International Journal of Bioresource Science
Citation: IJBS: **12**(02): 207-213, December 2025
DOI: 10.30954/2347-9655.02.2025.7

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

RESEARCH PAPER

Spray Drift Pattern Analysis of Different Sprayers

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Received: 20-09-2025 **Revised:** 25-11-2025 **Accepted:** 03-12-2025

ABSTRACT

A sprayer is a device used to spray a liquid, where sprayers are commonly used for projection of water, weed killers, crop performance materials, pest maintenance chemicals, as well as manufacturing and production line ingredients. Drift can be defined as spray which unintentionally reaches areas outside the target area, either as droplets, dry particles or vapour, during or after application on the target area. An increase in wind speed from 3 m/s to 5 m/s (at 2 m height) can double spray drift deposition. An experiment was conducted in a closed environment to find the spray drift analysis for different types of sprayers (Battery operated, Hi-tech, Knapsack, Rocker arm & Foot operated) with three different nozzles (Solid cone, flat fan & hallow cone) at different wind speeds (2, 5 & 10 km/hr) and different heights from ground level (50, 60 & 70 cm). Here, Rocker arm & Foot operated sprayers are used only with solid cone nozzle. The highest and lowest discharge rate was observed in battery operated sprayer with solid cone nozzle (1700 ml/min) and knap-sack sprayer with hallow cone nozzle respectively. The highest and lowest droplet size diameter at 50cm height was found in battery operated sprayer with solid cone nozzle (1.5 mm) and battery-operated sprayer with hallow cone nozzle (0.03 mm).

HIGHLIGHTS

- Increasing wind speed and spray height significantly increases spray drift during application.
- Different sprayer–nozzle combinations significantly influence discharge rate and droplet size distribution.

Keywords: Spray drift, Wind speed, Sprayer types, Nozzle types, Droplet size

Agriculture sprayers come in various design types, sizes, equipment and performance specifications. There is small, spot spraying agricultural sprayers up to very large sprayers with extensive land and plant spray coverage. Agricultural sprayers have been engineered this way to optimize their applicability and performance for the many scenarios, crops, vegetation, and soil that sprayers are used on (Balsari *et al*. 2017; Al Heidary *et al*. 2014). Agriculture sprayers are often used for applying water and water chemical solutions containing acids or caustic materials, often as crop-performance/pest-maintenance chemicals; *i.e.*, fertilizers, pesticides, etc. (Ray *et al*. 2024). There are several agriculture sprayers designed for spraying applications and designed to be versatile and suitable for various uses from spot applications, gardens, crops, row crops, crop trees, fruit, groves, vineyards, perimeter maintenance, livestock needs, weed control, pastures and rangeland. Also, there are optimum droplet size for different targets (Fox *et al.* 2008; Gil *et al.* 2014).

Drift can be deposited on nearby soil or water surfaces, or on vegetation (Carlsen *et al.* 2006). Drift from the application of crop protection products can cause damage to neighbouring crops, ecosystems, and human health. The term

How to cite this article: Harshavardhan, K., Prasanth, R.S., Sivakumar, S.S. and Santosh, D.T. (2025). Spray Drift Pattern Analysis of Different Sprayers. *Int. J. Bioresource Sci.*, **12**(02): 207-213.

Source of Support: IUCEA; **Conflict of Interest:** None

'pesticides' will be used hereafter as a generic term for crop protection products including herbicides, fungicides, insecticides, nematocides, etc. Pesticide drift may occur in three ways: Spray drift which is most common form of drift, vapour drift and blow (Donkersley and Nuyttens 2011). Relatively little work has been done on quantifying vapour drift and blow (Gil, *et al.* 2014), presumably because vapour drift and blow are less important than spray drift. In this report, we focus on spray drift which is referred to as a percentage of the applied dose to the crop. So, a study was attempted in AEC and RI, Kumulur to observe the amount of drift for different selected sprayers at different heights with different nozzles along with the droplet size of spray for each sprayer. The experiment was conducted in a closed environment to avoid variation in wind speed. Hence, the title "spray drift pattern analysis of different types of sprayers" has been contemplated.

MATERIALS AND METHODS

The following parameters were considered while measuring spray drift using different types of sprayers and nozzles. The independent parameters included the type of sprayer, type of nozzle, height of spraying (m), and wind speed (km/hr), as these factors directly influence the spray pattern and drift behavior. The dependent parameters measured were the volume of liquid collected at the target area (ml), the volume of liquid collected outside the target area (ml), and the volume of liquid evaporated (ml), which together helped in assessing spray efficiency, drift losses, and evaporation during application.

In the present study, A Battery-operated sprayer, Hi-Tech sprayer and a Knapsack sprayer was selected which can be operated with three different nozzles (solid cone, hallow cone and flat fan), a Foot operated and Rocker arm sprayer operating at a pressure of 14 to 18 kg/cm^2 was selected which can only be operated with a solid cone nozzle (Fig. 1). A solid cone, hallow cone and flat fan nozzles which has an operating pressure ranging from 3 PSI to 500 PSI, 40 to 8 PSI and 15 to 30 PSI respectively were selected (Fig. 2). A solid cone, hallow cone and flat fan nozzles which has an operating pressure ranging from 3 PSI to 500 PSI, 40 to 8 PSI and 15 to 30 PSI respectively were selected (Miller & Ellis 2000; Gil *et al*. 2014). A highly sensitive and accurate thermo anemometer was selected to measure the wind speed which has a measuring range of 0.0 to 140.0 km/hr (Nuyttens *et al.* (2007)). The resolution of the selected anemometer was 0.1 m/s. Basic accuracy was around ± (2% +1d). A 9V battery is used for Power supply. The meter size and vane size (H × W × D) was 150mm × 72mm × 35mm and 132mm × 66mm × 29.2mm respectively.

A laboratory setup was made in a closed environment (Fig. 3). The wind speed was maintained by using a blower and is measured using anemometer. A frame of size 2m × 2m × 1m is fabricated with 11 gauge (3.04 mm) thick MS square pipe. The periphery of the frame is covered with plastic sheet so that the spray cannot go outside from the frame. Semi-circular PVC pipes were kept at the bottom of the plastic sheet on the four sides of the frame to collect the spray drift. The experiments were conducted as a combination of five types of sprayers with three types of nozzles, three wind speeds (2, 5 & 10 km/hr) and at different heights (50, 60 & 70 cm from ground level).

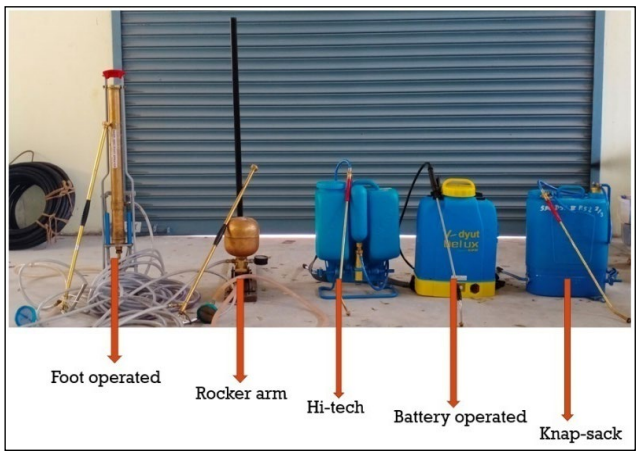

Fig. 1: Selected sprayers for measuring drift

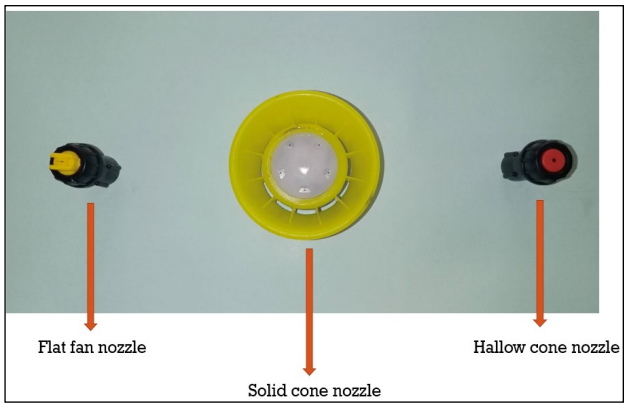

Fig. 2: Selected nozzles for measuring spray drift

A square shaped Photo sheet of 5 × 5 cm was selected and sprayed on it from a height of 50cm with all types of sprayers and nozzles with coloured water. Now the droplets on the photo sheet will not spread and stays at the position and within few seconds an exact mark of droplet was seen on the photo sheet. Now the photo sheets with the droplet marks are scanned and with help of "Image J" software the image is processed into binary as shown in fig. 4 & 5, and furthers the area of each droplet in the image were calculated as shown in figure 6. Mangado *et al*. 2013; Cerruto *et al.* 2019).

Fig. 3: Complete laboratory setup for measuring drift

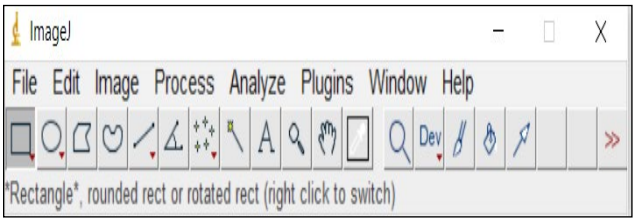

Fig. 4: Image J software

RESULTS AND DISCUSSION

Spray pattern

Spray pattern of the selected nozzles was checked on a level concrete ground and a circular shaped complete cover of the spray was seen in solid cone nozzle, a hallow shaped spray pattern was observed in hallow cone nozzle and a flat shaped spray pattern was found out in flat fan nozzle as shown in the Fig. 7.

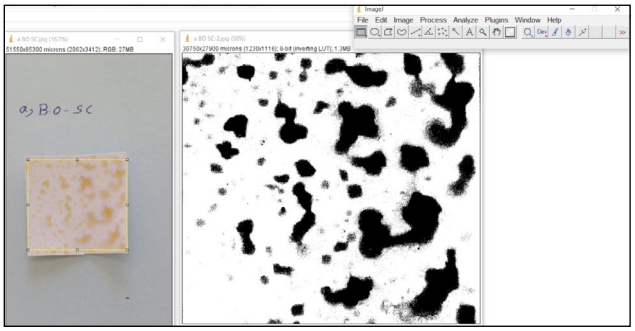

Fig. 5: Spray droplet marks on photo sheet, processing image in binary

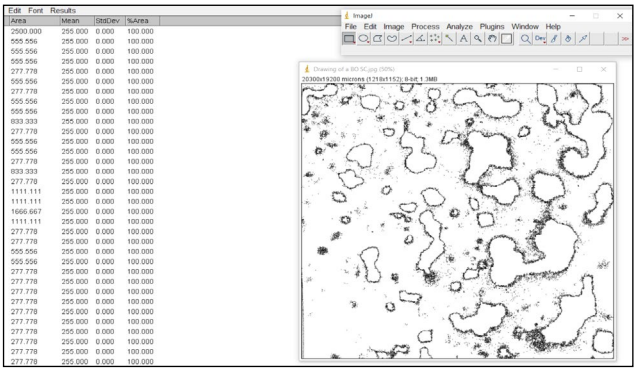

Fig. 6: Calculated area of each droplet in the selected image

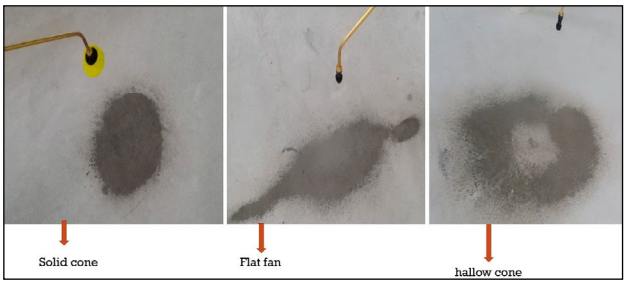

Fig. 7: Spray pattern of selected nozzles

The performance of solid cone nozzle with three different sprayers (BOS, HTS & KSS) was tested. The obtained results were graphed in a clustered bar chart as shown in Fig. 8. The spray pattern of the solid cone nozzle forms a solid cone-shaped spray pattern with a round impact area. Spray angles range from 15° to 170°. While operating with solid cone nozzle. It was found that water collected at the target area is more with battery operated sprayer (percentage of water collected out of target area is 2.7%). Water collected out of target area is found more with Hi tech sprayer and less with knap sack sprayer which is 3.9% & 3.0% respectively. The

obtained results shown that less drift was occurred at low wind speed i.e., 2 km/hr and at low height selected i.e., 50 cm from ground level. So, as the wind speed and height of spray is increasing there is a linear increase in the spray drift (Nuyttens *et al.* 2007; Balsari *et al.* 2017). Solid cone nozzle when operating with battery operated sprayer is giving the better results compared to the others. The quantity of spray discharge with solid cone was found more with battery operated sprayer followed by hi tech and knap sack sprayers. This was due to the constant spraying pressure maintained by the battery-operated sprayer when compared to the other sprayers. The droplet diameter of Solid cone nozzle is more with battery operated sprayer followed by Knapsack and hi-tech sprayers (Hewitt *et al.* 2009; Minov *et al.* 2014).

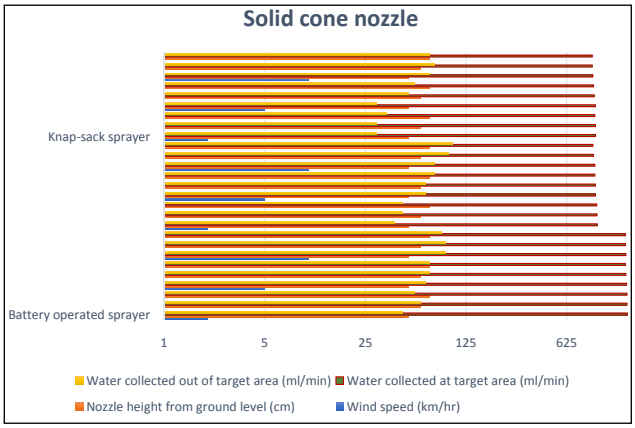

Fig. 8: Clustered bar chart showing water collected at the target area and out of target area with different sprayers at different wind speeds and heights for solid cone nozzle

Performance of a Flat fan nozzle with three different sprayers

The performance of flat fan nozzle with three different sprayers (BOS, HTS& KSS) was tested. The obtained results were graphed in a clustered bar chart as shown in Fig. 9. The spray pattern of the flat fan nozzle forms a flat or sheet shaped spray pattern with a flat impact area. Spray angles range from 0° to 170°. While operating with flat fan nozzle It was found that water collected at the target area is more with battery operated sprayer (percentage of water collected out of target area is 5.5%). Water collected out of target area is found more with Hi tech sprayer and less with knap sack sprayer which is 7.5 & 6.3% respectively. The obtained results shown that less drift was occurred at low wind speed i.e., 2 km/hr and at low height selected i.e., 50 cm from ground level. So, as the wind speed and height of spray is increasing there is a linear increase in the spray drift. Flat fan nozzle when operating with battery operated sprayer is giving the better results only when operating at 2 km/hr compared to the others. The quantity of spray discharge with flat fan was found more with battery operated sprayer followed by hi tech and knap sack sprayers. This was due to the constant spraying pressure maintained by the battery-operated sprayer when compared to the other sprayers. The droplet diameter of flat fan nozzle is more with knap sack sprayer followed by hi-tech and battery-operated sprayers.

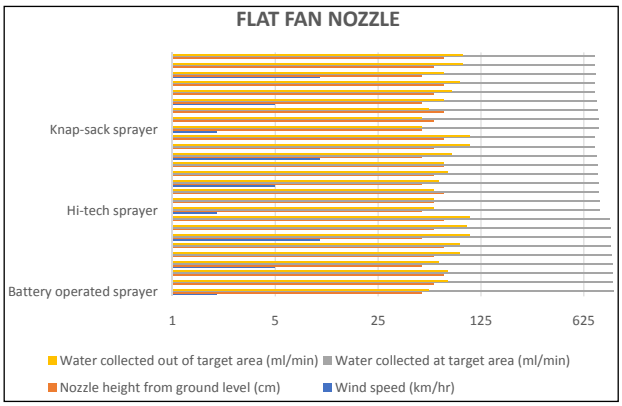

Fig. 9: Clustered bar chart showing water collected at the target area and out of target area with different sprayers at different wind speeds and heights for flat fan nozzle

Performance of hallow cone nozzle

The performance of hallow cone nozzle with three different sprayers (BOS, HTS & KSS) was tested. The obtained results were graphed in a clustered bar chart as shown in Fig. 10. The spray pattern of the hallow cone nozzle forms a ring-shaped spray pattern with a round impact area. Spray angles range from 90° to 130°. While operating with hallow cone nozzle It was found that water collected at the target area is more with battery operated sprayer (percentage of water collected out of target area is 8.6%). Water collected out of target area is found almost same with both Hi tech and knap sack sprayers which is 9.3% & 9.5% respectively. The obtained results shown that less drift was occurred at low wind speed i.e., 2 km/hr and at low height selected i.e., 50 cm from ground level. So, as the wind speed and height of spray is increasing there

is a linear increase in the spray drift. Hallow cone nozzle when operating with battery operated sprayer is giving the better results only at 2 km/hr compared to the others. The quantity of spray discharge with hallow cone was found more with battery operated sprayer followed by hi tech and knap sack sprayers. This was due to the constant spraying pressure maintained by the battery-operated sprayer when compared to the other sprayers. The droplet diameter of hallow cone nozzle is more with hi-tech sprayer followed by knap sack and battery-operated sprayers.

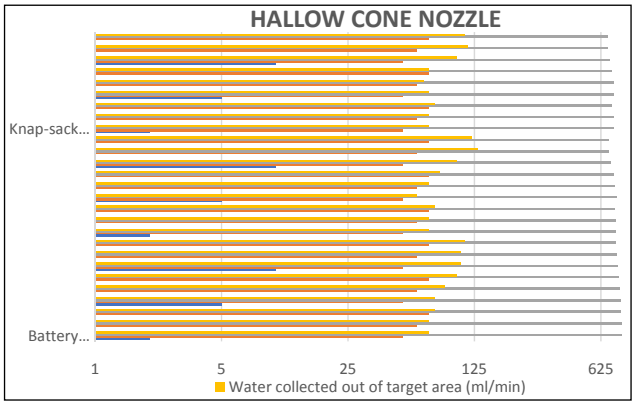

Fig.10: Clustered bar chart showing water collected at the target area and out of target area with different sprayers at different wind speeds and heights for hallow cone nozzle

Performance of a solid cone nozzle with Rocker arm and foot operated sprayers

The performance of solid cone nozzle with rocker arm and foot operated sprayers was tested. The obtained results were graphed in a clustered bar chart as shown in Fig. 4. The spray pattern of the solid cone nozzle forms a solid cone-shaped spray pattern with a round impact area. Spray angles range from 15° to 170°. While operating with solid cone nozzle It was found that water collected at the target area is more with rocker arm sprayer compared to foot operated sprayer. Water collected out of target area is found more with foot operated sprayer and less with rocker arm sprayer which is 9.09% and 7.09% respectively. The obtained results shown that less drift was occurred at low wind speed i.e., 2 km/hr and at low height selected i.e., 50 cm from ground level. So, as the wind speed and height of spray is increasing there is a linear increase in the spray drift. Solid cone nozzle when operating with rocker arm sprayer is giving the better results compared to foot operated sprayer. The quantity of spray discharge with solid cone was found more with foot operated sprayer followed by rocker arm sprayer. The droplet diameter of Solid cone nozzle is more with rocker arm sprayer than foot operated sprayer.

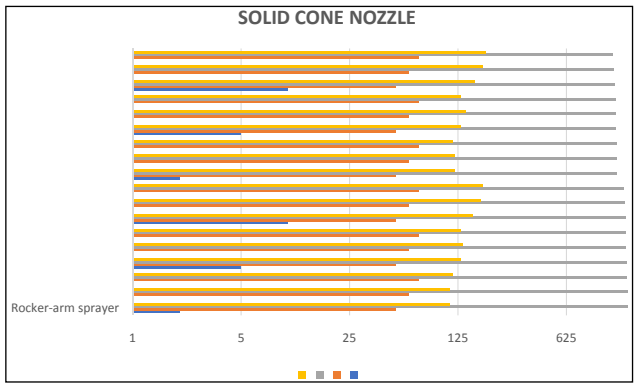

Fig. 11: Clustered bar chart showing water collected at the target area and out of target area with foot operated and rocker arm sprayers at different wind speeds and heights for solid cone nozzle

Discharge rate of sprayers

The discharge rate for hallow cone nozzle seems to be less in all the sprayers followed by flat fan and solid cone with all the three sprayers (BOS, HTS & KSS). When comparing rocker arm and foot operated sprayers with solid cone nozzle the discharge rate was found more with foot operated than rocker arm sprayer. The obtained results were shown as bar graph in Fig. 12.

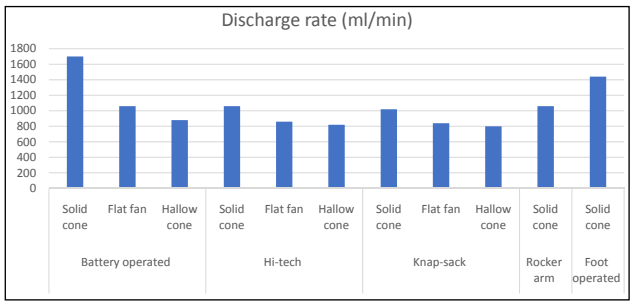

Fig. 12: Discharge rate of all selected sprayers with different nozzles

Droplet size of sprayers

The droplet diameter was observed to be low in hallow cone nozzle followed by flat fan and solid cone nozzles when operated by all the three sprayers (BOS, HTS & KSS). When comparing rocker arm and foot operated sprayers operating with solid cone nozzle the droplet size were found

greater with rocker arm sprayer compared with foot operated sprayer. The obtained results were shown as bar graph in Fig. 13.

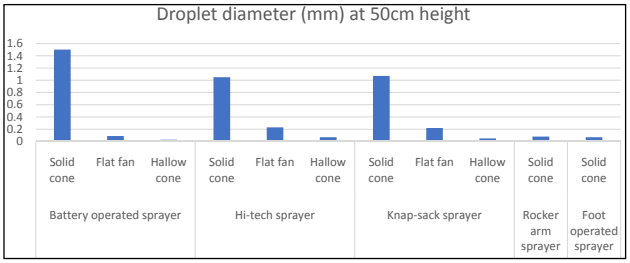

Fig. 13: Droplet size of all selected sprayers with different nozzles

CONCLUSION

From all the above results it is clear that wind speed, height of spray and nozzle type has a great impact on spray drift. "As the discharge rate is high the droplet diameter is high. As the droplet diameter is high the spray out of target area is less". Among all the three nozzles used (viz., Solid cone, flat fan and hallow cone) solid cone nozzle has low drift comparatively to other two. The values also indicate that as the height of spray increases, the drift is also increasing. Among all the three parameters considered, wind speed has a very great effect on the spray drift. At higher wind speeds even, the spray is not falling out of the target area and it is going along with the wind in its direction. Even though the nozzle used for both rocker arm sprayer and foot operated sprayer is solid cone, the drift is very great compared to other sprayers with solid cone which is due to very high pressure. The droplet size of the solid cone nozzle is high when operating with battery operated sprayer, hi-tech sprayer and knap sack sprayer but, droplet size is less with solid cone nozzle when using in rocker arm and foot operated sprayers. Among all the three nozzles solid cone is recommendable in order to have less drift followed by flat fan followed by hollow cone. Among all the three sprayers battery operated sprayer performance is far better comparing to others in terms of low drift.

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