The Bioscan 16(2): 143-148, 2021
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

EFFECT OF BOOM HEIGHT ON SPRAYING SWATH WIDTH OF JNKVV PUSH TYPE SOLAR AND BATTERY OPERATED SPRAYER

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KEYWORDS
JNKVV push type solar
Battery operated sprayer
Sprayer boom
Swath width

Received on :
25.11.2020

Accepted on :
09.05.2021

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ABSTRACT

The experiment was conducted to evaluate and measure the swath widths and spray angle produced by a spray boom held at four different heights above the ground whilst spraying with JNKVV push type solar and battery operated sprayer. JNKVV push type solar and battery operated sprayer is used to spray a chemical over a large area that helps in the growth of crops, reduce the expenditure on manual labour and are less time-consuming as compared with knapsack sprayer. The sprayer boom can be used for more than 50 cm row spaced crops and height adjustable boom for requirement of crop height. The swath width and spray angle of the sprayer during an application plays a critical role for chemical application. The sprayer boom was tested at different heights *i.e.* 40 cm, 80 cm, 120 cm, 160 cm from the ground level and found that the average swath width .*i.e.* 48.85 cm, 61.3 cm, 101.5 cm, 152.57 cm; average spray angle(degree) .*i.e.* 62.800, 41.920, 45.860, 50.980 respectively. It was analyzed that the height of spraying is directly proportional to the swath width. The spray angles of nozzles, pressure of spraying, height of spraying are responsible in enhancing the swath width. Coefficient of variation of average swath width at respective height were found to be 1.50 to 3.39, it means less variation in swath width at different heights.

INTRODUCTION

The major function of crop protection machinery is reduction in the population at the maturity stage of insects, pests, funguses, weeds and diseases *etc*., which are directly responsible for injuries within in the fields (Mathews, 1992 and Chetan *et al*. 2019). Insects, pests, funguses, weeds and diseases are the main constraints limiting agricultural yield (Mandi *et al*., 2016). Major techniques of controlling the insects, pests, funguses, weeds and diseases *etc*., contain preventing extensive periods of wetness on the leaf surface, cultural scouting, sanitation, and development of disease resistance varieties (Kumar and Srivastava, 2013). Chemical control had been sought as the most effective measure to control the spread of disease and results in combating disease appearing in the short period of time (Sumbula and Kurian, 2020). Several researchers have reported that timely application of chemicals is the best technique to manage early blight (Singh and Singh, 2006). Sprayers are mechanical devices that are specifically designed to spray chemicals speedily and effectively. The height of the sprayer boom during an application plays a critical role in the major goals of any chemical application with sprayer. Due to advancement in technology many companies have come up with different type of power sprayers, aerial sprayers, tractor mounted boom sprayers and self-propelled sprayers. These Sprayers are also quite costly and operate on diesel or petrol powered engines. Most of Indian farmers are completely dependent on agriculture, which comprises small, marginal, medium farmers. Therefore the small and medium scale farmers cannot afford this type of sprayers, because of high price. Hence, small and medium scale farmers are interested to use the hand operated backpack sprayer due its price, versatility, (Poratkar and Raut, 2013). The sprayer has the difficulties such as, it needs a lot of effort to push the liver up and down in order to create the pressure. Pressure required is high on the down stroke and low on the upstroke to spray and it causes inefficient spraying without pressure regulation (Miller and Bellinder, 2001). Back pain problems may arise during middle age due to carrying of 10-20 litre tanks on back (Shivarajakumar and Parameswaramurthy, 2014). As the fuel prices are increasing day by day, these sprayers have become uneconomic and need to be replaced by renewable energy sprayers. Renewable energy resources have been use in different types according to the nature of application (Khambalkar *et al*., 2016). Among all the renewable energy sources, solar energy is the most available resource and it is pollution free. Solar energy has got importance in sustainable modern economy. The farmers require reasonably useful methods for spraying chemicals in a large area, in minimal time and less cost. The spraying chemicals are very of very high price hence; equipment for even and efficient submission is needed (Bindrah and Singh, 1980). Approximately, 35% of the crop yield is injured if chemicals are not applied at correct time. The regular distribution of crop protection chemicals is a significant part for achieving the greatest efficiency of chemical application with minimum charges and less surrounding contamination (Visacki *et al*., 2016). The main helpful approach to increase the swath width of a sprayer is to adjust broader boom that helps the growth of crops, reduce the expenditure on manual labour and are less time-consuming (Ningthoujam and Shrivastava, 2018). Kumar, (2015) developed wheel driven boom sprayer's swath width and spray angle were 95 cm, 43.850 at height of 118 cm; 85 cm, 42.960 at height of 108 cm; 65 cm, 40.540, at height of 88 cm; 55 cm, 44.030 at height of 68 cm; 40 cm, 55.510 at height of 38 cm respectively. Zhang *et al*. (2015) concluded from his experiments that although weather conditions such as wind speed, wind direction and moment of wind as well as configuration of atomizer orientation, all impacted the spray swath width. There are three major factors, which influence sprayer calibration: Forward speed, swath width, and liquid flow rate (FAO, 2001). Sanchavat *et al*. (2017) were evaluated tractor mounted boom sprayer and found out the swath widths are 1235, 1294, 1375 mm at pump pressure 500, 600, 700 kPa respectively. The effective swath width depends upon the wind velocity, height of spray, spray angle and crop growth. Wider is the swath width of spray when the wind velocity is high (NIPHM Data). The best swath width and coverage obtained by certain design features like nozzle type, pressure, placement or nozzle spacing (Akesson). Therefore, the present study was aimed to assess the effect of boom height, spray angle on spraying swath width of JNKVV push type solar and battery operated sprayer.

MATERIALS AND METHODS

The studies were conducted at Farm Machinery and Power Engineering laboratory of College of Agricultural Engineering, JNKVV, Jabalpur during 2019-2020 to find out the effect of nozzle height and spray angle on the swath width of spraying of newly designed and developed JNKVV push type solar and battery operated sprayer. The details and specifications of developed sprayer are given in the Fig. 1. This sprayer has system to adjust the row to row width, height of spraying and increase or decrease in the boom length as per the crop requirement. Agro-climatic characteristics located at Jabalpur lies between 22°49' and 20°80'North latitude and 78°21' and 80°58' East longitude at an attitude of 411.78 meters above the mean sea level. The experiment was designed to find out the effect of height and angle of nozzle on swath width of spraying. Statistical analysis of swath width was also calculated with the help of appropriate statistical software and swath width, height was measured with 1meter tape and spray angle measured with suitable formula.

Independent Variable

Sprayer : 1 level (JNKVV push type solar and battery operated sprayer)

Height of spraying : 4 level (40, 80,120 and 160 cm)

Pressure : 1 level (2.29 kg/cm$^{2)}$

No of sprayer nozzles : 4 No

Replication : 3 levels

Dependent Variables

Swath Width, cm

Spraying angle of nozzles (N1, N2, N3, N4), degree

Spraying diameter, cm

Working principle

Push type JNKVV Solar and battery operated sprayer was designed to spray the chemicals in the fields. The designed push type solar sprayer mainly consists of a solar panel, charge regulator, battery, dc motor, pressure control valve, filter, switch, and tank. Handle fixed to trolley with nut and bolt adjustment for fixing different heights. The spray tank was connected to the boom with the aid of distributing flexible rubber hose passing through the DC motor. The vertical boom supporter was bolted at the front of the main trolley. The boom supporter was designed in the way that the boom height could be adjusted as per the crop height between 40 cm to 200 cm above the ground. The hose pipe of boom was also adjusted on the horizontal bar of boom supporter and four nozzles are adjusted to the hose pipe. The distance between each nozzle was 60 cm and this width is adjusted by aluminum clamps depending upon the crop width from 60 to 90 cm. The chemical in the spray tank is pumped to the flexible hose by the dc motor when the motor is started. Sun rays transfers into photovoltaic plate during the day time. Battery is charged by charge controller through PV panel and the electricity is stored in this battery. In order to supply reduced voltage from battery to pump a charge controller is used. The overall weight of developed push type solar photo-voltaic and battery operated sprayer was 30 kg. Technical specifications and working view of the developed JNKVV push type solar and battery operated sprayer unit shown in fig. 1.

Swath width and Spray angle

Is the effective width covered by the nozzle or boom assembly and can be calculated for a single nozzle or for an entire boom. Where a boom sprayer is to be used, the width of cover can be calculated by multiplying the number of nozzles by the distance between individual nozzles (FAO, 2001). The swath width of the developed sprayer unit was measured by spraying on flat dry floor and wetted diameter of area was measured by measuring tape. Spray angle of different nozzles is determined by taking its height 40, 80, 120 and 160 cm above the ground. Fig. 2 shows the spray angle calculation. (Dent *et al*. (1993)

Spray angle $\ddot{Y} = \tan\text{-}1(\frac{2h}{d})$

Where,

h = spray height, cm; and

d = spray diameter, cm.

Statistical Analysis

The data collected in the experiments was analyzed statistically. Analysis of variance was used to test the significance of each independent variable and their interaction with dependent variables. The data was analyzed by using IBM SPSS software.

RESULTS AND DISCUSSION

The trials were conducted to evaluate measurement of the swath widths produced by a spray nozzle held at four different heights (40, 80, 120, 160 cm) above the ground at the same time as spraying. Fig. 3 shows the swath width calculation in various heights.

Swath width at boom height of 40 cm

Table 1 and Fig. 4 shows the swath width of nozzles at height of 40 cm from the ground in 3 trails. Three trails were taken for the accuracy of results. The minimum and maximum swath

Table 1: Swath width at boom height 40 cm

S.no	Nozzle no	Nozzle swath width, (cm) Trail 1	Trail 2	Trail 3	Avg.	CV, (%)
1	N1	48	50	49	49	3.39
2	N2	45	47	49	47	
3	N3	47	49	49	48.4	
4	N4	49	51	53	51	
	Mean swath width, (μ)				48.85	
	Standard deviation, (Ã)				1.66	

Table 2: Swath width at boom height 80 cm

S.no	Nozzle no	Nozzle swath width, (cm) Trail1	Trail2	Trail3	Avg	CV,(%)
1	N1	61	63	59	61	
2	N2	59	60	58	59	3.08
3	N3	60	62	63	61.6	
4	N4	62	64	65	63.6	
Mean of swath width, (μ)					61.3	
Standard deviation, (Ã)					1.89	

Table 3: Swath width at boom height 120 cm

S. no	Nozzle no	Nozzle Swath width, (cm) Trail 1	Trail 2	Trail3	Avg	CV, (%)
1	N1	102	105	103	103.4	
2	N2	98	102	101	100.3	
3	N3	101	101	99	100.3	1.5
4	N4	103	102	102	102.3	
Mean of swath width(μ)					101.5	
Standard deviation(Ã)					1.53	

Table 4: Swath width at boom height 160 cm

S.no	Nozzle no	Nozzle swath width, (cm) Trail 1	Trail 2	Trail 3	Avg	CV, (%)
1	N1	151	153	155	153	1.69
2	N2	149	149	152	150	
3	N3	151	153	150	151.3	
4	N4	154	155	159	156	
Mean of swath width(μ)					152.57	
Standard deviation of swath width(Ã)					2.59	

width of nozzles was obtained 45 cm and 53 cm respectively. Whereas, average swath width was found to be 48.85 cm.

Table 1 shows coefficient of variation of nozzle was 3.39; it means swath width of nozzles was not more deviated. This showed variation in swath widths of the nozzle were below acceptable variation of 10 per cent as per the recommendation of swath width (Gomez and Gomez1984).

Swath width at boom height 80 cm

Table 2 and Fig. 5 show the swath width of nozzles from the height of 80 cm from the floor. From the three trails observed that 58 cm was the minimum swath width and maximum swath width was 65 cm at third trail of fourth nozzle. But observed that the average swath width of all nozzles were nearly same.

Table 2 characterizes coefficient of variation of three observations was 3.08. It means very less variation of swath width in nozzles was obtained. Swath width on sprayer depends on weather conditions, nozzle characteristics and angle of the spaying.

Swath width at boom height 120 cm

Swath width of individual nozzle at boom height 120 cm shows the fig. 6. Swath width is needed for uniform coverage of parallel passes. From the observations, minimum swath width was 98 cm; maximum swath width 105 cm and average swath width 101.5 cm was obtained.

Table 3 represents coefficient of variation was 1.50 it means less deviation was received from the individual swath widths. As the sprayer swath width is based on the treated area, the delivery rate will also be based on the treated area when band spraying of chemicals.

Swath width at boom height 160 cm

From the resultant fig. 7 shows more swath width was covered compared with the previous swath widths. A better distance is to be maintained for plant canopy and boom height in order to avoid the loss of chemical. This swath width is obtained from the maximum height of designed boom.

From the table 4 it was found that maximum height of boom obtained minimum swath width 149 cm and maximum swath

Particular	Specification
Length, cm	97
Width, cm	50
Height, cm	200
Weight, kg	34
nozzle	Hollow cone nozzle
Solar panel	12 V, 50 WP
Open Circuit Voltage (Voc), V	21
Short Circuit Current (Isc), A	2.82

Figure 1: Technical specifications and working view of the developed JNKVV push type solar and battery operated sprayer unit

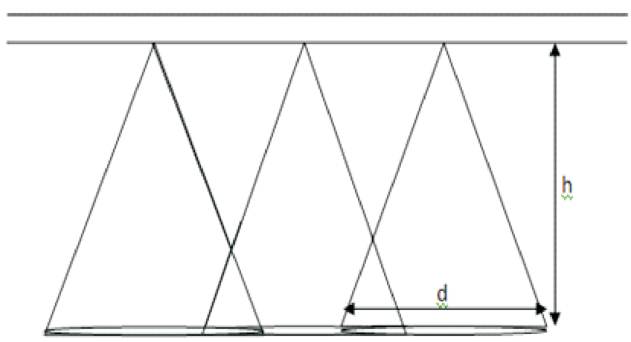

Figure 2: Drawing of spray angle calculation

Table 5: Average swath width at different heights of boom

S.no	Boom height, (cm)	Swath width, (cm) N1	N2	N3	N4	Mean, (µ)	Standard deviation,(Ã)	CV, (%)
1	40	49	47	48.4	51	48.85	1.66	3.39
2	80	61	59	61.6	63.6	61.3	1.89	3.08
3	120	103.4	100.3	100.3	102.3	101.5	1.53	1.5
4	160	153	150	151.3	156	152.57	2.59	1.69

Figure 3: Swath width calculation

Table 6: Spray angle of individual nozzles

S.No	Height of boom ,(cm)	Spray angle in degrees, (0) N1	N2	N3	N4	Avg. angle in degrees, (0)
1	40	62.97	60.87	62.35	65.04	62.8
2	80	41.74	40.48	42.11	43.36	41.92
3	120	46.62	45.36	45.36	46.11	45.86
4	160	51.11	50.23	50.61	51.98	50.98

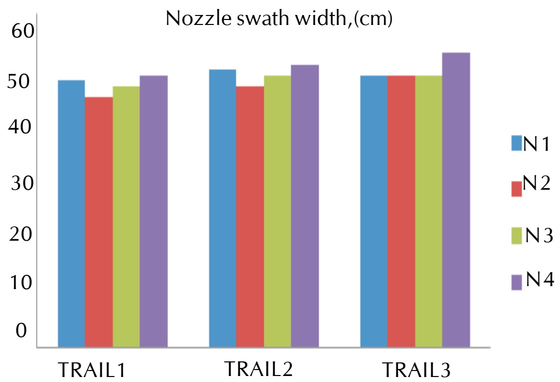

Figure 4: Swath width at boom height 40 cm

width was 159 cm. In this height droplets travelled more time in the air due to large height from the ground.

Table 4 explains the coefficient of variation was 1.69, it means less difference between the individual swath widths and similarities observed in all average swath widths of above trails. If the wind is too light or the spraying speed too high the swath width will decrease possibly causing overdosing and wasting chemicals. Swath width is the width of treated area over which spray droplets are distributed in one pass of the spraying. The swath width is used in sprayer calibration to calculate the sprayer's delivery rate and coverage. Statistically it was calculated that there is a significant difference between height and swath width of spraying at 5 % level of significance. It's depicted that more height has more swath width means more covering area in less time and more field capacity *i.e.*1 ha/h .Its save the cost and crop also by timely spraying.

Average swath width at different heights of nozzle

Swath width should be more to cover the plant area in single passage. It results in use of low chemicals with more area covered if the wind is too strong or gusty, it increases the swath width which will reduce the chemical application rate and increase the risk of damage.

From the table 5 and fig. 8 shows that the swath width was increased along the height of boom. Coefficients of variation of swath width at different heights are1.50 to 3.39, it means less variation in swath width at different heights.

Spray angle

Spray angle is another important parameter of nozzle performance that establishes the correct nozzle spacing overlapping and height of the application.

Spray angle is dependent on type of nozzle, orifice size and operating pressure. As pressure increases spray angle and swath width also increases. Spray angle of the nozzles was calculated in the jet system website. Table 6 shows the spray angles of nozzles (N1, N2, N3 and N4). The spray angle was calculated through the average swath width of nozzles.

The boom of the knapsack sprayer is not adjustable, so it boom always need to keeping at a constant height is difficult. Therefore it effects on uneven coverage of swath width. Lever operated Knapsack sprayer gives irregular swath width as maintaining a constant pressure is very difficult because of lack of consistent efforts of operator due to fatigue. And it takes more time and covers less swath width for the reason

Table 7: Comparisons of Knapsack sprayer with JNKVV push type solar and battery operated sprayer

S. no	Particular	Knapsack sprayer	JNKVV push type solar and battery operated sprayer
1	Crops	All crops	More than 50 cm row spaced dry land crops
2	Discharge	0.5 to 1 l/min	4 to 4.5 l/min
3	Pressure	Specified by manufacturers	Adjustable by valve for depends on crop
4	Field capacity	0.4ha/ day	1 ha / day
5	Number of rows covered	2	4
6	Spray angle	Specified by manufacturers	Varies with height of boom

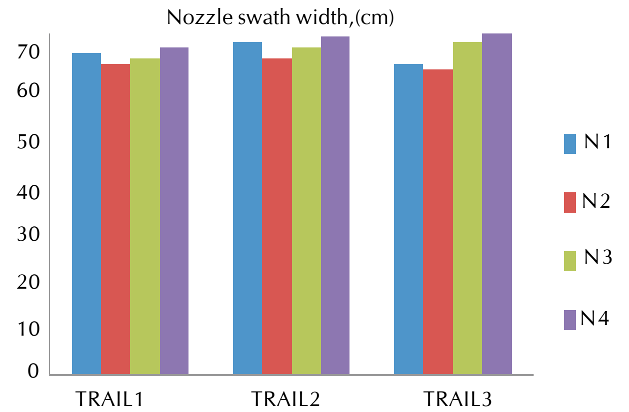

Figure 5: Swath width at boom height 80 cm

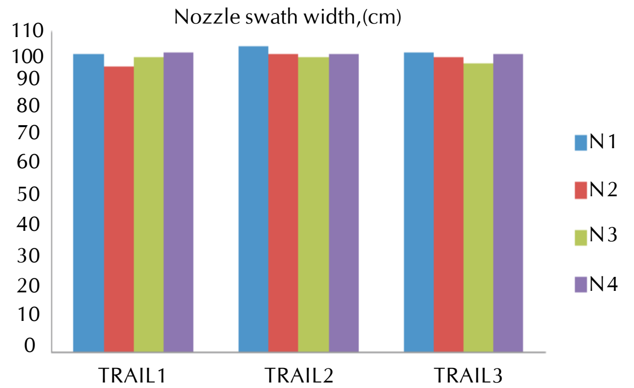

Figure 6: Swath width at boom height 120cm

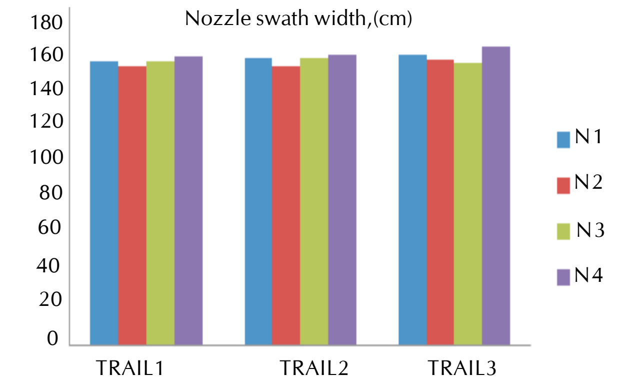

Figure 7: Swath width at boom height 160 cm

that it covers only one crop row at a time so continuous working is difficult with knapsack sprayer. The developed solar sprayer boom has four nozzles so it covers four rows and large swath width at a single action and it gives constant pressure from the nozzle and it has pressure regulator valve for pressure

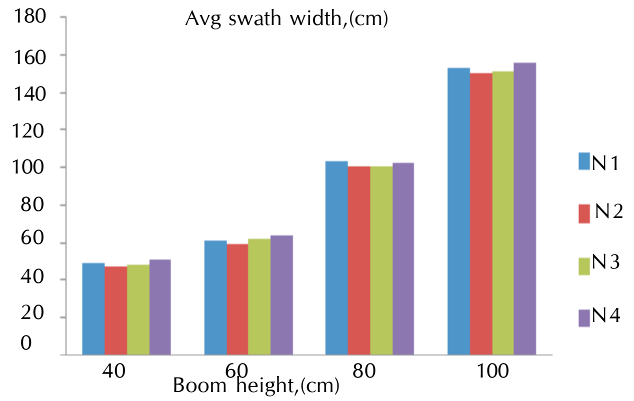

Figure 8: Average swath width at different heights of boom

adjustment. Above table(Table.7) shows the better performance of developed push type solar and battery operated sprayer unit. Spraying with solar sprayer unit requires less time consuming, less labour required, low management cost, less human fatigue and very efficient process compared to the conventional method of spraying. Operator feels more comfort with minimum health hazards by using the developed JNKVV push type solar and battery operated sprayer unit.

ACKNOWLEDGMENT

The present work was supported by Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agricultural Engineering, Jabalpur, Madhya Pradesh, India by giving infrastructure and technical facilities.

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