Indian Journal of Ecology (2022) 49(5) (SI): 2000-2004
DOI: https://doi.org/10.55362/IJE/2022/3774

Manuscript Number: 3774
NAAS Rating: 5.79

Quantification of Spray Drift of Wheel Operated Boom Sprayer for Assessing Environmental Risk

Obaid Zaffar and Sanjay Khar

Division of Farm Machinery and Power Engineering
Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu 180009, India
E=mail: obaidzaffar@gmail.com

***Abstract*:** In the present study a wheel operated boom sprayer was evaluated on the basis of spray drift. The study involved the use of water sensitive paper (WSP) to capture the off-target spray laid on ground at a distance of 50 cm from the edge of the boom carrying nozzle. The results indicated that the spray drift was maximum for a hollow cone nozzle at 9.1% and minimum for flood jet nozzle at 0.2%. The spray drift increased with an increase in the height of spraying because of more time span for water droplets to remain suspended in air. The spray drift also decreased with an increase in the number of nozzles carried on the boom of the sprayer. The decrease in the spray drift with an increase in number of nozzles was due to the decrease in the atomization of liquid thus producing large droplets which are comparably less prone to the drift as compared to the smaller droplets.

***Keywords*:** Wheel sprayer, WSP, Dropleaf, Spray drift

Pesticides are the chemicals or mixture of substances used in various agricultural practices to control or eradicate pests, weeds and diseases in plants. The pesticides include herbicides, insecticides, fungicides, rodenticides, nematicides and other chemicals based on their intended target organism. On the basis of their use, they are classified as defoliants, desiccants, fumigants and plant growth regulators. Pesticides have substantially aided in the development of agricultural yields by controlling pests and diseases, as well as in the control of the insect-borne diseases (malaria, dengue fever, encephalitis, filariasis, and other parasitic disorders) in the human health sector (Abhilash and Singh 2009). The use of a various pesticides on crop plants is essential to reduce losess. However, the excess use results in significant consequences not only to public health but also results in an impact load on the environment. The conventional agricultural practices demand pesticides use either in bulk or its pure form without any adjuvant. The major drawback of the conventional pesticides applications is the loss depending on the mode of application i.e., spray drift from the sprayers at the time of application and weather conditions. (Singh et al 2020). Spray drift is a portion of spray which unintentionally reaches outside the target area, either in the form of droplets, dry particles or vapour during or after the spraying application on the target area (Carlsen et al 2006). According to the Environmental Protection Agency (EPA 2019) and the American Society of Agricultural Engineers (ASAE Standards 2009) spray drift is the pesticide carried by the air action during the application process or immediately after spray application. The drift of the spray from pesticide applications can expose people, plants, animals and the environment to the pesticide residues that can cause health and environmental effects and property damage. The spray drift can lead to the litigation, financially damaging court costs, and appeals to restrict or ban the use of crop protection materials. Arvidsson et al (2011) observed that with the increase in the height from the drift increased to the tone of 0.94% for each height of 0.1m. It was also observed that the fraction of droplets having sizes less than 102 microns are more prone to the drift. In order determine the effect of wind speed on spray drift, wind tunnel was used to provide cross winds of 1, 2 and 3 m/s and reported that by the increment of height of 10 cm the spray drift increased to the tune of 33.5%. Thus, it was concluded closer the nozzle to the target lesser is the spray drift.

MATERIAL AND METHODS

The study to assess the spray drift characteristics of a wheel operated boom sprayer (Zaffar 2020) was conducted at the Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K India with three types of booms (boom carrying two, three and four nozzles) and three different types of nozzles i.e., fan type, hollow cone and flood jet nozzle at three different heights of 40, 50 and 60 cm.

Description of a Wheel operated sprayer: The wheel operated sprayer consists of a bicycle wheel of 640 mm diameter attached at the front end of the main frame. On the rear end of the main frame a sprayer pump is mounted the sprayer consists of eccentric mechanism by which the rotational motion of the front wheel was converted into the reciprocating motion of the pump. The pump is attached with the hose pipe which in turn is connected with the boom carrying nozzles for the spraying operation. The main components of the wheel operated sprayer are main frame, sprayer tank cum pump, boom stand, boom and nozzles (Fig. 1).

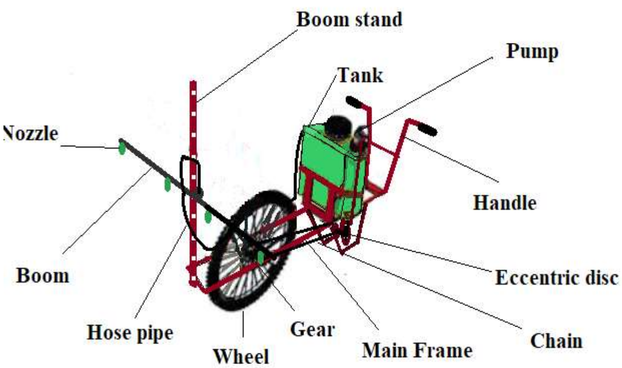

Fig. 1. Labelled figure of a wheel operated boom sprayer

Study area: The study was conducted at SKUAST Jammu on the knoll khol crop and spraying operation was done perpendicular to the wind direction. The size of the plot was 20 × 20 m^2 located at center of the university (32°65`29`` N, 74°80`71`` E) and represents a typical knol khol field at a mature crop stages 68-74% of leaf ground coverage and 0.25 m plant height.

Sampling setup: A total of 81 trials were performed to measure the spray drift deposition on the downwind side soil outside of the treated area (NW orientation) at 50 cm distance from the edge of the last nozzle.

Spraying technique: The spraying was done using a wheel operated boom sprayer in the field of the knol khol crop where the water sensitive papers were laid on about 50 cm from the extreme end of the nozzle. The spray drift was assessed on three types of the nozzles namely flat fan, hollow cone and flood jet nozzle at the three heights of the boom from the ground i.e. 40, 50 and 60 cm. The drift deposition was measured by analyzing the water sensitive paper after spraying of water over the mobile based software namely Dropleaf. The software provided the overall deposition of the liquid on the water sensitive papers which in turn determines the overall drift of the liquid from the specific nozzle at the specific height.

Meteorological conditions: The meteorological variables considered during the study were wind speed, temperature and relative humidity. The area has an average wind speed of 1.2 ± 1 ms^{-1}, maximum and minimum temperature of 31.2 and 18.5° respectively and also relative humidity of 84 and 44 at morning and night. (SKUAST- J 2020)

Design of experiments: To study the combined effect of different operational parameters namely type of nozzle, number of nozzles and height of the spraying on spray drift a factorial randomized block design of experiments was used with the three levels of variables for each.

Types of nozzle: The spray drift was assessed on three types of the nozzles i.e. flat fan nozzles, hollow cone nozzle and flood jet nozzle as these types of nozzles are readily used in agricultural spraying.

Flat fan nozzle: The flat fan nozzle is used for most of the broadcast spraying of herbicides and for certain insecticides when foliar penetration and coverage are not required. In order to maintain the uniformity overlapping of flat-fan nozzles is done. The overlap of approximately 30% of each edge is desirable in flat fan type of nozzles (Mulatu 2018) and same was kept during the experiments. There are two common designs of flat fan nozzle; elliptical orifice type and the deflection type. The one which we have adopted and is common in agricultural spraying is the elliptical orifice type. The spray pattern in this type of nozzle is formed by the exit of the fluid through a shaped orifice (Fig. 3). The slightly tapered

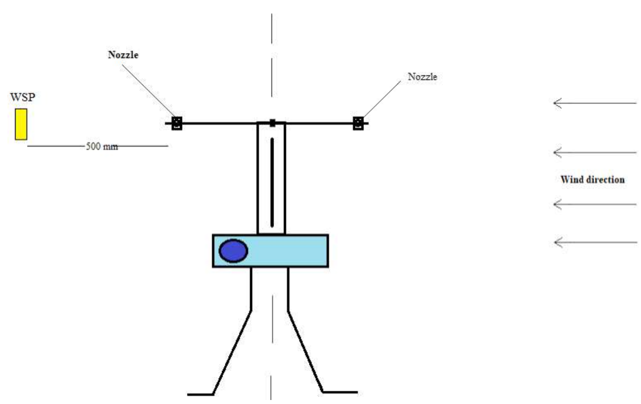

Fig. 2. Schematic diagram of spraying technique for the measurement of spray drift

nature of the flat spray patterns results in the spray distribution of not being entirely even. The components of the nozzles are; body, filter, washers, nozzle tip and nozzle head as shown in Figure 4.

Hollow cone nozzle: The hollow cone nozzles are primarily used when plant foliage penetration is essential for effective insect or disease control and when drift is not a major concern. The hollow cone contains a whirl chamber inside it which sets the whirl motion to the fluid (Fig. 5). The resulting turbulence breaks up the fluid into the droplets which are then shaped into a hollow cone as they exit the orifice. The components of the hollow cone nozzles are; body, whirl chambers, washers and nozzle head as shown in Figure 6.

Flood jet nozzle: The flood jet nozzles also called solid stream nozzles (Fig. 7) are ideal for high application rates and speeds, because they produce a wide-angle, flat fan pattern. Generally, the spray generated by the flood jet is not as uniform as the flat-fan type (TNAU 2015). The flood jet is the simplest of all nozzles, being little more than a circular orifice at the end of a funnel. The flood jet nozzles give the highest impact of any spray pattern as the full momentum of liquid is concentrated into a small area. The droplet size is irreverent in flood jet nozzles unlike other nozzles as the liquid is not atomized. The components are body, head, washer and nozzle tip (Fig. 8).

Height of the spraying: In the present study the spray drift potential of a wheel operated sprayer was analysed on the basis of three heights from the targeted surface keeping the coverage and recommended overlap in consideration. The height of the boom carrying the nozzles was kept 40, 50 and 60 cm above the targeted surface.

Number of nozzles: In order to assess the combined effect of the spray from more than one nozzle at a time over a spray drift three types of booms were used viz. boom carrying two nozzles, three nozzles and four nozzles at a nozzle to nozzle spacing of 50 cm maintaining proper spray coverage over the targeted area.

Spray Drift: Zande et al (2008) placed the collectors at the distance of 0-50 cm from the end of the last nozzle to measure the drift deposit horizontally. In the study the water sensitive papers were laid on the surface perpendicular to the direction of operation at about 500 mm away from the end of nozzle for all types of booms under the study. The water sensitive papers were than analyzed for spray coverage percentage or drift percentage using a dropleaf tool.

Dropleaf: Dropleaf is a smart phone application used to measure the quality of pest control spraying machine via image analysis. Dropleaf measures the effectiveness of spraying methods and nozzles using images of water sensitive papers (spray cards) either captured from a

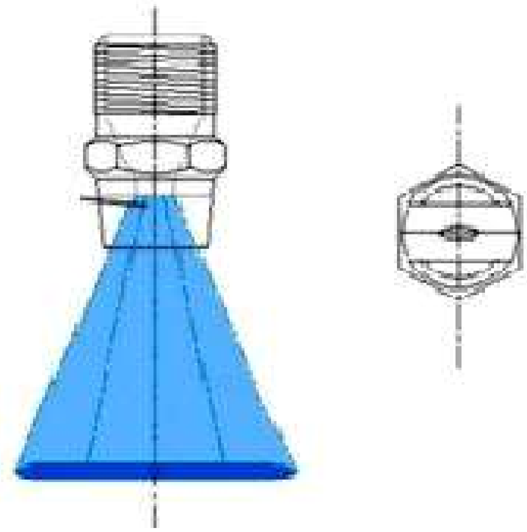

Fig. 3. Spray pattern of flat fan nozzle

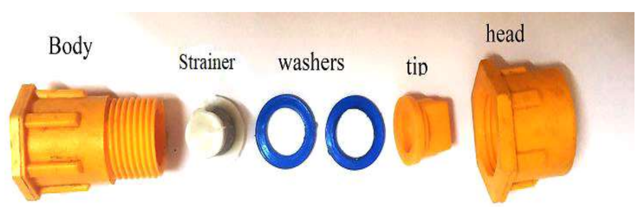

Fig. 4. Components of flat fan nozzle

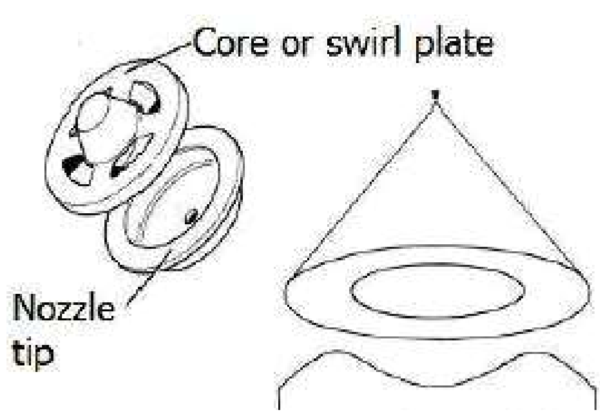

Fig. 5. Spray pattern of hollow cone nozzle

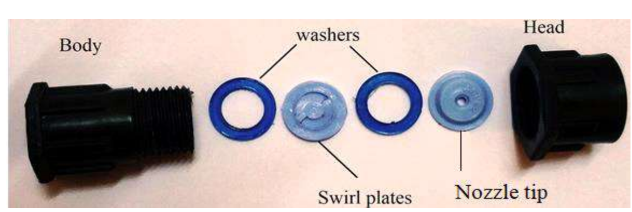

Fig. 6. Components of hollow cone nozzle

smartphone or loaded from the photo gallery. In the present study the dropleaf was used to measure the Spray drift coverage (%) to determine spray drift potential from the different types of nozzles mounted on a wheel operated boom sprayer.

RESULT AND DISCUSSION

Spray drift: The spraying operation was done perpendicular to the wind direction and spray drift was affected by nozzle type (N), type of boom (B) and height of boom (H) (Table 2).

Effect of nozzle type on the spray drift : The maximum drift of 8.9 % for a flat fan nozzle at a height of spraying of 600 mm having two nozzles (B_1) whereas minimum of 1.8 % for flat fan nozzle type was attained at a height of 500 mm having four nozzles (B_3). For hollow cone nozzle the maximum and minimum spray drifts of 9.1 and 1.3 % were attained at a height of spraying of 600 mm having two nozzles on the boom (B_1) and height of 500 mm having three nozzles on the boom (B_3). In case of flood jet nozzle N_3, the maximum and minimum spray drift of 6.4 and 0.4 % were achieved at a height of 600 mm and having two nozzles on the boom (B_1). The spray drift was maximum for a hollow cone and minimum for flood jet nozzles. The minimum spray drift for the flood jet nozzle may be due the design features which produced large sized droplets as compared to the flat fan and hollow cone nozzles. In case of flat fan nozzle and hollow cone nozzles, finer droplets are produced which are more prone to the drift. The main effect of nozzle type on spray drift was not statistically significant at 5% level of significance. The first level interaction N×B were statistically significant at 5% level of significance. The first order interaction N×H as well as second order interaction N×B×H were significant at 5% level of significance.

Effect of the number of nozzles: The maximum spray drift of 9.1 % for two nozzle boom was attained at 600 mm height of spraying having flood jet nozzles whereas minimum spray drift of 0.4 % for two nozzle boom (B_1) was attained at the height of spraying of 400 mm having hollow cone nozzles. The maximum and the minimum spray drift of 8.9 and 0.3% for the three nozzle boom B_2 was attained at a height of 600 mm having flood jet nozzle and at a height of 400 mm having hollow cone nozzle respectively. In boom having four number of the nozzles, the maximum spray drift of 3.7 % was attained at two-treatment combination i.e. spraying height of 600 mm for flat fan nozzle and 600 mm for flood jet nozzle while as minimum spray drift of 0.3 % was at 400 mm height of spraying for hollow cone nozzle respectively. The spray drift

Fig. 7. Flood jet nozzle

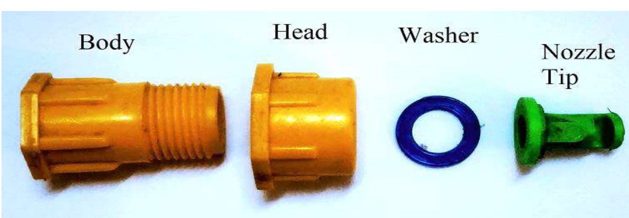

Fig. 8. Components of flood jet nozzle

Table 1. Treatment details for the assessment of spray drift from the sprayer

Independent variables	Levels	Dependent variables
Type of nozzles	Flat fan nozzles (N_1)	Spray drift
	Hollow cone nozzles (N_2)	
	Flood jet nozzles (N_3)	
Number of nozzle	Boom carrying two nozzles (B_1)	
	Boom carrying three nozzles (B_2)	
	Boom carrying four nozzles (B_3)	
Height of spraying	40 cm (H_1)	
	50 cm (H_2)	
	60 cm (H_3)	

Table 2. Effect of the nozzle type, number of nozzles and height of the spraying (mm) on spray drift

Nozzle type	No. of nozzles	Spray drift (%)		
		H_1	H_2	H_3
N_1	B1	4.4	5.3	8.7
	B2	4.1	5.0	8.9
	B3	2.8	2.8	2.9
N_2	B1	4.9	5.5	9.1
	B2	4.0	4.3	6.6
	B3	3.1	3.1	3.7
N_3	B1	0.4	4.2	6.4
	B2	0.2	0.4	2.2
	B3	0.3	0.7	1.9
CD (p=0.05)	(N)	=	0.04,	
	(B)	=	0.04	
	(H)	=	0.04	
	N × B	=	0.08	
	N × H	=	0.08	
	B × H	=	0.08	
	N × B × H	=	0.13	

decreased with the increase in the number of the nozzles on boom. The decrease of 33.3, 66.0 and 67.8% in spray drift was observed when the numbers of flat fan nozzles were increased from two to four at the height of 40, 50 and 60 cm respectively. In hollow cone nozzle, the decrease of 36.7, 76 and 59 % in spray drift was observed with the increase in number of nozzles from two to four. Similarly, for flood jet nozzle the decrease of 25, 83 and 70.0% in spray drift was observed with the increase in the number of nozzles from two to four. The decrease in the spray drift with an increase in number of nozzles is simply due to the decrease in atomization of the liquid thus producing large droplets which are comparably less prone to the drift as compared to the smaller droplets.

Effect of height of the spraying on spray drift: The maximum spray drift of 4.9 % for the height of spraying of 400 mm with two hollow cone nozzles whereas minimum spray drift of 0.2 % at the height of spraying of 400 mm with three nozzle boom for flood jet nozzle. The maximum and minimum spray drift of 5.5 and 0.4 % for the height of spraying of 500 mm was attained for two hollow cone nozzle boom and three flood nozzle boom. For the height of spraying of 600 mm the maximum and minimum spray drift of 9.1 and 1.9 % were attained for two hollow cone nozzle boom and four flood jet nozzle boom. The spray drift increased with an increase in the height of spraying. The increase of 49.4, 53.9 and 3.4% in spray drift was observed when the height of flat fan nozzles was increased from 40 to 60 cm for two, three and four nozzle booms respectively. In hollow cone nozzle, the increase of 46.1, 39.3 and 16.2% in spray drift was observed with the increase in the height from 40 to 60 cm. For the flood jet nozzle, the increase of 93.7, 90.9 and 84.2% was observed by increasing the height from 60 to 80 cm for two, three and four nozzle booms respectively. The increase in the spray drift with an increase in the height of boom may be due to more time span for water droplets to remain suspended in air which results in more drift due to the flow of wind. Nordby and Skuterud (2006) reported the same relationship between drift and height of the boom.

Received 29 July, 2022; Accepted 15 September, 2022

CONCLUSIONS

The present study concluded that the spray drift is directly linked with the type of the nozzle, height at which spraying is performed and number of the nozzles. It was observed that the height has a positive relation with spray drift i.e., the drift increases with an increase in the height of spraying and its magnitude depend on the type of nozzle. The hollow cone nozzle recorded maximum spray drift which may be due to its design features while the flood jet nozzles have the least spray drift. Thus, using proper nozzle at proper height of spraying the spray drift from an agriculture sprayer can be minimized.

REFERENCES

Abhilash PC and Singh N 2009. Pesticide use and application: An Indian scenario. *Journal of Hazardous Materials* **165**(1-3): 1-12.

Arvidsson T, Bergsrrom L and Kreuger J 2011. Spray drift as influenced by meteorological and technical factors. *Pest Management Science* **67**(5): 586-598.

ASAE 2009. *Spray nozzle classification by droplet spectra*. American Society of Agricultural Engineers.

Carlsen SCK, Spliid NH and Svensmark B 2006. Drift from ten herbicides after tractor spray application. *Chemosphere* **64**(5): 778-786.

EPA 2019. *Environmental Protection Agency. Introduction to pesticide drift*. Available online at https://www.epa.gov.

Hassen NS, Sidik NAC and Sheriff JM 2014. Effect of nozzle type on spray drift in banding application. *Applied Mechanics and Materials* **465**(466): 520-525.

Mulatu Y 2018. Fabrication and performance evaluation of ground wheel operated boom sprayer. *International Journal of Engineering Research* **6**(8): 16-23.

Singh A, Dhiman N, Kar AK, Singh D, Purohit MP, Ghosh D and Patnaik S 2020. Advances in controlled release pesticide formulations: Prospects to safer integrated pest management and sustainable agriculture. *Journal of hazardous materials*, 385:1-76.

TNAU 2015. Tamil Nadu Agriculture University. TNAU Agritech portal. http://agritech.tnau.ac.in/crop_protection.

Zaffar O 2020. *Development and Evaluation of a Wheel Operated Boom Sprayer for Small Holding Farmers*. M.Tech Dissertation, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India.

Zande JCV, Huijsmans JFM, Porskamp HAJ, Michielsen JMGP, Stallinga H, Holterman HJ and Jon DA 2008. Spray techniques: How to optimise spray deposition and minimise spray drift. *Environmentalist* **28**(1): 9-17.