PWM SPRAYERS

FACT SHEET

GRDC™ GRAINS RESEARCH & DEVELOPMENT CORPORATION

NATIONAL

FEBRUARY 2023

Pulse width modulation sprayers: what we have learnt, correct operation and looking ahead

Photo: Bill Campbell

KEY POINTS

- PWM sprayers are continuing to improve with new technology providing more consistent performance, individual section control and turn compensation
- Constant pressure maintains droplet size and spray quality over a range of speeds
- Low duty cycle operation can result in poor coverage especially with 10Hz systems
- Newer systems have high cycle frequency (15/30/100Hz) and combine other standalone spraying systems
- There are many misconceptions about the effective working speed range, correct size and determining the correct pre-set pressure
- When set up and operated correctly, PWM sprayers perform accurately

What is pulse width modulation?

Pulse width modulation (PWM) is a spraying system where the flow rate is controlled by a pulsing solenoid at each nozzle, unlike a standard spray system that directly controls the overall flow rate. The solenoid shuts nozzle flow on and off several times per second and is installed in place of the diaphragm check valve in conventional systems. The number of cycles of on and off (pulses) per second (Hz) can vary between systems. PWM systems maintain a constant pressure in the spray line, irrespective of speed, so that the spray quality remains constant. As the flow rate is required to change with speed, it is controlled electronically at the nozzle body by adjusting the length of time the high-speed solenoid remains open during each pulse. This causes the nozzles on the PWM system to 'pulse' on and off. The proportion of time that the solenoid is open is called the duty cycle, which can range 0 per cent (no flow) to 100 per cent (continuous flow) depending on target application volume, nozzle orifice, operating pressure and spraying speed.

PWM is often referred to as blended pulse, which describes the mixing of the spray droplets to produce even coverage on the spray target. The nozzles are operated in alternate pairs, with the adjacent nozzles having alternate timing. The alternate pulses, combined with overlapping spray patterns and the natural dispersion of droplets travelling in air, blend together to provide consistent coverage. There is often less blending with larger droplets,

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Table 1: The different PWM systems available in Australia showing the different duty cycle frequencies and additional 'hybrid' spraying systems functionality.

Manufacturer	Duty cycle frequency	Nozzle spacings	'Hybrid' spraying systems
Agrifac	100Hz	50cm	PWM, standard spray system with multi-step, twin fluid
John Deere ExactApply™	15/30Hz	38 and 50cm	PWM, standard spray system with multi-step
AIM Command™, SharpShooter®, PinPoint™, Raven Hawkeye®, DynaFlex	10Hz	50cm	PWM, standard spray system

so where permissible on the product label the boom height may need to be set higher to achieve double overlap of every second nozzle on the boom.

There are several PWM sprayers available in Australia (Table 1) and they each have subtle technical differences. Some of the manufacturers have incorporated other spraying systems, which can operate as standalone systems (independent to PWM) as required.

With a PWM spraying system, once the pressure is selected it does not change as spraying speed changes (unless the spraying speed or volume required exceeds 100 per cent, in which case the pressure will increase). The droplet size/spray quality does not change, which is a key feature of the PWM system, compared with conventional spraying systems. This means that a wider range of travel speeds can be used without any change in spray pressure compared with standard nozzles.

DUTY CYCLE FREQUENCY

Sprayers available in Australia run 10Hz, 15Hz, 30Hz or 100Hz cycle frequencies.

Duty cycle frequency describes the cycle per second that the regulating solenoid on each nozzle pulses. The earliest versions of PWM systems in Australia operated at 10Hz, but the new systems offer higher frequency cycling.

The John Deere ExactApply™ system (see Picture 1 - page 7) uses two sequenced 15Hz solenoids to give a 30Hz cycle frequency. The higher cycles per second technically give a wider working speed range. The higher the duty cycle, the more accurate the application at slower speeds and lower duty cycles.

DUTY CYCLE PERCENTAGE

PWM spraying systems were first introduced to Australia from Canada where spraying operations are subtly different. When first introduced to Australia many sprayers with PWM systems were fitted with nozzles that were too large for typical broadacre applications. This often resulted in low duty cycles and reduced efficacy. Since that time the technology has improved and understanding has increased of the influence of nozzle size, spraying speed, operating pressure and water volume on the duty cycle.

The ideal duty cycle is an openly debated aspect when diverging from published data and charts produced by manufacturers on working speed range and duty cycle operation. To operate a PWM system effectively, it should be operated at a high duty cycle (85 to 95 per cent) at the intended spraying speed. This will give a greater spraying speed range and will minimise potential efficacy issues associated with 'skips' at lower duty cycles that occur at slower spraying speeds such as headlands. Uniformity of coverage can be an issue below 50 to 60 per cent duty cycle, depending on cycle frequency, as there may not be sufficient overlap of the spray pattern from adjacent nozzles. This also occurs where boom heights are too low, total application volumes are low or droplet sizes large with low duty cycles.

The overlap is referred to as the on:off distance travelled. This aspect is discussed in more detail on page 6, with the different pulsing frequency (15Hz, 30Hz and 100Hz) systems. The newer higher frequency systems minimise skip issues. Only the most recent PWM systems display the duty cycle, allowing the operator to avoid low duty cycle operation and exceeding 100 per cent duty cycle. Flow rate is maximum at 100 per cent duty cycle, so exceeding 100 per cent duty cycle results in 'under-dosing'.

Figure 1: a) Water-sensitive paper picking up a skip while at high duty cycle. This could be due to low boom height impeding 'blending of the droplets' (Wilger SR04 medium spray quality).

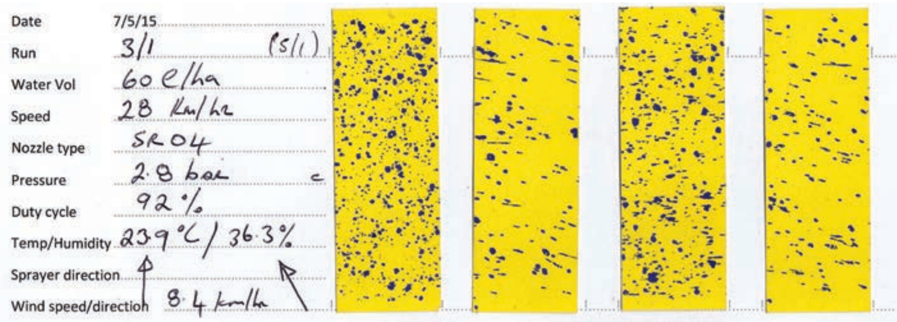
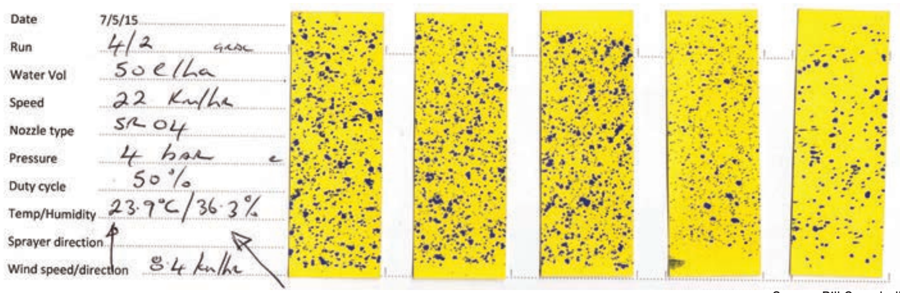


Figure 1: b) Water-sensitive paper showing poor coverage on the right two papers. The three papers on the left have good coverage for 50L/ha (Wilger SR04 medium spray quality).



Source: Bill Campbell

Checking coverage and skips with water-sensitive paper

Water-sensitive paper is an important visual tool for identifying and demonstrating under-dosing or poor coverage, which can lead to reduced efficacy. Figure 1A illustrates a complete miss and Figure 1B illustrates the coverage of just one nozzle (that is, no double overlap). At times it is possible to see skips even at higher duty cycles. Visual symptoms in paddocks, especially in knockdown and grass-selective spray situations, are tiger strips or small blocks of weeds about 50 x 10 centimetres in area. Not understanding the distance covered when nozzles are on or off is the main reason that effective speed range flexibility has been misrepresented when promoting PWM (see Figure 3).

PWM nozzle size selection process

Nozzle size selection is based on four primary factors: water volume, working speed, nozzle type and the desired operating pressure for the nozzle. Many PWM sprayers are operating with nozzles that are too big, compromising coverage when slowing down and operating at low duty cycles.

When selecting nozzles for a PWM sprayer it is best to treat it as a standard sprayer, so nozzle size selection will not be greatly different. The process to set-up, as with a standard sprayer, is to look at a nozzle chart with flow rate x nozzle size x speed for where 100 per cent duty cycle will occur and at what pressure the size nozzle will operate. Increase the pressure over this or put on a nozzle one size larger and the duty cycle will 'kick in' to reduce the effective flow. Unless a change is made in working speed, generally two sets of nozzles will be required for low and higher water volumes (as with standard sprayers).

TYPES OF PWM NOZZLES

There are a selection of flat fan and pre-orifice 'low-drift type' nozzles that can be used in PWM systems. The *GRDC Pulse Width Modulation - Standard Nozzle Selection Guide* (see pages 4 & 5) lists nozzles suitable for use. The correct nozzle selection is greatly influenced by the pre-set pressure and the optimal pressure range for the nozzle. The spray quality, water volume and coverage requirements are determined by the mode of action, the spray target/species and any drift considerations.

Wilger has a speciality range of pre-orifice nozzles SR, DR, MR and UR (Table 2) that are designed for PWM systems. Some are capable of producing larger droplet sizes with low driftable fines and some are capable of producing similar spray qualities to the air-inducted nozzles used in conventional spraying systems. These non-venturi nozzles can produce a wide range of droplet distribution characteristics.

Table 2: The relative spray qualities specifically (other sizes available) for 03, 04 and 05 Wilger pre-orifice nozzles. The DR, MR and UR are unique pre-orifice nozzles that produce larger droplets compared with other pre-orifice nozzles (see Useful Resources section).

BRAND		Wilger	Wilger	Wilger	Wilger
MODEL		SR-110	MR-110	DR-110	UR-110
Nozzle Size	BAR				
03 BLUE	1.5	C	VC	XC	
	2.0	C	VC	XC	not available in this size
	3.0	C	C	VC	
	4.0	M	C	VC	
	5.0	M	C	C	
	6.0	F	M	C	
04 RED	1.5	C	XC		
	2.0	C	VC	XC	UC
	3.0	C	C	XC	UC
	4.0	M	C	XC	UC
	5.0	M	C	VC	UC
	6.0	M	M	VC	
05 BROWN	1.5	VC	XC		
	2.0	C	XC	XC	UC
	3.0	C	VC	XC	UC
	4.0	C	C	XC	UC
	5.0	M	C	XC	UC
	6.0	M	C	VC	

PWM NOZZLES ARE AVAILABLE FOR 2,4-D APPLICATION

The 2020 Australian Pesticides and Veterinary Medicines Authority (APVMA) label changes for 2,4-D require application with a minimum of very coarse (VC) spray quality for most applications. For more details regarding APVMA 2,4-D application requirements, consult the GRDC *2,4-D Application Requirements* fact sheet. For nozzles that can meet this VC or larger specification, refer to the *GRDC Pulse Width Modulation - Standard Nozzle Selection Guide* (see pages 4 & 5). It is important when using larger droplets (coarser spray qualities) that the duty cycle can be maintained as high as possible to avoid skips, as larger droplets will not redistribute the same way as smaller droplets.

CAN AIR-INDUCTED NOZZLES BE USED?

It is not recommended to use venturi nozzles (air-inducted nozzles) with PWM as the fluid pulsing and rapidly changing fluid flow does not allow the venturi process to stabilise within the nozzle, resulting in uneven atomisation; that is, very large droplets and a large variation in droplet size. Growers who have used venturi nozzles have experienced efficacy issues on small grasses and poor activity with contact herbicides. The research paper by Butts et al. (2019) concludes venturi nozzles are not recommended for PWM systems as they may lead to inconsistent applications, specifically in regard to droplet size generation and nozzle tip pressure changes.

Larger droplets with PWM

As larger droplets have more momentum, coverage can be variable with low boom work height as the spray patterns of

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Pulse Width Modulation – STANDAR

		Pre-Orifice (RUN ABC									
BRAND		TeeJet®	TeeJet®	TeeJet®	Lechler	HARDI	ALBUZ®	ARAG®	ARAG®	Hypro®	Hypro®
MODEL		DG-110	TT-110	TTJ-60 twinjet	AD-110	LD-110	ADI-110	CFLD-C	CFLD-XC	LD-80	LD-120
DATE PUBLISHED		2013	2017	2017	2016	2011	2016	2023	2023	2018	2018
Nozzle Size	BAR										
015 GREEN	1.5		C		M	M				M	M
	2.0	M	M	not available in this size	M	M	M	not available in this size	not available in this size	M	M
	3.0	F	M		M	M	M			M	F
	4.0	F	F		F	M	F			M	F
	5.0		F		F	M				M	F
	6.0		F		F						
	7.0										
	8.0										
02 YELLOW	1.5		C	C	C	M		XC	UC	C	M
	2.0	M	C	C	M	M	M	VC	UC	C	M
	3.0	M	M	M	M	M	M	C	XC	M	F
	4.0	M	M	M	M	M	M	C	XC	M	F
	5.0		F	M	F	M		C	XC	M	F
	6.0		F	M	F			C	VC		
	7.0							C	VC		
	8.0							C	VC		
025 PURPLE	1.5		C	VC		C		XC	UC		M
	2.0	not available in this size	C	C	not available in this size	C	M	VC	UC	not available in this size	M
	3.0		M	C		M	M	C	XC		M
	4.0		M	C		M	M	C	XC		M
	5.0		F	M		M		C	XC		M
	6.0		F	M				C	VC		
	7.0							C	VC		
	8.0							C	VC		
03 BLUE	1.5		VC	VC	C	C		VC	UC	C	C
	2.0	C	C	C	C	C	C	VC	UC	C	M
	3.0	M	M	C	M	C	M	C	XC	C	M
	4.0	M	M	C	M	M	M	C	XC	M	M
	5.0		M	C	M	M	F	C	XC	M	M
	6.0		M	M	F			C	VC		
	7.0							C	VC		
	8.0							C	VC		
04 RED	1.5		VC	VC	C	C		XC	UC	C	C
	2.0	C	C	C	C	C	VC	VC	UC	C	M
	3.0	M	C	C	C	C	C	C	XC	C	M
	4.0	M	M	M	M	C	M	C	XC	M	M
	5.0		M	M	M	M	M	C	XC	M	M
	6.0		M	M	M		M	C	VC		
	7.0							C	VC		
	8.0							C	VC		
05 BROWN	1.5		VC	VC		C		XC	UC	C	C
	2.0	C	VC	C	data not available	C	data not available	VC	UC	C	C
	3.0	C	C	C		C		C	XC	C	M
	4.0	M	C	M		C		C	XC	C	M
	5.0		M	M		C		C	XC	M	M
	6.0		M	M				C	XC		
	7.0							C	XC		
	8.0							C	VC		

F – Fine, M – Medium, C – Coarse, VC – Very Coarse, XC – Extra Coarse, UC – Ultra Coarse. All data have been sourced from the manufacturers' websites as at February 2023.
Note: nozzle performance may vary and is dependent on the PWM system being used and how it is operated.
Always check current spray quality information according to ASABE S572.1

RD NOZZLE SELECTION GUIDE

February 2023

VE 1.5 to 2 BAR)

Hypro®	John Deere	John Deere	Wilger	Wilger	Wilger	Wilger	Wilger	Wilger	Wilger	
GRD-120	LDM-120	LDX-120	SR-80	MR-80	DR-80	SR-110	MR-110	DR-110	UR-110	
2018	2019	2019	2022	2022	2022	2018	2018	2018	2018	
										BAR
						M	C	C		1.5
M	not available in this size	M	C	C	VC	M	C	C	not available in this size	2.0
M		M	M	C	C	F	M	C		3.0
M		M	F	M	C	F	M	C		4.0
F		F	F	M	C	F	F	M		5.0
F		F	F	F	C	F	F	M		6.0
F		F								7.0
F		F								8.0
						M	C	VC		1.5
M	not available in this size	M	C	C	XC	M	C	VC	not available in this size	2.0
M		M	M	C	VC	F	M	C		3.0
M		M	F	M	VC	F	M	C		4.0
M		M	F	M	C	F	F	C		5.0
M		M	F	M	C	F	F	C		6.0
M		M								7.0
M		F								8.0
		M				M	C	VC		1.5
M	not available in this size	M	C	VC	XC	M	C	VC	not available in this size	2.0
M		M	M	C	VC	M	C	C		3.0
M		M	M	C	VC	F	C	C		4.0
M		M	M	C	C	F	M	C		5.0
M		M	M	C	C	F	M	C		6.0
M		M								7.0
M		M								8.0
C	XC	C				C	VC	XC		1.5
M	VC	M	C	VC	XC	C	VC	XC		2.0
M	VC	M	C	C	VC	C	C	VC	not available in this size	3.0
M	C	M	M	C	VC	M	C	VC		4.0
M	C	M	M	C	C	M	C	C		5.0
M	C	M	M	C	C	F	M	C		6.0
M		M								7.0
M		M								8.0
VC	XC	VC				C	XC	XC		1.5
VC	VC	VC	C	VC	XC	C	VC	XC	UC	2.0
C	C	C	C	C	XC	C	C	XC	UC	3.0
C	C	C	C	C	XC	M	C	XC	UC	4.0
M	C	M	M	C	VC	M	C	VC	UC	5.0
M	C	M	M	C	VC	M	M	VC		6.0
M		M								7.0
M		M								8.0
XC	XC	XC				VC	XC	XC		1.5
XC	XC	XC	VC	XC	XC	C	XC	XC	UC	2.0
VC	VC	VC	C	VC	XC	C	VC	XC	UC	3.0
VC	VC	C	C	VC	XC	C	C	XC	UC	4.0
C	C	M	C	C	VC	M	C	XC	UC	5.0
M	C	M	M	C	VC	M	C	VC		6.0
M		M								7.0
F		F								8.0

Important information

NOTE: This guide does not attempt to contain all nozzle brands, models or sizes that may be fitted to spray systems using pulse width modulation (PWM). It includes the most common or widely used nozzle types used with PWM spray systems. Nozzle manufacturers continue to release new nozzle models onto the market.

Growers should consult nozzle manufacturers and the manufacturers of PWM systems to determine the suitability of particular air-inducted nozzle type/s for their own PWM equipment to ensure that these products comply with APVMA approved product label requirements.

Information on the use of TeeJet® nozzles AITTJ, AITTI and AITT160 can be found at **https://www.teejet.com/spray_application/nozzles.aspx**

Disclaimer

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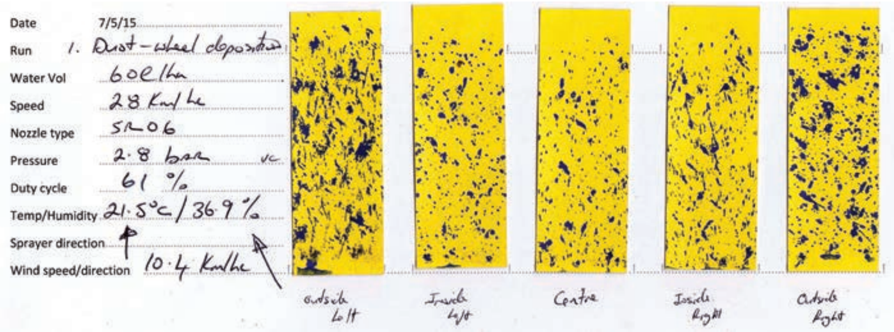
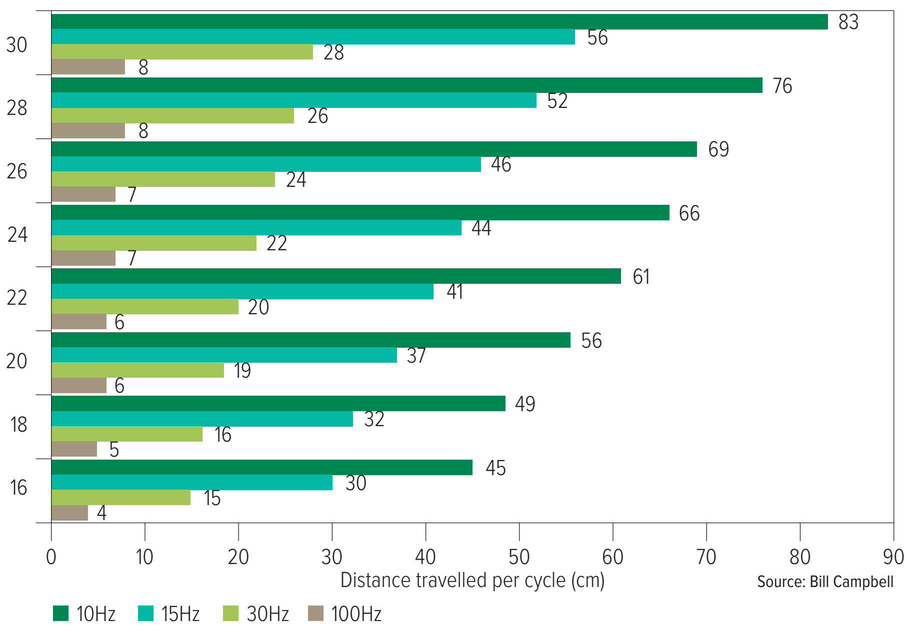
Figure 2: The effect when extremely large droplets are produced at a low duty cycle.



Source: Bill Campbell

Figure 3: The distance travelled for different pulsing frequencies (10, 15, 30 and 100Hz) at 100 per cent duty cycle.



Source: Bill Campbell

Figure 4: a) 100Hz PWM sprayer (80L/ha 2.75 bar) not set up correctly, low duty cycle operation < 50%, nozzle size too big. Left to right 8, 15 and 22km/h. Note the inconsistent droplet size and coverage.

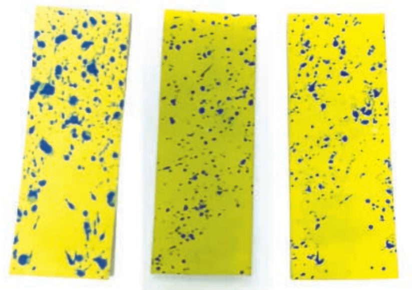
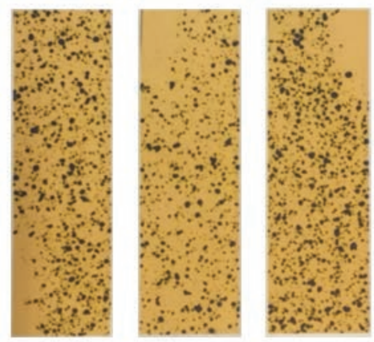


Figure 4: b) The same 100Hz PWM sprayer (80L/ha 2.4 bar) after replacing with correct nozzle type and size. Left to right 15, 19, 22km/h. Note the evenness of droplet size and coverage.



Source: Bill Campbell

adjacent nozzles do not readily blend or mix compared with smaller droplets. It is recommended to work at higher boom heights (700 versus 500 millimetres) when spraying with larger droplets, being aware that the drift component will travel exponentially. Figure 2 shows the effect when extremely large droplets and a lower duty cycle (61 per cent) are produced, hitting water-sensitive paper and splattering due to incorrect set-up.

Travel distance, pulse frequency and duty cycle interaction

Newer higher frequency systems running 15Hz, 30Hz or 100Hz, now in the field, offer a greater speed range without compromising coverage at lower duty cycle. The lower frequency with low duty cycle operation can compromise coverage. Figure 3 shows the distance travelled for different pulsing frequencies (10, 15, 30 and 100Hz). At 25 kilometres per hour, one cycle with 10Hz is 69cm, 15Hz is 46cm, 30Hz is 23cm and 100Hz is 7cm.

The example in Table 3 shows that with higher frequency systems, the overall distance travelled per cycle is significantly shorter and the on:off distances are also shorter, allowing greater mixing or blending of droplets. When looking at specific on:off distance at 60 per cent duty cycle (Table 4), the higher frequency gives greater compensation. Early indications from the field show greater flexibility and consistency from 10Hz to 15Hz and to 30Hz. Above this, greater benefits are not expected.

John Deere's ExactApply™ (15Hz and 30Hz) sprayer option of 38cm spacing offers greater nozzle overlap compared with the standard 50cm systems, giving improved droplet blending.

Importance of correct set-up and operation

PWM systems operating at 100Hz and 25cm nozzle spacing, appear to provide almost unlimited working speed and duty cycle. However, there are practical limitations to all systems including ensuring the correct nozzle configurations. The setting up and correct operational process for the different PWM sprayer systems is the same as for standard sprayers. Firstly, it requires calculating the flow rate (L/min/nozzle) based on water volume, working speed and nozzle spacing. Secondly, one must determine the required operating pressure to operate at a 100% duty cycle and the minimum pressure required to allow the PWM sprayer to

Table 3: The relative on:off distance for adjacent nozzles with 80L/ha at 25km/h 100 per cent duty cycle. With higher frequency systems the overall distance travelled per cycle is significantly shorter, allowing greater mixing or blending of droplets.

Duty cycle		50	60	65	70	75	80	85	90	95	100	%
Speed		13	15	16	18	19	20	21	23	24	25	km/h
10Hz	cm per duty-cycle	35	42	45	49	52	56	59	63	66	69	cm
	cm On per cycle	17	25	29	34	39	44	50	56	63	69	cm
	cm Off per cycle	17	17	16	15	13	11	9	6	3	0	cm
15Hz	cm per duty-cycle	23	28	30	32	35	37	39	42	44	46	cm
	cm On per cycle	12	17	20	23	26	30	33	38	42	46	cm
	cm Off per cycle	12	11	11	10	9	7	6	4	2	0	cm
30Hz	cm per duty-cycle	12	14	15	16	17	19	20	21	22	23	cm
	cm On per cycle	6	8	10	11	13	15	17	19	21	23	cm
	cm Off per cycle	6	6	5	5	4	4	3	2	1	0	cm
100Hz	cm per duty-cycle	3	4	5	5	5	6	6	6	7	7	cm
	cm On per cycle	2	3	3	3	4	4	5	6	6	7	cm
	cm Off per cycle	2	2	2	1	1	1	1	1	0	0	cm

Source: Bill Campbell

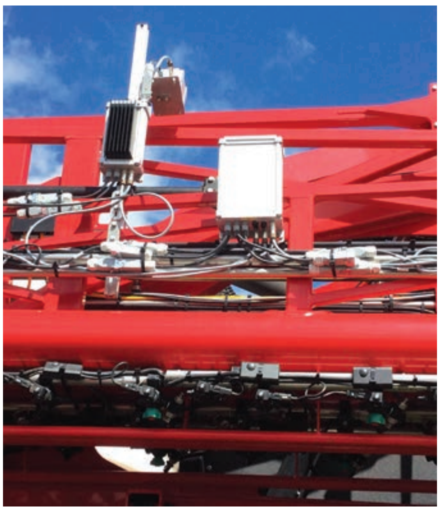
operate. The final step, once the 100% duty cycle pressure is known is to select a suitable nozzle with the required pressure range and the appropriate spray quality (droplet spectrum). Evenness of droplet deposition and consistency of coverage with PWM deteriorates when reducing duty cycle. There is a point where coverage is compromised, irrespective of higher pulse frequencies offered with the newer technology. It will be lower with higher frequencies. The set up of a PWM sprayer duty cycle can be influenced by changing water volume, nozzle size, nozzle type, pre-set pressure and working speed. It can be a tricky process but all these must line up. Figures 4a and 4b demonstrate the importance of getting all the components correct for good even coverage. The issue was corrected by using a smaller nozzle size and standard nozzle type.

Table 4: The relative on:off distance at 60 per cent duty cycle for 10, 15, 30 and 100Hz systems based on 100 per cent duty cycle at 25km/h as outlined in Table 3.

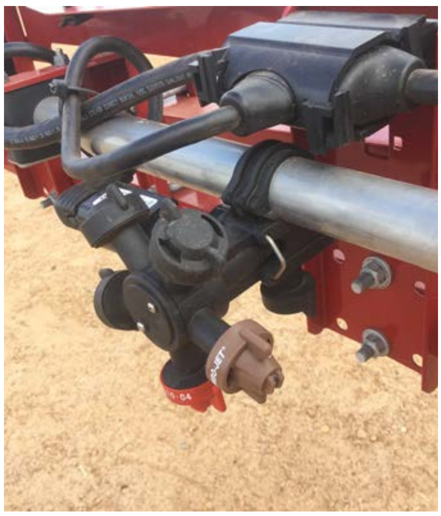
15 km/h at 80% DC						
Distance	Cycle frequency	10Hz	15Hz	30Hz	100Hz	
Total per duty-cycle	TOTAL	42	28	14	4	cm
On per cycle	ON	25	17	8	2.5	cm
Off per cycle	OFF	17	11	6	1.5	cm

Source: Bill Campbell

1. John Deere's ExactApply™ is a good example of the latest engineering and modulisation with multiple spraying systems within one carousel unit. It contains a standard spraying system, multi-step system and PWM.



2. The Agrifac multiple spraying system with standard, twin fluid, PWM – 100Hz, and new camera (back view) for weed-recognition technology.



3. Improved electronics and fully protected wiring on a new Case Patriot sprayer (2018). Note the modular nozzle body turret 'clip and play' components giving flexibility for endless configurations.

Photos: Bill Campbell

PWM HARDWARE AND APPLICATION ACCURACY

The reliability of the PWM hardware has improved with modulisation of the nozzle bodies, improved electronics and wiring harnesses (Picture 3).

All PWM systems have a 'redundancy' feature so with any electronic 'failure' they can operate as a standard sprayer. The basic principles of spraying and PWM have not changed but the John Deere ExactApply™ nozzle carousel (Picture 1) is a good example of the latest engineering and modulisation: each unit contains both standard spraying system, multi-step system and PWM. The PWM can be run at 15Hz or 30Hz, with single or a combination of nozzles.

New software minimises overlap, over and under-spray through individual nozzle headland section control and flow rate turn compensation as standard features.

An important consideration with turn compensation, if set up to work at higher end duty cycle (more than 90 per cent), is that operators must slow down around obstacles or when turning on headlands, as the maximum duty cycle will be reached by the outside boom.

FREQUENTLY ASKED QUESTIONS

How many sets of nozzles are needed?

Generally, most growers will require two sets of nozzles if working at a constant speed for a range of water volumes.

Can my PWM sprayer conform with the new 2,4-D VC spray quality permit requirements?

Yes, there are several options. Wilger has a specialised range of pre-orifice nozzles (MR, DR or UR types) that are designed for producing large droplets (VC, XC, UC spray qualities) and for droplet-drift management. The UR series is relatively new, producing 'ultra-coarse' droplets, one of the coarsest spray tips in the world designed for highly sensitive areas. The ARAG CFLD nozzle also conforms with these requirements.

What is the process for selecting the right nozzle?

First determine the flow rate required based on working speed and water volume by using a standard nozzle flow rate chart. Select nozzle size and 100 per cent duty cycle pressure. The sprayer will need to be operated at pressures 'slightly higher' so it is now working at 100 per cent duty cycle. This will then allow the selection of a suitable nozzle that gives the desired spray quality based on these higher pressures. The *GRDC Pulse Width Modulation – Standard Nozzle Selection Guide* references duty cycle for water rate and working speed, and nozzle selection options.

What does increasing pre-set pressure do to duty cycle?

Increasing the pre-set pressure would normally increase the flow rate, so with PWM systems if there is no change in spraying speed increasing the pressure will effectively reduce the duty cycle. Slowing down will also decrease the duty cycle.

USEFUL RESOURCES

- GRDC Fact Sheet – *Maintaining efficacy with larger droplets – New 2,4-D application requirements*: grdc.com.au/maintaining-efficacy-with-larger-droplets
- Fantastic Nozzles (fantasticnozzles.com.au/articles/pwm), Wilger (wilger.net), Capstan (capstanag.com) and Raven (ravenprecision.com) provide various reference material for choosing nozzles, spray quality charts and app-based Tip Wizards.
- GRDC *GrowNotes™ – Spray Application Manual for Grain Growers*: grdc.com.au/resources-and-publications/grownotes/technical-manuals/spray-application-manual
- GRDC *GrowNotes™ – Spray Application Manual for Grain Growers*: *Module 17: Pulse width modulation systems:* grdc.com.au/resources-and-publications/grownotes/technical-manuals/spray-application-manual/17grdcsm17pulsewidthmodulationsystems.pdf

REFERENCES

Butts, TR, Butts, LE, Luck, JD, Fritz, BK, Hoffmann, WC and Kruger, GR (2019) 'Droplet size and nozzle tip pressure from a pulse-width modulation sprayer'. *Biosystems Engineering 178, 52-69.*

MORE INFORMATION

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