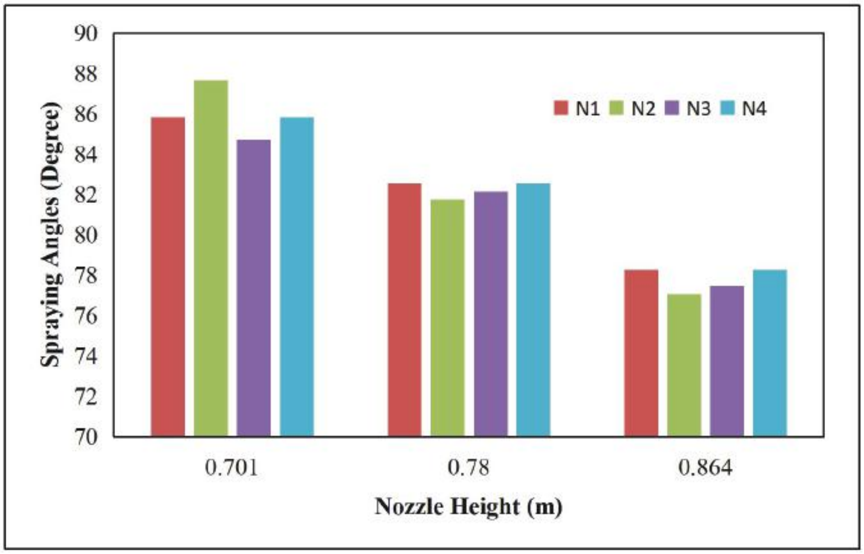


Fig. 11. Spraying angle variation at different boom height.

m), the measured coverage area expanded commensurately (39.39 m^2, 42.80 m^2, 60.45 m^2). This positive correlation demonstrated that elevating the boom height geometrically disperses the spray more widely, resulting in a larger effective coverage area per pass. This finding is critical for optimizing field efficiency and minimizing operational passes, while also needing consideration for potential off-target spray drift.

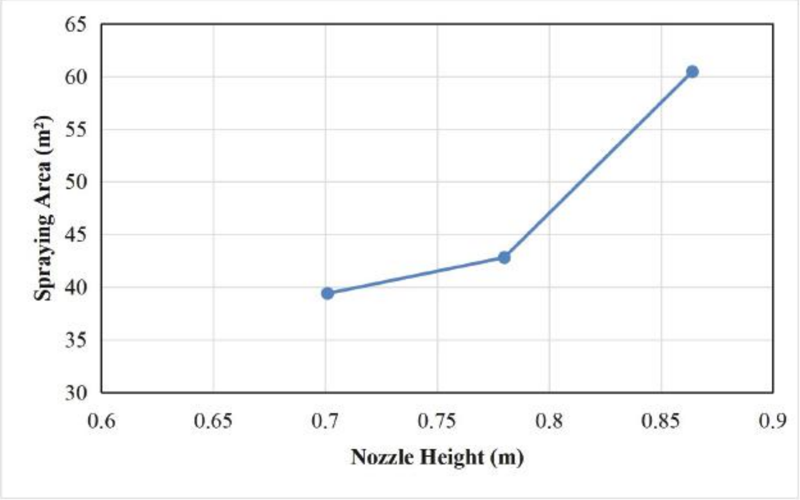


Fig. 12. Variation of spraying with different boom height.

Swath width analysis: Swath width refers to the effective width of the area uniformly treated by spray droplets during a single pass of the sprayer's boom, primarily dictated by the spread from individual nozzles. As presented in Figure 13, experimental results demonstrated a direct correlation between increasing boom height and an expanded swath width for nozzles N1, N2, N3, and N4. This phenomenon is geometrically consistent, as a greater vertical distance from the nozzle allows for broader dispersion of the spray cone before deposition.

However, observed variations, where some nozzles covered a wider area than others, indicate localized inconsistencies. These deviations are likely attributable to factors such as imprecise nozzle placement along the spray boom and/or variations in the sprayer's travel inclination (e.g., uneven terrain or operator handling), which can alter the effective spray angle and pattern uniformity. Precise control over boom height, nozzle alignment, and travel stability is therefore crucial for achieving optimal and consistent swath coverage.

Overlap percentage analysis: Overlap percentage is a crucial parameter in spray application, representing the degree to which adjacent spray swaths overlap to ensure uniform coverage across the treated area. Figure 14 illustrates the relationship between boom height and this overlap. The experimental results show that as the boom height increased from 0.701 m to 0.780 m, and further to 0.864 m, the measured overlap percentage correspondingly increased to 30%, 33%, and 36%, respectively.

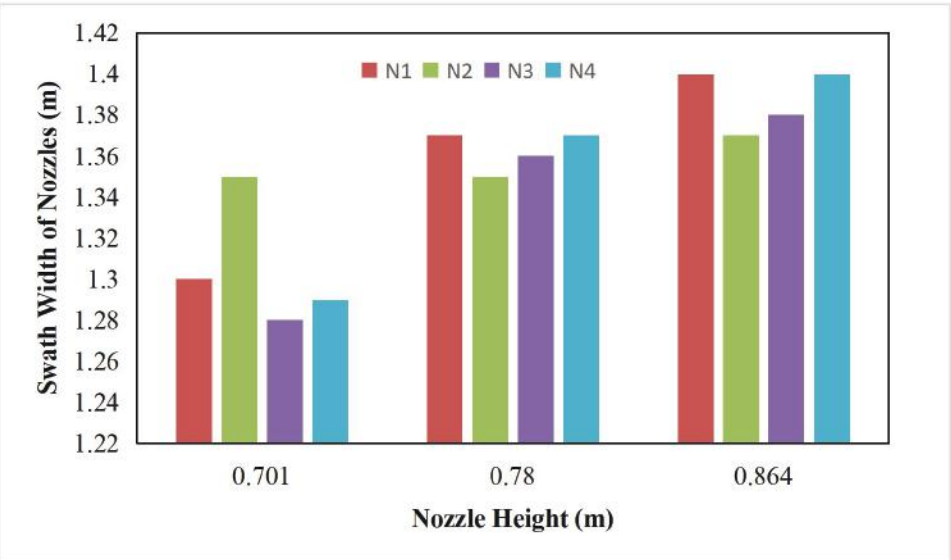


Fig. 13. Variation of swath width with different boom height.

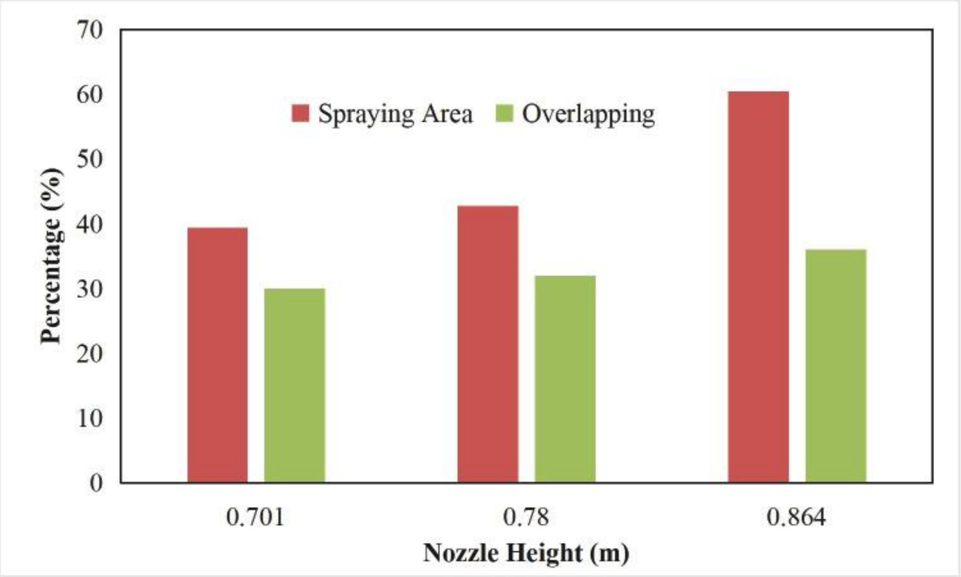


Fig. 14. Percentage missing and overlap area in different boom height.

This observed trend indicated that a higher boom height directly contributed to a greater percentage of overlap between spray passes. Scientifically, this occurs because, at increased heights, the spray pattern from individual nozzles widens significantly (as demonstrated by the increased swath width). If the sprayer's pass-to-pass distance remains constant, this wider spray pattern inherently leads to more significant overlap with the adjacent swath. While some overlap is necessary to ensure complete coverage and prevent untreated strips, excessive overlap can lead to over-application of chemicals, resulting in unnecessary pesticide use, increased costs, and enhanced environmental risk (Nuyttens *et al.,* 2007; Matthews *et al.,* 2014). Therefore, optimizing boom height is essential to achieve effective coverage without excessive chemical input.

Evaluation of the innovative power sprayer on eggplant field

The newly fabricated power sprayer underwent rigorous field evaluation within the designated research plots of the Agricultural Engineering Department, specifically on an eggplant (*Solanum melongena* L.) crop (Fig. 15). The primary objective of these field trials was to quantitatively assess the operational performance and efficiency of the sprayer under typical agricultural conditions.

The evaluation revealed an overall field efficiency of 80.86% for the power sprayer. This metric represents the proportion of theoretical maximum work that is actually achieved under real-world operating conditions, accounting for time losses due to turning at headlands, refilling the tank, minor adjustments, and other non-productive

Fig. 15. Field Evaluation on Egg Plant

activities (ASABE, 2006). An efficiency of over 80% indicates a well-designed machine that minimizes non-productive time, suggesting efficient operation and management during spraying.

Further analysis of the sprayer's operational capacity yielded a theoretical field capacity of 0.89 ha/hr and an effective field capacity of 0.72 ha/hr. Theoretical field capacity (TFC) is calculated based on the effective working width of the sprayer and the operational speed, assuming continuous operation without any interruptions. It represents the maximum area covered per hour (ASABE, 2006). Other sides, the effective field capacity (EFC), is a more realistic measure, reflecting the actual area covered per unit time under specific field conditions, accounting for all forms of lost time. The difference between TFC and EFC reflects the field efficiency, as EFC = TFC × Field Efficiency. For this instance, the EFC of 0.72 ha/hr signifies that the sprayer can effectively cover 0.72 hectares of eggplant crop in one hour, making it considerably faster than manual knapsack spraying (Matthews *et al.,* 2014).

During the field trials, the power sprayer maintained an average operating speed of 2.47 km/hr, which is crucial as it directly influences the application rate and spray uniformity. The optimal operating speed ensures sufficient spray coverage without excessive overlapping or under-application (Matthews *et al.*, 2014). The effective boom width of the sprayer was measured at 3.6 m, which represents the actual width effectively covered by the spray nozzles during a single pass. This width, combined with the operating speed, describes the area covered per unit time. For the estimated working area of 227.62 m^2 (0.023 ha) the sprayer completed the task in an average working time of 1.9 minutes, excluding a turning time of 0.35 minutes. This indicates that the power sprayer requires approximately 1.65 hours to cover 1.0 ha of land, whereas the traditional backpack sprayer would take about 7.35 hours for the same area (Rahman *et al.,* 2021). This specific data point expresses the rapid coverage achievable with the innovative power sprayer, especially for the small to medium-sized plots common in Bangladesh, indicating a significant reduction in labor and time requirements compared to traditional methods.

Collectively, these performance parameters high field efficiency, substantial effective field capacity, and a practical operating speed demonstrate that the innovative power sprayer is well-suited for efficient and timely agrochemical application on field crops including not only eggplant but also tomato and potato in Bangladesh.

Economic analysis of the powered sprayer Machine

A comprehensive economic evaluation was conducted to determine the feasibility and cost-effectiveness of the developed powered sprayer machine. The total fabrication cost of the machine was approximately Tk. 30,000, which includes expenditures for a modified bicycle frame and components, galvanized iron pipes, a 20-liter pesticide tank with gasoline engine, four spray nozzles, hose connectors, and labor charges for assembly and fabrication.

The fixed costs were calculated using the capital recovery method. These costs

Table 2. Approximate cost for the fabrication of a sprayer machine in the workshop

	Items	Cost (Tk.)
1.	Bicycle frame, fork and handle bar	3000
2.	Bicycle rim (27 and 12 inch), spokes, tire, and stand	2000
3.	Bicycle chain	200
4.	½ and ¾ inch G.I pipe and angle bar	2500
5.	20L sprayer tank with gasoline engine	20000
6.	4 Spray nozzle with connector and hose pipe	600
7.	MS rod and nut bolts	200
8.	Fabrication charge	1500
	Estimated Total Cost	30000

comprise annual depreciation and interest on investment, alongside taxes, insurance, and shelter, estimated at Tk. 49.37 per hectare. Specifically, the annual depreciation and interest cost amounted to Tk. 4,882.4, while charges for taxes, insurance, and shelter totaled Tk. 450, resulting in a total annual fixed cost of Tk. 5,332.4.

The variable costs were determined by accounting for repair and maintenance (Tk. 6.00/hour), lubrication (Tk. 6.70/hour), fuel

Table 3. Total operating cost incurred per hectare for the wheeled-powered sprayer machine

Fixed Cost Items	Estimated Purchase Price, Tk	30000.0
	Working Life, y	10
	Interest Rate, %	10
	Taxes, Insurance and Shelter (Housing), %	1.5
	Capital Recovery Factor (CRF)	0.1627
Fixed Cost (A)	Annual Depreciation and Interest Cost (ADIC), Tk/y	4882.4
	Taxes, Insurance and Shelter (Housing), Tk/y	450
	Total Fixed Cost, Tk/y	5332.4
	Total Fixed Cost, Tk/ha	49.37
Variable Cost Items	Repair and Maintenance Cost, Tk/h	6.0
	Lubrication Use, kg/h	0.0223
	Lubrication Cost, Tk/h	6.7
	Fuel Use, L/h	0.35
	Fuel Cost, Tk/L	135.0
	Labor Cost, Tk/day	600.0
	Average Working Hour per Year, h/y	200
	Equivalent Annual Cost Factor (EACF)	1.607
	Field Capacity, ha/h	0.72
	Annual Coverage, ha/y	144.0
Variable Cost (B)	Repair and Maintenance Cost, Tk/y	1200.0
	Labor Cost, Tk/y	24099.2
	Lubrication Cost, Tk/y	1338.0
	Fuel Cost, Tk/y	9450.0
	Total Variable Cost, Tk/y	36087.2
	Total Variable Cost, Tk/ha	250.6
	Total Operating Cost (=A + B), Tk/y	41419.6
	Break Even Point, ha	55.19

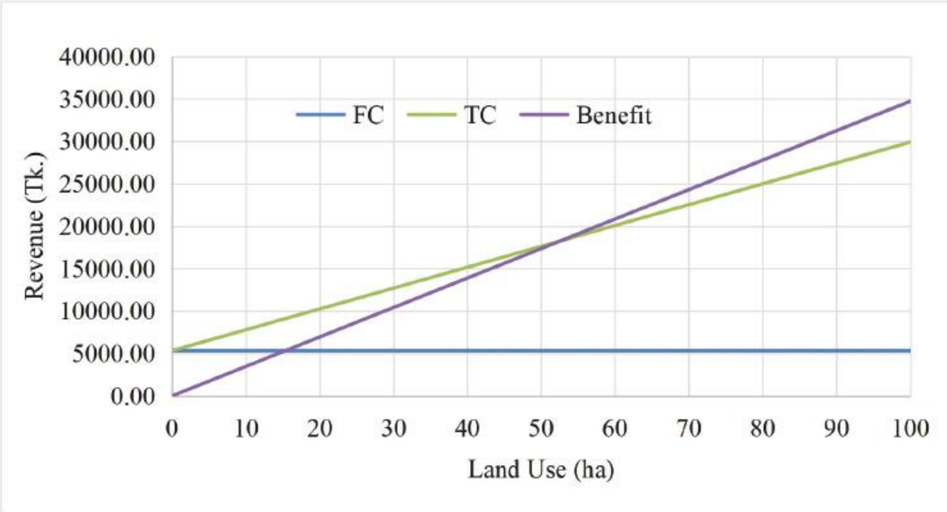


Fig. 16. Break Even Analysis of Powered Sprayer Machine.

consumption (0.35 L/hour at Tk. 135/L), and labor wages (Tk. 600/day). Based on an annual usage of 200 hours and a field capacity of 0.72 ha/h, the total annual variable cost was estimated at Tk. 36,087.2, translating to Tk. 250.6 per hectare.

Combining both fixed and variable costs, the total operational cost of the sprayer machine was calculated as Tk. 299.97 per hectare. A break-even analysis indicated that the machine would recover its initial investment after spraying approximately 55.19 hectares of crop land.

This economic assessment demonstrates that the developed powered sprayer is not only affordable but also financially viable for small to medium-scale farmers. It offers an efficient alternative to traditional manually operated sprayers, with the added benefits of reduced labor fatigue, improved field coverage, and enhanced spraying uniformity contributing to increased productivity and sustainability in crop protection practices.

Conclusions

The study successfully developed and evaluated a gasoline engine powered sprayer mounted on a mild steel frame with support wheels, aimed at overcoming the limitations of conventional pesticide application methods in Bangladesh. Both the laboratory and field performance assessments demonstrated that the sprayer offers improved operational efficiency, uniform spray distribution (CV = 1.92%), and reduced physical stain for the operator. With a field efficiency of over 80.86%, a working speed of approximately 2.47 km/h, and an affordable operational cost of Tk. 299.97 per hectare, this innovative sprayer design gives considerable promise for small to medium-scale farmers. The integration of mobility and power assistance addressed critical ergonomic concerns associated with traditional knapsack sprayers. The break-even analysis of 55.19 hectare of crop land, confirms the economic viability of the sprayer machine for regular agricultural use. This sprayer can play a vital role in enhancing crop protection practices, reducing labor dependency, and promoting mechanized agriculture in Bangladesh. Further trials across diverse vegetable fields and terrains are recommended to establish broader applicability and fine-tune the innovative power sprayer design for commercial dissemination.

Acknowledgements

The authors express their sincere gratitude to the Research Management Wing (RMW) of Gazipur Agricultural University, Bangladesh, for providing financial support to carry out this research project. This funding facilitated the successful development of an innovative power sprayer machine aimed at enhancing sustainable mechanization in Bangladesh. The authors also convey their heartfelt thanks to the technical staffs of the Department of Farm Machinery and Precision Engineering at the same university for their valuable support and assistance during the project.

Conflict of Interest

The authors affirm that no financial or commercial relationships that might be construed as a potential conflict of interest existed during the course of the research.

Author Contributions

Conceptualization and methodology, Md Mostafizar Rahman; validation, Md Mostafizar Rahman, and Khokan Mohanto; resources, Md Mostafizar Rahman; data curation, Khokan Mohanto; writing preparation of the initial draft, Md Mostafizar Rahman and Khokan Mohanto; writing, review and editing, Md Mostafizar Rahman; visualization, Md Mostafizar Rahman; supervision, Md Mostafizar Rahman. Authors have reviewed the manuscript in its current form and given their approval.

References

Angadi, R., L. G. Rohit, S. Changond and S. Kagale. 2017. Cam operated agrochemical pesticide sprayer. *Int. Res. J. Eng. Tech.* 6(1): 233–236.

ASABE. 2006. ASAE EP496.3: Guide for Applying Crop Sprayers. American Society of Agricultural and Biological Engineers (ASABE).

Atreya, K. 200*7. Pestici*de use knowledge and practices: A gender differences in Nepal. Environ. Res. 104(2): 305–311. https://doi.org/10.1016/j.envres.2007.01.001

Dasgupta, S.*, C. Meisner, D. Wheel*er, K. Xuyen and N. T. Lam. 2007. Pesticide poisoning of farm workers: Implications of blood test resu*lts from Vietnam. Int. J. H*yg. Environ. Health. 210(2): 121–132. https://doi.org/10.1016/j.ijheh.2006.08.006

Devi, K. G., C. SenthilKumar, B. Kishore and J. Chitra. 20*21. Design of cost-effecti*ve automated and semi-automated pesticide spraying robot. Design Eng. 9: 1723–1737.

Dhiraj, N. K., S. Vishal, *W. Prashik, A. Altaf,* T. Vikas and R. D. Gorle. 2016. Fabrication of automatic pesticides spraying machine. Int. Res. J. Eng. Tech. 3(*4): 912–916.*

*Gha*foor, A., F. A. Khan, F. Khorsandi, M. Ahmad and H. Imran. 2022. Development and evaluation of a prototype self-propelled crop sprayer for agricultural sustainability in small farms. Sustainability. 14(15): 9204. https://doi.org/*10.3390/su14159204*

Hossen, M. A. 2019. Mechanization in Bangladesh: Way of modernization in agriculture. Int. J. Eng. Trends Technol. 67(9): 69–77.

Kshirsagar, S., *V. Dadmal, P. Umak, G. Mun*de and P. R. Mahale. 2016. Design and development of agriculture sprayer vehicle. Int. J. Curr. Eng. Technol. 4: 405–408.

K*umar, C. S. 2015. Development an*d performance evaluation of single wheel driven boom sprayer. Int. J. Agric. Sci. Res. 5(5): 277–285.

L. P. *Raut, S. B. Jaiswal* and N. Y. Mohite. 2013. Design, development and fabrication of agricultural pesticides sprayer with weeder. Int. J. Appl. Res. Stu*dies. 2(11).*

Matthews, G. A., R. P. Bateman and P. C. H. Miller. 2014. Pesticide application methods (4th ed.). John Wiley & Sons.

Mulatu, Y. 2018. Fabrication and performance evaluation of gro*und wheel operated* boom sprayer. Int. J. Eng. Sci. 6: 16–23.

Nuyttens, D., M. De Schamphelei*re, K. Baetens, and B. Sonck.* 2009. Spray application technology and pesticide dose adjustment in *fruit growing. Agric. Eng. Int.*: CIGR J. 11: 1–14.

Rahman, M. M., K. Mohanta, U. M. Zamil and M. H. M. Oliver. 2025. Development and evaluation of a wheel-powered sprayer machine for marginal farmers. Tract. Agric. Mach. 92(1): 57–67.

Rah*man, M. M., M. R. Ali, M*. H. Oliver, M. A. Hanif, M. Z. Uddin, T. Hasan, K. K. Saha, M. H. Islam and M. Moniruzzaman, 2021. Farm mechanization in Bangladesh: A review of the status, roles, policy, and potentials. J. Agric. *Food Res. 6:* 100225.

Singh, S., D. Padhee, S. Sonwani and T. Sahu. 2020. Design, fabrication and evaluation of wheel operated sprayer. I. J. Curr. Microbiol. Appl. Sci. 9(1): 1649–1659.

Ware, G. W. and D. M. Whitacre. 2004. An introduction *to insecticides (4*th ed.). MeisterPro Information Resources, Willoughby, Ohio.

Yassin, M. M., T. A. Abu Mourad and J. M. Safi. 2002. Knowledge, attitude, practi*ce, and toxi*city symptoms associated with pesticide use among farm workers in the Gaza Strip. Occup. Environ. Med. 59(6): 387–393. https://doi.org/10.1136/oem.59.6.387

Zaffar, O. and S. Khar. 2022. Performance evaluation of a whee*l operated boom sprayer. Cur*r. Adv. Agric. Sci. 14: 78–82.

Zilpilwar, S., R. Yadav, K. Sakariya, and M. *Gahane. 2021. Ergonomic evaluation of battery* operated knapsack sprayer. Agric. Eng. Int.: CIGR J. 23(3): 182–189.