International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 11, Issue 3 [May.-June. 2022] PP: 60-71

Spray Parameters Analysis of a Medium Scale Self-Propelled Herbicide Boom Sprayer using Analysis of Variance (ANOVA) and Simple Linear Regression as tools.

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Abstract: *Manual pumping of the conventional weed control equipment in Nigeria, the Knapsack sprayer renders deposition of variable quantities of herbicide per area as the operator tries to maintain unattainable steady walking steps and constant pumping rate across the farm. The deposition of under doses and over doses across the farm results in ineffective weed control. To curb uneven deposition of pesticide and ensure effective crop protection, the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria in collaboration with Agricultural Engineering Department, Bayero University Kano, Nigeria developed a medium Scale Self-Propelled Herbicide Boom sprayer with a spray pump maintained at constant pumping pressure by the vehicle engine through a gearbox and v-belt and pulley transmission system. Two factors namely: Pumping pressure and Height of nozzle above target were seen to affect the spray parameters of Flow rate, Spray Volume distribution pattern, Droplet size and Swath. Laboratory evaluation was carried out to determine the values of the spray parameters when the pumping pressure and Heights of nozzles above target were varied at: (100 kPa, 200 kPa and 300 kPa) and (30 cm, 45 cm and 60 cm), respectively. The experiments were completely randomized and replicated three times. The results were subjected to Analysis of Variance (ANOVA) with DUNCAN Multiple Range test to determine if variations in the factors made significant impact on the parameters while Linear regression was employed to establish relationships where it exists between the factors and the dependent variables. The analysis showed that at 100 kPa pressure and 45 cm nozzle height above target, the Sprayer produces the most uniform Spray Volume distribution pattern with the least COV% of 15.13 %. The 100 kPa pumping pressure and 45 cm height of nozzle above target setting also renders droplet range which conforms to the coarse droplets size recommended for herbicide application on soil and foliage. With 0.3 ha/h Effective Field Capacity (EFC), at the most uniform application setting of 100 kPa pressure and 45 cm height, the study would take about three days of working three hours morning and three hours evening to cover the about 5 hectare majority farm holding in Nigeria. The Theoretical Field Capacity, TFC = 0.64, Maximum Application Rate, Effective Field Capacity and Field Efficiency are respectively 1,625 l/ha, 0.43 ha/h and 75%.*

Keywords: *Herbicide, Sprayer, Analysis, ANOVA, Regression*

Date of Submission: 25-05-2022 Date of Acceptance: 05-06-2022

NOMENCLATURE

Symbol	Description	Unit
h	Height	*cm*
l	length	*m*
Ha/h	Hectare/hour	m^2/h
p	Pressure	*kPa*
COV	Coefficient of variation	%
P	Power	*kW*
V	Flow rate	l/min; ml/min

Q	Volume discharge	*L (litters)*
T	Time	min
VMD	Volume Median Diameter	µm
EFC	Effective field capacity	*ha/h*
TFC	Theoretical field capacity	*ha/h*

I. INTRODUCTION

The Sprayer is a ‘Daihatsu Hijet’ mini-truck modified to a Boom Sprayer with some locally available components. The components include: One 25:1 Gear reducer, One intermediate Gearbox, Four steel wheels (0.9 m diameter each), One herbicide spray pump (1.5 kW), One herbicide tank (100 liters’ capacity), Spray boom with five impact nozzles, V-belts, pulleys and other connection accessories such as strainers, hoses and clips. The mini-truck has a 32 kW, 3-Cylinder inline petrol engine which drives the sprayer in direct drive, through its gearbox, a Gear Reducer and the rear axle to achieve low farm speeds at the wheels. The engine also powers the spray pump through V-belt transmission. A double grooved pulley attached to the output shaft of the gearbox transmits motion through V-belts to an intermediate gearbox which delivers motion to the Spray pump. The intermediate gearbox lever is used to start and stop the spray pump as and when necessary. Hoses connect the spray pump to the 100-liters capacity herbicide tank and also to the nozzles at the back of the vehicle frame. The boom sprayer moves on four steel wheels each of 90 cm diameter, offering higher ground clearance to allow post-emergence application without destroying growing crops. The 12.7 cm width of the steel wheel hub extends the vehicle track from 124.5 of the original Daihatsu Hijet mini-truck to 150 cm to permit movement in between ridges of 75 cm apart commonly used in Nigeria.

Plate I shows the Medium Scale Herbicide boom Sprayer with the rear chassis carrying the spray pump, chemical tank and other spraying appurtenances. The boom with nozzles is seen held on its attachment affixed at the rear end of the chassis. The intermediate gearbox which receives motion from the Daihatsu Hijet mini-truck gearbox and transmits to the spray pump is also indicated. The machine has the spray pump actuating lever positioned into the driver’s cabin to enable engaging and disengaging the spray pump with ease. The machine’s pertinent specifications are given in Table 1.

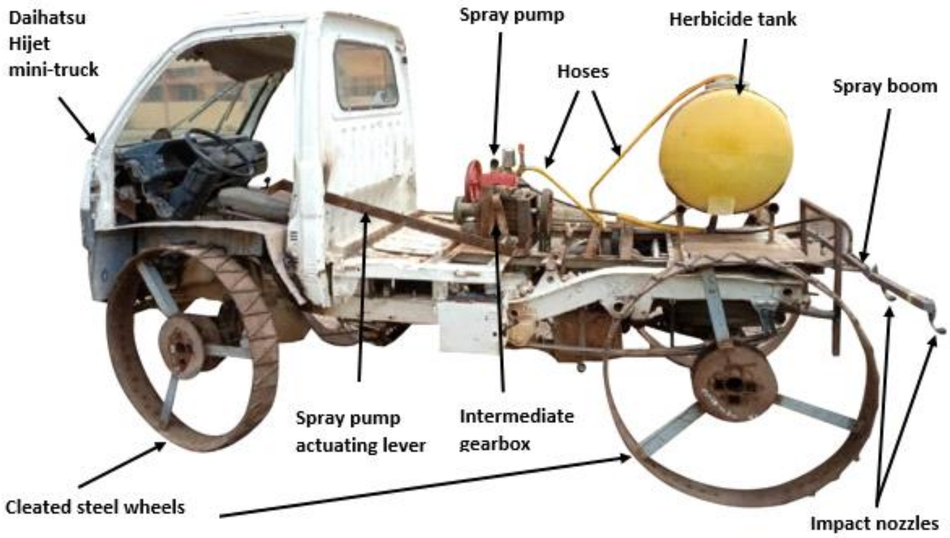


Plate I: Self-propelled herbicide boom sprayer

Table 1: Medium Scale Self-propelled herbicide boom sprayer specifications

Engine power:	32.25 kW
Track	150 cm
Pump	1.5 kW
Ground clearance	35.56 cm
Transmission ratio	300:1
Wheel diameter:	90 cm
Boom width	200 cm
No. of Nozzles	5

The experimental test rig for the laboratory experiments is a patternator (Plate II). It consists of twenty-two slanting channels underneath the nozzle spray. Water is employed as the test fluid. Tubes for collection of water running into each channel are placed under each channel outlet. The Medium Scale Herbicide boom sprayer was parked outside the laboratory with rear tires raised to prevent ground movement when the gearbox is engaged to power the spray pump. The boom of the sprayer is detached and mounted above the patternator table and connected by a long hose to the spray pump on the Sprayer. The hose from the spray pump is indicated in the picture. The heights of the nozzles above the patternator table are adjustable to enable experiments to be carried out at the various heights. A pressure gauge is placed close to the nozzles to read the pressure. The spray pump is driven by the engine of the vehicle through the gearbox and v-belt transmission such that vehicle forward speeds of 3.2 km/h, 6.21 km/h and 7.34 km/h corresponding to Gear 1, Gear 2 and Gear 3 respectively yield pumping pressures of 100 kPa, 200 kPa and 300 kPa. There are two factors which influence the spray parameters namely: the pumping pressure, occasioned by the vehicle forward speed and height of nozzle above target. The recommendation of McGinty et al., (2014) that coarse herbicide droplets (300 – 400 VMD) be applied for weed control alongside the report of Holfman (2018) that coarse droplets for herbicide application are produced at low pressures of 100 kPa to 267 kPa informed varying the pressure at three levels of 100 kPa, 200 kPa and 300 kPa..

The report by Summer (2012), that nozzle spacing of 50 cm and height of nozzle above target from 38 cm to 60 cm are the usual practice for the common fan nozzles was adopted. The height of nozzles above target was varied at (30 cm, 45 cm, 60 cm); while the flow rate, droplet size and swath were determined. Also, the volumes collected by the twenty two collection tubes across the patternator during each experiment were employed to determine the spray volume distribution pattern across the entire settings. Spray volume distribution pattern is a critical sprayer parameter since the essence of spraying is to evenly deposit herbicide to achieve the desired results. Irregular or variable deposition implies deposition of over and under doses which is ineffective, destructive and most times wastage of chemical and man hour. The Experimental layout drafted using the Chart of Random numbers are shown in Table 2.

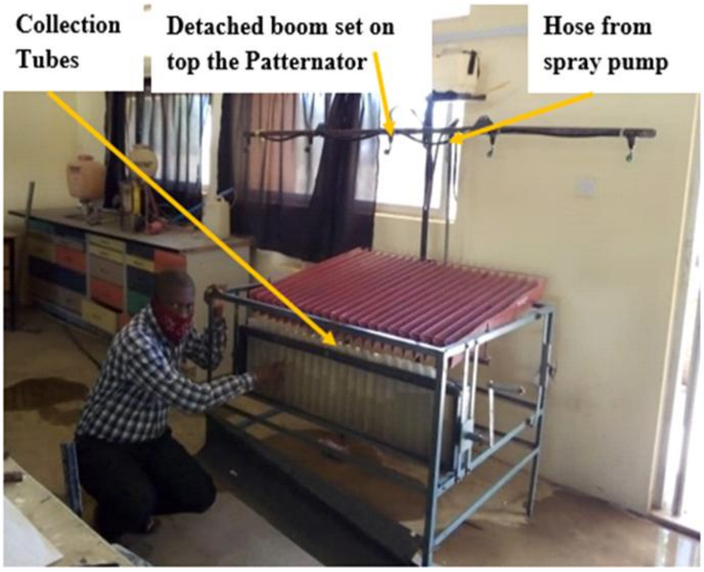


Plate II: Patternator test rig inside the laboratory. The detached boom is mounted on the test rig

Table 2: Experimental Layout

P_3H_2	P_2H_1	P_2H_3
P_2H_3	P_3H_2	P_3H_2
P_3H_3	P_2H_2	P_1H_3
P_1H_2	P_3H_1	P_1H_1
P_1H_1	P_3H_1	P_1H_2
P_2H_1	P_3H_3	P_3H_1
P_1H_2	P_3H_3	P_1H_3
P_3H_3	P_2H_2	P_1H_1
P_2H_1	P_1H_3	P_2H_2

The procedure for the determination of the flow rate, swath and droplet sizes are as follows:

- Flow rate: Polythene sacks are tied to the boom such that liquid discharge from the nozzles collect in the sacks. After timed flow at the chosen pressure, the volumes are each measured using the graduated measuring cylinder. The flow rates were determined using expression given below.

$$V = Q/t \text{ l/min (Matthews 1979)} \qquad (1)$$

Where
V = Flow rate (l/min.)
Q = Average discharge in liters
T = Average time for discharge in minutes

- Spray volume distribution pattern: The spray pattern of single impact nozzle is tapered. To achieve uniform distribution on a boom of multiple nozzles, a degree of overlap of the spray patterns is required because spray distribution from a nozzle is generally more in the central region, reducing towards the outer edges, following a normal distribution. The patternator test at various heights enables the determination of the height that gives the most uniform spray volume distribution. The position corresponding to minimum coefficient of variation is selected as the best placement for the nozzles on the boom at the particular height of the nozzles from the target and at the given working pressure (Khurana et al., 2007).

The nozzle spray volumes were collected in the twenty two test tubes. The averages, standard deviation and coefficient of variations of the experiments were calculated and recorded.

- Droplet size: Glass slides were uniformly coated with magnesium oxide by burning two 10 cm strips of magnesium ribbon. Droplet samples were collected on the coated slides, at the various test pressures. The samples collected were then observed under a microscope fitted with a field Graticule eyepiece for precise droplet size measurement (Matthews, 1979). With the aid of mechanical stage of the microscope, the craters were lined in series on Graticule in which droplets are classified as 50 microns, 100 microns 200 microns and 400 microns.
- Swath: The spray from common agricultural nozzles including impact nozzles are cone shaped. Figure 1 depicts the spray pattern from overlapping multiple nozzles. The red, blue and green lines show that at any horizontal position along the Nozzle Height above target, the Spray volume distribution pattern and Swath must vary. Laboratory test is required to determine effect of variations in height on swath, thereby determine the height and swath which offers the optimum uniform deposition of herbicide. At the test height and pressure, the horizontal width covered by the spray during the three replications are measured using a meter tape. The average gives the swath for the particular pressure and height.

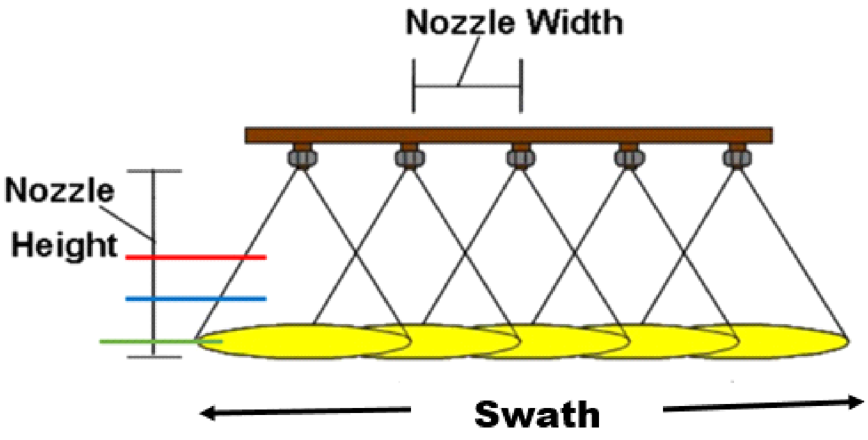


Figure 1: Spray pattern from multiple nozzle

Table 2 is the laboratory experimental results. The table depicts values of Flow rate, Coefficient of variation of volumes collected at each pressure/height setting for the flow volume distribution pattern, droplet size and swath for each of the experiments at the three pumping pressures: (100 kPa, 2000 kPa, and 300 kPa), and at the three heights of nozzles above target: (30 cm, 45 cm, and 60 cm).

Table 3: Laboratory experimental results

No.	Height of nozzles above target (cm).	Pump pressure (kPa)	Coefficient of variation (COVs %)	Flow rate (L/min)	Swath (m)	Droplet Size (µm)
1	30	100	30.6708	7583	3.5	400
2	30	100	29.3663	13600	3.6	400
3	30	100	30.1172	17500	3.7	400
4	30	200	27.1254	7583	4	300
5	30	200	27.6271	13600	4.1	300
6	30	200	26.734	17500	4.2	300
7	30	300	23.8893	7583	4.4	250
8	30	300	23.8912	13600	4.5	250
9	30	300	23.7168	17500	4.6	250
10	45	100	15.2579	7582	3.6	400
11	45	100	15.4206	13601	3.7	400
12	45	100	15.2112	17501	3.9	400
13	45	200	15.6853	7584	4.4	300
14	45	200	15.94	13601	4.5	300
15	45	200	15.65	17501	4.6	300
16	45	300	15.915	7584	4.9	250
17	45	300	15.2777	13601	5.2	250
18	45	300	15.2978	17501	5.2	250
19	60	100	16.3421	7582	3.5	400
20	60	100	16.7142	13602	3.7	400
21	60	100	16.4685	17502	3.8	400
22	60	200	28.8026	7582	4	300
23	60	200	28.7281	13602	4.1	300
24	60	200	28.022	17502	4.3	300
25	60	300	30.2728	7581	4.8	250
26	60	300	30.4054	13602	5	250
27	60	300	30.4326	17502	5.1	250

Analysis of variance (ANOVA) is a statistical test for detecting differences in group means when there is one parametric dependent variable and one or more independent variables. ANOVA is warranted in experimental designs with one dependent variable that is a continuous parametric numerical outcome measure, and multiple experimental groups within one or more independent (categorical) variables. In ANOVA terminology, independent variables are called factors, and groups within each factor are referred to as levels (Sawyer, 2017). ANOVA is a statistical technique to analyze variation in a response variable (continuous random variable) measured under conditions defined by discrete factors (classification variables, often with nominal levels). Frequently, we use ANOVA to test equality among several means by comparing variance among groups relative to variance within groups (random error). Ronald Fisher in 1918 pioneered the development of ANOVA as the extension of the t and the z tests for analyzing results of agricultural experiments. Today, ANOVA is included in almost every statistical package, which makes it accessible to investigators in all experimental sciences (Larson, 2008).

Comparisons of means procedures are also known as means separation or multiple comparisons. They are not statistical designs. They are methods or means of comparing different statistical means or averages within the designs. In any design in AVOVA table, F-cal for treatments can be either significant or not significant. If F-cal for treatments is not significant (there are no real differences between the treatment means), therefore, there is no need to compare the treatment means. If F-cal for treatments is significant (there are real differences between the treatment means), therefore, there is a need to compare the treatment means. ANOVA simply shows without the details of whether there are real differences between the treatment means or not. To get the real differences between the treatment means separation methods are employed. Ducan Multiple Range test (DMRT) is one of the most common methods used in comparing treatment means. DMRT summarizes the way in finding several significant differences with increasing values which, depending on the extent of the distance between the treatment means after arranging them. It is used to make all possible comparisons between treatment means. It is used to compare the mean of control treatment with the rest of the treatment means (Dafaallah, 2019).

The concept of linear regression was first proposed by Sir Francis Galton in 1894. Linear regression is a statistical test applied to a data set to define and quantify the relation between the considered variables (Chang 2004). It is a statistical technique widely applied by researchers in many fields to describe the nature of the relationship between variables. The relationship between the variables can be positive or negative, linear or non-linear. In regression, the variables are categorized into independent variable and dependent variable. The dependent variable is a response variable that can be predicted by the independent variable. Hence, the independent variable is also called predictor variable (Foong *et al.*, 2018). Schneider et al., (2010) explains that Regression analysis is a type of statistical evaluation that enables three things:

- Description: Relationships among the dependent variables and the independent variables can be statistically described by means of regression analysis.
- Estimation: The values of the dependent variables can be estimated from the observed values of the independent variables.
- Prognostication: Risk factors that influence the outcome can be identified, and individual prognoses can be determined.

II. METHODOLOGY

SAS (Statistical Analysis System) software is comprehensive software which deals with many problems related to Statistical analysis, Spreadsheet, Data Creation and Graphics. It is a layered, multivendor architecture. It is a software system for data analysis and report writing. Analysis of variance (ANOVA) with Duncan multiple range test (DMRT) processed through Statistical analysis system (SAS) software on the experimental results enabled the determination of the spray characteristics of the Medium Scale Herbicide boom sprayer, with regard to flow rate, spray volume distribution pattern, droplet size and swath at the various heights of nozzles above target and pumping pressure settings. The outcomes of the ANOVA/DMRT for each of the parameters were further subjected to linear regression analysis using Excel Spreadsheet 2010; to determine the relationships between the factors and the spray parameters in deploying the equipment.

III. ANALYSIS RESULTS

Flow Rate: The flow rates of the Prototype sprayer at three heights of nozzles above target and three pressures are presented in Table 4. The upper section of the table displays results for height variations, while the lower section displays the results for pressure variations. The variation of height at different levels did not produce any significant difference with respect to flow rate of the self-propelled herbicide boom sprayer. However, variations in pressure significantly affect the flow rate of the Self-propelled herbicide boom sprayer. Increase in the pumping pressure results in increase in the flow rate. Linear regression analysis of the effect of variation in pressure on flow rate is shown in Figure 2.

Table 4: Flow rates of the herbicide boom sprayer at three nozzle heights above target and three pressures

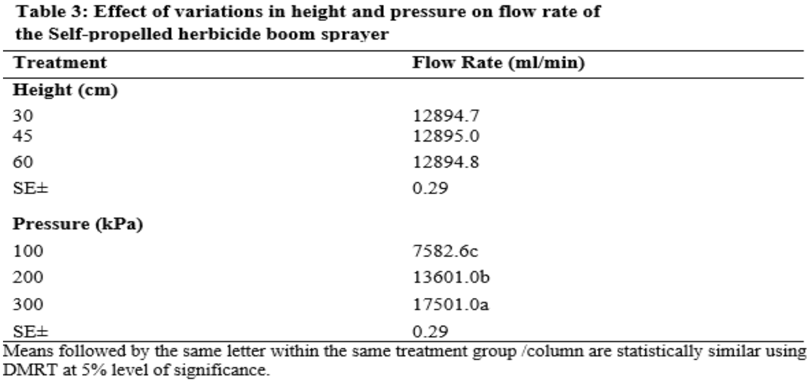


Table 3: Effect of variations in height and pressure on flow rate of the Self-propelled herbicide boom sprayer

Treatment	Flow Rate (ml/min)
Height (cm)	
30	12894.7
45	12895.0
60	12894.8
SE±	0.29
Pressure (kPa)	
100	7582.6c
200	13601.0b
300	17501.0a
SE±	0.29

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

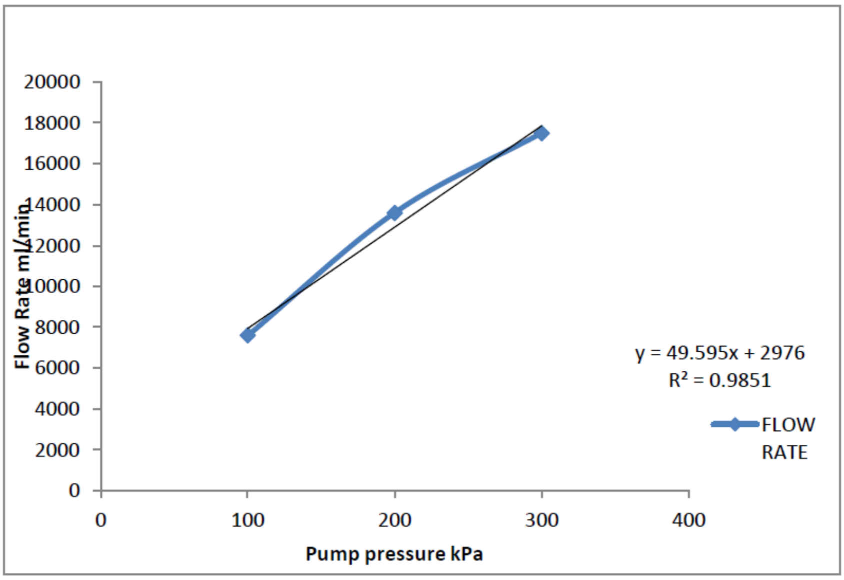


Figure 2: Effect of pump pressure on flow rate

Figure 2 shows that the effect of pump pressure on the flow rate is a near linear relationship which can be represented by a linear regression model equation. Increase in pump pressure is proportional to increase in flow rate. A feature of the novel boom sprayer is that at the recommended 100 kPa pump pressure for herbicide application small quantity of diluent would be required.

Spray Volume Distribution Pattern: The Coefficient of variation (COV %) for the Spray volume distribution pattern at the three heights of nozzles above target and pressures of 100 kPa, 200 kPa and 300 kPa are depicted in Tables 5a, 5b and 5c, respectively. The different coefficient of variations (COVs) at the various heights show that varying the height above target at different levels on the Self-propelled herbicide boom sprayer significantly affects the spray volume distribution pattern of the self-propelled herbicide sprayer. It can be noticed that pressure variations do not affect the spray volume distribution pattern of the prototype sprayer.

Table 5a: The COV % for the spray volume distribution pattern of the boom sprayer at the three heights of nozzles above target and 100 kPa pressures

Treatment	Coefficient of variation (COV %)
Pressure (kPa) /Height (cm)	
P100+H30 cm	30.05a
P100+H45 cm	15.13c
P100+H60 cm	16.49b
SE±	0.270

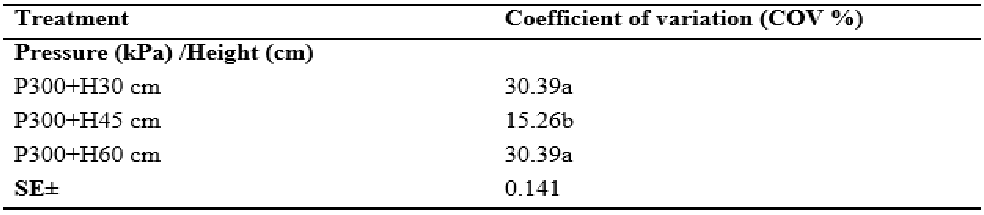
Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

Table 5b: The COV % for the spray volume distribution pattern of the boom sprayer at the three heights of nozzles above target and 200 kPa pressures

Treatment	Coefficient of variation (COV %)
Pressure (kPa) /Height (cm)	
P200+H30 cm	37.33a
P200+H45 cm	15.32c
P200+H60 cm	27.14b
SE±	0.617

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance

Table 5c: The COV % for the spray volume distribution pattern of the boom sprayer at the three heights of nozzles above target and 300 kPa pressures



Treatment	Coefficient of variation (COV %)
Pressure (kPa) /Height (cm)	
P300+H30 cm	30.39a
P300+H45 cm	15.26b
P300+H60 cm	30.39a
SE±	0.141

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

The linear regression analysis of the effect of height of nozzle above target on the spray volume distribution pattern at 100 kPa, 200 kPa and 300 kPa are depicted in Figure 3a, 3b and 3c respectively. The height of nozzles above target play very important role in spray volume distribution of the spray boom. If the boom height is lower than the optimum height above target, uneven spray dispersion can occur. A lower boom will prevent proper overlap or even cause a complete lack of application. These cases are problematic because weeds can develop resistance to herbicides when they receive sub-lethal doses. In the area directly under the nozzle, severe over application can occur, which results in wasted product and is environmentally harmful to the crop. Also, if the height of the boom above target is higher than the optimum height, droplet drift can increase. This would result in application to areas that was not intended to be treated and under dozing of targeted areas as much herbicide would be lost to drift. Hence the need to ascertain the optimum height and pumping pressure for the most uniform spray volume distribution.

Tables 5a shows high coefficient of variation COV% at 30 cm height of nozzle above target while the COV% at heights of 45 cm and 60 cm are low indicating that application at 100 kPa pressure can be expected to be fairly uniform at heights of nozzles above target of 45 cm and 60 cm but irregular at height of nozzle above target of 30 cm. Table 5b at pumping pressure of 200 kPa depicts large COV% at both heights of nozzles above target of 30 cm and 60 cm. The least COV% is recorded at 45 cm height of nozzle above target. The same behaviour is depicted at Table 5c pumping pressure of 300k. The least COV% is recorded at height of nozzle above target of 45 cm. For the three pressures, the COV% remained close and low at height of nozzles above target of 45 cm. The least COV of 15.13 % is achieved at speed of 3.2 km/h corresponding to pressure of 100 kPa which is the rated pressure for impact nozzles (Jones 2006). Hence, spraying at forward speed of 3.2 km/h and 100 kPa pressure assuredly ensures the most uniform deposition of the boom sprayer when the height above target is 45 cm.

The linear regression analysis shown in Figure 3a, Figure 3b and Figure 3c confirm the above inferences. Figure 3a shows that the point with the lowest COV% when spraying at 100 kPa is 45 cm mark. For heights below 45 cm, the COV% increases steeply while heights above 45 cm depicts gradual increase in COV%. Similarly, Figure 3b depicts that when spraying at 200 kPa, the effect of height of nozzle above target and COV% is not linear and that heights below and above 45 cm record higher COV% than the 45 cm height. Steep increases of COV% are marked at heights below 45 cm and heights above 45 cm. Also, when spraying at 300 kPa the 45 cm height is the height with the least COV%. The relationship is not linear and heights above 45 cm register steeper increases in COV% than heights of nozzles below 45 cm. The 45 cm height of nozzles above target is the optimum height to achieve uniform deposition of herbicide on soil and foliage using the novel boom sprayer.

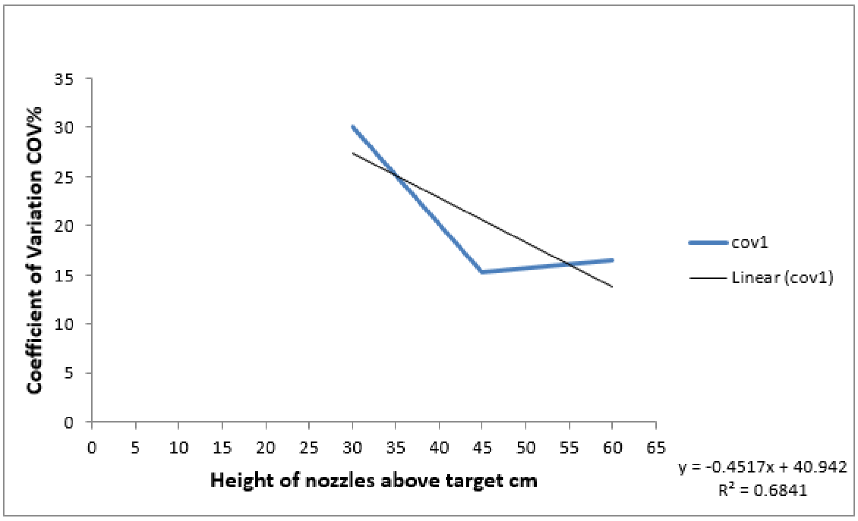


Figure 3a: Effect of height of nozzles above target on COV% at 100 kPa pump pressure

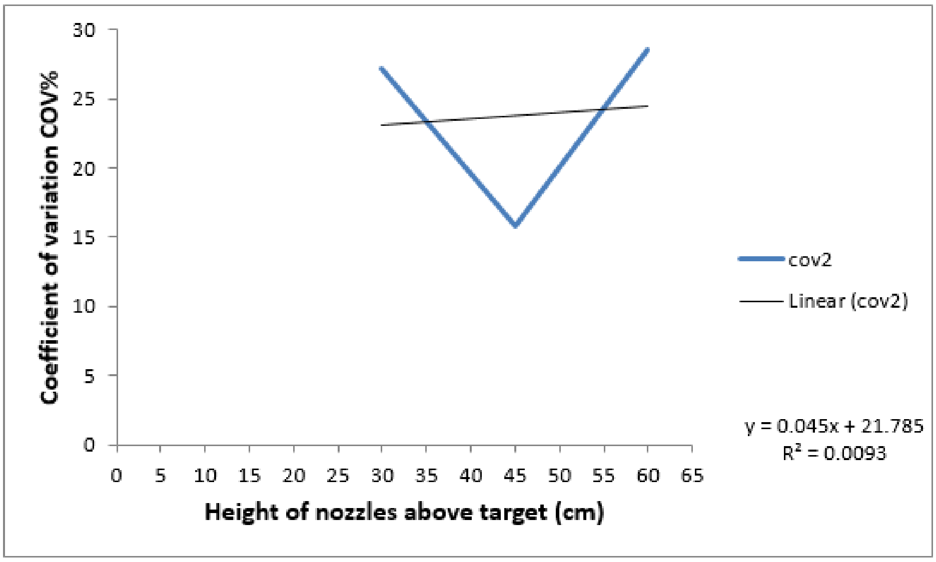


Figure 3b: Effect of height of nozzles above target on COV% at 200 kPa pump pressure

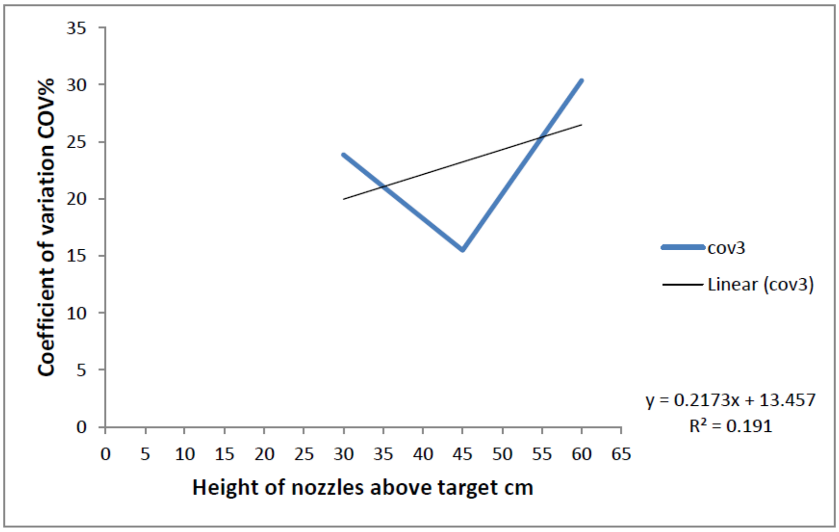


Figure 3c: Effect of height of nozzles above target on COV% at 300 kPa pump pressure

Droplet Size: The mean droplet spectrum of the sprayer at three heights of nozzles above target and three pressures are presented in Table 6. The upper section of the table displays results for height variations, while the lower section displays the results for pressure variations. Spraying at the heights of 30 cm, 45 cm and 60 cm respectively does not show any significant difference on droplet size range of the boom sprayer in all the test fields. The values are statistically the same. However, pressure variations significantly affect the performance of the droplet size range. The sprayer produces choice range for herbicide application of about 300 - 400 µm VMD; at the pressure of 100 kPa It is followed by 200 kPa while 300 kPa significantly produced the least droplet size range (200-250 µm VMD). The linear regression graph is presented in Figure 4.

Table 6: Droplet spectrum of the boom sprayer at three nozzle heights above target and three pumping pressures

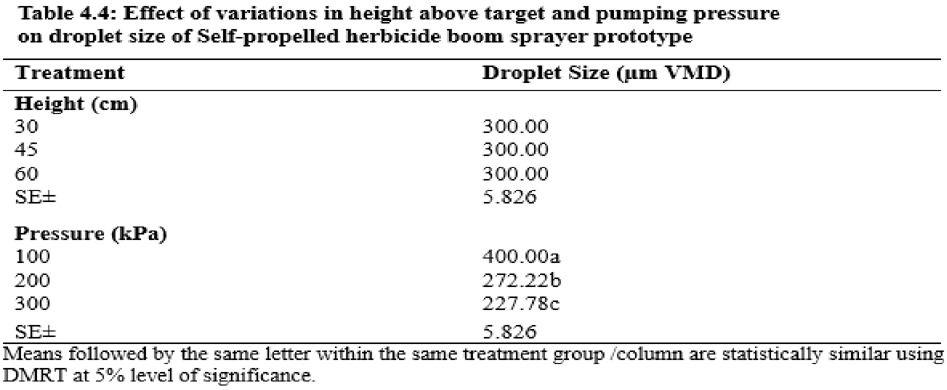


Table 4.4: Effect of variations in height above target and pumping pressure on droplet size of Self-propelled herbicide boom sprayer prototype

Treatment	Droplet Size (µm VMD)
Height (cm)	
30	300.00
45	300.00
60	300.00
SE±	5.826
Pressure (kPa)	
100	400.00a
200	272.22b
300	227.78c
SE±	5.826

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

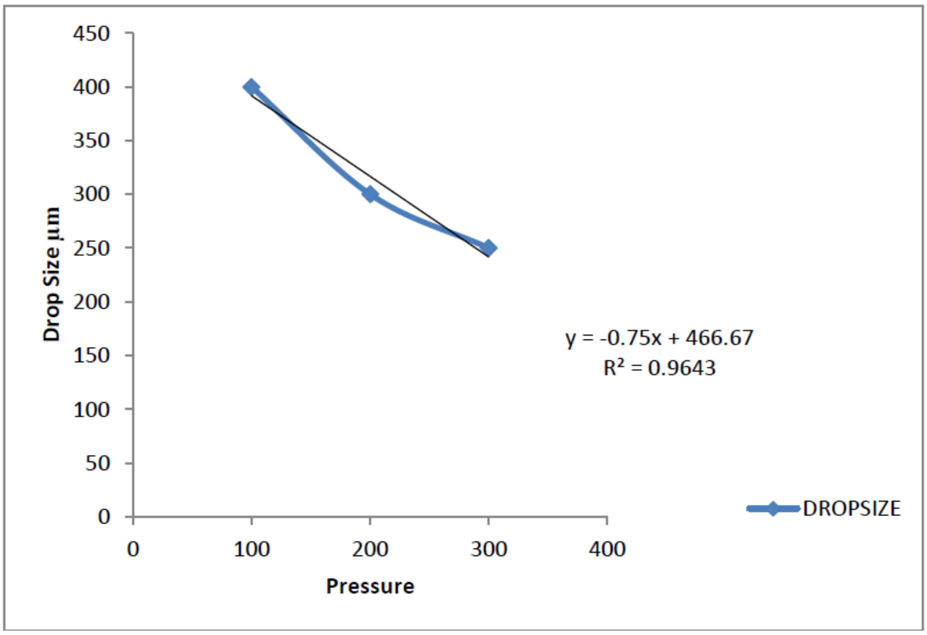


Figure 4: Effect of pump pressure on droplet size

The figure shows that the effect of pump pressure on droplet size is a near relationship which can be represented by a linear regression model equation. The pump pressure is inversely proportional to the droplet size. The lower the pump pressure, the bigger the droplet size. The self-propelled sprayer produces coarse droplets suitable for herbicide application at pump pressure of 100 kPa as recommended by Jones (1990) for impact nozzles.

Swath: Table 7 shows the effect of height above target and pressure on swath of self-propelled herbicide boom sprayer. The upper section of the table displays results for height variations, while the lower section displays the results for pressure variations. Variations in height above target of the self-propelled herbicide boom sprayer prototype significantly affects the performance of swath width of the machine. Elevating the sprayer at the height of 60 cm produced the highest swath of the self-propelled herbicide boom sprayer followed by height of

45 cm while at the height of 30cm produced the least swath. Also, applying pressure at varying rate significantly affects the performance of swath width of the self-propelled herbicide boom sprayer.

Table 7: Swath of the boom sprayer at three nozzle heights above target and three pumping pressures

Treatment	Swath (m)
Height (cm)	
30	3.71c
45	4.12b
60	4.98a
SE±	0.016
Pressure (kPa)	
100	4.11c
200	4.28b
300	4.42a
SE±	0.016

Means followed by the same letter within the same treatment group /column are statistically similar using DMRT at 5% level of significance.

Applying pressure at 300 kPa significantly produced the highest swath followed by the application rate of 200 kPa while the application of pressure at 100 kPa produced the least swath of the self-propelled herbicide boom sprayer. Thus, the highest Swath of 5.2 m is recorded at the highest height above target of 60 cm and highest pressure of 300kPa. Similarly, the lowest swath of 3.5 m is recorded at the lowest height above target of 30 cm and lowest pressure of 100 kPa. Figure 5 and figure 4.5 linear regression curves showing the Effect of pressure on swath and the effect of height of nozzles above target on swath respectively.

Linear regression depicts that effect of pressure on swath and effect of height of nozzles above target are both linear and can each be represented by linear regression model equations. Thus, the greater the pressure, the greater the swath. Similarly, higher height of nozzle above target will engender bigger swath and vice versa. At the optimum performance setting of 45 cm height and 100 kPa pressure, the machine achieves a swath width of 4.1 m.

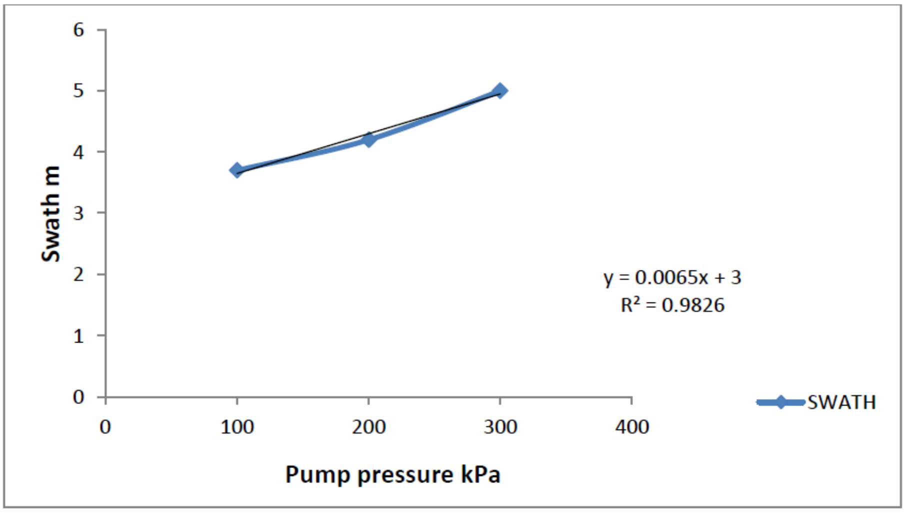


Figure 5a: Effect of pump pressure on swath

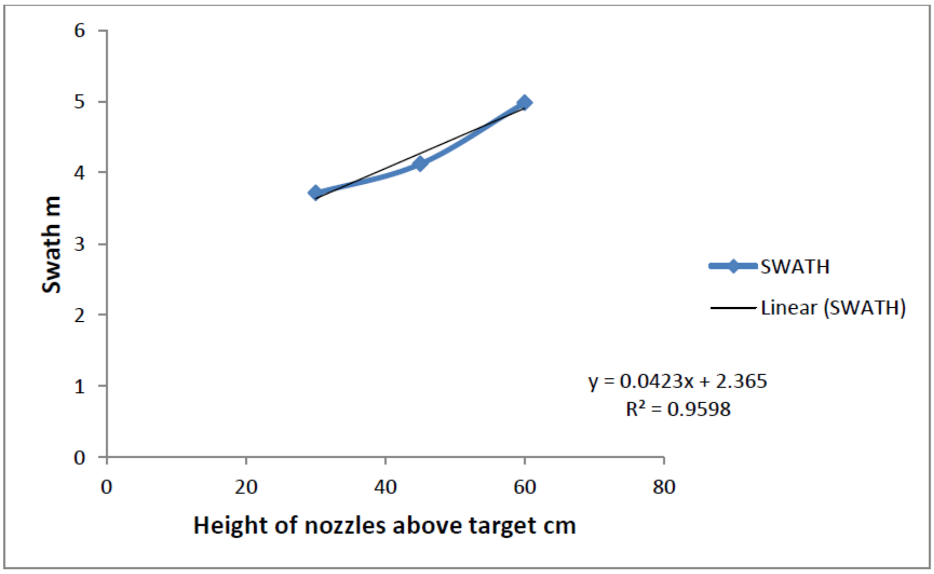


Figure 5b: Effect of height of nozzles above target on swath

IV. CONCLUSION

Laboratory evaluation shows that at 100 kPa pressure and 45 cm nozzle height above target, the Sprayer produces the most uniform Spray Volume distribution pattern with the least COV% of 15.13 %. The 100 kPa pumping pressure and 45 cm height of nozzle above target setting also renders droplet range which conforms to the coarse droplets sze recommended for herbicide application on soil and foliage. With 0.3 ha/h Effective Field Capacity (EFC), at the most uniform application setting of 100 kPa pressure and 45 cm height, the study would take about three days of working three hours morning and three hours evening to cover the about 5 hectare majority farm holding in Nigeria. The Theoretical Field Capacity, TFC = 0.64, Maximum Application Rate, Effective Field Capacity and Field Efficiency are respectively 1,625 l/ha, 0.43 ha/h and 75%.

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