AGRITOPIC

August 2021

FERTIGATION

INTRODUCTION

Fertigation is the application of fertilisers dissolved in irrigation water. It provides another means of applying fertiliser nutrients to the soil and can be used to complement or replace application in other ways, i.e. dry application through tractor-drawn equipment. Fertigation is most commonly used in tree crops, and for post-plant application of fertilisers in annual crops. Nutrients that are mobile in the soil, i.e. nitrogen (N), potassium (K), sulfate sulfur (SO_4^{2-}), magnesium (Mg) and boron (B), are most suited to fertigation. Properly designed and operated irrigation systems allow water and nutrients to be placed in the zone of greatest root activity, allowing rapid utilisation by plants.

With the necessary equipment, fertigation is easy and convenient, and can save time, labour, machinery and maintenance costs, and fuel. Soil compaction can also be minimised by reducing the number of passes with wheeled equipment.

Fertigation is particularly suited to those situations where there is a need to split the nutrient usage into a number of applications during the growing season, as it is possible to apply the fertiliser on a more regular basis than is practical where other application methods are used. Under certain conditions, this may allow better recovery and utilisation of applied plant nutrients, particularly where leaching is possible. Soils differ in their ability to hold nutrients, with leaching losses most likely to occur on sandy soils.

Uniform water application is important, through good design and system maintenance, to allow even fertiliser application. So too is accurate irrigation scheduling to minimize over-watering, which may result in nutrient loss and soil acidification.

While leaching is the more common way in which nutrients are lost below the root zone, nutrients may be lost on cracking clays with surface (flood) irrigation systems, if water (and dissolved fertiliser) flows down cracks and continuous large pores (old root paths) in dry soil.

Fertigation can often be performed when other types of application are not possible, such as when aerial application is not possible due to bad weather, or the soil is too wet to carry agricultural equipment. This may necessitate watering just to apply fertiliser but prevents deficiencies from occurring.

With the possible exception of foliar sprays, fertigation is one of the quickest ways to correct an existing nutrient deficiency, particularly for the macronutrients (nitrogen, phosphorus (P), potassium, sulfur (S), calcium, and magnesium) which are required in the largest amounts. Plant foliage can be burnt if the macronutrients are applied at high rates in foliar sprays.

1. PRODUCTS

Incitec Pivot Fertilisers does not market a complete range of fertilisers for use in fertigation programs. The company, however, recognizes that fertigation has an important role to play in balanced fertiliser programs, and has prepared this Agritopic to assist customers in developing their fertiliser programs. This Agritopic focuses on those products in common usage in in Australia.

Fertilisers can be injected into fertiliser lines as suspensions or in solution. These can be prepared on farm by using:

- Microfine suspension grade products (wettable powders, flowables);
- Dry soluble solids;
- Ready prepared Liquids.

Not all fertilisers are soluble in water. The following rules of thumb, to be applied in the order given, are useful in determining the solubility of fertiliser salts in water, although there may be exceptions.

A) All ammonium, nitrate, potassium, sodium and chloride salts are soluble.

B) All oxides, hydroxides and carbonates are insoluble.

C) All sulfates are soluble except for calcium sulfate.

Using these rules for commonly used calcium and magnesium compounds:

- Calcium nitrate is soluble (Rule A);
- Calcium carbonate and magnesium carbonate (lime, dolomite and magnesite) are insoluble (Rule B);
- Magnesium sulfate (Epsom Salts) is soluble but calcium sulfate (gypsum) isn't (Rule C).

These rules are also helpful in determining the compatibility of fertiliser salts in solution, by considering the solubility of any potential reaction products. For example:

- Ammonium sulfate and calcium nitrate are soluble (Rule A).
- Mixed together in solution, the possible reaction products are ammonium nitrate and calcium sulfate.
- Ammonium nitrate is soluble (Rule A), but calcium sulfate is not (Rule C).

If ammonium sulfate and calcium nitrate are dissolved together, calcium sulfate (gypsum) will be precipitated as a sediment in the mixing tank. They are incompatible together in solution.

Dry soluble solids

Many commonly used granular fertilisers are unsuitable for use in fertigation programs, the reasons being:

(i) The fertiliser is insoluble, contains part of its nutrient content in insoluble forms, or has low solubility, e.g. SuPerfect (Single Superphosphate).

(ii) The fertiliser is soluble, but contains insoluble impurities, granulation or coating agents, which may block filters and nozzles. The granular grades of MAP and DAP sold by Incitec Pivot Fertilisers, for example, contain around 15% insolubles, which will be deposited as a sediment on the bottom of mixing tanks. They are intended for dry application to the soil only.

Incitec Pivot Gran-am (granulated ammonium sulfate) contains granulation and coating agents, which may cause a sediment to be precipitated on the bottom of the tank, and a scum to form on the surface of the water in the mixing tank. This may not be a problem when irrigating through equipment with large nozzles, e.g. travelling irrigators, but is likely to cause problems with blockages of filters and nozzles when irrigating through equipment with fine apertures, e.g. micro-jets in drip and trickle irrigation systems.

(iii) Alternative products are available that are either more soluble in water (allowing higher concentrations to be achieved), or dissolve more quickly, e.g. have a finer particle size. For example, potassium chloride (Muriate of Potash), potassium sulfate (Sulfate of Potash) and potassium nitrate (Nitrate of Potash) are all soluble in water, but potassium chloride and potassium nitrate are more soluble, allowing more concentrated potassium solutions to be prepared. Similarly, Solubor is a more soluble source of boron than Borax.

Fine crystalline products will dissolve more quickly, with less agitation, than coarse crystals and granular products. Fine crystalline products, however, will more readily absorb atmospheric moisture, and are prone to setting in storage. With some fertilisers, it is better to market them as prills than as fine powders. Granular grades of urea, while chemically identical to prills, dissolve more slowly as the granules are harder and larger.

A fine particle size does not mean that more concentrated solutions can be prepared, it simply allows the product to dissolve more quickly.

Many fertiliser salts are available as “Soluble Solid” or “Solution Grade” fertilisers. With some products, the price differential between these and granular fertilisers, which are applied dry to the soil, is not that great. Soluble fine P fertilisers, such as MAP, cost appreciably more than the granular grades.

Solutions

Solutions are prepared by dissolving soluble solids in water. Many fertilisers are available as both Soluble Solids and as ready prepared Solutions. The latter are convenient to use, avoiding the need to dissolve solid fertilisers on farm. Solutions can be added mixed with other fertilisers, by pouring them into the mixing tank, or injected directly into the irrigation line.

Urea Ammonium Nitrate (UAN) solution is the most commonly used fertiliser solution in fertigation programs. It is a concentrated solution of urea and ammonium nitrate. Concentrations vary, with that used in Australia containing 42.5% N w/v. UAN has a specific gravity of 1.32, and contains 32% N w/w. While it is a liquid, water only makes up about 20% of its weight.

Suspensions

Insoluble products such as calcium carbonate (lime) cannot be dissolved in water, but if ground to a fine particle size, can be suspended in water. Microfine powders and liquid suspensions are available for use in fertigation programs, e.g. Liquid Lime.

2. ANALYSES

The analyses of commonly used Soluble Solids are shown in the table below.

Typical Analyses and Water Solubility of Commonly Used Soluble Solid Fertilisers

Product and Chemical Name	Formula	Analysis					Solubility
		% N	% P	% K	% S	Other	kg/100 L at 20^{o} C
Urea	$CO(NH_2)_2$	46	-	-	-	-	105
Ammonium nitrate	NH_4NO_3	34	-	-	-	-	192
Sulfate of Ammonia (Ammonium sulfate)	$(NH_4)_2SO_4$	21	-	-	24	-	75
Technical grade MAP (Monoammonium phosphate)	$NH_4H_2PO_4$	12	26	-	-	-	37
MKP (Monopotassium phosphate)	KH_2PO_4		22.5	28			23
Muriate of Potash (Potassium chloride)	KCl	-	-	51	-	-	34
Potassium nitrate	KNO_3	13	-	38.3	-	-	32

Sulfate of Potash (Potassium sulfate)	K_2SO_4	-	-	41.5	16.5	-	11
Calcium nitrate *	$Ca(NO_3)_2.4H_2O$	12	-	-	-	17% Ca	129
Epsom Salts (Magnesium sulfate)	$Mg SO_4.7H_2O$	-	-	-	12.4	9.6% Mg	71

***** This calcium salt is not used as a fertiliser.

Yaraliva® Calcinit, a commercial calcium nitrate fertiliser, has the formula $5Ca(NO_3)_2 \cdot NH_4NO_3 \cdot 10H_2O$, and a solubility of 250 kg/100 L at 20^0C. It contains 15.5% N and 19% Ca.

The analyses and the Specific Gravity of some commonly used liquid fertilisers are shown below.

Typical Analyses and Specific Gravity of Commonly Used Liquid Fertilisers

Product	Chemical Name	Specific Gravity	Analysis (w/v)			
			% N	*% P*	*% K*	*% S*
UAN	Urea Ammonium Nitrate	1.32	*42.5*			
APP	Ammonium Polyphosphate	1.4	*14*	*21*		
KTS	Potassium Thiosulfate	1.47			*30*	*25*
ATS	Ammonium Thiosulfate	1.33	*16*			*34*

3. SOLUBILITY

The maximum solubility of a fertiliser in water, while temperature dependent, is a physical constant. Good agitation and a fine particle size will allow a fertiliser to dissolve more quickly, but they do not alter the outcome.

As a fertiliser solution becomes more concentrated, it becomes increasingly difficult to dissolve more fertiliser. Once the fertiliser solution is saturated, no more fertiliser can be dissolved, no matter how much agitation is applied. As a guide, no more than 50% of the maximum should be used when preparing fertiliser solutions on farm for fertigation (injection into irrigation lines). Higher concentrations than this can be achieved, but a lot more effort (agitation and time) is required.

Some fertilisers are endothermic. When dissolved in water, they cause the temperature of the solution to fall. This makes it harder to dissolve the fertiliser as solubility is reduced in cold water. An example is Urea. Nitrate fertilisers are also endothermic, e.g. ammonium nitrate, potassium nitrate and calcium nitrate. When preparing fertiliser solutions with any of these products, a lower practical limit, e.g. 25% of the maximum, is suggested.

Urea will dissolve in its own weight of water, i.e. 100 kg in 100 L, with good agitation and heating. In practice, 25% urea solutions should be prepared on farm, e.g. 50 kg urea to a 200 L or 44 gallon drum.

The following table can be used as a guide to on-farm practical limits in the preparation of fertiliser solutions. The figures may vary from those quoted in other publications but are representative of what can be achieved.

Guidelines to the Practical Solubility of Solid Fertilisers in Water

Product	**Solubility (kg/100 L @ 20^{0}C)**		
	Maximum – for a saturated solution	**Practical Solubility**	
		(50% of maximum)	(25% of maximum)
Urea	105	-	**26**
Ammonium nitrate	192		**48**
Ammonium sulfate	75	**38**	-
Tech grade MAP	37	**19**	-
MKP	23	**12**	-
Muriate of Potash	34	**17**	-
Potassium nitrate	32	-	**8**
Sulfate of Potash	11	**6**	-
Yaraliva® Calcinit	250	-	**63**

Water quality and the presence of other fertilisers in the solution may affect fertiliser solubility. It is often reduced when two or more fertilisers are dissolved together. An exception is urea and ammonium nitrate, which have enhanced solubility when mixed together in solution, a key to the manufacture of concentrated Urea Ammonium Nitrate (UAN) solutions. Likewise, the inclusion of ammonium nitrate with calcium nitrate in Yaraliva® Calcinit enhances the solubility of the calcium nitrate.

4. COMPATIBILITY

When preparing fertiliser solutions containing two or more different fertiliser salts for injection into irrigation lines, it is possible that precipitate (sediment) may form. This occurs if reaction products form which are either insoluble or less soluble than the original products. The resultant precipitate may settle to the bottom of the mixing tank, or block filters and emitters. Hence some products should not be mixed together.

Urea, ammonium nitrate, potassium chloride (Muriate of Potash) and potassium nitrate are compatible in solution with one another, and most other fertilisers. Reaction products may form when phosphorus, sulfur, calcium and magnesium and trace element fertilisers are used in solution. The sediment usually forms immediately, and without agitation settles to the bottom of the mixing tank.

Suspended sediment may block filters and nozzles, particularly in drip and trickle irrigation systems, and under-tree sprinklers. Blockages result in inefficient application of water and nutrients and consume time. For example, calcium sulfate (gypsum) will be precipitated when calcium nitrate is mixed with products such as ammonium sulfate, potassium sulfate, potassium thiosulfate (KTS) and magnesium sulfate.

When some fertilisers are mixed together in solution at high concentrations, less soluble reaction products may form, and be precipitated. Examples are:

- Potassium sulfate (which has a solubility of 11 kg/100 L at 20^{O}C, may form if potassium nitrate (32 kg/100 L) is mixed with ammonium sulfate (75 kg/100 L. This contrasts strongly with the other reaction product, ammonium nitrate, which has a solubility in water of 192 kg/100 L) at 20^{O}C.

- Potassium nitrate crystals may form if undiluted Urea Ammonium Nitrate (UAN) and potassium thiosulfate (KTS) are mixed together.

In these cases, the precipitate can be dissolved by adding water to the spray tank, and agitation. The precipitate will only form in concentrated solutions in the mixing tank. It will not occur after the fertiliser solution has been injected into the irrigation line, as by this stage, the fertiliser solution is greatly diluted in the irrigation water.

In the absence of specific compatibility information from suppliers, the following tables may be of assistance in determining which products can be mixed together in the one tank.

Compatibility Chart for Commonly Used Solid Fertilisers in Solution

Ingredient	Urea	Ammonium Nitrate	Ammonium Sulfate	MAP & MKP	Potassium Chloride	Potassium Nitrate	Potassium Sulfate	Calcium Nitrate	Magnesium Sulfate
Urea	**OOO**	✓	✓	✓	✓	✓	✓	✓	✓
Ammonium Nitrate	✓	**OOO**	✓	✓	✓	✓	✓	✓	✓
Ammonium Sulfate	✓	✓	**OOO**	✓	**P**	**P**	✓	**X**	✓
MAP & MKP	✓	✓	✓	**OOO**	✓	✓	✓	**X**	**X**
Potassium Chloride	✓	✓	**P**	✓	**OOO**	✓	✓	✓	✓
Potassium Nitrate	✓	✓	**P**	✓	✓	**OOO**	✓	✓	**P**
Potassium Sulfate	✓	✓	✓	✓	✓	✓	**OOO**	**X**	✓
Calcium Nitrate	✓	✓	**X**	**X**	✓	✓	**X**	**OOO**	**X**
Magnesium Sulfate	✓	✓	✓	**X**	✓	**P**	✓	**X**	**OOO**

✓ Compatible **X** Incompatible **P** Precipitate may form in concentrated solutions
NR Not Recommended

Compatibility Guide for Commonly Used Solutions

Product	**UAN**	**APP**	**KTS**	**ATS**
UAN	000	✓	**D**	✓
APP	✓	000	✓	✓
KTS	**D**	✓	000	✓
ATS	✓	✓	✓	000

✓ Compatible.

D Dilute the KTS in an equal amount of water before adding UAN. If this is not done, potassium nitrate crystal will form in the mixture. Should this occur, the potassium nitrate crystals can be re-dissolved by adding more water to the solution.

5. OPTIONS FOR APPLYING NON-COMPATIBLE PRODUCTS

Where there is a need to apply fertilisers that are incompatible, options include:

1. Apply the fertilisers at different times, e.g. alternate between the products each time the crop is irrigated;

2. Use two mixing tanks and injectors. Precipitate is less likely to form in the irrigation lines than in the mixing tanks, as the nutrient concentration is greatly diluted, and there is less time for reactions to occur. Precipitate which does form is unlikely to settle (as can happen in mixing tanks) as it will be kept in suspension by water movement in the lines.

6. WATER QUALITY

Phosphorus, sulfur, calcium and magnesium and trace element fertilisers may be affected by water quality. Precipitate may form if the water is hard (high in calcium and magnesium), alkaline (high pH) or contains carbonate. Calcium and magnesium fertilisers themselves make the water harder. The precipitate that forms may cause blockages or contribute to scale formation. Scale may shorten the life of equipment, which is costly to replace.

Where precipitate or scale is likely to form, fertiliser solutions should be prepared immediately prior to use. Do not allow the solution to stand for an extended period, e.g. overnight, as this increases the risk or amount of precipitation, and the settling of sediment in the bottom of mixing tanks. Alternative application methods may need to be used.

NOTE: Nutrient-enriched irrigation water may also result in increased microbial activity, causing blockages in irrigation lines and emitters in trickle irrigation systems.

7. MIXING

When preparing fertiliser solutions, fill the mixing tank with water to near capacity, leaving space for the added fertiliser, which should then be added slowly while agitating. Fertilisers should not be pre-mixed in a small amount of water before being added to the tank. This makes it harder to dissolve the fertiliser. The lower the concentration, the easier it is to dissolve fertiliser, the reason the fertiliser should be added directly to the mixing tank. Fertiliser solutions should be prepared just prior to use, and not allowed to stand for an extended period, to minimise sediment formation and settling in tanks.

8. DETERMINING FERTILISER REQUIREMENTS

Fertigation is convenient, allows crops to be spoon-fed during the growing season, and in crops such as strawberry grown under plastic, is the only practical way of fertilising the crop after planting. Fertigation may result in increased crop yields and quality, and improved recovery of nutrients such as nitrogen and potassium.

Soils vary in their fertility, and crops in their nutrient requirements. While there are many essential plant nutrients, these do not all have to be applied in fertiliser programs. Local district and crop advice should be sought on fertiliser requirements. In many situations, there is no need to change overall fertiliser application rates where fertigation is used. Fertigation simply provides an alternative to applying fertilisers dry to the soil.

If, as a result of improved irrigation and management practices, crop yields are increased, extra nutrient will be required to sustain the higher level of production. On the other hand, if the adoption of fertigation practices allows nutrient recovery by crops to be enhanced, and losses, e.g. leaching and denitrification, are minimised, it may be possible to reduce fertiliser rates.

Soil and plant tissue analysis can be used to monitor changes in soil fertility and plant nutrient status, with adjustments being made to fertiliser programs where necessary. Soil sampling methods developed for situations where fertilisers are applied in other ways may not be appropriate where fertigation and under-tree sprinklers, drip or trickle irrigation systems are used. Soil fertility in the wetted soil around the emitters will change with time. It will be in this soil that plant roots proliferate, in their search for moisture and nutrients. It may be wise to take soil samples from the same area. However, the critical values will be different (higher) than those developed where other fertiliser practices have been used. Existing interpretation data may not be applicable, but soil analysis can be used to monitor changes in soil fertility over time.

Plant tissue analysis, e.g. of leaves, petioles or sap, can play a vital role. It allows the crop's nutrient status to be monitored regularly, so that adjustments can be made to nutrient application rates, particularly nitrogen and potassium. In annual crops, soil analysis can be used to determine if there is a need for pre-plant soil amendments, e.g. lime and planting fertiliser requirements. Thereafter, plant tissue tests can be used to fine-tune the fertigation program.

9. SALT ACCUMULATION

Soluble salts will move with water in the soil and can accumulate at the edge of the wetting front. These salts may be present in the irrigation water, be added to the water for fertigation purposes, or be picked up from the soil, including residual fertiliser from past applications.

With drip and trickle irrigation systems, and under-tree sprinklers, these salts can accumulate at the perimeter of the wetted area. In furrow irrigated row crops, some of the dissolved salts will move upwards into the hill. Should these salts accumulate in areas where crop roots are growing, or seeds or seedlings are to be planted, or be moved into such areas by subsequent irrigation, rainfall or cultivation, crop damage may occur.

10. APPLICATION TIPS

Observe the principles listed below, many with the objective of preventing contamination of the water source or nearby streams. High nitrate levels in drinking water, for example, can be detrimental to humans, livestock and wildlife; while contamination of surface waters with fertilisers, particularly those containing nitrogen and phosphorus, may cause weed growth and algal blooms.

(i) Maintain a neat storage, mixing and injection area. This promotes safe handling and facilitates early recognition and clean-up of any spills and leaks.

(ii) Prevent drainage from the mixing area into streams, dams or bores.

(iii) Prevent back-flow from the irrigation lines into the water supply. This is more likely to occur where suction systems, on the inlet side of the pump, are used to introduce fertiliser solutions.

(iv) Where flood irrigation systems are used, contain and re-use tail water on-farm. If this cannot be done, allow excess water to re-enter reticulated water supplies for use on other irrigated farms where the same crops are grown. Livestock should be denied access to tail-water, to avoid any risk of urea or nitrate poisoning. This is also important for other reasons, e.g. it is particularly important if pesticides have been used for which a nil MRL (Maximum Residue Level) applies to livestock products, e.g. various insecticides in meat. Do not allow tail water to escape to watercourses and enter streams.

(v) Prepare fertiliser solutions as close as possible to the time of use. Do not allow to stand for an extended period, e.g. overnight. This can help minimise precipitation and settling in mixing tanks in some instances.

(vi) Inject fertiliser solutions upstream of filters, so that insoluble contaminants are screened out.

(vii) Acid and chlorine may be required in drip and trickle irrigation systems to prevent scale formation and clean out lines. Seek information from the suppliers of these products on their use.

(viii) Always add acid to water, never water to acid.

(ix) Inject acids downstream of filters, to prevent damage to the filter.

(x) Flush injectors and lines after use, to minimise corrosion and scale formation, and extend the life of gaskets.

(xi) Avoid injection into empty lines.

(xii) With travelling irrigation systems, the fertiliser solution must be injected continuously at a constant rate (and concentration).

This also applies to furrow and flood irrigation systems. It is sometimes recommended that fertigation be delayed until the water has advanced half way down the furrow. This makes application more complex, and is unnecessary, provided a good distribution uniformly is achieved. Tail-water can be blended with head-water and re-used.

With fixed line systems, inject during the middle half of the shift, i.e. use the first quarter to ensure the system is operating properly, the last quarter to flush the system. Where leaching is likely, e.g. in sandy soils in areas of high rainfall, it is often advocated that fertilisers containing nitrate and other mobile nutrients be introduced late in the shift

(xiii) Where fixed line overhead sprinkler irrigation systems are used, and the foliage is wetted by the irrigation water inject the fertiliser solution over as long as period as possible so as to dilute the concentration. Do not inject the fertiliser solution from the start, i.e. make sure the foliage is properly wetted first; or at the end so that as much of the fertiliser solution as possible is washed from the leaves.

(xiv) Solutions containing chloride and ammonium are among those most likely to burn plant foliage, the latter more so if the water is alkaline.

(xv) Crops vary in their tolerance of fertiliser solutions, those most likely to show foliar burn include sunflower, tobacco, beans, strawberry and carrot.

11. CARE OF EQUIPMENT

Fertilisers can be applied through most irrigation systems, e.g. flood, furrow, sprinkler, drip and trickle systems, and through fixed line and travelling systems. With travelling systems, the fertiliser solution needs to be injected continuously at a controlled rate.

Fertiliser solutions can be introduced into irrigation water in various ways, including gravity feed systems near head ditches for flood and furrow irrigation, suction devices on the inlet side of centrifugal pumps, pressure differential (venturi) systems on the outlet side of pumps, or high pressure injectors, which introduce the solution into the main at a higher pressure than that present in the spray-line.

Specialist advice should be sought from the suppliers of irrigation equipment in choosing and setting up a fertigation system. Fertilisers are corrosive. Mixing tanks should therefore be made of polypropylene, fibre-glass or stainless steel. Avoid the use of mild steel. Plastic fittings (nylon or polypropylene) are adequate for fertilisers, but if agricultural chemicals are to be injected as well (not a common practice in Australia), stainless steel is recommended.

Copper and copper alloys (brass) can be corroded by fertilisers, e.g. nitrate solutions. As electric motors contain copper wiring, and internal combustion engines use copper fuel lines, these should be protected from irrigation spray, e.g. from centre pivots. Fertigation injectors should be flushed after use, to prevent scale forming, and extend the life of gaskets and metals.

12. NUTRIENT APPLICATION

Nitrogen

Nitrogen fertilisers are commonly applied through fertigation systems. Fertigation allows nitrogen supply to be matched with plant demand. Plants take up nitrogen continuously throughout the growing season. If too much nitrogen is applied at any one time (as is possible with other application methods), excess vegetative growth may occur. In some crops, this may affect harvested yield and/or quality.

Fertigation also reduces the potential for nitrogen to be lost through leaching or denitrification, as there is no need to apply more fertiliser than is necessary to meet the immediate plant requirements. Fertiliser use efficiency may be improved. On some farms, it may be possible to reduce nitrogen application rates due to the improved utilisation of applied fertiliser nutrients.

Anhydrous Ammonia (82% N)

Some use is made of anhydrous ammonia (Incitec Pivot Big N) in surface (flood) irrigation systems, e.g. furrow irrigated cotton crops, though there are limits to the length of the rows (maximum of 600 metres) in which it may be used, as ammonium may be stripped from the irrigation water by clay particles in the furrow. Anhydrous Ammonia is not suitable for use through sprinkler irrigation systems, as ammonia will be lost through volatilization from the water droplets. Ammonia solutions are corrosive, and alkaline. The high pH can cause carbonate and bicarbonate to precipitate, which may block nozzles or cause scale to form on the inside of pipes and fittings if anhydrous ammonia were to be used through reticulated (piped) systems.

Urea (46% N)

Economically priced, and the most commonly used nitrogen fertiliser in fertigation programs. The normal grades of urea can be used in fertigation programs. There is no need to use a low biuret grade, which is used in foliar sprays. A small particle size, e.g. prills, allows the product to dissolve more quickly, though granular grades of urea may be used. Granules require more agitation and take longer to dissolve, on account of the larger particle size. Urea is a non-ionic compound and is compatible in solution with virtually all other fertilisers. Urea is less likely to burn foliage if leaves are wetted where overhead sprinkler irrigation systems are used than other commonly used nitrogen fertilisers.

Urea Ammonium Nitrate (UAN) (42.5% N w/v)

A ready to use solution of urea and ammonium nitrate. Together, these products have greater solubility in water than either product on its own, allowing a concentrated 42.5% N w/v (32% N w/w) solution to be prepared. Like urea and ammonium nitrate, UAN has wide compatibility with other fertilisers.

Ammonium Nitrate (34% N)

Little use is made of straight ammonium nitrate fertilisers nowadays in Australian agriculture. It is a more costly source of N that urea, and is classified as a Dangerous Good and as being Security Sensitive. Ammonium nitrate can only be supplied to licensed users. Incitec Pivot Fertilisers does not market a straight ammonium nitrate fertiliser.

Incitec Pivot Cal-Am cannot be used in fertigation programs. Cal-Am is comprised of 80% ammonium nitrate and 20% calcium carbonate, which is insoluble.

Calcium Nitrate

While more commonly thought of and used as a calcium fertiliser, calcium nitrate may also be used as a non-acidifying nitrogen fertiliser in high value horticultural crops where other N fertilisers such as urea or UAN may cause soil acidification around drip and trickle irrigation emitters and under-tree sprinklers. Its cost precludes the use of calcium nitrate as a N fertiliser in broad-acre crops.

Notes

Nitrogen fertilisers such as urea and ammonium nitrate, and fertilisers in which they are used (UAN), have an acidifying effect on the soil. In annual crops and pasture, this can be addressed using broadcast applications of lime. In perennial crops where underground drip and trickle irrigation systems, or under tree sprinklers are used, soil acidification will be most evident around the emitters, and is best addressed through the irrigation lines. Non-acidifying fertilisers, e.g. calcium nitrate, may be used in place of urea and ammonium nitrate, or alternatively suspension grade microfine liming materials, e.g. Liquid Lime, may be applied through the irrigation water. This is discussed in more detail under “Calcium” in Section 12.5.

Caution may be required where fertilisers containing ammonium nitrogen are applied through sprinkler irrigation systems, particularly where the pH of the irrigation water (either inherently or as a result of adding alkaline fertiliser) is high. While not a common occurrence, ammonia gas may form in water droplets remaining on the leaves, particularly if the pH is above 7.0. This may result in foliar burn as free ammonia is toxic at low concentrations to plant tissue.

Urea may also be converted to ammonium in irrigation water in which the enzyme urease is present. This is least likely to occur where the water is sourced from underground, and most likely to occur where surface water is used, i.e. from dams and streams, particularly if the water contains algae and has high microbial activity. The conversion of urea to ammonium can be limited by preparing urea solutions for irrigation immediately prior to use.

Phosphorus

Granular phosphorus fertilisers, e.g. Incitec Pivot DAP, MAP and SuPerfect, are not suitable for use in fertigation programs. These products are only intended for dry application to the soil.

Soluble Fine (Solution) grades of monoammonium phosphate (MAP) and monopotassium phosphate (MKP) may be used, or solutions such as ammonium polyphosphate (APP) and Phosphoric Acid to supply phosphorus.

Little use is made of phosphorus in fertigation systems in **annual** crops. Phosphorus is mostly taken up early in the life of a crop and is important in stimulating root growth and early plant development. Hence, in annual crops, phosphorus is best applied with or near the seed at planting, or along the position of the intended crop row, and then incorporated into the soil. Fertigating with phosphorus after planting, unless it is done for supplementary purposes, is too late. Furthermore, unless underground irrigation emitters are used, phosphorus applied during the growing season through overhead irrigation systems will remain close to the soil surface, and not reach the zone of major root growth. Unlike nitrogen, phosphorus does not move far from the site of application.

In **perennial** crops, e.g. orchards and vineyards, where other nutrients, e.g. nitrogen and potassium, are being applied through fertigation, it can be convenient to apply phosphorus in the same way. This can be done once a year, e.g. in the spring at the start of the main growing season, or split into smaller doses. Phosphorus does not need to be applied on each occasion that nitrogen and potassium are applied, allowing other fertilisers with which phosphorus fertilisers may be incompatible to be applied at separate times.

Where crops such as strawberry are grown with a **plastic mulch/sheeting**, fertigation allows additional phosphorus (and other nutrients) to be applied to the soil after planting. Phosphorus is necessary to replace that removed in harvested fruit, and that not being returned to the soil in leaf fall and litter. Normal dry application methods to the soil are not possible under these conditions, leaving the choice of how nutrients are applied after planting to fertigation and foliar sprays.

<u>Notes</u>

Of the soluble solids, MAP is used where there is no need for fertiliser potassium. Either MAP or MKP may be used if potassium is required, with the balance of the potassium requirement being applied in another form. Plants take up a lot more nitrogen and potassium and phosphorus.

MAP and MKP are incompatible in solution with calcium and magnesium fertilisers and metallic salts, e.g. zinc sulfate. In hard water, phosphate ions may combine with calcium and magnesium, causing scale to form in irrigation equipment and lines, and block filters.

Potassium

Like nitrogen, potassium is particularly suited to fertigation. It is taken up in large quantities (second to nitrogen), and is particularly important late in the growing season in fruit and flower formation, and boll-filling in cotton. In various horticultural crops, fertigation allows nitrogen and potassium application rates to be manipulated during the growing season, with the amount of potassium relative to that of nitrogen (K:N) being increased late in the growing season.

Potassium is subject to fixation in certain soils and leaching in sandy soils. Some soils cannot supply potassium fast enough to meet crop demands during periods of rapid growth. Crop utilisation of applied nutrients and produce quality are often enhanced where potassium is applied through fertigation.

There are three commonly used solid potassium fertilisers.

<u>Potassium chloride (Muriate of Potash)</u>

The most commonly used, because it costs less. There are, however, situations where the application of chloride (Cl^-) should be avoided, e.g. in crops where chloride affects the quality of farm produce, or where the soil and/or irrigation water is high in chloride.

<u>Potassium sulfate (Sulfate of Potash)</u>

Can be used instead of potassium chloride where there is a need to avoid chloride, but is considerably less soluble than potassium chloride or potassium nitrate. Potassium sulfate is incompatible with calcium nitrate in solution.

<u>Potassium nitrate (Nitrate of Potash)</u>

Can also be used in place of potassium sulfate where chloride is detrimental, and there is a need to choose a more soluble product than potassium sulfate. Potassium nitrate is popular for late season application in vegetable and fruit crops, when there is a need to increase the potassium and reduce the nitrogen rate. Potassium nitrate causes the temperature of the solution to fall when dissolved in water. The nitrogen in potassium nitrate is non-acidifying to the soil.

Potassium may also be applied as potassium thiosulfate (KTS), a solution containing 30% K and 25% S w/v.

<u>Notes</u>

The solubility of the three potassium salts discussed above in water is shown in the table below.

Solubility (kg/100 L) of Potassium Salts at Various Temperatures

Product	10^0C	20^0C	30^0C
Potassium chloride	31	34	37
Potassium sulfate	9	11	13
Potassium nitrate	21	32	45

The solubility of all three products is not that high, when compared to many other fertilisers. Urea, for example, will dissolve in its own weight of water. This means that when preparing concentrated solutions, it is the solubility of the potassium that often limits the overall concentrations that may be used. To overcome this, potassium suspensions are used overseas, where suspension fertilisers are prepared locally and used quickly, before they have a chance to settle. This rules out their importation into and use in Australia.

Sulfur

Like nitrogen, sulfur is an important constituent of protein, but sulfur is only required in about one-tenth of the amount and is less commonly limiting. If there is a need to apply sulfur, this can be achieved by using one of the following products in the fertigation program:

- Ammonium Sulfate (Sulfate of Ammonia)
- Ammonium Thiosulfate (ATS)

Notes

Potassium sulfate also contains sulfur, but it would not normally be used as a source of sulfur, unless potassium was also required, and there was a need to avoid the use of potassium chloride. Some irrigation waters contain sufficient S to adequately meet crop and pasture demands.

Calcium (Ca)

Calcium and its compounds are important for two reasons, firstly as a nutrient, and secondly as soil ameliorants, i.e. to improve soil structure, or raise the soil pH (correct acidity). Much higher rates are required for soil amelioration, generally in terms of tonnes per hectare, than as a nutrient (kg/ha).

Calcium – the Plant Nutrient

Calcium is required for healthy root growth and strong cell walls, e.g. for firm fruit. Symptoms of deficiency include blossom-end rot in tomatoes.

Calcium is immobile in plants, i.e. it is not readily relocated from old to young plant tissue. Plants are therefore dependent on a continuous supply of calcium. Anything that interferes with root uptake of calcium and its translocation within plants may result in calcium deficiency. This includes hot and dry weather. Fruit and vegetable crops are more likely to show symptoms of calcium deficiency if the crop become moisture-stressed, even in soils with a good calcium content. Proper watering is essential.

Fertigation is an effective way of supplying calcium in a soluble form that is readily available for plant uptake, e.g. as calcium nitrate, in horticultural crops that are susceptible to calcium deficiency. Applying calcium this way on a regular basis during critical growth stages can help prevent or reduce the incidence of calcium deficiency in fruit and storage organs, e.g. stems, roots and tubers.

Fertigation with calcium nitrate is most effective when applied through drip and trickle irrigation systems, or under tree sprinklers. This positions the calcium where the bulk of the crop roots are to be found.

Placing the calcium into wetted soil where the roots are most active maximises utilisation and uptake. This is much more effective than applying calcium nitrate through irrigation systems that wet all the soil, e.g. flood and overhead sprinkler systems, or applying calcium fertilisers dry to the soil. The latter is likely to be ineffective.

As calcium is quite immobile in plants and is not readily relocated from old to young tissue, calcium nitrate will need to be applied weekly, and possibly twice per week. Suggested application rates are:

- For trickle irrigation in **tomatoes** in warm weather when and where blossom-end rot may be a problem, apply calcium nitrate at 65 kg/ha once a week, or at 30 kg/ha twice a week from first fruit set onwards.

- In other **vegetable crops**, a suggested application rate is 20 - 50 kg/ha per week for the first three to four weeks after transplanting for leaf vegetables, from the on-set of flowering for fruit, and after tuber initiation in potatoes.

The rate at which any other nitrogen fertiliser is applied should be adjusted, taking into consideration how much nitrogen is applied as calcium nitrate, so as to apply the correct rate of nitrogen.

<u>Calcium – Its Role in Correcting Soil Acidification</u>

Many fertilisers can contribute to soil acidification, particularly when applied at high rates, e.g. nitrogen fertilisers such as urea and UAN. Where these fertilisers are applied to a restricted area or volume of soil, e.g. through drip and trickle irrigation systems or under-tree sprinklers, this soil may acidify at a faster rate than the surrounding areas.

One method of managing localized soil acidification around irrigation emitters is to apply all the nitrogen in the nitrate form, e.g. as calcium nitrate. When used as a non-acidifying nitrogen fertiliser, the rate at which calcium nitrate is applied will be dictated by the nitrogen requirements of the crop, rather than the rates detailed above for use as a calcium fertiliser.

Yaraliva® Calcinit, a commercial calcium nitrate product, contains 15.5% N, so it needs to be applied at three times the rate of urea, when used as a nitrogen fertiliser. Potassium nitrate is another product that does not acidy the soil. It contains 13% N and 38.3% K. Potassium nitrate is used as a potassium fertiliser. Where used, the amount of nitrogen applied in other forms can be reduced accordingly.

Liming materials might also be directed at the same volume of soil through the irrigation water but suffer from the disadvantage of being insoluble. Pulverised lime, the grade of lime most commonly used in Australia, can be applied dry to the soil, but is unsuitable for fertigation, as it is almost insoluble (1 – 2 g/100 L). Lime requires further processing before it can be used in fertigation systems. Superfine lime products that remain in suspension are available for this purpose.

Other alternatives are burnt lime and hydrated (or slaked) lime. Burnt lime (calcium oxide) is obtained by heating ordinary pulverised lime (calcium carbonate). Burnt lime is caustic and must be handled with care. Slaked lime or calcium hydroxide is obtained by allowing burnt lime to hydrate (absorb water). While both these products are more soluble than pulverised lime, they are best described as sparingly soluble (about 100 – 200 g/100 L).

Calcium sulfate (gypsum), which is sparingly soluble (around 250 g/100 L), does not correct soil acidity.

Notes

Calcium nitrate is incompatible in solution with phosphates, e.g. MAP and MKP, sulfates, e.g. potassium sulfate, magnesium sulfate, zinc sulfate; and boron (B).

Foliar sprays may also be used to apply calcium in horticultural crops at critical growth stages.

Magnesium (Mg)

Soluble magnesium salts include magnesium nitrate and magnesium sulfate (Epsom Salts). These products are incompatible in solution with phosphates, e.g. MAP and MKP, calcium nitrate and Solubor.

Fertigation is a convenient way to apply supplementary magnesium during the growing season in high value horticultural crops. On calcareous soils, fertigation may be the most effective way to apply magnesium to the soil, targeting it in a readily available soluble form where roots are actively foraging, through drip and trickle irrigation systems and under tree sprinklers. The suggested rate for magnesium sulfate in fertigation programs is 25 - 30 kg/ha per application. Three or more applications may be required at fortnightly intervals during peak growth periods.

Fertigating with magnesium sulfate avoids the risk of leaf burn from foliar sprays.

Boron

Commonly used boron fertilisers are Solubor (20.5% B) and Boric Acid (16.5 – 17.5% B).

Boron behaves similarly to nitrate-nitrogen in the soil, in that it is very mobile. Like nitrogen, boron can burn plant roots if applied at high rates and/or to a small area or volume of soil. Therefore, it is best to split the seasonal or crop requirements into a number of applications during the growing season (typically less than 0.5 kg/ha/application of Solubor).

Details on annual or seasonal boron requirements can be found in the Boron Agritopic. Care should be exercised to ensure that recommended rates for the crop are not exceeded, as boron toxicity is easily induced.

Once taken up by the plant and incorporated into plant tissue, boron is immobile. It is not readily relocated from old leaves to the growing points. In this respect it is similar to calicum. Regular applications of boron help ensure a continuous supply of boron is available for plant growth, and help minimise leaching losses on sandy soils.

Fertigation with boron is only recommended where at least 50% of the soil is wetted to reduce the risk of toxicity. Do not fertigate with boron in:

- crops that are sensitive to boron toxicity,
- tree or vine crops with dripper irrigation systems,
- tree crops with poor water distribution from under-tree sprinklers,
- tree crops with sprinklers situated close to the butts of the trees.

Fertigation with boron is safe through overhead sprinkler and flood irrigation systems. Boron is incompatible in solution with calcium, magnesium, and metallic salts, e.g. zinc sulfate.

Copper (Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn)

The metallic trace elements are available in various forms.

<u>Oxides</u>

Oxides are insoluble in water, and therefore unsuitable for fertigation, unless micro-fine suspension grade products are used.

<u>Sulfates</u>

Sulfates are water soluble. Soluble fine grades should be used. The granular zinc sulfate monohydrate product marketed by Incitec Pivot Fertilisers is intended for dry application to the soil and is not recommended for use in solution.

Chelates

Chelates are organic compounds that form a claw-like ring around metal ions such as zinc. When applied to the soil, the chelate protects the metallic ion in the soil, delaying the formation of insoluble compounds. Plant roots are able to absorb the trace element directly from the chelate. The chelates have wider compatibility in solution than the sulfates. Chelates are typically several times more expensive than other forms of trace elements.

Metallic trace elements may be applied through fertigation systems under certain circumstances, but are not commonly used, as other application methods are likely to be more effective. In contrast to boron, the metallic trace elements are immobile in the soil. If surface-applied, e.g. through sprinkler irrigation systems, they will be slow to move into the soil, particularly if it has a high clay content. Chelates may possibly move further into the soil than the sulfates.

Hence, fertigation during the growing season in short season annual crops will be a relatively ineffective way to apply these nutrients, unless the emitters are buried in the crop row, as the nutrients will not reach the area where the bulk of the crop's roots are feeding. Fertigation is likely to be more successful in perennial crops, e.g. where tree roots are feeding close to the soil surface, or sub-surface emitters are used.

The effectiveness of soil applications of these nutrients (including fertigation) varies. **Iron** and **Manganese** are amongst the most abundant elements in soils. A deficiency of either is rarely a result of there being inadequate amounts of the nutrient in the soil, but because that present is in forms which plants cannot utilise. The same fate will await Fe and Mn applied to the soil, it will be rapidly converted to plant - unavailable forms. For this reason, it is generally better to apply iron and manganese as foliar sprays, where practical, than to apply them to the soil.

If iron and manganese are applied to the soil, regular applications are likely to be required, and it will be best if these are applied through systems in which the volume of wetted soil is restricted, e.g. drip and trickle systems, and under tree sprinklers, to reduce fixation losses in the soil.

With **Copper** and **Zinc**, there is no need for split applications. A single application can remain effective for a considerable period of time, depending on such factors as the rate at which it is applied. One or two applications per year should suffice.

Notes

Copper will not be required where copper fungicides are used or have been used extensively in the past.

Zinc may not be required where zinc-based dithiocarbamate fungicides are used, e.g. mancozeb.

Molybdenum (Mo)

Molybdenum is required in the least amount of all the essential plant nutrients. In plants, molybdenum is very mobile, and readily relocated from old to young tissue during the growing season. Hence, while it is possible to fertigate with molybdenum, in crops one or two foliar sprays in the seedbed and early in the growing season is normally all that is required, and a more practical approach.

Sodium molybdate and ammonium molybdate are soluble sources of molybdenum.

FURTHER READING

Agritopics are available on each of these nutrients, in which their application is discussed in more detail.

WARNING

The information contained in this Agritopic is for use as a guide only. The use of fertilisers is not the only factor involved in producing a high yielding pasture or crop. Local soil, water, climatic and other conditions should be also taken into account, as these can affect pasture or crop responses to applied fertiliser.

Before using fertiliser, seek appropriate agronomic advice. Fertiliser may burn and/or damage crop roots or foliage. Foliar burn to the leaves and fruit is most likely to occur when wetted by concentrated fertiliser solutions.

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