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REVIEW ARTICLE

Review of shielded herbicide sprayers and effects of different spray shields in spray deposition and particle drift

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ABSTRACT

Effective use of pesticides (Insecticide, Fungicide, Herbicides etc.) in the crop is of concern since many years. Pesticide applied through conventional sprayers is lost through drift due to many machine factors (nozzle type, nozzle pressure, height of spraying etc.) and environmental factors (wind direction, wind speed, temperature and relative humidity etc.). For efficient weed control sprayer must able to spray herbicides at root zone and lower ground heights. Mechanical devices, such as protective shields which cover the sprayer boom or individual nozzles, may contribute to reduce the amount of spray being displaced during windy conditions. This paper reviews work carried out by various researchers on development of different shielded sprayers for insecticide & herbicide application and their role in drift reduction and efficient droplet deposition.

Keywords: Shielded sprayer, volume median diameter, drift, herbicide

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INTRODUCTION

Due to intensive agriculture and development of technology in the field of agriculture there is vast scope for controlling weeds by using herbicides. The use of herbicides for weed control is limited to some major crops like rice and wheat in the high productivity areas of north-western India. However, with growing labor scarcity and increasing cost of manual weeding, herbicides are now becoming popular because of their cost effectiveness and better weed control.

Controlling or minimizing spray drift is an important goal for anyone applying crop protection products. Minimizing drift can improve pest-control results, reduce pesticide waste, and minimize off-target damage. Drift is also a concern for bystanders, neighbors, and others who may be impacted by the off-target movement of pesticides. Pesticide manufacturers are constantly addressing the subject of drift as they develop products and prepare labels to advise applicators on ways to minimize off-target movement. Research focused on drift minimization should help develop proper application strategies.

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In India, some popular types of herbicide application equipment available are knapsack sprayer, compression knapsack sprayer, motorized knapsack sprayer, tractor mounted sprayer, etc.

Hydraulic boom sprayer is popular for herbicide application to control the weeds. Also, hydraulic boom sprayer when used for weed control causes drift, can reduce effectiveness of herbicides, creates environmental problems, affect health of operator, lack of weed control and damage to adjacent crops. For efficient weed control sprayer must able to spray herbicides at root zone and lower ground heights. Mechanical devices, such as protective shields which cover the sprayer boom or individual nozzles, have advantage to reduce the amount of spray being displaced during windy conditions.

MATERIALS AND METHODS

Various researchers developed different sprayers for application of herbicides in different crops. Use of efficient herbicide machines can increase work rate, save labor and herbicides. Here a number of studies are demonstrated in the development of different sprayer to apply herbicides to control weeds and shielded sprayers to minimize drift while applying the herbicides. The following work has been carried out in past in development of herbicide application equipment and effects of different spray shields in drift reduction and spray deposition is reviewed and discussed as under.

EQUIPMENTS FOR HERBICIDE APPLICATION

The selection of a weed control method is influenced by the type and condition of the crop, the type and size of the weeds, the equipment available and the time of treatment (Bainer et al., 1963). However, herbicides applied by field sprayers have been used most frequently because of their ability to control a broad spectrum of weed species, their proven efficacy, and their low cost compared to manual labor, such as hand hoeing.

Wyse and Habstritt (1977) developed a contact type herbicide applicator roller-wiper absorbing pad of carpet. Messersmith and Lym (1985) tested the roller-wiper technique for use in leafy spurge control. Cohen and Shaked (1982) developed a carpet recirculating glyphosate applicator for row crops using a carpet recirculatory applicator.

Tewari and Mittra (1982) developed and patented a manually pushed herbicide applicator for row crops. He reported that the performance of sponge roller in Arhar crop was excellent and uniformity of application achieved was 100 per cent. The herbicide solution required was 100–120 l/ha.

Welker (1985) developed a surface-roller wiper to apply herbicides to broadleaf weeds in turf. They compared roller wiper and sprayer applications for drift hazards. No evidence of herbicide drift was found when 2, 4-D was applied with a roller wiper.

Welker (1985) developed a hand roller herbicide wiper for lawns and gardens. He reported that excellent control of broad leaf weeds was achieved using 2, 4-D, Paraquat and with no evidence of herbicide drift. Several herbicide applications are done by researcher for inter row weeds.

Many researchers have attempted to detect weeds in crop fields with machine vision systems (Woebbecke et al., 1992; Zhang and Chaisattapagon, 1995;), because weed detection at the time of spraying could be very valuable for cutting chemical costs and reducing environmental contamination. However, these vision systems based on morphological or texture parameters generally needed a relatively high image resolution, and the detection algorithms were quite complicated and computationally expensive for real-time systems (Mayer et al., 1998).

A few real-time field systems have been developed by the researchers. The photo sensor based plant detection systems (Hanks, 1996) can detect all the green plants (weed and crop plants) and spray only on the plants. A machine-vision guided precision band sprayer for small-plant foliar spraying demonstrated a target deposition efficiency of 2.6 to 3.6 times that of a conventional sprayer, and the non-target deposition was reduced by 72% to 99%.

Stout (1992) proposed simple methods such as banding herbicide spray on crop rows and cultivating between the rows. Models of weed-crop competition can be used to determine a bio-economic threshold for herbicide application (Barritt and Witt, 1987). Some researchers even tried to further reduce the dosage and found that a rate of 1/8 of the labeled rate of post-emergence herbicides can still suppress weeds without appreciable yield losses (Willis and Stoller, 1990).

Chancellor and Goronea (1993) studied the effects of spatial variability of weeds on the site-specific application advantages. They found that at intermediate levels of herbicide application, the input efficiency increased approximately 40% for simulations of spatially modulated application on irrigated wheat. To realize spatial modulated (zone selective) herbicide application, detection based on a simpler, more reliable characteristic is needed for practical spraying systems (Thompson et al., 1991).

Hank and Beck (1998) developed method and evaluated that the utilize state of the art of weed sensing technology in weed detection technology in row crop production system. Single hood and commercial size eight row systems were evaluated. Saving in glyphosate spray solution was ranged from 63 to 85% compared to conventional hooded spray system with continuous application.

Tangwongkit et al. (2006) developed a tractor mounted site-specific, real time herbicide applicator for variable rate herbicide application between sugarcane rows. Using the software-based machine vision system, the picture frames captured by the web camera were processed and the quantified greenness level due to weeds was used to actuate the controllers of a sprayer pump system. At five operation speeds tested, the prototype could spray on green targets correctly. The application flow rate accuracy was about 91.7%. The laboratory performance evolution revealed that this variable rate method could be used to decrease the herbicide quantity by 20.6%.

Carballido et al. (2013) designed a field prototype sprayer for inter- and intra-row herbicide application for precise weed control operation in sugar beet fields. This equipment enabled a one-pass SH treatment over the seed line (band width 14 cm) and NSH treatment between crop rows (band width 36 cm).Experimental trail showed that the median density of weeds in the experimental plots decreased from 43.5 weeds m^2 (before application) to 12 weeds m^2 (after application).

Tewari et al. (2014) developed a six-row tractor mounted microprocessor-based herbicide applicator for weed control in row crops. A control system was developed to apply the correct quantity of the herbicide based on site specific weed information. It comprises a camera for capturing the images of weeds, MATLAB software for image acquisition and processing, laptop, a serial port communication for communicating between laptop and controller, a proximity sensor to sense the position, a microcontroller for controlling the application of herbicide through relay and solenoid valves for variable rate herbicide application. The device has been developed for crops with row-to-row spacing of 350-450 millimeters. Field test results of the machine indicate an average of 50% saving in the amount of herbicide, with weeding efficiency of 90%.

EFFECTS OF SPRAY SHIELDS ON SPRAY DEPOSITION AND PARTICLE DRIFT

Ford (1984) carried out comparative studies to investigate the effectiveness of three different kinds of shields on a sprayer boom. All tests were carried out with spraying systems 650067 nozzles. Two of the three shields tested a porous one and the power-aspirated winnower, reduced drift by 85 and 95 per cent respectively. The third shield, which was made from plastic film and which covered the nozzle both at front and back, performed poorly.

Fehringer and Cavaletto (1990) measured downwind drift from a standard boom sprayer and a hooded boom using an 8002 flat-fan nozzle. During each sprayer test, four meteorological parameters (wind direction, wind speed, temperature and relative humidity) and two droplet sizes were investigated. It was concluded that drift from hooded sprayers is highly dependent on the droplet spectrum. For instance, decreasing the spray-droplet spectrum volume median diameter (VMD) from 320 mm to 100 mm increased the drift three-fold. The hooded sprayer reduced drift by a factor of 1.8 to 2.75 times compared with a standard sprayer.

Maybank et al. (1990) conducted a series of 10 field trials to determine if shielding the individual nozzles along a sprayer boom reduced drift. They used 110-degree flat fan nozzles in four trials, and 80-degree nozzles in the other six trials. The results of their experiments indicated that in the wind speed range of 15 to 30 km/h, the shields effectively reduced off target drift from a flat fan pattern nozzle with a nominal flow rate of 0.75 lpm by a factor of about two. It was also indicated that the swath deposit uniformity was good for both nozzles and found unaffected by the addition of the nozzle shields.

Shields have been considered as economically viable alternatives to expensive air-assisted sprayers. Furness (1991) compared a simple shield, mounted vertically in front of a boom with conventional nozzles, with an air-assisted system which consisted of a set of rotary sleeve atomizers in the center of a shrouded axial fan. It was concluded that shields are ‘‘simple, cheap and reliable, with no moving parts, whereas axial fans are complex, expensive and high in power requirement by comparison’’.

Thomas et al. (1991) studied effect of protective shields on drift and deposition characteristics of field sprayers. The use of an 80 flat fan tip (8001) at a pressure of 275 kPa and a ground speed of 8 km/h resulted in 7.5% of the 50 l/ha spray solution drifting off the target area. The use of protective cones with 8001 tips without lowering the boom reduced airborne drift by 33% at a 20 km/h wind speed, while a 65–85% drift reduction was accomplished with the combination of solid or perforated shielding and lowering the sprayer boom. Increasing the application rate to 100 l/ha by using 8002 tips reduced drift of the unshielded sprayer by 65%. Decreasing application rate to 15 l/ha by using 800017 tips increased drift by 29% despite the use of a shield. Off-target drift increased with increasing wind speeds for all sprayers, but the increase was less for shielded sprayers and coarser sprays

Wolf et al. (1993) conducted field trials to determine the effectiveness of shields in reducing off-target movement of droplets. Sprayer booms ranging in width from 10 to 13.5 m and equipped with commercially available shields were operated in a field of wheat at wind speeds ranging from 10 to 35 km/h. The results indicated that all shielding devices tested reduced airborne drift compared with conventional boom sprayer. Although solid or perforated shields were more effective than cones. Wolf et al. indicated that shields which cover the entire boom reduce visibility and access to the nozzles, and could damage susceptible crops by wiping herbicide residues from the shield onto other crops in a subsequent application.

Cenkowski et al. (1994) investigated the effectiveness of porous and solid shields on sprayer booms for the reduction of wind velocity in the vicinity of a nozzle. It was concluded that shield material as well as location of the shield had a significant effect on wind speed reduction within the region sheltered by the shield.

Ozkan et al. (1997) tested nine different designs of shields for reduction of spray drift. All nine shields tested during this study effectively reduced drift. Even the least effective shield design produced a 13 per cent reduction in the drift value. A double-foil shield produced the best spray-deposit result with a reduction of 59 per cent in Dc compared with the same nozzles spraying without the shield. The shields were effective even when used with nozzles with higher flow rates (producing a smaller percentage of spray volume in small droplets). However, the use of larger capacity nozzles reduced drift more than smaller capacity nozzles with even the most effective shield.

Lawrence et al. (1998) developed a canopied sprayer for accurate application of herbicides. A canopied sprayer that attaches to a row-crop tractor having a standard category I or II three-point hitch and a PTO was designed and constructed. This sprayer delivered broadcast- and band-applied herbicides to small plots without causing drift-related injury to non target crops planted in adjacent plots. Use of this sprayer eliminated wind-blown drift, and ensured the confinement of herbicides to target plots, alleys, and borders.

Sidahmed et al. (2004) designed two symmetrical multi-foil shields to minimize spray drift in both upwind and downwind travel directions. One shield was a symmetrical double foil that induced direct air assist (an air jet acting directly on the spray droplets), while the other shield was a symmetrical triple foil that induced both direct air assist and an air curtain (an air jet forming a pneumatic shield in front of or behind the spray nozzle). Wind tunnel experiments were conducted to compare the effectiveness (in terms of drift reduction) of these shields with an upwind-oriented double foil shield, using two different nozzles (8001 and 8003), three levels of pressures (138, 276, and 414 kPa), and an average wind tunnel air speed of 6.2 m/s. All three shields reduced drift significantly compared to unshielded spraying. The best performance in terms of drift reduction was achieved by the symmetrical triple foil shield (61 per cent), followed by the symmetrical double foil shield (55 per cent), and then the double foil shield (48 per cent).

CONCLUSION

Manual weeding is costly, time consuming and labours are not available easily. Weeding with herbicides can increase work rate and save time and cost. The various literatures reviewed, shows that use of shielded herbicide sprayer for weed control can increase uniformity in herbicide application and its efficiency, minimize crop contamination, reduce spray drift thereby protect environment and health effects on operator. It can also increase work rate, save labor, time and herbicides. The shielded herbicide sprayer can be beneficial to reduce spray drift up to 95% depending on tip size, operating pressure, and wind speed than unshielded sprayer.

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