MEETING VARIABLE APPLICATION GOALS WITH NEW APPLICATION TECHNOLOGY

Thomas M. Wolf, Agriculture and Agri-Food Canada, Saskatoon Research Centre

Key words:
Application, application technology, spray drift, fungicides, pesticide application, environment

Spray applicators are tasked with applying pesticide efficiently, with maximum efficacy and least environmental impact. Given the wide variety of conditions in which crops are grown, this can be a daunting task, and not all these goals can be met simultaneously. In this paper, management practices will be discussed and research results that explore a number of pesticide application scenarios will be presented.

SPRAY DRIFT

One of the enduring challenges with pesticides is the reduction of spray drift. This is becoming more important each year, for several reasons:

- Pesticides are commonly found in surface, ground, and precipitation water.
- Many of our fungicides and insecticides can be very toxic to birds, fish, or their food.
- The use of 2,4-D ester and other volatile formulations remains high, and new weed control products often contain these in a tank mix.
- The public is scrutinising the use of pesticides and human exposure.
- Regulators are restricting pesticide use based on concerns about the environment.

Factors That Govern Drift Risk

Several factors are important in determining how much spray will drift, and these primarily involve weather conditions and sprayer setup. Obviously, the best way to prevent drift is to spray only in the correct conditions with a properly adjusted sprayer. It is therefore important for an operator to have some understanding of how these are interrelated.

Weather Conditions

The most important weather factors are:

- wind speed
- atmospheric stability
- temperature and relative humidity (Delta T)

Wind Speed:

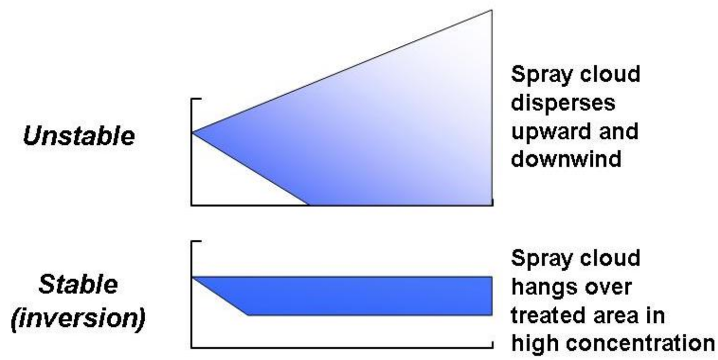
All other things remaining constant, spray drift increases linearly with increasing wind speed. For example, an 8001 tip applying 50 L/ha will lose about 3% drift at a 10 km/h wind speed, 7% at 20 km/h, and 11% at 30 km/h. This doesn’t mean that calm conditions are ideal for spraying. At very low wind speeds, the drift cloud can move in an unpredictable direction and cause damage. As a result, spraying is best done when there is some wind, and when the operator can be sure that wind direction has stabilised.

The effect of wind speed is a function of spray quality. For example, coarse sprays are less sensitive to increased wind speeds than fine sprays. But even with good drift reducing technologies, drift will still occur, and there are always maximum wind speeds above which no spraying should be done. Operators must use their judgement and be aware of downwind effects at all times.

Atmospheric Stability:

Under normal sunny daytime conditions, the atmosphere is said to be "unstable". This means that air near the ground is much warmer than air above. Under these conditions, there is considerable turbulence in the atmosphere, and adjacent air layers mix readily with each other. So if the air contains some drift, this drift is quickly dispersed upward and downward, diluting it with clean air and reducing its impact.

The opposite of an unstable atmosphere is a "stable" atmosphere ("temperature inversion"). Inversions occur when air near the ground is cooler than air above it, typically at nights with limited cloud cover and light to no wind. Under inversion conditions, turbulence is suppressed and suspended spray may hang over the treated area in a concentrated cloud for a long time. Winds after an inversion are very slow and unpredictable in direction, and when they occur, a concentrated spray drift cloud is moved off the treated area and can cause considerable damage at its destination. For this reason, drift potential is high during a temperature inversion. Fine sprays are particularly sensitive to inversion drift. Applicators should avoid spraying during temperature inversions, regardless of the application method. Most serious drift complaints involve spraying under inversion conditions.



Air Temperature and Relative Humidity

Small water droplets can rapidly evaporate to a smaller size, predisposing themselves to drift. Temperature and relative humidity affect how quickly droplets evaporate. For example, under warm and humid conditions (20º C and 80% relative humidity), a 100 µm droplet evaporates completely in 57 seconds. Under hotter, dry conditions (30º C and 50% relative humidity), the same droplet is evaporated in 16 seconds. A 50 µm droplet would last only 4 seconds under the hot and dry conditions, enough time to fall only 15 cm. From a drift perspective, droplets large enough to withstand drift may evaporate down to a size which makes them drift-prone in the time they spend between the nozzle and the target plant.

Unstable Conditions	Stable Conditions (inversions)
• sunny days	• nights
• some wind	• no or little wind
• predictable wind direction	• unpredictable wind direction
• disperse spray	• keep spray concentrated

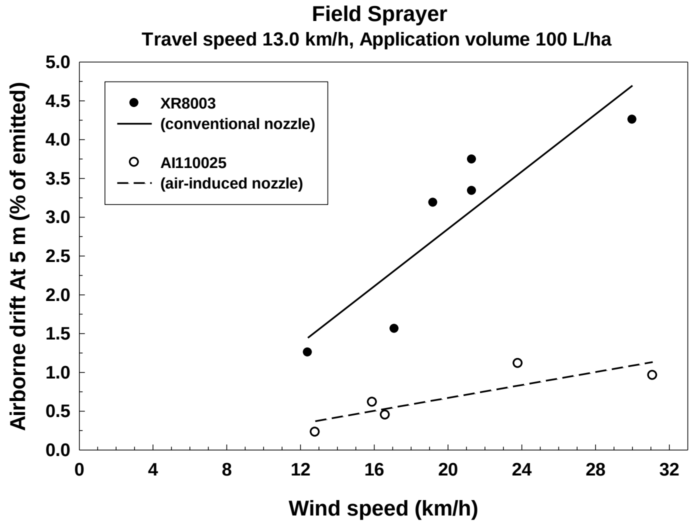
Sprayer Settings

For all sprayers, drift reducing methods focus on three approaches:

- reducing the proportion of small droplets in the spray cloud (spray quality)
- protecting the spray from wind (boom height and shrouding)
- diluting the spray solution (carrier volume).

Spray Quality

The most effective way to reduce drift potential is to apply coarse sprays that minimise the proportional contribution of small droplets (< 150 µm). Droplet size can be varied in a number of ways. The selection of a nozzle and spray pressure are the most important parameters.



Effect of droplet size on off-target spray drift. Boom height was 60 cm.

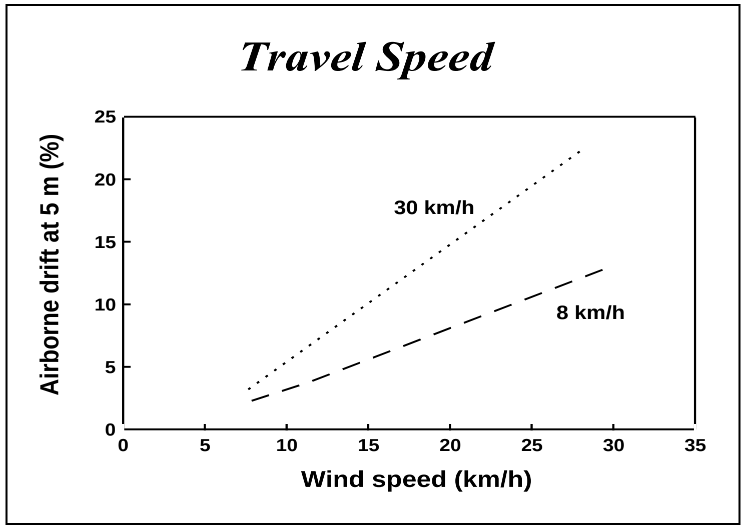
- **Pressure:** For any given nozzle, lower pressures result in coarser sprays. Drift potential can vary by a factor of three within a nozzle's recommended pressure range. The lowest recommended pressure will minimise drift risk. Operators should ensure that spray patterns remain uniform at the lower pressures.
- **Flow Rate:** For any given nozzle, a larger orifice (nominal flow rating) will produce a coarser spray.
- **Nozzle Types:** Conventional flat fan nozzles or hollow cone nozzles can be quite drift prone. Low-drift nozzles are available from many manufacturers. These use a combination of pressure and flow rate to produce a spray that can reduce drift from 50 to 95% for a given flow rate. Many of these nozzles can be operated at higher pressures without increasing drift potential significantly. This is one of the most important and widely used means of drift reduction for ground application, and will be discussed in more detail at the end of this presentation.
- **Nozzle Fan Angle:** With most nozzle types, narrower fan angles produce larger droplets. If wider fan angles are used, booms should be lowered to compensate.
- **Carrier Volume:** Most herbicides work equally well between 50 and 200 L/ha. Use of higher carrier volumes is a very effective way of reducing drift, for two reasons. First, if travel speed is maintained, a larger nozzle is used to apply the higher volumes. This results in a coarser, less drift-prone spray. Second, the spray solution is more dilute at the higher volume. This means that drift will contain less active ingredient, and therefore have less potential for causing damage.

Travel Speed

Fast travel speeds have three main effects on how spray behaves after it leaves the nozzle. Faster speeds:

- increase sheet breakup and cause a finer, more drift-prone spray to be produced.
- cause the spray to stay aloft longer because it gets swept back due to air resistance.
- often require higher boom heights on uneven ground.

On the other hand, when maintaining a constant carrier volume and pressure, faster travel speeds require the use of larger flow-rate nozzles (=coarser sprays), reducing drift potential.



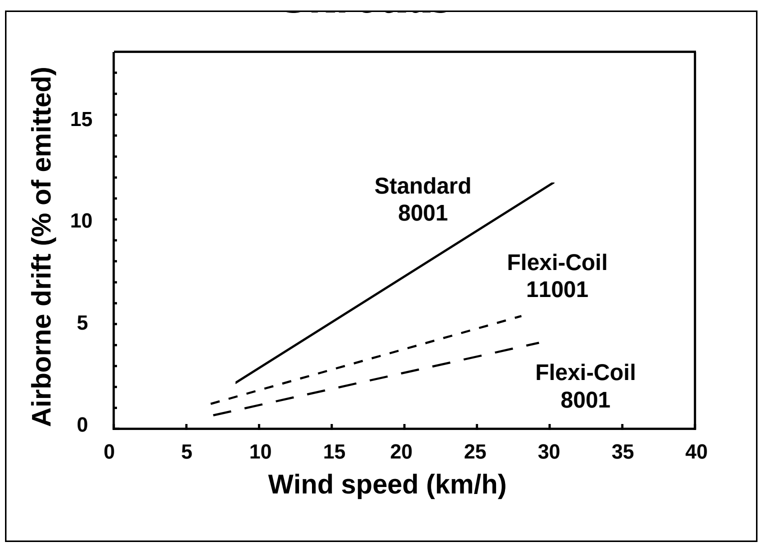
Effect of travel speed on spray drift. 30 km/h travel speed conducted using XR11002 tips applying 30 L/ha. 8 km/h travel speed done using XR8001 tips applying 50 L/ha.

Boom Height

Spray can be protected from wind by lowering the boom to the minimum recommended setting. For 80º fan angles, this is 45 cm, and for 110º fan angles, 35 cm. Remember that 110º nozzles create finer sprays than 80º nozzles, so the ability to lower them closer to the ground doesn't really afford much more drift protection. Also remember that suspended booms of self-propelled sprayers are likely to sway during operation, so booms need to be high enough to compensate for that. By orienting the spray forward or backward, boom height can be reduced as long as the nozzle to target distance is maintained at the minimum recommended in the direction the nozzle is oriented in.

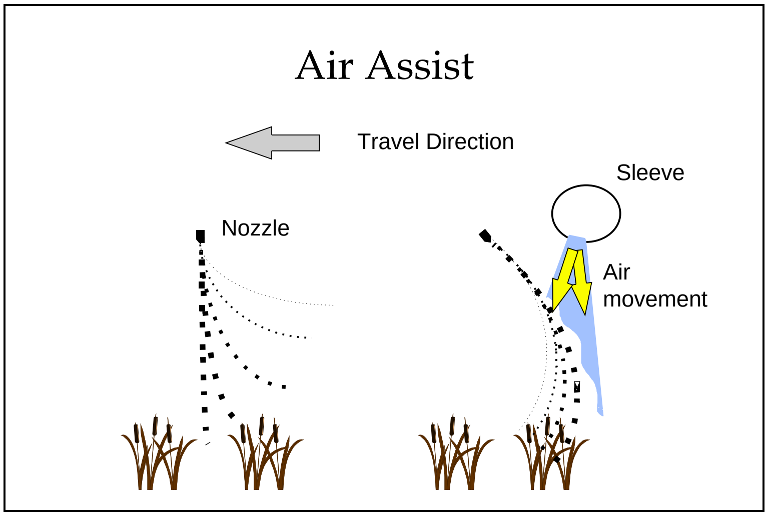
Shrouds

Shrouds reduce drift. In field testing, shrouds were able to reduce drift from an 8001 tip applying 50 L/ha by about 75%. Drift from the finer spray produced by 11001 tips was not as easily prevented. Some booms may not be able to accommodate shrouds, in those cases cones may be appropriate. Cones allow greater ground clearance for suspended booms, and won't contaminate susceptible crops with spray residue on the shielding material. Protective cones have been shown to reduce drift by 30 to 50%. Unfortunately, we don't yet know how these shrouds perform on high clearance sprayers moving at faster travel speeds. An operator should expect shrouds to become less effective at the higher travel speeds. A combination of shrouds and low-drift tips, although not yet tested under field conditions, would provide the best overall drift protection, better than shrouds alone or low-drift tips alone.



Reduction of drift with shrouds. Application volume was 50 L/ha.

Air Assist



Air assist carries drift-prone droplets to their intended target.

The use of air assist to reduce drift is sound in principle, but more difficult to put into practice. In principle, a fast-moving droplet is more drift-resistant than a slow-moving droplet of equal size. The idea behind air assist is to use an air stream to carry the emitted spray downward toward the target, imparting speed and preventing it from hanging in the air and being exposed to wind. It is important to set the direction and velocity of the airblast to match the prevailing atmospheric and crop canopy conditions. For example, too strong an airblast into a small crop canopy, such as seedling wheat, can result in the airblast rebounding off the ground. Any spray not intercepted by the canopy will return upward into the airstream and is prone to drift. Tests have shown that drift will increase if the airblast is too strong. When spraying into a dense canopy, for example to desiccate a pulse or apply fungicide to canola, a strong airblast is more appropriate to obtain better canopy penetration. Ultimately, air assist must be adjustable to be useful and requires an experienced operator for maximum benefits.

The Importance of Active Ingredient

Some herbicides (2,4-D ester) and insecticides are prone to vapour drift and can seriously hurt plants, animals and humans. Vapour drift can occur even when there is no particle (droplet) drift, and even dry spray deposits can send vapours into the atmosphere.
Vapour drift increases with air temperature, therefore the application of volatile products should be avoided on, or just preceding, hot days. Total losses depend on temperature, soil and leaf moisture, and the vapour pressure of the active ingredient.

What Can be Done to Avoid Drift Complaints?

- Be prepared. Make sure you have product on hand and are aware of the weather forecast to avoid panic.
- Know your surroundings. Are there sensitive crops nearby? Shelterbelts? Does the family in the nearby yard know you're spraying?
- Measure wind speed and wind direction using a proper anemometer and compass before spraying. Record this and other weather conditions (sunny, air temperature) in a log book. It will come in handy if there's a complaint.
- Make sure the wind is blowing away from sensitive areas.
- Don't spray under high wind speeds or dead-calm conditions. At night, temperature inversions, usually associated with calm conditions, allow the spray cloud to "hang" for a long time. This cloud can do a lot of damage once winds come up.
- Use low-drift technology whenever possible. Recognise its limits and stop spraying when it gets too windy.
- Drive as slowly as your schedule allows.
- Keep boom height as low as possible. Consider getting automatic boom height adjustment.

- Lower spray pressure near sensitive areas.
- Avoid spraying volatile products on or immediately before hot days. Even dried spray deposits can volatilise and drift.
- Get trained and updated regularly.
- Be professional and courteous and respect the concerns of others.
- Phone an expert if you're not sure what to do.

Droplet Size and Efficacy

It is relatively easy to minimise drift by using a coarser spray. However, the primary reason for the spraying operation is to control the target pest, and this goal should not be compromised. It is known that coarser sprays can be less well retained by difficult-to-wet weeds (grasses such as foxtail or broadleaves such as kochia). Easy-to-wet plants such as pigweed or smartweed easily retain coarse sprays. Venturi nozzles can maintain equivalent weed control under most conditions as long as spray patterns are good and pressures are optimised for the target weed (broadleaf weeds: >3 bar, grassy weeds, 4 – 6 bar). The primary reason for poor performance of coarse sprays is not due to the larger droplet size, but rather due to poor spray patterns resulting from operation at lower pressures.

Low-Drift Nozzles:

Pre-orifice: If an applicator wants the benefit of a coarser spray without changing carrier volumes, a good solution is to use a pre-orifice low-drift nozzle (for example Spraying Systems Drift Guard (DG) series, Turbo TeeJet (TT) series, Albuz ADI, Hypro LD, Hardi LD, or Wilger ComboJet MR and DR). These nozzles can be used at conventional pressures, and will result in about 50% less drift. They work by using an extra orifice in the nozzle. This **pre-orifice** meters the spray at the required flow rate and pressure, and the regular **exit-orifice**, which creates the spray pattern, is somewhat larger than this. Because of the exit orifice's larger size, there is a pressure drop between the two, in effect creating a low-pressure tip which can be operated at regular pressures.

Venturi: Venturi nozzles are the latest addition to the drift-fighting toolbox. Also known as "air induction" or "air inclusion" nozzles, these ultra-low-drift nozzles represent a more sophisticated version of the pre-orifice nozzle. An internal venturi or jet draws air into the nozzle through small aspiration holes in the side of the nozzle body, which mixes with the spray liquid. The spray emitted from the nozzle contains large droplets filled with air bubbles, and virtually eliminates fine, drift-prone droplets. The bubble-containing droplets are more easily retained by leaves, and provide similar coverage to finer, conventional sprays when used at volumes >50 L/ha. Dramatic reductions in drift have been observed with these tips. Most venturi nozzles produce sprays rated as "Coarse" to "Very Coarse", but there are some differences between models. Key features to watch for are pressure ranges, ease of cleaning, and the ability to fit onto existing hardware.

Optimising Venturi Nozzle Performance: Manufacturers of the nozzles don't provide much information on how best to use them. The biggest problem appears to be occasional reductions in grass control with some herbicides, especially with the coarsest sprays. Fortunately, all problems that have been encountered so far can be controlled by the applicator.

A problem can appear once an applicator wants to maximise drift reduction at all cost: It's nearly impossible to eliminate drift entirely without paying some price in spray coverage. Venturi nozzles have allowed us to maintain good efficacy even though they are quite coarse. But there is a limit. With grassy weeds, or possibly with very low carrier volumes, too coarse a spray, combined with poor pattern uniformity, can cost you weed control efficiency.

The most important thing is to strike some kind of compromise when choosing a nozzle. If you're trying to target grasses, avoid the coarsest sprays. Secondly, if you already have a coarse spray, increase the pressure to at least 4 bar, higher if possible. This makes the spray a bit finer, improves patterns, but doesn't impact drift protection very much. Finally, don't cut corners with herbicide rate, staging or water volumes, especially when growing conditions are poor. The coarser sprays are less forgiving of these shortcuts.

Four Rules for Nozzle Selection

1. Choose the best *nozzle type* for your needs

Conventional Flat Fan

Advantages: reliable performance, allows lowest water volumes
Disadvantages: drift prone, can't use high pressures

Pre-Orifice

Advantages: reduce drift 50%, reliable efficacy at lower volumes, good for grassy weeds
Disadvantages: Need slightly higher pressures than conventional flat fan

Low-Pressure Air Induced

Advantages: reduce drift 50 to 70%, can use reasonable pressure, good for grassy weeds higher pressures or volumes
Disadvantages: Need >50 L/ha, >2 to 3 bar

High Pressure Air Induced

Advantages: reduce drift 70 to 90%,
Disadvantages: Must use higher pressures (>4 bar) and more water (>70 L/ha) for grassy weeds

2. Watch you water volume

The coarser your spray, the higher your water volume must be. There are two main reasons for this. (i) you must have enough droplets per square centimetre to hit your target. This is most critical for pre-seed burnoff, where weeds are smallest, and low-volume, coarse sprays will likely miss weeds entirely. (ii) you need sufficient coverage on your target for the pesticide to do its job. This is most important for contact herbicides such as bromoxynil, glufosinate, and reglone, and for insecticides and protective fungicides. It is also important for grassy weeds, most of which have a hard time retaining very large droplets.

3. Use the right pressure for your nozzle

The most common reason for performance complaints is when the spray pressure of a low-drift nozzle was too low, resulting in insufficient overlap between nozzles (see next point). Air-induced nozzles require higher pressures to operate properly. If your sprayer cannot produce sufficiently high pressures, you should not be using these nozzles. Try to do most of your spraying at these pressures: Conventional, 1.5 – 3 bar, pre-orifice, 2 – 4 bar, low-pressure air-induced, 3 – 4 bar, high pressure air-induced, 4 to 6 bar. Higher pressures increase drift, but less so for air-induced nozzles.

4. Ensure good patterns

The coarser droplets produced by low-drift sprays will go where they're pointed. There is only one chance to get uniform coverage across the boom. Finer sprays from conventional nozzles can re-distribute themselves with wind or turbulence, covering up mistakes. For coarse sprays, try to achieve a nozzle pattern width that is twice your nozzle spacing at the target height. Do this by selecting wider angle nozzles, increasing pressure, or adjusting boom height. This will ensure that the coarsest droplets at the pattern edge are mixed in with the more abundant, finer droplets found in the middle of a pattern.

WATER VOLUMES

Low water volumes save time, and low-drift nozzles reduce drift. Can we use them together to get the best of both worlds? Probably not. Very coarse sprays provide fewer droplets than conventional sprays, and if we also use less water, we may have insufficient coverage. What is the point beyond which an applicator should not venture?

Overall Conclusions

In order to optimise pesticide effectiveness, applicators must be prepared to balance their productivity and attention to environmental protection. No single nozzle or application volume will do all jobs optimally.

In general, our research results have shown that low-drift nozzles, particularly air-induced technologies, are able to reduce drift significantly (by 75% or more) while maintaining good performance over a wide variety of conditions. They are particularly well suited to the application of fungicides and broadleaf herbicides. When applying grassy herbicides, higher pressures and/or higher water volumes should be used with low-drift nozzles to maintain effective targeting.

Dense canopies are best penetrated by a combination of slower travel speeds and higher water volumes. Finer sprays or higher spray pressure had little or no effect in penetration of such canopies.

Contact details

Thomas M. Wolf
Agriculture and Agri-Food Canada, Saskatoon Research Centre
107 Science Place, Saskatoon, SK, S7N 0X2
Email: WolfT@agr.gc.ca
Ph: +01 306 956 7635

Appendix

The following is a typical nozzle recommendation for a producer, arrived at some consultation that established their cropping system (direct seeding), herbicides (mostly systemic, with an emphasis on grassy weed control), fungicides (primarily wheat and canola, target top of canopy), sprayer type (high clearance, travelling at 14 mph), and tolerance for drift.

I am recommending low-pressure air-induced nozzles for your sprayer. These nozzles provide good drift protection and are proven to give good coverage under a variety of applications. The most important thing to remember is to use sufficient water (within reason, more is usually better, except for glyphosate) and to ensure your spray pressure stays within the recommended range. Too low a pressure (<30 - 40 psi) results in poor spray patterns that may reduce control. I think your sprayer monitor can be set up to give you an audible warning when you reach a certain minimum pressure. There is no real penalty for going to higher pressures in terms of drift, but you may increase the wear on your hoses and fittings, and reach the limits of your pump capability. Most John Deere sprayers can reach 120 psi – you don't need to go that high.

1. **Glyphosate for pre-seed burnoff**
   - Apply product in 5 US gpa (50 L/ha)
   - Nozzle choices:
     1. SprayMaster (Hypro) Ultra Lo-Drift 120-02
     2. Greenleaf AirMix 11002
     3. Air Bubble Jet 11002
   - Operate both between 40 and 60+ psi (about 12 to 16+ mph)
     - Lower pressures increase droplet size and may reduce coverage. Higher pressures make spray a bit finer, but have no large effect on drift potential. AirMix and ABJ are a bit finer than Ultra-Lo-Drift. This means slightly more drift, but also better coverage. All three tips are good quality and work well, but AirMix is least expensive (about $6.00 per tip). Spraymaster is available from John Deere.

2. **In-crop herbicides other than glyphosate**
   - Apply product in 8 US gpa (80 L/ha)
   - Nozzle choices:
     1. SprayMaster (Hypro) Ultra Lo-Drift 120-03

2. Greenleaf AirMix 11003
3. Air Bubble Jet 11003

- Again, aim for 40 to 60+ psi with these tips. At speeds of 12, 14, and 16 mph, they will operate at about 45, 60, and 80 psi, respectively, which are good values.
  - When applying Liberty, apply product in 10 to 12 US gpa. This product has a contact mode of action and requires better coverage than other products. If you want, you can use the same tips, but slow down to about 10 mph to increase application volume. Or else, use the fungicide nozzles.

3. Fungicides

- Apply product in 10 to 15 US gpa (100 to 150 L/ha)
- Nozzle choices:

1. Albuz AVI Twin 120-04
2. Lurmark TwinCap with two Greenleaf AirMix 11002

The AVI Twin is a new air-induced double nozzle that sprays two fans, one 30 degrees back, the other 30 degrees forward. This will give you good spray coverage for fusarium headblight control, and can also be used against sclerotinia in canola. The Lurmark TwinCap does the same thing, but you have to assemble it and insert two separate nozzles. The ABJ does not fit into the regular TwinCap, you have to get a custom unit from an ABJ reseller.

  - With fungicides, slightly more water and slower travel speeds improve overall coverage and canopy penetration. Aim for about 12 US gpa, 12 mph. At these speeds, the 04 tips will be operating at about 60 psi, about perfect. Again, aim for 40 to 60+ psi with these tips.