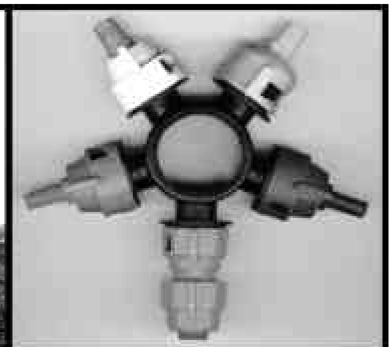
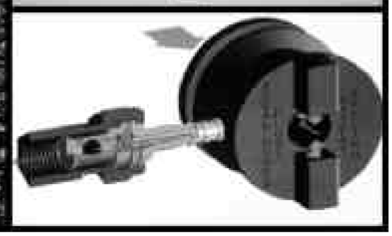
Effectiveness of Air Assist & Electrostatic Spraying Systems 1998

Second Edition

Green Leaf Venturi Nozzles | **Air Bubble Jet Nozzles** | **John Deere Ultra Nozzles**

Spray-Air's Shear Guard Plus
Melroe's Energized Spray Process
Spectrum's Air/Electrostatic
Willmar's Air Trak





Cooperators:

Ag Depot - A Millstreet Company
Agricore - Bean Business Unit
Greenleaf Technologies, Inc.
Spray-Air Canada Ltd.
Spectrum Electrostatic Sprayers (Canada) Inc.

Agrium
AgrEvo Canada Inc.
Zeneca Agro
Dupont Canada
Monsanto Canada Inc.
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ALBERTA FARM MACHINERY RESEARCH CENTRE

Effectiveness of Air Assist & Electrostatic Spraying Systems

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Introduction

Air Induction, Venturi, Air Shear, ESP, Air Bubble Jet...confused?

Just when producers and custom spray applicators started to use and feel comfortable with extended range and low drift nozzles, air induction, venturi-type nozzles are introduced. Alberta Farm Machinery Research Centre (AFMRC) personnel were flooded with questions regarding spray drift, coverage and efficacy which needed addressing before the 1998 spraying season.

In addition, several other spraying systems developed in the past few years are being used by producers and custom applicators. Melroe's Energized Spray Process (ESP) system, Spectrum's Electrostatic/Air system, Spray-Air's Shear Guard Plus, Kyndestoft's Air Bag and Rogator's Airtec system all incorporate new spraying technologies. Some new spraying technologies emerge as accessories that can be fit to existing sprayers or as optional equipment when purchasing new sprayers. All use air and/or electrostatics to improve the transport of a spray droplet to its intended target. Improved spray deposition means less adverse environmental impact with increased production if biological activity is improved. The additional cost of these new systems can be as low as $1000 or as high as $50,000.

Competition is stiff in the spraying business so new technologies are introduced into the market quickly without much research data on effectiveness. Due to the size of some new spraying options, the power and cost to operate them, chemical companies and researchers find them difficult to incorporate into typical scientific research programs. The lack of research data ushers producer skepticism. It's difficult to prove the new technology's spraying effectiveness and whether the extra cost is worth it if chemicals applied according to label rates are effective in a wide range of growing and spraying conditions. In spite of limited efficacy research, the sprayer and new spray technologies have become increasingly important to farm profitability, and successful spray manufacturers are participating in more efficacy and drift management research on their products.

AFMRC's Research Sprayer & Research Studies

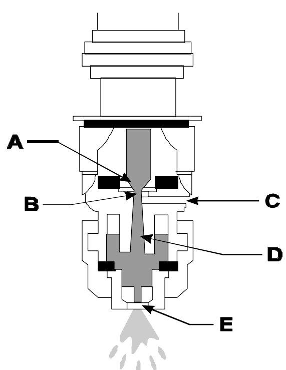
To encourage research with new sprayers, AFMRC built two plot-size sprayers with a 6 m (20 ft) spraying swath. The research sprayers include state-of-the-art monitoring, controlling and chemical injection systems. Four spraying systems and three nozzle types were selected and mounted on each sprayer. The selection process eliminated the need to test all the different nozzle types and spraying systems currently available. All current spraying technologies were considered. Selection depended on spray deposition, spray droplet size, droplet transport medium and sprayer manufacturer's cooperation. The nozzles included extended range (XR), wide-angle Turbo TeeJet (TT) and air induction (venturi). The air/electrostatic systems included Spray Air's Shear Guard Plus, Melroe's Energized Spray Process, Spectrum's Air/Electrostatic and Willmar's Air Trak.

AFMRC's Research Sprayer.

Spray drift and distribution tests were conducted using a wind tunnel and spray patternator, respectively. It will take another year before all nozzles and combinations of settings are done completing database information. Efficacy and spray deposition tests were started at three sites in 1997 and six sites in 1998. Each site represented a different type of spraying application or crop condition. Conventional conditions incorporate post emerge and preharvest herbicide applications in cereal crops. Other conditions include fungicide applications in edible beans and potato desiccation. At least two more trial seasons are required to determine differences in weed kill and eliminate errors in growing conditions. Only some drift and efficacy results will be discussed in this presentation. **All results discussed in this report are preliminary at this time.**

Air Induction (Venturi) Nozzles

The air induction or venturi-type nozzles are new to North America, though European farmers have been using them for some time. Early versions used compressors to pump air into the nozzle chamber. AFMRC tested this type of nozzle in the early 1990's but did not like the idea of having compressors and air hoses attached to each nozzle. Today's air nozzle is based on the same principle but uses a venturi to introduce air into the nozzle chamber. The result is a nozzle tip that fits into existing nozzle caps.

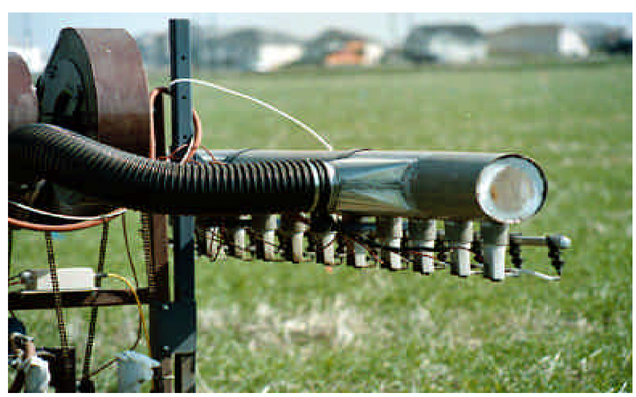


Air Venturi Nozzles.

The diagram shows how venturi nozzles work. The spray solution passes through a tapered passage (A) in the nozzle. As the passage diameter decreases, the spray is accelerated through. At the tapered passage outlet (B), a vacuum is created causing air to be sucked from outside the nozzle tip through one or two holes (C). The spray solution and air are mixed in chamber (D) before exiting the nozzle tip (E). The compression in the mixing chamber results in air bubbles forming inside the liquid spray droplets. This produces larger spray droplets that, according to some nozzle manufacturers and distributors, have a positive affect. Spray drift can be reduced significantly without sacrificing spray coverage and chemical efficacy. It should be noted that the internal orifice regulates flow and the external tip shapes the spray.

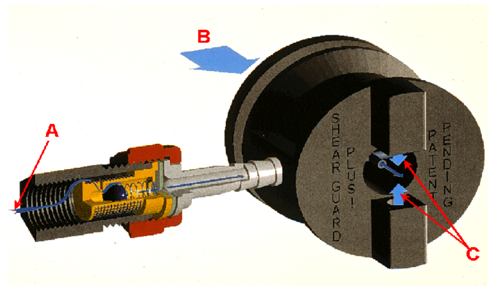
Spectrum's Electrostatic Sprayer

Spectrum's sprayers use air shear and electrostatic technologies in combination. The nozzle assembly houses an electrode and liquid delivery system (*basically a tube that's flared*). Air forced into the nozzle assembly atomizes the liquid solution into uniform droplets 50 to 60 microns in size. The electrode charges the spray before it exits the nozzle assembly. A tractor's 12-volt battery is transformed to 10,000 volts at the electrode. According to Spectrum, the high velocity air stream and electrically-charged spray improve droplet movement and deposition, resulting in a more efficient delivery of spray to the target.


Spectrum's Air/Electrostatic System.

Spray-Air's Shear Guard Plus

Spray-Air's Shear Guard Plus nozzle was introduced in 1996 a couple of years ago. The diagram shows how the Shear Guard Plus nozzle works. The spray solution is metred through an orifice (A) into a delivery tube. The main air stream (B) passes over and around the delivery tube. As the spray solution exits the small tube it is atomized by the air stream. A spray pattern is formed by two jets of air (C) replicating a flat fan nozzle pattern. In addition, the main air stream physically opens the crop canopy exposing the target for spray. According to the manufacturer, this increases spray penetration and target coverage. Air velocity and droplet size can now be controlled to minimize spray drift.



Spray-Air's Shear Guard Plus Nozzle.

Willmar's Air-Trak

Willmar's Air-Trak system uses air assist and conventional nozzles in combination. The Air Trak system uses Spray-Air's Air Shear Guard system to provide a curtain of air in front of the spray. The air stream and spray are angled to intersect at the target. According to the manufacturer, the system reduces spray drift and increases deposition in adverse conditions.

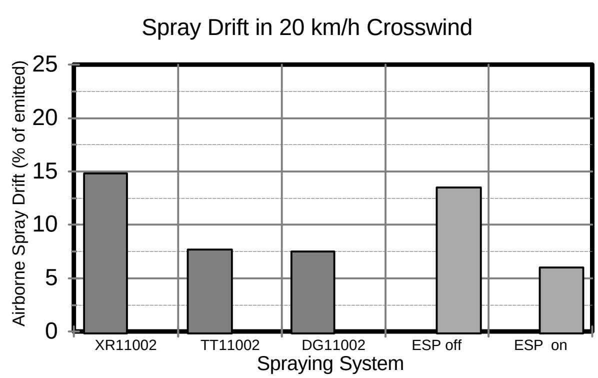
Energized Spray Process System

Melroe's Energized Spray Process (ESP) was introduced to Western Canada in the spring of 1997. Flooded with questions regarding the system's effectiveness, AFMRC conducted efficacy and drift tests comparing the ESP system with conventional and venturi nozzles, and air assist spraying. Drift tests were conducted in Strathmore and efficacy studies were conducted in Bow Island. A farmer from the Strathmore area provided AFMRC with an ESP sprayer.

The ESP charging system operates off the Spra-Coupe's 12-volt battery and uses standard nozzles. It delivers 40,000 volts to the chemical solution before it reaches the nozzles. By charging the chemical solution, an electrostatic field is created between the nozzle and the crop. According to the manufacturer, the electrostatic field increases the spray droplet velocity and deposition surrounding the plant leaf for more thorough coverage resulting in less spray drift and more chemical on the intended target.

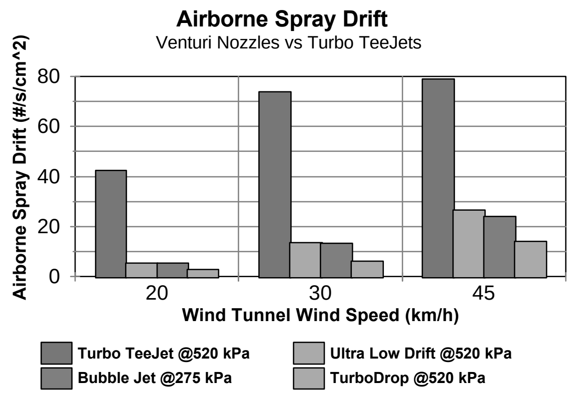
Drift Results

The airborne spray drift graph shows the effectiveness of two spraying systems and three nozzle types. Conventional spraying nozzles included extended range XR11002, wide-angle Turbo TeeJet TT11002 and low drift DG11002 nozzles (*details in AgriFuture97 proceedings and AFMRC report*). ESP spray drift tests were conducted under slightly different conditions, in a wheat crop that was 250 mm (10 in) high. The sprayer was operated at 23 km/h (14.5 mph) to give an application rate of 28 L/ha (2.5 gpa). Nozzle spacing and height were set at 760 and 355 mm (30 and 14 in), respectively. Nozzle height was specified by Melroe Company.

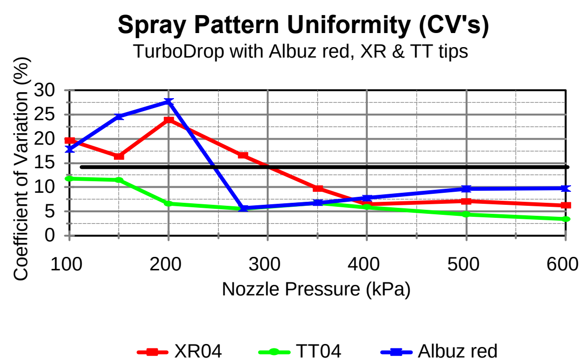


Five trials were conducted with the ESP system in wind speeds averaging 20 km/h (12 mph). Another five trials were done with the ESP system turned off to represent conventional spraying conditions. Airborne spray drift was 13.5% with the ESP system turned off and 6% with the system turned on, a reduction of more than 50%. The ESP system was as effective as low drift TT11002 and DG11002 nozzles. However, operating at 355 mm (14 in) is difficult. Most high clearance sprayer booms operate above 700 mm (27 in). Since AFMRC was dependent on a farmer's Spra-Coupe, testing was limited to one set-up. Our experience in drift research indicates the ESP system would not be as effective at higher spraying heights.

Drift trials for venturi nozzles so far have been conducted only in wind tunnel conditions. Venturi nozzles tested included John Deere's Ultra, Greenleaf Technologies TurboDrop (TD) and Air Bubble Jets. The graph shows airborne drift 4 m (13 ft) downwind of the nozzles. The results are compared to Spraying System's wide-angle TT nozzles. The TT nozzles were used as the reference nozzle because of good performance in windy spraying conditions. When compared with TT nozzles, all venturi nozzles tested reduced airborne spray drift. For example, using TT nozzles in a 30 km/h (20 mph) headwind, the amount of airborne spray measured was 70 drops/s/cm^2 (180 drops/s/in^2). With venturi nozzles, the amount of airborne droplets measured was reduced below 15 drops/s/cm^2 (40 drops/s/in^2). Greenleaf's TD had the lowest airborne drift density. Note, Greenleaf's venturi (TD) was used with Spraying System's TT tip. That same combination resulted in better spray patterns over a wider range of pressures.



This graph shows the coefficient of variation (CV) (*spray pattern uniformity*) from Greenleaf's venturi operating with its own Albuz tips, Extended Range (XR) and Turbo TeeJet (TT) tips. Spray patterns are considered good if the CV falls below 15%. All tips produced good spray patterns at pressures above 300 kPa (44 psi). The Albuz and extended range tips did not produce acceptable spray patterns at pressures below 300 kPa (44 psi) . Normally, venturi-type nozzles produce unacceptable spray patterns below 300 kPa (44 psi). However, the TT tips produced good spraying patterns at all pressures tested from 100 to 600 kPa (15 to 90 psi). With TT tips, operators can use pressures as low as 100 kPa (15 psi). This is an advantage when using automatic rate controllers since speeds can be significantly reduced without sacrificing spray coverage.



The CV is also used to indicate flow rate uniformity among nozzle tips. For some venturi-type nozzles, the CV was 5% at low pressures and less than 2% at high pressures. CV's below 3% indicate all nozzles have similar flow rates. Most venturi-type nozzles should be used at pressures above 300 ka (44 psi), preferably above 400 ka (60 psi). Some exceptions include Greenleaf's TD with TT tips, Air Bubble Jet and Lurmark's Ultra Lo-Drift nozzles.

Efficacy Results

Some sprayer manufacturer's advised caution on releasing efficacy results since the data was based only on two years study, limited chemicals and test conditions.

Efficacy trials were conducted on edible beans at two sites in 1997 comparing electrostatic, air shear and venturi nozzle spraying systems with conventional nozzles. The experiment was a random block design with four replications of each spraying system. Table 1 shows the sprayers' operating conditions and results. Benlate (*benomyl*) was used to control white mold infection. The trials were done during the first fungicide application. Disease incidences were lower than normal, probably due to cool temperatures in spring and warm dry weather in July 1997. White mold infection at Site One was too low and inconsistent for proper analysis. Site Two disease incidence was higher than Site One. Site Two results showed Spray-Air's Shear Guard Plus and ESP sprayed plots had lower levels of mold infection suggesting they were more effective than conventional and venturi spraying systems.

Table 1. White Mold Infection in Edible Beans (1997 Results)

Spraying System	Commercial Name	Nozzle Number	Nozzle Pressure (kPa)	Application Rate (L/ha)	White Mold Infection (%)
None (Check)					20.1a
Conventional	TeeJet	XR11003	276	170	4.6b
Venturi	TurboDrop	TD110-025	415	170	6.2ab
Air Shear	Shear Guard Plus	white	140	55	1.7c
Electrostatic	ESP	Std 8001	275	55	1.9bc

Values with the same letter are not significantly different from each other (P=0.05)

In 1998, efficacy trials in edible beans were repeated during the second fungicide application using two fungicides, Benlate (*benomyl*) and Ronilan (*vinclozolin*). White mold disease incidence was very high, averaging 79% at the untreated checks and 46% for the sprayed plots. Generally, the plots sprayed with the air assist systems had lower incidences of white mold infection, averaging 43% versus 49% with nozzles. Treatments sprayed with Spectrum's Air/Electrostatic system had the lowest incident of white mold infection, averaging 43% with Benlate and 33% with Ronilan. There was no difference in control among the nozzle types applying Benlate at 170 L/ha (15 gpa). There was some difference when applying Ronilan where the XR and TT nozzles faired better than the venturi TD nozzles.

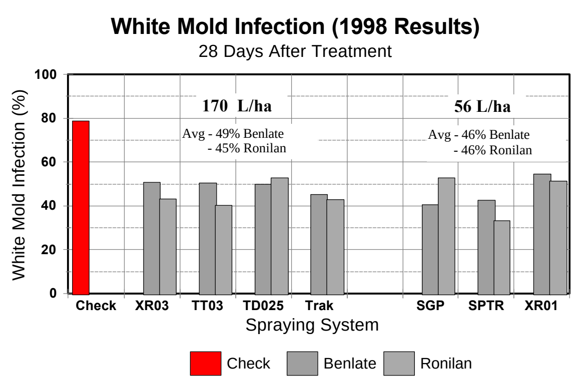


Table 2 shows spraying systems and results desiccating edible potatoes with Reglone. Reduction of potato plant biomass is shown to indicate the spray system's effectiveness. Two days after spraying the potato samples were weighed to measure plant biomass. A high biomass reduction indicates faster plant material dry down. Results were similar among the different nozzle types when used at a recommended water rate of 225 L/ha (20 gpa). The 56 L/ha (5 gpa) of water carrier treatments faired better than the 225 L/ha (20 gpa) treatments.

Table 2. Potato Crop Desiccation (1998)
Biomass Reduction Two Days After Treatment

Spraying System	Commercial Name	Nozzle Number	Nozzle Pressure (kPa)	Application Rate (L/ha)	Biomass Reduction (%)
None (Check)				0	0
Conventional	TeeJet	XR11004	276	225	27
Wide-Angle	Turbo TeeJet	TT11004	276	225	24
Venturi	TurboDrop	TD110-03	415	225	27
Air Assist	Air Trak	TT11004	276	225	30
Conventional	TeeJet	XR11001	276	56	35
Air/Electrostatic	Spectrum	‘4916-20	260	56	36

Table 3 shows the operating conditions of each spraying system and results in a post emerge spraying application. Puma and Refine Extra were applied by each spraying system at recommended and half the recommended chemical rate. All treatments had very good to excellent control (*91 - 100%*) of all weeds present, regardless of spraying system. Infestation of wild oats was low and not rated. Even applying Refine Extra at 50% of label rate resulted in excellent weed control. Venturi nozzles, air shear and electrostatic spraying systems showed neither adverse or better results.

Table 3. Puma & Refine Extra - Spring Wheat 1998
Visual Assessment 21 Days After Treatment

Spraying System	Commercial Name	Nozzle Number	Nozzle Pressure (kPa)	Application Rate (L/ha)	Kochia Control @ 100% rate	Kochia Control @ 50% rate
None (Check)				0	0	0
Conventional	TeeJet	XR11002	276	110	99	97
Wide-Angle	Turbo TeeJet	TT11002	276	110	99	96
Venturi	TurboDrop	TD110-025	415	110	93	98
Air Shear	Shear Guard Plus	white	145	56	98	96
Air/Electrostatic	Spectrum	‘4916-20	260	56	95	95

Wild oat infestation poor for rating control

Results so Far

Spray Drift:

- Turbo TeeJet (TT) nozzles reduced spray drift by 50%.
- Some air induction (venturi) nozzles reduced spray drift by 90%. Effect of nozzle size was negligible. Effect of nozzle manufacturer and pressure operating range are significant.
- Low pressure air induction nozzles reduced droplet drift density by 35 to 60%.
- High pressure air induction nozzles reduced droplet drift density by 60 to 90%.

Spray Coverage:

- Spray coverage is very good with extended range, wide angle, air assist and electrostatic spraying technologies.
- Spray coverage is good with high pressure air induction (venturi) type nozzles at pressures above 400 kPa (60 psi).
- Spray coverage is good with low pressure air induction (venturi) type nozzles at pressures above 140 kPa (20 psi).
- Low volume spraying is possible with a combination Greenleaf venturi & Turbo TeeJet tip.

Efficacy:

- Info based on only two seasons work (more research studies required to determine effects of spraying technology).
- AFMRC - no effects of sprayer in post emerge spraying of cereal crops.
- Some air assist and electrostatic sprayers were more effective in fungicide and desiccation applications.
- ECW Initiative - chemical products within groups 2, 4, 9 and 22 performed well with air induction nozzles. Within groups 1 and 6, some reduced control was noticed.

Addendum

Many farmers requested additional tests and information on air induction - venturi type nozzles. The tests focussed on differences among the various manufacturers' air induction nozzles regarding drift, percent coverage, spray droplet size, etc. AFMRC's preliminary tests, and farmers own visual assessments or tests, quickly showed air induction - venturi-type nozzles performed differently among manufacturers. Conventional nozzles performed similarly among nozzle manufacturers. Spray drift, coverage and efficacy were similar and testing was limited to a set of nozzles from one manufacturer. Not so with air induction nozzles. Spray drift, coverage and efficacy depended on the nozzle manufacturer's design and common factors such as nozzle size, pressure and operating height.

Tests were conducted in laboratory conditions using a wind tunnel, spray patternators and field test tracks to measure the nozzles' spray drift, coverage *(%)*, droplet density *(#/cm^2)* and size *(VMD)*. Several differences were found between nozzle manufacturers. Spray characteristics were unlike conventional nozzles when different pressures and nozzle sizes were used. For example, when pressure was increased with conventional nozzles, spray droplets got smaller, droplet density and coverage improved and drift increased. When large nozzle sizes were used, spray droplets got coarser and drift decreased. This was not so with several air induction nozzles, as illustrated by graphs on the next page. These graphs show airborne drift results from several air induction nozzles and Spraying System's wide angle Turbo TeeJet nozzles (*reference point).* Note, airborne spray drift results were normalized (*# of droplets/cm^2/L of spray*) to factor out differences in flow due to nozzle size and pressure.

Drift results, from Turbo TeeJet nozzles, showed what normally happens with conventional nozzles operating in windy conditions. Drift increased with increased operating pressure and decreased with larger nozzles. For years, one way to reduce spray drift was to use larger nozzles so a large amount of water was used. With air induction nozzles, spray drift increased with increased pressure but not as much. Using larger air induction tips resulted in nearly the same level of drift as small tips. Airborne drift results from the TurboDrop originals, Spraymaster Ultra's and TurboDrop/Turbo TeeJet venturi nozzles showed this to be the case. These air induction nozzles reduced airborne drift density by 60 to 90% when compared with wide-angle Turbo TeeJet nozzles. Note, Turbo TeeJet nozzles reduced spray drift by 50% (*7 to 8% chemical drift in 20 km/h crosswinds*) when compared with extended range (XR) nozzles. The 90% reduction was calculated comparing the smaller tips. What does all this mean? Farmers and custom applicators can be as confident applying chemicals with small tips and low water volumes as they were with the large tips and high water volumes of the past.

The TurboDrop/Turbo TeeJet (TD/TT) venturi and wide angle nozzle combination resulted in the lowest level of spray drift, averaging more than 90% in reduction when compared with Turbo TeeJet nozzles. With this combination nozzle pressure and size did not affect drift much. Although drift levels were very low, caution is advised when using this combination, especially with the larger venturis. Spray droplets are very coarse and may affect herbicide efficacy, though the droplets are uniform in size and coverage. Efficacy data, collected by Expert Committee on Weeds Applications Technology Group, showed reduced control with Group 1 and 6 chemicals using air induction nozzles at low pressure, producing very coarse droplets. Greenleaf Technologies are the only manufacturers with 01 and 005 venturis. Combined with Turbo TeeJet tips, low application rates are possible with little increase in spray drift.

Among air induction (venturi) nozzles, drift levels were higher using Air Bubble Jet (ABJ) and TurboDrop XL (TDXL) nozzles. Even so, these air induction nozzles reduced spray drift by 35 to 60% when compared with Turbo TeeJet nozzles at the same operating pressures. These nozzles also have spray drift characteristics similar to conventional nozzles, where drift increased with pressure and decreased with larger tips. Drift results from the ABJ and TDXL suggest these air induction nozzles do not produce spray droplets which are as coarse as other induction nozzles previously mentioned.

The last graph compares all air induction nozzles against Turbo TeeJet nozzles at a spraying pressure of 525 kPa (75 psi). What became evident is the nozzles operating range became a factor. Air induction nozzles designed to operate at conventional nozzle pressures, between 100 and 400 kPa (15 and 60 psi), reduced drift less than air induction nozzles designed to operate at pressures between 300 and 800 kPa (40 and 120 psi). AFMRC categorized air induction nozzles based on spray drift, coverage and droplet size characteristics, under either low or high pressure air induction nozzles. Low pressure air induction nozzles operate best at 275 kPa (40 psi) with an operating range between 100 and 400 kPa (15 and 60 psi). They can be operated up to 500 and 700 kPa (70 and 100 psi) if spray drift is not a concern. These nozzles are well suited for conventional type sprayers with limited pump pressure and where efficacy is a concern. These include Billericay Farm Systems Air Bubble Jet, Greenleaf Technologies TurboDrop XL and possibly Lurmarks Ultra-Lo-Drift. The Ultra-Lo-Drift air induction nozzles are presently being tested by AFMRC.

High pressure air induction nozzles operate best between 400 and 525 kPa (60 to 75 psi), improving coverage and decreasing the number of very coarse droplets. Pressures below 400 kPa (60 psi) are not recommended. With some high pressure air induction nozzles, flow variation was too high at low pressures. Spray patterns are similar to standard flat fan nozzles at low pressures. Also, at low pressures, spray droplets may be too coarse, thus affecting efficacy with some chemicals. However, these nozzles are well suited for custom applicators that can attain higher pressures. As shown by the graphs, drift was still significantly low with high pressure air induction nozzles operating at 525 to 700 kPa (75 to 100 psi).

High pressure air induction nozzles have limits. Drift levels were high, near Turbo TeeJet levels at 45 km/h (28 mph) wind speeds and 800 mm (30 in) operating heights.