

Optimization of Operational Parameters for Tractor Operated Swinging Lance Sprayer by Using ASPEE-SPGF Spray Guns

Arudra Srinivasarao^{1*}, Tapan Kumar Khura¹, Roaf Ahmad Parray¹,
Indra Mani¹, H. L. Kushwaha¹ and Susheel Kumar Sarkar²

¹Indian Agricultural Research Institute, Division of Agricultural Engineering, New Delhi, India.

²Indian Agricultural Statistics Research Institute, Division of Agricultural Statistics,
New Delhi, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author AS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TKK, RAP, IM and HLK managed the analyses of the study. Author SKS assisted in statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Spraying is one of the critical operations in agriculture. The importance of the use of chemical pesticides was well recognized in agriculture. Consumption of pesticides was increasing year by year, on the other hand, wastage of chemical pesticides also alarming due to excess application of pesticides. The quality spraying affects several operational factors. Tractor operated swinging lance sprayer developed for obtaining uniformity in spraying. Four operational factors such as spacing between spray guns, spray gun height, swing angle and pressure were considered to evaluate and optimize the operational factors for effective swath width. Full factorial design considered using Minitab software tool, 243 experiments ($3^4 \times 3$) conducted for the study. The main effects of each factor, 2-way interaction effects and 3-way interaction effects are significant at 5% level of significance. The swath width is significantly influenced by swing angle followed by spacing

*Corresponding author: E-mail: arudra.srinivasarao@gmail.com;

between spray guns for both the spray guns. The percentage contribution of swing angle, spacing between spray guns, height of spray gun and operating pressure on swath width was 44.37%, 37.62%, 2.51% and 2.02% respectively. The optimum combination of operational parameters for effective swath width was $s_3 - h_2 - a_3 - p_2$. The obtained optimum operation combination for swath width significantly improved the performance of spraying activity.

Keywords: ASPEE-SPGF; full-factorial design; Minitab; optimization; swinging lance sprayer.

1. INTRODUCTION

Agriculture which accounts for about one-seventh of the GDP provides sustenance to nearly two-third of the Indian population. Food grain production increased from 52 million MT in 1951-52 to 295.67 million MT in 2019-20 (Anonymous, 2020). The important role played by plant protection practices is well recognized. Agriculture in developing countries suffers most because of the high incidence of various pests. Annual production loss due to pests estimated in India is US\$ 42.66 million [1]. Application of pesticide in recommended dose not only reduces the input cost of chemical but also reduces the ill effects due to excess application of pesticide on crop and environment. Improvement of application techniques permits the effective use of chemicals and to reduce drift and harmful residues have become increasingly important.

In India, majority of farmers are using knapsack sprayer to apply plant protection chemicals and growth regulators. Knapsack sprayers are popular due to its low cost and ease of operation. The main drawback with knapsack spraying is of poor distribution pattern and labour intensive [2]. In knapsack spraying technique, more than 80% of chemicals are deposited on the ground, which is not desirable [3]. Over dosage of pesticide leads to many problems, such as environmental pollution and chemical waste [4].

Farmers are using tractors as a versatile machine for various field operations. Even though tractor operated boom sprayer and self propelled boom sprayers with multiple nozzle are available commercially, small and marginal farmers are not attracting towards boom sprayer due to high purchase cost. Farmers are now showing interest towards tractor mounted sprayer fitted with two spray guns with hose length of 60 -300 m and operates with tractor PTH driven pump. To operate this type of sprayer requires four persons, of which two are for operating spray guns, one for driving tractor and another for adjusting hose pipe and filling chemical [5]. This type of spraying technique

purely depends on skill of the operator and there are chances of over dosage of pesticide, missing of pesticide. A tractor operated gun sprayer is not recommended technology due to its non-uniform spraying pattern. Hence, elimination of manual intervention with automatic operation of spray gun can improve the uniformity pattern.

Hence, present work undertaken to develop tractor operated swinging lance sprayer. Developed tractor operated swinging lance sprayer has four factors such as Spacing between spray guns(s), spray gun height (h), swing angle(a) and operating pressure (p) each can adjust at three levels. To standardize optimum operational parameters 243 experiments, need to run ($3^4 \times 3$). To the author's knowledge, no significant work carried out on swinging lance spraying technique and no significant research findings reported. In the present study the influence of various operational parameters and optimum combination of parameters for better performance of swinging lance sprayer were identified for effective application of chemical on the crops like chilly, groundnut, gram, and tobacco.

2. MATERIALS AND METHODS

2.1 Development of Tractor Operated Swinging Lance Sprayer

The developed swinging lance sprayer consists of MS frame for mounting of various components such as chemical tank, DC motors, pump, hose pipes, spray guns and three point hitch system. The mounting frame have provision to adjust spacing between spray guns (2 m, 2.6 m and 3.2 m), to adjust height of spray guns (0.9m, 1.2m and 1.4m) from the ground and to adjust swing angle (100° , 110° and 120°). The developed sprayer has three pressure adjustments (250PSI, 300PSI and 350PSI). Pump of sprayer runs with tractor PTO and V-belt drive used for power transmission. DC motors operates with tractor battery (12 V), provision given to operate each spray gun separately, if required. A schematic diagram of developed sprayer is shown in Fig. 1.

It has a 400L capacity chemical tank with hydraulic agitation mechanism in order to maintain the homogeneity of liquid spray. The technical specifications of developed sprayer considered for present study is shown in Table 1.

2.2 Evaluation of Swinging Lance Sprayer

The operational parameters considered for this study and their levels were shown in Table 2. Tap water used for conducting experiment. A full factorial design created by using minitab.17 software tool. In total, 243 experiments (3⁴*3) were conducted to evaluate the effect of various

operational parameters on sprayer performance. For each run, operational parameters such as spacing between spray guns, spray gun height, swing angle and pressure were adjusted as per design. Initially, the left spray gun operated for 2 minutes whereas the right spray gun was in off condition. The wetted perimeter on a concrete floor for the left spray gun marked with orange color (Fig. 3). Later, the right spray gun operated for 2 minutes whereas the left spray gun was in off condition. The wetted perimeter on a concrete floor for the right spray gun marked with blue color.

Table 1. Technical specifications of developed swinging lance sprayer

Units	Particulars	Details
Source of power	Tractor	35 hp
Tank	HDPE chemical tank	400 L
Pump	Type	Hydraulic piston pump
	Make and model	ASPEE, PS/16
	Recommended rpm	950 rpm
	Required power	3 hp
	Suction capacity	36 L/min
	Max.pressure	400 PSI
Spray gun	Number of guns	2
	Make and model	ASPEE, SPGF-80cm
	Pressure required	200 PSI
	Handle rotation	360°

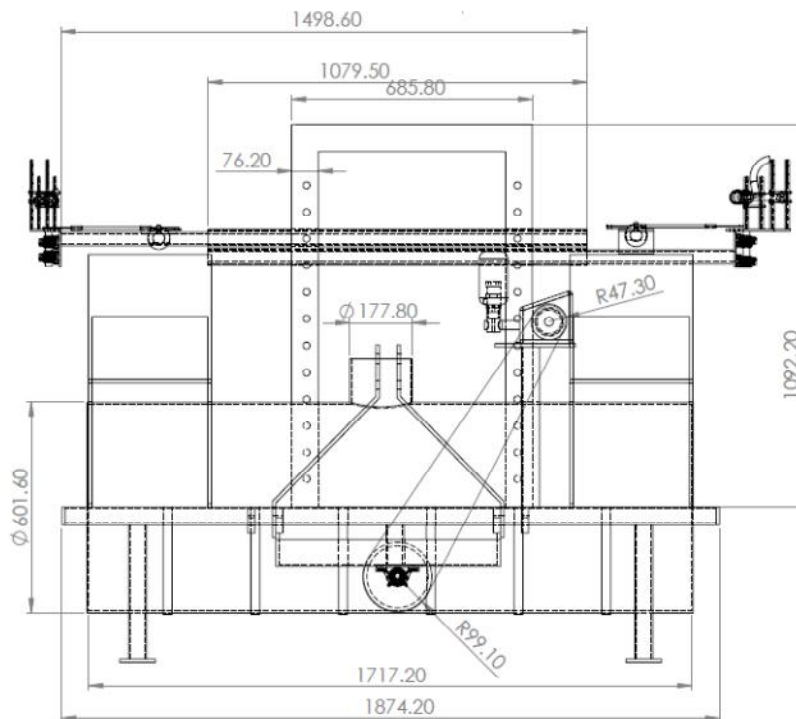


Fig. 1. Schematic diagram of developed tractor drawn swinging lance sprayer



Fig. 2. ASPEE SPGF-80 cm spray guns used for the experiment



Fig. 3. Marking of wetted perimeter for left spray gun

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance of Swath Width

Analysis of variance table created with minitab software tool by considering general full factorial design. ANOVA table for swath width is given in Table 2. It is clear from the ANOVA table that the main effects of each factor, 2-way interaction effects and 3-way interaction effects are significant at 5% level of significance. It was also indicated that the overall F-test is significant at 5% level indicating that the model as a whole accounts for a significant portion of the variability in the dependent variable. ANOVA gives the operational parameter that mostly affects the performance characteristics. From ANOVA table, it was found that swath width is significantly influenced by swing angle followed by spacing

between spray guns for both the spray guns. The percentage contribution of swing angle, spacing between spray guns, height of spray gun and operating pressure on swath width was 44.37%, 37.62%, 2.51% and 2.02% respectively.

3.2 Effect of Operating Parameters on Sprayer Performance

The effect of operational parameters on swath width was shown in Fig. 4. It is observed that swath width increased with increase in spacing between spray guns and swing angle. It is also observed that swath width decreases with increase in spray gun height, as the pressure increases swath width also increased up to certain level and a further increase in pressure reduces swath width, similar kind of results reported by Udaybhaskar et al. [6]. Trend of

interaction effects on swath width is shown in Fig. 5. From interaction effects graph, it is observed that swing angle increases swath width also increased for all pressure ranges, however more swath width observe for 300 PSI pressure. Similarly, spacing between spray guns increases swath width also increased for all pressure ranges, however more swath width observe for 300 PSI pressure, similar kind of results reported by Nageshkumar et al. [7]. Given interaction effects graph is self explanatory, the other interaction effects on swath width can examine from the given graph.

3.3 Optimization of Operational Parameters for Obtaining Effective Swath Width

Optimization plot obtained from Minitab.17 software tool is shown in Fig. 6. From Fig. 6, it was noticed that the highest swath width obtained at spacing between spray guns at 3.2m, spray gun height at 1.2m, swing angle at 120° and operating pressure at 300 PSI. Therefore, the predicted optimum operational parameters for obtaining maximum swath width is $s=3.2m$, $h=1.2m$, $a=120^\circ$ and $p=300PSI$. The swing angle

of 120° resulted in better and efficient coverage of pesticides [8]. It was reported that medium pressure such as 250 to 300 PSI obtained large swath width due to large size of spray particles [6]. The optimum combination was represented as $s_3 - h_2 - a_3 - p_2$ for swath width. From the optimization plot, with given combination an effective swath width of 11.32m could be attained. In actual experiment, swath width of 11.40m attained at $s_3 - h_2 - a_3 - p_2$ combination (experiment run 42).

Contour plots examining the relationship between operational parameters and swath width is shown in Fig. 7. From Fig. 7(a) it was found to be high level of swing angle and medium level of spray gun height leads to generate more swath width. Fig. 7(b) shows that more swath width could be attained at medium level of pressure and medium level of height. It is clear from Fig. 7(c) that medium level of spray gun height and high level of spacing between spray guns could yield more swath width. Fig. 7(d-f) depicts that high level of spacing between spray guns, high level of swing angle leads to generate more swath width.

Table 2. Analysis of variance table for swath width

Source	DF	Adj SS	Adj MS	F-value	P-value	%contribution
Model	64	49.6151	0.7752	19.87	0.000	98.76
Linear	8	43.4711	5.4339	139.26	0.000	86.53
Spacing	2	18.8989	9.4494	242.17	0.000	37.62
Height	2	1.2626	0.6313	16.18	0.000	2.51
Angle	2	22.2937	11.1469	285.68	0.000	44.37
Pressure	2	1.016	0.508	13.02	0.000	2.02
2-way interactions	24	3.7738	0.1572	4.03	0.003	7.51
Spacing * height	4	0.5981	0.1495	3.83	0.023	1.19
Spacing * angle	4	0.2874	0.0719	1.84	0.170	0.57
Spacing * pressure	4	0.7246	0.1811	4.64	0.011	1.44
Height * angle	4	1.6892	0.4223	10.82	0.000	3.36
Height * pressure	4	0.0536	0.0134	0.34	0.845	0.11
Angle * pressure	4	0.421	0.1052	2.70	0.068	0.84
3-way interactions	32	2.3702	0.0741	1.90	0.088	4.72
Spacing * height * angle	8	0.9359	0.117	3.00	0.029	1.86
Spacing * height * pressure	8	0.4848	0.0606	1.55	0.216	0.96
Spacing * angle * pressure	8	0.6812	0.0852	2.18	0.088	1.36
Height * angle * pressure	8	0.2683	0.0335	0.86	0.568	0.53
Error	16	0.6243	0.039			
Total	80	50.2394				

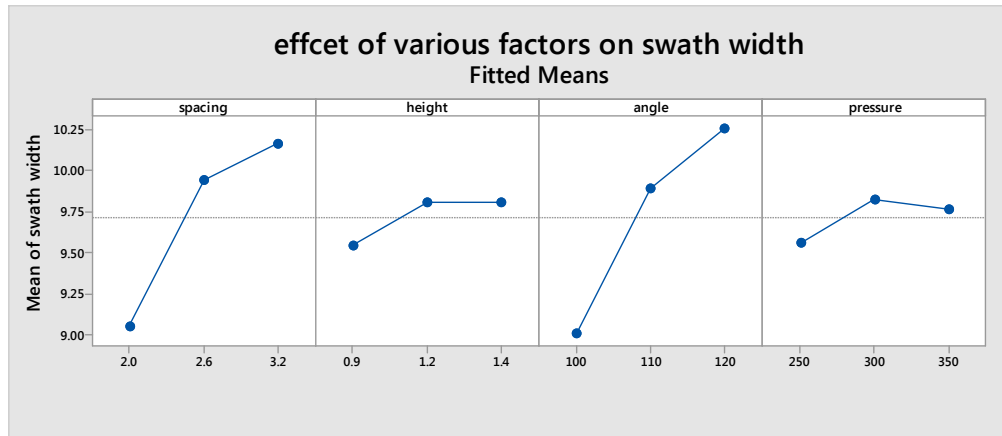


Fig. 4. Graph showing effect of operational parameters on swath width

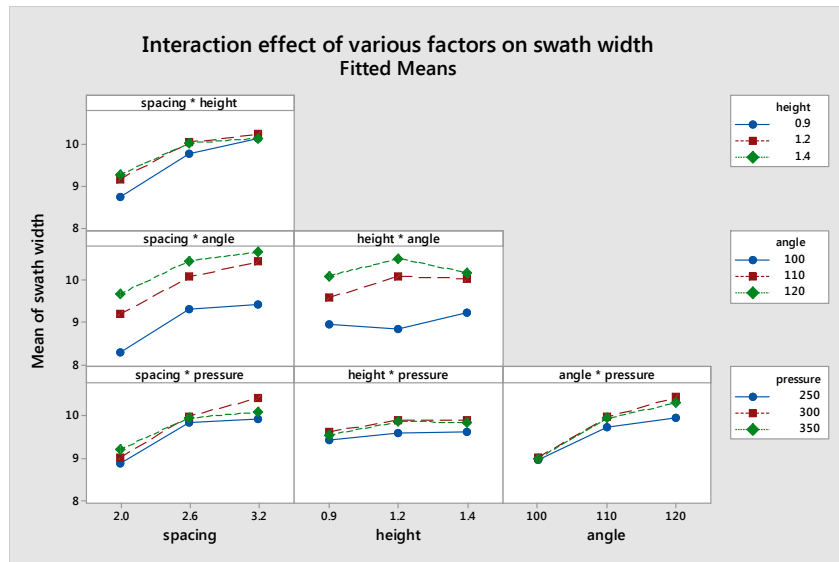


Fig. 5. Graph showing interaction effects of operational parameters on swath width

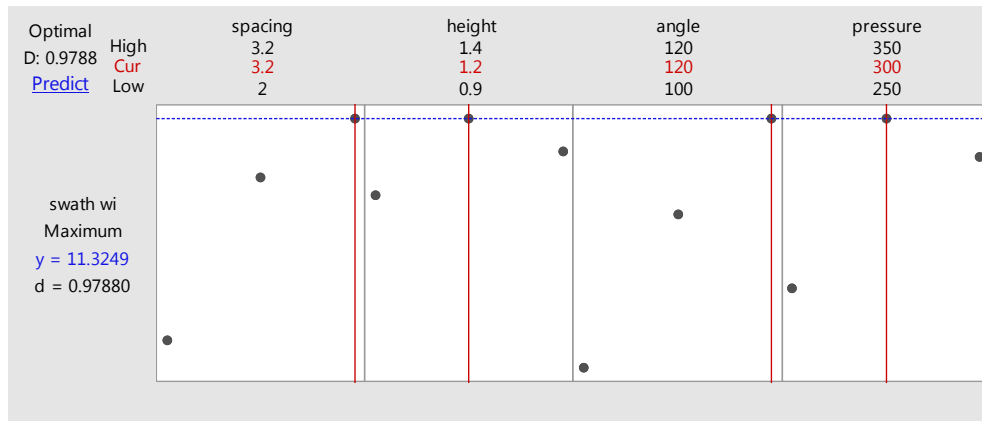


Fig. 6. Optimization plot for effective swath width

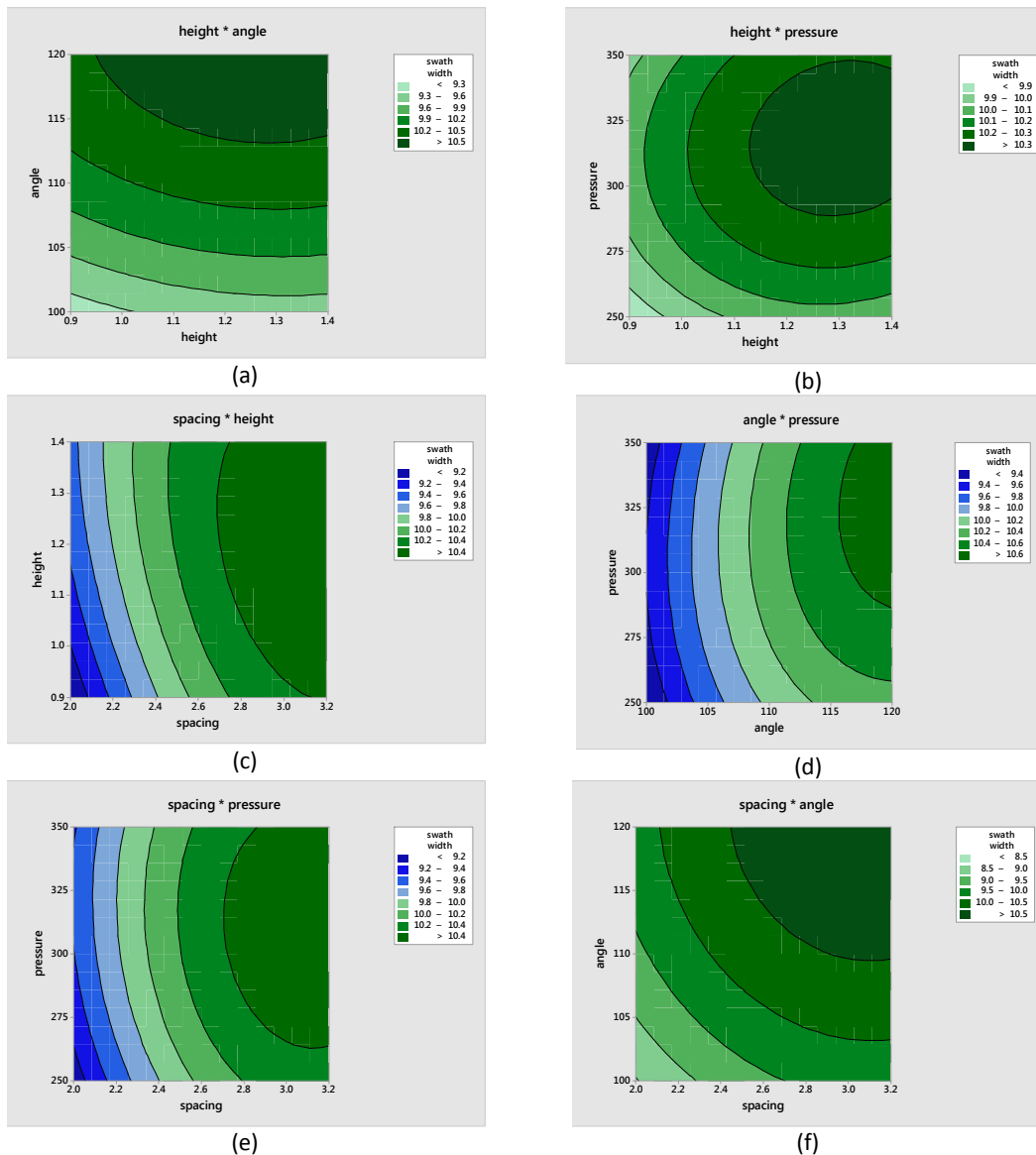


Fig. 7. Contour plots of swath width (a) height Vs angle (b) height Vs pressure (c) spacing Vs height (d) angle Vs pressure (e) spacing Vs pressure (f) spacing Vs angle

4. CONCLUSION

The main effects of each factor, 2-way interaction effects and 3-way interaction effects are significant at 5% level of significance. It was also indicated that the overall F-test is significant at 5% level indicating that the model as a whole accounts for a significant portion of the variability in the dependent variable. The swath width is significantly influenced by swing angle followed by spacing between spray guns for both the spray guns. The percentage contribution of swing angle, spacing between spray guns, height of

spray gun and operating pressure on swath width was 44.37%, 37.62%, 2.51% and 2.02% respectively. The optimum combination of operational parameters for effective swath width was $s_3 - h_2 - a_3 - p_2$. The obtained optimum operation combination for swath width significantly improved the performance of spraying activity.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our

area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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