GRAINS RESEARCH & DEVELOPMENT CORPORATION

GRDC GROWNOTES

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 16
Overview of the spraying systems available Strengths and limitations

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Key points

Before purchase, a number of factors should be taken into account when selecting a spraying system:

- **the range of application volumes and the range of spraying speeds required;**
- **the crop types to be sprayed, canopy size and stubble conditions;**
- **the products to be applied and the label requirements, including spray quality and downwind buffers of the products likely to be used;**
- **limitations of the current spraying system, as a guide to what may be needed; and**
- **the opportunity to access reliable service for the system when required.**

1. Introduction

There are several spraying systems available, either as options on new sprayers or as retrofits to existing sprayers.

When trying to decide between the various options, the key question the operator must ask themselves is what he/she requires the sprayer to be able to do. Often this process starts with identifying if a standard spraying system will limit your ability to operate the machine in the most efficient manner possible for your enterprise.

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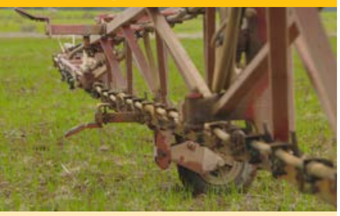


Spray systems - single line

Possible limitations of the 'standard' spray system

Using a 'standard' single spray line fitted with an automatic rate controller where the flow rate (litres per hectare) is controlled by manipulating the pressure can have two possible limitations:

- **the speed range that can be achieved from a single set of hydraulic nozzles (usually only 5 to 8 kilometres per hour) before the nozzles may no longer perform correctly. This is particularly noticeable when slowing the spraying speeds. The resulting reduction in pressure at the nozzle may cause the fan pattern to collapse, or, where a minimum setting is engaged in the rate controller, overdosing can occur; and**
- **the change in spray quality (droplet size) that occurs with most hydraulic nozzles when the rate controller adjusts pressure to match the travel speed (to maintain the sprayer output).**

Often the speed range and spray quality can be managed when the average spraying speed of the sprayer is relatively low (16km/h or less) and by using large enough headlands.

However, in situations where the average spraying speed is higher (usually above 20km/h) and the paddock contains contour banks or washouts, trees or obstacles, raised beds, or is set up for furrow irrigation with narrow tail drains, it may not be possible to maintain a narrow range of spraying speeds or to use larger headlands.

Spraying systems that can increase the practical speed range in the paddock

Spraying systems that can assist the operator to manage larger variations in the range of spraying speeds in the paddock include:

- **pulse width modulation (e.g. Case AIM Command®, Capstan SharpShooter®, Raven Hawkeye® and TeeJet DynaJet®);**
- **VariTarget® nozzles;**
- **some twin fluid systems (where air is injected into the nozzle using a compressor); and**
- **multi-step systems (such as dual booms, two or three-step systems on a single line, or multiple step using up to four nozzle sizes at each nozzle position).**

Of these systems, pulse width modulation is the only one that will maintain the pressure in the spray line and can therefore maintain spray quality as the spraying speed changes.

Some twin fluid systems may be able to maintain spray quality over a smaller range of spraying speeds. With the other systems, spray quality will vary according to the actual spraying speed and application volume selected.

PLAY VIDEO

Pulse Width Modulation - how it works.

2. Overview of pulse-width modulation

Pulse width modulation (PWM) systems can provide constant pressure in the spray line, which maintains a constant spray quality.

The flow rate (L/ha) is electronically controlled by PWM, where the nozzle rapidly turns on and off (pulses) many times each second. The length of each pulse is varied by the controller to match the travel speed; longer pulses = more flow, shorter pulses = less flow.

The pulse-width modulation nozzle body

The model shown is an earlier version, where a standard nozzle body is mounted in front of the PWM solenoid.

Source: Case

The Case AIM Command®, Capstan SharpShooter®, Raven Hawkeye® and TeeJet DynaJet® PWM systems operate at 10 hertz(or 10 cycles of open and closed per second). The percentage of the time that the nozzle is open (relative to closed) is known as the duty cycle. It is important that the duty cycle is high enough to ensure good coverage.

With a 10-hertz system it is good practice to operate the system above 70 per cent duty cycle at your average speed, and not let the system drop below 50 per cent when slowing down if using coarser droplets. Operating at closer to 100 per cent at your average spraying speed will provide the greatest practical speed range.

Strengths of PWM

- Pressure in the spray line remains constant, so droplet size does not change during spraying (unless the operator chooses to change the pressure to manipulate droplet size).
- When operating the system at close to 100 per cent duty cycle at the normal spraying speed, the effective speed range is at least half that of your spraying speed.
- Control of the flow rate and on/off occurs at the nozzle, which introduces the ability to have auto-section control that can operate individual nozzles.
- The ability to adjust pulse width allows for innovations such as turn compensation and increased flow on individual nozzles adjacent to the wheel tracks.

Possible limitations of PWM

- When a PWM system pulses at 10 hertz, it is usually not possible to run air-induction nozzles effectively on the line with the pulsing nozzle bodies. However, many systems are also fitted with a standard spray line where other hydraulic nozzles (such as air-induction) may be mounted, although with some set-ups it may take quite some time to change between the two lines.
- If the orifice size of the nozzles fitted to a PWM system is too large for the application volume and spraying speed, the duty cycle will be too low. With nozzles producing a coarse spray quality, operating at a low duty cycle (e.g. at low spraying speeds) may result in patchy coverage. As a rule of thumb it is best to select nozzle sizes that are not more than one-third larger in orifice size than you would normally choose for the same application volume and spraying speed on a standard boom.

For more information on how Pulse Width Modulation works, go to Module 18: Single line and multi-step systems

3. Variable-rate nozzle bodies

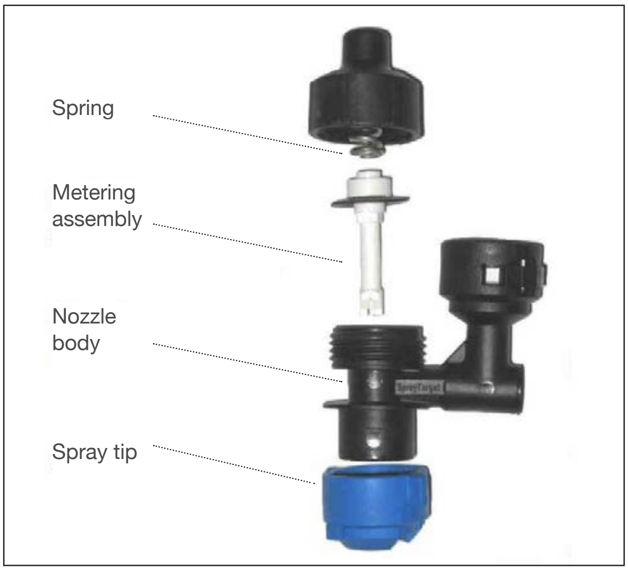
A single VariTarget nozzle effectively gives the operator flow rates that are equivalent to using two or three different nozzle sizes. For example, the blue coarse nozzle will maintain a coarse droplet size from 0.57L/min up to 1.5L/min. This range in flow rates is similar to going from an 02 orifice through to an 04 orifice (note, the blue nozzle can produce a wider range of flows, but the droplet size does reduce at higher pressures).

These systems employ a retrofit nozzle body that reduces changes in pressure at the nozzle created by changes in the spray line pressure. Minimising the change in pressure at the nozzle minimises changes in spray quality, when compared to operating a standard hydraulic nozzle.

VariTarget nozzle bodies reduce the variation in pressure at the nozzle as sprayline pressure and flow rate increase.

Source: VariTarget®

Exploded view of a VariTarget nozzle body



Strengths

- **Less expense than re-plumbing the whole boom.**
- **The operator can utilise the existing plumbing and automatic rate controller.**
- **A very good option for variable-rate fertiliser applications when using streaming nozzles.**

Possible limitations

- **The nozzle body tends to 'stick out' from most boom designs, increasing the risk of damage.**
- **The nozzle choice is limited (e.g. only a single type for producing coarse spray qualities).**
- **Spray quality data according to ASABE S572.1 is often difficult to find, and requires some interpretation, droplet size information is based on droplet size classed Dv 0.1, 0.5 and 0.9.**

4. Twin fluid and air-assisted systems

There are three general ways in which air is currently used as a part of some spraying systems. These include air-assisted sprayers, twin fluid systems and air-shear systems.

4.1 Air-assisted sprayers

Air-assisted spray systems use a standard spraying system and standard hydraulic nozzles to produce the spray droplets.

Normally the air is generated by one or more large fans, and the air is transported using an air bag which is delivered as a 'curtain' or 'twin curtains'. The air system is used to constrain and transport the droplets to the target and is completely separate from the liquid delivery.

The air volumes are relatively high, while the air velocity is normally relatively low (often less than 70 to 80km/h), but is generally enough to suit spraying speeds less than 20km/h.

Assistance can be retrofitted to many spraying systems, improving canopy penetration and reducing drift potential.

Photo: Bill Gordon

A Hardi® Twin Force air-assisted boom

Strengths

- Using conventional nozzles means that these systems are generally easier to understand, and selecting the spray quality is the same as it would be for a normal sprayer.
- Air assistance offers the potential for reduced downwind buffers (no-spray zones) due to the reduction in drift potential.
- Improved canopy penetration for fungicide applications and late season desiccation of large crops.
- Air assistance can be retrofitted to many spraying systems.

Play Hardi® twin force boom video: www.youtube.com/watch?v=JgvN3abkXYY

Possible limitations

- Where minimal ground cover or crop canopy is present it is possible to increase the drift potential if the spray quality, air speed and orientation of the air stream are not correctly set up.
- The width of the boom the system is able to be fitted to may be limited (e.g. often less than 36 metres), depending on the manufacturer's current range.

4.2 Twin fluid systems

Twin fluid systems utilise air from a compressor injected into the spray liquid, which is delivered through hydraulic anvil-style nozzles.

These systems operate the nozzles similar to the way that standard air-induction nozzles work, but rather than using a Venturi to draw air into the nozzle, a compressor is used to inject air into the nozzle body. The volume of air or air pressure is set by the operator or adjusted by a controller. This allows the nozzle to produce either air-included or solid droplets.

TeeJet® AirMatic nozzle bodies

The TeeJet® AirMatic regualtes both liquid and air flow to control the spray quality produced (not all twin fluid systems can do this).

Photo: Bill Campbell

By controlling the air pressure from the compressor the droplet size can be adjusted, so that a range of spray qualities can be obtained from a single nozzle and orifice combination.

Liquid flow is regulated by a standard automatic rate controller. However, there are two main differences in the systems that are available: those that require air pressure to be adjusted manually and those that can do this automatically.

Some twin fluid spray systems will automatically adjust the air flow in response to the liquid flow, while in others the air flow must be adjusted manually. The ratio of air to liquid is critical and has a large impact on the range of droplet sizes produced. In systems where the air flow is fixed, increasing liquid flow due to increases in speed can actually produce larger droplets.

Systems where the air pressure has to be adjusted manually (standard AirTech® or Optispray®)

These systems usually have the ability to hold a spray quality over a slightly wider range of speeds than a standard single line sprayer. Generally, the Optispray® has a wider range of operating speeds than the standard AirTech® system.

Systems that can adjust the air pressure in response to liquid flow.

These systems maintain the spray quality as spraying speed changes (examples include AirTech® fitted with a 'Magic Box' or the TeeJet® Airmatic).

Strengths

- **Spray quality can be adjusted without changing nozzles, by adjusting the air pressure supplied to the nozzle.**
- **Some systems can adjust air pressure automatically to maintain droplet size as flow rate changes in response to changes in spraying speed.**
- **The system utilises only one set of nozzles, with a range of inserts or restrictors that can be changed for large changes in the target application volume (L/ha).**

Possible limitations

- **A single orifice size (inserted into nozzle body) may not cover all application volumes without adjusting spraying speeds.**
- **The increase in the range of spraying speeds is modest compared to some other options.**
- **The inserted orifice that controls the flow rate may need to be changed to maintain spray quality when switching application volume, or increasing the spraying speed.**
- **Nozzles are typically angled backwards, which may increase drift potential.**
- **Compressors may alter the weight and balance of the sprayer, and may require additional maintenance.**
- **Increasing liquid flow rates without increasing air flow tends to increase the size of the droplets, as well as the range of droplet sizes produced.**

4.3 Air-shear systems

Air-shear systems use relatively high-speed air to impact on a stream of liquid to produce the droplets. The relationship between the air speed (indicated by air pressure in the air delivery system) and the liquid flow is critical for droplet size (spray quality) and the uniformity of the droplet spectrum.

Air-shear systems must be operated according to the manufacturer's specifications for the system to perform at its best.

A Miller SprayAir fitted to a Nitro sprayer

Photo: McIntosh Distribution

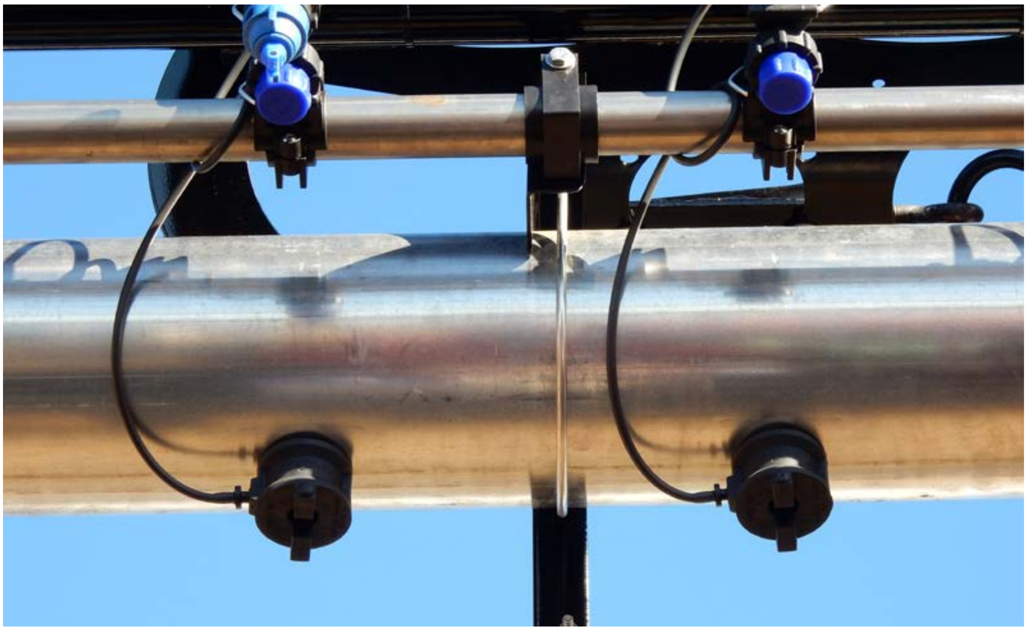
Air-shear systems tend to produce a more even range of droplet sizes when set up to produce smaller droplets (typically fine to medium spray qualities). As the droplet size is increased, the range of droplet sizes produced also tends to increase.

Air-shear systems tend to have a relatively narrow range of operating parameters where the system can perform at its optimum. Operating outside of the manufacturers' recommended spraying speeds and application volumes will generally result in reduced spray coverage or increased drift potential.

SprayAir systems are also fitted with standard nozzle bodies, to allow the operator to switch between air shear and standard hydraullic nozzles such as air induction for better drift control.

Photo: Graham Betts

The Miller SprayAir nozzles at the base of the air-delivery tube.



Summary of systems that use air

All spraying systems that utilise air require the operator to spend time 'experimenting' to find the optimum spraying speed, droplet size and air flow to match the canopy and the conditions.

Using water-sensitive paper (WSP) and image analysis tools such as the SnapCard App, is a valuable way to assess spray deposits on crop canopies or standing stubble. When evaluating the coverage obtained, operators should consider testing a range of travel speeds and air volumes or pressures at a range of application volumes. Often each system will have a series of 'sweet spots' where the all the parameters required line up to give great coverage.

Sprayers that use air can greatly improve penetration into large crop canopies. However, great care is required in fallow and low ground-cover situations, as there is potential for increased drift if the operator gets the airspeed wrong.

PLAY VIDEO

Single line multi-step system. The ARAG Selectron 4 nozzle system

5. Multi-step booms

Multi-step booms are fitted with more than one nozzle per nozzle outlet, with a rate controller that can be programmed to switch between the nozzles as the spraying speed changes. This effectively increases the range of spraying speeds available, or the range of application volumes that can be obtained without having to change the nozzles on the boom.

5.1 Two-tier or two-step dual booms

One of the original application systems developed to increase the speed range (and range of application volumes) of the boom sprayer was the use of two boom lines and a dual boom controller.

Typically these systems would operate the first boom line up to a nominated speed (or equivalent pressure or total flow rate through the boom) and then it would turn on the second line as well, so that **both** were operating. This is called a two-step or two-tier system, switching from one boom to both booms.

Two-step dual booms were introduced when extended range (XR) flat-fan nozzles were commonplace. XR nozzles are generally designed to operate from 1 bar to 4 bar, which is the increase in pressure required to double the flow rate (e.g. 4 x pressure = 2 x flow rate). With two-step dual booms, both spray lines are usually fitted with nozzles that have the same orifice size. When the pressure in the first boom line hits 4 bar, the second boom also switches on, and the pressure in both spray lines initially drops back to 1 bar, then increases as speed the increases.

This system would allow the operator to effectively double the speed range that would have been achievable with a standard boom fitted with a single spray line. Unfortunately XR nozzles cannot achieve a coarse spray quality in the orifice sizes that are commonly used on this system.

The ability to produce a coarse spray quality from smaller orifice sizes typically requires the use of pre-orifice or air-induction nozzles, which generally have a minimum operating pressure of 2 bar.

Nozzle selection for a coarse spray quality on the two-step system is more difficult because of the 4-fold increase in pressure required to double the flow rate. When using air-induction nozzles, often a larger orifice size (e.g. 025 or lilac) nozzle is fitted to the first line and smaller orifice size (e.g. 015 or green) nozzle fitted to the second line. This way the pressure does not drop too much for the nozzles to function when the second line engages.

5.2 Three-tier or three-step dual booms

The early versions of this system also utilised two spray lines, the major modification when compared to the two-step systems is in the automatic rate controller functions of the sprayer.

As the name suggests, this system changes in three steps: from the first boom, then to the second boom (on its own), then it switches both booms on. The transitions are determined by the operator who selects the speeds, pressure or flow rates that determine the changes from one boom to the next, for them to both occur.

This system provides an even greater speed range than the two-step systems, with almost three times the operating speed range of a standard single-line sprayer.

Three-step systems are also much better suited to the use of pre-orifice and air-induction nozzles.

When using air-induction nozzles, typically the first boom is usually fitted with smaller orifice size nozzles than the second boom. For example, it is common to have 015 nozzles (green) fitted to the first boom, and 02 (yellow) fitted to the second boom. Together, they produce the equivalent flow rate of an 035 sized orifice, but with the spray quality of the 015 and 02 nozzles.

PLAY VIDEO

Spray systems – 3 step dual boom

5.3 More recent versions of three-tier or three-step systems on a single spray line

A more recent version of the three-step system is the use of a single spray line fitted with narrower nozzle spacings (such as 0.25-metre spacing instead of 0.50m spacing), combined with on/off switching at the nozzle (rather than the whole boom section) using either air shut-off valves or electric shut-off valves.

A Goldacres® RapidFire system

The Goldacres® RapidFire is a three-step dual boom fitted to a single spray line, using air valves to control the nozzles.

Photo: Bill Gordon

With the three-step on a single line system, the odd nozzles (e.g. the first, third, fifth, etc.) will act as the first boom, and the even nozzles (second, fourth, sixth, etc) will act as the second boom (or vice versa), which then turns a single spray line into the equivalent of a three-tier or three-step dual boom system capable of running the equivalent of first boom, then the second, then both.

Alternatively, the nozzles can be aligned one behind the other on a single line, operating as a three-step system.

Strengths of a three-step system

- **Provides a large range of spraying speeds available to the operator.**
- **May reduce the need for nozzle changes when a change in application volume is required.**

Possible limitations of a three-step system

- **There are speed and volume combinations where the pressure at the nozzle can be too low to operate many air-induction nozzles effectively.**
- **Changing spray quality may require the transitions between nozzles to be reprogrammed, or the operator to change one or more sets of nozzles.**
- **For the versions using narrower nozzle spacing (alternating between odd and even nozzles), the plumbing of the nozzle bodies on the single spray line must be carefully considered, particularly on the boom ends. The sprayed width of each 'boom' could differ when operating at higher and lower speeds (e.g. odd line versus even line, or single line versus full boom), which may affect the overlap of the spray patterns at the boom ends.**
- **Operating at spraying speeds where a transition between nozzles is programmed to occur can cause the system to attempt to alternate between boom lines, causing pressure and spray-quality variations.**

5.4 Multi-step systems

There are several multi-step systems commercially available, where up to four nozzle sizes are fitted into the nozzle body at each nozzle outlet on the boom.

The sprayer's rate control system can be programmed to transition between individual nozzles, or to operate any combination of the four at the same time to match the application volume, spraying speed and desired spray quality.

Switching between nozzles can be controlled by using either air valves or electric nozzle shut-off valves, which are also a very useful feature when using boom recirculation and auto section control to prevent pressure spikes in the line when sections shut off.

Four nozzles in a single nozzle body provide the largest possible range in spraying speed and application volume.

Photo: Bill Gordon

A Goldacres® quad nozzle body

Depending on the plumbing arrangement and the valve types used on the nozzle bodies, some systems may also offer the ability to have single nozzle section control.

Electronic control at the nozzle provides instant switching and allows for single nozzle section control.

Photo: Graham Betts

An Arag® Selectron multi-step system with 4 nozzles per outlet

Strengths of multi-step booms

- They provide the largest increase the effective speed range, helping to prevent overdosing or nozzles collapsing when the sprayer slows down.
- They greatly increase the range of application volumes of any spraying system.
- By combining two or more nozzles, it can avoid the need for changing nozzles when changing spray jobs.

Possible limitations of multi-step booms

- Spray quality of each nozzle will change with pressure in response to changes in spraying speed.
- Selecting for a particular spray quality may require careful nozzle selection, or an adjustment to the speed, volume or pressure at which the nozzles are programmed to transition from one orifice size to another orifice size.

For more information on multi-step systems, see Module 17: Pulse width modulation systems

Play A YouTube clip on the Arag® Selectron system: www.youtube.com/watch?v=ue_b-0Egtns

6. Comparison of the systems for different requirements

It is difficult to make a direct comparison between spraying systems that is relevant to every spray operator and the needs of each grain-growing enterprise.

Table 1 below ranks each spraying systems' capacity to meet certain requirements. In some categories a function may not be currently available (indicated by 'X') or may be an option, which is indicated by a question mark.

Table 1 A comparision of the various spraying systems based on their ability to respond to various operator needs.

Category or functions compared (relative to a standard single line sprayer)	Standard single line	VariTarget® nozzles	Three-step dual boom	Multi-step boom	Air assistance (fitted to single line)	Twin fluid	Air shear	Pulse width modulation
Effective speed range	L	H	M	H	L	M	L	M
Effective volume range	L	H	M	H	L	M	L	M
Droplet size control (without changing nozzles or spraying speed)	L	L	L	M	L	M	M	H
Drift reduction (without changing nozzles or spraying speed)	L	M	L	M	H	L	M	H
Canopy penetration	L	L	L	L	H	L	M	L
Knowledge required for nozzle selection / set-up parameters	L	L	M	H	L	H	H	M
Need for nozzle changes	H	M	M	L	H	M	M	M
Suitability for variable-rate application	L	H	L	L	?	L	L	M
Turn compensation	X	X	X	?	X	X	X	H
Single nozzle section control	?	X	?	H	?	X	X	H
Ease of manintenance and decontamination	H	H	M	M	M	L	L	M

L = low **M** = medium **H** = high **X** = not at present **?** = perhaps

Various operators will place different levels of importance on certain functions. For example, for some operators speed or volume range may be more important than canopy penetration; alternatively, ease of decontamination may be more important than single nozzle section control.

7. Conclusion

The decision as to which spraying system may be the most appropriate for your operation requires careful consideration. Access to service from a reliable machinery dealer is often the key to the system you should choose.

Always base the decision on what you require the system to do on a list of your actual range of spraying speeds (or preferred spraying speeds), along with the range of application volumes and spray qualities you require for the products you plan to use. Also consider types of functions you think will be useful, such as boom recirculation or single nozzle section control, to ensure they are supported by the system you are interested in.

Often the best place to start is by noting what limitations your current system may be placing on how efficiently you can operate, and where potential savings in product or increases in efficacy could be made with an improved spraying system.

NEXT MODULE

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 17 Pulse-width modulation systems How they work and set up considerations