The Society for engineering in agricultural, food, and biological systems

Paper Number: AA03-003
An ASAE Meeting Presentation

Spray Mix Adjuvants for Spray Drift Mitigation

I. W. Kirk, ASAE Life Member

Agricultural Research Service, USDA, 2771 F&B Road,
College Station, Texas 77845-4966 USA

Written for presentation at the
2003 ASAE/NAAA Technical Session
Reno, Nevada, USA
December, 2003

Abstract. *Numerous drift reduction adjuvants and spray deposition aids are available to applicators of crop production and protection chemicals. Performance of many of the newly introduced drift control adjuvants has not been well documented for aerial application. Since there are no product labeling or efficacy regulations for these adjuvants, applicators must rely on experience or information in the technical literature for evaluating their performance. Twelve new drift control adjuvants were selected for atomization studies in a wind tunnel to document their performance as applicable to aerial application. Spray droplet size is the primary factor that applicators can control to influence spray drift. Atomization performance of spray adjuvants in a wind tunnel is closely related to their performance under field conditions. The adjuvants were mixed in a blank emulsifiable concentrate tank mix at their maximum recommended label rate for aerial application. Atomization data were collected with a laser spectrometer on the first and eighth passes through a gear pump. The eighth pass simulates any effect of shear breakdown and loss of effectiveness of the adjuvant from bypass and recirculation in the spray tank during application. Most of the adjuvants move the droplet spectra classification from fine to medium. The most effective adjuvant moved the droplet spectra classification from fine to coarse. This performance information will aid aerial applicators in selecting drift reduction agents to meet the drift mitigation criterion for a given application.*

Keywords. Aircraft, nozzles, drift, spray, droplet size, adjuvant, wind tunnel

The author is an ASAE Member Engineer and is solely responsible for the content of this technical presentation. Please contact the corresponding author at i-kirk@tamu.edu for additional information. The technical presentation does not necessarily reflect the official position of the American Society of Agricultural Engineers (ASAE), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by ASAE editorial committees; therefore, they are not to be presented as refereed publications. Citation of this work should be as follows: Kirk, I. W. 2003. Spray Mix Adjuvants for Spray Drift Mitigation. ASAE Meeting Paper No. AA03-003. St. Joseph, Mich.: ASAE. Trade names are mentioned solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture, or ASAE, and does not imply endorsement of the product over other products not mentioned. For information about securing permission to reprint or reproduce a technical presentation, please contact ASAE at hq@asae.org or 616.429.0300 (2950 Niles Road, St. Joseph, MI 49085-9659 USA).

Introduction

Spray droplet size has long been recognized as the most important variable that aerial applicators can influence to mitigate spray drift from the application site (Yates et al., 1976; Bouse et al., 1988; Bird et al., 1996; Anon., 1997). Sprays with coarse droplet spectra drift less than sprays with fine droplet spectra, but applicators must also consider droplet size for optimum efficacy of the applied material. Spray nozzle selection is the first factor for aerial applicators to consider in determining spray droplet size or spectrum. Secondary considerations are those operational factors that influence atomization such as nozzle angle or deflection relative to the airstream, aircraft speed, and spray pressure. The auxiliary factor often considered for drift reduction by aerial applicators, after nozzle selection and operation, is spray mix additives or adjuvants. There are many types of spray adjuvants with classifications such as surfactants, spreaders, stickers, deposition aids, activators, humectants, antifoamers, wetting agents, and drift reduction agents. Soaps and oils of various types were some of the materials first used as spray adjuvants, but products designed and formulated for specific purposes have been available for several years. Water soluble synthetic polymers were the dominant components of most of the adjuvants that were first designed and marketed for spray drift control (Bouse et al., 1988). These materials were generally effective in increasing spray droplet size and reducing the content of fine droplets that are more prone to drift from the application site. More recently, natural and other polymers, often formulated as dry materials, have been marketed for spray drift reduction. There is only limited technical literature on aerial performance of the newer drift reduction adjuvants (Wolf et al., 2002, 2003; Hewitt, 2003; and Wolf and Gardisser, 2003).

The modern era of adjuvant science was bolstered by the First International Symposium on Adjuvants for Agrochemicals in 1986 and subsequent publication of the symposium proceedings (Chow et al., 1989). Spray drift became a significant issue with the introduction and use of phenoxy herbicides and the associated off-target damage to sensitive vegetation. Spray drift continues as an industry issue with enhanced concerns about environmental trespass, threatened and endangered species, and associated regulatory actions (Mulkey, 2001).

The scientific and technical community has responded to these issues and actions in several venues. A technical committee of the American Society of Agricultural Engineers (ASAE), through its Cooperative Standards Program, developed a standard, ASAE S572 AUG99, (Womac et al., 1999 and ASAE Standards, 2003) that was fashioned after a similar standard developed by the British Crop Protection Council (BCPC) (Doble et al., 1985 and Southcombe et al., 1997). Both standards characterize sprays by ranges of droplet sizes. The BCPC used spray quality for the general term for all of the droplet size categories; the ASAE standard uses the general term – droplet spectra classification (DSC) to define the droplet size categories. The ASAE standard defines DSC categories ranging from Very Fine (VF) through Fine (F), Medium (M), Coarse (C), Very Coarse (VC), to Extremely Course (XC). The ASAE standard will be used in the USA for classifying agricultural sprays on product labels and in regulatory actions. DSC values are a part of current nomenclature and understanding of agricultural sprays and are consequently a part of this presentation on performance of spray drift adjuvants.

Objective

The objective of this study was to determine the effectiveness – based on increased droplet size, reduction of fine droplet content, and resistance to pump shear degradation – of some of the recently-introduced drift reduction adjuvants for typical aerial spray applications.

Materials and Methods

Drift reduction adjuvants (table 1) were obtained from product manufacturers and commercial sources for this study.

Previous research indicated that inadequate amounts of drift reduction adjuvants in the spray mix could result in increased incidence of driftable fine droplets (Bouse, et al., 1988). Consequently, the maximum recommended label rate for aerial application for each product was used for the respective spray mixes. A blank emulsifiable concentrate (EC) product mixed with tap water was used as the spray mix for testing each spray drift reduction adjuvant. The spray mix was made up of 90 percent tap water and 10 percent EC blank plus the recommended maximum label rate of the respective adjuvant for aerial application. The EC blank (Hewitt, 2002) was made up of 92 percent w/w Aromatic 150 (ExxonMobil Corporation, Houston, Texas), 1.6 percent w/w Toximul 3454F (Stephan Company, Northfield, Illinois) and 6.4 percent w/w Toximul 3453F (Stephan Company, Northfield, Illinois). This EC blank spray mix was considered reasonable because many pesticides are formulated as emulsifiable concentrates. Also, the performance of a drift adjuvant in water alone is of little consequence. Spray mixes of 115 L (30 gal) were prepared according to manufacturer's directions for each drift reduction adjuvant. The EC blank was added in the mixing sequence specified by the adjuvant label for addition of the pesticide. The spray mixing process typically lasted about 10 minutes with spray tank agitation provided by an engine driven aircraft centrifugal pump.

Table 1. Spray drift reduction adjuvants, principal functioning agents (PFA), and rates used for atomization analyses.

Adjuvant	Principal Functioning Agent (PFA)	% PFA	Adjuvant Rate in Spray Mix	Formulation
Airex DC	Acrylamide copolymer, humectants Ammonium sulfate (Terawet Corporation)	35 15	1.56 %v/v (2 oz/gal)	Liquid

Array	Proprietary blend of micro homogenized organo modified elasto polymers and ammonium salts (Rosen's, Inc.)	100	1.68 % w/w (14 lb/100gal)	Dry
Border EG 250	Proprietary blend of nonionic water soluble HRG polymers (Precision Laboratories, Inc.)	75	0.075 % w/w (10 oz/100gal)	Dry
Cell-U-Wett	Sodium cellulose glycolate (Griffin Corporation)	99.5	0.18 % w/w (1.5 lb/100gal)	Dry
Control	Polyvinyl polymer (polyacrylamide) (Garrco Products, Inc.)	35	0.0625 % v/v (8 oz/100gal)	Liquid
Corral Poly	Polyvinyl polymer (polyacrylamide) (Agriliance, LLC)	30	0.0625 % v/v (8 oz/100gal)	Liquid
Direct	Polyvinyl polymer (polyacrylamide) (Precision Laboratories, Inc.)	30	0.0313 % v/v (4 oz/100gal)	Liquid
In-Place	Amine salts of organic acids, Aromatic acid, Aromatic and aliphatic petroleum distillate (Wilbur-Ellis Company)	100	3.06 % v/v (1 part/ 4 parts chemical)	Liquid
Intac Plus	Blend of copolymers and organosilicone surfactant fluid (Loveland Industries, Inc.)	15	0.781 % v/v (3 oz/acre)	Liquid
SanAg 41-A	Polyacrylamide polymer Polysaccharide polymer (Sanitek Products, Inc.)	27 3	0.0375 % w/w (5 oz/100gal)	Dry

StrikeZone PPS	Proprietary blend of nonionic water soluble organic polymers and ammonium salts (Helena Chemical Company)	100	1.44 % w/w (12 lb/100 gal)	Dry
Valid	Lecithin, Emilsifiers, Glycols and Defoamer (Loveland Industries, Inc.)	100	0.125 % v/v (16 oz/100gal)	Liquid

A wind tunnel previously described by Bouse et al. (1988, 1990) consisting of an engine driven centrifugal fan fitted with a converging duct with internal flow straighteners was used to generate a high-speed airstream. An aircraft boom section with a centrally-located single nozzle was placed in the exhaust airstream. The spray nozzle selected for the study was a CP-03 (The CP Products Company, Inc.) for use on agricultural aircraft. An orifice size of 0.078 and a deflector angle of 30° were used for all tests. Spray pressure was maintained with an electrically powered gear pump (Teel 1P785, Dayton Electric Mfg. Co.) at 210 kPa (30 psi) and airspeed at the nozzle was maintained at 225 km/h (140 mph) during each atomization test. The by-pass from the gear pump during an atomization test was directed to a second tank so there would be no uncontrolled recirculation through the pump. A PMS laser spectrometer (Particle Measuring Systems, Inc.), OAP-2D-GA1 probe and PC data acquisition system was used to image and size 12,000-18,000 spray droplets in four horizontal atomization scans of the probe through the spray plume. The laser scanning position was 0.75 m (2.5 ft) downstream from the spray nozzle. The height of the plume was measured and scans through the spray plume were made at 1/8, 3/8, 5/8, and 7/8 levels in the plume. These scans were replicated three times on the same spray mix of each drift reduction adjuvant. The typical time for these three replications was about 20 minutes. The remaining spray mix was then passed through the gear pump to the second tank and then back and forth to accumulate 7 passes through the pump. Each of these passes through the pump lasted about 6 minutes. The atomization scans were then repeated on the eighth pass of the spray mix through the pump. Atomization scans were made on the water and EC blank spray mix (without addition of drift reduction adjuvant) to serve as a basis or standard for determining the relative effectiveness of the respective drift reduction adjuvants. Statistical analyses were completed on selected atomization parameters with the SAS GLM Procedure (SAS System v8.02, SAS Institute, Inc., Cary, N.C.).

Results and Discussion

Wind tunnel atomization results for the EC blank spray mix alone and with twelve spray drift reduction adjuvants are presented in table 2. *Intac Plus* and *Valid* were ineffective in altering the atomization properties of the EC blank spray mix. *In-Place* degraded spray drift atomization properties of the EC blank spray mix.

Droplet Spectra Classification

The droplet spectra classification (DSC) for the EC blank spray mix was Fine. *Array*, *Border EG 250*, *Cell-U-Wett*, *Control*, *Corral Poly*, and *StrikeZone PPS* increased the DSC to at least Medium for both the first and eighth passes through the pump. *Direct* increased the DSC to Medium for the first pass through the pump, but the DSC was degraded to Fine on the eighth pass through the pump. *Corral Poly* increased the DSC to Coarse for the first pass through the pump, but the DSC was degraded to Medium on the eighth pass through the pump. *Airex DC* and *SanAg 41-A* changed the spray drift atomization properties of the EC blank spray mix, but not enough to increase the DSC from the Fine category to a Medium category.

The similarity of DSC's for the different spray drift adjuvants and significant differences in spray droplet size and spray drift mitigation parameters reflects on the very broad nature of the DSC categories. It further indicates that applicators can benefit in spray drift mitigation by appropriate attention to other atomization parameters in addition to guidelines such as DSC that may be specified on product labels.

Spray Droplet Size

The parameters typically used to characterize droplet size of agricultural sprays are $D_{V0.1}$, $D_{V0.5}$, $D_{V0.9}$, and Relative Span (ASAE S327.2 FEB03, ASAE Standards, 2003). *In-Place*, *Intac Plus*, and *Valid* were ineffective in changing the spray droplet size properties of the EC blank spray mix. The other drift reduction adjuvants increased each of the droplet size parameters to different levels as noted by the parameter significance levels in table 2. *Corral Poly* provided significantly larger droplet size spectra than the other drift control adjuvants; *Control* was second best relative to increasing spray droplet size parameters. *Corral Poly* and *Control* are liquid formulations of polyvinyl polymers. *Border EG 250*, *Cell-U-Wett*, and *StrikeZone PPS* were the three next-best adjuvants for increasing spray droplet size parameters; these three drift reduction adjuvants are dry formulations of synthetic or natural polymers.

Relative Span is a measure of the range of droplet sizes in the mid eighty percent of the droplet size spectrum. Relative Span of the EC Blank spray mix was low in this study. *Corral Poly* and *Control* had the highest Relative Spans measured in this study, but the values were only slightly above 1.0, indicating that the drift control adjuvants were reasonably effective in moving the spray droplet size spectrum up-scale without excessively widening Relative Span.

Spray droplet size parameters for most of the drift reduction adjuvants decreased significantly after undergoing shear stresses from eight passes through the gear pump, but the two products reflecting better spray spectrum properties for drift mitigation were better after eight passes than the next best products were on the first pass through the gear pump. It is interesting to note that droplet size parameters for four of the five dry formulated adjuvants – *Array, Border EG 250*, *Cell-U-Wett*, and *StrikeZone PPS* – did not degrade from eight passes through the gear pump.

Spray Drift Mitigation

The percentages of the spray volume in droplets less than 100 µm diameter (%<100µm) or less than 200 µm diameter (%<200µm) are general indicators of the spray drift propensity of a given spray droplet spectrum. The spray volume in droplets less than 100 µm diameter were in a relatively narrow spread of values, but statistical significance values for these properties were relatively consistent with the other atomization parameters. The %<200µm was reduced from 12.4 percent with the EC blank alone to relatively low single digit values, except for the adjuvants – *In-Place*, *Intac Plus*, and *Valid*, which were previously noted as ineffective in influencing the spray drift properties of the spray mix. The percentage of the spray volume in spray droplets larger than 400 µm diameter was increased by an average of 45 percentage points by use of the various drift control adjuvants, not considering the three adjuvants that were ineffective in the EC blank spray mix. *Corral Poly* provided significantly lower percentages of driftable fine droplets (%<200µm), and higher percentage of droplets greater than 400 µm diameter (less prone to drift) than the other adjuvants; *Control* was second best relative to these same parameters. Both of these adjuvants are liquid formulations of polyvinyl polymers;

however, the three next-best adjuvants relative to these same parameters – *Border EG 250*, *Cell-U-Wett*, and *StrikeZone PPS* – are all dry formulations of synthetic or natural polymers.

Table 2. Spray spectrum parameters for twelve drift reduction adjuvants in an EC blank spray mix as compared to the EC blank spray mix with no drift reduction adjuvant.

Adjuvant		Spray Spectrum Parameters[a] [b]							
		$D_{V0.1}$	$D_{V0.5}$	$D_{V0.9}$	RS	%<100µm	%<200µm	%>400µm	DSC[c]
EC Blank		191 n	278 k	385 j	0.69 f	0.6 c	12.4 c	8.0 m	F
Airex DC	First Pass	227 k	338 h	517 ghi	0.86 bc	0.3 e	5.3 gh	29.9 j	F
	8th Pass	221 l	329 ij	495 hi	0.83 cd	0.4 d	6.0 fg	26.8 kl	F
Array	First Pass	232 ij	357 g	534 fgh	0.84 bcd	0.4 d	5.0 hi	37.0 i	M
	8th Pass	232 ij	355 g	544 fg	0.88 bc	0.3 e	4.9 hij	36.1 i	M
Border EG 250	First Pass	253 de	403 d	624 c	0.92 b	0.3 e	3.5 m	50.6 de	M
	8th Pass	249 e	392 e	601 cd	0.89 bc	0.3 e	3.7 lm	48.3 ef	M
Cell-U-Wett	First Pass	236 ih	369 f	568 def	0.90 bc	0.3 e	4.6 ijk	41.3 gh	M
	8th Pass	240 fg	376 f	568 def	0.87 bc	0.3 e	4.3 ijklm	43.2 g	M
Control	First Pass	274 c	463 c	753 b	1.03 a	0.2 f	2.6 n	63.9 c	M
	8th Pass	255 d	409 d	619 c	0.89 bc	0.3 e	3.5 m	52.3 d	M
Corral Poly	First Pass	307 a	529 a	879 a	1.08 a	0.2 f	1.5 o	75.9 a	C
	8th Pass	288 b	484 b	774 b	1.01 a	0.2 f	1.9 no	68.5 b	M
Direct	First Pass	241 fg	368 f	550 efg	0.84 bcd	0.3 e	4.0 klm	40.4 h	M
	8th Pass	231 jk	344 h	496 hi	0.77 de	0.3 e	4.8 hijkl	30.6 j	F
In-Place	First Pass	166 p	249 m	338 k	0.69 f	1.3 a	21.8 a	3.1 n	F
	8th Pass	177 o	258 l	354 jk	0.69 f	0.9 b	18.3 b	5.0 n	F
Intac Plus	First Pass	190 n	276 k	386 j	0.71 ef	0.6 c	13.1 c	8.1 m	F
	8th Pass	189 n	276 k	380 j	0.69 f	0.6 c	12.6 c	7.4 m	F
SanAg 41-A	First Pass	221 l	336 hi	512 f	0.87 bc	0.4 d	6.2 f	29.1 jk	F
	8th Pass	215 m	327 j	489 i	0.85 bcd	0.4 d	7.0 e	25.3 l	F
StrikeZone PPS	First Pass	238 gh	371 f	573 def	0.90 bc	0.3 e	4.5 ijkl	41.8 gh	M
	8th Pass	243 f	388 e	589 cde	0.89 bc	0.3 e	4.1 jklm	47.0 f	M
Valid	First Pass	193 n	281 k	383 j	0.70 ef	0.6 c	11.6 d	7.7 m	F
	8th Pass	190 n	279 k	385 j	0.68 f	0.7 c	12.4 c	8.0 m	F

[a] ASAE S327.2 FEB03 (ASAE Standards, 2003).

[b] Parameter values by column with the same letters or groups of letters are not significantly different at 0.05 level of Duncan's New Multiple Range Test.

[c] ASAE S572 AUG99 (ASAE Standards, 2003).

Summary

Off-target drift of sprays applied for crop production and protection is a significant issue related to damages caused outside of sprayed areas. Spray droplet size is a major factor influencing off-target drift of sprayed materials. Spray mix adjuvants are marketed for reducing spray drift. The primary effect of these adjuvants is increasing spray droplet size and reducing the driftable fine component of the spray spectrum. Simulated agricultural sprays were atomized in a wind tunnel with drift reduction adjuvants in the spray mix at rates and conditions typical of aerial spray application. The effectiveness of the adjuvants in increasing spray droplet size is different for different adjuvants. Based on these wind tunnel studies with the EC blank spray mix, the drift retardant adjuvants in this study – except for *In-Place*, *Intac Plus*, and *Valid* – should provide a measure of spray drift mitigation in commercial use. The measure of drift mitigation attained with drift reduction adjuvants is a matter that applicators can balance or optimize based on adjuvant performance and economics to achieve drift mitigation goals for a given application.

Acknowledgments

Special appreciation is expressed to drift adjuvant manufacturers and suppliers for providing materials for this study. P. C. Jank, provided technical support with data collection, processing, and compilation.

References

Anon. 1997. A summary of aerial application studies. Spray Drift Task Force. For more information contact David R. Johnson at Stewart Agricultural Research Services, Inc., P.O. Box 509, Macon, Missouri 63552.

ASAE Standards, 50th Ed. 2003. St. Joseph, Mich.: ASAE.

Bird, S. L., D. M. Esterly, and S. G. Perry. 1996. Off-target deposition of pesticides from agricultural aerial spray applications. Journal of Environmental Quality 25:1095-1104.

Bouse, L. F., J. B. Carlton, and P. C. Jank. 1988. Effect of water soluble polymers on spray droplet size. Transactions of the ASAE 31(6):1633-1641, 1648.

Bouse, L. F., I. W. Kirk, and L. E. Bode. 1990. Effect of spray mixture on droplet size. Transactions of the ASAE 33(3):783-788.

Chow, P. N. P., C. A. Grant, A. M. Hinshalwood, and E. Simundsson. 1989. Adjuvants and Agrochemicals, Volumes I and II. Boca Raton, Florida: CRC Press.

Doble, S. J., G. A. Matthews, I. Rutherford, and E. S. E. Southcombe. 1985. A system for classifying hydraulic and other atomizers into categories of spray quality. Proceedings of British Crop Protection Conference -- Weeds, 3, 1125-1133.

Hewitt, A. J. 2002. Personal communication. Stewart Agricultural Research Service, Inc. Macon, Missouri.

Hewitt, A. J. 2003. Tank mixing and spray performance: do all products drift alike? Agricultural Aviation 30(2):22-25.

Mulkey, M. E. 2001. EPA, OPP-00730; FRL-6792-4. Pesticides; Draft guidance for pesticide registrants on new labeling statements for spray and dust drift. Federal Register 66(163):44141-44143.

Southcombe, E. S. E., P. C. H. Miller, H. Ganzelmeier, J. C. Van De Zande, A. Miralles, and A. J. Hewitt. 1997. The international (BCPC) spray classification system including a drift potential factor. Proceedings of The 1997 Brighton Crop Protection Conference -- Weeds. 1, 371-380.

Wolf, R. E., D. R. Gardisser, and C. Minihan. 2002. Practical field demonstrations for drift mitigation. ASAE Paper No. 02-AA07. St. Joseph, Mich.: ASAE.

Wolf, R. E., D. R. Gardisser, and C. Minihan. 2003. Comparing drift reducing tank mixes for aerial applications. Agricultural Aviation 30(2):14-21.

Wolf, R. E., and D. R. Gardisser. 2003. Field comparisons for drift-reducing/deposition-aid tank mixes. ASAE Paper No. AA03-002. St. Joseph, Mich.: ASAE.

Womac, A. R., R. A. Maynard II, and I. W. Kirk. 1999. Measurement variations in reference sprays for nozzle classification. Transactions of the ASAE 42(3): 609-616.

Yates, W. E., N. B. Akesson, and D. E. Bayer. 1976. Effects of spray adjuvants on drift hazards. Transactions of the ASAE 19(1):41-46.