



SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 7

Mixing and decontamination

Avoiding potential problems

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Key points

- Always finish clean, so you can start clean
- Read product labels for formulation type, mixing requirements and decontamination instructions
- Plan the mixing operation, including the equipment required
- Use the correct mixing order, and, if in doubt about compatibility, do a jar test

1. Importance of correct mixing and clean equipment

There are many farm chemicals, adjuvants and water conditioners that have the potential to interact when they come into contact with each other, particularly if they have not been sufficiently diluted or fully dissolved.

These interactions may affect their solubility, where a gel or insoluble precipitate (solid) is formed. This is known as physical incompatibility, which effectively reduces the applied rate by reducing the availability of the product in the spray solution and may result in filter screen and nozzle blockages and uneven application. Physical compatibility should always be checked before mixing new products together or adding multiple products to a tank mix by conducting a jar test.

Physical incompatibility can occur when:

- products are passed through mixing equipment without fully flushing the system with clean water before other products are added (e.g. the concentrates come into contact);
- products are not fully dissolved or dispersed in the main spray tank before additional products are added;
- multiple products are mixed in low water volumes;
- or products are mixed into poor quality water.

Even when products are physically compatible (able to be mixed together), interactions can still occur that may affect the level of efficacy that can be expected from the products as compared to when they are applied individually, particularly if they are applied in a tank mix of multiple products.



► See section 5 of this module and the accompanying video for more information on the jar test procedure.



When products such as water conditioners are not fully dissolved before additional products are added, reactions can occur in the tank.

Photo: Bill Gordon



Interactions between the products in the tank, or at the target, can reduce the level of uptake and translocation, or they may affect how a product works at a specific site within the pest or plant. This is known as biological incompatibility.

It is important to understand how products need to be mixed to minimise interactions and incompatibility. This includes being able to remove residues of previous applications from the spraying and mixing equipment through the correct decontamination process, which will help to prevent possible interactions with new tank mixes or damage to crops during future applications.

Always refer to product labels and manufacturers' guides for compatibility, mixing requirements and the recommended decontamination agents.

2. Decontamination agents

The highest risk of crop damage usually comes from herbicide residues remaining in the sprayer (blindspots, inside tank, ceiling and hose) or mixing equipment. However, all residues pose the risk of interactions with future tank mixes if they are not correctly removed from the spraying system and mixing equipment. Most labels provide information on the cleaning agents required to remove product residues, but applicators need to be aware that the cleaning process is just as important as the cleaning agent used.

Always check the expiry date of cleaning agents and the amounts of each product that are required to be added to the volume of water held by the tank or mixing equipment. Never mix chlorine (bleach) and ammonia as a reaction can occur that results in the emission of a toxic gas.

Table 1 is a **guide** to selecting decontamination agents prepared from information included in the NSW DPI management guide *Weed control in winter crops 2016*, the Nufarm/Croplands decontamination guide, the Kenso Agcare 'Boomsprays: cleaning and decontamination boomsprays' (www.kenso.com.au/page/attachment/19/boom-decontamination-guide) and product labels.

Table 1 Decontamination and cleaning agent guide.

Selected herbicide groups	Chemistry	Examples of active ingredients	Herbicide examples	Cleaning product and rate per 100L water
A	DIMs	Clethodim Sethoxydim Butoxydim Tralkoxydim	Select [®] , Sequence [®] , Sertin [®] , Factor [®] , Achieve [®]	500mL liquid detergent Dynamomatic or 1L Absolute Boomer, or 120g Nufarm Tank and Equipment Cleaner, all as per label instructions
	FOPs	Clodinafop Haloxypop Fluazifop Diclofop Quizalofop	Topik [®] , Verdict [®] , Fusilade [®] , Diclofop, Targa [®]	
	DENS	Pinoxaden	Axial [®]	
B	Imidazolines	Imazapic, Imazapyr, Imazamox, Imazethapyr, Various combinations of Imidazolinones actives	Flame [®] , Arsenal [®] , Raptor [®] , Spinnaker [®] , Skipper [®] , Onduty [®] , Intervix [®] , Lightning [®] , Sentry [®]	120g of Nufarm Tank and Equipment Cleaner or very thorough water clean
	Sulfonylureas	Chlorsulfuron, Iodosulfuron-methyl, Metsulfuron-methyl, Sulfosulfuron, Triasulfuron, Mesosulfuron-methyl	Lusta [®] , Tackle [®] , Hussar [®] OD, Ally [®] , Associate [®] , Monza [®] , Logran [®] , Logran [®] B-Power, Atlantis [®]	
C	Triazines	Atrazine, Simazine, Prometryn	Atrazine, Simazine, Gesagard [®]	Water, with 120g Nufarm Tank and Equipment Cleaner or 1L Absolute Boomer as per label instructions or tank mix partner/s requirements
	Ureas	Diuron	Diuron	
	Nitriles	Bromoxynil	Bromicide [®]	
D	Dinitroanilines	Trifluralin, Pendamethalin	Treflan [®] , Triflur Xcel [®] , Stomp [®] , Rifle	
F	Pyridinecarboxamides Pyridazinones	Diflufenican, Picolinafen, Norflurazon	Brodal [®] , Nugrex, Sniper [®] , Paragon [®] , Zoliar [®]	Nufarm Tank and Equipment Cleaner as per label instructions
G	Diphenylethers, Trioloinones, Pyrimidindiones	Oxyfluorfen, Carfentrazone-ethyl, Saflufenacil	Goal [®] , Hammer [®] , Affinity [®] , Sharpen [®]	100g alkaline detergent: Omo, Spree, Surf, or 1L Absolute Boomer [®] as per label instructions
H	Pyrazoles	Benzofenap, Pyrasulfotole	Taipan [®] , Velocity [®] , Precept [®]	Nufarm Tank and Equipment Cleaner as per label instructions
	Isoxazoles	Isoxaflutole	Balance [®] , Palmero [®]	500g alkaline detergent e.g. Omo, Spree, Surf, or 500mL liquid detergent e.g. Dynamo Matic, or 300mL fresh Chlorine bleach containing 4% chlorine as per label instructions

Selected herbicide groups	Chemistry	Examples of active ingredients	Herbicide examples	Cleaning product and rate per 100L water
I	Benzoic acids	Dicamba	Kamba®	120g Nufarm Tank and Equipment Cleaner
	Phenoxy-carboxylic acids (Phenoxys)	MCPA (Dimethyl-amine), MCPA (Ethyl Hexyl Ester), MCPA (Iso-Octyl Ester) MCPA (Potassium Salt), 2,4-DB, 2,4-D (Dimethylamine and Diethanolamine), 2,4-D (Ethylhexyl Ester)	Nufarm MCPA 720, Agritone® 750, Nugrex, Paragon®, Bromicide®, Broadside®, Trooper® 242, Ozcrop 2,4-DB, Empress 2,4-DB, Amicide®, Surpass® 475, Estericide Xtra 680	2 L household ammonia, (to make a 1% solution in the tank) followed by 120g Nufarm Tank and Equipment Cleaner as per label instructions
	Pyridines	Clopyralid, Fluroxypyr, Triclopyr	Lontrel®, Archer®, Starane®, Comet®, Grazon™	120g Nufarm Tank and Equipment Cleaner as per label instructions, or 500g washing soda (crystalline sodium carbonate) + 4L kerosine, or 2L Ammonition
J	Thiocarbamates	Tri-allate	Avadex® Xtra	Water, with 120g Nufarm Tank and K Equipment Cleaner or 1L Absolute Boomer
K	Chloroacetamides, Isoxazoline	S-Metolachlor, Pyroxasulfone	Dual Gold®, Bouncer®, Sakura®	
L	Bipyridils	Paraquat, Diquat, Paraquat + diquat	Gramoxone®, Reglone®, Spray.Seed®	Thorough water clean, or as per tank mixing partner/s requirements
M	Glycines	Glyphosate	Glyphosate, Roundup products, Weedmaster®, Touchdown®, Wipe-out	
N	Phosphinic acids	Glufosinate-Ammonium	Basta®, Liberty®	
Q	Triazoles	Amitrole	Amitrole, Illico, Para-Trooper	Water, with 120g Nufarm Tank and Equipment Cleaner or 1L Absolute Boomer
Z	Arylamino-propionic acids	Flamprop-m-methyl	Oat Master, Mavro, Farnoz Judgement	

The cleaning products mentioned in this table are not the only products available for decontamination.

3. Suggested cleaning process

ALWAYS water flush the spray system at the completion of mixing or spraying.

One of the most critical steps in reducing the level of residue in the tank, pump and plumbing is to ensure the sprayer and mixing equipment are completely clean after use. Thoroughly flush the mixing and transfer system with water as soon as mixing has taken place, and flush the spray equipment with clean water immediately after spraying has been completed. Delaying the water flush by even an hour can more than double the amount of product that may bind to tank linings, hoses and other fittings.

Most products will require further cleaning and decontamination using an appropriate cleaning agent, even after the water flush has been completed.

There are a range of commercial cleaning agents available for decontaminating spray equipment. It is essential that spray operators refer to product labels and manufacturers' technical information to ensure the correct cleaning agent is used. Always ensure that chlorine-based products are 'fresh' and other agents are used before the recommended expiry date.

Steps in the cleaning process

Step 1: Select a suitable area for the wash-down and cleaning process

Cleaning the sprayer can present risks to the person doing the cleaning, bystanders and to the environment, through build-up of residues in the soil or from run-off into water courses. Always use appropriate personal protective equipment (PPE) and select an area that is well grassed, where run-off from the washing process cannot enter water courses. It is useful to identify several appropriate locations on the farm so that the cleaning site can be moved to prevent the build-up of residues in the soil.

Step 2: Remove external residues from the sprayer before starting

If booms and nozzle bodies are covered in dust and chemical residue, pressure-wash the boom, nozzle and filter bodies and tank exterior before starting the decontamination.

Step 3: Immediate water flush

Knockdowns

Start with an empty tank. Plan ahead for the final load of any spray job by only mixing as much product as is required for that tank. As soon as spraying has stopped, complete an in-field water flush and spray out the remaining contents of the tank onto a suitable fallow paddock.

Residual herbicides

Residual herbicides pose a significant risk to future crops and the environment so require special attention to minimise those risks.

It is still critical to conduct an in-field water flush, however disposing of the diluted product may present a significant risk when compared to other products with little or no residual effects.

If the operator has a dedicated disposal system then tank contents should be drained into this. However, the majority of growers still don't have these facilities, so an alternative strategy needs to be used.

The most common approach to disposal of tank contents after the water flush has been completed is to spray them out onto the paddock the original mix was applied to, provided the application will not exceed the maximum registered rate for the product and the plant-back period will not be significantly affected.

Where the total rate of applied product or the potential plant-back period are of concern, the following procedures may be of assistance.

- **Consider the volume of water that can be transferred from the flush tank (fresh water tank) to the main tank as well as the application rate being used to work out how many hectares this volume could spray, e.g. a 500-litre flush tank could spray an area of 5ha at a rate of 100L/ha;**
- **Consider what volume remains in the tank (that cannot be sprayed out) at the end of each load, e.g. 50L remains in the sump and pump;**
- **If 500L from the flush tank is added to the remaining 50L, the tank mix would be at 9 per cent of the original rate. So if we reduce the initial application rate for the last 5ha of a paddock by 9 per cent from 100L/ha to 91L/ha (after we have completed the water flush by adding the contents of the fresh water tank to the main tank) then spray this diluted product over the same 5ha area again at 100L/ha. We would only be putting the equivalent of the original rate over the last 5ha, and we would have flushed and diluted what is left in the tank; and**
- **Before leaving the field, add enough decontaminating agent to neutralise the remaining diluted product in the tank (i.e. 50L). Move the sprayer to the selected cleaning site and drain the neutralised contents, and continue with the decontamination process.**

Step 4: Pre-clean the spray system and mixing equipment with water

Pre-cleaning is an additional step to the in-field water flush and is important to dislodge any built-up residues from the spray system and tank. In some instances where salt or amine formulations of phenoxy-type products (Group I) and some suspension concentrates have been used, it may be necessary to add a softening agent (usually cloudy ammonia, unless cleaning with chlorine bleach as the cleaning agent) to help remove hard or stubborn residues.

Add clean water to the tank to about one-quarter to one-third of the full capacity, and add the softening agent where appropriate. Run the solution through the lines and nozzles for about two to three minutes, then, with the nozzles turned off, run the sprayer agitation and tank-rinse nozzles at the same time for at least 15 to 20 minutes.

Spray out the tank contents onto an appropriate field or fallow area and drain the tank completely at the selected cleaning site.

Inspect tank and spray system for any residue remaining on ledges and sumps, pressure-wash with clean water using PPE, and flush and drain the tank at the selected cleaning site.

Step 5: Use cleaning agents (where recommended), or complete this step with clean water

Add enough of the recommended cleaning agent(s) to clean a full tank. If products were mixed using an induction hopper, add the cleaning agent and some fresh water through this system. Where a separate mixing vat was used, decontaminate this system separately from the sprayer.

Add enough clean water to fill the tank to about one-quarter to one-third of the full tank volume. Agitate the mix and run the solution through the lines and nozzles for about two to three minutes, then, with turned nozzles off, run the sprayer agitation with the cleaning agent for at least 15 to 20 minutes. If a tank-rinse nozzle is fitted, use this at the same time.

Remove and clean nozzles, drain filter bowls, and remove the filters and o-rings. Remove the diaphragm from non-drip nozzle bodies. Clean the fittings, nozzle bodies and other areas where components have been removed.

Soak o-rings, filters, diaphragms and nozzles in a separate bucket with the cleaning agent for at least 15 to 20 minutes. Rinse with water, then clean again with warm soapy water. Inspect all items then rinse again with clean water.



TIP

Do not leave plastic nozzles in chlorine (bleach) solutions for more than half an hour, as some may become brittle.

Fill the tank with clean water (in addition to the water and cleaning agent already in the tank) to the point of over flow, close the lid and ensure it is in contact with the tank contents. Allow this to stand for several hours, preferably overnight. Fill the induction hopper to the point of overflow and also allow this to soak for the same period of time.

After soaking for an extended period, drain the induction hopper and flush with clean water. Agitate the tank again for 5 to 10 minutes, then flush the lines with the contents of the tank (water and cleaning agent), run the boom one section at a time, with the end tap open. Turn the boom valves on and off several times to ensure they are working and cleaned.

Replace all o-rings, filters, diaphragms and nozzles.

Spray out any remaining contents of the tank (to a previously unsprayed fallow area).

Step 6: Inspect the internal surfaces of the tank

If residues are still found on ledges and other areas of the tank, use a pressure washer to remove these and allow the contents to completely drain.

Repeat step 5 again, then move to step 7.

Repeating step 5 is particularly important for many Group B (especially sulfonylureas) and some other pre-emergent products, suspension concentrate formulations, some Group A herbicides and especially for Group I herbicides.

Step 7: Final water rinse – internal

For products where thorough cleaning with water is all that is required, **skip to step 8 (below).**

If a cleaning agent is required, use a pressure washer to thoroughly clean the internal walls, roof and ledges within the tank with clean water and allow the contents to drain completely. This may require more than one pressure wash for products that present a risk to future crops.

Once the tank is clean, fill the tank to about one-quarter to one-third of its capacity with clean water and repeat the high-pressure flush of the whole boom, followed by flushing individual sections one at a time.

Check nozzle patterns while flushing with clean water, note and replace any with a poor pattern.

Drain the water and rinsing from the tank onto a well-grassed area, ensuring run-off cannot enter a water course.

Rinse with clean water, flush the spray system and completely drain the tank and system.

Step 8: Final clean – exterior

Use a pressure washer to clean the exterior of the sprayer and booms to remove any remaining residues and dirt from the entire spray rig.



► For more information see the 2010 UK Health and Safety Executive (HSE) report 'Decontamination of agricultural sprayers' www.hse.gov.uk/research/rrpdf/rr792.pdf

4. Mixing products correctly

Using the correct mixing order can mean the difference between a successful spray job or spending a lot of time cleaning out the sprayer. Thinking about the mixing operation before you start and making a plan can save a lot of time and effort on the day you want to spray.

4.1 Always plan the mixing operation

Before any mixing operation there are several things to consider:

- **consult all product labels and ensure the appropriate PPE and spill kit are available;**
- **consider the mixing and measuring equipment required, such as measuring vessels and accurate scales (electronic balance);**
- **plan where the mixing and cleaning operations will occur;**
- **calculate and record how much product, adjuvant and water will be required – it may be useful to develop a mixing plan or spreadsheet to assist;**
- **record the mixing order – ask advisers to list products on their recommendation in the order that they should be mixed;**
- **record how much product is used – then adjust product inventories at the completion of spraying; and**
- **it is useful to have a whiteboard at the mixing site or on the mixing trailer to take notes as you go.**

Figure 1 Spray load calculator

Paddock	Sample paddock			Total area	200
TASK	Summer knockdown				Total spray tank loads
Recommendation		Rate	g/kg/mL	Total required	
Carrier	Water	50	L	10,000	2.00
Adjuvant*	Water conditioner	1	kg	100	
Adjuvant*	Wetter	0.2	L	20	
Chemical	Knockdown	1.5	L	300	
Chemical	Spike	0.3	L	60	
Chemical				0	
Chemical					
*rate based on volume %					
Full tank loads		Tank volume	ha/tank load	No. full tank loads	
		5000	100.00	2.00	
		Rate		Amount/load	Mixing order
Adjuvant*	Water conditioner	1	kg	50.00	1
Adjuvant*	Wetter	0.2	L	10.00	4
Chemical	Knockdown	1.5	L	150.00	2
Chemical	Spike	0.3	L	30.00	3
Chemical	0	0	0	0.00	

4.2 The mixing order

The wrong mixing order, or not allowing enough time for products to fully disperse and dilute before the addition of new products to the tank, can lead to problems with tank-mix stability or poor results in the paddock.

The mixing order of farm chemicals is determined by the products' solubility and the solvent and surfactant systems, which are dictated by the formulation type.

Knowledge of the formulation type is critical to getting the mixing order right for tank mixes of more than one product.

Always add products according to their formulation type

Pesticides come in a wide range of formulation types. These formulations are based on solvents and surfactant systems, which are tailored to the physical and chemical properties of the active ingredient. Some water-soluble actives, such as paraquat or glyphosate, can disperse easily in the tank mix. At the other end of the spectrum, fat or oil-soluble products, such as emulsifiable concentrate (EC) formulations, dislike the water environment, so their formulation package has to be designed to allow the active ingredient to disperse in water.

When different products are mixed together their solvents and surfactants may start to interfere with each other. Sometimes this can hinder the dispersion of the more water-sensitive actives.

The whole idea of a mixing order is to give the least-robust or least-soluble products a chance to disperse and be diluted by the water before introducing the next product. Mixing should always follow the label instructions. Where the label information is not clear or is insufficient for the tank mix you are thinking about using, the following information is provided as a guide.

Mixing order: add formulation types to the tank mix, from first to be added to last to be added.

Water conditioners

Water conditioners, such as ammonium sulfate to reduce hardness of water, or acidifiers and buffers for lowering or adjusting the pH levels, are introduced to create an optimised water environment for the introduction of chemicals. They should be added to the tank mix first.

Allow 10 minutes for crystalline ammonium sulfate to dissolve and disperse in the tank.

Dry products

After water conditioners are added, dry formulations are the next to be added to the tank mix.



Wettable powders are not that common any more. They have to be fully dispersed in water before any other pesticide can be added. They generally have a large surface area. To disperse correctly their surfactant system should not be compromised with any other surfactant system.

Water dispersible granules (WDGs) or dry flowables (DFs) are the next types of product to be added to the tank mix. They are not as sensitive as wettable powders, but are best dispersed before any other surfactant system is introduced.

Dry products also need time to disperse. Allow 10 minutes for full dispersion before introducing other products.

Flowables and suspension concentrates

Flowables and suspension concentrate (SC) products are an improvement on WDGs because they come as an 'already wetted' slurry. To improve the dispersion of SC products, they need to be introduced into the tank mix before any products formulated as emulsifiable concentrates, other 'oily' substances or many oil-based adjuvants.

Emulsifiable concentrates

EC formulations generally have a strong solvent component, often indicated on the label as part of the active ingredients and listed as a number of grams per litre (g/L) of hydrocarbon solvent.

The high level of solvents means that the surfactant system in products formulated as ECs can interfere with dry formulations and flowables. They have to be introduced into the tank mix after the dry products have been fully dispersed in enough water to allow sufficient dilution.

Soluble liquids

These are products that have surfactant systems that allows them to readily disperse in water. Soluble liquids are not usually affected by the surfactant systems of other formulations. This category includes paraquat and liquid glyphosate products.

Additional surfactants

Where recommended on the product label, additional surfactants should be added last to the tank-mix, after the water volume has been increased to about 95 per cent of the total tank mix volume. However, some oil-based adjuvants may need to be added before the soluble liquids, so always check the product label for mixing instructions.

4.3 Possible variations to the standard mixing order

There several situations where the standard or recommended mixing order may vary, due to changes in the formulation or surfactant system used by the manufacturer. Always consult product labels and manufacturers' technical information for the appropriate mixing order for a particular tank mix.



► For further information on mixing requirements, refer to the GRDC Fact sheet '[Mixing requirements for spraying operations](#)'

4.4 Where to get information on formulation types

Many products have the formulation type included in their name on the label, or on the safety data sheet (SDS). However, many labels do not mention the formulation type at all. Some manufacturers have published lists (e.g. Nufarm's *Boomspray application guide*).

If in doubt, the most comprehensive source is the Australian Pesticides and Veterinary Medicines Authority (APVMA) PubCRIS database. To access the PubCRIS database, use the following steps:

- Google 'APVMA';
- tap the subheading 'Search PubCRIS' in the search results;
- on the APVMA search page type the product name into the search field – e.g. 'Fastac' – and click on the search symbol, or hit 'return'/'enter';
- scroll down the page; the search result will be 'Fastac Duo Insecticide' – click on the product name;
- a screen with product details will come up – the first 'General' screen states product type: emulsifiable concentrate.

5. Checks for physical compatibility – the jar test

A jar test is an easy way to check for physical compatibility of products. It is recommended when unusual product mixes are used, when mixing products for the first time or when substituting brands (e.g. switching between generic and non-generic products).

'Jar test' results are quick and will provide a good indication of what is likely to happen in the tank.

The ratios of product and water used should mimic the field rates. While it is called a jar test, the best container is an elongated clear glass cylinder (or bottle) with an appropriate lid or seal capable of holding a minimum volume of 1 litre. Only glass jars or bottles (not food containers) that can be fully decontaminated and cleaned at the end of the process should be used. Appropriate PPE should be used when handling undiluted products.

5.1 Jar test – water volume

The easiest way to simulate actual tank-mix ratios is to divide everything by 100. For example, 70 litres per hectare (L/ha) becomes a 0.7L volume in the jar. It is a good idea to use the same water source that is going to be used to spray with. If the initial mixing takes place with 60 per cent tank capacity of water, this should be reflected in the jar test as well. For example, 60 per cent of 0.7L would amount to 0.42L ($0.7 \times 0.6 = 0.42$) for the initial volume of water in the jar.



◀ [Mixing - conducting a jar test](#)

5.2 Jar test – product rates

Product rates for the jar test should also use the field rate divided by 100.

For example: a rate of 2L/ha, or 2000 millilitres per hectare (mL/ha) becomes 20mL per test, a rate of 800mL/ha becomes 8mL per test, and so on.

Adjuvants can be a little trickier because they are mixed at a rate per 100L. For example, 2000mL per 100L of water with a liquid AMS becomes 20mL per litre. For a tank mix to be applied at 70L/ha, the total jar test volume would be 0.7L, not a whole litre. The amount of liquid AMS to add to the total jar volume of 0.7L would be 14mL (20mL per litre x 0.7L = 14mL).

It is useful to have some syringes to measure small volumes. They are easily obtained from pharmacies or medical supply shops and come in various sizes; 3mL and 20mL should provide sufficient volume variation. Dry products require scales: a portable scale (electronic balance) should provide reasonable accuracy in the 10 – 20 gram range.

5.3 Conducting the jar test

The mixing order should be the same as that used in the field. Shaking the jar after mixing will simulate agitation. When dry products are used they should be fully dissolved before the next product is introduced (this may require a separate container to dissolve dry products, if that is what you do in the field). Waiting for products to fully dissolve may take some time, for example, when using crystalline ammonium sulfate, but this is also what will be required for the actual tank mix.

After the mixing is finished the jar should be left to stand for 5 minutes.

Table 2 An example of field rates and the rates to be used for a jar test.

Example of volumes in a jar test (one-hundredths of a hectare rate or volume)			
Field rates		Jar volume or amount	
Total application volume	70L/ha	$70 \div 100 =$	Final jar volume 0.7L
Initial mix – starting water volume	60% tank capacity	$0.7 \times 0.6 =$ or $0.7 \times 60\%$	Initial jar water volume 0.42L
Liquid AMS	2000mL per 100L	$2000 \div 100 \times 0.7 =$	14mL
2,4-D	800mL per ha	$800 \div 100 =$	8mL
Glyphosate	2000mL per ha	$2000 \div 100 =$	20mL

Possible results of the jar test

- The jar contains a **homogenous solution**. This is where the whole mixture appears consistent in appearance. This is the best result a jar test can produce. The mixed solution seems to be stable and suggests that the planned tank mix is physically compatible and products will be able to be mixed in the tank.
- The jar contains thick **layers or banding in the profile**. This indicates that the solution is not stable without agitation. If some shakes of the jar can make the solution homogenous again, and it stays this way for two minutes before layers start to form slowly again, it can be assumed that agitation should overcome the problem.

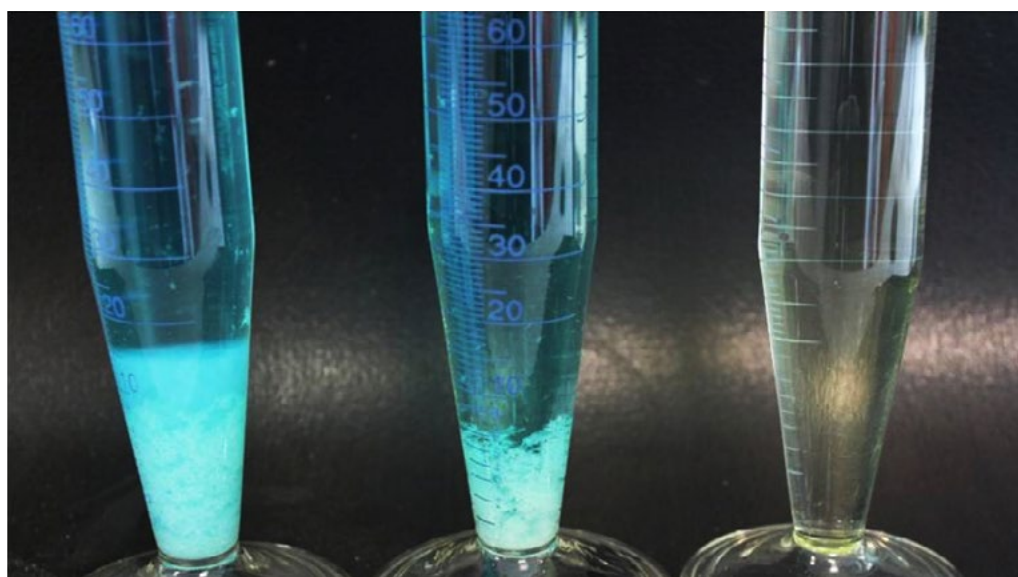
However, if the banding returns within about 30 seconds, it is a strong indication that there will be a problem with the tank mix that even good agitation may not be able to overcome.

- There is **sediment or precipitate** on the bottom of the jar. This indicates strongly that the mix is not physically compatible or the mixing procedure was not right, e.g. adding 2,4-D before allowing sufficient time for crystalline ammonium sulfate to dissolve.



Three possible outcomes of the jar test: Left – layers forming, middle – sediment produced, right – well mixed ►

Photo: Nufarm Ltd



If there seems to be a problem after several attempts at the jar test, there may be solutions. The mixing process can be made more robust by:

- **using more water, e.g. the use of almost 100 per cent of the tank volume rather than only 60 per cent as the initial volume of water added to the jar. In the previous example, that would mean to attempt the mix starting with 0.7L in the jar instead of 0.42L;**
- **the use of a more suitable water source could help, e.g. tap or rainwater instead of bore water;**
- **allowing more time for products to disperse before the addition of further products;**
- **using a different brand of the same active ingredient (if available), as a different surfactant system may be used.**

A jar test will provide information on physical compatibility only. It will not provide any information on biological compatibility (possible losses or gains in efficacy).

6 Importance of water volume for mixing

The volume of water that products are added to plays a big role in their ability to dissolve or fully disperse. The more dilute the product is before additional products are added, the greater the likelihood of successful mixing.

In recent years the trend by manufacturers has been to increase the amount of active ingredient grams per litre included in their products. Often this is achieved by modifying or changing the surfactant system. When using a new product, or one with an increased rate of active ingredient, never assume it can be mixed with other products in the same way that similar products have in the past. Often more recently released products, or products with an increased rate of active ingredient, will recommend that the product is mixed into a higher initial volume of water than similar or older versions of the product.

6.1 Care with mixing vats and handling equipment

When using a mixing vat to pre-mix products be aware of the total volume that the vat is able to hold and the amount of product that can be safely added to the vat before transferring it to the spray tank.

Many mixing vats can hold a total volume of about 1000L, whereas the total tank mix volume may be anywhere between 3000L and more than 6000L. When using a mixing vat with a total volume of less than 60 to 80 per cent of the total tank volume, do not attempt to add more than one product at a time into the vat as the total water volume in the vat will usually not be enough to allow for correct mixing.

If the operator wants to pre-mix enough product for an entire load for the spray rig, this should be done in a tank or vessel of equivalent volume to the sprayer's tank size. When using this type of system it may require its own agitation, and will also need a similar decontamination process to the actual spray tank and spray system.



► **Further information on water quality requirements and test procedures can be found in the GRDC Fact sheets ‘[Mixing requirements for spraying operations](#)’ and ‘[Spray water quality](#)’**



Water quality test strips can be used to assess pH and water hardness in the field. ►

Photo: Hach.com

7. Importance of water quality for mixing operations

Water quality can also play a role in the ability of products to fully dissolve, disperse or interact with other products. When using water from a source where the quality is unknown, it is always important to determine the water quality before mixing many products.



In-field tests of basic water-quality parameters such as pH, total hardness and salinity can be done with test strips available from suppliers of swimming-pool products or major hardware stores.

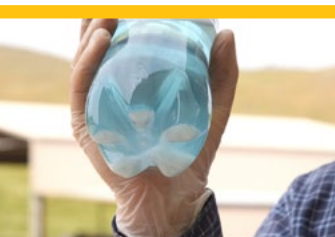
However, other parameters, such as bicarbonate levels, need to be determined by a suitable laboratory test.

Further information on water quality requirements and test procedures can be found in the GRDC Fact Sheets ‘Mixing requirements for spraying operations’ and ‘Spray water quality’.

7.1 Crystalline ammonium sulfate

Crystalline Ammonium sulfate (CAMS) is one of the most commonly used tank-mix additives in Australia and should receive a special mention. Only use CAMS products that are registered as spray adjuvants, and always follow the label instructions.

As a water conditioner CAMS should be added first in the mixing process. While adding a salt into water sounds simple enough, there are some important steps to take to ensure that the tank mix is stable.



Ammonium sulphate

7.1.1 Potential issues with using CAMS

Water temperature Crystalline ammonium sulfate needs to absorb energy to dissolve. The only way it can obtain the energy required is to remove heat from the water (an endothermic reaction), effectively cooling the water down. The temperature drop that occurs will depend on the amount of CAMS added to the water.

When starting to mix CAMS it is important to start with a high water volume in the tank, about 60 per cent of the total tank mix volume. If the total application volume per hectare is only 50L/ha or less, it is a good idea to increase the initial water volume for mixing to 80 per cent of the total tank mix volume. This is particularly important during winter when the water is already cold as the cooling effect of adding CAMS can make the mixing of products to follow more difficult. As a rule of thumb, the warmer the water is, the easier the mixing becomes.

Time to dissolve It is essential that all the CAMS is fully dissolved before other products are introduced into the tank mix, especially when using 2,4-D. Depending upon the quality of the CAMS, water temperature, agitation and concentration of CAMS, it is common for it to take up to 10 minutes to fully dissolve. Often it is not practical to stop the agitation to see if all the CAMS has dissolved in a dark tank filled with an opaque solution water. The best option is to allow 10 minutes after adding the last bag of CAMS before introducing the next product. If water quality is poor it may be a good option to have another tank the same size as the main spray tank to treat all the water to allow time for the interactions to occur before product is added.



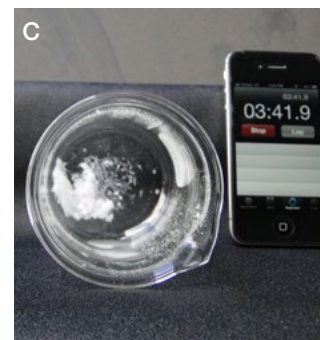
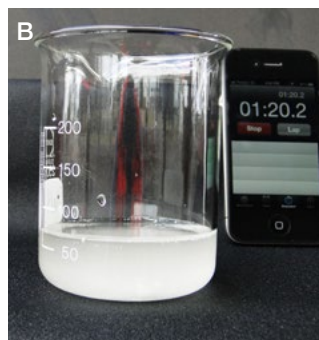
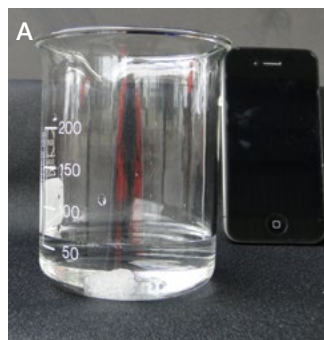
A. When low water volumes are used, or water quality is poor, CAMS may be difficult to dissolve.

B. In less than two minutes, product begins to settle out of the mix.

C. Not allowing the CAMS to fully dissolve before adding a 2,4-D product can cause an incompatibility leading to precipitation in the tank. ►

Photos: Nufarm Ltd

The impact of adding 2,4-D before CAMS has fully dissolved



Product quality. The quality of CAMS batches, even within the same brand, can vary considerably. It is best for the operator to assume that the quality of the batch may be low. Filters should be checked regularly and the mixing time should always be budgeted at 10 minutes per tank.

7.1.2 Potential solutions to issues with CAMS

When suitable conditions for spraying exist, time is at a premium. Many applicators may not want to wait an extra 10 minutes or more to allow CAMS to fully dissolve. There are two ways to avoid the additional time:

- **Use liquid ammonium sulphate, which is already pre-dissolved and has the impurities filtered out. It is a ready-to-go, very user-friendly form of ammonium sulphate that can easily be used through chemical transfer systems. The use rate is 2L/100L rather than one kilogram (kg)/100L. The higher transport weight and the pre-mix service can result in roughly a doubling of the price of CAMS, but it may be a cost-effective solution considering the time saved.**
- **Use a pre-mix vat or tank. CAMS can be pre-mixed and pre-filtered before the tank mix is prepared. CAMS can easily be pre-dissolved at a rate of 500 grams per litre of clean water, even at lower water temperatures. If CAMS is dissolved at this rate, the operator can use 2L of the pre-dissolved product in place of 1kg of the original crystalline form. There are a number of pre-mix vats on the market with very high agitation and excellent flow performance that can help speed up this process. When pre-mixing CAMS it is useful to ensure an in-line filter with a coarse screen is in place to remove any larger particles and impurities.**



TIP

The solubility of a common crystalline ammonium sulfate product registered as a spray adjuvant is stated on the safety data sheet as 754g/L at 20°C in water (of good quality). However, to fully dissolve this amount would take quite a long time.

8. Summary

- **To get the best out of products applied, it is important to plan the mixing operation.**
- **Know what products are going to be mixed. Always consult the product label for information on the mixing and decontamination requirements for each product you intend using.**
- **Use a jar test to check the physical compatibility of the tank mix.**
- **Check water quality and, where required, use water conditioners to help prevent problems on the day when spraying is to take place.**
- **Always finish clean, so you can start clean.**

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS
Module 8 Calibration of the spray system Ensuring accuracy
