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Aerial Application Optimization

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Abstract. Aerial application is the number one means of applying fungicides to corn and remains a nearly equally important service for soybeans, wheat, and numerous other crops. As the disease control and plant health segment has grown over the past five years the visibility of aerial application to those unfamiliar with agriculture has also grown. At the same time, customer expectations for aerial services and the cost of managing an aerial operation remain high, and the entire crop protection industry faces regulatory pressures. Research and evaluation of, and investment in, various tools, technology, and services to optimize aerial application were initiated in 2008 and 2009 to meet the numerous challenges. For the purposes of this paper, application optimization includes minimizing drift and other non-target incidents, maximizing efficacy, improving efficiency for the operator, and stewardship of the industry. Investment in and evaluation of mapping technologies was initiated to determine the ability of applicators to view routes and obstacles and evaluate wind direction before leaving the ground. Studies were initiated in 2008 and continued in 2009 to evaluate application volume, application equipment, droplet size, and coverage for impact on efficacy and drift potential, as well as efficiency for the aerial operator. Initiatives were also undertaken to improve participation in Operation SAFE (Self-regulating Application & Flight Efficiency) Fly-Ins. Based on the results of these evaluations and initiatives, the agricultural aviation industry has the tools and technology available to meet the needs and expectations of a diverse group of customers, which include growers, regulators, and the public.

Keywords. Global positioning systems, aerial imaging, mapping, pattern testing, rotary atomizer, hydraulic nozzles, droplet size spectrum, volume mean diameter, relative span

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Introduction

The Plant Health segment, which includes fungicides for the major cropping systems, has grown dramatically over the past five years. Reasons for the surge in fungicide use since 2004 include strong commodity prices, concerns about Asian soybean rust, and introduction of the active ingredient pyraclostrobin, a more active strobilurin fungicide that controls a broad spectrum of diseases, provides plant health benefits, and helps increase crop yields.

Because aerial application is the number one means of applying fungicides to corn and remains a nearly equally important service for soybeans, wheat, and numerous other crops, demand for aerial services and visibility to the public has grown. Regulatory pressures, customer expectations, and the cost of doing business are some of the challenges facing the industry due to this demand and visibility. Technology, tools, and services to meet the demands of application optimization are available to the industry, and include Operation SAFE (Self-Regulating Application and Flight Efficiency) Fly-Ins, global positioning systems (GPS) and mapping and work-order systems, and application technology.

Operation S.A.F.E., developed in 1981, was designed to clearly demonstrate that agricultural aviation recognizes its responsibility to minimize the potential for adverse health and environmental effects of agricultural chemical application. The backbone of Operation S.A.F.E. is the Professional Application Analysis Clinic – the Operation S.A.F.E. Fly-In. Professional application analysis clinics are a key part of Operation S.A.F.E. (NAAA website). The NAAA posts names of members who participate in Operation S.A.F.E. clinics. Participants as of September 2009 were 103, 230, 253, and 91 for 2006, 2007, 2008, and 2009, respectively. (The 2009 season had not been fully reported at the time of this printing.) In addition, many aviators participate in fly-ins but because they are not NAAA members their names are not posted. In 2009, BASF sponsored or co-sponsored 10 Fly-Ins where over 100 aircraft “flew over the string” at least once. A push for greater attendance was initiated by working with aerial operators and state associations to send invitations and entice participants with offers of gift certificates, meals, and giveaways. A general observation of SAFE analysts is that the smaller the group, the greater the opportunity to learn and make more passes. For example, Alan Corr, analyst in Nebraska, worked with 29 planes completing 240 passes by 23 June 2009 (Ag Air Update September 2009). While Operation SAFE Fly-Ins are not new to the industry, they remain an important service and opportunity for aerial applicators.

The fungicide application season remains logistically challenging due to a brief period of application timing, new farms and fields every year, out-of-area pilots, and late decision-making by growers. As the disease control and plant health segment continues to expand, efficiency and coordination among growers, retail agricultural service providers, and aerial applicators will be needed to ensure success. As early as 2001, Giles and Downey, working with ground rigs, reported that GPS and GIS technology can be used to create quality control maps and sense critical parameters of application. The authors stated that productivity, compliance, and efficacy of application can be established from this data, yet widespread use of this technology for aerial applications had not been observed.

Aerial application nozzle types, volumes, and adjuvant systems have been evaluated in different ways and with various objectives. Fritz et al. (2005) evaluated conventional nozzles, rotary atomizers, and electrostatic technology at various rates and droplet size for increasing spray deposition on wheat heads. They found that 2 gpa and a Dv0.5 of 350 microns worked best for spray deposition on wheat heads, followed closely by an electrostatic system at 1 gpa and a Dv0.5 of 150 microns. The authors also found that higher volume applications (5 gpa) resulted in near minimum deposition on wheat heads.

A follow-up study by Kirk et al. (2004) demonstrated that fine droplet spectrum sprays applied with rotary atomizers maximized deposition on wheat heads, and that medium droplet spectrum provide the least deposition regardless of spray volumes between 2 and 10 gpa.

In 1997 the spray Drift Task Force issued a summary of major issues impacting drift. They concluded that when good application practices are followed, minimizing drift to “levels approaching zero” is possible.

Kirk (2003) tested seven different drift control agents to determine impact on droplet size, reduction of fine droplet content, and resistance to pump shear degradation. He concluded that six out of the seven agents increased droplet size but varied in effectiveness.

Lan et al. (2007) evaluated drift control agents and measured deposition (in-swath and downwind), droplet size, coverage, and number of drops and compared the drift control agents to an emulsifiable concentrate blank. The various treatments had a significant impact on measured parameters. In general, the drift control agents increased droplet size, decreased downwind movement of the spray solution, and increased the percent area covered. Not all drift control agents performed the same. The authors state that adjuvants can alter spray performance, and a balance between coarse droplets and optimum efficacy must be considered.

Methods

Operation SAFE Fly-Ins

A brief and informal survey was conducted to determine why applicators have attended a fly-in. A series of questions were asked of a small sub-set of fly-in participants (Table 1). Each participant was asked their level of agreement with each statement and answers recorded.

Table 1. Survey of aerial applicators who have attended an Operation SAFE Fly-In.

The reason I attended an Operation SAFE Fly-In in 2009 was:						
		Strongly Disagree	Disagree Somewhat	Agree Somewhat	Agree	Strongly Agree
		1	2	3	4	5
1	There was a give-away of some kind					
2	I received an invitation from another aerial applicator or the state aerial applicator association.					
3	I knew my aircraft needed work.					
4	Fly-ins are a good opportunity to socialize with other aerial applicators.					
5	The Fly-In was conveniently located.					
6	I would be more likely to participate in a fly-in if there were fewer aircraft and only my own team attending					
7	I would be more likely to participate in an Operation SAFE Fly-In if there was less down time and less waiting around.					

Mapping and Work-Order Technology

BASF personnel have carefully evaluated numerous mapping and work-order systems over the past three years and new systems have come available annually. Numerous aerial applicators and retail agriculture providers have been consulted to help determine what features are most important. The greatest needs indentified included customer and field identification, forecasting and pre-planning, in-season planning and payload delivery, payload completion alerts and reporting.

Aerial Application Equipment, Adjuvants, Volume

Studies were conducted in Mississippi, Colorado, Illinois, and Indiana in 2009 to evaluate applications of Headline EC fungicide (active ingredient pyraclostrobin) with various adjuvants, delivery systems, and at carrier volumes of 1 and 2 gallons per acre (gpa) total volume. For the purposes of this paper, the volume applied will mean the total volume of Headline EC fungicide, adjuvant system, and water. Note that 1 gpa is not a registered use and is not legal for commercial applications. Headline was applied at a rate of 6 fluid ounces per acre in all treatments.

Spray deposition and droplet size distribution was collected using water sensitive paper and white Kodak brochure paper cards. Water sensitive paper was positioned every 6 feet at 45 degree angles to the wind direction. Red dye was added to each treatment to enhance droplet appearance on the white cards. Card analysis was conducted utilizing the Stainmaster 1.0.9 program. Data presented include the NMD, Dv0.1, Dv0.5, Dv0.9, and Relative Span (RS). The RS value was calculated as

$$RS = (Dv0.9 – Dv0.1)/Dv.05$$

In Colorado, Headline was applied with 8 Micronair AU5000 rotary atomizer units with standard blade settings at the fourth position for a 65 degree angle and 5,500 rotations per minute (rpm). The aircraft was a Weatherly 620 B. Headline treatments included Headline applied in 1 gpa with crop oil concentrate, 1 gpa with a drift control agent, 1 gpa with a crop oil concentrate and drift control agent, and Headline in 2 gpa with a drift control agent.

In Mississippi, Headline in 1 and 2 gpa and a high load oil was applied with either 10 Micronair AU5000 rotary atomizer units with standard blade settings at the fourth position for a 65 degree angle and 5,500 rotations per minute (rpm) or CP11TT hydraulic nozzles fitted with swivel mounts and adjusted to 90 degrees. The aircraft was a Thrush Turbo N. Headline treatments included 1 and 2 gpa with crop oil concentrate applied with the rotary atomizers and the CP11TT hydraulic nozzles.

The Indiana location included Headline plus oil or a drift control agent in 1 and 2 gpa applied with rotary atomizers or 1 gpa applied with TK6 ceramic hollow cone hydraulic nozzles. For the 1 gpa delivered with hollow cone nozzles, 120 nozzles were used and set at zero degrees with a spray pressure of 80 lbs/in^2. A 2 gpa treatment was also included utilizing flat fan 1515 nozzles set at 60 degree angles with 80 lbs/in^2. Aircraft used included an Air Tractor 402 and an Air Tractor 502.

A Turbine Thrush and a Thrush 600 aircraft were used for the Illinois location. The Turbine Thrush was equipped with 11 ASC rotary atomizers with blades set at 3.5 angle for 4200 rpm. Aircraft speed was 140 mph. The Thrush 600 was equipped with hollow cone nozzles type D8-45 and D4-45, oriented straight back (0 degrees), spray pressure of 40 lbs/in^2, and an aircraft speed of 115 mph.

Results

Operation SAFE Fly-Ins

Based on the survey questions, convenience, with an average score of 4.1, and less downtime, with a score of 4.3, were the the most important attributes for attending a fly-in. Receiving an invitation from another applicator or the state association was also important, with an average score of 3.8. The lowest score, with a 1.1 average, was “there was a give-away of some kind” (Table 2).

Table 2. Summary of survery results for aerial applicators who have attended an Operation SAFE Fly-In.

		Average Response 1 = Strongly Disagree 5 = Strongly Agree
1	There was a give-away of some kind.	1.1
2	I received an invitation from another aerial applicator or the state aerial applicator association.	3.8
3	I knew my aircraft needed work.	3
4	Fly-ins are a good opportunity to socialize with other aerial applicators.	3.5
5	The Fly-In was conveniently located.	4.1
6	I would be more likely to participate in a fly-in if there were fewer aircraft and only my own team attending.	3.0
7	I would be more likely to participate in an Operation SAFE Fly-In if there was less down time and less waiting around.	4.3

Mapping and Work-Order

Imaging and GIS Systems improve logistics, efficiency, and profitability for aerial applicators, retail providers, and growers. Based on evaluations of currently available systems and conversations with customers, among the most important features of a mapping and work-order system include easy-to-use GPS coordinates, a clear map, a database of growers and field shapefiles that can be saved and re-used each season, as-applied maps, reporting functionality, and coordination with accounting and invoicing systems. Benefits of a robust system include savings of time, money and labor, and increased efficiency, security, and peace-of-mind. Table 3 includes a comparison of old and new technology and the benefit that can be expected by utilizing a mapping and work-order system.

Table 3. A general comparison of work-order and mapping systems and benefits of electronic based systems.

Old System	New Technology	Benefit of New Technology
Paper based	Electronic communication	Time
Hand-sorting orders	Reviewing, grouping orders electronically	Money
Start over each season	Database of fields, growers ready	Labor
Counting mile markers	Straight line to the field	Efficiency Time Money
Hoping grower saw the application	Instant notification	Time Security
Hand-written invoices	Coordinated accounting systems	Time Labor Accuracy
Hope for a nice field upon arrival	View formations, farms, highways before lift-off	Safety Time
Limited tracking	Electronic data submissions	Stewardship Security Peace of Mind

Aerial Application Equipment, Adjuvants, Volume

Rotary atomizers performed well at all locations and at 1 and 2 gpa producing a narrow spectrum of droplet size based on the relative span (RS) value (Tables 4 - 7). As Hoffman et al. (2008) explain, the RS is an indication of the droplet size around the median value. They also state that the RS "can be thought of as the amount of control over the atomization process that an operator has for a particular combination of application conditions". The RS of 1 gpa volumes ranged from 0.59 to 0.79, and at 2 gpa the RS ranged from 0.52 to 0.99. The slightly higher RS at 2 gpa may be due to a combination of reaching the maximum volume limits of the rotary atomizers in combination with a drift control agent.

In Mississippi, the RS for CP11TT nozzles was 0.74 and 0.72 for 1 and 2 gpa, respectively (Table 5). This was very close to the RS for the rotary atomizers, which was 0.76 and 0.83 for 1 and 2 gpa, respectively, at the same location. The ratio of VMD:NMD was almost one to one for both rotary atomizers and CP11TT nozzles, which is another indicator of droplet size uniformity.

The hollow cone TK6 hydraulic nozzles used at the Indiana location produced RS values of 0.58 and 0.72 with a high load oil and a high load oil plus drift control agent, respectively (Table 6). The addition of the drift control agent increased the Dv0.5 from 179 to 314 microns using the TK6 nozzles. The drift control agent did not increase droplet size at 1 gpa when the Headline

mixture was applied with rotary atomizers. A drift control agent may not be suitable for the numerous and small orifices of the TK6 hydraulic nozzles.

Rotary atomizers were compared to hollow cone nozzles at the Illinois location at both 1 and 2 gpa volumes (Table 7). The hollow cone D8-45 nozzles produced the highest relative span value at 2 gpa. At 1 gpa, the hollow cone D4-45 nozzles had a RS value comparable to rotary atomizers at 1 gpa.

Drift control agents used in these evaluations increased droplet size in four out of five times where the comparison was made (Tables 4, 6, and 7). More importantly, the RS value was not necessarily higher when a drift control agent was added, and the VMD:NMD ratio remained close to 1:1. Based on these evaluations, the drift control agents worked as designed without creating excess variation in the droplet spectrum.

Conclusions

Challenges remain to conducting more fly-ins and increasing participation, including cost, logistics, timing, and weather conditions. Improving the convenience and reducing waiting time at fly-ins may improve attendance, while offering gifts of appreciation for attending seem to be low priority for aerial applicators. Coordination and cooperation from the industry is needed to ensure continual Operation SAFE Fly-In success.

Global positioning systems and mapping technologies are widely available to aerial applicators and have the potential to be an important part of optimizing every crop protection application made to any crop. Not all systems provide the same features and benefits, and aerial applicators should evaluate the needs of their customers before choosing a system. Improved safety, stewardship, and efficiency are key benefits of a good system.

Based on these evaluations and data gathered in these studies, droplet size spectrum can be highly controlled using various delivery systems at both 1 and 2 gpa, although 1 gpa is not a registered use for Headline. Low RS values were achieved with most combinations, and VMD:NMD ratios were often close to 1:1, another indication of uniform droplet sizes. Sufficient attention must be given to the application equipment including selection of nozzle size, type, angle and pressure to achieve a tight droplet spectrum and droplet uniformity. The adjustment of the rotary atomizer is also of great importance – blade size and blade angle with respect to airspeed and flow rate per minutes must be within the capacity of the atomizer. Concerns of drift with different systems and volumes can all be minimized, since droplets in the very fine classification were limited.

Table 4. Evaluation of crop oil concentrate and a drift control agent at 1 and 2 gpa carrier volume in Colorado with rotary atomizers.

Equipment[a]	Volume (gpa)[b]	Adjuvant[c]	NMD	Dv0.1	Dv0.5	Dv0.9	RS
RA	1	COC	120	111	178	252	0.79
RA	1	DCA	174	169	284	371	0.71
RA	1	COC+DCA	130	119	201	284	0.82
RA	2	Dep	140	151	291	438	0.99

Table 5. Evaluation of rotary atomizers and CP11TT hydraulic nozzles at 1 and 2 gpa in Mississippi.

Equipment[a]	Volume (gpa)[b]	Adjuvant[c]	NMD	Dv0.1	Dv0.5	Dv0.9	RS
RA	1	HL oil	130	111	168	238	0.76
RA	2	HL oil	130	112	178	261	0.83
CP11TT	1	HL oil	140	124	182	259	0.74
CP11TT	2	HL oil	150	125	166	245	0.72

Table 6. Evaluation of rotary atomizers, TK6 hydraulic nozzles, and flat fan hydraulic nozzles at 1 and 2 gpa in Indiana.

Equipment[a]	Volume (gpa) [b]	Adjuvant[c]	NMD	Dv0.1	Dv0.5	Dv0.9	RS
RA	1	HL oil	178	168	245	328	0.65
RA	1	HLoil+DCA	160	152	225	274	0.54
RA	2	HL oil	180	155	249	286	0.52
TK6	1	HL oil	150	141	179	245	0.58
TK6	1	HL+DCA	120	145	314	374	0.72
FF 1515	2	HL oil	199	196	504	574	0.75

Table 7. Evaluation of rotary atomizers and hollow cone hydraulic nozzles at 1 and 2 gpa in Illinois.

Equipment[a]	Volume (gpa) [b]	Adjuvant[c]	NMD	Dv0.1	Dv0.5	Dv0.9	RS
RA	1	COC	140	119	168	215	0.57
RA	1	COC+DCA	160	144	214	269	0.58
RA	2	COC	141	126	189	301	0.92
D4-45	1	COC	160	146	218	282	0.62
D8-45	2	COC	163	149	275	441	1.06

[a] RA = Rotary atomizer; CP11TT = CP11TT hydraulic nozzle; TK6 = TK6 hydraulic nozzle; FF 1515 = Flat fan hydraulic nozzle; D4-45 & D8-45 = hydraulic nozzles

[b] gpa = gallons per acre. PLEAE NOTE THAT 1 GPA IS NOT A REGISTERED USE.

[c] COC = crop oil concentrate; DCA = Drift Control Agent; HL oil = High load oil

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