*Current Journal of Applied Science and Technology*

***39(31): 14-20, 2020; Article no.CJAST.61250***
***ISSN: 2457-1024***
*(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)*

# Effect of Nozzle Height on Spray Overlapping of JNKVV Push Type Solar and Battery Operated Sprayer

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***Authors' contributions***

*This work was carried out in collaboration between both authors. Author AKS designed the study. Author KP performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Authors KP and AKS managed the analyses of the study. Both authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/CJAST/2020/v39i3130984
Editor(s):
(1) Dr. Chien-Jen Wang, National University of Tainan, Taiwan.
Reviewers:
(1) Muhammad Abdurrahman, Federal University Dutse, Nigeria.
(2) Suleyman Adak, Mardin Artuklu University, Turkey.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61250

***Original Research Article***

***Received 12 July 2020***
***Accepted 18 September 2020***
***Published 10 October 2020***

## ABSTRACT

Study was conducted at the Department of Farm Machinery and Power Engineering workshop, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh to determine the nozzle spacing and boom height of JNKVV push type solar and battery operated sprayer on the basis of width of overlapping of spraying. It is difficult to obtain the consistent width of the overlapping between adjacent nozzles for the commonly used spraying. Coefficient of variation of nozzles overlapping varies according to the spray height and nozzle spacing. Precision guidance and precision sprayer control have substantial promise to reduce input application overlap, thus saving chemicals, fuel, and time during the application process. It was found that the overlapping increases with increase in height of the boom. The results were obtained by the overlapping test for boom height and nozzle spacing, there was no overlapping obtained up to height of 80 cm. The overlapping varied from 39 cm to 43 cm and mean overlapping was 41.3 cm at nozzle height 120 cm and nozzle spacing of 60 cm. An average overlapping of nozzles varies from 29 cm to 34 cm at nozzle spacing of 70 cm and boom height of 120 cm. At the boom height of 160 cm and nozzle

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space of 70 cm, spray overlap fluctuates from 79 to 85 cm. The overlapping at nozzle space 80 cm varies from 19 to 22 cm and mean overlapping was 22 cm at the boom height of 120 cm and nozzle space 80 cm. The overlapping varies from 70 cm to 74 cm in nozzle series at the boom height of 160 cm and nozzle space 80 cm. As per the crop cultivation practices, adjusted the boom height and spacing to reduce overlapping of spraying.

*Keywords: JNKVV push type solar and battery operated sprayer; overlapping; nozzle spacing and boom height.*

## 1. INTRODUCTION

Development in agriculture mechanization is extremely related to the lack of farm labour and industrial development in India and in foreign countries. The existing belief of excess labour and farm animals in the nation is not according to the requirement [1]. Sprayers are mechanical devices that are specifically designed to spray chemicals speedily and simply. These chemical sprayers are normally used on fields to spray chemicals as a means of yield manage. Chemical is applied by farmers broadly on conventional agriculture process as this method requires less labour and distribution is simple [2]. Excessive agro-chemicals are being used to improve crop production to meet the food security challenge with growing population. Gaps or overlaps in the chemical spraying patterns can result in under or over application of chemicals thus causing environmental issues [3]. As far as Indian scenario is concerned, more than 75 percent farmers are belong to small and marginal land holding [4].The small and medium scale farmers' spray using manually operated backpack knapsack sprayers which are laborious, time consuming and possess narrow swath width [5]. In the lever operated backpack sprayer, one has to use left hand or right hand or both the hands to give pressure [6]. The manually operated backpack sprayers used by farmers also have negative health impacts as the worker is in proximity to the chemical being sprayed. About 40% of all the fields could be affected due to non-uniform chemical spray or late spraying [7]. The spray features of sprayer nozzles are significant criteria in the application of chemicals because of their ultimate result on the efficiency of the spraying process. Droplet size and velocity influences the formation of the spray deposits and the drift capability of the droplets [8]. This analyses suggest that, even when considering only private advantages of input reductions, the value derived from a precision spraying method can be substantial [9]. Consequently, during chemical spraying, the single nozzle lance sprayers is swung from side to side while walking to cover the spacing between crop rows that generally leads to under-and-over chemical spraying [10]. Thus, overlapping evaluation of push type solar and battery operated sprayer having four nozzles was made for their application efficiency, spray output uniformity and accuracy during spraying. However, the World Health Organization states approximately one million illness cased due to manual chemical spraying in the crops [11]. Frequent chemical spraying with the same crop or a suboptimal practice can lead to resistance in pests and diseases. Improved spraying techniques could be superior to the sustainable use of the crop protection inventions [12].

## 2. METHODS AND MATERIALS

In this paper, the overlapping variation at nozzle space on the boom height of 60 cm, 70 cm, 80 cm (one more value missing here) and at height of 40 cm, 80 cm, 120 cm, 160 cm respectively were taken for push type solar and battery operated sprayer with the help of 1metre tape on march 9$^{th}$ 2020 between 11am to 3 pm. The present experiment was carried out at Farm Machinery and Engineering laboratory, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. Agro-climatic characteristics are 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. Fig. 1 repersents the view and technical specifications of the developed JNKVV push type solar and battery operated sprayer unit. Statistical analysis of spray overlapping was also calculated in appropriate statistical software. Solar photovoltaic panel charges a 12V, 7Ah battery which, in turn, operates a DC motor. This DC motor activates a pump which further pumps chemicals, stored in the form of a solution / liquid, through a nozzle, thereby, creating a spray.

| Particular | Values |
|---|---|
| Length, mm | 970 |
| Width, mm | 500 |
| Height, mm | 2000 |
| Weight, kg | 34 |
| Solar panel voltage, V | 12 |
| Solar panel power, Wp | 50 |
| Open Circuit Voltage (Voc), V | 21.00 |
| Short Circuit Current (Isc), A | 2.82 |

**Fig. 1. Technical specifications of the developed JNKVV push type solar and battery operated sprayer**

**Working:** JNKVV push type solar and battery operated sprayer was designed to spray the chemicals in the fields with more than 50cm row to row spacing. The designed JNKVV push type solar and battery operated sprayer mainly consists of a solar photo voltaic panel, charge controller, lead acid battery, pump, pressure control valve, filter, on and off switch, and 20 liter capacity tank. Handle was adjusted to designed trolley with nut and bolt arrangement for fixing different heights for different crops. The sprayer tank was connected to the boom with the aid of distributing flexible rubber hose passing through the pump. 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 40cm to 200cm above the ground. The hose pipe of boom also adjusted on the horizontal bar of boom supporter and four nozzles were fixed to the hose pipe. The distance between each nozzle was 60cm and this width is adjusted by aluminum clamps depending upon the crop width from 60 to 90cm. The chemical in the solar sprayer tank is pumped to the flexible hose by the pump when pump is started. Solar rays' transfers into photo voltaic plate during the day time. Battery is charged by charge controller through PV panel and the electricity is stored in this lead acid battery. In order to supply reduced voltage from battery to pump, a charge controller is used. Charge controller automatically stops the pump when battery voltage becomes below 10.3 V. The overall weight of JNKVV push type solar and battery operated sprayer is 35 kg.

## 2.1 Spray Overlap

The overlap is the width covered by two adjacent nozzles divided by the width covered by a single nozzle, expressed in per cent (%). Spray overlap by spraying clean water onto a flat surface (concrete) and drying patterns were observed. It mainly affects spray pattern and coverage of the sprayer depends on the boom height and nozzle spacing [13]. The test was done on a cement floor. The sprayer was tested under boom heights at 40, 80, 120, 160cm and at nozzle spacing of 60, 70, 80cm. The overlapping of sprayer represents by Fig. 2. The developed solar and battery operated sprayer gave constant pressure, better uniformity of spraying from the nozzle and it has pressure regulator valve for pressure adjustment. Continuous working is difficult with knapsack sprayer and covers one row with single passage.

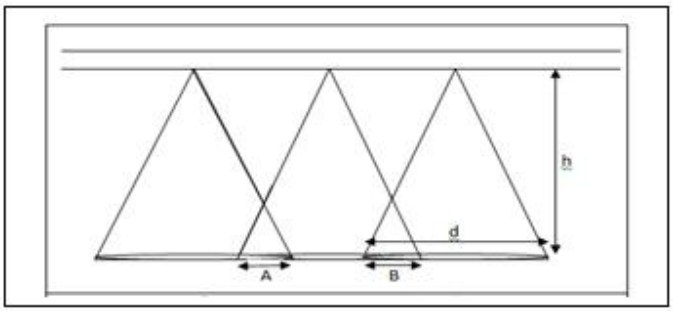


**Fig. 2. Overlapping of spraying**
*h- height of spray*
*d-diameter of spray pattern*
*A and B- represents overlapping of spray*

## 2.2 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 at 5 and 1 percent level of significance. The data was analyzed by using appropriate SPSS software.

## 3. RESULTS AND DISCUSSION

Spraying with JNKVV push type solar and battery operated sprayer requires less time, less labour, low management cost, less human fatigue and the process is very efficient compared to the conventional method of spraying. Operator feels more comfort with reduced health risks by using the developed unit. Only one labour is sufficient for operating sprayer and large area can be covered with single passage. The time required in the field while operating was 1min for covering 40m length and width is adjustable based on row to row space of crop that was more than 50cm. Therefore, the theoretical field capacity, actual field capacity and field efficiency of developed sprayer unit are 0.45ha/h, 0.38ha/h and 84.45% respectively. The speed of the developed sprayer unit depends on walking speed of the operator.

## 3.1 Overlapping of Sprayer

### 3.1.1 Overlapping at nozzle space 60cm

Fig. 3 indicates that the spray overlap test between nozzles $(N_1 - N_2,\ N_2 - N_3,\ N_3 - N_4)$ No overlapping observed at the boom height of 40 to 80 cm at nozzle space of 60cm. Nozzles at the height of 120cm, the overlapping varied from 39 to 43cm and mean overlapping was 41.3cm. Similar trails were conducted at the height of boom 160cm and the overlapping varies from 85 to 92cm.

From Table 1 it shows that the variation in overlap of the nozzle was within the range of 5 – 30 percent [14]. The percentage of coefficient of variation shows the percentage overlap between

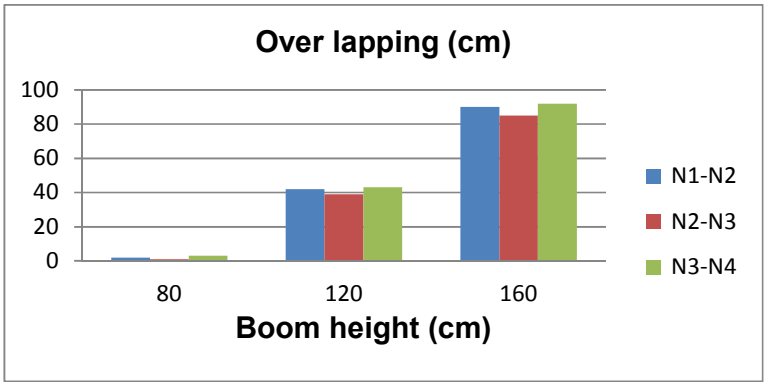


**Fig. 3. Overlapping at nozzle spaces 60cm**

the nozzles, which was 4 to 5 percent. This indicates very small variability of overlap between consecutive adjacent nozzles. It means variance in the overlapping was observed at height of boom higher than 120cm. Percentage of coefficient of variation of nozzle at height 120 cm was 5.03 and at height 160 cm was 4.04.

### 3.1.2 Overlapping at nozzle space 70cm

From the Fig. 4, it shows no overlapping up to the height of the boom 120 cm. Overlapping increases along with the height of boom due to increase in the angle of spray with height of the boom. At the boom height of 120cm, average overlapping of nozzles $(N_1 - N_2,\ N_2 - N_3,\ N_3 - N_4)$ varies from 29 to 34cm. Spray overlap fluctuates from 79 to 85 cm at the boom height of 160cm.

From Table 2, it is observed that percentage of coefficient of variation of overlapping of nozzles decreases with increase in the height of boom of sprayer. This means that the uniformity and coverage of the spray was good. Coefficient of variations was shown from the height more than 120cm. Percentage of coefficient of variations at these two heights varies from 3.7 to 7.9.

Most uniform pattern was achieved with proper overlap of the nozzle spacing. From the experiment, nozzle spacing on the boom spray angle and boom height determine proper overlap of the sprayer. Getting the proper boom height for a given nozzle spacing is extremely important in achieving appropriate overlapping of sprayer.

### 3.1.3 Overlapping at nozzle space 80 cm

From Fig. 5, shows overlapping of nozzles and the space between the nozzles were 80 cm and the height of nozzles adjusted to 40 and 120cm. Overlapping of nozzles $(N_1 - N_2,\ N_2 - N_3,\ N_3 - N_4)$was not observed when height was 40cm and 80cm. The overlapping of spray at height 120cm varies from 19 to 22cm and the mean overlapping was 22cm. At the height of 160cm the overlapping varies from 70 to 74cm in nozzle series.

In this observation from Table 3, percentage of coefficient of variation of nozzles also varies from 2.78 to 13.6, it shows overlapping of nozzles with less variation. Nozzle patterns need the correct overlap to achieve a uniform spray pattern under the boom. Less overlap may result in fewer droplets depositing in the overlap region resulting in poor coverage and reduced pesticide performance.

**Table 1. Overlapping at nozzle spaces 60cm**

| S.No | Height (cm) | Overlapping(cm) | | | Mean (cm) | Std dev(σ) | CV (%) |
|---|---|---|---|---|---|---|---|
| | | $N_1$–$N_2$ | $N_2$–$N_3$ | $N_3$–$N_4$ | | | |
| 1 | 40 | No | No | No | No | No | No |
| 2 | 80 | 2 | 1 | 3 | 2 | 1 | No |
| 3 | 120 | 42 | 39 | 43 | 41.34 | 2.08 | 5.03 |
| 4 | 160 | 90 | 85 | 92 | 89 | 3.60 | 4.04 |

**Table 2. Overlapping at nozzle space70cm**

| S.No | Height (cm) | Overlapping (cm) | | | Mean (cm) | Std dev(σ) | CV (%) |
|---|---|---|---|---|---|---|---|
| | | $N_1$–$N_2$ | $N_2$–$N_3$ | $N_3$–$N_4$ | | | |
| 1 | 40 | No | No | No | No | No | No |
| 2 | 80 | No | No | No | No | No | No |
| 3 | 120 | 32 | 29 | 34 | 31.6 | 2.51 | 7.94 |
| 4 | 160 | 81 | 79 | 85 | 81.6 | 3.05 | 3.73 |

**Table 3. Overlapping at nozzle space 80 cm**

| S.No | Height (cm) | Overlapping (cm) | | | Mean(cm) | Std. dev. (σ) | CV (%) |
|---|---|---|---|---|---|---|---|
| | | $N_1$–$N_2$ | $N_2$–$N_3$ | $N_3$–$N_4$ | | | |
| 1 | 40 | No | No | No | No | No | No |
| 2 | 80 | No | No | No | No | No | No |
| 3 | 120 | 22 | 19 | 25 | 22 | 3 | 13.6 |
| 4 | 160 | 72 | 70 | 74 | 72 | 2 | 2.78 |

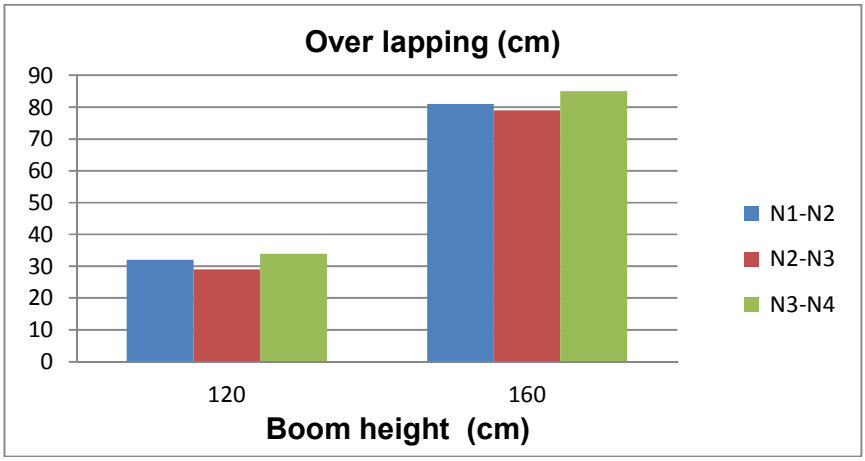


**Fig. 4. Overlapping at nozzle space at 70cm**

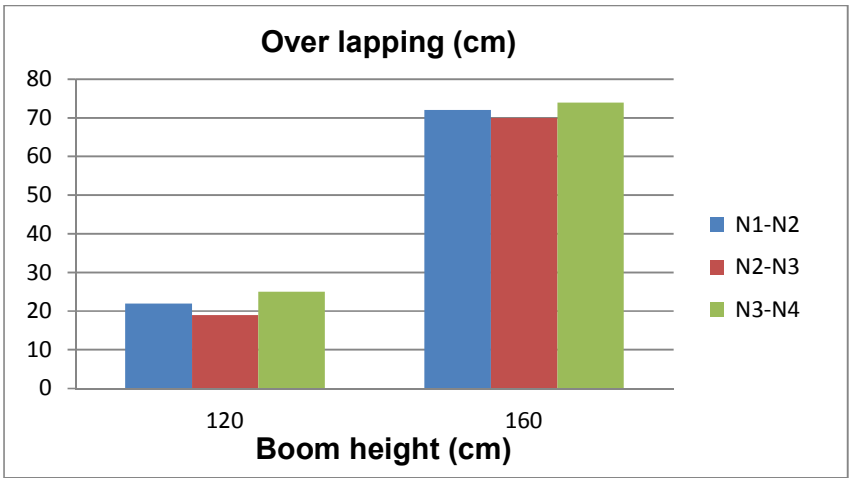


**Fig. 5. Overlapping at nozzle space 80 cm**

## 4. CONCLUSION

From the results obtained, it was observed that overlapping of spray decreases with increase in space between the nozzles. And the sprayer has managed to maintain percentage of coefficient of variation of nozzle, overlapping during the laboratory test were CV of nozzle overlapping 4.04 to 5.03% at nozzle space60 cm, CV of nozzle overlapping 3.73 to 7.94 % at nozzle space 70 cm, CV of nozzle overlapping 2.78 to 13.6 % at nozzle space 80 cm. From the overlapping results, at different boom heights and nozzle spaces, newly developed JNKVV push type solar and battery operated sprayer is able to cover one hectare of area within an hour with a superior uniformity of spraying. The important practical technique to raise the productivity of a sprayer is to use a broader sprayer boom.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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