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Innovative and Efficient Pesticide Spraying Technologies for Residue Free Farm Produce

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Abstract- **Entomological studies have established that in numerous cases, smaller droplets of pesticide spray provide greater biological efficacy per unit mass of pesticide than do the larger droplets for achieving insect control. Thus, the recent concept of spraying is to spray the target pest more efficiently by selecting optimum droplet size and density for maximum retention and coverage. Customarily, more chemical than theoretically needed is often applied due to the variability in field conditions and the need to ensure complete coverage. In such a situation, Variable rate spraying system and the Electrostatic spraying system can be effectively utilized. The variable rate sprayers and air-atomizing electrostatic sprayers are overcoming the deficiencies of conventional sprayers. The variable rate pesticide spraying has the potential to reduce pesticide amount and cost as well as off target contamination of environment. Electrostatic charging increases spray deposit level, reduces waste and greatly improves spray distribution for better insect and disease control. Therefore the use of these two technologies can ensure the spraying of pesticides within in acceptable limit and ensure residue free farm produce for healthy life of human being.**

Key Words: - Variable rate spraying, Electrostatic spraying, Pesticide Spraying.

I. INTRODUCTION

In order to protect food and fiber crops against insect, disease and weed pests, usage of agricultural chemicals such as insecticides, fungicides and herbicide is essential (Law, S.E. 1995a). Although there are concerns about potential risks to human health and the environment from pesticides use, the practice of pesticide-free crop production is not practical with present technologies (Oerke et al., 1994; Oerke, 2006). Also, the reports indicate that anticipated maximum yield for a variety of crops would be reduced by 20 to 40 percent if pesticides are not used during production. The goal of pesticide application is to deliver effective and uniform dose of chemicals to the target areas in a safe and timely manner. Entomological studies have established that in numerous cases, smaller droplets of pesticide spray provide greater biological efficacy per unit mass of pesticide than do the larger droplets for achieving insect control (Law, S.E.,1995b and Fraser, R.P.,1958). Thus, the recent concept of spraying is to spray the target pest more efficiently by selecting optimum droplet size and density for maximum retention and coverage. However, the droplet size requirement of many target pests are not always clear as there are conflicting requirements in relation to safety, coverage or cost. Customarily, more chemical than theoretically needed is often applied due to the variability in field conditions and the need to ensure complete coverage. In such a situation, Variable rate spraying system and the Electrostatic spraying system can be effectively utilized. These technologies are briefly explained as follows.

II. VARIABLE RATE SPRAYING SYSTEM

Variable rate spraying is used to measure the spatial variability of input needs within a farm field, prescribe site-specific application rates that match varying crop needs; and to apply those inputs as prescribed. Variable rate spray applications using intelligent control systems can greatly reduce pesticide use and off-target contamination of environment in nursery and orchard productions. By automatically spraying the optimal amount of spray mixtures into tree canopies and stopping spraying beyond target areas, the intelligent sprayer with automatic control can significantly reduce the amount and cost of pesticides for growers, reduce the risk of environmental pollution by pesticides, and provide safer and healthier working conditions for workers. The ultimate goal of the intelligent (variable rate) sprayer is to reduce pesticide consumption by turning the sprayer off when there is no target to spray (by detecting the gaps between trees) and by applying the optimum level of spray mixture in accordance with the characteristics of the target tree (size, shape and foliage density). The actual level of input savings realized will vary from field to field depending on the degree of spatial variability and the quantity of chemical inputs applied. Conventional spray equipment used in nurseries and orchards has some problems with spray efficiency and safety. For example, usually high percentage of chemicals is wasted in the form of drift of droplets, over spraying, run-off, and off-target deposition. This misdirected pesticide not only reduces the effectiveness of the application and waste

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growers money, it also increases the potential of environmental contamination (Deveau, 2009).

2.1 Need of Variable Rate Spraying

The level of inefficiency and inaccuracy is even higher in orchard and nursery applications than field crop sprayers. When using conventional spray equipment and flow rate estimation, most nursery crops are over sprayed. Less than 30% of pesticide sprayed actually reaches nursery canopies while the rest are lost (Zhu et al., 2006). Lack of proper spray equipment and technology is blamed as the reason for this high chemical input. In contrast to other field crops, orchard and nursery crops have great diversity in their form, size, canopy structure and density and can vary greatly with production circumstances. There is no universal delivery equipment or method that can address all these complex diversities. Most of the pesticides applied using current sprayers is being wasted in the form of off target losses such as airborne drift, sedimental drift, runoff, and evaporation. It is common to see a mix of different sizes of trees in an orchard or a nursery, such as shown in Fig. 1and 2. Often, there are huge gaps between these young trees. When treating these orchards and nurseries using the conventional sprayers, much of the pesticide will be wasted because it is impractical for applicators to manually adjust sprayer settings to match target tree canopy size and shape after application starts, due to the demands of pest pressure and labor costs. The spray output of a conventional sprayer cannot be adjusted once the sprayer is turned on; a constant amount of liquid is sprayed regardless whether there is a target or not, or whether the target tree is tall or short (Fig. 3), narrow or wide. In an orchard or a nursery, with growing different species of tree crops, canopy size, shape and density vary. Therefore, significant amount of pesticide is wasted between trees and into open areas above short trees or around trunks below canopies. With the rising cost of pesticides and growing public concerns about the potential contamination of the environment caused by excessive use of pesticides, new pesticide application equipment and strategies can help to reduce the consumption of pesticides.

2.2 Variable-Rate Spraying Methods

The variable-rate spraying can be used with or without a GPS system. The two basic technologies for variable-rate spraying are map-based and sensor-based.

Fig. 1 An apple orchard with different sizes of tree canopies

Fig. 2 A typical nursery production plot with different canopy sizes and shapes

Fig. 3 Overspray of a nursery sprayer when using the same setting to treat different size crops in the same production line

2.2 Variable-Rate Spraying Methods

There are a variety of VRA technologies available that can be used with or without a GPS system. The two basic technologies for VRA are Map-based and Sensor-based.

2.2.1 Map based variable-rate spraying

In the map based system, the applied rate is changed according to a prescription map generated with previous

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survey. The crop characteristics of nurseries and orchards change considerably during a growing season and the crop life cycle, prescription maps for variable application rates need to be updated frequently, thus making map based variable-rate spraying very expensive (Mooney et al., 2009). Hence, it is not widely accepted.

2.2.2 Sensor based variable-rate spraying

In the sensor based system, applied rate is adjusted through information gathered in real time by sensors. With sensor based variable-rate spraying, sensors mounted on the application equipment detect crop structure information that controllers process and use to control spray outputs as needed, in real time. Thus sensor based variable-rate spraying is better suited in nurseries and orchard chemical applications than map based variable-rate spraying.

2.3 Major Steps in Variable Rate Sprayer Development

The first step is to utilize different types of sensors such as ultrasonic sensor and laser sensor to detect target crops or tree characteristics. This step includes data acquisition and data processing to obtain target characteristic information. The second step is to develop variable rate delivery equipment by modifying commercially available sprayers by implementing sensors and controllers.

2.4 Performance of Variable Rate Sprayers

Giles et al. (1987, 1988 and 1989) retrofitted a conventional air-blast orchard sprayer by integrating ultrasonic sensor technology into a sprayer control system to measure foliage volume and then control the spray output. Spray savings ranging from 28% to 35% and 36% to 52% were reported in peaches and apples, respectively. In addition, compared with a standard sprayer, the sensor-controlled sprayer had a significant reduction in off-target loss. Gil et al. (2007) modified a multi nozzle air-blast sprayer with three ultrasonic sensors and three electro-valves. The nozzle flow rate was modulated in real time as a function of crop width in a vineyard, as measured with the ultrasonic sensors. The canopy in vineyard was divided into three height sections, each covered by one ultrasonic sensor and one electro-valve controlled nozzle. A saving of 58% percent was reported compared with conventional constant rate application while deposition quality on leaves, uniformity of liquid distribution and capability to reach the inner parts of the crop remained similar. Using the same sprayer tested by Gil et al. (2007), Llorens et al. (2010) compared conventional spray application and variable rate application in three vine varieties at different crop growing stages. The variable rate application was reported to have an average of 58% savings in application volume with similar or even better leaf deposition.

III. ELECTROSTATIC SPRAYING

The electrostatic spray produces uniform and fine droplets with better droplet adhesion and spread, higher deposit efficiency, lower environmental contamination, lower application rate, less application expenses and longer residual action than conventional sprays. Electrostatic sprayers come in different types and structures. However, the electrostatic nozzle and electrostatic generator, which are indispensable components, remain the same for all sprayer types.

3.1 Working of Electrostatic nozzle

The heart of the air-assisted electrostatic sprayer is the patented "air atomizing induction-charging" nozzle, which was invented and refined at the University of Georgia. Air and liquid enter the rear of the nozzle separately. The air moves through the nozzle at a high speed and intersects the liquid at the nozzle tip (Fig. 4), causing the formation of spray droplets that are 30 to 60 microns in diameter. The air pressure required is 15 to 60 psi, and the liquid pressure is below 30 psi. In comparison, a hydraulic sprayer would require nearly 3,000 psi to achieve equivalent atomization. As the spray is atomized, the droplets pass an electrode (Fig. 4) that induces a negative charge on each one. The force of the turbulent air stream then propels the charged droplets deep into the plant cover. Positive electrical charges on the plant surface cause a natural attraction between the plants and the droplets. Following the natural lines of force, some of the droplets wrap around the plant's leaves and stems to coat their undersides (Fig. 5). Canopy penetration, wraparound effect, Under-leaf and stem coverage, reduced leaf burn, fewer refill trips and self-cleaning nozzles are the advantages of electrostatic nozzles.

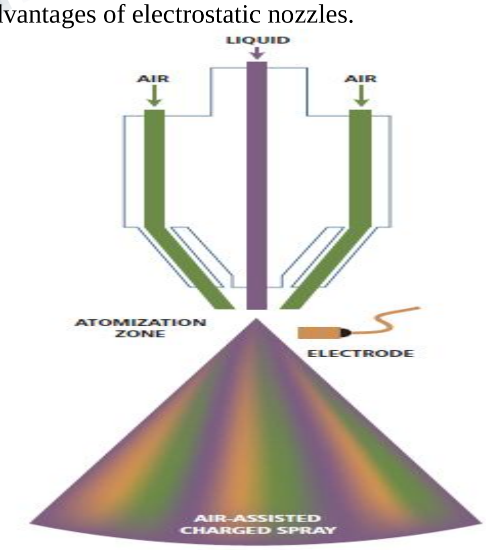

Fig 4. Electrostatic nozzle

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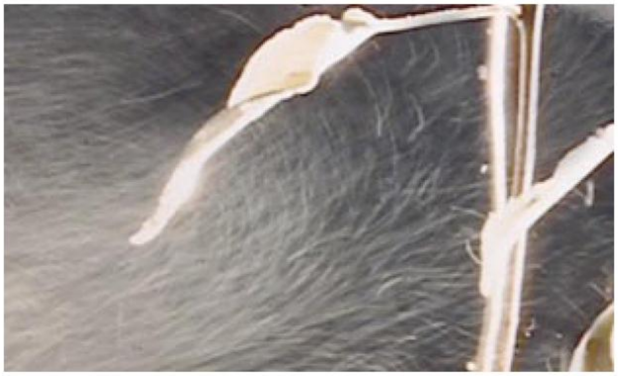

Fig. 5 Electrostatically charged spray droplets reverse direction and defy gravity to coat stems and the undersides of leaves.

3.2 Air-Assisted Electrostatic Spraying

Air-assisted electrostatic sprayers produce spray droplets which are 900 times smaller than those produced by conventional sprayers. These tiny droplets are carried deep into the plant canopy in a high-speed air-stream. The result is more than twice the deposition efficiency of both hydraulic and non-electrostatic air assisted sprayers. Electrical charging causes a natural force of attraction between the spray droplets and the plant, similar to the attraction between items of clothing created by the tumbling of clothes dryer. The charge on the droplets is small, but the force pulling the spray towards the plant is up to 75 times greater than the force of gravity. Droplets literally reverse direction and move upwards, against gravity, when passing a leaf surface (Fig. 5). This remarkable phenomenon by which the spray coats the undersides of the leaves and the backsides of the stems is known as electrostatic "wraparound." Spray coverage is the uniformity of spray droplets on plant surfaces. Electrostatic sprayers achieve greater spray coverage by combining air turbulence with tiny, evenly sized spray droplets. The benefits are better insect and disease control because the chance of contact is greater, reduced chemical burn because chemicals do not accumulate in large single deposits.

3.3 Research on Air-Assisted Electrostatic Sprayers

A report from the University of California clearly states, "If the chemical rate were reduced by three-fold when using the electrostatic unit, the amount (deposited) onto plants would still be greater than the conventional at full rate. But, the amount of chemical moving off-target would be one-tenth that of the conventional application." In a test comparing a conventional hydraulic hand sprayer with an air assisted electrostatic system, the hydraulic sprayer deposited only 16% of spray on the plants while the ESS unit deposited 60% on the plants. This is a remarkable four-fold difference in efficiency.

The studies to analyze spray deposition and coverage, insect and disease control and worker safety are explained as under.

3.3.1 Spray deposition and coverage on plants

Deposition testing demonstrates sprayer efficiency by measuring the amount of spray deposited on the plant. Results of a study conducted on Broccoli (in which plants form hard-to-penetrate, deep, dense canopies with many leaf layers) showed that the air-assisted electrostatic system deposited 72% more active ingredient than the conventional sprayer and 49% more than the uncharged air-assisted sprayer. To control most insect and disease problems, it is important to cover interior plant regions. Deposition measurements made on the inner parts of the broccoli plants showed that the electrostatic sprayer deposited two times more spray than either the conventional hydraulic sprayer or the uncharged air-assisted sprayer. The larger outside leaves shield the inner canopy, and the lower leaves lie against the mulch. Results of field trials in strawberry (which are difficult to spray effectively due to the shape of the plant and the density of the canopy) show that an electrostatically charged sprayer deposited 2.4 times more spray per leaf than a conventional high-pressure strawberry spray rig.

3.3.2. Insect and Disease Control

The previous reports showed improved spray deposition with air assisted electrostatic sprays. The bottom line for the grower, however, is control of insects and diseases. Researchers conducted commercial field trials using low-toxicity chemicals in side-by-side comparisons of a grower's normal field sprayer and the air assisted electrostatic sprayer for control of Lepidoptera and onion thrips. Results discovered that Bacillus thuringiensis reduced the Lepidoptera populations an average of 86% with the electrostatic system but only 47% with a conventional system. When applying synthetic pyrethoid chemicals (SP) to onion thrips, the results were a 62% reduction with the electrostatic system, compared to only a 31% reduction with the conventional sprayer.

3.3.3. Worker safety

A significant test revealed that workers applying charged spray experience very low levels of chemical exposure and no more than they would experience when applying uncharged spray. The test consisted of handgun spray trials comparing deposition with and without the charging on. The test results indicated that 3.3 times more chemical reached the plants with the charged spray.

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IV. CONCLUSION

Variable rate sprayers and air-atomizing electrostatic sprayersare overcoming the deficiencies of conventional sprayers. The variable rate pesticide spraying has the potential to reduce pesticide amount and cost as well as off target contamination of environment. In air-atomizing electrostatic sprayers air delivery reduces drifting and increases spray penetration and turbulence within the plant canopy. Electrostatic charging increases spray deposit level, reduces waste and greatly improves spray distribution for better insect and disease control. Therefore the use of these two technologies can ensure the spraying of pesticides within in acceptable limit and ensure residue free farm produce for healthy life of human being.

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