University of Southern Queensland

Incitec Pivot Fertilisers

Variable Rate Spray Technology User Guide

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Disclaimer

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Abstract

Variable Rate Technology (VRT) refers to the application of products such as fertilisers, pesticides, herbicides, and fungicides in broadacre agriculture at varying rates across a field, rather than applying a uniform rate throughout. The desired goal of applying variable rate technologies in agriculture is to improve yields and turnover, increase cost savings on product and labour, environmental impacts including soil health/quality and reducing the amount of chemical output to the environment.

This guide will focus on the requirements to perform VRT application of fertiliser which involves the precise and targeted application of fertiliser based on the specific needs of different areas within a field to achieve a uniform nutrient level throughout. There are two key components to this guide:

1. A general overview of the VRT technology stack mapped into autonomy levels. Example product names and costs are provided for two of the biggest tractor manufacturers – John Deere and Case IH.
2. A detailed report on the implementation that UniSQ procured as part of this project, as an example of the process in action.

The project team at the University of Southern Queensland was successful in upgrading technology stack onboard existing machinery to accurately perform variable rate applications with liquid fertiliser. The team completed the full workflow of soil sampling, prescription map generation, precision application, and review of yield and grain quality maps in collaboration with Incitec Pivot Fertilisers and MCA Ag at a trial site at the TOSARI farm. The resulting yield and grain quality maps showed a uniform end-point for the field, with initial variability reduced to a maximum disparity of less than 15% between the lowest nitrogen rate and the highest.

Contents

1. Proposed Technology Stack

The approach for mapping VRT technologies was to break them apart into ten levels:

1. Manual variable rate
2. VRT controller
3. Telematics back to office
4. Automatic tractor guidance
5. Section control
6. RTK autosteer
7. Headland management system
8. Nozzle control
9. Automatic tendering
10. Full autonomy

The detailed breakdown for these autonomy levels is presented in a multi-page table starting on the next page. These steps of autonomy start with the minimum technology to perform variable rate application through manual speed control and zone rate changing, with outlined autonomy layers to improve efficiency, accuracy, and quality with each autonomy component. The UniSQ machine that performed the VRT application has employed up to Step 8 of this technology stack.

Technology Pathway to Autonomy (Tech Stack)	Description	Tractor Manufacturer			
		John Deere	**Case New Holland (CNH)** +Raven Precision	**Approximate Cost** **($AUD)**	**Cumulative Cost** **($AUD)**
1. Manual Variable Rate	Rates can be controlled within a margin across a boom and with variable speed. A grower could apply variable nitrogen (N) across known zones	-	-	Variability Mapping Yield, EM, soil, etc.	Variability Mapping
2. Variable Rate Technology Controller	Acts as the brain of the sprayer, takes the prescription map and interprets it to apply chemical spatially	✓ GreenStar™ Rate Controllers[1]	✓ Case IH AFS section and rate control (AccuControl, ISO Task Controller, Field-IQTM) ✓ NH PLMR input control systems (IntelliRate™, ISO Task controller, Field- IQTM) ✓ Raven RCM[2]	$2,650-$3,500 Rate Controller	Low: $2,650 High: $3,500
3. Machine to office communication "Telematics"	Allows wireless transfer of prescription (Rx) maps to the machine	✓ JDLink™ Connect[3] (mobile comms, optional satellite) data transfer to Operations Center	✓ Case IH AFS Connect™ [4] ✓ NH PLMR Connect™ ✓ ClearVU [5]	$650 Gateway[6] $2,250 Activation	Low: $5,550 High: $6,400

(ie date recording and management; remote monitoring and control)	from agronomist, grower or IPF				
4. Automated Tractor Guidance (ie GPS Autosteer)	Allows automated steering correction, without RTK (+-30cm)	✓ AutoTrac™ (GPS autosteer) [7]	✓ Case IH Advanced Farming Systems (AFS) components (e.g. AccuGuide – GPS autosteer) ✓ NH Precision Land Managent (PLM) components (e.g. Intellisteer™ – GPS autosteer) ✓ Raven SmarTrax™ [8] ✓ Raven Slingshot	$2,500-$3,000 Kit $1,300-$3,000/year	Low: $8,050 $1,300/year High: $9,400 $3,000/year
5. Section Control	Allows individual sections of boom to be switch on or off, increasing efficacy of variable rate applications	✓ JD Section Control (+AutoTrac™) [9] ✓ GreenStar™ Rate Controllers	✓ AFS Section and Rate Control ✓ PLM™ IntelliView IV[10] Section Control ✓ Raven RCM	- No additional cost if purchased for VRT above	-
6. RTK GPS Autosteer	RTK GPS correction (+-3cm accuracy)	✓ StarFire™ RTK[11]	✓ AFS Vector Pro ✓ PLM™ RTK ✓ Raven Slingshot RTK[12]	$6,200 Receiver[13] $2,250 Radio[14] $11,350 Activations	Low: $27,850 $1,300/year High:$29,200 $3,000/year

UniSQ

7. **Headland Management System**	Allows the machine to turn automatically	✓ AutoTrac™ Turn Automation[15] (tractor must have AutoTrac from factory)	✓ Headland Management Control	$7,000/year	Low: $27,850 $8,300/year High:$29,200 $10,000/year
8. **Nozzle Control**	Allows individual nozzle control across the boom	✓ Individual Nozzle Control Pro (PWM) ✓ ExactApply[16] (Only on Boomspray Machines)	✓ AIM Command Pro ✓ AIM Command FLEX™ (PWM) ✓ IntelliSpray™ ✓ Raven Hawkeye 2[17] (PWM)	$700-$1,000/ Nozzle with install kit.	Assuming 24 nozzles Low: $44,650 $8,300/year High:$54,200 $10,000/year
9. **Automatic Tendering**	Automatic/ Automated Tendering of chemical to spray tank	✓ Load Command[18] (4940 Sprayers), rapid fill not automatic ✓ Autofill Concept[19]	-	~$5,000, no retrofit kit in Australia yet IPF Demo unit $50,000+ -cost can be reduced by using an existing tank, 2in lines and a petrol pump. ~$6,050 -$4,750/IoT -$1,000/pump -$200 in hose -$200 in camlocks	Not available through upgrade path. Standalone purchase only.

				(Pump will need to be started with choke) $50/month subscription	
10. Full Autonomy	The driver is removed from the cab. Perception and additional safety features are incorporated.	✓ 8R Autonomous Tractor[20] ✓ Autonomous Sprayer Concept ✓ Electric, autonomous tractor concept	✓ New Holland Autonomous T5 concept ✓ Case Cabless Autonomous concept[21] ✓ Raven OmniPower™ [22]	$86,000/year based off subscription model from SwarmFarm[23] Robotics >$750,000 for Autonomous 8R	Not available through upgrade path. Standalone purchase only.

Notes:

Most new tractors and self-propelled boom sprayers contain all hardware up to Automation **Step 6**, with the additional note that you will need to factor in additional costs for a new or upgraded booms prayer and VRT controller if using a tractor. Many self-propelled boom sprayers now also come with nozzle control from the factory. Additional costs for these systems include activations and yearly subscriptions as above.

The IPF demonstration sits at **step 8.**

UniSQ

2. Case Study – Precision Application on a Croplands Sprayer

This section of the user guide provides a detailed project case study which was undertaken by the UniSQ team in collaboration with Incitec Pivot Fertilisers to demonstrate the outlined technology stack in a commercial and practical agricultural trial. The case study provides an example of the process and requirements to perform VRA trials with full utilisation of the technology, from data collection, data analysis, map generation, machine implement requirements and enhancements, and a broadacre trial application of liquid fertiliser Easy-N across a 46-hectare field of wheat.

The case study for VRT application has been broken down into the core progression, from a starting point which many growers already utilise in their workflow, the steps for upgrading equipment and hardware for accurate autonomy, generating prescription maps for field nutrient requirement and an overall cost analysis of input to return. Various key aspects of the prescription map generation will be dependant on regional constraints such as climate, soil type and crop type, along with field size and application amount, and so the steps documented n this report may need to be adapted for each use-case. Elements such as the method of collecting soil sample data and developing a prescription map will be different for new users/growers and agronomists alike, and depending on the scale of the broadacre field in the trial area the machine requirements such as total number of nozzles, boom length and tank capacity will all be different.

2.1 Starting point – Croplands Sprayer

The starting point for UniSQ was with a tractor and no sprayer available, so not even Step 1 (manual VRA) was possible. The tractor was a John Deere 6120R which was pre-fitted with most preliminary technology requirements including automated GPS guidance, RTK auto-steer, machine to office telematics via JD Operations Centre, sprayer implement section control and headland management system through the JD Greenstar display. These are all common features which can be installed and configured on newer model tractors from various brands such as John Deere (JD) or Case New Holland (CNH), and are often available to be added to older machines as well.

The project team's next step was to acquire an sprayer to mount on the back of the 4066R of a suitable size and width for the small tractor, as well as fit it out with technology to enable precision application.

A croplands sprayer (pictured on the 4066R in Figure 1) was procured through a local partner – Toowoomba Spray Shop. The basic features of the sprayer were:

- 1300 litre main tank capacity
- Wash tank and flush tank fitted
- Three sections with self-levelling centre section
- 12 metre width, 25 nozzles across
- Hydraulic pump onboard for section pressure control (instead of through PTO)
- Hydraulic boom folding to reduce size when not in use

Figure 1. Croplands 3-section sprayer mounted on John Deere 4066R

2.2 Precision application technology

The *Raven Hawkeye 2* was selected as the rate control technology enhancement to be installed onto the croplands section sprayer. The key benefits to the Hawkeye 2 compared to alternatives are primarily the emphasis on efficiency and precision. The unit is capable of being installed with various farm management software and machinery operation terminals allowing for a versatile variable rate application upgrade for most existing sprayers. The system features individual on/off nozzle control valves that operate with PWM duty-cycle control for extremely fast and high accuracy allowing the machine to autonomous compensate for acceleration, turning, contours, and headlands to avoid over- and under-spray during operation. Photos of the Rate Control Module (RCM) and the NCV2 PWM Nozzle controllers are shown in Figure 2, and some key datasheets for the Hawkeye 2 system are appended in Appendix A including modes of operation for the RCM module, technical specs for the nozzle control valve (NCVs), and a Gen 1 vs. Gen 2 performance comparison.

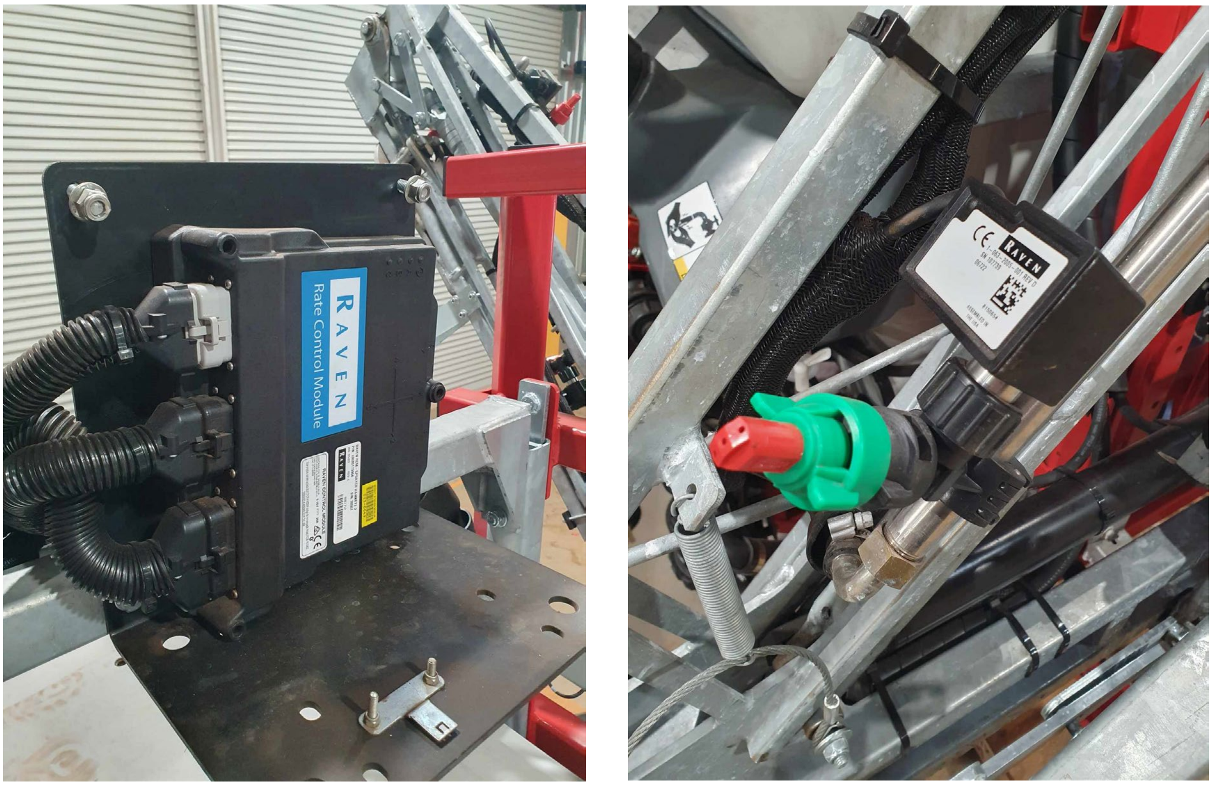


Figure 2. Raven rate control module (left) and Hawkeye 2 nozzle controller (right)

Installation of this unit onto the project teams croplands section sprayer was conducted by Raven technicians onsite. Alongside the RCM module and individual NCV2 PWM controllers which attach to the nozzle body where the diaphragm would typically be located, the sprayer was also fitted with a pressure sensor inline with the manual pressure gauge, a flow meter inline with the main flow line to the 3-pressure regulator sections, and a solenoid (on/off) on the hydraulic pump. These primary added features to the sprayer allow the RCM to monitor the current pressure, flow rate and control the pump which can all be viewed from the cabin console. This is an important feature for consideration of nozzle selection, as the RCM and NCV2 PWM duty-cycle control which alter flow rates and pressures during a prescription mapped task will affect the types of nozzles utilised.

For the TOSARI wheat field, the 46 ha field required varied application rate from 30-140 L/ha. Selection of a suitable nozzle type depending on the agronomy recommendations and reference to a nozzle chart to watch application pressure and speed (chart in Appendix B). The NCV2s control both of these parameters during operation, and so selection of a “middle-ground” target rate from the expected operating range should suffice to avoid over/under pressure warnings. The Red SJ3-04 SteamJet nozzles fitted onto the sprayer can be seen in Figure 1.

While the Raven RCM system can be procured and outfitted in a tractor with the Raven Viper4 in-cab screen, the versatility of the module allows the Raven RCM to be integrated with various third-party displays, including the JD Greenstar which has been utilised in this case study and can be seen in Figure 3. During installation Raven technicians can load the Raven management software and configure the functional settings during the commissioning of the system and throughout testing. Various calibration settings, mode selection, and sensor outputs such as tank level, application speed, flowrate, and pressure, can all be viewed from the screen in-cab. This is also where application rate setup can be performed, or prescription maps can be loaded for sprayer task setup. The mode run for this case study was “Standard” and for a detailed explanation of the different modes in which the Raven RCM can operate and the different functions each provides.

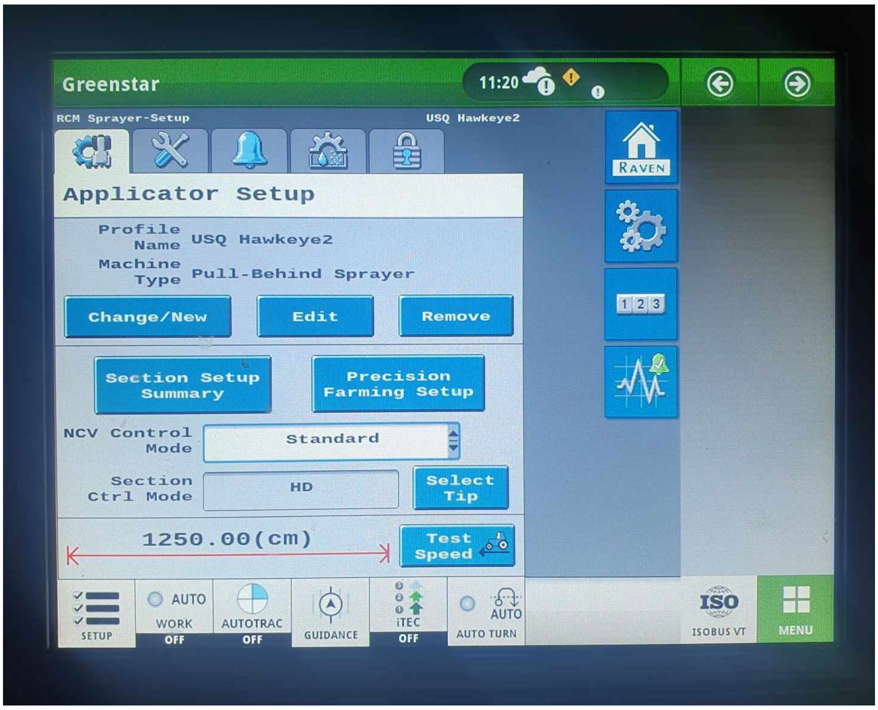


Figure 3. Raven control displayed on John Deere Greenstar display

The sprayer installation also required various cable harnessing, to which the majority is extensive harnesses from the RCM to the NCV2 PWM nozzle controllers. The RCM is connected to the tractor via ISOBUS on the CAN Bus Network, and alongside the ISOBUS connection the RCM is powered by a proprietary power connection which Raven technicians will need to install and route tractor side to the machine's battery. A final connection was also installed to connect to a master foot-switch in-cab for full system on/off control for the operator.

2.3 Variable Rate Prescription Mapping

A prescription map, in the context of variable rate fertiliser application, is a spatial map that provides specific recommendations for the application of fertiliser product in different zones of a field. These recommendations as previously mentioned are based on data analysis, allowing farmers to customise fertiliser rates according to the specific needs of different areas within their fields, where the goal of prescription maps is to optimize nutrient application, improve crop yields, and reduce input costs.

2.3.1 Soil Testing and Data Collection

The precision fertiliser application conducted at TOSARI was an in-crop application, after the pre-sowing treatment. The first step for the team was to perform soil testing to determine the current nutrient levels across the application area. This is performed with soil coring to extract core samples of the soil at various depths, and at random/sparse locations in-field, where it is recommended to divide field area into blocks with a minimum of 1 sample location per 2 hectares in broadacre scenarios. Generally, the greater the number of core samples across the field, the more accurate a precision map for the nutrient content that can be generated.

Figure 4. Retrieving soil samples at TOSARI

Note: Always refer to specific soil sampling guidelines provided by agricultural extension services or relevant research institutions, as the various considerations and process of data collection may vary based on the crops or environmental conditions in your region.

Soil coring can be performed in various methods, and there are several key variables to consider before gathering core samples. Depending on the crop type and soil type, this can affect the depth at which samples will need to be collected, such as the root zone of the planted crop. Furthermore, the field area/size, elevation and climate should be considered to determine the sampling pattern, where utilising a systematic pattern ensures a representative dataset is obtained, such as random locations within outlined zones, or evenly distributed gridded sampling. Additionally, consider sub-sampling where if the application zone/area is quite large it can be beneficial to gather multiple samples at various divided zones and depths, and mix these samples to create a composite sample across that zone which provides a more representative average of the site. Much of this process should be consulted with a grower's onsite agronomist or external partner to ensure quality data is collected. Lastly, when gathering samples, contamination and technique is critical and precaution should be made when cleaning hardware to use appropriate chemicals to clean probes etc, that will not contaminate the nutrient samples with foreign products.

The process of soil coring and the hardware required will vary depending on the number of core samples required and how fast the samples need to be collected. One method is to perform sampling by hand, using a 4-stroke motorised post driver (Figure 5 left) to drive a core probe (Figure 5 right) into the soil, and then remove it with a hand-jack. Once removed the sample can be extracted from the probe and depending on the depth, the sample should be divided into several sub-depths to be individually packaged, and geo-tagged, ready for lab analysis.

Figure 5. Materials for collecting soil samples by hand

Additionally, this same process could be performed with vehicle mounted soil coring rams, which typically utilise hydraulic drivers and chain jacks to remove the core sample. The process of sampling remains the same, as this method mostly improves the efficiency of gathering a larger quantity of samples quickly. The core ram depicted below which has been utilised by the University of Southern Queensland for various VRT and soil analysis projects is the Wintex MCL3 (shown in Figure 6). This is a powerful sampler designed to sample to depths of up to 2m irrespective of the soil type, with a hydraulic control system for lifting the mast into working position, positioning the mast on the ground, driving the probe into the soil with a jackhammer and rotating the attached probe for clean and efficient removal. This specific soil sampler and similar alternatives are popular among the agricultural industry and research institutes for its reliability and capacity to be installed/mounted on Can-Am vehicles, John Deere Gators, Trailers, and various other utility vehicles.

Figure 6. Example of vehicle-based soil testing with a Wintex MCL3.

After extracting a soil sample from the probe, samples will need to be divided into separate depths which will be individually assessed for their nutrient content. Typically, there will need to be 2-3 different depths analysed for reliable translation of the data into an accurate spatial map. In the trial at TOSARI, a 46-hectare field of wheat was divided into four zones, with 4-6 samples per zone depending on their irregular size. Each sample was taken at a depth of 90 cm, where the sample was then split into 4 individual depth sections (0-10 cm, 10-30 cm, 30-60 cm, 60-90 cm). At minimum, 500 g of soil product was required per depth section, per zone, meaning there would be four bags of 500 g of soil from the desired depths per zone. The 0-10 cm surface soil from the 4-5 sample locations in a zone were then all mixed, and 500 g of the total collected sample were bagged, with the GPS coordinates/geo-location of where the soil had originated in a field attached to the bag (this is repeated for each depth section). Collected samples are then required to be dried and crushed, to ensure that any lumped clay soil is sufficiently mixed in the bag for accurate and reliable lab-analysis results.

2.3.2 Data Analysis and Map Generation

Once the depth samples have been acquired and individually bagged and labelled with their GPS location in-field, the samples are then ready to be dried and crushed prior to sending away for lab analysis, which for this project case study, samples were sent to *Nutrient Advantage – Incitec Pivot AUS*. Nutrient Advantage allow samples to be delivered via postage (using the bags shown in Figure 7) for direct soil laboratory analysis, where the results are then available online for spreadsheet download, and future prescription mapping. Figure 8 shows an exported result from Nutrient Advantage for one of the zone depth section samples from the Incitec Pivot Project and VRT case study mentioned previously. Here we can see that the sample was gather from zone 4 at depth 4, (60-90 cm), and its testing type, and specific results are outlined. Additional information such as GPS location, and many other nutrient values such as average percentile etc. are provided with all lab results in an exportable Excel Spreadsheet format.

Figure 7. Soil sample bag

It should also be noted that the data collection process of soil sampling can be outsourced to external providers such as *Precision Agriculture AUS* mentioned previously, which can be useful when assuring that correct data is obtained and removes the requirement for growers to acquire more advanced soil sampling hardware, although outsourced contracted data collection and the soil lab analysis both have impending costs.

Nutrient Advantage®

LAB RESULTS REPORT

Sample No		022313957
Paddock Name		Tosari
Sample Name		Z4D4
Sample Depth (cm)		60 - 90
Sampling Date		23/06/2023
Test Code		E38
Sample Type		Soil
Analyte	**Unit**	**Result**
Soil Colour		Grey
Soil Texture		Clay
Moisture	%	37
pH (1:5 Water)		9.0
pH (1:5 CaCl2)		7.6
Electrical Conductivity (1:5 water)	dS/m	0.18
Electrical Conductivity (Sat. Ext.)	dS/m	1.1
Chloride	mg/kg	12
Nitrate Nitrogen	mg/kg	6.7
Ammonium Nitrogen	mg/kg	2.5
Sulphur (MCP)	mg/kg	6

Figure 8. Soil test results from Nutrient Advantage.

Once the lab soil results are received, an Rx Prescription Map can be generated, which can then be uploaded to the machine ready for application via John Deere Operations Centre (JD Ops) or by manually uploading when the operator is in-cab. The PWM flowrate and pressure nozzles will then automatically switch liquid rates as the machine moves through the field into the various zones.

Whilst UniSQ went through the full process for receiving N recommendations by *Precision Ag AUS* based on the currently available soil N and the required N to meet the yield target, the farm managers of the Tosari Crop Research Centre (TCRC) opted to use their own prescription map for the precision application (shown in Figure 9). The rate map which was generated for the wheat field has 4 main zones with a range of application rates ranging from 33 L/ha up to 140 L/ha. The logic behind the recommendation was to assess how much N each zone currently had (pre-plant N from soil tests 0-60 cm + urea application after emergence) compared to the estimated required N of 270 kg/ha for a 6 t/ha yield target. The amount of easy N recommended for each zone is exactly the amount required to bring each zone up to the 270 kg/ha N number. Assumptions for in-crop mineralisation, protein, soil bulk density, nitrogen use efficiency and effective depth were made in forming the N target.

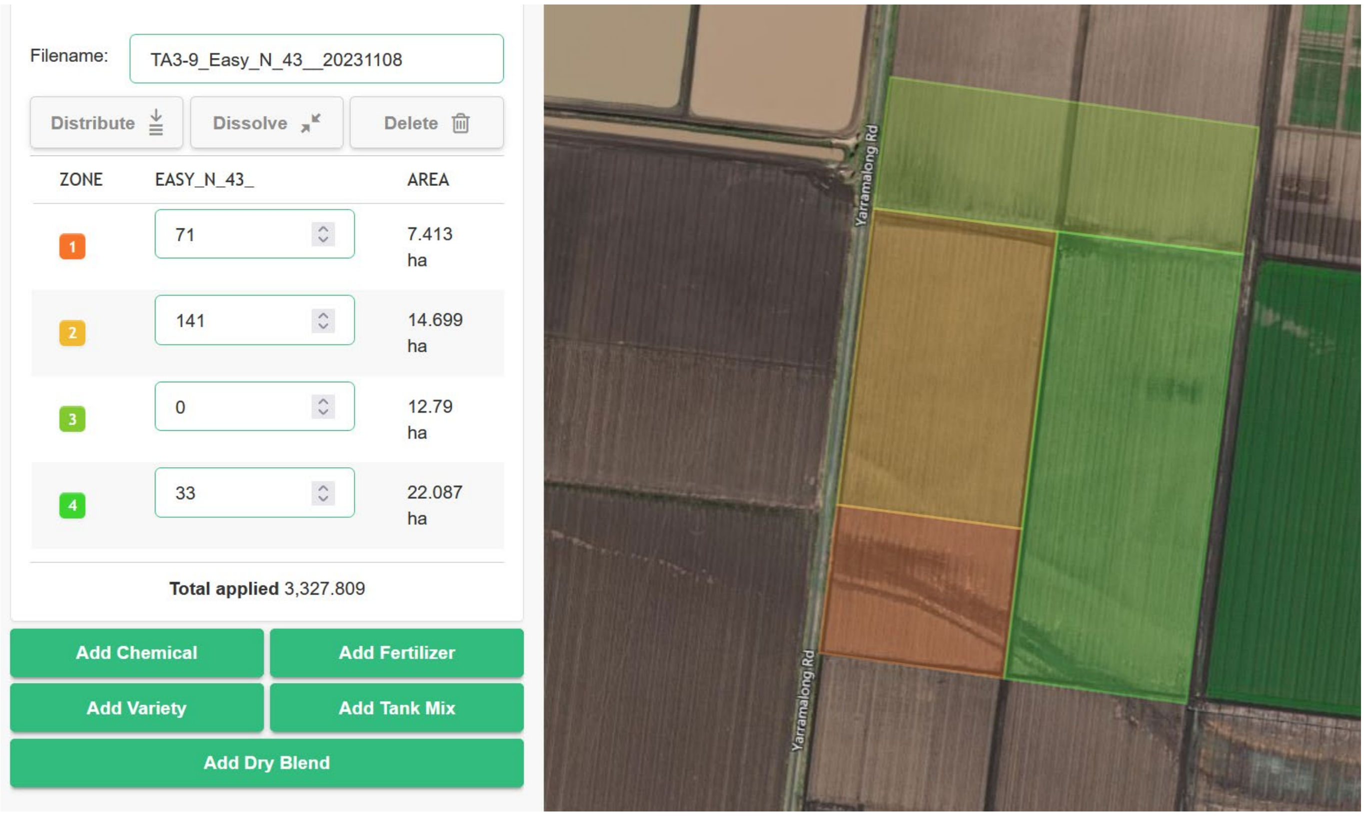


Figure 9. Prescription map for Easy-N fertiliser.

The precision application was executed on August 11, 2023, with IPF personnel present to observe parts of the application. Figure 10 shows a picture of the application in progress, and Figure 11 shows an as-applied map summarising the performance of the sprayer as well as the yield map for the field.

Figure 10. Sprayer applying Easy-N to a wheat field. The streams can be seen in front of the tractor wheel.

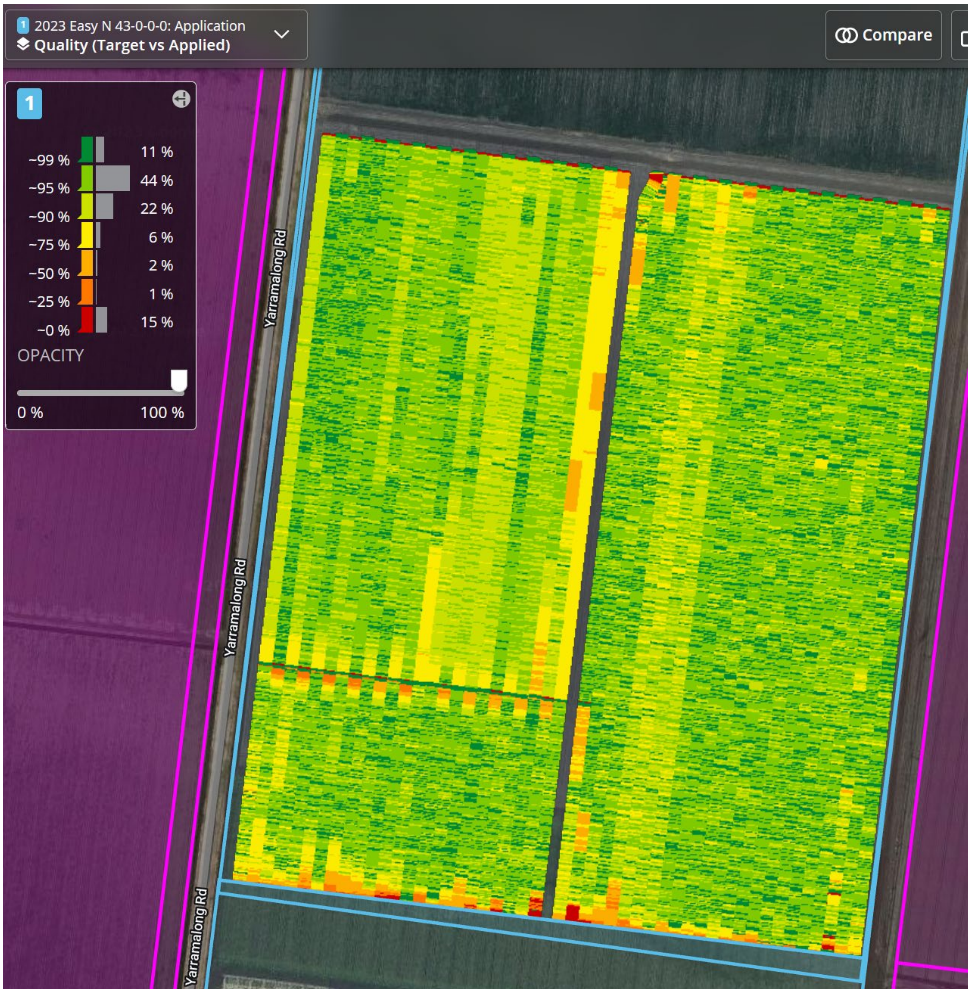


Figure 11. As-applied quality map showing 90+ percent application quality over most of the field.

Some of the key takeaway points from the as-applied analysis were:

- Total of 31244 L applied vs target of 3194 L (98% of target easy-N applied)
- Over 50% of the field was 95%+ quality, over 80% was 90%+ quality.
    - Comment from Raven is that this is OK for factory calibrations, fine-tuning from ground staff will improve it.
- Most of the red is an artefact from a different field, the '15%' reading is more like 5% in truth.
- Red and orange spots at field edges indicate that the nozzles turned on too much when starting a row and then normalised back to target rate.

Evidence of the bottom two dot points is provided in Figure 12, showing both the extra red section off-field and the high nozzle rate when entering a field.

The metric for success for the precision application is the yield data for the field. Yield map were collected from the harvester, and small samples of grain from each of the management zones was collected by hand for nutrient analysis, both of which are shown in Figure 13. The result show no visible difference in yield across the management zones which is an indicator of success, and the nutrient analysis shows a maximum spread of 15% in nitrogen content across the field. The zone with no applied N was also hah the highest nutrient level at the time of the yield sample, validating the choice of input levels for the management zones.

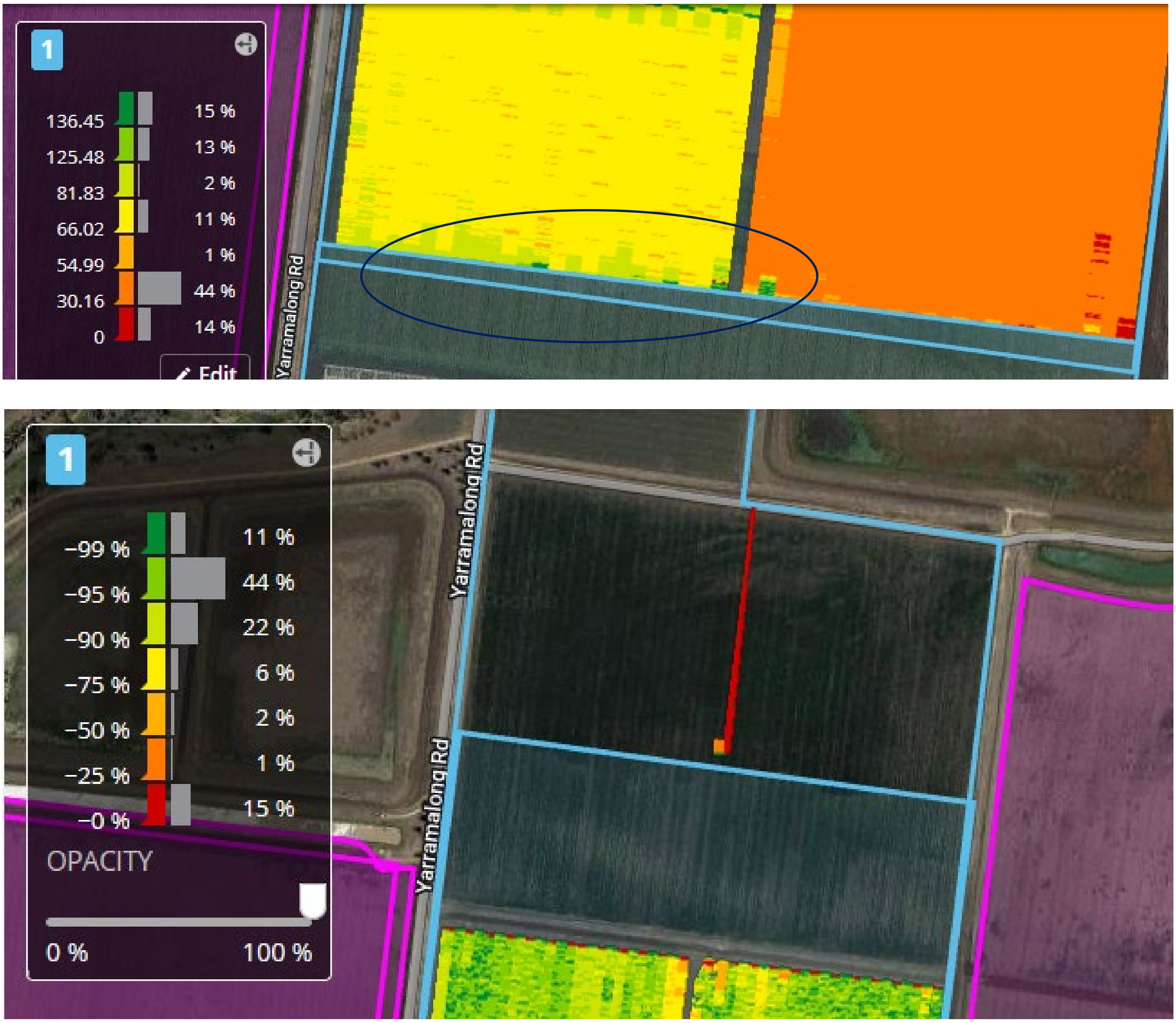
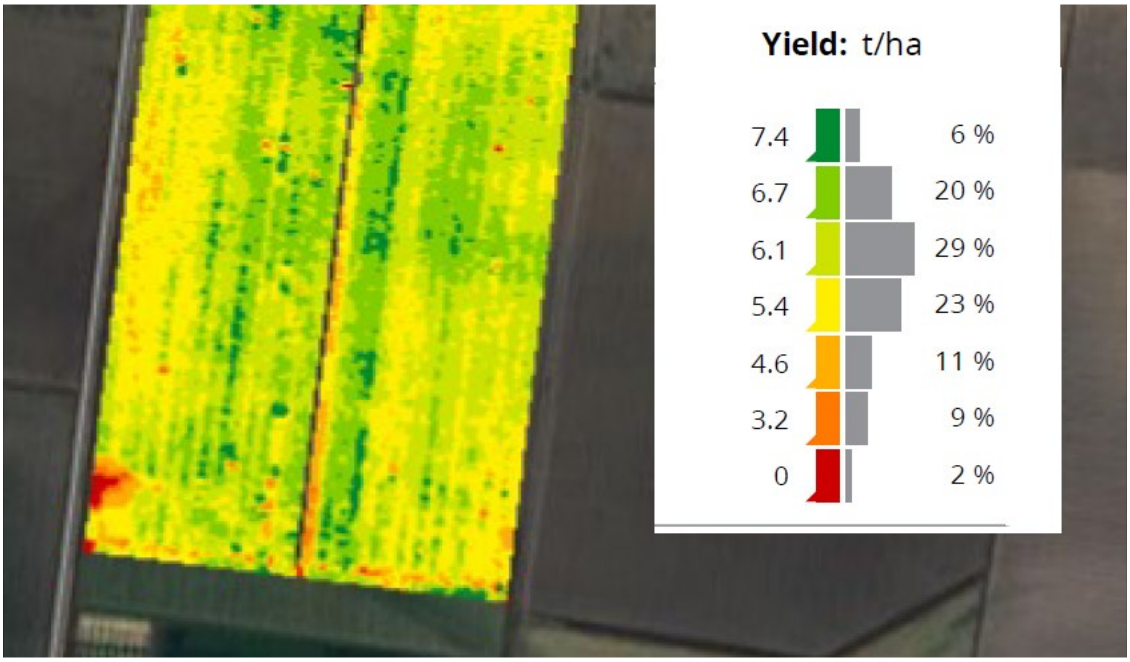


Figure 12. As-applied map showing areas of high initial flow rate (circled in top), and as-applied quality map showing section off the top of the Figure 11 map.



SUMMARY REPORT

MCA Farming		**Service Provider:**	NA Pro Cfree Soil
1149 Millmerran-Leyburn Rd		**Advisor/Contact:**	Bede O'Mara
Tummaville		**Phone:**	0417 896 377
QLD 4350		**Purchase Order:**	UQ Liquids Auto

Sample No		130322107	130322104	130322105	130322110	
Paddock Name		TA2-TA9	TA2-TA9	TA2-TA9	TA2-TA9	
Sample Name		Zone 1 30kgN (71L/ha)	Zone 2 60kgN (141L/ha)	Zone 3 Nil 0N (0L/ha)	Zone 4 30kgN (71L/ha)	
Sample Depth (cm)		N/A	N/A	N/A	N/A	
Sampling Date		13/11/2023	13/11/2023	13/11/2023	13/11/2023	
Test Code		CT815	CT815	CT815	CT815	
Sample Type		Tissue	Tissue	Tissue	Tissue	
Analyte	**Unit**	**Result**	**Result**	**Result**	**Result**	**Result**
Total Nitrogen (Combustion)	%	2.10	2.30	2.40	2.10	

Figure 13. Volume map and nutrient analysis of the yield. The two key fields from the nutrient report are the Sample Name (showing input N) and Total Nitrogen.

2.4 Cost Analysis

The cost for the project team to execute the precision application of liquid fertiliser was as follows (all numbers are approximate):

- Tractor: $0 (already owned)
- 1300L three-point linkage sprayer $50,000
- Raven technology (RCM, Viper display + Hawkeye 2): $25,000 (supplied in-kind by Raven)
- Total: $75,000

Additionally, a spreadsheet to quantify the return on investment for the equipment has been submitted as Item 5 of the final report. The inputs for the spreadsheet are:

- Tractor and sprayer cost (initial + yearly costs)
- Farm size
- Cost of Urea
- Cost of liquid fertiliser
- VRT savings as percentage of product (taken from studies)
- N application rate (assuming uniform application)

The primary source of expected savings are through the reduced use of fertiliser while preserving target yield of the crop. The output of the spreadsheet is an expected number of years to pay off the investment into VRT (shown in Figure 14).

Inputs			Output	
Farm Size (Ha)	200		Farm Size (Ha)	200
Cost of Urea ($/kg N)	$ 4.00		Initial Machinery Cost ($)	$ 48,925.00
Increased cost of liquid N (GRDC)	20.0%		Total Sampling Cost ($)	$ 8,250.00
VRT Savings (33.3-56.2% over uniform) (Guerrero and Mouazen, 2021)	30.0%		Cost Uniform Urea	$ 320,000.00
N applied (Total units/ha)	400		Cost Uniform Liquid	$ 384,000.00
Automation Target Stage	8		Cost VRT Liquid	$ 277,050.00
If Stage 8 or above, how many nozzles on sprayer?	24		Ongoing costs	$ 17,400.00
Soil Sampling Cost ($/Ha)	$ 41.25		**ROI/year**	**$ 25,550.00**
			Years to Pay off	**2.24**

Figure 14. Example ROI calculation from cost-benefit spreadsheet.

Appendix

Appendix A: Raven Hawkeye 2 RCM modes of operation and NCV specifications

Note: Further information on the Hawkeye 2 product can be located in the User Guide which can be downloaded and accessed from ravenprecision.com from their available product documentation portal: https://portal.ravenprecision.com/ProductDocumentation/Category?categoryId=3

Rate Control Module (RCM) modes of operation:

		Modes of Operation					
		Conventional /Bypass	On/ Off	Standard	Variable Pressure (VP)	High Flow	Tiered Nozzle
Compatible Features	Nozzle Used	Bypass	NCV	NCV	NCV	NCV + Bypass	NCV + (Electronic) Bypass
	Recommended NCV Tip Size[1]	NA	02-15	02-15	02-15	02-15	02-15
	Speed Range	NA	NA	Good	Best	Good	Good
	Turn Compensation	NA	NA	Good	Best	Good	Good
	Pressure Control[2]	Range	Range	Target	Range	Target	Target
	Coverage	Best	Best	Good	Better	Good	Good
	Direct Injection[3]	Yes	Yes	Yes	Yes	Yes	Yes
	Wireless Diagnostics	Yes	Yes	Yes	Yes	Yes	Yes
	Automated Priming[4]	Yes	Yes	Yes	Yes	Yes	Yes
	Product Recirculation[5]	No	Yes	Yes	Yes	No	Yes
	Droplet Indicator	Yes	Yes	Yes	Yes	No	No
	Air Induction Tip Compatiblity[6]	Yes	Yes	No	No	No	No
	Operating Frequency	NA	NA	10 Hz	10 Hz	10 Hz	10 Hz
	Nozzle Flow Offsets[7]	No	No	Yes	Yes	Yes	Yes
	Hawkeye HD Individual Nozzle Control and Manual Override NCV Off[8]	No	Yes	Yes	Yes	No	Yes
	Virtual Sections[9]	No	Yes	Yes	Yes	No	No

Nozzle Control Valve (NCV) technical specifications:

		U.S.	Metric
Dimensions	Height	2.9 in.	7.32 cm
	Width	2.7 in.	6.73 cm
	Depth	1.6 in.	40 cm
	Weight	approximately 8.0 oz.,	approximately 0.225 kg
Power	Operating Voltage	10.5 to 36 VDC nominal	
Input/Output	Max. Operating Pressure	120 PSI	827.4 kPa
Environmental	Operating Conditions	14° to 167° F	-10 to 75° C
	Storage Conditions	-40° to 185° F	-40° to 85° C
	Relative Humidity	10 to 95%	

Raven Hawkeye feature comparison:

Feature Comparison	Hawkeye	Hawkeye 2
Max Nozzle Count	105	192
Base Sections	16	16
Individual Nozzle / Section Control	Optional (HD)	Optional (Premium)
Max Sections	105	192
Turn Compensation	Standard	Standard
PWM Frequency	10 Hz	10 Hz
NCV Nozzle Rating	IP67	IP69k
NCV Connector Interface Rating	IP67	IP69k
Blockage Detection	No	Standard
Flow Rate @ 5PSI pressure drop	.62 GPM	.65 GPM
Flow Rate @ 10PSI pressure drop	.89 GPM	.95 GPM
PWM Valve Flow (80psi, 18mph, 20")	22 GPA	32 GPA
Operating Pressure Range	10 - 80 psi	10 - 120 psi
Operating NCV Input Voltage	9 - 16 VDC	10.5 - 36 VDC
CANBus Network	End Terminator (2)	Internal Terminator in NCV
CANBus Network	1	3

Appendix B: StreamJet SJ3 Fertiliser Nozzle Chart

StreamJet SJ3 Fertilizer Nozzles

Typical Applications:

- Excellent for application of liquid fertilizer on bare ground or in standing crop.
- 3-stream pattern is ideal for directed application.

Features:

- VisiFlo® color-coding system.
- Three solid streams of equal velocity and capacity.
- Removable metering orifice for easy cleaning.
- Ten sizes for a wide range of application rates.
- Equally spaced distribution at 20" (50 cm) height.
- Use with Quick TeeJet® cap 25598-*-NYR.
- All acetal construction for excellent chemical resistance.
- See page 141 for liquid density conversion factors.
- Recommended operating pressure: 20–60 PSI (1.5–4 bar).
- Solid stream pattern minimizes leaf burn and virtually eliminates drift.

Optimum Spray Height

50 cm	50 cm
75 cm	75 cm
100 cm	100 cm

How to order:

Specify tip number.
Example:
SJ3-03-VP – Polymer with VisiFlo color-coding

	bar	CAPACITY ONE NOZZLE IN l/min	l/ha 50 cm 4 km/h	6 km/h	8 km/h	10 km/h	12 km/h	16 km/h	20 km/h	25 km/h	30 km/h	35 km/h
SJ3-015-VP (100)	1.5	0.44	132	88.0	66.0	52.8	44.0	33.0	26.4	21.1	17.6	15.1
	2.0	0.50	150	100	75.0	60.0	50.0	37.5	30.0	24.0	20.0	17.1
	2.5	0.54	162	108	81.0	64.8	54.0	40.5	32.4	25.9	21.6	18.5
	3.0	0.58	174	116	87.0	69.6	58.0	43.5	34.8	27.8	23.2	19.9
	4.0	0.65	195	130	97.5	78.0	65.0	48.8	39.0	31.2	26.0	22.3
SJ3-02-VP (50)	1.5	0.57	171	114	85.5	68.4	57.0	42.8	34.2	27.4	22.8	19.5
	2.0	0.64	192	128	96.0	76.8	64.0	48.0	38.4	30.7	25.6	21.9
	2.5	0.70	210	140	105	84.0	70.0	52.5	42.0	33.6	28.0	24.0
	3.0	0.78	234	156	117	93.6	78.0	58.5	46.8	37.4	31.2	26.7
	4.0	0.85	255	170	128	102	85.0	63.8	51.0	40.8	34.0	29.1
SJ3-03-VP (50)	1.5	0.91	273	182	137	109	91.0	68.3	54.6	43.7	36.4	31.2
	2.0	1.01	303	202	152	121	101	75.8	60.6	48.5	40.4	34.6
	2.5	1.10	330	220	165	132	110	82.5	66.0	52.8	44.0	37.7
	3.0	1.18	354	236	177	142	118	88.5	70.8	56.6	47.2	40.5
	4.0	1.31	393	262	197	157	131	98.3	78.6	62.9	52.4	44.9
SJ3-04-VP (50)	1.5	1.17	351	234	176	140	117	87.8	70.2	56.2	46.8	40.1
	2.0	1.32	396	264	198	158	132	99.0	79.2	63.4	52.8	45.3
	2.5	1.45	435	290	218	174	145	109	87.0	69.6	58.0	49.7
	3.0	1.56	468	312	234	187	156	117	93.6	74.9	62.4	53.5
	4.0	1.75	525	350	263	210	175	131	105	84.0	70.0	60.0
SJ3-05-VP (50)	1.5	1.42	426	284	213	170	142	107	85.2	68.2	56.8	48.7
	2.0	1.63	489	326	245	196	163	122	97.8	78.2	65.2	55.9
	2.5	1.82	546	364	273	218	182	137	109	87.4	72.8	62.4
	3.0	1.96	588	392	294	235	196	147	118	94.1	78.4	67.2
	4.0	2.18	654	436	327	262	218	164	131	105	87.2	74.7
SJ3-06-VP (50)	1.5	1.69	507	338	254	203	169	127	101	81.1	67.6	57.9
	2.0	1.97	591	394	296	236	197	148	118	94.6	78.8	67.5
	2.5	2.21	663	442	332	265	221	166	133	106	88.4	75.8
	3.0	2.40	720	480	360	288	240	180	144	115	96.0	82.3
	4.0	2.63	789	526	395	316	263	197	158	126	105	90.2
SJ3-08-VP	1.5	2.32	696	464	348	278	232	174	139	111	92.8	79.5
	2.0	2.74	822	548	411	329	274	206	164	132	110	93.9
	2.5	2.94	882	588	441	353	294	221	176	141	118	101
	3.0	3.13	939	626	470	376	313	235	188	150	125	107
	4.0	3.50	1050	700	525	420	350	263	210	168	140	120
SJ3-10-VP	1.5	2.73	819	546	410	328	273	205	164	131	109	93.6
	2.0	3.30	990	660	495	396	330	248	198	158	132	113
	2.5	3.55	1065	710	533	426	355	266	213	170	142	122
	3.0	3.91	1173	782	587	469	391	293	235	188	156	134
	4.0	4.44	1332	888	666	533	444	333	266	213	178	152
SJ3-15-VP	1.5	3.91	1173	782	587	469	391	293	235	188	156	134
	2.0	4.64	1392	928	696	557	464	348	278	223	186	159
	2.5	5.29	1587	1058	794	635	529	397	317	254	212	181
	3.0	5.86	1758	1172	879	703	586	440	352	281	234	201
	4.0	6.76	2028	1352	1014	811	676	507	406	324	270	232
SJ3-20-VP	1.5	5.58	1674	1116	837	670	558	419	335	268	223	191
	2.0	6.48	1944	1296	972	778	648	486	389	311	259	222
	2.5	7.31	2193	1462	1097	877	731	548	439	351	292	251
	3.0	8.05	2415	1610	1208	966	805	604	483	386	322	276
	4.0	9.31	2793	1862	1397	1117	931	698	559	447	372	319

Note: Always double check your application rates. Tabulations are based on spraying water at 70°F (21°C). See pages 136–157 for useful formulas and other information.

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