MIXING AND BATCHING FOR AGRICULTURAL CHEMICAL APPLICATION

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A TECHNICAL GUIDE WITH CASE STUDIES OF AUSTRALIAN GRAIN GROWERS AND SPRAY CONTRACTORS

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Mixing and batching for agricultural chemical application: a technical guide with case studies of Australian grain growers and spray contractors

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Acknowledgement also extends to Bill Gordon, Graham Betts, Shane Koenig and others who have contributed to the information delivered in this booklet as well as the information presented in numerous other GRDC publications and resources relating to agrochemical spraying.

GRDC contact details:
Ms Maureen Cribb
Integrated Publications Manager
PO Box 5367
KINGSTON ACT 2604

Email: Maureen.Cribb@grdc.com.au

Design and production:
Coretext, www.coretext.com.au

About the author:
Bill Campbell is an independent agronomist and application specialist based out of Geraldton, Western Australia. Bill has a Bachelor of Science (Agriculture) from the University of Western Australia and practical expertise in herbicides and resistance, and on-the-ground spray application.

Bill comes from a farming background and in more recent years has worked with Farmanco Management Consultants (for three years) and Nufarm (for 16 years), developing an immense depth of knowledge of agronomy as well as base chemistries, formulations and their use. He is now a private agronomist providing advice to farm businesses state-wide on spray purchasing decisions, setting up and configuring sprayers, and evaluating new sprayer technologies. Bill has been configuring and setting up broadacre boom sprayers since 2004, and his interest has led him to develop expertise in all facets of spray application. Bill has an extensive understanding of all spray technologies, with a particular focus on taking the theory and science and giving it a practical focus.

In 2014-15 Bill Campbell worked with NSW application specialist Bill Gordon to deliver workshops in advanced application across WA as part of GRDC's national program.

In 2018-19, he produced a number of technical fact sheets for GRDC on spraying efficiencies, spraying systems, spray technologies and the new pulse width modulation (PWM) nozzle guide. He currently oversees the GRDC standard nozzle and PWM nozzle guides.

COVER: Aerial image of spray rig on Matt Hill's farm at Esperance, WA.
PHOTO: Evan Collis

Caution: Research on Unregistered Agricultural Chemical Use
Any research with unregistered agricultural chemicals or of unregistered products reported in this document does not constitute a recommendation for that particular use by the author/s or their organisation.

All agricultural chemical applications must accord with the currently registered label for that particular pesticide, crop, pest and region.

Contents

Introduction

This case study booklet has been developed as part of a series of GRDC-run workshops on spray calibration and application to increase spray efficiency and efficacy in the Western Region (GRDC Project: BCC1910-001SAX). Growers attending the workshops showed particular interest in the various mixing and batching set-ups on display, and it was suggested that a booklet that compiled various good ideas would be of benefit.

The workshops highlighted the fact that minimising the 'fill and ferry' time is one of the most effective ways to maximise hectares sprayed in broadacre agriculture. In response, this guide showcases several Australian grain growers who are achieving this safely and efficiently. The case studies cover a range of operation sizes (both grower and contractor) and crop mixes in different rainfall zones. They explore the individual requirements – such as farm infrastructure, equipment and staff management – needed to service their spray operations. The booklet also collates innovative ideas from growers and spray contractors for building and setting up equipment for agrochemical mixing and batching operations.

Bill Campbell. Photo: Supplied

Good knowledge of chemical formulations and the correct mixing order (refer to page 8) are key to successful mixing and batching. To assist growers, this guide summarises common agricultural chemical formulations and provides a brief overview of common mishaps that can occur and tips on how to avoid them. Fastest is definitely not always the best when it comes to mixing chemicals!

Links to numerous GRDC resources on agricultural spraying are also provided. A lot of useful information (fact sheets, videos and manuals) is already available if growers wish to explore the topic further.

Agrochemical formulations

Most mixing and batching issues arise from mixing errors. These can be avoided by adhering to the correct mixing order and allowing sufficient time between additions of chemical products.

Key considerations

- Always follow the correct mixing order and allow sufficient time between the addition of different products.
- When preparing multiple-product tank mixes, check the physical compatibility of the products beforehand.
- Water volume is critical for good mixing and stability. Fewer problems are associated with larger water spray volumes, as there is more 'room' in the solution for the various components to disperse, dissolve or emulsify and remain in suspension.
- Always read and follow the product label compatibility advice and the manufacturer's mixing guidelines.
- Use good quality water, especially for multiple-product mixes, as poor water quality can lead to issues.
- Adjuvants may be used to improve the physical compatibility of certain tank mixes.
- When mixing a batch for the first time, conduct a jar test (see 'Other spray resources' on page 43) that replicates the tank mix. This will reduce the risk of financial losses and time-consuming and environmentally unfavourable outcomes in cases where the mix does not turn out as intended.

The importance of chemical formulation, adjuvant type and mixing order

Growers and contractors applying sprays must understand the different chemical formulations they are using and the required adjuvant for each of the products they intend to mix. This will determine the mixing order of chemicals and the time required between each addition to allow chemicals to completely disperse or dissolve and reach a stable suspension or emulsion. The manufacturer's product label should provide this information. As a rule, when applicators follow the instructions major problems can be avoided.

Common agrochemical formulation types are wettable powders (WP), water-dispersible granules (WDG), dry flowables (DF), flowables (F), emulsifiable concentrates (EC) and aqueous concentrates (AC) or soluble liquids (SL). Products or active ingredients that are the most difficult to disperse or dissolve, or require the most time, are generally added first to the spray tank. Table 1 outlines some of the features and issues associated with different agrochemical formulations.

Water volume

Correct water volume is critical for good mixing and stability. Fewer problems tend to occur when the spray volume is high as there is 'more room' in the solution for the various components to be dispersed, dissolved and remain suspended in solution. When mixing large amounts of product and multiple products, using larger volumes of water reduces the frequency of most mixing issues.

Water quality

Poor water quality can result in poor compatibility of formulations, so it is important to know what the water quality is and how to treat it when using different products. Water quality can affect the spray solution in two ways: it can contribute to physical incompatibility, where the products do not mix, drop out of suspension or form sludges; and, it can cause chemical incompatibility, which occurs when the impurities in the water react with products being added. It is also possible for certain products to chemically react together.

Adding multiple herbicides to poor quality water can result in physical incompatibility due to surfactant overloading causing precipitates to drop out of solution and settle, sometimes forming residues like thick paste. This occurs when too high a proportion of the added surfactants are taken up with conditioning or softening the water. This can result in there being insufficient surfactant to keep active ingredients in suspension. This tends to occur with DF products in water with high total dissolved solids (TDS). This is known to occur with high-load potassium glyphosate products when mixed with DF products such as simazine, atrazine or diuron. Using an alternative water source is recommended, though adding more wetting agent in a large volume of water can occasionally help. Refer to the GRDC *Water quality for spraying operations* fact sheet (see 'Other spray resources' at the end of this publication), which outlines water quality parameters and describes this interaction in more detail.

Poor water quality can also adversely affect the efficacy of spray jobs, for example, when glyphosate is added to hard water and a chemical reaction forms less-efficacious glyphosate salts, or when water of high pH causes the decay (alkaline hydrolysis) of certain insecticides and fungicides. These effects are particularly likely when a batch remains in the tank for an extended period of time, when large volumes of water are used, or when small amounts of product are added.

Mixing time

Not allowing adequate mixing time for dry and granular products to completely disperse is a common problem, especially when high-capacity pumping equipment, bulk chemical packaging and large mixing vessels are used.

Table 1: Characteristics and common issues of different types of chemical formulation.

Chemical formulation types	Characteristics	Common issues
Dry products: wettable powders (WP), water-dispersible granules (WDG) and dry flowables (DF)	Dry products, such as wettable powders, water-dispersible granules and dry flowables, must be added to the water first as they have a very large surface area to be wetted. These formulations are very small particles of the active ingredient which have been ground or milled into micron-sized particles. Each of them has a particular surfactant system (always read the label) with a dispersing action that provides a protective layer of wetting agent that helps keep the particles in suspension. These formulations require a minimum volume of water in which to be completely dispersed and form a stable suspension; this state must be attained before any oil-based products are added. Water-dispersible granules and dry flowables must undergo an additional process in which the dry granule (or extruded material) completely disintegrates into the individual particles that will ultimately form the suspension and disperse.	If the active particles contact oily materials before being fully dispersed, the oil phase will absorb into the dry powder or granules. This will make the particles heavier, stickier and more waterproof and cause them to settle to the bottom and to stick to other particles, tank surfaces and other equipment. This can result in very large 'glugs'.
Flowables (F) and suspension 'flowable' concentrates (SC)	With flowables, the micron-sized particles are already wetted 'in the drum' but are still in a concentrated slurry form. These particles disperse and suspend at a faster rate than dry products. Flowables have a surfactant system that aids in dispersing the concentrated slurry and maintains the particles in suspension (in a similar way to dry products). They also need to be fully dispersed and suspended in solution before oil-based products are added.	If flowables are added to a minimal volume of water, followed by the addition of an emulsifiable concentrate, the concentrated mix may become unstable. A similar situation occurs if the correct mixing order is not followed and a flowable is added to an emulsifiable concentrate or spray oil that is already pre-mixed in the tank. This can inhibit the dispersion of the concentrated slurry in the water and interfere with suspending agents that maintain the individual micron-sized particles in suspension.
Emulsifiable concentrates (EC)	Emulsifiable concentrates contain an oil-based (and therefore insoluble) active ingredient which is solubilised in another solvent and added to an emulsifier. When put into water, it forms an oil-in-water emulsion (that is, micron-sized oil droplets become suspended in the water). The resulting mix looks opaque to milky. Emulsifiable concentrates are relatively quick to 'bloom' and form a uniform emulsion or mixture. In good quality water, they form a stable oil-in-water emulsion.	Care should be taken not to introduce water into the drum while the last of the mix is being sucked out, as a thick glug can form. Only add water at the very end to rinse drums into the tank. Water with a high salt content or ionic strength will affect emulsifiable concentrate formulations, as it inhibits the pesticide or herbicide from blooming and forming a complete emulsion. Refer to the section on pesticides and liquid fertilisers in Table 2 for more information on this issue.
Aqueous concentrates (AC) or soluble liquids (SL)	The last product type to be added to a chemical mix is the aqueous concentrates or soluble liquids, such as Glyphosate CT and 2,4-D amine. These are added last as the active ingredient is already dissolved in water and is therefore only being diluted in the spray tank mix.	Unless there is a chemical incompatibility, there are minimal mixing issues with aqueous concentrates or soluble liquids, as they are generally salt solutions that dissolve in water.

Induction systems

Large batching mixers are best suited for pre-dissolving and dispersing dry or granulated products, whereas liquid chemical formulations are best inducted directly into the sprayer tank (in the correct mix order). Many mixing issues can arise when large batching systems are used, due to the fact they are designed to induct and pump large volumes of product and water. Extreme caution is advised.

To avoid glugs and other mishaps, using all equipment correctly, mixing accurate volumes and following proper order and process are imperative. Bringing concentrated products into contact with each other will usually result in an undesirable interaction unless specific steps are taken. Ideally, only one or two products of similar formulation types should be inducted, dissolved and prepared for dispersal in the spray tank at a time. It is most important not to add all products together in a relatively small volume of water as this creates a hyper-concentrated mix which has the potential to be physically unstable and can cause a chemical reaction. Not allowing sufficient time for dispersing can cause flocculation in the tank, and the resulting sediment can block nozzles and filters.

These principles also apply to smaller chemical induction systems, which are common on all sprayers, where the chemical is added to a small hopper and inducted with water. The mix can suffer when excess air is inducted with emulsifiable concentrates and oils, as this can cause reverse emulsion of oils and will create excess foaming of DF, suspension 'flowable' concentrate (SC) and AC formulations.

As the latest batching and mixing systems can pump faster than products can be dispersed, adequate intervals and correct sequencing of product additions is crucial, just like observing the speed limit.

The same rules apply to all mixing and batching systems. Although it depends on the number and formulation type of the products being added, simply make sure you follow the correct mixing order and allow sufficient time and sufficient water.

General guidelines for mixing agrochemicals

- Allow sufficient time for dry, granular and suspension concentrate products to disperse and suspend in the spray tank solution.
- Ideally, allow a complete 'turnover' of tank volume for each product:
  tank volume (litres) / pump capacity (litre per minute) = minutes to allow for mixing.
- Slow down when mixing complex tank mixes.
- Use higher water volumes when planning complex tank mixes; more water aids mixing and improves compatibility.
- Cold water slows dispersion and/or emulsification, so when using cold water, add the product to a larger volume of water and use a slow mixing process for DF, WDG, SG and EC products (steps 3 to 6).
- Fully empty your tank before starting a new mix. Otherwise, dry and granulated products will absorb any remnant oily solution and might glug.
- Do a jar test if in doubt.
- Use good quality water, as poor water quality can affect mixing and compatibility.

Tips for mixing when using induction systems

- Large batching mixers are best suited to pre-dissolving and dispersing dry or granulated products.
- Avoid adding all products together into a relatively small water volume as this creates a hyper-concentrated mix.
- Allow plenty of dispersion time after adding each product to the batcher and the boom spray tank.
- When inducting chemicals via 'granny pot' or batching systems, allow sufficient agitation time of the sprayer's tank for the products to disperse and mix.
- Avoid introducing excess air when inducting emulsifiable concentrates and oils as this can cause reverse emulsion of oils and excess foaming of DF, SC and AC formulations.

Tank mixing order guide

STEP	FORMULATION/EXAMPLE PRODUCT
1	**WATER** Fill the tank with 70% water. Start agitation and keep agitating throughout the following steps.
2	**WATER CONDITIONERS** (for example, ammonium sulfate, citric acid) Do NOT add water conditioners with an oily component such as Hot-up® or LI 700® at this step.
3	**WETTABLE POWDERS** (WP), **WATER DISPERSIBLE GRANULES** (WDG) (for example, powdered trace elements)
4	**DRY FLOWABLES** (DF), **SOLUBLE GRANULES** (SG) (for example, Simazine DF, Atrazine DF, Roundup Ready® Plantshield SG)
5	**SUSPENSION 'FLOWABLE' CONCENTRATES** (SC) (for example, Atrazine SC, Propyzamide SC, Overwatch® SC, liquid trace elements) If using LI 700® for acidification, add 0.1% LI 700® NOW. Wetters may be added NOW if using ECs. Defoamers may be added NOW if there is excessive foaming.
6	**EMULSIFIABLE CONCENTRATES** (EC) (for example, Trifluralin EC, Clethodim EC)
7	**AQUEOUS CONCENTRATES** (AC), **WATER SOLUBLE LIQUIDS** (SL) (for example, glyphosate, paraquat, Amicide Advance) Refer to 2,4-D amine product label when mixing 2,4-D amine with glyphosate. Follow this sequence: 7.1. Fill tank to 90% with water. 7.2. Add 2,4-D amine product. 7.3. Add glyphosate. 7.4. Add other adjuvants. 7.5. Add remaining water.
8	**OIL DISPERSION** (OD) (for example, Atlantis® herbicide) (an uncommon formulation type)
9	**ADJUVANTS** Add wetter and oil adjuvants
10	**FILL TANK TO 100 PER CENT** Add liquid urea ammonium nitrate (UAN) LAST. Continually agitate and apply mix as soon as possible.

Source: Bill Campbell, Bill Campbell Consulting

Common mixing mishaps

Mixing and batching errors can produce ‘glugs’ and gluey residues, oily creams and excessive foam, which can block filters and nozzles. These scenarios may lead to poor spray efficacy, damage crops and the environment, and waste expensive chemicals and time.

Table 2 presents information to help growers avoid these problems when mixing and batching chemicals. Some of the information has already been discussed in Table 1 in relation to formulation type, but Table 2 investigates specific issues in more detail. The information provided in Table 2 has been compiled with assistance from and resources developed by Bill Campbell, Shane Koenig and Nufarm Australia.

Table 2: Common issues caused by errors in mixing and batching.

Issue	Description of issue	What you see	How to avoid
Oil absorption by dry products	Oil absorption by dry products can occur: • when dry products are added to the remains of a previous tank mix containing oily products; or • when ECs or oils are added too quickly to a tank mix, and previously added dry products have not had sufficient time to completely dissolve or disperse.	Oil absorption by dry products results in the formation of a thick, greasy sludge. It is likely that significant quantities of this oily sludge will not be able to be re-suspended and homogenised. Occasionally, and depending on the volume of sludge generated, the mix can be recovered by adding more wetting agent (or a speciality compatibility agent) and more water, and agitating it. However, this rarely works. Disposal of the sludge is problematic.	Ensure adequate decontamination of the mixing and batching equipment and sprayer after the tank has held mixes containing oily and dry products. Allow plenty of time for dry products to completely dissolve and be suspended in solution before oily products are added.
Adding an oily adjuvant as a water conditioner before adding dry products	Products such as LI 700® are multipurpose oily adjuvants containing lecithin that acidify the mix and act as a wetting agent and penetrant. Issues arise when these products are added to a mix as a water conditioner for acidification or buffering of the water before dry products are added.	The oily adjuvant will absorb into the dry powder or granules, causing the particles to become heavy, sticky and more waterproof. The particles will settle to the bottom and stick to other particles and to the surfaces of the tank and equipment, forming a lot of gluggy material.	**DO NOT** use an oily multipurpose acidifier such as LI700® before adding dry products. If the mix needs to be acidified, and if dry powder or granules are to be added to the mix, only add LI700®-type products AFTER dry products are completely dissolved and dispersed. Alternatively, use a standalone non-oily acidifier/buffer.

Table 2: Common issues caused by errors in mixing and batching (continued).

Issue	Description of issue	What you see	How to avoid
Surfactant overloading when using poor-quality water	When poor quality water is used, a higher proportion of the contained surfactant is used up conditioning the water rather than keeping the active chemical in suspension. Using poor quality water when mixing multiple products increases the likelihood of physical incompatibility between additives.	Surfactant overloading can cause chemical products to drop out of suspension and form a residue that settles on the bottom as a thick paste.	Use good quality water, particularly when adding multiple active chemicals in a single spray mix. Adding extra wetting agent and using a larger volume of water also minimises the risk of surfactant overloading issues. Remedial action with speciality compatibility agents such as Supa Link® is possible, but first do a jar test to see if the product can correct a tank mix that has dropped out of suspension.
Reverse emulsions when using oil or EC products	A reverse emulsion can occur when oil adjuvants and/or ECs are added to a mix when these products are added: • to a relatively small volume of water; • to very cold water; or • too quickly via induction from a granny pot. Some oils with low surfactant or emulsifier levels are more likely to create a reverse emulsion. Oils and ECs are designed to be added to a large volume of water so that the emulsifier in the product can provide an interface between the oil particle and the water. This is what makes an EC 'emulsifiable'. As a rule of thumb, a water volume greater than 15 times the volume of the additive should be used. EC Duo formulations can be mixed with a lower water volume.	A reverse emulsion appears as thick, oily, creamy glugs. It can block filters, spray lines and nozzles and form a layer on the surface of the spray tank mix.  **Oily, creamy glug (formed by reverse emulsion) after it had been purged from blocked sprayer lines.** Photo: Bill Campbell	To avoid creating a reverse emulsion: • follow the correct mixing order; • use sufficiently large volumes of water; • avoid using very cold water; • allow sufficient time between product additions; and • avoid induction systems that introduce excessive air in the process. Once a reverse emulsion has been created, it is very difficult to fix or reverse. Adding more wetting agent and/or more water will NOT help. Sometimes a particular speciality compatibility product may work. Seek expert advice.

Table 2: Common issues caused by errors in mixing and batching (continued).

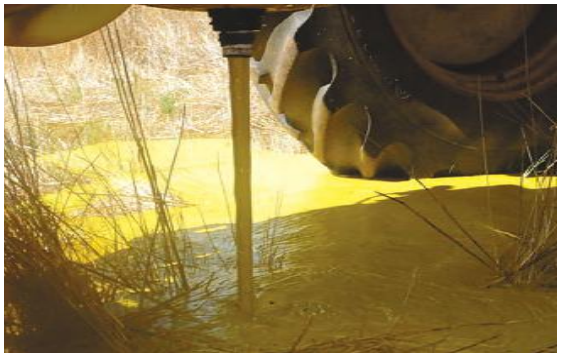
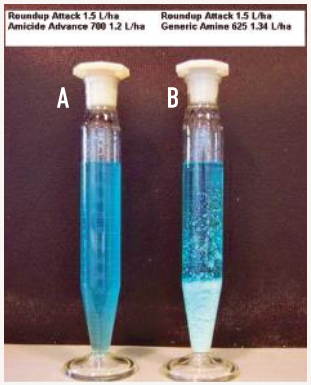
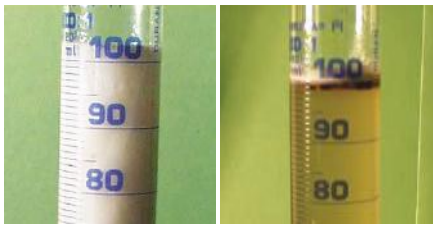
Issue	Description of issue	What you see	How to avoid
Mixing SCs or flowable products with bipyridyl herbicides such as paraquat or Spray.Seed®	Certain flowables and SCs contain cationic surfactants which can react with anionic surfactants in paraquat and Spray.Seed®. Not all SCs react in this way, as different manufacturers use different surfactants and their products have subtle formulation differences. It is extremely important to follow the compatibility information on the label when mixing SCs or flowables with some formulations. For example, the new paraquat 360 formulations require the addition of a surfactant for 'optimum' activity against weeds. The labels state that alkylaryl ethoxylates, alcohol alkoxylates, soyal phospholipid/propionic acid surfactants or esterified and emulsified oil-based products can be used.	The chemical reaction that occurs between cationic and anionic surfactants can produce greasy glue-like substances and stringy residues.	Where possible, use a DF formulation instead of an SC formulation. Many SCs (particularly the triazines) are now manufactured as DFs to avoid this issue. If SCs or flowable formulations must be used with paraquat or Spray.Seed®, using a larger volume of water and adding them to a larger tank generally avoids the issue. Importantly, when making multiple tank loads, completely empty the tank prior to mixing the next batch as any remaining spray mixture will react with the next lot of SC.
Poor compatibility of certain glyphosates with DF, SC and WDG formulations	High-load glyphosates, and specifically potassium salt glyphosates, can have poor tank-mix compatibility with DF, SC and WDG formulations. However, this is not the case for all potassium salt glyphosates. Other factors also influence these unstable tank mixes, which generally relate to incompatible (and insufficient amounts of) surfactants between the glyphosate and the DF, SC and WDG formulations. Note that in glyphosate formulations both the salt and the adjuvant play an important role in determining the compatibility of the glyphosate with other formulations. Glyphosate products contain several possible forms of glyphosate salts, the major ones being isopropylamine (IPA), monoammonium (NH4) and potassium (K). They also contain adjuvants, or blends of adjuvants, at different concentrations. Some high-load glyphosate formulations contain small amounts of surfactant, which is insufficient in multiple-product tank mixes. This is known as surfactant overload. The different formulation surfactants can also be incompatible. It is important to understand how glyphosate products are formulated and their components.	Poor compatibility between high-load (and specifically potassium salt) glyphosates and DF, SC and WDG products can cause the mix to curdle and settle, forming a thick sludge in the bottom of sprayer tanks and blocking filters and spray lines.  **A big mix of products gone wrong – trifluralin, atrazine and glyphosate plus insecticide.** Photo: David Peak	Some chemical companies who make DF, SC and WDG products do not recommend that their products be used with potassium salt glyphosate. Always read the label. If in doubt, do a jar test of the mix to determine the stability. Adding wetting agent can overcome surfactant overload or adding a compatibility agent, such as Supa Link®, can assist. Poor quality water can also contribute to the instability of these mixes.

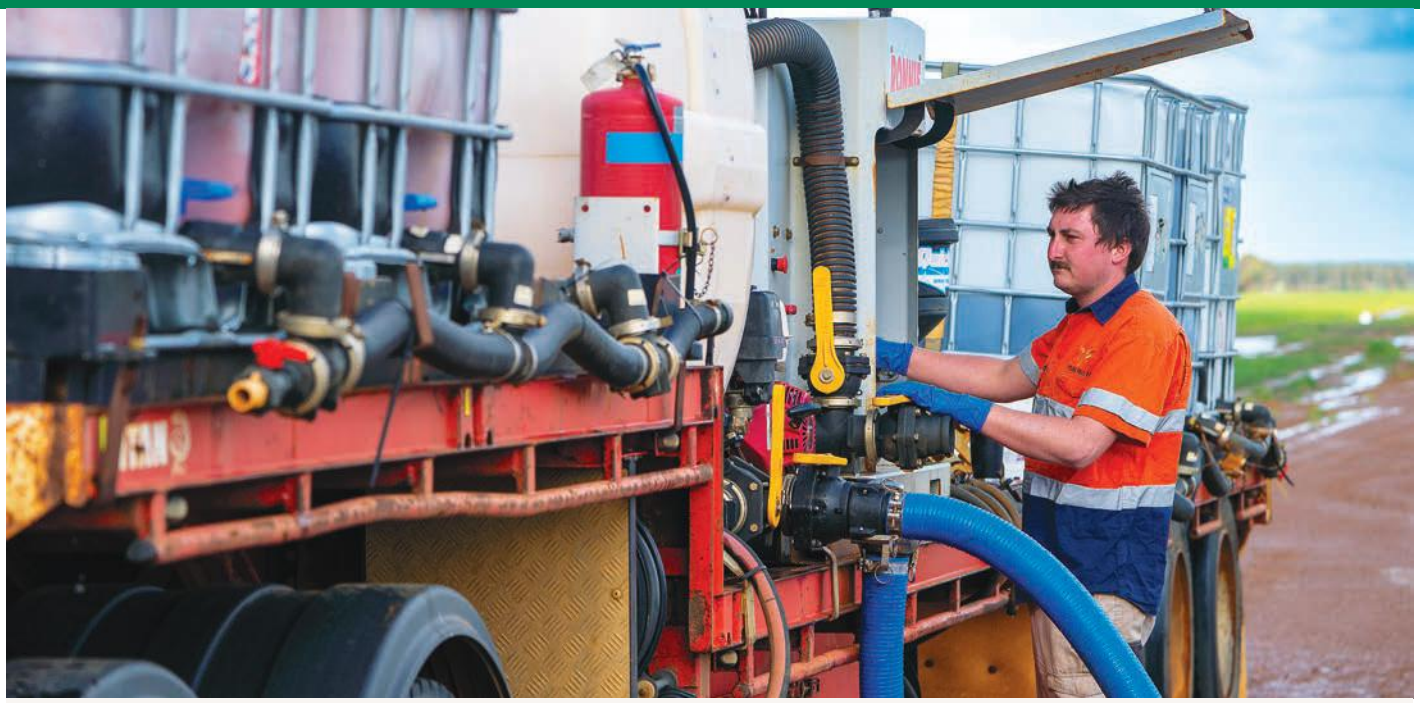
Table 2: Common issues caused by errors in mixing and batching (continued).

Issue	Description of issue	What you see	How to avoid
Cold water can affect DF formulations when used with oil-based or EC product mixes.	DF formulations, such as the commonly used simazine, atrazine and diuron, can be affected by cold water, whereby the surfactant requires a longer time than is standard to achieve complete dispersion. This becomes an issue when oil-based products or ECs are added according to standard timeframes, but because of the cold water the DF has not fully dispersed.	When oil-based products are added before the DF formulation has had sufficient time to disperse, the undispersed dry product absorbs the oil-based product or EC and forms a thick sludge. It is very difficult to resuspend the spray tank contents and expert advice should be sought. Cold water is primarily a winter issue when sourced from smaller plastic and metal tanks and where sprayers have been left full overnight.	Avoid mixing with cold water. Water obtained from large tanks, cement tanks or directly from bores generally maintain constant temperature overnight. When there is no choice but to use cold water, allow additional mixing time for DF products to completely disperse. Granular ammonium sulfate (AMS) can cause cold-water issues as it participates in an endothermic reaction that chills the water. To mitigate this, liquid AMS can be used, or granular AMS can be pre-dissolved and allowed to warm to the ambient air temperature.
Cold water can affect diflufenican (DFF) products when used with bromoxynil (such as Jaguar®)	Tank mixes with DFF and bromoxynil co-mixed products can precipitate some of the DFF active ingredient when added to very cold water and/or when using low water volumes.	Small amounts of DFF crystallise out of the spray solution to form a toothpaste-type residue, which can block filters and nozzles. As only very small amounts are formed in each batch, it can take multiple tank loads for the residue to build up and cause problems.	Avoid cold water. Refer to previous section When there is no choice but to use cold water, add products slowly, allow additional mixing time and use larger volumes of water.
Foaming	Excess foam can form when there is excessive agitation and sparge, often at the start of a tank mix when there is a small volume of water or when air is introduced due to using a smaller induction system. Some chemical formulations also have a propensity to foam. Dry powders and granules have surfactants added to aid the dispersion of the particles, which lowers the surface tension. When added to the tank first, they readily create foam.	Foam forms in the tank, rapidly expanding to a large volume and spilling out of the tank as it fills. Foam can cause issues with pumping towards the end of a spray tank and can be difficult to remove when cleaning the spray tank.	To avoid foaming: • follow correct filling operations of the batching system; • avoid excessive agitation; and • start the tank mix with a higher volume of water. De-foaming products can be used if there is excess foam; however, they don't always solve the problem. It is possible to 'drop' foams by spraying directly with methylated alcohol spirits.
Dissolving crystalline or granular ammonium sulfate (AMS)	Dissolving AMS causes an endothermic reaction that reduces the temperature of the water in which it is dissolved. This can cause tank mixing issues such as: • poor dispersion and product drop of DF formulations; • reverse emulsions, when adding oils to spray tanks; and • precipitation of some active ingredients.	Refer to the sections on reverse emulsions and cold water, where these effects are more fully discussed.	Ammonium sulfate, which is water soluble, must be fully dissolved before the next product is added. Time to dissolve will vary according to the quality of the AMS, the volume of water in the tank, water temperature and degree of agitation. Work carried out in the laboratory at Nufarm shows that granular AMS can take five to nine minutes to completely dissolve. The issues caused by low water temperature can be mitigated by using liquid AMS or pre-dissolving granular AMS and waiting for the solution to return to the ambient air temperature.

Table 2: Common issues caused by errors in mixing and batching (continued).

Issue	Description of issue	What you see	How to avoid
Mixing 2,4-D amine with AMS and glyphosate, causing insoluble salts to precipitate	Mixing 2,4-D amine with AMS and certain glyphosate formulations can result in chemical antagonism that causes an insoluble precipitate to drop out of solution. This occurs when: • additives are mixed in the wrong order; • they are mixed without sufficient water volume; • they are mixed too quickly into a concentrated solution; or • AMS crystals or granules are not completely dissolved in the spray tank. There are specific guidelines for mixing 2,4-D amines with AMS and glyphosates, based on their formulation chemistry. Both glyphosates and 2,4-D amine are salt solutions and can be quite reactive if not mixed correctly. The successful mixing of glyphosate and 2,4-D amine depends on the compatibility of the specific salts.	The insoluble precipitate that drops out of solution can block filters and nozzles. It also contributes to poor efficacy as less active product remains in the spray mix.  **Comparison of the more compatible Amicide Advance® 700 with a generic amine 625 product after 15 minutes. a) Amicide Advance® 700 1.2 litres per hectare (L/ha) + glyphosate 540 potassium salt 1.5L/ha at 50L/ha. b) Generic amine 625 1.34L/ha + glyphosate 540 potassium salt 1.5L/ha at 50L/ha.** Photo: Nufarm	To avoid this issue, the most important thing to do is to read the label of the 2,4-D amine product for additional mixing guidelines and information on the intricacies of tank mixing of partner products. For instance, the label of Nufarm's Amicide Advance® 700 includes compatibility information, recommended water rates and suggested ratios for mixing with glyphosate.
Compatibility issues between certain chemicals and liquid fertiliser (urea ammonium nitrate)	Urea ammonium nitrate (UAN) fertilisers are sometimes recommended as a water substitute in some pesticide or herbicide spray mixes, as they provide a nitrogen top-up at the same time as increasing operational efficiencies. They are only suitable for certain tank mixes and crops, however, and can cause compatibility and efficacy issues, along with the risk of crop scorch. Most pesticides and herbicides used in Australia are specifically formulated to be used in water that has total dissolved solids (TDS) of <3000 parts per million (ppm). However, UAN fertilisers exceed these specifications with a TDS range of 400,000 to 800,000ppm. TDS measures the minerals and inorganic salts in a solution, and high TDS reduces the ability of a product to emulsify or bloom.	Extremely salty water or fertiliser carriers with high TDS may produce a layered or broken emulsion in the spray mix or what is known as 'creaming'. The layering in the spray tank produces a non-homogenous spray solution when sprayed, initially as a fertiliser and water mix and then followed by the creamy concentrated pesticide or herbicide. This can reduce the efficacy of the pesticide or herbicide and cause crop phytotoxicity damage.  **a) Water 40L/ha + LVE MCPA 500mL/ha, time zero minutes, nil agitation. The EC is blooming as it is added to the water without agitation. b) UAN 40L/ha + LVE MCPA 500mL/ha, time zero minutes, nil agitation. Without agitation, ECs do not bloom or emulsify in many concentrated nitrogen fertilisers.** Photo: Bill Campbell	To avoid this issue, ensure the TDS specifications of the pesticide or herbicide are compatible with the solution used. If in doubt, only use water, and do not replace water with UAN in the mix.

Grower case studies



Joel Desmond with equipment on Matt Hill's farm at Esperance, WA. Photo: Evan Collis

LARGE ON LOGISTICS'
Matt Hill and Mick Young

With considerable investment in water supply infrastructure, the SurePoint QuickDraw automated batching system, and well-thought-out paddock and property layout, Matt and Mick have maximised spray efficiency across many hectares.

Requirements and considerations

Matt and Mick's set-up:

- incorporates an efficient, self-contained, mobile chemical cartage and batching semitrailer;
- has to be able to cover a large area – up to 5000 hectares can be sprayed when the semitrailer is stocked and set up at a water supply point;
- has to be self-sufficient with two spray operators – they do their own sprayer filling via the automated, computerised SurePoint system;
- has a dedicated, purpose-built, large chemical warehouse to ensure safe chemical storage; and
- avoids potential contamination and spray mistakes across crop types with a simple water flush circuit.

The SurePoint QuickDraw pre-programmed automated batching system replaces manual measurement of product amounts. Photo: Bill Campbell

"Really thinking through the logistics, such as property layout and fill locations, and investing in quality equipment and storage has really paid off for us efficiency wise."
– Matt Hill

Efficiency is maximised with this self-contained mobile cartage trailer.
Photo: Evan Collis

Snapshot of batching and spray operations

GROWERS: Matt Hill and Mick Young

BUSINESS NAME: Young Hill Farms

FARM LOCATION: Beaumont/Esperance, WA

PROPERTY SIZE: 15,600ha on two separate blocks (main farm: 13,000ha, second block: 2600ha)

CROP TYPE: (average number of sprays per crop)
Wheat (5), barley (7), canola (5)

SPRAYER DETAILS:
Two Agrifac 8000 litre/48.5 metre self-propelled (SP) sprayers

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST:
SurePoint QuickDraw computerised (automated) batching system mounted on a drop deck semitrailer

$120,000

ESTIMATED HECTARES SPRAYED PER YEAR:
77,500 to 93,000ha

AVERAGE FILL TIME USING BATCHING SET-UP:
12 minutes

AVERAGE LOADS SPRAYED PER DAY:
Four per machine

COMMON CHEMICAL FORMULATIONS USED:
Flowable or liquid formulations wherever possible (as these are all that can be handled by the SurePoint system)

LABOUR AND LOGISTICS: Two dedicated spray operators (doing the mixing, batching and filling)

One support staff (setting up, shifting and stocking the chemical trailer)

SPRAY RECORD KEEPING:
AgriTrack and My John Deere

TIP FOR MAXIMISING EFFICIENCY:
Work sprayers in adjacent paddocks to allow both sprayers to use mixing and batching equipment.

WATER SOURCE: Mainly dam water, plus a 400,000L rainwater tank at the main chemical warehouse adjacent to the airstrip for aerial spray work and other SP operations

WATER POINTS: 12 × 100,000L tanks running off solar pumps. These are located strategically so each tank covers about 2000ha and the average distance to fill points from paddocks is 500m.

WATER VOLUMES USED: Summer sprays: 60L/ha

Knockdowns: 70L/ha

Winter sprays where good coverage required (including fungicides): 80L/ha

Urea ammonium nitrate (UAN) fertiliser: 50 to 100L/ha

CROP DESICCATION: aerial application

WATER QUALITY ISSUES/CONSIDERATIONS:
The dam water is considered of average quality.

CONTAMINATION MITIGATION:
Pre-programmed in the SurePoint QuickDraw

Group B herbicides are added directly into a dedicated Group B sprayer by its own induction system to avoid contamination of other induction and mixing systems.

A high-volume direct-fill water circuit is completely separate from mix-and-batch systems.

The fill-and-batch system in detail

- The SurePoint QuickDraw is a pre-programmed, automated batching system mounted on a drop deck semitrailer.
- Six liquid products can be inducted via their own suction circuit with the SurePoint system from 1000L intermediate bulk container (IBC) shuttles. The system is programmed to induct chemicals into minimum water volumes in the correct sequence and mixing order. The automation process requires bottom or gravity-feed liquids.
- The semitrailer has four racks holding a total of 14 × 1000L IBC shuttles; two racks with four IBC shuttles plumbed together, and two racks with three IBC shuttles plumbed together.
- Each rack holds the IBC shuttles on a slight forward angle so they can be completely emptied.
- Linked IBC shuttles have a simple water flush circuit for flushing lines and final rinsing.
- Each chemical product is on its own suction circuit and is also plumbed to the water circuit to completely remove and wash the chemical from the line to the SurePoint batch system.
- If required, small volume liquids and dry products can be added via a small granny pot. Smaller volumes can also be decanted into 1000L IBC shuttles at a purpose-built station in the chemical warehouse.
- When using a semi-concentrate, hot-batching process, the SurePoint system is linked to a secondary 2000L batch tank so that the sprayers can also suck the mixture directly from this batch tank. Immediately before the spray operator leaves, the operator activates the computer to begin pre-mixing the next semi-concentrate brew. The automated system starts mixing the next brew.
- The SurePoint system automatically shuts down once the nurse mixing tank is full. This feature has been used to remotely measure and fill a water tanker.
- A bulk diesel fuel container (1700L) and fill reel for sprayers are mounted on the chemical and mixing trailer.

Best features	Limitations and desirable additions
• Operations are easy and simple. • A large number of hectares can be sprayed as the trailer holds 14 × 1000L IBC shuttles, plus Enviro Drums and ammonium sulfate (AMS). • Each chemical is on its own circuit, avoiding cross-contamination. • The mixing and batching trailer is completely self-contained.	• The system is currently not set up for batching large volumes of dry or granule products. This could be achieved through a separate induction and batching process. • It is not set up to transport full loads of pre-mixed chemicals, although a smaller tank for concentrated mixing can be loaded onto the sprayer along with additional water.

The chemical storage shed is fit for purpose – it keeps chemicals out of the weather and safely contained. Photo: Bill Campbell

TAG TEAM BATCH AND FILL

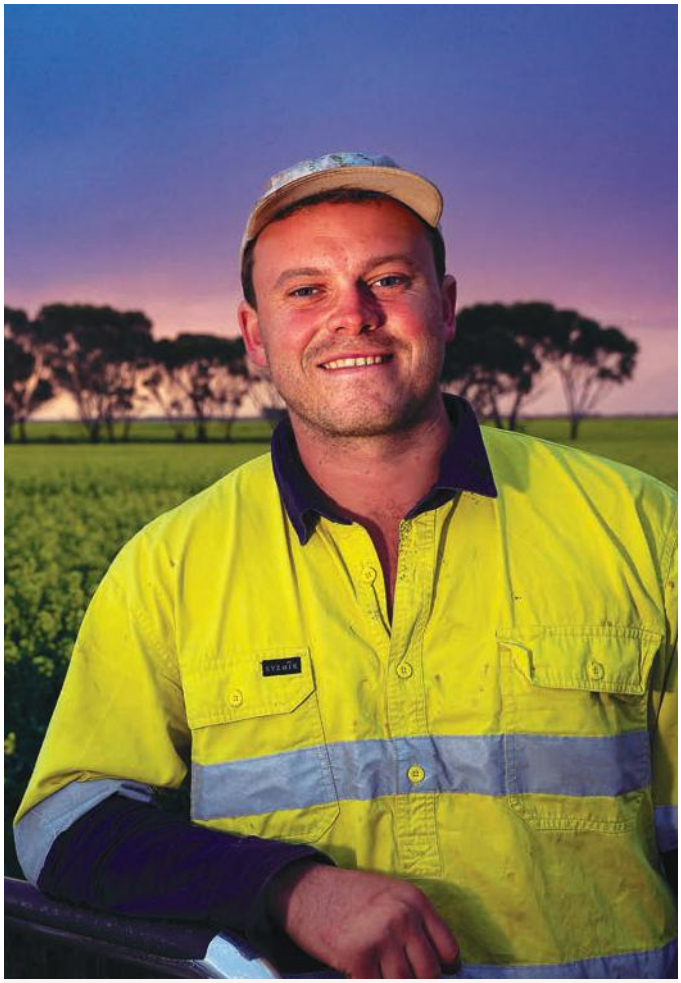
Phil and Tom Longmire

This is an efficient and unique two-person spraying operation that uses a tag team system to pre-batch granules and dry product for the next spray operator. This means products have time to dissolve and can be pumped straight into the sprayer.

Requirements and considerations

Phil and Tom's set-up:

- is fully mobile, comprising a self-contained, chemical-cartage curtainsider truck and batching trailer;
- maximises the hectares that can be sprayed in a day (when the truck and trailer are fully stocked, 1000ha (pre-seeding) and 2000ha (post-seeding) can be sprayed per day);
- is efficient, as it can mix two batches at once, or it can load one sprayer with semi-concentrate from the previously mixed hot batch and top up with water, while batching for the next sprayer; and
- avoids contamination (the three measuring and batching systems are completely separated and have direct induction of chemicals; there is a Group B dedicated sprayer and induction system; and crop types are block seeded).



Tom Longmire, Coorong Pastoral Co. Photo: Evan Collis

Snapshot of batching and spray operations

GROWERS: Phil and Tom Longmire

BUSINESS NAME: Coorong Pastoral Co.

FARM LOCATION: Condingup, WA

PROPERTY SIZE: 5700ha cropped (six properties in adjoining locations)

CROP TYPE: (average number of sprays per crop) Wheat (6 to 8), barley (6 to 8), canola (6), pulses (6)

SPRAYER DETAILS: SP Goldacres 8000L/36m, Arag Seletron Fastrac 8330 on 3m tramline Beverley 7000L/36m Arag Seletron

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST: Flat-top tautliner curtainsider truck towing a tri-axle trailer. Set-up includes two Handler IV 870L-capacity batch-induction systems. $55,500

ESTIMATED HECTARES SPRAYED PER YEAR: 40,000ha

AVERAGE FILL TIME USING BATCHING SET-UP: 12 to 15 minutes

AVERAGE LOADS SPRAYED PER DAY: 1000ha or five to six loads per day

COMMON CHEMICAL FORMULATIONS USED: Flowable and liquid formulations, as well as granules

LABOUR AND LOGISTICS: Two spray operators (doing the mixing, batching and filling)

SPRAY RECORD KEEPING: John Deere 4640 shared coverage

TIP FOR MAXIMISING EFFICIENCY: If time is limited during filling for complex loads, the Beverley spray operator completes batches between fills to improve the efficiency of the SP sprayer.

WATER SOURCE: Mainly dam water (which is good quality) and rainwater after good rainfall

WATER POINTS: 50,000L tanks that are located at each fill location, equipped with 3-inch (7.6-centimetre) fill points

WATER VOLUMES USED: Summer sprays: 57 to 67L/ha (120ha batch loads)

Knockdowns: 80L/ha

Winter sprays where good coverage is required (including fungicides): 80 to 100L/ha

UAN fertiliser: 35 to 50L/ha product only, 60 to 80L/ha product/water mix

Other: aerial insecticides 30L/ha

WATER QUALITY ISSUES/CONSIDERATIONS: Dam water (good quality) or rainwater

CONTAMINATION MITIGATION: The three measuring and batching systems are completely separate and have direct induction of chemicals. There is a dedicated Group B sprayer that only uses the induction system for these chemicals. Crop types are block seeded with enough chemical stored on the truck and/or trailer for each location.

While the sprayer is being filled, the spray operator is batching the next load for the second sprayer. Photo: Bill Campbell

The fill-and-batch system in detail

- The flat-top tautliner Curtainsider truck with tri-axle trailer holds the complete set-up, including three independent measuring and batching systems.
- The trailer holds two Handler IV 870L-capacity batch-induction systems.
- An additional dual-axle trailer can be hooked up as a third batch-and-fill station, holding two 1000L IBC shuttles and three 110L Enviro Drums.
- The truck contains three cone-bottom measuring vessels (two 200L and one 100L), all fitted with Sotera chemical induction pumps on their own independent circuit, thereby avoiding cross-contamination for smaller-volume products (for example, grass-selective herbicides, insecticides or adjuvants).
- Each measuring cone has a sprinkler or water flushing and cleaning system and lighting behind the cone so volumes can easily be seen at night.
- There is independent direct induction for the three different products contained in the 1000L IBC shuttles.
- The tri-axle trailer allows five 1000L IBC shuttles to be stored.
- There is an independent, direct-induction, high-volume, water-only circuit that fills the sprayer with water. This is a separate circuit from the mix-and-batch systems to avoid contamination.
- Smaller-volume products are measured and left in the cone-bottom measuring tanks. During filling, all products are sucked to the Handler IV 870L batching tanks while the next low-volume mix is prepared.

Best features	Limitations and desirable additions
• Each spray operator supports the other by pre-batching or pre-measuring chemical volumes. • A large number of hectares can be sprayed due to the amount of chemical storage available. • Each chemical is on its own induction or fill circuit to eliminate cross-contamination. • The system is completely contained and mobile. • Chemical lines can be easily decontaminated.	• Adding a dual 3-inch (7.6cm) fill point for simultaneously adding chemical and water would be beneficial. • Adding an independent water feed for sprinklers on the triple-axle batching trailer would support operations. • Adding a five-inlet feed manifold with flush from 1000L IBC shuttles would be helpful. • An extra 100L cone-bottom measuring vessel in the truck to make four in total would help.

This fully stocked truck and trailer set-up allows up to 2000ha to be sprayed when set up at a water point. Photo: Bill Campbell

EFFICIENCY WITH EXPANSION

Gray Robertson and John Pepall

With a significant expansion in 2021 when they leased a second property, Gray and John are pushing the limits of efficiency as they seek to cover 7400ha of cropping land across multiple locations with a single sprayer. Throw in some additional contract spraying and limited access to water on one of the leased farms, and it becomes a bit of a juggle.

Requirements and considerations

Gray and John's set-up:

- must be able to cart high volumes of water as there is no access to water at their second leased property;
- comprises a truck and repurposed Hydra Boom trailer which is highly manoeuvrable and can handle tight roads in smaller paddocks;
- is simple, and easy to operate and clean; and
- maximises sprayer efficiency by parking the truck and trailer in the same paddock to minimise ferrying time and storing a large volume of chemical and water sufficient for spraying three loads in one session.

Gray Robertson Photo: Evan Collis

Snapshot of batching and spray operations

GROWERS: Gray Robertson and John Pepall

BUSINESS NAME: PR Farming

FARM LOCATION: Katanning and Nyabing, WA

PROPERTY SIZE: 7400ha of cropping on three separate blocks (the main farm is 4700ha and leased farms are 1500ha and 3200ha)

CROP TYPE: (average number of sprays per crop)
Wheat (up to 4), barley (up to 4), canola (4), pulse crops (up to 4)

SPRAYER DETAILS: One John Deere R4060 6000L/36m and ExactApply™ 38cm nozzle system

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST:
20,000L water tanker truck towing a cut-down, modified Beverley Hydra Boom sprayer with a 3800L nurse tank and Handler 160L

$50,000

ESTIMATED HECTARES SPRAYED PER YEAR: 44,000ha

AVERAGE FILL TIME USING BATCHING SET-UP: 10 to 15 minutes

AVERAGE LOADS SPRAYED PER DAY: Two to three in winter and early spring; four to six desiccation sprays in late spring

COMMON CHEMICAL FORMULATIONS USED:
Flowable, liquid and granular

LABOUR AND LOGISTICS: One dedicated spray operator at any one time (doing the mixing, batching and filling) on rotation.
One support staff (ferrying the truck to the sprayer in paddock, restocking)

SPRAY RECORD KEEPING: My John Deere (and recorded manually on paper)

TIP FOR MAXIMISING EFFICIENCY: Use lull periods in the spraying program or after the last sprayer load of the day has been taken, to travel to and fill from the scheme water tanks.

WATER SOURCE: Scheme water supplemented by rainwater

WATER POINTS: Two 50,000L and two 22,000L tanks (none located at the Nyabing property where water needs to be carted).

Water volumes used: Summer sprays: 60L/ha

Knockdowns: 70 to 80L/ha

Winter sprays where good coverage is required: (including fungicides): 70 to 100L/ha

Late season in-crop spraying/crop desiccation: 100L/ha

Contract spraying: 70 to 80L/ha

WATER QUALITY ISSUES/CONSIDERATIONS: Scheme or rainwater only (which also applies to contract spraying)

CONTAMINATION MITIGATION: There are non-return valves from the water tank to the nurse tank.

The plumbing has been constructed to minimise dead spots.

A full-system decontamination (with chlorine) of the nurse tank and sprayer is done before spraying sensitive crops.

The repurposed Beverley Hydra Boom acts as a semi-concentrate hot mix tank which is pulled behind the water truck. Photo: Bill Campbell

The fill-and-batch system in detail

- A 20,000L water tank is mounted on an eight-wheel truck. Another truck that carries 12,000L of water when required is on standby.
- The 20,000L water truck tows a cut-down and modified Beverley Hydra Boom, with the 3800L tank used as the nurse tank.
- There are two pumps on the nurse tank: one 1.5-inch (3.8cm) pump for mixing the hot tank and a 3-inch (7.6cm) pump for filling up the sprayer. Generally two to three semi-concentrate hot batches are mixed in the nurse tank at any one time – up to 3000L total volume.
- 1000L of hot mix is pumped from the nurse to the sprayer while water from the truck (delivered via another 3-inch (7.6cm) pump) tops up the sprayer.
- The nurse tank has a Sotera chemical transfer pump, and a Handler 160L was recently purchased to replace the Mixaider for mixing larger quantities of dry chemical more efficiently.
- Larger quantities of liquid chemical can be drawn directly by the mix pump into the semi-concentrate hot mix tank. All lines are flushed with water after batching is complete.
- There is some chemical storage for up to two 1000L IBC shuttles and other smaller chemical containers.
- The truck carries kitchen scales and measuring buckets for measuring out smaller quantities of chemicals.

The 20,000L of stored water on the truck has to last, as their second leased property has limited access to water. Photo: Bill Campbell

"With 7400ha of cropping land spread over three locations and 75 kilometres, on top of some contract spraying, we've had to make sure we are maximising the efficiency of our spray rig." – Gray Robertson

Best features	Limitations and desirable additions
• The truck and trailer are highly manoeuvrable – they are yet to be bogged! • Drivers do not need a multi-combination (MC) licence to operate the truck and trailer. • The system is quite simple to operate and very easy to clean, as Gray and John have worked hard to eliminate dead spots. • The Sotera pump has long hoses that can reach into drums located either on or off the nurse trailer. • The Handler 160L batch mixing tank mixes larger quantities of dry product very well.	• It would be preferable to be able to store more chemical on the trailer and/or truck. • A larger purpose-built dry chemical induction system would be advantageous. • Dust is an issue for the small motors on the nurse trailer; they need replacing prematurely. A Donaldson aftermarket air filter system has assisted with this somewhat. • A non-steel water tank would be preferable to avoid having to dump water periodically due to rust build up and water staining (although it is easy to repair). • Gray and John would love a Load Command system, but it is hard to justify the cost. The next best option is a 4-inch (10.2cm) fill system. • Better agitation of the nurse tank would be ideal, as even with their well-designed system, there is one dead spot where some chemical product settles. • Another sprayer would be great!

SWEET AND SIMPLE
Anthony and Trevor Farrell

Note: After two generations of farming, Anthony and Trevor Farrell have recently sold their farm.

A large capacity, but relatively simple and versatile, nurse truck set-up allows batching to be done close to spray operations. The system supplies enough water and chemical for a day's worth of spraying.

Requirements and considerations

Anthony and Trevor's set-up:

- uses a versatile and simple nurse truck that can be parked close to the point of use and used by a solo spray operator for the day;
- has a large water-storage capacity on the nurse truck (30,000L), which allows for a good day's spraying to be done before the truck needs refilling;
- allows for quick water refill (two 1000L/min pumps at the water source can fill truck within 15 minutes); and
- can handle multiple chemical types, as the nurse truck is equipped to handle both liquid and granular products.

Anthony (left) and Trevor Farrell. Photo: Bill Campbell

Snapshot of batching and spray operations

GROWERS: Anthony and Trevor Farrell

BUSINESS NAME: KW and V Farrell

FARM LOCATION: Yuna, WA

PROPERTY SIZE: 5500ha cropped area

CROP TYPE: (average number of sprays per crop)
Wheat (3), lupins (4), canola (3)

SPRAYER DETAILS: CASE IH Patriot® SP 4430 6000L/36m

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST:
Truck and trailer with water storage (two 15,000L tanks) and can carry eight 110L Enviro Drums in place of two 1000L shuttles, equipped with a cone-bottom measuring vat, a granny pot for measuring smaller volumes and a self-made mixing tank for granulated product

$20,000 (excluding truck and trailer cost)

ESTIMATED HECTARES SPRAYED PER YEAR: 20,000ha

AVERAGE FILL TIME USING BATCHING SET-UP: 10 minutes

AVERAGE LOADS SPRAYED PER DAY: Six loads
(made possible by the 30,000L water-storage capacity on the nurse truck)

COMMON CHEMICAL FORMULATIONS USED:
Flowable and liquid formulations, granules

LABOUR AND LOGISTICS: One spray operator (doing the mixing, batching and filling). One support staff as required (shifting and stocking the chemical trailer)

SPRAY RECORD KEEPING: Entered manually in Agworld paddock planning book

TIP FOR MAXIMISING EFFICIENCY: Efficiency comes from the ability to fill the sprayer in the paddock as well as a well-maintained farm road network.

WATER SOURCE: Reasonable quality bore water and rainwater where possible

WATER POINTS: A 110,000L tank (next to the main home sheds) and a 230,000L tank (at the north-western end of the property) that are equipped with two 1000L/min pumps to fill the nurse tank within 15 minutes

WATER VOLUMES USED: Summer sprays: 70L/ha; Knockdowns: 70L/ha; Winter sprays where good coverage is required (including fungicides): 70 to 80L/ha; UAN fertiliser: 40 to 70L/ha

WATER QUALITY ISSUES/CONSIDERATIONS: Rainwater and bore water. The bore water is good quality and suitable for all spraying on the farm.

CONTAMINATION MITIGATION: The spray operator is responsible for mixing the chemicals in the correct order, applying the mix according to product rates, and decontaminating the tanks and equipment.

Two 15,000L water tanks on the nurse truck allow for six spray loads before refilling is necessary – a good day's work. Photo: Bill Campbell

The fill-and-batch system in detail

- The system comprises a truck trailer equipped with two 15,000L water tanks and up to two 1000L IBC shuttles containing chemicals that can be located on the back of the trailer. This is the preferred size of container.
- The chemical is measured from an IBC shuttle into a graduated cone-bottom measuring vat and then delivered via a 1.5-inch (3.8cm) hose to the pump, where it is mixed with water.
- External drum gauges are used for measuring chemicals from 110L Enviro Drums, which can also be stored at the back of the truck trailer in place of one of the 1000L IBC shuttles.
- A granny pot is used for measuring smaller volumes of chemicals.
- Granular products are dissolved in a self-made mixing tank.
- Each chemical is mixed with water in the pump and then delivered into the sprayer.

Best features	Limitations and desirable additions
• A quick fill system allows for a fast turnaround time between the nurse truck and sprayer and the water source to the nurse truck. • The spray operator is self-sufficient for a full day's spraying. • The nurse truck can be used at seeding to store UAN fertiliser for banding.	• Installing a second pump would allow water and chemical to be inducted at the same time, keeping in mind that care would be required to avoid mixing mishaps. • Adding safety railing and an access ladder would be ideal.

The nurse truck trailer is loaded up with a 1000L IBC shuttle and 110L Enviro Drums linked to the cone-bottom measuring vat, which inducts directly into the pump where the chemical is mixed with water and pumped to sprayer. Photo: Bill Campbell

"The ability to spray out six loads without needing to refill the nurse truck saves time and keeps our spraying operations agile." – Anthony Farrell

Spray contractor case studies

QUICK AND EASY
Andrew Irving

This new, purpose-built batching set-up housed on the back of a drop deck trailer has been constructed with mobility, ease of use and rapid sprayer loading in mind. The Handler IV deals well with granular products and secure chemical storage has room for up to five pallets or IBC shuttles.

Requirements and considerations

Andrew's set-up:

- is highly mobile (the batching trailer needs to be able to manoeuvre on various farm tracks and laneways with ease);
- can spray 300ha before refilling when the batching trailer is fully stocked;
- is capable of rapid sprayer loading (in eight to 10 minutes via twin loading arms on each side of the trailer, one for hot mix, the other for water);
- can run multiple sprayers (three) and move from farm to farm, as this contracting operation requires a degree of self-sufficiency in addition to the existing fixed water points; and
- is a simple system that is easy to use and decontaminate.

Snapshot of batching and spray operations

CONTRACTOR: Andrew Irving

BUSINESS NAME: AF Irving & Co

FARM LOCATION: Cunderdin, WA

SPRAYER DETAILS: Two Agrifac Endurance II 8000L/49m, one RoGator RG1300 6300L/45m

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST: $100,000

ESTIMATED HECTARES SPRAYED PER YEAR: 120,000 to 160,000ha, within a 100-kilometre radius

AVERAGE FILL TIME USING BATCHING SET-UP: Eight to 10 minutes

AVERAGE LOADS SPRAYED PER DAY: Five to 10 per sprayer

LABOUR AND LOGISTICS: Three spray operators, casual staff for pre-batching operations

TIP FOR MAXIMISING EFFICIENCY: Only mix enough chemical for one load in the Handler IV in case weather conditions or spray plans change.

WATER SOURCE: Scheme water, which all their clients have access to

WATER POINTS: Tanks of various sizes ranging from 25,000L to 200,000L water storage

AVERAGE DISTANCE FROM WATER POINTS TO PADDOCK: Maximum 5km

WATER VOLUMES USED: Summer sprays: 50 to 60L/ha; Knockdowns: 50 to 60L/ha; Winter sprays where good coverage is required (including fungicides): 70 to 80L/ha; UAN fertiliser: 30 to 100L/ha

Other: green-on-brown weed seeking (100L/ha)

CONTAMINATION MITIGATION: All chemical is sucked through a venturi with a clean water flush.

The drop deck trailer carries 27,000L of water and is equipped with a Handler IV 870L batching system. Photo: Bill Campbell

The fill-and-batch system in detail

- The 13.5m drop deck semitrailer stores 27,000L of water and up to five pallets or 1000L IBC shuttles of chemical.
- The trailer also holds a Handler IV 870L-capacity batch-induction system. One spray load is batched at a time in case weather conditions and/or spray plans change.
- Twin 1400L/min pumps run chemical and clean water.
- All chemical is sucked through a venturi with a clean water flush, minimising the potential for contamination.
- Sprayers are loaded via twin loading arms (two on each side of the trailer); the 3-inch (7.6cm) arms run clean water and the 2-inch (5cm) arms run hot mix.
- All pipe work is 75 millimetre stainless steel or polyethylene.

Best features	Limitations and desirable additions
• The system is quick and easy to use and decontaminate. • Having completely separate clean water and chemical lines reduces the contamination risk. • Sprayer loading is quick and ferry time is minimised by having a highly mobile batching truck and trailer.	• The system is not automated, so relies on having skilled operators to work it. • It is a relatively new set-up so further limitations have not yet been identified.

"The speed at which we can now fill sprayers in the paddock with this new batching set-up, in addition the relatively easy usability of it, should increase the efficiency and flexibility of our contract spraying operations." – Andrew Irving

UTE BEAUT
Jack Standfast

This highly mobile batching set-up stores 4600L of water (enough for a spray load), two 1000L chemical IBC shuttles and 400L of diesel, allowing the sprayer to stay in the paddock.

Photo: Bill Campbell

This simple set-up using a repurposed dog trailer is small, which means that Jack's casual staff do not need truck licences. It is quick to move between clients' properties so can arrive in time to prepare a chemical load before the sprayer arrives.

"One key feature we find handy is that the trailer is road registered and can be towed by a ute. This is beneficial during busy times when labour options are limited."
– Jack Standfast

Requirements and considerations

Jack's set-up:

- is road registered and mobile (the batching and mixing unit can be towed behind a ute), letting staff without a truck licence travel relatively quickly between client properties;
- has good water storage (the 4600L water tank on the batching trailer holds enough for a spray load so sprayers do not need to leave the paddock); and
- minimises fill time and maximises spraying time by using 3-inch (7.6cm) pumps.

Snapshot of batching and spray operations

CONTRACTOR: Jack Standfast

BUSINESS NAME: Agroc Contract Farming

AREAS SERVICED: Goondiwindi, Queensland

SPRAYER DETAILS: Two Goldacres SP sprayers 4000L/36m

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST: 4600L sump tank, Flash Vat 180L mixing vat and two 3-inch (7.6cm) Banjo pumps on Honda motors, as well as chemical storage for two 1000L IBC shuttles, all mounted on a custom-built dog trailer

$50,000 (including trailer)

ESTIMATED HECTARES SPRAYED PER YEAR: 30,000 to 50,000ha

AVERAGE FILL TIME USING BATCHING SET-UP: Around six minutes (depending on the chemicals being used)

AVERAGE LOADS SPRAYED PER DAY: Six to eight in winter, seven to 10 in summer

LABOUR AND LOGISTICS: Two spray operators, one casual staff during busy periods (water carting and batching)

TIP FOR MAXIMISING EFFICIENCY: Ute and trailer can arrive at the next client's property ahead of the sprayer and have the first chemical load waiting in the paddock.

WATER SOURCE: Mainly bore water

WATER POINTS: Usually drawing from tanks

AVERAGE DISTANCE FROM WATER POINTS TO PADDOCK: 5 to 10km

WATER VOLUMES USED:
Summer sprays: 50 to 100L/ha (depends on chemical systemic vs. contact)

Knockdowns: 50 to 100L/ha (depends on chemical systemic vs. contact)

Winter sprays where good coverage is required (including fungicides): 80 to 100L/ha

Crop desiccation, late season in-crop work: 100 to 150L/ha

CONTAMINATION MITIGATION:
All mixes are currently directly added into sprayer, which does not use a concentrated 'hot batch' process.

The vat is properly rinsed with clean water after the chemical has been transferred out.

A good manifold design means there are no dead spots in containers where chemical can sit.

The fill-and-batch system in detail

- All equipment is mounted on a custom-built dog trailer that is road registered and can be towed behind a ute.
- The trailer holds a 4600L tank, a Flash Vat 180L mixing vat, two Banjo pumps on Honda motors, a 400L diesel tank and a 12V pump.
- The Flash Vat 180L mixing vat features options for drum rinsing, vat rinsing and vat agitation, and a hand wash gun. The vat is also plumbed into a manifold system built using Banjo manifold fittings. These are extremely easy to assemble, modify and repair as required. The Banjo manifold system provides suction from the Flash Vat and suction from two 1000L IBC shuttles. It also has a 1-inch (2.5cm) line for a Micromatic fitting for Enviro Drums or use of a probe.
- A separate 3-inch (7.6cm) pump is used to fill the 4600L tank, keeping it chemical free.
- The 4600L tank holds enough water for one spray load in addition to water for flushing and rinsing.
- One chemical load at a time is batched in the tank for each sprayer (there is no concentrated 'hot' mix), in case of a breakdown or change in weather conditions.
- The system allows two 1000L IBC shuttles of chemical to be stored.

Best features	Limitations and desirable additions
• The road-registered dog trailer can be towed by a ute (meaning a truck licence is not required). • The system is highly mobile and can cart water, chemical and fuel to the sprayer in the paddock. • It has the ability to fill the sprayer within six minutes using the 3-inch (7.6cm) pumps, which keeps the sprayers operating for longer.	• The biggest limitation is that the trailer only carries one spray load of water and two 1000L IBC shuttles of chemical. A least one 1000L IBC shuttle needs to be swapped out daily, requiring a trip to the chemical storage location. • From an occupational health and safety (OHS) perspective, it would be good to install a clean water shower and/or eye wash set-up.

The Flash Vat 180L mixing vat features options for drum rinsing, vat rinsing and vat agitation, and a hand wash gun. Photo: Bill Campbell

FIT FOR PURPOSE
Haiden Agars

As a one-sprayer contractor covering a large area and often dealing with small, undulating paddocks, Haiden's batching set-up mounted on a rigid truck allows him to move quickly between clients and squeeze into corners of paddocks with ease.

Haiden Agars, spray contractor. Photo: Bill Campbell

Requirements and considerations

Haiden's set-up:

- has been designed so there is no lost spraying time (the truck ferries chemical mixes to the sprayer, and is easily able to refill and batch the next chemical mix between sprayer loads, minimising mistakes);
- maximises OHS by incorporating ground-level access to the granny pot, taps and connections so the operator does not have to climb onto the truck;
- incorporates 1000L of water storage on the truck as some clients do not have the necessary water infrastructure for refill; and
- allows for thorough decontamination (every part of the system in contact with chemical – including the sprayer – is flushed with water and All Clear® DS prior to moving to next client).

The fill-and-batch system in detail

- The batching equipment and nurse tank are mounted to a highly manoeuvrable, rigid truck. The nurse (hot) tank has a 7000L capacity and the clean water storage tank has 1000L.
- A fold-down granny pot lets the operator work at ground level during filling. Access to all taps and connections is also from ground level.
- Micromatic suction probe is connected to the granny pot and the clean water system provides fresh water for rinsing.
- The freshwater fill hose is coiled next to the main tank and can easily be dragged out to water source tanks as required.
- A 2-inch (5cm) Honda pump delivers clean water to the nurse tank, flush tank and granny pot, and a duplicate pump provides power for agitation and rinsing sprinklers, and pressure to a venturi used to suck chemical from storage containers. This second pump also powers the transfer of chemical from the nurse tank to the sprayer.
- The system only batches one full sprayer tank at a time, requiring the batching truck operator to return to the water and chemical storage point between sprayer loads to refill before returning with the mixed load.

Best features	Limitations and desirable additions
• The design is simple, making it easy to use. • The rigid truck is highly manoeuvrable, allowing easy access into corners of paddocks, narrow laneways and shed infrastructure. • There are no delays caused by large distances between fill points and paddocks being sprayed, so the sprayer is not held up.	• On uneven ground there are sometimes issues with fully emptying the nurse tank; up to 80L can remain. A tilt tray could be useful. • The speed of suction from chemical storage containers could be increased. • While the venturi is in use to suck chemical out of storage containers, the nurse tank agitation is not able to run. It would be good if both could be operated simultaneously.

The batching set-up includes a 7000L nurse 'hot' tank, 1000L clean water storage tank and granny pot that lowers to ground level for easy access. Photo: Bill Campbell

"The batching set-up I have created works very well for my contracting enterprise. Although not the fastest batching system, batching a load occurs easily within the time the sprayer is operating so no spray time is lost." – Haiden Agars

The rigid truck is highly manoeuvrable, able to be parked in tight paddock corners and traverse narrow farm laneways. Photo: Bill Campbell

Snapshot of batching and spray operations

CONTRACTOR: Haiden Agars

BUSINESS NAME: Agars Ag Contracting

AREAS SERVICED: Wagin, West Arthur, Williams, Narrogin, Dumbleyung, Woodanilling and Kojonup, WA

SPRAYER DETAILS: One RoGator 1300C 6300L/36m

BATCH AND/OR FILL SYSTEM AND ESTIMATED COST:
Batching equipment mounted on a rigid truck, including 7000L hot tank, 1000L clean water tank, fold-down granny pot, two 2-inch (5cm) pumps

$15,000 (excluding the truck)

ESTIMATED HECTARES SPRAYED PER YEAR: 33,000ha

AVERAGE FILL TIME USING BATCHING SET-UP: 15 minutes (if nurse tank located in the same paddock)

AVERAGE LOADS SPRAYED PER DAY: Four loads at 78ha/load

LABOUR AND LOGISTICS: One spray operator, one casual staff (doing the nurse tank operation and escorting/piloting)

TIP FOR MAXIMISING EFFICIENCY:
It takes much longer to spray a load than to batch the next load, so the batching operator is never under pressure to mix fast. This minimises mistakes.

WATER SOURCE:
Various – dam water, rainwater and bore water

WATER POINTS: Usually drawing from tanks

AVERAGE DISTANCE FROM WATER POINTS TO PADDOCK:
5 to 10km. Most clients have one single water point per farm block.

WATER VOLUMES USED:

Summer sprays: 60 to 100L/ha

Knockdowns: 60 to 80L/ha

Winter sprays where good coverage is required (including fungicides): 80L/ha and above

Crop desiccation, late season in-crop work: 80 to 100L/ha

UAN fertiliser: 10 to 70L/ha

Water rates are generally decided by the client and/or their agronomist; they are mostly determined by water availability on the farm at the time of spraying.

CONTAMINATION MITIGATION:
Decontamination of the sprayer and batching tanks is done with AgNova Technologies' All Clear® DS. Approximately 2.5L of this product is diluted in 600 to 1000L of clean water and circulated past every system that has had chemical contact. The nurse tank is decontaminated while the last load is being sprayed. It then ferries the water plus All Clear® DS mix to the sprayer for decontamination before moving to the next client.

The clean water tank is never used for chemical.

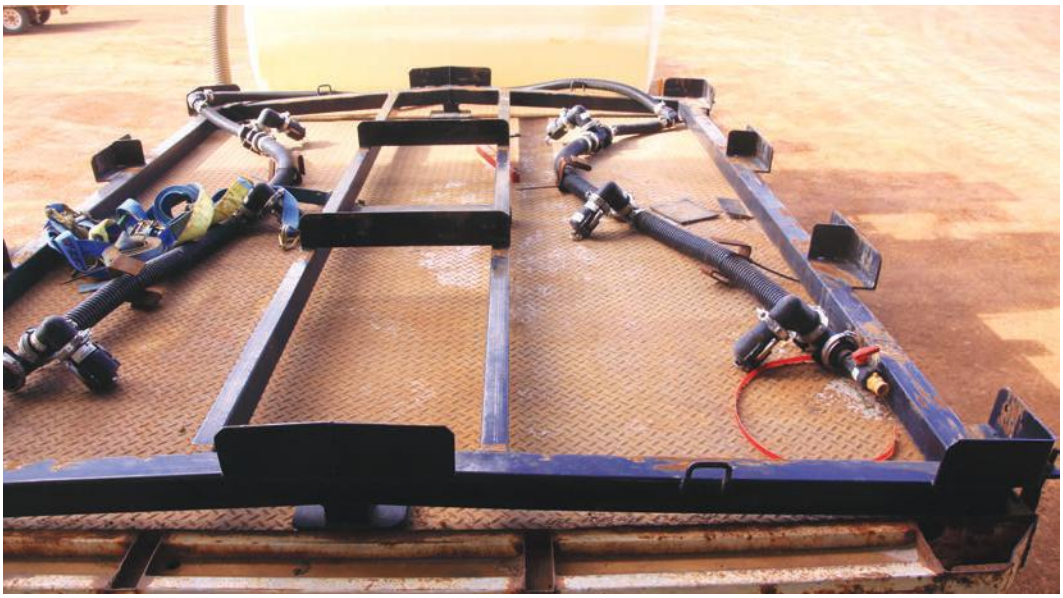
Good set-up ideas for mixing, batching and supporting spraying operations

This section showcases some of the innovative ideas and systems that growers and spray contractors have developed to make agricultural chemical mixing and batching more efficient. With the development and widespread use of larger-capacity sprayers in the past five to 10 years, much of the support equipment has been developed on-farm out of necessity to match the larger spray rig capacity. Necessity is the mother of invention: with innovation comes efficacy, and the on-farm 'hands-on' experience gives the day-to-day practicality.

Self-draining 1000L IBC shuttle racks

Young Hill Farms, Beaumont/Esperance

These angled, steel racks located on a truck tray allow the 1000L IBC chemical shuttles to be completely emptied. The IBC shuttles currently feed a SurePoint QuickDraw automated batching system, but they could easily be used in other kinds of batching systems. Also note that, in this case, the manifold plumbing connects three IBC shuttles with a 1-inch (2.5cm) camlock fitting and includes a tap for clean water flushing of remaining chemical.



Photos: Bill Campbell

Granular ammonium sulfate and fertiliser mixing tanks

Broun Farms, Coorow

Having a central fill point connected to 240-volt power for tank agitation allows for the timely pre-dissolving of larger volumes of ammonium sulfate (AMS), fertilisers and granule products prior to direct induction into the sprayer. Dissolving AMS causes an endothermic reaction that cools the water, so pre-dissolving the product minimises mixing issues caused by cold water, as the water temperature can normalise with time.

These scales have been set up to measure chemical volume; this method requires knowledge of the specific gravity (relative density) of products. Most chemical applicators use some sort of volumetric measurement as flow meters are not accurate across products of different viscosities and densities.

Photos: Bill Campbell

Cone-bottom measuring vats

Longmire Farms, Condingup

These cone-bottom measuring vats are an easy and accurate way to measure chemical. In this set-up, each measuring cone is run on its own separate circuit so there is no cross-contamination between chemicals. They are easily filled to a specific volume directly from 1000L IBC shuttles or 110L Enviro Drums and are individually inducted into the sprayer. These measuring cones have their own freshwater sprinkler system that rinses and decontaminates them, and lighting from behind shows levels when filling at night.

Photos: Bill Campbell

Pre-measuring into specific 110L Enviro Drums before induction

Marrone Farms, Wubin

This is a very simple method of accurately measuring large volumes of product from 1000L IBC shuttles. Although not part of a fully closed system, the method is systematic and avoids compatibility issues. Induction of chemical from the 110L Enviro Drums to the sprayer is done through the sprayer's induction system. At the same time, a separate freshwater circuit fills the sprayer. Different-coloured drum lids make it easier to avoid cross-contamination.

Photos: Bill Campbell

Chemical pumping with a diaphragm pump

McGinniss Farms, Hines Hill

This old ex-sprayer diaphragm pump has been modified specifically for inducting large volumes of chemical. Chemical applicators commonly experience difficulties when transferring large volumes of viscous chemicals; using a positive-displacement pump overcomes these issues. Care is required when using a system like this to avoid cross-contamination.

Photo: Bill Campbell

Fill pipe gantry

Broun Farms, Coorow

These types of pipe gantries are becoming more popular as they are a good way of storing and handling fill pipes. This gantry set-up has two pipes: a grey pipe (with the red tape) for mixed chemical and a black pipe (with a blue mark that is not visible in the photo) for fresh water only.

Photo: Bill Campbell

Truck-mounted fill pipe gantry

Della Bosca Farms, Southern Cross

This is a good example of a truck-mounted fill pipe gantry set-up that requires minimal handling of hoses. The 2-inch (5cm) hose is used for chemical and the 3-inch (7.6cm) hose carries fresh water. The gantry is easy to swing out for filling and stores away safely during transport.

Photo: Bill Campbell

Mobile chemical and pumping trailer

Williamson Farms, Yuna

This tri-axle trailer is primarily used for carrying chemical to watering points. The addition of a simple pumping and induction system has created a mobile unit that can be transported easily to multiple water supply points and different farms. It consists of a Honda 3-inch (7.6cm) poly pump with a small measuring-cone induction vat and Micromatic coupling induction system. The two sprayers involved in this operation generally work apart, with the sprayers dedicated to different jobs or crops in different locations. This versatile trailer system is relatively cheap to set up.

Photos: Bill Campbell

Ex-drill support truck converted to nurse truck

Wandel Farms, Scadden

This large, six-wheel-drive, drill support truck has been converted into a well-thought-out and practical set-up that services a large mixed-cereal, pulse and oilseeds operation. The truck has separate chemical and fill circuits to avoid contamination and good pumping and water capacity. It has sturdy racking for storing 1000L IBC shuttles, 110L Enviro Drums and smaller chemical containers, and houses five cone-bottom measuring vats along with a large granular mixing system.

Photos: Bill Campbell

‘Mini’ mobile batching and mixing trailer

Pearse Farms, Mingenew

This small trailer is highly mobile, lightweight and simple. It has batching, mixing and pumping systems mounted to its frame. The trailer contains everything required for filling sprayers with moderate capacity.

Photos: Bill Campbell

Manifold for high-capacity chemical and water fill

Perks Farms, Condingup

This is a good example of large capacity individual water and chemical circuits that can be used for dual manifold filling of pre-mixed chemical and/or water.

Photo: Bill Campbell

Manifold for high-capacity chemical and water fill

Hyde Farms, Dalwallinu

A simple manifold can increase pumping capacity from multiple tanks with 2-inch (5cm) plumbing into 3-inch (7.6cm) pipe with additional off-take. Note the large filter cartridge (50 micron) for pre-filtering. This set-up highlights the need for better plumbing and greater pumping capacity when purchasing and installing water storage for spraying. Also note that the tanks are raised on a cement and earth bund for gravity feeding, which assists when using the sprayer pumping system.

Photos: Bill Campbell

Manifold for tanker, hot batch and water

Crusher Farms, Lake Grace

This tanker set-up is built around a well-thought out manifold system. It is a newly refurbished tanker, set up as a chemical tanker, for batching and filling in the paddock. It consists of a 24,000L fresh water-only tank and an 8000L hot mix tank with well-thought-out pumping and induction equipment for chemicals and chemical storage. Up to three 2000L hot mixes are pre-batched and constantly agitated if required. The sprayer is simultaneously filled from a gantry with the hot mix and top-up water. This chemical tanker will soon also be configured as a B-double, coupled to an additional 30,000L of fresh water for working at a remote farm (35km away) that does not have scheme water. This will easily allow for four to six loads to be sprayed in a day at 70 to 80L/ha. Chemical storage will be extended, allowing an additional two 1000L IBC shuttles to be carried above the existing storage deck.

Photos: Bill Campbell

IBC shuttle platform

Pearse Farms, Miling

Concrete culvert blocks have been used as raised 1000L IBC shuttle stands at a main water supply source. This is a very neat, tidy and sturdy set-up that allows gravity feed to pumps or a batching plant. Note the location of the drum trolley near the water and UAN tanks.

Photo: Bill Campbell

Other spray resources

Spray resource	Web link	QR code
	*Fill-and-ferry savings optimise hectares sprayed on any given day* (2019) GRDC fact sheet grdc.com.au/resources-and-publications/all-publications/publications/2019/spraying-efficiency	
	*Mixing requirements for spraying operations* (2019) GRDC fact sheet grdc.com.au/resources-and-publications/all-publications/factsheets/2019/mixing-requirements-for-spraying-operations	
	*Water quality for spraying operations* (2019) GRDC fact sheet grdc.com.au/resources-and-publications/all-publications/publications/2019/spray-water-quality	
	*Decontamination of spraying, mixing and transfer equipment* (2019) GRDC fact sheet grdc.com.au/resources-and-publications/all-publications/factsheets/2019/decontamination-fact-sheet	
	*Spray application manual for grain growers* (2017) GrowNotes™ (includes over 20 modules with instructional videos) Jar test: go to module 7: Mixing and decontamination, Mixing – conducting a jar test (includes 'how to' video) grdc.com.au/resources-and-publications/grownotes/technical-manuals/spray-application-manual	
	*Adjuvants – Oils, surfactants and other additives for farm chemicals used in grain production* (2019) grdc.com.au/resources-and-publications/all-publications/publications/2018/adjuvants-booklet	
	'Spray drift' GRDC web page grdc.com.au/resources-and-publications/resources/spray-drift	

TANK MIXING ORDER GUIDE

Step	Formulation/example product
1	**WATER** Fill the tank with 70 per cent water. Start agitation and keep agitating throughout the following steps.
2	**WATER CONDITIONERS** (for example, ammonium sulfate, citric acid) Do NOT add water conditioners with an 'oily' component such as Hot-up® or LI 700® at this step.
3	**WETTABLE POWDERS** (WP), **WATER-DISPERSIBLE GRANULES** (WDG) (for example, powdered trace elements)
4	**DRY FLOWABLES** (DF), **SOLUBLE GRANULES** (SG) (for example, Simazine DF, Atrazine DF, Roundup Ready® Plantshield SG)
5	**SUSPENSION 'FLOWABLE' CONCENTRATES** (SC) (for example, Atrazine SC, Propyzamide SC, Overwatch® SC, liquid trace elements) If using LI 700® for acidification, add 0.1 per cent LI 700® NOW. Wetters may be added NOW if using ECs. Defoamers may be added NOW if there is excessive foaming.
6	**EMULSIFIABLE CONCENTRATES** (EC) (for example, Trifluralin EC, Clethodim EC)
7	**AQUEOUS CONCENTRATES** (AC), **WATER-SOLUBLE LIQUIDS** (SL) (for example, glyphosate, paraquat, Amicide Advance®) Refer to 2,4-D amine product label when mixing 2,4-D amine with glyphosate. Follow this sequence: 7.1. Fill tank to 90 per cent with water. 7.2. Add 2,4-D amine product. 7.3. Add glyphosate. 7.4. Add other adjuvants. 7.5. Add remaining water.
8	**OIL DISPERSION** (OD) (for example, Atlantis® herbicide) (an uncommon formulation type)
9	**ADJUVANTS** Add wetter and oil adjuvants last.
10	**FILL TANK TO 100 PER CENT** Add liquid urea ammonium nitrate (UAN) LAST. Continually agitate and apply mix as soon as possible.

Source: Bill Campbell, Bill Campbell Consulting. *General guidelines for mixing agrochemicals*

P Level 4, 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604
T 02 6166 4500 **F** 02 6166 4599 **E** grdc@grdc.com.au