E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(11): 205-211
Received: 26-08-2025
Accepted: 01-10-2025

AR Kolekar
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

Amol S Ghadge
Assistant Professor, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

AM Gore
Assistant Professor, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

BS Gholap
Assistant Professor, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

Mangal A Patil
Associate Dean, Department of Agriculture Engineering, DYP-ATU, Talsande, Maharashtra, India

AP Kshirsagar
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

PP Mane
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

AN Nikam
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

AS Zure
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

Corresponding Author:
AR Kolekar
B. Tech Student, Department of Agriculture Engineering (FMPE), DYP-ATU, Talsande, Maharashtra, India

Development and performance evaluation of engine operated walk type sprayer

AR Kolekar, Amol S Ghadge, AM Gore, BS Gholap, Mangal A Patil, AP Kshirsagar, PP Mane, AN Nikam and AS Zure

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i11Sc.4234

Abstract
A Engine operated walk type sprayer machine was developed in the Department Farm Machinery and Power Engineering, D. Y. Patil agriculture and technical University, Talsande, Kolhapur. The developed engine operated walk type sprayer was tested on the experimental field for optimization of the operating parameters for brinjal and wheat crop. The speed noted 3, 3.5, 4 km/h and width of operation 2.6, 2.8, 3 m. The quantity of the chemical solution after the calculation was 178 l/ha. The fuel consumption rate was 1.5 l/ha. Average Theoretical Field efficiency is 0.98 ha/h. Average effective field capacity is 0.95 ha/h. Field efficiency is ratio of effective field capacity and theoretical field capacity. Average field efficiency is 90.11%. Fixed cost is 26.75 ₹/h, Variable cost is 229.25 ₹/h, total cost is 256 ₹/hr. Break-even point of the sprayer was 9.09 yrs. Overall, in operation and economic point of view the Developed engine operated walk type sprayer was found satisfactory performance.

Keywords: Introduction, material and method, result and discussion, conclusion, reference

1. Introduction
The need for agricultural production and nutrients is continuously rising worldwide due to the rapid growth of the global population. It is estimated that by the year 2050, agricultural productivity will need to increase by approximately 60 percent to meet the demands of the growing population (Harvey, 2013). Currently, nearly 25-35 percent of global agricultural production is lost due to insects and plant pathogens (Mansouri-Rad, 2007). Studies have shown that pests cause significant losses in most crops worldwide. These losses are estimated to be as high as 50 percent in rice, 41 percent in potatoes, 40 percent in coffee, 39 percent in maize, 32 percent in soybeans, 30 percent in barley, and 26 percent in sugar beets (Oerke and Dehne, 2004). Furthermore, it has been reported that the total global potential loss due to pests could range from about 50 percent in wheat to more than 80 percent in cotton production. The use of pesticides has become an integral part of global agriculture, and it has been reported that 30 to 35 percent of crop losses could be prevented from the harmful effects of pests and diseases through the use of pesticides (Dhole and Jadhav, 2018). Brinjal is an important crop in India, where farmers are facing an acute labor shortage for spraying operations. Pests and diseases pose a serious threat during the plant's growth. Currently, farmers use manually operated knapsack sprayers and motorized sprayers. A manually operated knapsack sprayer can cover 0.4 hectares per day (over 6 working hours), while a motorized knapsack sprayer fitted with a petrol engine can cover 1.2 to 1.6 hectares per day (also over 6 working hours). As a result, many farmers prefer using engine-operated sprayers mounted on frames for spraying purposes. Typically, farmers spray 5-6 times on brinjal crops throughout the growing season. However, achieving uniform spraying with manually operated sprayers is challenging. As the height and density of the crop increase with its growth stage, the effectiveness of manual spraying decreases. Wheat is the second most important cereal crop and the main food crop in the northern and north-western parts of India. India is the second-largest producer of wheat, accounting for about 14% of the world's total production. The country produces approximately 110 million tonnes (MT) of wheat each year. As per the Second Advance Estimates for the

agricultural year 2022-23, wheat production in India is estimated at 112.18 million tonnes, which is 4.44 million tonnes higher than the production achieved during 2021-22. Wheat production is susceptible to several diseases caused by fungi, bacteria, viruses, and environmental factors. These diseases can significantly reduce yields and quality if not properly managed. Chemicals used for crop protection, such as insecticides, herbicides, fungicides, acaricides, molluscicides, and nematicides, are applied to plants, soil, and water to control pests and diseases.

2. Review of literature

Khedkar and Shahare (2009) developed an air assisted three outlet type sprayer in order to overcome the limitations (excess labour and time) associated with the conventional method of spraying. It was observed that the droplet diameter of BCN nozzles were found to be better while as spray characteristics i.e. volume deposition, uniformity coefficient was found better with HCN/PA and droplet density with NMD/S. The results revealed that the prototype had the swath width of 7.5m with actual field capacity of1.13ha/h at 2 km/h travel speed. The field efficiency of the sprayer was found to be 75.4 percent.

Shivaraj and Parmeshwar murthy (2014) developed a wheel and pedal operated sprayer that uses reciprocating pump with an accumulator to provide a continuous flow of liquid to create necessary pressure for the spraying action. This wheel operated pesticide spray equipment consumed less time and avoided the pesticide from coming from front of the nozzles which could come in contact of the person who sprays pesticides.

Akhilesh *et al*., (2016) developed a push operated four wheeled pesticide spraying machine. The spraying was done by a toothed wheel which was attached to the drive wheel on one side and piston of pump, converting rotational motion of toothed wheel into liner motion of pump. The machine took seven hours to complete spraying of one hectare of land with the swath width of 3 m and carrying capacity of tank can be adjusted from 20-40 litres.

3. Materials and Methods

3.1 Description of Engine operated walk type sprayer

Table 1: Specifications of Engine operated walk type sprayer

S. N	Parameters	Value
1	Source of power	2 Stroke Engine
2	Reciprocating pump	2 numbers stroke length 65 mm and 50 mm of piston diameter
3	Boom length, mm	2250
4	Number of nozzles	6
5	Pressure control device	Pressure relief valve
6	Power transmission	Piston
7	Ground clearance, mm	300
8	Tank capacity, l	20
9	Cost of unit, Rs	10000
10	Field capacity, ha/h	0.87
11	Cost of operation, Rs/ha	150
12	Engine, cc	33

3.2 Development of Engine operated walk type sprayer

The engine-operated walk type sprayer at the College of D.Y. Patil Agriculture & Technical University, Talsande, Kolhapur, was developed to address the challenges associated with conventional sprayers. To enhance the application rate, the sprayer unit was modified by fabricating a spray boom with a suitable width and increasing the number of nozzles. Additionally, a nozzle adjustment facility was incorporated. All nozzles on the boom can be adjusted according to the row spacing and the height of the crop. The sprayer unit was fabricated with the modified version of the spray boom. A separate power source, in the form of a petrol engine, was provided to generate sufficient pressure for the sprayer. The engine power is utilized to operate the sprayer unit. The functional components of the developed sprayer are explained below.

Plate 1: Engine operated walk type sprayer

3.2.1 Spray boom

The engine operated walk type sprayer was able to cover 1 ha per hr. The length of boom is 240 cm. It was made from mild steel. The 6 Nos. of Nozzles were used and fitted to spray boom with the help of clips.

Plate 2: Spray boom

3.2.2 Pump

A 2 stroke 33 cc engine was used as a main source of power in this sprayer. The power sprayer has an engine of brass metal and works on petrol as a fuel. It uses Ruixing diaphragm type carburetor and highly mobile single 18 mm diameter S.S. piston pumps developing maximum pressure of 400 psi. Fuel tank has a capacity of 1000 ml. The weight of the chemical tank without chemical was 8.250 kg.

Plate 3: Pump

3.2.3 Petrol engine
The Petrol engine acts as power source for operating the sprayer unit. The power generated by the engine is transferred to the pump. This petrol engine is 2-stroke. Plunger diameter was 18 mm and heavy brass aluminium pump. 33 cc engine was used.

Plate 4: Petrol Engine

3.2.4 Hose pipe
The length of the boom pipe was 450 cm. 6 nozzles was fitted to pipe. That pipe made from PVC material. Pipe was used to supply the chemical from pump to the nozzle.

3.2.5 Number of nozzles
Based on the pump output and nozzle throughout, the number of nozzles to be placed on the boom is calculated. With the row spacing of 450 mm, a total number of 6 nozzles. The spray boom length is fitted with 6 spray nozzles of hollow cone type and can be adjusted according to the row spacing.

3.3 Field Performance Evaluation
The observations recorded pertaining to the sprayer unit for field test are:
1. Speed of operation
2. Field capacity
3. Effective field capacity
4. Theoretical field capacity
5. Field efficiency
6. Quantity of chemical solution sprayed
7. Fuel consumption

4. Results and Discussion
4.1 Performance evaluation of developed engine operated walk type sprayer
The field trials were conducted to evaluate the performance of developed engine operated walk type sprayer. Trials were conducted at Ghunki. The testing was done and determined theoretical field capacity, effective field capacity and field efficiency for engine operated walk type sprayer. The observations of all results noted and tabulated in Table 2. The performance evaluation of performance of developed engine operated walk type sprayer was carried out by performing different experimental run as discussed in M & M section. To minimize number of experiment to find out interactions of independent and dependent parameters "Design Expert 13'' software was used and accordingly combination of parameter for 13 experiment to be conducted were finalized. Accordingly, 13 runs for two independent and three dependent parameters were carried out. The experimental run and observed responses by using RSM (Surface Response Method) are given in Table 2.

Table 2: Experimental run and operational response of developed engine operated walk type sprayer by using response surface method

Run	Forward Speed	Spraying height	TFC	EFC	FE
1	3	45	0.78	0.76	97
2	3.5	60	0.98	0.94	95.92
3	3.5	60	0.98	0.94	95.92
4	3.5	38	0.78	0.76	97
5	2.7	60	0.78	0.76	97
6	4	45	1.04	1.02	98.08
7	3.5	60	0.98	0.94	95.92
8	3.5	60	0.98	0.94	95.92
9	4.2	60	1.06	1.02	98.08
10	3.5	60	0.98	0.94	95.92
11	4	75	1.04	1.02	98.08
12	3	75	1.05	1.02	97.14
13	3.5	81	1.05	1.02	97.14

4.1.1 Effect of different independent parameters on response parameters (dependent parameters indicator)
The effect of operational parameters on the performance of engine operated walk type sprayer is studied and discussed in following subsequent headings. Response surface methodology is used for analysis of observed responses after eliminating some nonsignificant terms and predicted models is tested for adequacy and fitness using analysis of variance.

4.1.1.1 Theoretical field capacity
The ANOVA given in Table 3 indicates that, the high value of model F (13.0) suggesting reduced cubic model could be successfully used to fit experimental data ($p<0.001$). P-values less than 0.05 indicate model terms are significant. As per F values indicated in Table 3 the linear term forward speed and spraying height had significant effect on theoretical field capacity at 1 per cent level of significance respectively. Similarly, the interaction terms forward speed × spraying height, had significant effect on droplet size at 5 per cent level of significance. Non-significant lack of fit is good. The R^2 (0.94) for these model is good. The predicated R^2 is (-2.3) for this model was also in agreement with adjusted R^2 (0.87). A negative predicted R^2 implies that the overall mean may be a better predictor of this model. The Effect of forward speed and spraying on theoretical field capacity is shown in Fig.1

Table 3: ANOVA for study of effect of forward speed, spraying height on theoretical field capacity

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.1310	7	0.0187	13.00	0.00618*	Significant
A-Forward speed	0.0392	1	0.0392	27.22	0.0034*	S
B-spraying height	0.0364	1	0.0364	25.31	0.0040*	S
AB	0.0182	1	0.0182	12.66	0.0163**	S
A^2	0.0016	1	0.0016	1.09	0.3449	
B^2	0.0021	1	0.0021	1.48	0.2781	
A^2B	0.0016	1	0.0016	1.09	0.3452	
AB^2	0.0027	1	0.0027	1.85	0.2319	
A^3	0.0000	0				
B^3	0.0000	0				
Residual	0.0072	5	0.0014			
Lack of Fit	0.0072	1	0.0072			
Pure Error	0.0000	4	0.0000			
Cor Total	0.1382	12				

*AT 1% Level of significance, **At 5% level of significance

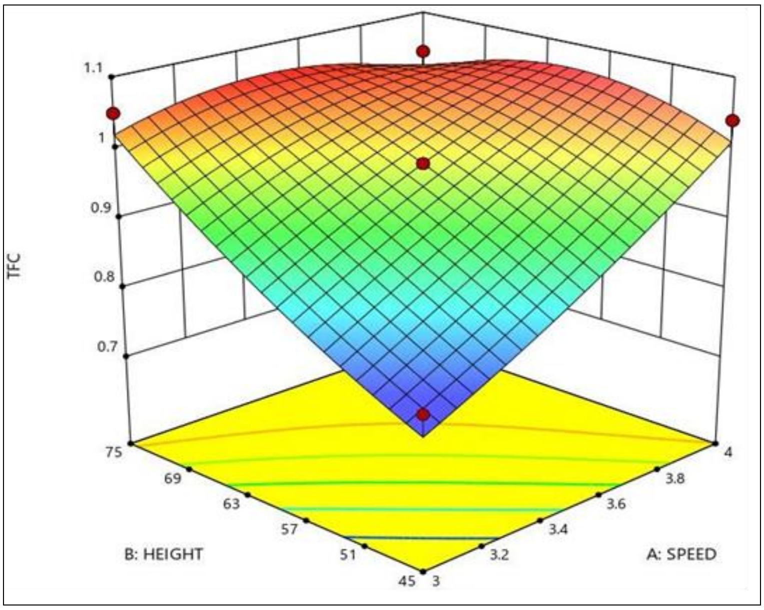

Fig 1: Effect of forward speed and spraying on theoretical field capacity

4.1.1.2 Effective field capacity

The ANOVA given in Table 3 indicates that, the high value of model F (10.08) suggesting reduced cubic model could be successfully used to fit experimental data ($p<0.001$). P-values less than 0.05 indicate model terms are significant. As per F values indicated in Table 3 the linear term forward speed and spraying height had significant effect on effective field capacity at 1 percent level of significance respectively.

Table 4: ANOVA for study of effect of forward speed, spraying height on effective field capacity

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.1192	7	0.0170	10.08	0.0108*	Significant
A-speed	0.0338	1	0.0338	20.00	0.0066*	S
B-height	0.0338	1	0.0338	20.00	0.0066*	S
AB	0.0169	1	0.0169	10.00	0.0250**	
A^2	0.0005	1	0.0005	0.3152	0.5988	
B^2	0.0005	1	0.0005	0.3152	0.5988	
A^2B	0.0014	1	0.0014	0.8579	0.3968	
AB^2	0.0014	1	0.0014	0.8579	0.3968	
A^3	0.0000	0				
B^3	0.0000	0				
Residual	0.0085	5	0.0017			
Lack of Fit	0.0085	1	0.0085			
Pure Error	0.0000	4	0.0000			
Cor Total	0.1277	12				

*AT 1% Level of significance, **At 5% level of significance

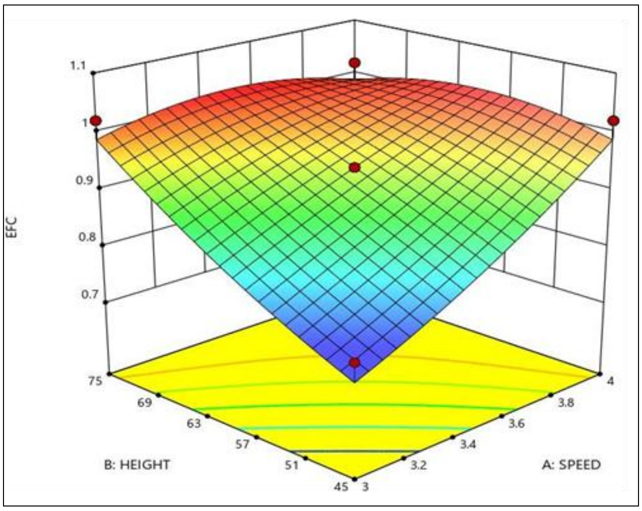

Fig 2: Effect of forward speed and spraying on effective field capacity

Similarly, the interaction terms forward speed × spraying height, had significant effect on droplet size at 5 per cent level of significance. Non-significant lack of fit is good. The R^2 (0.93) for these model is good. The predicated R^2 is (-3.2) for this model was also in agreement with adjusted R^2 (0.84). A negative predicted R^2 implies that the overall mean may be a better predictor of this model. The Effect of forward speed and spraying on effective field capacity is shown in Fig.2.

4.1.1.3 Field Efficiency

The ANOVA given in Table 43 indicates that, the high value of model F (43.86) suggesting reduced cubic model could be successfully used to fit experimental data (p<0.001). P-values less than 0.05 indicate model terms are significant. As per F values indicated in Table 3 the linear term forward speed and spraying height had significant effect on effective field capacity at 1 percent level of significance respectively. Similarly, the interaction terms forward speed × spraying height, had significant effect on droplet size at 5 per cent level of significance. Non-significant lack of fit is good. The R^2 (0.98) for these model is good. The predicated R^2 is (-0.02) for this model was also in agreement with adjusted R^2 (0.96). A negative predicted R^2 implies that the overall mean may be a better predictor of this model. The Effect of forward speed and spraying on field efficiency is shown in Fig.3.

Table 5: ANOVA for study of effect of forward speed, spraying height on field efficiency

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	8.95	7	1.28	43.86	0.0003*	significant
a-speed	0.5832	1	0.5832	20.00	0.0066**	
B-height	0.0098	1	0.0098	0.3361	0.5872	
AB	0.0049	1	0.0049	0.1680	0.6988	
A^2	5.36	1	5.36	183.70	< 0.0001	
B^2	2.87	1	2.87	98.48	0.0002	
A^2B	0.0004	1	0.0004	0.0144	0.9091	
AB^2	0.0303	1	0.0303	1.04	0.3545	
A^3	0.0000	0				
B^3	0.0000	0				
Residual	0.1458	5	0.0292			
Lack of Fit	0.1458	1	0.1458			
Pure Error	0.0000	4	0.0000			
Cor Total	9.10	12				

*AT 1% Level of significance, **At 5% level of significance

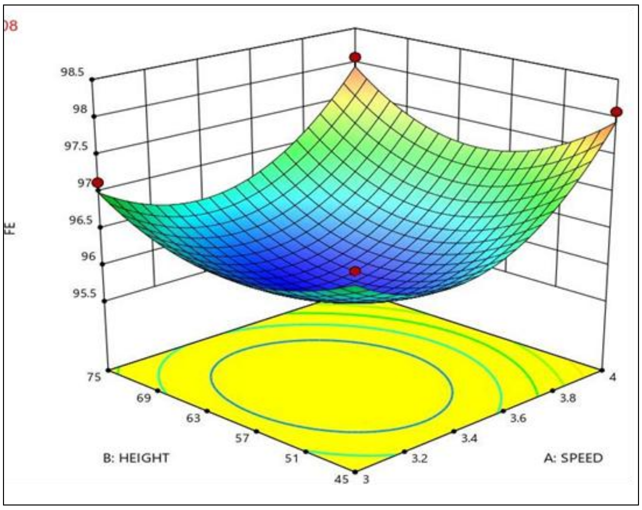

Fig 3: Effect of forward speed and spraying on field efficiency

The engine operated walk type sprayer tested for brinjal crop as discussed.

Table 6: Test conditions of developed Engine operated walk type sprayer.

	Particulars	
a)	**Condition of field and soil**	
1	Location	Ghunki
2	Length (m)	60
3	Width (m)	20
4	Area (m^2)	1200
5	Type of soil	Black cotton soil
b)	**Condition of crop**	
1	Name of crop	Brinjal
2	Variety of crop	Ramik Dev
3	Age in day after planting	90
4	Planting method	Manually
5	Row spacing (cm)	135
6	Plant spacing (cm)	75
7	Plant population	1040
8	Height of plant	1 m
c)	**Condition of operation**	
1	Skill of operation	Semi-skill
2	Wage of operator Rs/day	300

Table 7: Field performance of developed Engine operated walk type sprayer.

	Particulars	
1	Date of test	31/12/2024
2	Actual operating time	9.83 min
3	Travelling speed	3 km/hr
4	Actual area covered	0.12 ha
5	Fc	0.87 ha/hr
6	Fe	90.11%
7	Effective width	2.8 m
8	Plant damaged	No
9	Work quality	Good
10	Clogging	No
11	Labour requirement	1

Testing on crops

Plate 5: Spraying on brinjal crop using developed Engine operated walk type sprayer

Plate 6: Spraying on wheat crop using developed Engine operated walk type sprayer

4.2 Speed of operation
During field trials, the speed of operation for engine operated walk type sprayer has been measured. For spraying operation, the engine operated walk type sprayer is operated at an average travel speed of 3 km/hr.

4.3 Field capacity
During the field trials, the time losses involved during spraying operation has been noted and the average field capacity of the engine operated walk type sprayer was found to be
0.87a/hr.

4.4 Quantity of chemical solution
For brinjal crop, the recommended quantity of pesticide is thoroughly mixed with water and the chemical solution is prepared. The average chemical quantity of chemical solution for brinjal has been found to be 178 l/ha.

4.5 Fuel consumption
The quantity of petrol requirement for spraying operation has been measured. The average fuel consumption (Petrol) for spraying operation on brinjal crop using engine operated walk type sprayer was found to be 1.5 l/h.

5. Conclusion
- In field testing, performance parameter of developed engine operated walk type sprayer was found the average values of theoretical field capacity, effective field capacity, and field efficiency was 0.98 ha/h, 0.95 ha/h and 90.11%.
- In field testing the effect of forward speed and spraying height on theoretical field capacity was found to be significant.
- In field testing the effect of forward speed and spraying height on Effective field capacity was found to be significant.
- In field testing the effect of forward speed and spraying height on field efficiency was found to be significant.
- Operation cost of Engine operated walk type sprayer was found to be 294.25 ₹/ha.

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