A Review of the Spray Drift Literature for Ground Applications

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Abstract

This article is a summary review of the scientific, trade, and Extension literature of recent research and other documents discussing practices designed to minimize spray (particle) drift. The search included nearly 300 reviewable documents from 2005 to 2011 that met certain criteria. After eliminating duplicates, this summary comprised 82 referenced items from multiple sources. The review was organized into the following categories: air-blast sprayers, nozzles, buffers, the environment, simulation models, adjuvants, and miscellaneous (ex. reports and Extension publications). Aerial application was not included. Each item reviewed was summarized to provide a brief overview of the project or document and to report any conclusions that may help reduce spray drift. From these summary statements, the author has prepared a separate paper (see following article) discussing recommended drift-reduction practices.

Keywords: spray drift, best management practices, application, spray nozzles, air-blast sprayers, spray shields, buffer zones, windbreaks, drift-control agents, computer models

Introduction

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. Discussions are ongoing in the regulatory sector on how to curtail the problems caused by pesticide drift. 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.

Materials and Methods

Crop Life America supported a review of the recent drift literature as a special project for the application industry. The goal was to provide a list of strategies that could be used to develop best management practices to minimize spray (particle) drift. The review searches the literature for specific strategies in the areas of air-blast applications, ground boom broadcast applications to fields, applications to rights-of-way, and applications made with handheld sprayers. The review focused on drift literature after 2004 and encompassed an extensive database search of Agricola (National Agricultural Library) and the American Society of Agricultural and Biological Engineers (ASABE) publications library. Additional database searches (ex. Dissertation Abstracts International) did not locate any other relevant studies. For ease of reading, the review has been organized into what the author considered to be the major sections: air-blast sprayers, nozzles, buffers, the environment, simulation models, adjuvants, and miscellaneous (ex. reports and Extension publications). Each section lists the article reviewed by title and citation and includes a brief summary (author's interpretation) of the research completed. The items within each section appear in alphabetical order by author. As a follow-up to this review, a separate article in this journal (following this one) summarizes the practices/strategies for reducing drift that are reported here.

The Review

Section 1 – Air-Blast Sprayers

Ade et al., 2005. Vineyard evaluation of a recycling tunnel sprayer.

An air-assisted sprayer and a tunnel sprayer with a recycling system were used to compare distribution quality and losses to the soil. The trials were completed in a vineyard at two growth stages. The results show that losses to the ground with the tunnel sprayer were less than 5 percent of the sprayed liquid at both growth stages – much lower than with the conventional fan sprayer. Leaf retention of spray was about 87 percent of that sprayed. Efficacy over the season was not significantly different between the two sprayers. The results establish that the tunnel sprayer equipped with an air-circulation system is more efficient and has less drift than the conventional air-blast sprayer.

Ade et al., 2007. Recycling tunnel sprayer for pesticide dose adjustment to the crop environment.

A recycling tunnel sprayer was used in vineyard field trials to determine the influence of leaf density and spray flow rate on plant and ground pesticide deposits. As reported in previous studies by this research team, spray losses to the ground were minimal: less than 2 percent of that sprayed in all comparisons of flow rate and vine growth stage. When operating beneath the dripping limit, canopy density and flow rate did not affect losses. The researchers state that with this system, it would be very easy to calculate the amount of material retained. This would allow for a highly precise distribution of the required dose during a single spraying operation at a specific growth stage.

Baldoin et al., 2008. Field testing of a prototype recycling sprayer in a vineyard: Spray distribution and loss.

A prototype recycling sprayer was tested in a vineyard to measure spray distribution and off-target movement. A design incorporating wrap-around booms with nozzles mounted in air spouts was used in the field study. The sprayer also had a centrifugal fan to provide converging air through ducts to help transport the pesticide to the vine canopy. Vertical and horizontal air curtains were added to the rear and lower edges of the tunnel to aid in the process. The recycling device saved 32 percent of the active ingredient.

Balsari et al., 2005. A system to assess the mass balance of spray applied to tree crops.

Initial work with an adjustable metal frame and grid system to facilitate sampling of spray losses during applications to trees or vines was reported in this paper. The system was designed to develop an alternative to the proposed International Standards Organization (ISO) methodology for classifying orchard/vineyard sprayers according to drift risk. Another goal was to facilitate the study of spray mass balance discharged to target plants, ground, and atmosphere. A follow-up to assess progress on this work is warranted.

Behmer et al., 2010. Evaluation of low-drift nozzles in agrochemical applications in orchards.

This study was designed to evaluate the distribution of pesticide and to quantify drift in fruit orchard applications. An air-blast sprayer was used to conduct the study and compare air-induction hollow-cone nozzles to conventional hollow-cone nozzles. The results show that both nozzles produced equal amounts of deposits in the tree canopy, with minor amounts measured in the upper parts of the canopy. The low-drift nozzles produced 75 percent less drift than the standard nozzles. However, on the ground under the tree row, collections were 50 percent higher. It was concluded that low-drift nozzles in fruit orchards are effective in reducing drift.

Chen et al., 2011. An experimental variable rate sprayer for nursery and orchard applications.

A precision air-assisted sprayer with variable flow rate of individual nozzles was tested for treating ornamental nurseries and fruit trees. The sprayer was developed with the following features: a laser scanner adapted to the sprayer to detect canopy characteristics; five-port, air-assisted nozzles, each coupled with a pulse width modulation valve to control the delivered spray; and an automatic flow-rate controller to minimize pressure fluctuation. Treatments compared the new sprayer, the same sprayer without the features, and a conventional air-blast sprayer in an apple orchard at three different growing stages. Measurements were made for spray deposition and coverage inside canopies as well as airborne and soil losses. The findings show that the variable-rate sprayer produced uniform spray deposits in the canopy, reduced the spray volume by as much as 47 to 73 percent, and had significantly less off-target movement, both in the air and on the ground.

Derksen et al., 2006. Effect of application variables on spray deposition, coverage, and ground losses in nursery tree applications.

An experiment with multiple treatments was conducted to compare an experimental cross-flow fan sprayer and a conventional axial-fan orchard sprayer while treating several rows of four-year-old multistem trees. Variations in spray deposits and coverage across multiple rows were generally less with the cross-flow sprayer. However, the axial-flow sprayer produced the highest deposits in the first row nearest the sprayer. Although reducing fan speed improved nearest row coverage, decreasing the volume of spray did not affect the coverage in that same row. The fan orientation on the tower/cross-flow sprayer did not affect canopy deposits but did minimize drift. The findings in this study also suggest that applicators can use different spray volumes and speed settings to improve efficiency with orchard spraying.

Derksen et al., 2007. Coverage and drift produced by air induction and conventional hydraulic nozzles used for orchard applications.

This study compared conventional hollow-cone nozzles (D3-25 and D4-25) to a drift-reducing venturi nozzle, Turbodrop XL (Greenleaf). A conventional axial-flow sprayer was used to make applications to the outside row of a semi-dwarf apple tree block. The Turbodrop had the lowest downwind drift. There were relatively few differences in canopy spray deposits among all nozzle treatments, though the Turbodrop XL typically had reduced underleaf coverage.

Di Prinzio et al., 2010. Effect of pressure on the quality of pesticide applications in orchards.

This study was designed to evaluate the effect of spray pressure on distribution and loss of pesticide while spraying fruit trees using a conventional air-blast sprayer. The pressures evaluated were 1,800 kPa and 500 kPa. Samples were collected in the trees, in columns, and on the ground. The results showed no differences in the total quantity collected from the leaves. It was also found that the lower-pressure treatment resulted in one-third less drift. However, there were no differences in the amount on the ground with the low-pressure treatment placing a higher concentration of material on the ground near the sprayed tree row. It was concluded that low-pressure applications were a valid way to reduce drift without affecting deposits on the trees.

Fox et al., 2008. A history of air-blast sprayer development and future prospects.

A historical review of air-blast sprayers was provided in this article. Sprayer designs have changed dramatically over the last several years, mainly in response to the changing size of orchard trees. It is easier to produce more uniform coverage with less drift when spraying small trees. Designs that incorporate towers, directed jets of air, and tunnels can greatly reduce airborne drift and give more uniform coverage. Applicators can better match the sprayer parameters of airspeed and direction, application volume, and droplet spectra to tree size, shape, and density.

Garcia-Ramos et al., 2009. Field evaluation of an air-assisted sprayer equipped with two reversed rotation fans.

The effects of forward speed, air volumetric flow, and the number of active fans on spray deposition and coverage in a peach orchard were studied using an air-assisted sprayer equipped with two reversed rotation fans. Deposition and canopy penetration increased when the air volumetric flow was increased. The number of active fans had a significant effect on increasing the deposition and coverage, while forward speed had no significant effect.

Geva and Broday, 2008. Less spray and lower chemical rates for vineyards.

A surrounding sprayer was built and evaluated to achieve more efficient applications to vineyards and orchards, thus reducing drift and runoff. The objective of the field trials was to determine if smaller amounts of spray solution with smaller droplets could impact drift and runoff. The surrounding sprayer and a conventional fan sprayer were compared, using nozzles selected to generate medium- and fine-droplet spectra. The surrounding sprayer working pressure was at half the pressure of the conventional system (6, 12 bar). Water-sensitive paper was placed in the tree canopy to measure differences at three height levels. Downwind drift was collected outside the vineyard. Sufficient coverage was measured on the collectors, with the surrounding sprayer showing better foliar coverage. Less drift was found while using the fine-sized nozzles compared to medium-sized nozzles.

Gil, 2007. Inspection of sprayers in use: A European sustainable strategy to reduce pesticide use in fruit crops.

This paper discussed compulsory inspection of sprayers as a means to achieve better control of the application of plant-protection products. Results from a survey and discussions with several European members with training experience suggest that such a system would benefit the pesticide application process.

Jamar et al., 2010. Comparative performance of recycling tunnel and conventional sprayers using standard and drift-mitigating nozzles in dwarf apple orchards.

This work studied the effect of using a tunnel sprayer vs. a standard axial-fan sprayer to reduce pesticide inputs and drift. It was reported that when tunnel sprayers were equipped with a recovery/recycling system, spray mixture solution savings ranged from 28 to 32 percent. This same study reported that when used in the tunnel sprayer, ATR conventional hollow-cone nozzles outperformed a drift-mitigating TVI air-induction cone nozzle for coverage. However, there were no significant differences between these two nozzles. At the same time, there was little difference in spray sedimentation. The study concluded that traditional ATR nozzles might be more suitable for spraying apple orchards than air-induced TVI nozzles.

Landers, 2010. Developments towards an automatic precision sprayer for fruit crop canopies.

Several trials were completed to evaluate spray system designs that would promote a more directed airflow into the canopy while regulating the airflow speed to reduce drift. By using a specially designed vertical patternator, correct nozzle orientations for the canopy zone could be adjusted, further improving deposition and reducing drift.

Landers and Gil, 2006. Development and validation of a new deflector system to improve pesticide application in New York and Pennsylvania grape production.

Testing of a new air deflector on the Kinkelder sprayer was undertaken by the research team from Cornell University. This sprayer is notorious for high wind speeds and air-shear nozzles that create large amounts of drift, resulting in poor coverage. In vineyard trials, the deflector provided for horizontal flow, which increased canopy deposition (25 percent) and reduced drift.

Larzelere and Landers, 2010. Development of a spray monitoring system for a vineyard canopy sprayer.

New sprayers with adjustable louvers to keep the airflow in the canopy and sensors to monitor canopy growth were evaluated for their ability to reduce drift, increase canopy deposition, and reduce pesticide use. In field trials involving three novel methods of airflow adjustment, drift was reduced by 75 percent and deposition was increased by 30 percent. Infrared sensors were used to monitor canopy growth to adjust application rates, resulting in a 40 percent reduction in pesticide use.

Pai et al., 2008. Adjusting air blast sprayer airflow based on tree foliage density.

This paper reports on an electromechanical system to adjust the air output from an air-blast sprayer. The system used a moving air-deflector plate actuated by the sensor that determined the foliage density. Two trials were completed to evaluate this system. The first evaluated the role of the deflector plate position in modifying the air flow/penetration across trees with different foliage densities. The second measured the movement of spray droplets with varying deflector plate positions. Differences in air penetration across various tree canopy densities were found. There was also an effect on the spatial movement of droplets. The results indicated that a change in air volume could help reduce drift in orchard applications.

Panneton and Lacasse, 2006. Pollution reduction from a spray recovery sprayer.

A spray recovery system designed for apple orchards was adapted for use in vineyards to evaluate its ability to reduce ground contamination and airborne drift. A conventional air-blast sprayer set for vineyard spraying and a recovery sprayer were compared. Airborne drift was reduced by a factor of 3 and ground deposits by a factor of 4 at the wind speeds evaluated when using the recovery sprayer. The results showed that the recovery sprayer was an effective way to reduce ground losses, airborne drift, and buffer zone widths.

Panneton and Phillion, 2011. Leaf deposition with fixed sprinklers, low drift and conventional nozzles in apple orchards.

Dwarf trees in an apple orchard were sprayed using a permanent sprinkler system that was installed above the tree canopy. The system was centered on the tree row and positioned so that one sprinkler could cover two trees. A radial sprayer equipped with conventional nozzles was another treatment; the third treatment was the same (radial) sprayer using low-drift nozzles. A ratio of bottom-to-top leaf deposit was compared for all three systems. For the low-drift nozzles the ratio was near 1, greater than 1 for the conventional nozzles, and close to 0 for the sprinklers. Leaf coverage with the low-drift nozzles was not significantly different from coverage with the conventional nozzles for all locations in the tree, except in the lower portions where the low-drift nozzles produced higher deposits. It was concluded that the low-drift nozzles resulted in more deposition and had less coverage variability among the various tree locations measured.

Van de Zande et al., 2008. Nozzle classification for drift reduction in orchard spraying: Identification of drift reduction class threshold nozzles.

The development of a nozzle classification system to identify the drift-reduction potential of spray nozzles used in fruit crop spraying was undertaken based on drop size measurements. Two nozzle types, Albuz TVI 80025 and Lechler ID 9001, formed the endpoints for the classification system. These nozzles were used to rank the volume fraction of droplets smaller than 100 microns as a drift-potential predictor. Nozzles were identified at 50, 75, 90, and 95 percent drift reduction. These nozzles were the TeeJet DG 8002, Albuz AVI 80015, Lechler ID 9001, and Albuz TVI 80025.

Wenneker and van de Zande, 2008. Drift reduction in orchard spraying using a cross flow sprayer equipped with reflective shields (Wanner) and air injection nozzles.

A reference (cross-flow fan) sprayer was compared with a Wanner sprayer with reflective shields to measure the effect on reducing spray drift to the soil surface outside an apple orchard. The reference sprayer used Albuz ATR nozzles at 200 L/ha. The Wanner sprayer used the ATR nozzles at the same setting. The Wanner sprayer reduced downwind drift in an area 3.0 to 7.0 m downwind by 69 percent in early growth stages and 58 percent in the fully developed growth stage. At 4.5 to 5.5 m downwind, drift was reduced by 71 and 62 percent in similar growth stages. In another comparison (using Lechler ID venturi nozzles on the Wanner sprayer with shields), drift was reduced by 94 and 95 percent for similar growth stages. It was concluded that a sprayer with shields using coarse droplets is very effective in reducing off-target drift.

Zhou and Landers, 2010. A study of dosage adjustment for pesticide application in vineyards.

Traditional application rates for treatments in vineyards and orchards typically do not vary with season. Rates are based on ground area and do not allow for different row widths, variety, trellis designs, and other factors. Dosage adjustment according to fruit canopy characteristics has been developed. Methodology for evaluating three methods – Unit Canopy Row, Dosaviña (new software for volume calculation), and Fruit Wall

Area – compared to traditional rates and the pros and cons for each were presented in this paper.

Zhu et al., 2006. Foliar deposition and off-target loss with different spray techniques in nursery applications.

A conventional air-blast sprayer was used to evaluate spray deposits in crabapple trees and on the ground when using conventional hollow-cone nozzles, air-induction nozzles, and conventional hollow-cone nozzles with a drift-retardant material. Airborne and ground deposits were also investigated. A wind-tunnel evaluation was conducted to compare the treatments without air assist for both downwind and airborne deposits. Droplet size distributions were also measured. No significant differences for tree coverage or ground deposits were found in the field study among the three treatments. Even at a reduced application volume of 700 L/ha (half of normal), the tree canopies received more spray than needed. A large portion of the spray was deposited on the ground. Drift was reduced with both the air-induction nozzle and the hollow cone with drift retardant in the wind tunnel, but the difference was not significant in the field study. This finding would not support using air-induction nozzles or drift-retardant material to reduce off-target drift or ground accumulation. The findings in this study would support lower application volumes to reduce pesticide waste. Another conclusion was that it is not necessary to place a large-capacity nozzle at the top of the air-blast sprayer, especially in orchards with shorter canopies.

Section 2 – Nozzles

American Society of Agricultural and Biological Engineers, 2009. ASABE Standard S572.1: Spray nozzle classification by droplet spectra.

A standard, *Spray Nozzle Classification by Droplet Spectra*, was first developed by the ASABE Pest Control and Fertilizer Application Committee and officially approved in 1999. It now has its first revision approved. The standard defines droplet spectrum characteristics for the classification of spray nozzles, relative to specified reference fan nozzles. A main purpose of the standard is to provide nozzle users with droplet size information – primarily to indicate off-site spray drift potential but also to promote application efficacy. Nozzle classification is divided into eight categories (the original standard had six): extremely fine (XF), very fine (VF), fine (F), medium (M), coarse (C), very coarse (VC), extremely coarse (XC), and ultracoarse (UC). XF and UC are the newly added categories.

Bjugstad and Hermansen, 2009. Field measurements of spray drift potential in strawberry.

This was a trial measuring drift from different strawberry spraying systems. Drift samplers/collectors were placed 2 m behind the nozzles. Forward travel speed was used to generate wind speed in calm conditions. Measurements were taken at two different growth stages to evaluate the filtering effect of leaf density. Drift was reduced by as much as 75 percent when comparing May-to-August leaf densities. Of the systems tested, the tunnel sprayer with end curtains was 10 and 13 percent lower than the reference sprayer, and 55 and 37 percent lower without the end curtains at the two growth stages, respectively. On the tunnel sprayer, the end curtains were effective in reducing drift. It was also learned that when using 80015 flat-fan nozzles, drift was significantly greater when at the higher setting (200 mm) than at the lower (100 mm). Air-injection nozzles reduced drift significantly.

Guler et al., 2007. Spray characteristics and drift reduction potential with air induction and conventional flat-fan nozzles.

Laboratory tests were completed to evaluate spray drift potential, spray coverage, droplet size, and spray pattern width of various air-induction and conventional flat-fan nozzles with similar orifice sizes. Droplet sizes were measured using laser imaging, spray coverage was determined using water-sensitive paper during boom applications, and ground and airborne spray deposits were measured in a wind tunnel. Sealing air-intake holes on air-induction nozzles was also evaluated to learn of any effects on air-induction characteristics. In this study, it was reported that the air-induction nozzles had 2.10 to 2.75 times larger exit orifice areas, even at an equivalent nominal flow rate, than conventional flat-fan nozzles. When comparisons were made with equal-sized orifice areas and equal liquid flow, no significant differences were found in droplet size, spray pattern width, spray coverage, ground spray deposit, or airborne drift between conventional, regularly operating air-induction, and plugged air-induction nozzles. The researchers concluded that desirable spray characteristics of air-induction nozzles could be achieved using conventional nozzles with the equivalent orifice size operated at a reduced pressure.

Nuyttens et al., 2007. The influence of operator controlled variables on spray drift from field sprayers.

Field studies were completed to measure drift from horizontal boom sprayers, looking at different drift-reducing spray application techniques. A reference sprayer flat-fan nozzle was compared to low-drift and air-inclusion nozzle designs at varying orifice sizes, spray pressures, driving speed, and spray boom heights. Downwind horizontal drift collectors were placed according to the ISO 22866 sampling technique. Reported findings show that lower speeds, reduced boom height, larger nozzle orifice sizes, and lower spray pressures generally reduced drift. Among nozzle types studied, the air-inclusion designs were most likely to reduce drift followed by the low-drift and the standard flat-fan nozzle types. Drift amounts were closely linked to the droplet size characteristics of the sprays.

Nuyttens et al., 2009a. Droplet size and velocity characteristics of agricultural sprays.

This study was done to evaluate droplet size and velocity characteristics using a phase Doppler particle analyzer (PDPA) laser. Standard, low-drift, and air-inclusion nozzle types were evaluated at various orifice sizes and pressures. It was reported that in general, larger droplet sizes correspond to higher droplet velocities; smaller droplets, to lower velocities. Nozzle type and size also influenced the velocities measured. For the same droplet size, velocities were highest with the flat-fan nozzle, followed by the low-drift and air-inclusion types. The researchers reported that velocity reductions for the latter two types were affected by the preorifice and venturi designs. This information is useful in understanding how droplets can better penetrate canopies, resulting in less drift.

Nuyttens et al., 2009b. Influence of nozzle type and size on drift potential by means of different wind tunnel evaluations.

Wind-tunnel tests were used to evaluate 10 different spray nozzle types for airborne and fallout spray volumes. Drift-reduction potential percentages comparing reference sprays using flat-fan nozzles to nozzles designed to reduce drift were calculated to measure the differences. Three comparisons were used: the first-moment airborne spray profile, an integration of the airborne spray profile, and an integration of the fallout deposit curve. As expected, the results showed that the designated drift-reduction nozzle types did lower the drift potential when compared to the flat-fan nozzles.

Nuyttens et al., 2010. Comparisons between indirect and direct spray drift assessment methods.

This work studied the effect of using three different drift-assessment tools to evaluate the drift characteristics of 10 different nozzles. The three tools used were a PDPA laser, a wind tunnel, and field drift experiments. The effects of nozzle size and type were studied. The sizes studied were ISO 02, 03, 04, and 06. The types were standard flat fan, preorifice flat fan, and air-induction flat fan. A reference ISO 110-03 flat fan was also included. Results show that with indirect assessments (wind tunnel and PDPA), drift-assessing experiments can be made that are directly comparable and repeatable. These experiments are also suitable for relative assessments of drift. However, measuring the proportion of the volume of droplets under 75 microns was best suited to represent the drift potential in the field studies. The data from these drift measurements and a statistical drift-prediction equation for the reference spraying may give a realistic estimate of drift for the conditions of this study.

Qi et al., 2008. The classification of the drift risk of sprays produced by spinning discs based on wind tunnel measurements.

This study assessed the drift potential of spinning discs using a wind tunnel as the measuring tool. Drift profiles from standard flat-fan nozzles were compared to the spinning discs. With the flat fan as the standard and using similar droplet sizes, it was reported that the spinning discs drifted much more than the flat fans. The greatest differences were measured at higher wind speeds and smaller droplet sizes. A classification system for spinning discs was proposed from this data.

Wolf, 2005. Comparing downwind spray deposits of four flat-fan nozzle types measured in a wind tunnel and analyzed using DropletScan.

A wind tunnel was used to measure the drift-potential differences for four flat-fan nozzle designs at different application volumes (gallons per acre; GPA) and at the manufacturer-recommended operating pressures. The nozzle designs and spray pressures used were the XR flat fan (173 kPa), TT flat fan (242 kPa), Combo-Jet DR (342 kPa), and the air-induction flat fan (345 kPa). Downwind droplet movement was collected using water-sensitive paper as the collector with comparisons of percent area coverage measured using DropletScan software. Higher-volume applications had less drift for all nozzle types, but differences were not as great for the drift-reducing designs (TT, DR, AI). In general, the conventional flat-fan nozzles created significantly more drift than those with drift-reducing designs.

Zhu et al., 2006. Development of a canopy opener to increase spray deposition and coverage inside soybean canopies.

Field studies using a mechanical canopy opener were conducted to determine if improved canopy penetration could be achieved. When compared to applications in canopied soybeans, the opener design improved coverage at multiple depths within the canopy. Though not a component of the field studies, improving deposition within the canopy may also indicate less drift potential.

Section 3 – Buffers

de Jong et al., 2008. Estimated nationwide effects of pesticide spray drift on terrestrial habitats in the Netherlands.

This paper reports on an evaluation in the Netherlands using field trials to estimate the effects of drift on different species groups at various distances from treated plots. Drift measurements were taken using standard agricultural practices to help model the deposition outside the treated area. It was determined after reviewing periods ranging from 1998 to 2010 that changing application practices during those years have reduced drift amounts. The use of narrow, unsprayed buffer zones was considered a major factor in reducing drift. It was also reported that extending the width of the buffer area would have an even larger impact on reducing the amount of deposition outside the treated area.

de Schampherleire et al., 2009. Deposition of spray drift behind border structures.

This study evaluated the effectiveness of windbreaks as a border structure to reduce drift. Initial testing was conducted in a wind tunnel using artificial screens and plastic Christmas trees. The screens reduced spray drift in the sheltered region, but significant deposition peaks were found behind the screens. These peaks indicated that though the filters reduced the wind speed and captured deposits, wind currents were still present and accelerated over the top of the screens. In field scenarios where natural windbreaks were equal to or taller than the spray nozzle release point, less drift was measured. There was more measured deposition at short distances in the natural settings compared to the artificial. However, the peaks found in the artificial settings did not occur in the natural settings.

Lazzaro et al., 2008. Role of hedgerows in intercepting spray drift: Evaluation and modeling of the effects.

This study evaluated the use of hedgerows as a way to reduce drift from air-assisted sprayers into surrounding, untreated areas. This Italian study considered three hedgerow scenarios – zero, single, and double hedgerow – with the sprayers working parallel and perpendicular to the hedgerow, releasing spray at 1 to 2 m. The hedgerows 7 to 8 m high proved effective in reducing drift from 82 to 97 percent. The presence of a double hedgerow did not change the level of drift reduction. This data was used to develop a model to help predict drift magnitude in relation to wind speed and optical porosity of the hedgerow.

Vischetti et al., 2008. Measures to reduce pesticide spray drift in a small aquatic ecosystem in vineyard estate.

A study was conducted to evaluate the effect of buffer zones and tree row buffers on reducing pesticide drift into bodies of water while spraying vineyards. It was determined in the study that spray drift occurred over a distance of 24 m and that the use of tree rows in front of a body of water downwind from the application greatly reduced spray drift. It was also reported that when the data in this experiment was compared to the Drift Calculator procedure (model), the model failed when the procedure was used for short distances.

Section 4 – Environmental

Fritz et al., 2008. Low level atmospheric temperature inversions and atmospheric stability: Characteristics and impacts on agricultural applications.

This study examined inversion periods for strength, time of occurrence, and duration. During the monitoring period, stable and very stable atmospheric conditions (which are responsible for most drift) mostly occurred between 6:00 p.m. and 6:00 a.m. About half of the monitored inversions occurred after 4:00 p.m. Unstable conditions tended to dominate between 6:00 a.m. and 6:00 p.m. Thus, applicators should take extreme caution when spraying in the very early morning (before 6:00 a.m.) and in the evenings, particularly when wind speeds are below 2 m/sec.

Section 5 – Simulation Models

Baetens et al., 2007. Predicting drift from field spraying by means of a 3D computational fluid dynamics model.

A computational fluid dynamics model in 3D for investigating and understanding drift from field sprayers was developed. The 3D approach permitted an understanding of the influence of deviation in wind direction by better analyzing the wake behind a windscreen and the effects of changing nozzle orientation. Field experiments based on the international standard ISO 22866 were used to validate the model's accuracy. Experiments were conducted using a 27-m boom sprayer with 54 nozzles operating at 2.22 m/sec. The wind was perpendicular to the spray tract, allowing the model to predict drift differences resulting from various boom heights, wind velocities, wind deviation from the perpendicular, and the injection velocity of the nozzles. Taking into account these factors, boom movements had the greatest impact on the variations in drift values. This impact was followed by variations in wind velocity and nozzle injection velocities. Wind deviation from the perpendicular actually reduced the amount of drift. Small variations in driving speed had little impact on drift values.

Balsari et al., 2007. A test bench for the classification of boom sprayers according to drift risk.

This group set out to find an alternative sprayer classification procedure that did not require evaluating the drift risk of sprayers operating in stable wind conditions during field experiments. A test bench was developed to measure drift potential generated by boom sprayers. Comparisons between the bench test system and ISO methodology were made using a conventional boom sprayer equipped with traditional and air-induction flat-fan nozzles. Treatments were done at 50, 80, and 100 cm. The results showed that the test bench method had a higher repeatability than the field test. The test bench system was also less time-consuming.

Ellis and Miller, 2010a. A spray drift model for assessment of ground deposits from boom sprayers.

A pesticide spray drift model developed for use in the United Kingdom to assess boom sprayer drift at short distances (less than 20 m) is being adapted for use in the United States to predict spray drift or surface water deposits up to 200 m. The model was tested using data from the Spray Drift Task Force (SDTF) for single nozzles and size. The model shows that droplet size distribution is the main nozzle parameter to predict drift for distances greater than 10 m. Other factors influencing spray drift prediction are boom height, wind speed, and evaporation.

Ellis and Miller, 2010b. The Silsoe Spray Drift Model: A model of spray drift for the assessment of non-target exposures to pesticides.

A computer model used to predict nontarget exposures to pesticides was extended to include the effects of multiple nozzles on a boom and a forward speed so that the model could better simulate application conditions appropriate to current field practice, (particularly in the United Kingdom). The model was specifically developed to improve estimates of bystander dermal and inhalation spray drift exposure. It was validated against three experimental datasets of downwind airborne spray and ground deposit for FF110 conventional flat-fan nozzles spraying over either short grass or 0.65-m tall wheat crop. The model closely agreed with measurements, but future work is required to validate it against other nozzle designs.

Endalew et al., 2010. An integrated approach to investigate the orchard spraying process: Towards a CFD model incorporating tree architecture.

A computational fluid dynamics (CFD) model that allows the simulation of the spraying process for different sprayers is presented in this paper. The model considers the effects of wind velocity, turbulence, and the nature of the canopy on air-assistance distribution. Orchard experiments were performed on the air profile from three different air-assisted orchard sprayers. The model results compared well to the actual measured profiles for airflow distribution, with accuracies as high as 80 percent.

Garratt and Kennedy, 2006. Use of models to assess the reduction in contamination of water bodies by agricultural pesticides through the implementation of policy instruments: A case study of the Voluntary Initiative in the UK.

A study was conducted to evaluate the benefit of water quality models to examine how changes in farmer behavior could impact pesticide contamination of water bodies. Scenarios were developed to represent different standards of practice with respect to pesticide-use behavior. One observation regarding spray drift was that surface water contamination was more likely when the spray boom was close to the water body and product usage was high.

Gil et al., 2007. Atmospheric loss of pesticides above an artificial vineyard during air assisted spraying.

This research assessed drift while making air-assisted sprays in an artificial vineyard. Three experiments were performed to evaluate method, quantify upward movement of sprayed droplets, and investigate the influence of climatic variables on drift. Fine and very fine droplet sprays (Brighton Crop Protection Conference; BCPC) were used. Very fine sprays contributed more drift at 2.5 m above the ground (9.0 to 10.7 percent) than fine sprays (5.6 to 7.3 percent). During stable air conditions, the drift was traced along the mean wind direction over the crop. In unstable air conditions, the drift plume was larger and moved to higher levels above the crop. From this study, a statistical model (based on simple multiple regression, including droplet characteristics and climatic variables) was developed to estimate spray loss just above the crop. This method was considered suitable to quantify spray drift and to study the influence of several variables on the amount of pesticide released into the atmosphere with air-assisted sprayers.

Gil et al., 2008. Influence of micrometeorological factors on pesticide loss to the air during vine spraying: Data analysis with statistical and fuzzy models.

Measuring spray drift losses over vine crop applications made with air-assisted spray systems were evaluated using linear multiple regression and fuzzy logic inference models. Fine and very fine sprays were tested, with the significant variables for multiple regressions being wind speed, air temperature, and wet bulb depression. For the very fine sprays, atmospheric stability was also significant. Spray losses were predicted using fuzzy inference systems with high determination coefficients. In summary, both analysis tools can be combined with mathematical modeling to evaluate air pollution and spray drift from field tests.

Hiscox et al., 2006. Quantifying the amount of aerial spray in the air over time for vector control operations.

The purpose of this work was to develop a technique to measure aerosol mass remaining in the air after spraying. Remote light detection and ranging (lidar) measurements of airborne spray plumes were evaluated in combination with drop size distributions and spray rates to estimate the amount of material remaining in the air and drifting in real time. Lidar is an optical remote-sensing technology that can measure properties of a target by illuminating it with light, often using pulses from a laser. It was observed that fine spray droplets (37.3 microns) in the air decreased rapidly for one to two minutes, then remained nearly constant and drifted with the air currents. From related studies, it is argued that analysis of lidar images of spray plumes is an accurate and efficient way to estimate turbulence values for spray transport models.

Hoffman et al., 2007. AGDISP sensitivity to crop canopy characterization.

This aerial-based evaluation of model systems was undertaken to help model users understand the effects various inputs have on system outcomes. The main objectives were to quantify (1) the effects of different crop canopy characteristics (height and canopy closure) on spray deposition and downwind movement, and (2) how the results compared to spray movement and deposition using AGDISP. Multiple trials were conducted in cotton fields at various canopy heights and growth stages. It was reported that the model actually overpredicted the deposition close to the canopy when compared to field measurements. However, at higher canopy heights the model and field measurements were more closely matched. Though this is an aerial study, applicators are cautioned that the model use for applications with ground boom sprayers close to the canopy may not as accurately predict deposition, especially if the canopy is more than 80 percent closed.

Kruckenberg et al., 2010. An interactive spray drift simulator.

This group is reporting on the development of drift-prediction software used as a management tool to determine the effects of applying pesticides under certain operating conditions. This program links DRIFTSIM (a software program that predicts droplet movement based on size and wind speed) with a global positioning system simulator to obtain a two-dimensional drift prediction for simulated ground-based sprayers. The program was evaluated using a variety of operating conditions to determine the effects on drift deposition levels. The results show the importance of choosing the largest nozzle orifice size, operating under lower wind speeds, and spraying at the lowest possible boom height. Using the model to simulate multiple swath applications showed patterns of increased and reduced application rates due to spray drift.

Labri and Salyani, 2010. Spray model to predict deposition in air-carrier sprayer applications.

A model was developed to predict on-target deposition of spray material from air-carrier sprayers accounting for evaporation, drift, and ground deposition. The model simulates the mass dispersion of the spray material as the spray plume or cloud passes through several connected compartments in the direction of the application. The tree canopy submodel accounts for foliage distribution, which will represent the canopy resistance to spray transport and deposition. Using spray volume rate, air velocity, sprayer ground speed, target canopy distance, and canopy foliage density as input factors, multiple simulations of the model measured deposition. The results showed that target canopy distance contributed the most to the mean deposition. Spray volume rate and canopy density were also found to significantly contribute. It was concluded that the model can help spray applicators plan spray programs.

Nuyttens et al., 2006. PDPA laser-based characterization of agricultural spray nozzles.

Multiple nozzle and pressure combinations were evaluated and spray quality was categorized based on the BCPC classification scheme using measured droplet size spectra. The study results confirmed the importance of nozzle type and flow rate in determining droplet size and velocity. The data was to be used for a computational fluid dynamics model to predict spray drift from nozzles based on nozzle type and flow rate.

Teske and Thistle, 2010. Considerations of spray cloud relative humidity effects on evolving droplet size in the simulation of fine droplet motion using AGDISP.

In an experiment measuring downstream relative humidity from a nozzle spraying water, it was found that the effective relative humidity within the spray cloud was 50 percent higher than under ambient conditions. Implications of this finding were explored using Spray Drift Task Force data. Another finding was that AGDISP model predictions were now only twice as high as measured deposition data.

Teske and Thistle, 2011. Technical note: A comparison of single spray path ground boom sprayer deposition patterns.

This technical note is provided to clarify a comparison of data presented in an earlier paper by these authors (see Teske et al., 2009b). This note further summarizes the data on a one-on-one basis, providing a way to improve the interpretation and use of this information. The data in question was the SDTF from 1995 and the Canadian data from Wolf and Caldwell (2001; not included in this paper). It appears that caution should be taken in using the high-boom scenario in AgDrift Tier 1. It is now reported (Ellis and Miller, 2010a) that high booms may decrease off-target deposition close to the application area but increase deposition farther downwind.

Teske et al., 2009a. Considerations of time step and evolving droplet size in the simulation of fine droplet motion using AGDISP.

In advance of the release of AGDISP version 8.22 (2009), a reexamination of the algorithms for droplet size distribution, evaporation rate impact on droplet size, and the behavior of the integration time step were undertaken.

Teske et al., 2009b. Initial development and validation of a mechanistic spray drift model for ground boom sprayers.

This work involved the initial stages of the development of a spray drift model for ground boom sprayers. It was based on the same approach as the aerial spray model AGDISP. However, for ground boom scenarios, the wake and turbulence of the aircraft are removed, and there is more emphasis on the nozzle orifices. The model predicts the spray deposition downwind from the application area.

Teske et al., 2011. A review of computer models for pesticide deposition prediction.

This is a review of approaches to analytical pesticide deposition modeling for ground boom and orchard air-blast sprayers as described by modeling approaches commonly used in aerial spraying. The review maintains that the model results can be used to predict downwind spray deposition comparable to field datasets. Validation studies have increased confidence in using models such as AGDISP as a precision tool. The models that were originally used to look at nearby deposits are now being used to predict results from entire spray programs.

Wolters et al., 2008. Field experiment on spray drift: Deposition and airborne drift during applications to a winter wheat crop.

This group performed field experiments to evaluate techniques to measure spray deposition and airborne drift during conventional boom sprayer applications to winter wheat. Various horizontal collectors and positions were compared along with both passive and active air-sampling techniques to measure airborne deposits. The experimental findings showed little variation in sampling technique. When compared to estimates of spray deposits using the IMAG Drift Calculator, the findings agreed only for areas located 0.5 to 4.5 m from the last nozzle. There was a four-fold overestimation of the drift at 2 to 3 m. Thus, it was concluded that the calculator had a high level of uncertainty for deposition at close distances.

Zhu et al., 2005. A windows version of DRIFTSIM for estimating drift distances of droplets.

A Windows version of a computer simulation tool to determine the relative effects of various factors on spray drift was released by the USDA group at Wooster, Ohio. This version of DRIFTSIM was developed to rapidly estimate the mean drift distances of water droplets discharged from sprayers. A flow-simulation program of drift distances up to 200 m at temperatures ranging from 50°F to 86°F, release heights of 0 to 6.5 ft, initial droplet velocities of 0 to 154 ft/sec, relative humidity of 0 to 100 percent, wind speed of 0 to 32.8 ft/sec, and droplet sizes of 10 to 2,000 microns were part of the calculation. Included with the drift distances are measurements of Dv0.1, Dv0.5, and Dv0.9 droplet size distributions. The results of the findings from using DRIFTSIM were verified using a single-droplet generator and the wind tunnel.

Zhu et al., 2010. A portable pixel recognition system for evaluating the distribution of spray deposits.

A portable scanning system was developed that could quickly evaluate spray deposit distribution on deposit collectors without using laser technology. The system is built from a handheld business card scanner, coupled with a computer, and is programmed to read deposit cards (water-sensitive paper). The software is DepositScan. It is designed to evaluate spray deposit and report the findings with typical droplet descriptions, including size and distribution, numbers, and percent area coverage. Observations of nominal-sized spots were measured using a stereoscopic microscope and verified the accuracy of the system. The portable scanning system offers a convenient solution for on-the-spot evaluation of spray quality under various working conditions.

Section 6 - Adjuvants

Guler et al., 2006. Wind tunnel evaluation of drift reduction potential and spray characteristics with drift retardants at high operating pressures.

Laboratory tests were conducted to evaluate drift potential from a hollow-cone nozzle spraying at high pressure (1,655 kPa) with three different drift-retardant materials. Droplet sizes were determined in a wind tunnel using a laser imaging system, and a portable spray patternator was used to determine spray width. The volume median diameter (VMD) of the droplets from the hollow-cone nozzle spraying mixtures containing water only, polyvinyl polymer, nonionic colloidal polymer, and a polyacrylamide polymer drift retardant was determined. These values were 201, 222, 239, and 210 microns, respectively. The spray pattern width did not change with the different spray mixtures. The polyacrylamide polymer drift retardant produced the highest amount of airborne deposit, followed by the polyvinyl and nonionic colloidal materials. The same results were found for the ground drift potential except that the nonionic and polyvinyl values were reversed.

Hoffmann et al., 2011. Air and spray mixture temperature effects on atomization of agricultural sprays.

A wind-tunnel assessment was conducted to study the effect of solution temperatures on atomization. Dynamic surface tension and viscosity were also measured across the same range of temperatures. It was determined that in general, as temperatures of the solutions increased, dynamic surface tension and viscosity decreased. The decrease in both of these physical properties was directly related to the decrease in spray droplet size for all the nozzle types and wind speed tested. The researchers concluded that though an effect was measured in this study, it was unlikely that solution temperatures would vary enough to make a major difference in the drift risk of any given application.

Jones et al., 2007. Effect of two polysaccharide adjuvants on glyphosate spray droplet size and efficacy.

Droplet spectra were examined using a laser droplet analyzer to determine the effect of adding drift-control adjuvants to spray mixtures. Field efficacy studies were also completed to determine the effect of postemergence applications of glyphosate on weeds. The results indicated that the addition of drift-control adjuvants decreased the percentage of spray volume with small-diameter droplets (< 141 microns). Field efficacy was not affected. The researchers concluded that these types of adjuvants could prove valuable in managing drift.

Stainer et al., 2006. Droplet size spectra and drift effect of two phenmedipham formulations and four adjuvants mixtures.

A wind-tunnel evaluation to determine the drift-potential effect of multiple adjuvants on an emulsifiable concentrate (EC) and suspension concentrate (SC) formulation of a pesticide was conducted using hollow-cone, flat-fan, and air-induction nozzles. The VMD and percentage of volume under 100 microns were determined using a Malvern particle-size analyzer. The EC formulation produced a smaller VMD and had a larger drift potential than the SC even with no adjuvants added. The drift potential increased as the percentage of small droplets increased.

Williams et al., 2008. The influence of the extensional viscosity or very low concentrations of high molecular mass water-soluble polymers on atomization and droplet impact.

At very low concentrations, water-soluble polymers were shown to produce typical shear-thinning characteristics under shear, and strain-hardening behavior under extension above a critical strain rate. When measured with laser diffraction, the addition of polymers was shown to increase the size of the droplets produced in atomization by agricultural spray nozzles. This was attributed to the increase in extensional viscosity at the strain rates developed under pressure in the spray nozzle and was a function of both polymer concentration and molecular mass. It was concluded that very low concentrations of high molecular mass polyacrylamides significantly influence the size of droplets formed during atomization and contribute to droplet bounce characteristics. Large extensional viscosities generated above a critical strain rate are responsible for both processes.

Zhu et al., 2008. Influence of spray additives on droplet evaporation and residual patterns on wax and wax-free surfaces.

Comparisons of evaporation times and the wetted area of single droplets were measured under different relative humidity conditions in a controlled laboratory setting. The spray mixtures used to form the droplets included different combinations of water, a polymer drift retardant, a surfactant, and two insecticides. The evaporation was investigated on the surface of crabapple leaf surfaces using hydrophilic and hydrophobic glass slides. Adding surfactants into the spray mixtures greatly increased the droplet wetted area and reduced the evaporation time. Adding the drift-retardant material into the spray mixture slightly increased evaporation time and decreased the droplet coverage area. Increasing the relative humidity also increased the evaporation time but had little effect on the coverage area. It was also determined that both the evaporation time and coverage area increased as the droplet size increased.

Section 7 – Miscellaneous (ex. reports and Extension publications)

Antony et al., 2008. An online mapping tool to inform pesticide applicators of sensitive areas.

This project was established to allow producers of sensitive crops to inform pesticide applicators about the location of these crops. The tool was built on a Google Maps interface, creating an online map to enable pesticide applicators to view locations of sensitive crops. First, the growers register the locations of their crops on the website. Applicators can then use this information to plan pesticide applications to avoid drifting onto the crops. This project is now known as Driftwatch.

Blaine et al., 2008. An assessment of agricultural producers' attitudes and practices concerning pesticide spray drift: Implications for Extension education.

This journal article summarizes findings of a survey of agricultural producers concerning their practices and attitudes regarding pesticide spray drift. Results indicate that the growers' approaches in managing drift are diverse and complex. Growers tend to use multiple strategies to reduce drift and are flexible in their attempts to do so. Since farm profitability is a major concern, programs and regulations designed to reduce drift should emphasize cost-effective compliance.

Carlsen et al., 2006. Drift of ten herbicides after tractor spray applications: Primary drift (droplet drift).

Five field experiments were conducted to investigate the primary drift of 10 herbicides. In general, drift deposits were common to all spray equipment used; spray was detected up to 150 m off-target. The differences reported could be explained by different droplet sizes, wind velocities, formulations, and the filtering effect of vegetation. The evaporation speed of certain tank-mix solutions was less important but was still a factor. The researchers sensed a need to further investigate the solution effect as a contributor to spray drift. For this study, the findings indicated that the physical properties of the spray process and the conditions of an application (equipment and weather) were the major causes of drift.

Felsot et al., 2010. Agrochemical spray drift; assessment and mitigation—A review.

This paper provides a critical review of spray drift studies and practices for reducing the potential impact of spray drift with an international perspective. The review starts with a historical overview and then considers the current need to include drift in risk assessments analyzing the regulation and use of crop protection products. Models currently in use that estimate downwind drift are reviewed to point out features and limitations. Finally, mitigation recommendations (i.e., best management practices) worldwide are characterized; suggestions are presented for harmonizing mitigation assessment.

Hanna and Schaefer, 2009a. Drift management considerations.

This Extension Service publication reviews the basic principles for operating field sprayers and reducing spray drift. The basic premise is that increasing droplet size is the key. The standard practices recommended to accomplish this are listed. These include: operating at a lower pressure, using a larger nozzle orifice size, maintaining the lowest possible boom height to provide uniform overlap across the application swath and field, using low-drift nozzle designs such as venturi or air induction, and driving at slower speeds near field borders when using a spray rate controller to lower pressures. Certain weather factors are also included, such as spraying when wind speeds are 3 to 10 miles per hour and avoiding wind blowing toward sensitive areas. Applicators are also cautioned against spraying in dead calm conditions. Additionally, applicators are advised to review how far droplets can travel based on size and wind speed. The Ohio State DRIFTSIM software is recommended as a tool for that purpose.

Hanna and Schaefer, 2009b. Spray drift potential increases during warm weather applications.

This Extension document discusses the effect of temperature and humidity on spray drift. The higher the temperature and lower the humidity, the faster evaporation occurs. Evaporation results in smaller droplet sizes. These smaller droplets may then move off-target with the prevailing winds. These distances can be determined using DRIFTSIM. The DRIFTSIM model includes temperature and humidity in its calculations. Additionally, the article states that the amount of drift can be reduced by adding drift-retardant additives to the spray solution.

Hipkins et al., 2009. Droplet chart / selection guide.

This publication reviews the focus on controlling drift that crop protection labels are beginning to provide. Label information includes specific suggestions on droplet spectra needed for optimum efficacy and minimum drift for fungicide, insecticide, and herbicide applications. The authors review the ASABE Standard S572 classification scheme and stress the importance of basing nozzle selection not only on orifice size but also on droplet size. Applicators are cautioned against selecting a nozzle orifice size that will produce fine and very fine droplets.

Klein, 2009. Managing spray drift.

This Extension document summarizes work done earlier by Smith et al. at Mississippi State University (see Appendix A of Klein's document). Smith's work evaluated more than 100 studies involving drift from ground sprayers. Of the 16 variables considered to influence downwind drift, three were deemed most important. According to Smith, wind speed had the most influence on downwind drift (doubling the wind speed increased drift by 700 percent). Boom height was another critical factor (doubling the boom height from 18 to 36 inches increased drift 350 percent). The third critical variable was increasing the distance downwind, which caused drift to decrease (doubling the downwind distance decreased drift fivefold). Klein also discussed the influence of spray pressure and spray speed on drift. He cautioned that when using a rate controller to maintain constant field application rates (GPA), the pressure will increase when application speeds are increased. Increased pressure will not only influence the spray flow from the nozzle but may also reduce droplet size. If this happens, it may mean that you have exceeded the manufacturer's suggested operating pressure range.

Miller et al., 2011. Methods for minimizing drift and off-target exposure from boom sprayer applications.

This paper examined options for using different flat-fan nozzle angles as a way to reduce spray drift resulting from booms that operate at more than optimum height. It was concluded that 80º and 65º fan angles would substantially reduce drift risk when operated at 0.7 and 0.9 m above the crop/soil. This was comparable to similar drift potential from 110º angles at 0.5 m. However, the researchers would still recommend using the lowest possible boom heights as an important part of any drift-control strategy.

Ozkan and Womac, 2005. Best management practices for boom spraying.

This publication provides a list of best management practices for effective spraying of crop protection products. As with all recommendations, the process starts with the label for specific guidelines and requirements. From there, a comprehensive list of recommended practices is discussed, which provides detailed information on preparing the spray system for application. Included is a specific list of recommendations to reduce spray drift.

Wilson et al., 2008. Selecting drift-reducing nozzles.

This Extension publication is a detailed discussion of the various nozzle types available to apply crop protection products. It includes excellent images and descriptions of the basic nozzle types available both to reduce drift and to maintain excellent pest control. A discussion of the basic pesticide application issues is also highlighted. A main caution expressed is that though drift is a major concern, it is also prudent to choose nozzles that will control the target pest. A key point is that one nozzle type may not be suitable for all pesticide applications.

Wolf, 2009. Best management practices for herbicide application technology.

There are three main goals when applying crop protection products today: effective pest control, an efficient (and reasonably priced) operation, and low (reduced) drift. Putting all three of these goals into one plan will likely require compromise. Since not all applications can occur at the optimal time, adjustments must be made to accommodate various conditions (such as wind speed and direction) that may influence the outcome. Bigger, more powerful, and faster sprayers may be needed to cover the target areas more quickly. All these factors will affect nozzle selection and (ultimately) performance. Thus, nozzle selection and proper use are critical to a successful application. This publication takes a closer look at the importance of travel speed as influenced by modern spray systems. It also discusses the many approaches to nozzle selection necessary to ensure an effective, efficient, and safe pesticide application.

Wolf, 2010. Hand sprayer calibration steps worksheet.

This publication describes a simple procedure that can be used to calibrate a handheld sprayer system (ex. handgun on an ATV, backpack system, or simple pump-up sprayer). Another part of this document discusses how to adapt a backpack or handheld sprayer to minimize drift. It is recommended that a spray management valve be added to the system to help maintain a constant operating pressure and flow rate. The document further explains how either spray system (backpack or handheld sprayer) can be converted to flat-fan nozzle types. This will allow drift-reducing nozzles to be included on these sprayers.

Wolf and Bretthauer, 2009. Droplet size calibration: A new approach to effective spraying.

This publication explains in detail how to calibrate a boom sprayer to achieve a desired droplet size. It first reviews the steps involved to calibrate for (select) the proper nozzle orifice size to achieve the desired application goal in gallons per acre. The authors then go through the steps needed to further decide the proper droplet spectra (which in the future will be dictated by the crop protection product label).

Wolf et al., 2009. An evaluation of ATV-mounted boomless spray nozzles for weed control.

This publication summarizes a research study to evaluate boomless nozzles for use in pasture and roadside applications of weed-control products (herbicides). The study found that although boomless nozzles are designed for use in areas where boom sprayers are not practical, they may not always provide good weed control. It was also learned that the spray from boomless nozzles may be greatly influenced by wind, which may affect pattern quality, swath width, efficacy, and drift potential. Droplet sizes created by these ATV-mounted spray systems and the boomless nozzles were typically larger than required for good herbicide efficacy, especially over the 12- to 15-ft widths being sprayed.

Summary and Conclusions

This publication arose from a request by Crop Life America to conduct a review of recent drift literature for the benefit of the application industry. The purpose was to develop a publishable list of techniques/practices for minimizing spray (particle) drift. The resulting publication is a review of drift literature. It summarizes efforts of researchers to develop drift-reducing application strategies.

The main goal was to document all publications after 2004 with data on drift reduction. The review specifically addressed practices for air-blast applications, ground boom broadcast applications to fields, applications to rights-of-way, and applications made with handheld sprayers. It includes relevant drift literature between 2005 and 2011. Due to time constraints and other factors, the review was terminated on September 1, 2011.

The National Agricultural Library was the repository for much of the general drift literature reviewed. The ASABE publications library was also an excellent source of both peer-reviewed journal articles and basic reports on drift research. Many times, basic reports (meeting presentations) were later developed into peer-reviewed articles. This review initially included nearly 300 documents that met the criteria for this search. After eliminating duplicate reports, unrelated topics, and aerial applications, this document comprised 82 referenced items. The review is divided into sections based on content as it relates to drift reduction. Each section lists the article title, citation, and a brief summary of each publication. The sections contain the following number of items: air blast, 24; nozzles, 10; buffers, four; environment, one; simulation models, 22; adjuvants, six; and miscellaneous (ex. reports and Extension publications), 15.

The summaries of each citation in this paper are the basis for the article that follows, “Drift-Reducing Strategies and Practices for Ground Applications.” That article lists and discusses the practices found in the research cited here. Using information from these two reports, pesticide manufacturers should be better able to refine drift-reducing application strategies as they develop labels and directions for use guidelines.

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