Tarım Makinaları Bilimi Dergisi (Journal of Agricultural Machinery Science)
2008, 4 (2), 193 - 198

Technological Solutions to Problems Associated with Application of Pesticides

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Abstract: Pesticides have played a key role in increasing yields. However, improper and excessive use of pesticides has resulted in pollution of the natural resources, and has paused a serious threat to the safety and health of the people applying pesticides. Research is continuing in universities and industry around the world to develop new methods and equipment to address these concerns. A general review of the problems associated with application of pesticides, and possible solutions to these problems are discussed in this paper.
Key words: Pesticide application, sprayer, spray drift, nozzles, pesticide contamination.

INTRODUCTION

The world population has been increasing at a much faster rate during the last 50 years. It was approximately 1 billion in 1804. It took 118 years to reach the 2 billion mark, and only 37 years to reach 3 billion in 1959. Since then, almost every 12 to 14 years the world population has been increasing by 1 billion. This trend is likely to continue into the future Arable land available per person was about 4200 m^2 in year 2000. This is projected to decrease to 1800 m^2 per person by the year 2030. Some argue that pesticides are extremely dangerous to human health and the environment, and we should practice pesticiede-free crop production. However, reports indicate that anticipated maximum yield for a variety of field crops will be reduced by 20 to 40 percent if no pesticides are used during production of these crops (Oeke et al, 1994).

For the reasons explained above, it is unrealistic to meet the food demands of the world without the help from pesticides. The amount of pesticide use in the world has been increasing over the years, and is likely to continue to rise in the foreseeable future. However, there are many inefficiencies and health and safety concerns associated with pesticides, especially the ones appllied in spray form (Hoppin et al, 2007; Kamel et al., 2007, Lee et al., 2007; Martinez-Haro et al., 2007). Depending on the soil type, topography and weather conditions pesticides may find their way into both surface and ground water resources (Barbash and Pesek, 1996; Barbash et al., 1999; Hunt et al., 2006).

Also, most of the pesticides produced in the last decade are more potent and requires more precision in application. They also pause a greater risk to the environment and to the applicators in terms of safety and health issues.

Most of the problems associated with pesticides are caused by uninformed and uneducated applicators during the spraying process. These problems can be grouped in five major categories: a) health and safety of applicators, b) pollution of air, c) pollution of water resources, and d) improper disposal of pesticide containers, and e) excessive use of pesticides. Follwing is a review of these major problems and possible technological solutions that may minimize these problems.

PROBLEMS and POTENTIAL SOLUTIONS

Problem 1: Applicator Safety

Applicators need to do a better job with application of pesticides because the pesticides used today are more expensive and potent than pesticides used in the distant past. The margin of error when using pesticides is much smaller now than what it was 10-20 years ago. In other words, an error made today may result in crop damage or reduced pest control while the same error made with chemicals used 20 years ago could have been within the safety margin and still be effective.

An extensive study conducted by scientists (Alawanja, 2008) in the U.S.A. shows that farmers who used agricultural insecticides experienced increased neurological symptoms, even when they were no longer using the products. Data from nearly 90000 farmers in states of North Carolina and Iowa (U.S.A.) linked use of insecticides, including organophosphates and organochlorines, to reports of reoccurring headaches, fatigue, insomnia, dizziness, nausea, hand tremors, numbness and other neurological symptoms (Kamel et al., 2007). Kamel, et al (2006) also found that "individuals who had applied pesticides on more than 400 days in their lifetime had nearly a two-fold greater risk of Parkinson's disease compared to those who had applied pesticides for fewer days". Gladen et al. (1998) studied 26793 licensed private pesticide applicators in Iowa and North Carolina. Questionnaires were completed by the applicators and their spouses. The results of this study indicated that "many indirect exposure opportunities exist; for example, 21% of homes are within 50 yards of pesticide mixing areas, 27% of applicators store pesticides in their homes, and 94% of clothing worn for pesticide work is washed in the same machine as other laundry".

Solutions:

Overall, the first step towards reducing applicator exposure to pesticides is by educating them about the health and safety concerns associated with pesticides. In the U.S.A., federal laws require that persons buying, sellng and/or applying restricted use pesticides must carry a pesticide applictor license. They have to attend educational programs, and pass an exam the first time they receive their licenses. This license is valid for three years. When they want to renew their licenses, they are obligated to atttend certain number of hours of educational programs. Some of the topics included in these educational programs are: toxicity levels of pesticides, protective clothing and other items one should wear during application of pesticides, calibration of sprayers, best management practices for safe and efficient applicatiion of pesticides, proper rinsing and disposal of pesticide containers, and environmental concerns associated with pesticides and how these concerns can be reduced to minimum.

Unfortunately, even the best intentions such as the educational programs in the U.S.A mentioned above are not likely to eliminate the safety and health risks associted with pesticides. Recent research has focused on development of application systems that does not heavily rely on human factor. One of these concepts is establishment of fixed structures in an orchard. Landers et al. (2006) developed such a system to spray pesticides in a high-density orchard. The system, similar to a fixed irrigation system, included two 19mm plastic pipes (1 and 2 m above ground) positioned horizontally (laterals) through the canopy of the apple trees. Each pipe contained a series of nozzles along the length of the pipe. A mixture of pesticide and water is pumped from a trailing application unit which included: a tank carrying water only; a centrifugal pump to pump water from tank to the nozzles; and a system to inject pesticides into the horizontal laterals. With this system, once it is turned on, the applicator does not have to be present at the application site. One other advantage of such systems is that the spraying can be done any time, including at night, when there will be no bystanders or passerbys at the site of application, nearly eliminating any chance of their exposure to pesticides.

Another approach to reducing the applicator's exposure to pesticides is using sprayers that can be controlled from a remote location by utilizing GPS and automated guidance technologies. Remote control can be accomplished by: using radio frequencies and a joy stick; creating an electromagnetic field by cables burried under the ground and sensors on the sprayer to determine the path of the sprayer; or some other electro-mechanical sensors that turn a sprayer traveling on a fixed path on or off at designated positions in the application area.

There is an emphasis in research to reduce the health risks that applicators face when handling pesticides. Findings of a recent study indicate that most of the applicator exposure to pesticides occurs while transporting, loading, and mixing chemicals. Older large sprayers required the applicators to climb up a stair to empty the pesticide container into the sprayer tank. This has created a huge physical safety risk as well as the risk of spilling the pesticides on the exterior of the sprayers and on the ground. Currently, almost all the new sprayers manufactured by reputable companies include a small induction tank (Figure 1) to mix and transport pesticides into the sprayer tank.

Figure 1. Modern sprayers are equipped with a chemical induction tank and several other smaller tanks

It is designed so that the unit is at a height that would not require the applicator to lift the pesticide container any higher than 50-75 cm above the ground. New sprayers also come with two additional tanks: a small clean water tank to wash hands and other body parts that may be exposed accidentally to pesticides; and a second, larger (100-150 L) tank that carry clean water to rinse interior and exterior of the sprayer in the field, away from the farmstead when the spraying is completed.

Problem 2: Pollution of water resources

Pollution of surface and ground water resources by pesticides is a serious concern. Studies that show evidence of water pollution by pesticides are too numerous to mention in this article. In the United States, the US-EPA's National Pesticide Survey found the 10.4% of community wells and 4.2% of rural wells contained detectible levels of one or more pesticides (US-EPA, 1992). Lampman (1995) tested wells in mostly agricultural southwestern Ontario in Canada. Results of this study showed that water samples from 35% of the wells showed detectable levels of at least one pesticide.

Usually, it is not the pesticides sprayed over crops (non-point source) that cause the problems. There is usually a point-source problem behind a potential pesticide pollution case. Point-source pollution usually results from a) accidents happening during transportation of pesticides, b) improper pesticide mixing loading sites, c) mixing and loading sites being close to water sources, especially the wells drilled on farm site, d) inadequate and improper storage facilities, and e) illegal dumping of leftover spray mixtures in sprayer tanks.

Solutions:

If there is any chance pesticdes may be carried, by air or by surface runoff, to nearby water sources, crops that require spraying pesticides should not be grown in such areas. These areas, as much as possible, should be set aside for grazing animals. If crops must be produced, all the precautions should be taken to keep off target deposition of pesticides to minimum.

Pesticide applicators should be encouraged to build a pesticide storage facility on their farms (Figure 2). This facility should also include a concrete mixing/loading area which should have a rinsate collection pit, and several rinsate storage tanks. Concrete pad should have a gentle slope towards the rinsate collection pit. After mixing/loading of pesticides, and calibration and rinsing of sprayer exterior surfaces are done, the liquid collected in the pit should be pumped to one of the storage tanks.

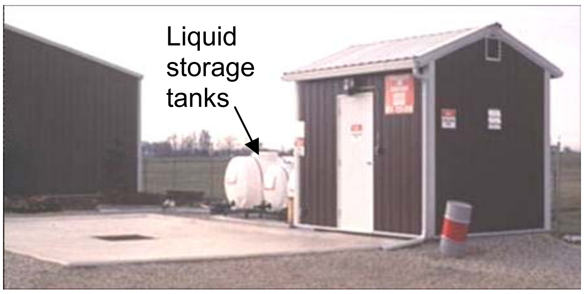

Figure 2. Properly designed pesticide storage and mixing loading facility.

The stored liquid can be transferred to the sprayer tank at a later time when the sprayer tank is refilled again to do more spraying. Detailed information on the design of a farm-scale pesticide storage facility is given in a publication by Veenhuizen and Ozkan (1993). Use of in-line injection systems (Figure 3) should be encouraged to avoid the potential problem of the applicator emptying the leftover spray mixture in the field after spraying is completed. With these systems, the pesticide and water are kept in separate tanks. Any excess water is left in the water tank and excess pesticide remains in the pesticide tank.

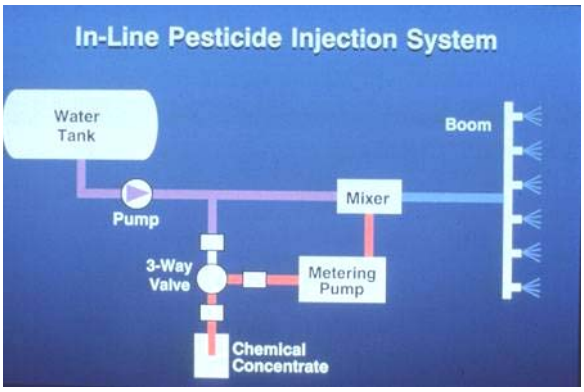

Figure 3. Schematics of an in-line pesticide injection system.

Problem 3: Too many small, unrinsed, discarded pesticide containers.

Small, unrinsed, and improperly discarded pesticide containers can create both waste disposal problems, as well as increasing the risk of pesticides finding their ways to water resources. In 1984, pesticide applicators in the U.S. generated 80 Million empty pesticide containers. It is very likely that some of these containers may not have been properly rinsed before they were discarded. Research indicate that up to 90 ml of pesticide may be left inside a 20L container after normal emptying. This may look like a small amount, but when considering the fact that hundreds of millions of pesticide containers are discarded without proper rinsing, the magnitude of the problems brought by the containers could be rather significant.

Solutions:

Educational efforts and regulatory eenforcements must be increased to make sure that the small containers are properly rinsed before discarding. U.S. EPA guidelines recommend at least the "triple rinsing" procedure to clean empty containers. However, a more effective approach is power rinsing of the containers with high-pressure liquid jets. Much of the chemical induction hoppers (as shown in Figure 1) have inside a set of nozzles that clean interior of the pesticide containers using high-pressure liquid discharged from the rinse nozzles (Figure 4). We must reduce the number of small pesticide containers discarded haphazardly. Every effort should be made to discourage the pesticide applicators from purchasing pesticides packaged in small containers.

Figure 4. Chemical induction hoppers with pressure rinsing nozzles.

Most commercial applicators in the U.S.A have abandoned using small containers. Instead, they buy pesticides packaged in large tanks (up to 1800L), and they return the tank with the remaining unused pesticide inside to the manufacturer of the pesticide. They get credit for the unused portion of the pesticide.

Problem 4: Pollution of air with pesticides

One of the important functions of the nozzles on a sprayer is to produce droplets to distribute the pesticide applied onto the target as uniformly as possible. Conventional nozzles produce droplets usually ranging from 10 ɥm to 1000 ɥm. A portion of the spray material discharged from the nozzles in very small droplets never reach the target. These extremely small droplets may travel several hundred meters before depositing onto a non-target area causing damage on the host crop. Some extremely fine droplets never deposit on anything. These airborne droplets may evaporate in the atmosphere and travel for even greater distances. Zhu et al. (1994) have shown that for typical applications with boom type sprayers, droplets of 100 ɥm or less often drift out of the intended swath, and 50 ɥm or less diameter droplets, completely evaporate before reaching the target. Majewski et al. (2000) conducted a study of the occurrence of pesticides in rain at paired agricultural and urban sites in three geographically different regions along the Mississippi River Valley. Their study showed that "a variety of pesticides was detected in every rain sample collected during April through September 1995". This situation is likely to cause long-term problems for both the environment, and the health of human and animals living in the area.

Solutions:

Several possible solutions have been suggested to combat spray drift. Most of these solutions are centered around three major concepts: 1) not spraying at all when the weather conditions are not favorable, 2) reducing the volume of spray contained in small droplets, 3) altering the flight paths of small spray droplets by mechanical means to increase efficiency of deposition on the target.

Although most operators are aware of spray drift and the problems associated with it, treatment of a field during unfavorable weather conditions may be unavoidable when the pest population is at a level such that further delay in spraying may result in total crop loss. Realizing this fact, most researchers and equipment manufacturers have been focusing their attention to developing equipment and chemicals to reduce drift. Some manufacturers have introduced "low-drift" nozzles that reduce the volume of spray contained in small droplets. Other companies have developed chemical additives called "drift retardants" to achieve the same goal: reducing the volume of spray contained in small droplets.

Several recent developments have been aimed at modifying existing equipment to increase deposition efficiency of the more effective small droplets while reducing the potential for drift. In general, this has been accomplished by using either air-assist technology or some kind of shield or shroud to overcome the drift-producing air currents and turbulence that occur near the nozzle during spraying.

Problem 5: Too much pesticide is used

The targets being sprayed are seldom uniform in size (height and width), density of canopy, spacing between plants, surface characteristics, etc. In spite of this fact, sprayers used today are operated at a constant rate. For example, canopy of the tree fruit crops often is not uniform. There are often gaps in the canopy near the tops of trees. Sometimes trees die and are replaced with much smaller trees, which increases the irregularity of the canopy. As a result, we lose pesticide that is sprayed through these gaps in the tree canopy.

Another way we waste chemicals is to spray the entire field regardless of the severity of the pest problem. Some large sections of a field may not even have the problem at all, but the conventional sprayers are not equipped with sensors to turn the sprayer on and off, or spray only the amount that is needed to treat the target crop based on crop growth conditions.

Solutions:

The utilization of electronic sensors, monitors, and computer automated controllers in sprayers has increased significantly in the last decade. On-the-go change of application rate of agricultural chemicals and change of plant population using information provided by satellites orbiting the earth is no longer a theory. Technologies to accomplish these tasks are now available to farmers. Major tasks involved in Variable Rate Apllication Technology (VRAT) include: 1) identification of a given location in the field (longitude, latitude, altitude); 2) collecting site-specific information regarding soil physical characteristics, soil nutrient content, areas infested with pests, crop yield, etc.; 3) using computer hardware and software to store this information; 4) processing and analyzing this data; and 5) using proper equipment to do the actual application of chemicals on-the-go in accordance with the information stored in the on-board computer. So far, the most popular application of VRAT has been in the area of fertilizer application. This technology allows farmers to apply variable fertilizer rates based on the existing fertility of the soil and the crop needs, to each small division of a field.

VRAT concept for pest control (weeds, insects, diseasses) is more challanging than VRAT for fertilizer applications. Application of VRAT for pre-emergence weed control has been the next promising area. With new technology using GPS and GIS, it is now possible to identify and isolate weedy areas of the field. By overlying weed maps along with soil maps, farmers can determine proper herbicide rates based on weed pressure, soil type and organic matter content. Using this information and the variable-rate technology, farmers can achieve weed control that uses the right amount of herbicides for each area of the field.

During the last decade, several companies have developed canopy sensors that are aligned with a nozzle or group of nozzles. If these sensors detect canopy, the sensor(s) are turned on, if no canopy is detected, the nozzle(s) are turned off. Several types of sensors have been used, including infrared, ultrasonic, and imaging systems that detect the color of chlorophyll in leaves.

CONCLUSIONS

Pesticides will continue to play a key role in meeting the food demands of the rapidly increasing world population. However, pesticides, if not applied properly may cause both short and long-term problems such as health and safety of the applicator, and environmental pollution. Fortunately, technologies and procedures aoutlined briefly in this puplication have the potential to reduce such problems to minimum. This will largely dependent on education of pesticide applicators and their willingness to adopt the technologies mentioned in this paper.

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