Air-Assisted Boom Sprayers as a Model for Introducing Drift Reducing Technologies to US Pesticide Labels: Conclusions from Published Literature

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Introducing drift-reducing technologies (DRTs) to US pesticide registration risk assessments will require agricultural industry and regulatory agency agreement on principles, protocols and verification of drift reduction. Regulators need credible evidence documenting the likely magnitude of reduced spray drift deposition at various downwind distances, and DRTs must benefit growers through reduced costs or greater flexibility in allowable application conditions. To illustrate the first steps in the process outlined by Sayles et al., 2004, we focused on air-assisted boom sprayers (AABS) as a potential DRT, defining AABS as a boom sprayer that directs ambient air along the boom length so that spray is accelerated downward towards the ground or crop. We identified relevant publications that directly and indirectly support the assumption that AABS has the potential to reduce spray drift. Researchers in North America and Europe have demonstrated the potential for drift reduction through reduced downwind deposition and through increased deposition in crops; however, we also noted limitations to the use of AABS as a DRT. The usual standard for US drift exposure calculations is deposition on bare ground or short grass. Under these standard conditions, air-assisted sprayers may produce increased drift compared to conventional sprayers. Applicators will need to adjust the level of air assistance to minimize upward reflection of air-entrained droplets and match nozzles/droplet size to the level of air assistance. Demonstrating the full range of drift reduction potential of an AABS will require testing and verification procedures that include tests in the presence of crop canopy as well as comparison to standard bare ground deposition curves.

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An Application Computer Program (DRIFTSIM) to Predict Drift Distances of Water Droplets From Field Sprayers

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Computer simulation provides a means of determining the relative effects of various factors on spray drift while field experiments to measure spray drift have the limitation that many variables cannot be controlled. An application computer program (DRIFTSIM) was developed to rapidly estimate the mean drift distances of discrete sizes of water droplets discharged from atomizers on field sprayers. The program interpolates values from a large database of drift distances originally calculated with FLUENT. The simulation of drift distances up to 200 m included temperatures (10° to 30°C), discharge heights (0 to 2.0 m), initial downward droplet velocities (0 to 50 m/s), relative humidity (10 to 100%), wind velocities (0 to 10 m/s), droplet sizes (10 to 2000µm), and 20% turbulence intensity. The program requires about 15.5 Mb of disk space. Variables can be either in metric or English units and input can be either individual droplet sizes or size classes with portion of volume in each class. The program prompts the operator for values of spray variables. Many inexpensive, portable computers would be sufficient to run the program.

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Association of 2,4-D Residues in Air/Deposition Samples with Wine Grape Vineyard Injury in U.S. Pacific Northwest

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This poster examines the results from an extensive field monitoring program that was initiated in the spring of 2003 for evaluating off-target aerial movement of the cereal-grain herbicide 2,4-D to wine grape vineyards in the Walla-Walla Valley WA. In this monitoring program, high-volume two-stage air samplers were used to routinely (biweekly) collect airborne 2,4-D residues over a 24-hour interval at 6 vineyard locations. At these monitoring locations, wet/dry deposition samples were also routinely collected. Deposition and high volume air samples were analyzed for 2,4-D free acids by gas chromatography with electron capture detection. 2,4-D was routinely observed in air samples at all vineyard locations. A plant injury rating system was developed using representative Merlot cultivars from 5 Walla Walla vineyard locations. The leaves were numbered and noted as to when they were fully expanded for accurate leaf position dating. The expanded leaf positions were inspected and ranked (0 to 5) to index the severity of leaf injury from phenoxy-type herbicide exposure, and to approximate the day of herbicide exposure. Vineyard symptomology from phenoxy-type injury ranged from light to severe and was associated with air and deposition residues observed at the various vineyard locations. Severe vine injury and high 2,4-D residues in air and deposition samples at one vineyard location were associated with an localized off-target drift incident. The combined 2003 air residue and plant index data also indicated that chronic vineyard injury allegedly from regional off-target 2,4-D movement remains a concern in the Walla Walla Valley.

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Best Management Practices for Orchard Spraying: Protecting Water Quality in the Hood River Basin of Oregon

Steve Castagnoli, Oregon State University, Hood River, OR,US

There are approximately 15,000 acres of fruit orchards in the Hood River Valley requiring intensive pest management programs. Beginning in 1999, water quality monitoring conducted by the Oregon Department of Environmental Quality (DEQ) indicated exceeding of state water quality standards for pesticides in area streams, including the organophosphate insecticides chlorpyrifos and azinphos-methyl. Spray drift from orchard spraying was recognized as a likely source of water contamination. In response, the Hood River Grower-Shipper Association and OSU Mid-Columbia Agricultural Research and Extension Center conducted an intensive outreach program supporting grower adoption of orchard pest management practices designed to protect water quality while providing effective orchard pest management. Outreach efforts focused on best management practices (BMPs) for pesticide handling and application, which were communicated through presentations during annual grower meetings, field days, pesticide education trainings, one-on-one field visits, newsletters, and a BMP handbook and website. A survey of growers conducted in 2004 indicated increased knowledge and adoption of BMPs. Subsequent water quality monitoring by DEQ and OSU indicated generally reduced frequency and concentration for chlorpyrifos detections, but increased incidence of azinphos-methyl detections exceeding water quality standards. The BMPs for pesticide use are considered to be an important component of an overall program for reducing pesticide loading of the environment that also includes the development and adoption of improved pesticide spray application technologies and IPM programs including alternatives to chemical control.

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Combining Spray Drift and Plant Architecture Modeling

Gary Dorr, Jim Hanan, Nicholas Woods, Paul Kleinmeulman, Stephen Adkins Barry Noller, The University of Queensland, Australia

Vegetation type and structure can play an important role in determining the amount of spray drift moving away from a treated area. While there have been numerous attempts at modelling the movement of spray droplets from both ground and aerial application, the inclusion of canopy or downwind vegetation parameters within these models have often been either non-existent or very simplistic. Plant architecture informatics is an emerging discipline for the study of dynamic 3D-plant architecture in relation to the environment. It enables investigation of relationships between plant architecture and environmental entities such as spray droplets and insects. The plant architecture model utilises a set of growth rules expressed in the Lindenmayer systems (L-systems) formalism and programmed using L-studio software. By combining the plant architecture models with spray drift modelling it is possible to greatly extend the predictive ability of various vegetative structures to limit spray drift.

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Comparing Droplet Size and Velocity of Different Hydraulic Nozzle Spray Plumes.
Paul Kleinmeulman, Gary Door and Nicholas Woods, The University of Queensland, Australia

A significant proportion of pest control and crop production materials are applied to foliar and soil surfaces through liquid spraying processes. Biological efficacy and non-target contamination is often strongly affected by the transport and deposition characteristics of spray droplets and the spray target geometry. Droplet size and droplet velocity in particular have a significant effect on canopy capture and this will in turn affect the probability of off target deposition. An Oxford Laser Imaging System was used to quantify droplet size and velocity data across the spray sheet for three nozzles over a range of pressures and two formulations (water only and water + 0.1% Agral). An extended range flat fan (XR110015) was compared to a Turbo TeeJet® flat fan (TT110015) and an Air Induction (AI110015) hydraulic nozzle. This shows the difference in droplet size and velocity across the spray sheet of the three nozzles due to the effect of pressure and formulation. Modeling of the whole process can subsequently take place using this data to determine the probability and potential for spray drift for each of the nozzles.

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Cotton Response to Simulated Drift Rates of Seven Hormonal-Type Herbicides
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Cotton response was evaluated when 2,4-D ester, 2,4-D amine, dicamba, clopyralid, picloram, fluroxypyr, and triclopyr were applied at rates simulating spray drift during the 6 to 8 leaf stage at Manhattan and Hesston, Kansas. Herbicide rates represent 0, 1/100, 1/200, and 1/300 of the use rate. The use rates were 561, 561, 280, 561, 210, 561, and 561 g ai/ha for 2,4-D amine, 2,4-D ester, clopyralid, picloram, fluroxypyr, triclopyr, and dicamba, respectively. Injury from 2,4-D amine and 2,4-D ester were similar and was greater than that of other herbicides. The order of phytotoxicity was 2,4-D>picloram>dicamba>fluroxypyr>triclopyr>clopyralid.. All herbicides caused characteristic symptoms of hormonal-type herbicide except triclopyr and clopyralid that caused severe bleaching and chorosis. By 8 weeks after treatment, plants recovered from herbicide injury symptoms of all herbicides except, 2,4-D, picloram, and dicamba. All rates of 2,4-D and the two highest rates of picloram, and dicamba caused flower abortion. This research clearly showed that cotton is extremely susceptible to simulated drift rates of 2,4-D.

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Drift Characteristics of Spray Tips Measured in a Wind Tunnel
Robert E. Wolf, Kansas State University, Manhattan, KS 66506

A wind tunnel, water-sensitive papers (wsp),and DropletScan software was used to collect and compare the movement of spray droplets downwind from 22 different ground sprayer nozzles. The wind tunnel was equipped with a plant canopy and a single nozzle boom to simulate a field application. A constant wind speed of 4.6 m/s was used for the test and all nozzles were individually tested with a perpendicular orientation to the wind direction. Each nozzle was tested at a flow rate of 1.5 liters per minute and a pressure of 276 kPa. Water-sensitive papers were placed at canopy height 1, 2, and 3 meters downwind to collect the spray droplets escaping the spray swath. Percent area coverage for each wsp was generated by DropletScan for comparative purposes. High amounts of coverage would support an increased potential for spray drift. At the 1-meter location, the amount of coverage ranged from a high of 99 percent with traditional flat-fan nozzles to a low of 8 percent with the chamber design turf flood. The venturi nozzles as a group performed best overall with coverage's ranging from 36-9 percent with no significant differences in coverage found between the top seven drift reducing nozzles. The group mean for the venturi nozzles was 20 percent. This is compared to the flat-fan group at 90 percent, the preorifice and chamber nozzles at 42 percent, and the hollow cones at 72 percent. This study supports the use of drift reducing nozzles as a means for minimizing the potential for spray drift.

Drift Hazard Assessment Using CART – Cumulative Agrichemical Residue Tracking

John-Paul Praat, Lincoln Ventures Ltd, Hamilton, New Zealand and Jerzy. A. Zabkiewicz, Plant Protection Chemistry$_{NZ}$, Rotorua, New Zealand

The risks from off-site movement of agrichemicals as spray drift continues to be a concern from both economic and environmental points of view. Regulators set acceptable limits for residues, partly based on risk assessments, and these in turn lead to regulated or estimated buffer zones as a means of reducing risk from direct exposure to spray drift. However, the spray drift hazard is largely determined by the actions of the sprayer operator and site attributes at the time of spraying. Much is known about spray application and spray drift but this information is not readily available to an operator at the time of spraying. Development of a system to address these problems and the issues surrounding cumulative residues from multiple sources in areas of intense agricultural or horticultural activity has been initiated. The system is known as CART - Cumulative Agrichemical Residue Tracking, specifically relates to the application of pesticide sprays by ground based equipment and involves collection and management of spatial and temporal spray deposit data. It will have the ability to model single and multiple event scenarios, either in advance of the event, after the event or based on historical records. The application of pesticide residue dissipation rates in plant, soil and water will provide an estimate of the likely risk from the cumulative seasonal or geographical use of agrichemicals.

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Drop Sizing and Imaging of Agricultural Sprays Using Particle/Droplet Image Analyses

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To date most of the drop sizing systems used to classify nozzle performance with the BCPC scheme have been based on laser diffraction, phase-doppler or optical array spectrometry. Many of the recent developments in nozzle technology produce sprays with drops containing air inclusions. Because these internal structures can cause uncertainty with techniques that rely on diffraction or scattering there has been renewed interest in drop sizing using Particle/Droplet image analysis (PDIA). This paper examines the PDIA techniques used in the Oxford Lasers VisiSizer system. Identifies the hardware requirements and system set-up, for use in drop sizing and general image applications. The PDIA system utilises a short duration pulsed laser and a digital camera. The output from the pulsed laser is expanded through a diffuser arrangement to illuminate the area behind the drops. The camera looks at the illuminated area and captures images of the drops. Drops appear black on a light background. By using a short pulse duration laser motion blur is eliminated. For good size information drop movement should be less then one percent of the drop diameter during the laser pulse. To size drops in the images the PDIA system uses advanced analysis software and a combination of linear and depth of focus calibration methods to ensure the correct size information. The PDIA software identifies the drops in the image and determines the position of the drop in relation to the plane of focus and reports size information. Once the drop position has been determined the software implement a range of rejection and correction parameters to ensure the size information reported is statistically correct.

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Educating and Training Pesticide Applicators in Australia

John Kent, Charles Sturt University, Wagga Wagga, NSW Australia

Education and training of pesticide applicators in Australia has undergone significant changes in the last 15 years. However, industry sectors are inconsistent in their adoption of training and a more coordinated approach is required. Regulatory requirements for pesticide user training vary. The national authority regulating pesticide sale mandates training for users of specified high-risk pesticides. State-based control-of-use legislation varies considerably from no requirement to

compulsory training for all commercial users. Some States require contractors to be trained and licensed, others do not. The national agchem industry requires training of all personnel in the distribution and product sale chain. A variety of government and private training organisations train pesticide users to standards set within nationally endorsed competency levels. The leading ChemCert Australia industry accreditation program, delivered through a national network of approved trainers, incorporates legislation, label interpretation, safety, environmental protection, spray drift management, adjustment and calibration of application equipment, record keeping and risk management. Informal local industry seminars and extension programs are provided for various industry clients by consultants, education institutions and government agencies. Vocational education and training sector courses in agriculture, horticulture and environmental management incorporate competency-based pesticide user training. University courses rarely embrace significant studies in pesticide application technology and management. Through a range of excellent programs, significant progress has been made in educating and training pesticide users and managers in Australia, however, better coordination, integration and funding is needed.

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Effect of Drift Control Adjuvants on Efficacy and Spray Patterns of Roundup D-Pak™ and Roundup WeatherMax™ Applied with Extended Range Spray Nozzles

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Both laboratory and field studies were conducted in 2003 to determine the effect of drift control adjuvants, (HM9752- blend of polymeric viscosity modifies and ammonium sulfate, HM2005B-blend of plant nutrients and water soluble organic polymers and HM2006-blend of nonionic water soluble organic polymers and ammonium salts), on spray patterns and efficacy of glyphosate applied without surfactant as Roundup D-Pak˙ and with surfactant as Roundup WeatherMax˙. Earlier research has shown that herbicide application is influenced by pattern of spray delivery and by size of spray droplets wherein smaller droplets result in greater drift from the target area. Previous studies using an Insitec Measurement System laser particle analyzer have shown that these drift control adjuvants will increase droplet size of glyphosate formulations both with and without surfactants as applied with TeeJet Extended Range 110015VS spray nozzles. Percent control over all the plant species in the field study at 2 WAT with glyphosate applied with and without surfactant respectively was: no drift control adjutants, 93 to 100% and 79 to 94%; with HM9752 at 9lb./100 gal, 95 to 100% and 96-100%; with HM2005B at 9lb./100 gal, 95 to 100% and 91-98%; and with HM2006 at 9lb./100 gal, 95 to 100% and 91-99%. The width of the spray patterns with glyphosate applied with or without surfactant and without the addition of drift control adjuvants, was 45 inches and with the addition of each of the drift control adjuvants was 35 to 40 inches. Results showed that the drift control adjuvants used in this study applied with glyphosate both with and without surfactant either increased or had no effect on the efficacy of this herbicide. The spray pattern for each glyphosate mixture was adequate to provide uniform application with the spray nozzles positioned 19 inches apart along the boom.

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Effect of Sprayer Speed on Spray Drift

Jan van de Zande, WUR-A&F, Wageningen, The Netherlands

As the need for timely applications of crop protection products is more pronounced but farm sizes are growing the needed capacity for spraying is apart from increasing working widths more often managed by speeding up sprayers. This can be done as sprayers are more and more having good suspension systems that allow higher speeds in the field with minimal sprayer boom movements. However little is known on what the effect of sprayer speed is on spray drift. In a series of experiments the effect of sprayer speeds of 6 and 12 km/h is evaluated. The experiments are performed with two nozzle types; a standard flat fan (XR11004) and allow drift pre-orifice flat fan nozzle (DG11004), both sprayed at 3 bar pressure. These combinations were sprayed both with and without air assistance (Hardi Twin Force). Spray drift was measured to the soil surface next to a sprayed potato field. Also airborne drift at 5m distance from the edge of the field was measured. Results show an increase in spray drift with increasing speed. The effect of the low drift nozzle could

not compensate for the increase in spray drift because of the increase in sprayer speed. The drift reduction because of the use of nozzle type or air assistance decreased with increasing speeds. Drift reduction classification differs for different speeds.

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Estimating Pesticide Exposure Among Agricultural Communities in Washington Caused by Volatilization from Sprayed Fields

Jaya Ramaprasad, Cole Fitzpatrick, Michael Yost, Rich Fenske, University of Washington, Seattle

Previous research (Ramaprasad et al., 2004) has shown that volatilization may be an important source of inhalation exposure to pesticides with vapor pressures comparable or greater than the vapor pressure of methamidophos ($8x10^{-4}$ mmHg at 25^oC). Volatilization is a function of temperature. We estimated the increased risk from volatilization of extensively used pesticides and fungicides from sprayed fields in Washington state using an empirical relationship between flux and vapor pressure developed by Woodrow et al (1997).Usage patterns and meteorology (temperatures in the agricultural regions in the state can go higher than 100^o F) were taken into consideration. In order to identify populations that are at increased risk from agricultural spray drift we are working on crop type classification from satellite data. Preliminary results will be presented. This work is part of a larger research program to identify susceptibilities in children.

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Field Demonstrations: A Key to Reducing Drift Problems in Oregon's Grass Seed Industry

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An educational program aimed at reducing herbicide drift from grass seed fields was conducted over a ten-year period in the southern Willamette Valley of Oregon, USA. At the beginning of the program, grass seed crops were routinely sprayed with ester formulations of 2,4-D at excessive spray pressures (60 to 90 psi). Spraying was often delayed in the spring until temperatures warmed to levels where volatility could occur. Drift damage to sensitive crops and nearby urban landscapes became a serious issue in the 1990's. To address the problem, initial educational efforts focused on meetings and newsletters to increase awareness and knowledge of drift control; however, the methods used had negligible impact on changing grower spray practices. A different approach was needed, so we decided to conduct an on-farm research and demonstration program using two types of field trials. First, research plots were used to verify that amine formulations of 2,4-D applied at low pressures provided control of broadleaf weeds comparable to ester formulations. Next, larger scale demonstration plots were established using the field sprayers on grass seed farms. We equipped the sprayers with drift reduction nozzles (air induction) in exchange for farmer's participation. The on-farm field plots conducted in the community demonstrated the effectiveness of coarser spray patterns less prone to drift. In 2004, a survey of grass seed farmers found over 60% made changes in spraying practices to reduce drift as a result of the program. Field demonstrations were a key part of this effort.

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Field Test Comparisons of Drift Reducing Products for Fixed Wing Aerial Applications

Robert E. Wolf, Kansas State University, Manhattan, Kansas, USA

A field study was conducted to determine the influence of adding spray drift control products to tank mix solutions for fixed wing aerial applications. Downwind horizontal and vertical drift was collected on water sensitive paper (wsp) for measurement and analyzed with DropletScanT software. Percent area coverage for the horizontal and vertical drift profiles was used as a means to separate differences in treatments. Average crosswind speed was used as a covariant to account for deviation in wind velocity during each treatment. Covariate-adjusted least squares means were computed for each combination of product and airplane at three wind speeds according to observed percentiles during the study (low - 6.8 Km/h, medium - 11.3 Km/h, and high - 18.5 Km/h). These means were compared within wind speed group using pair wise t-tests to report the differences found at each horizontal and vertical distance. Summary data was reported representing a worst case scenario utilizing the low or 6.8 Km/h wind speed profile. From the summary data, a low-score performance value was complied for each product over all the horizontal and vertical distances to determine product rank. When compared to water, results show that some of the products did not provide any benefits for drift reduction and in fact may have increased the drift potential. A few of the products exhibited the potential to reduce the amount of drift.

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Flow Characterization of a Full-Scale, Weather-Independent Spray Testing Facility
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Field testing of agrochemicals using various spray application technologies is necessary for optimizing deposition of the pesticide onto the plant canopy and minimizing ambient drift. However, field spray testing is dependent upon the weather, which requires considerable investment in time and resources. Battelle's Ambient Breeze Tunnel (ABT) provides a wind vector-controlled facility for full-scale testing and evaluation of numerous types of spray generating systems and spray materials. The ABT facility is approximately 150 ft long, and has a 20 ft x 20 ft (center height) cross-section. A large blower at the exhaust end of the ABT provides uniform wind speeds up to 5 mph. High-efficiency filters at the exhaust end aid in minimizing the release of generated materials into the environment. Turbulence characteristics within the ABT were experimentally and theoretically examined at several downwind cross-sections and ambient wind speeds. The purpose of this work was to identify two homogeneous regions that will permit independent investigation of the dynamics of spray plume formation and turbulent diffusion. Measured velocity fluctuations were found to dissipate with distance down the length of the ABT, consistent with wind tunnel characteristics. Zones of uniform turbulence within three downwind cross-sections were identified, from which average flow characteristics were obtained by direct reduction of measurement data. Standard deviations of wind direction and plume concentration distribution were derived using models available from the literature. Results of the ABT characterization demonstrate the feasibility of using the ABT to conduct full-scale spray system evaluations for pesticide deposition and drift studies.

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Influence of Reference Nozzle Choice on Spray Drift Classification
Jan van de Zande, WUR-A&F, Wageningen, The Netherlands

The BCPC spray quality classification system utilises the Lurmark 31-03-F110 (F110/1.2/3.0) flat fan nozzle to discriminate the threshold between the classes of fine and medium spray. This reference nozzle has also now been used to classify the spray drift potential for other spray nozzle-pressure combinations. This paper discusses whether such a reference nozzle can be described in general terms (F110/1.2/3.0 or ISO 03) or needs more detail by specifying source of manufacturer, type and construction material. Comparisons of performance were made between twelve equivalent rated commercially available nozzles for spray distribution on a patternator, and spray quality and drop speed measurements with a PDPA laser. Drop size and speed data have then been used to calculate spray drift potential for standard conditions with the IDEFICS drift model. Despite identical commercial ratings, large differences can occur for spray distribution and spray quality. Calculated spray drift potential for some nozzle types could even be double that of the currently used BCPC Fine/Medium reference nozzle. It is concluded that for the classification of nozzles towards spray drift reduction classes, a unique, a detailed specification of reference nozzle is needed. Nozzles from different manufacturers of alternative designs and construction materials do affect performance too much to be freely chosen as a reference, despite their consistent specifications for spray pressure, flow rate and top angle (ISO 03 series).

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Interactive Effects of Spray Quality, Air Induction, and Herbicide Mode of Action on Weed Control

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Experiments were conducted to evaluate the relative importance of herbicide rate (full label rate and either 0.75 or 0.5 x), spray quality (medium, coarse, and very coarse), and air-induction (with or without) on post-emergent weed control using 8 different modes of action (Groups 1, 2, 4, 6, 8, 9, 10, and 22) on broadleaf and grassy weeds. A total of 90 experiments were conducted over three years in Manitoba, Saskatchewan, and Alberta. Analyses of variance were conducted on weed control, and the frequency of significant effects was tabulated for each variable. Herbicide rate was the most important determinant of weed control, having significant effects in 49% of cases (63% for grasses, 44% for broadleaves). Spray Quality had a significant effect on weed control 21% of the time (34% and 17% for grasses and broadleaf weeds, respectively). Air induction had relatively minor effects, being significant in only 15% of cases for both grasses and broadleaves. On grasses, Group 2 products were less sensitive to herbicide rate, spray quality, and air-induction than Group 1 products. On broadleaves, Group 2 and 4 products were among the least sensitive to spray quality. Group 9 was sensitive to herbicide rate and spray quality, although overall control rarely dropped below 80%. In contrast, Group 10 was less sensitive to these variables but overall levels of control were below those of Group 9.

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Modelling Canopy Interactions For Drift Mitigation

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The information generated by this research is aimed at the development of practical drift mitigation strategies for broadcast air-assisted spraying of fruit crops in the UK. Previous field studies have shown that off-target drift contamination decreases significantly between the beginning of flowering (i.e. worst-case drift condition) and full-leaf development. This paper describes a modelling approach that links the changes in off-target drift contamination to the structural changes of the target orchard. The model utilises information about the optical transmission range probability distribution of the target orchard. This information is derived from a tractor mounted LIDAR system that provides an idealised optical analogue of spray droplet transmission in the target trees closest to the sprayer. Results are presented to compare the use of different dose adjustment methods for reducing the risk of drift contamination during the application of plant protection products.

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Modeling Wind Tunnel Drift Measurements

Gary Dorr, Nicholas Woods, Andrew Hewitt, Jim Hanan, Paul Kleinmeulman, Barry Noller, Stephen Adkins, The University of Queensland, Gatton Australia

Wind tunnels have been used by a number of research groups to evaluate the risk of pesticide drift contamination from boom sprayers. These typically determine the horizontal drift distribution from 2m to 7m downwind and the vertical drift distribution at 2m downwind of a single nozzle operated at controlled conditions. A combined ballistic and random walk model of the wind tunnel drift measurements is being developed. It is proposed that the model will eventually incorporate factors such as the initial droplet size and velocity, entrained air, vortex generated by the spray plume, boundary effects due to the wind tunnel, droplet evaporation and wind tunnel characteristics. Preliminary model outputs are compared to results from drift measurements in the 1.75 m wide, 1.75m high and 10m long working section of the wind tunnel located at the University of Queensland, Gatton Campus.

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Preliminary Evaluation of the Effect of Upwind/Downwind Boom Switching and Propeller Direction on Drift of Aerially Applied Spray
Steven J. Thomson, USDA ARS, Stoneville, MS, US

A study was conducted to provide preliminary data on the effect of alternate boom switching and propeller direction on aerial spray drift. Nine alpha cellulose spray sampling sheets were placed in the swath and at three sample lines 104, 134, 195, and 317 meters downwind, perpendicular to the flight path. At each sample line, the alpha cellulose samplers were placed 30-m apart. High volume (Hi-Vol) vacuum motor air samplers with 10.2-cm diameter TFA2133 glass fiber filters were placed at the same intervals and locations downwind as the alpha cellulose samplers. Malathion at a rate of 19 L/ha was applied from the aircraft through fifty D6-46 hollow cone tips. Five total replications were conducted over two days. Each replication had four treatment combinations of boom switch (left or right, on or off) and airplane direction. For each treatment, four passes were made applying 0.11 kg chemical/ha on each pass. Swath width was 23-m and tips were directed straight down to induce measurable drift. Wind was steady, producing highly favorable conditions for testing on both days. For chemical concentration from fallout sheets, preliminary data showed no significant effect of boom switching or flight (and propeller) direction on spray concentration downwind. Samples from Hi-Vols showed similar results, but a weak interaction effect was seen between downwind distance and boom switching. Further testing is proposed to incorporate use of a new reference spray technique and string sampler for detection of airborne spray.

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Preliminary Results of an Automated On/Off Spraying System for Aerial Application
Dr. Dan Martin, USDA-ARS, APMRU, College Station, TX, US

A Gibsland GA fixed wing aircraft equipped with a computer controlled, variable rate spraying system was field tested for automated on-off spray capability. A rhodamine dye was added to the spray tank as an indicator of presence and quantity of material applied. The spray was applied over a one millimeter cotton string which was analyzed with a fluorometer to detect the commencement and cessation of application. Field tests indicated that the automated spray system could cut on and off to within fifty feet of the desired location. Precision application inherently reduces drift by reducing the overall amount of applied chemical. Variable rate aerial application testing is underway and preliminary results of this research will be presented.

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Reducing Drift and Improving Deposition in Orchards
Andrew Landers and Muhammad Farooq, Cornell University, Geneva, NY, US

99% of pesticides applied to fruit trees in North-East USA are via traditional airblast sprayers. Apple trees were traditionally grown on 20 feet rows, 20 feet tall. Modern plantings are much closer and shorter. Frequently large plumes of spray drift over and past the target, particularly in early season when very little target area exists. Trials have been conducted at Cornell University to study how changes in fan speed affect air speed, volume and direction. Indoor trials were conducted using a Gill sonic anemometer (Gill Industries, Hampshire, UK) to determine airflows. Field trials were conducted in an orchard, (20 feet rows, 11 feet trees) using an AgTec P300 (AgTec Minnesota) sprayer fitted with airshear nozzles operating at two fan speeds, 2076 rpm (540 rpm PTO) and 1557 rpm (405 rpm PTO). Drift was detected using Water sensitive cards (Syngenta, North Carolina) and analyzed using DropletScan (WRK, Cabot, AR) image analysis software. At a fan speed of 2076 rpm, drift was detected up to 80 feet from the target row where 10% card coverage occurred. Reducing fan speed by 25%, resulted in considerably less drift, with card coverage at 20 feet and 40 feet from the target row being 16% and 0.20% respectively. Reducing fan speed increased droplet size from 351 microns VMD at 2076 rpm to 460 microns VMD at 1557 rpm. Reducing fan speed provides a simple, inexpensive way of reducing drift. Methods of fan speed reduction include lowering engine speed, fitting a hydraulic motor to provide infinitely variable speed control, or applying an air restrictor.

Reducing Drift and Improving Deposition in Vineyards

Andrew Landers and Muhammad Farooq, Cornell University, Geneva, NY, US

Pesticide application in vineyards, via airblast sprayers, requires adjustment of the sprayer to direct spray into the canopy zone as it develops over the growing season. Early season applications require less air than mid to late season applications. The objective of this study was to investigate airflow characteristics and the impact of nozzle orientation on drift reduction. Air flow restrictors, similar in shape to doughnuts have been constructed to reduce airflow from the sprayer. When airflow was restricted by 20%, the doughnuts reduced drift by up to 75% in field trials under certain wind conditions. Airspeed can also be adjusted by altering engine speed or by fitting a hydraulic motor. An Italian vertical patternator (MIBO, Turin) was used to study the correct orientation of the nozzles. Results have shown potential for reducing drift and improving deposition by carefully adjusting nozzle orientation. It was also observed that adjustments in nozzle orientation on both sides of the sprayer should be independent and in consideration of airflow rate and direction on each side. The best spray pattern for the grape zone in var. Concord vines using a Berthoud S600EX airblast sprayer occurred when the right hand side nozzles were pointing horizontally and the top two nozzles were 20o below horizontal on the right side, to counteract the upward movement of the air from the fan. The uniformity in the canopy zone also improved on the up-stroke side from 42% in the grower's setting to 79% in the best setting. The uniformity, however, was not affected on the down-stroke side.

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Reducing Driftable Fines in Aerial Application of Pesticides by Controlling Nozzle Environment

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Spray drift is one of the most significant issues facing aerial applicators. Material not applied to the target crop or pest is a financial loss for the farmer and a potential liability for the applicator. Off-site drift also represents an environmental liability, particularly as habitat and water quality concerns demand greater attention with larger buffer and/or no-spray zones. Current practice delivers liquid material through a nozzle, under pressure, and utilizes air shear for at least a portion of the atomization, creating a range of droplets with those less than 200 microns, known as fines, particularly susceptible to off-site drift. As airspeed increases, so does the effect of air shear on the spray leaving the nozzle, resulting in further shatter/fracture producing even more fines, leading to more off-site drift. Control of nozzle environment allows control of air velocity where atomization occurs, reducing driftable fine production and reducing off-site movement of spray material. Control of nozzle environment is accomplished using a chamber having 3-sections, called a Reverse Venturi Atomization Chamber (RVA). Air enters the first section (diffuser), with a restricted opening, and flows into a larger area (settling chamber) where air velocities are reduced, the nozzle is located, and where atomization occurs. The atomized spray and air then travel through the third chamber (constrictor) where they are accelerated to match the aircraft's air speed. By reducing the air speed were atomization occurs, the atomization profile produces fewer fines, leading to less drift. Data to date, using the RVA chamber, with commercially available nozzles, has demonstrated up to a 74% reduction in fines at 100 mph and 58% reduction in fines at 150 mph airspeed.

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Regional Pesticide Recommendations of the U.S. Fish and Wildlife Service for Protection of Threatened and Endangered Species

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Application of pesticides can potentially impact animal and plant species that have been listed as threatened or endangered under the Endangered Species Act of 1973. The U.S. Fish and Wildlife Service (Service) has recently developed a reference document entitled “Recommended Protection Measures for Pesticide Applications in Region 2 of the U.S. Fish and Wildlife Service” that contains information on protecting threatened and endangered (T&E) species in the Service’s southwest region (Region 2) of Arizona, New Mexico, Oklahoma, and Texas. The overall purpose of the document is to provide recommendations to Service personnel, government agencies, and pesticide users for pesticide applications in Region 2 that potentially involve T&E species, migratory birds, and national wildlife refuges or fish hatcheries. The document recommends specific protection measures based on a screening-level hazard assessment for various pesticide toxicities. As part of the hazard assessment process, active ingredients of pesticides are classified according to a system of pesticide ecotox classes and toxicological groupings of species. The ecotox class ratings for a given pesticide are used to approximate adequate buffer zones for individual species with respect to physical characteristics of pesticide spray drift and/or residues in surface runoff. Pesticide protection measures suggested in the reference document can be used in Endangered Species Act processes such as Service consultations with Federal agencies and development of Habitat Conservation Plans.

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Research to Reduce Potential Damage From Spray Drift Loss by the USDA-ARS Application Technology Research Unit

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For over two decades, several research programs related to spray drift reduction have been conducted at the USDA-ARS Application Technology Research Unit (ATRU) in Wooster, Ohio. Capture efficiency studies investigated using nylon filter screens, cotton floss, plastic tapes, cellulose filters in high volume air samples for effectiveness in collecting spray drifts in the field and wind tunnel. The ATRU staff investigated droplet sizes, spray patterns, and drift reduction using various drift retardant additives in a wind tunnel, and developed a test stand system to evaluate shear effects on spray drift retardant performance. A simple viscometry system was developed to measure viscosity at high shear rates for spray mixes containing different drift retardants composed of either polyethylene oxides, polyacrylamides, or a polysaccharide. The ATRU conducted nursery field experiments to determine off-target drift loss in a commercial nursery using electron beam and conductivity analysis. FLUENT software and a wind tunnel to were used to design shields with various shapes to reduce spray drift potential from sprayers fitted with conventional hydraulic nozzles. Wind tunnel and atomization studies demonstrated the potential for air induction nozzles to reduce drift. Drift reduction nozzles have been incorporated into efficacy evaluations in disease and insect management trial and in some cases, demonstrate little loss in efficacy for the larger droplet applications. Studies of the drift potential of conventional, axial fan sprayers as well as tower sprayers in semi-dwarf apple canopies as well as shade trees and other nursery crops reveal the effect of sprayer configuration and spray direction.

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Results from Field Scale Trials Comparing Air Induction And Standard Flat Fan Nozzles at Reduced Volumes

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To test if it is possible to offer increased work rates, without loss of biological efficacy at reduced volumes using fungicides in winter wheat using drift reducing air induction nozzles compared with standard flat fan nozzles. Also herbicides for total weed control at reduced volumes with air induction nozzles. A series of four field trials were carried out using, commercial, farm crop sprayers in winter wheat during the 2002 - 2003 season. The fungicides were generally applied at T2 and T3 growth stages at application rates of 100 l/ha and 50 l/ha. Air Induction nozzles producing "small" droplets were compared with standard flat fan nozzles of the same size. The trials were taken through to harvest and the yields recorded. No significant differences in yields were found for any of the treatments. It is therefore suggested that drift reducing air induction nozzles, with "small" droplets could be used, where appropriate, to increase work rates. For the herbicide trial similar applications to the above were made to ascertain the degree of weed control in set aside and also stubble cleaning. The weed control was similar in both cases leading to the same conclusions as for the fungicide trials.

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Risk Assessment of Malathion Drift to Home Gardens in the Boll Weevil Eradication Program
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The Boll Weevil Eradication Program is a cooperative effort between federal agencies, state governments, and cotton growers to systematically eliminate the cotton boll weevil from the United States using integrated pest management techniques including coordinated applications of malathion. USDA Animal and Plant Health Inspection Service monitoring of this program provided field information on malathion application intervals and residues from drift on vegetation near gardens. These data were used to assess the risk to human health from the consumption of contaminated vegetation, which is thought to provide the greatest exposure risk to humans living next to cotton fields in the Program. The estimated dose of malathion ingested from contaminated vegetation was compared to EPA-determined reference doses for malathion. Acute and chronic hazard quotients were calculated using known ranges of the different parameters in order to account for their variability. No acute or chronic risks from program-applied malathion were found, except for when chronic estimations used worst-case scenario parameters in the calculations. These estimations used the highest malathion residues, the highest remaining residues after washing, and the greatest consumption of vegetables. It is unlikely that this estimated chronic risk posed any threat, as it assumed a worst-case daily intake of malathion over a year whereas the chemical was in use by the program for approximately two months. Based on this work, recommendations were made to reduce the worst-case chronic risk scenario.

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Simulated Drift of Glyphosate and Imazamox on Winter Wheat
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Off-target movement of many herbicides can have a significant influence on the growth and development of winter wheat. Glyphosate and imazamox are common pre-plant burndown and postemergence herbicides that may be applied to fields in close proximity to wheat in the spring. Consequently, drift of these herbicides onto wheat at critical stages of growth and development can cause serious injury and yield reductions. Field research was conducted at Hays and Manhattan, Kansas in 2002 and 2003, to determine the effects of simulated drift of glyphosate and imazamox on winter wheat. Glyphosate and imazamox at 1/100X, 1/33X, 1/10X, and 1/3X of typical field use rates were applied individually to wheat in the early jointing or the early flower stages of growth. The 1X use rates of glyphosate and imazamox were 840 g ae/ha and 35 g ai/ha, respectively. Crop injury was evaluated at 2 and 4 weeks after treatment, and wheat was harvested at the end of the season to determine yields and the viability of the harvested seed. A significant interaction occurred among the locations and years, probably due to differences in precipitation amounts and distribution through the growing season. Wheat injury and yield loss increased as herbicide rate was increased, with minimal effect from either herbicide at the 1/100X rate, and near complete kill and yield loss of wheat from both herbicides applied at the 1/3X rate, regardless of application stage. The greatest differences between herbicides and treatment stages occurred at the 1/33 and 1/10X rates. In general, wheat injury and yield reduction was greater from glyphosate than imazamox. Wheat injury and yield loss generally was greater from herbicide treatment at the jointing stage than at the heading stage of wheat development. Drought stress on the wheat at Hays in 2002 appeared to reduce the effect of the herbicide treatments on the wheat compared to the other year and location. Correlation analysis suggests that visual injury is an accurate indicator of future yield reductions. Germination tests on the harvested grain sample suggested that the viability of the wheat seed was not reduced if plants survived the herbicide treatment and produced a harvestable seed.

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Spray Drift Potential in Citrus Applications
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Rapid expansion of urban developments in Florida and proximity of the residential areas to citrus groves has made the drift issue more critical than ever. In some cases, it has become a limiting factor for continuation of certain operations. To mitigate the problem, a series of drift experiments were conducted in a citrus grove. The objective of the research was to collect data on drift potential of the citrus sprays and identify sprayers and operating variables that could reduce spray drift from commonly practiced applications. Five air-carrier sprayers were used in the experiments. The sprayers were equipped with various hydraulic nozzles or rotary atomizers and included air-blast and air-curtain air delivery systems with conventional low-profile and tower configurations. Spray volume rate ranged from 230 to 4,380 L/ha at ground speeds of 2.4 - 5.8 km/h. Spray solutions, containing a fluorescent tracer, were applied to 4.5 - 5.5 m tall orange trees, in 3–5 replications. Drift deposits were sampled on vertical polyester string targets or on filters of high-volume air samplers, positioned at two sides of the spray row. The experiments showed that every application has some drift potential but the magnitude of drift deposits could vary by sprayer design, operating variables, and prevailing weather conditions. In general, sprayers with tower configuration, larger nozzles (droplets), higher application rates, and lower ground speeds showed less potential for the above canopy spray drift. Overall, drift potential of the tested citrus applications appeared to be less than 8% of the applied rate, under unstable weather conditions.

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The Effect of a Herbicide and Additives on Spray Particle Sizes Size Distribution

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The American Society of Agricultural Engineers Pest Control and Fertilizer Committee developed ASAE S572, Spray Nozzle Classification by Droplet Spectra. This standard defines droplet spectrum categories for the classification of spray nozzles, relative to specified reference fan nozzles discharging spray into static air or so that no stream of air enhances atomization. The droplet spectra produced by single elliptical orifice reference nozzles with specified: liquid mixture (water), liquid flow rates, operating pressures, and spray angles. All of which are specified by the standard establish the threshold of division between nozzle classification categories. Generally the Standard is based on spraying water through the reference nozzles and nozzles to be classified. However, spray liquid properties may affect droplet sizes. Most if not all classification of nozzles have been done with water. Research was accomplished with a Helos/Vario-KF Analyzer with R6 lens, which by laser light diffraction, can determine particle size from 0.5 to 1770 microns. This poster will display the effects on spray particle size and spray particle size distribution that Roundup Weather Max with ammonium sulfate has with and without Array, Border and Placement with water compared to water. The nozzles used were Spraying Systems Extended Range, Turbo TeeJet, Turbo Flood and Air Induction. Both the herbicide and additives affected particle size and particle size distribution. Some nozzles are affected more than others and would result in the nozzle receiving a different droplet Spectra classification.

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Yield and Physiological Response of Nontransgenic Cotton to Simulated Glyphosate Drift

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Field studies were conducted in 2001 in Lewiston-Woodville, NC and in 2002 at Clayton and Lewiston-Woodville, NC to investigate the response of nontransgenic cotton to simulated glyphosate drift in a weed-free environment. Nontransgenic cotton variety ŒFibermax 989, was planted in a conventional seedbed at all locations. Glyphosate treatments were applied early postemergence (EPOST) at the 4-leaf growth stage of cotton at 0, 8.7, 17.5, 35, 70, 140, 280, 560, and 1,120 g ai/ha and represents 0, 0.78, 1.55, 3.13, 6.25, 12.5, 25, 50, and 100% of the commercial use rate, respectively. Rates as low as 140 g/ha caused lint yield reductions depending on year and location. When averaged over all locations, lint yield reductions of 4, 49, 72, and 87% compared with nontreated cotton were observed with glyphosate rates of 140, 280, 560, and 1,120 g/ha, respectively. Visual injury and shikimic acid accumulation were evident at glyphosate rates greater or equal to 70 g/ha. Collectively, visual injury and shikimic acid accumulation at 7 DAT might be used as a diagnostic indicator to predict potential yield reductions from simulated glyphosate drift.