5.7 **Fertigation**

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**Key points**

- Fertigation can provide flexible and precise application of crop nutrients, but requires an efficient irrigation system and good management.
- In pressurised systems, venturi injection and positive displacement pumps are alternative fertigation methods.
- In surface irrigation systems, fertigation is typically limited to ‘water-run urea’. Irrigation performance and the volume of tailwater created are critical considerations for efficient fertigation. If irrigation is non-uniform, the water flow rate changes, or the rate of urea addition changes, then the uniformity of fertiliser application will be affected.
- Not all fertilisers are suitable for fertigation as some are insoluble. Furthermore, the compatibility of different fertiliser products should be checked before applying simultaneously.
- It takes some time for fertiliser to move through the irrigation system, which should be taken into consideration when determining fertigation run times and flushing duration.

Fertigation is the practice of applying fertiliser in a liquid form to a crop via the irrigation system. Using the irrigation system to apply fertiliser reduces the need to use mechanical operations and sometimes eliminates them altogether. More and more we are seeing greater percentages of annual crop fertiliser requirements being applied via fertigation, to the point where some cropping systems receive 90-100% by this method. When combined with an efficient irrigation system, both nutrients and water can be manipulated and managed to obtain the maximum possible yield of marketable production from a given quantity of these inputs.

Fertigation is typically used to address fertiliser deficiency which inhibits plant growth, labour and operational efficiencies. Fertigation has many advantages and disadvantages. The advantages include:

- fertiliser can be applied directly to the root zone optimising plant growth
- nutrients can be applied any time during the growing season based on crop need
- highly mobile nutrients such as nitrogen can be carefully managed to ensure rapid crop uptake
- fertiliser can be applied quickly to address any deficiency issues
- minimal crop damage
- tractor operations are reduced, saving fuel, wear and labour
- well-designed injection systems are simple to use and suit automation
- little amounts of fertiliser applied often leads to reduced off site impacts
- reduced loss of fertiliser due to unseasonal weather

Disadvantages of fertigation include:

- heavily reliant on the efficiency of the irrigation systems distribution uniformity
- heavily reliant of overall irrigation infrastructure design / layout depending on injection point
- potential issues during wet weather

Fertigation is used in overhead (centre pivot and lateral move), drip and surface irrigation systems.
Fertigation in Pressurised Systems

The two main injection systems used in overhead and drip irrigation systems are Venturi injectors and positive displacement (pressure) pumps.

Venturi injection

Venturi injectors come in several sizes and can be operated under different pressure conditions. Venturi injectors are only usable on closed pipe systems as they are set up in a shunt pipeline parallel to the main irrigation pipeline close to the pivot or lateral structure.

Requiring at least a 20% differential pressure to work properly, irrigation water from the main pump is passed through the venturi unit, creating a pressure differential between the water bypassing the unit and the fertiliser solution in the tank. This pressure differential causes the solution to be drawn up into the mainline. The gate valves and flow rate control the rate of the fertiliser solution applied. The venturi draws all the fertiliser until the tank is empty. Venturi injectors do not require external power to operate but some units utilise a small booster pump in the shunt pipeline to produce a differential pressure. Injection rates of 10 to 20,000 litres per hour can be achieved.

Figure 5.7.1 demonstrates how the concentration level remains reasonably constant over time or throughout the fertigation cycle with fluctuations only due to variable pressure differential. This constant is only achievable when a large fertigation tank is in place and all fertiliser is in solution as no extra water is added during the process.

Figure 5.7.1. Injected concentration over time using a venturi system
The advantages include:
- no moving parts – typically manufactured from plastic
- requires little maintenance
- gate valves control fertiliser injection rates with some accuracy
- large volumes can be mixed and stored on site
- reduces OH&S issues in dealing with fertiliser

Disadvantages include:
- requires a closed pipe system
- requires pressure loss in main irrigation line (can be up to 33 per cent)
- automation is difficult but not impossible

**Positive displacement**

This is the most common method of injection of fertiliser into irrigation systems and is very accurate. The three systems available are electric injection pumps, piston-activated pumps and diaphragm activated pumps. Piston-activated and diaphragm-activated pumps are both hydraulic injection pumps. Electric injection pumps include single or multiple piston, diaphragm, gear and roller pumps. These can be regulated to achieve the desired rate by:
- adjusting the length of the stroke of piston pumps
- metering flow
- manipulating pump speed at the pulley
- using a variable-speed motor
- semi-automation via electronic pulse water meters

Advantages include:
- simple and effective
- relatively easy to install
- no pressure loss in the main irrigation line
- automation is relatively easy
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Figure 5.7.3. Injected concentration over time using a Positive Displacement (Direct Injection) system

Direct Injection

Figure 5.7.4. Schematic of a Positive Displacement (Direct Injection) system

Fertigation in Surface Irrigation Systems

For surface irrigation systems, water-run urea is the primary fertigation method used. The urea is added to the irrigation water at a point where it can dissolve and thoroughly mix before being applied to the field. This is usually at a culvert or drop structure in the supply channel or head ditch. There will be some loss of nitrogen to the channel and tailwater must be recirculated to minimise losses and off-field impacts. Research has shown similar recovery of water-run and soil-applied urea by cotton.

Water-run urea will be distributed through the profile with the irrigation water and is readily available for crop uptake. Water-run urea can be applied using the following methods:
• Applying urea to dry soil ahead of the irrigation event – losses can be high where urea is broadcast onto a moist soil surface
• N Buggy type equipment that delivers a measured weight of urea directly to the irrigation water flowing through an irrigation channel. The rate of fertiliser addition can be regulated according to flow rate.
• In some areas, urea solutions are available and can be delivered on-farm. A constant head tank containing a float-valve mechanism to maintain a constant flow of dissolved fertiliser into the channel is required. Changing the flow rate of the fertiliser solution or the irrigation water can vary the N application rate.

The uniformity of nitrogen application will be related to the uniformity of the irrigation event. It is possible to achieve furrow irrigation distribution uniformity in excess of 90%, in which case the application of nitrogen will be reasonably even along the field length. However, if the irrigation is not uniform, it is most likely that more nitrogen will be applied at the head ditch end of the field with less applied at the tail drain end.

Similarly, poor irrigation efficiency will lead to losses of nitrogen as well as water. Water lost below the root zone as deep drainage will take nitrogen with it. Whilst tailwater recycling will capture that nitrogen that leaves the field with the irrigation runoff, further nitrogen losses may occur in the on-farm storage.

Without knowledge of the efficiency and uniformity of the irrigation event in which water-run urea is applied, it is impossible to be certain of the amount of nitrogen that has actually been applied to the crop root zone. This makes precise nutrition management difficult.

Anhydrous ammonia should not be injected into irrigation water as considerable losses from volatilisation of ammonia can occur. Under windy conditions losses of 25% per hour have been recorded. This leads to uneven application and poor crop responses. Additionally, when anhydrous ammonia molecules (NH3) dissolve in water they are transformed into positively charged ammonium ions (NH4+). These are attracted to the negative charged clay particles in the soil. As a consequence, the ammonium ions may be removed from irrigation water near the head ditch rather than being distributed uniformly down the furrow. This is not a problem with urea which has no charge and is more evenly distributed with the irrigation water.

Most fertilisers are salts that dissolve when mixed with water and can be strongly adsorbed by the soil and organic matter, and may not be evenly distributed throughout the field and soil profile with applied irrigation. This is particularly important with zinc and phosphorus which is strongly held by the soil. Fertilisers of these nutrients should not be applied using water—run technology in surface irrigation systems.

Using these rules, calcium nitrate is soluble (rule A). Calcium carbonate and magnesium carbonate (lime & dolomite) are insoluble (rule B). Magnesium sulfate (Epsom salts) is soluble but calcium sulfate (gypsum) isn’t (rule C).

Consideration also needs to be given to these rules of thumb when different fertilisers are mixed in solution and applied together as it is possible that a precipitate (sediment) may form. For example, if calcium nitrate and potassium sulfate are mixed together they separate and reform as potassium, nitrate and calcium sulfate (gypsum)

It is generally safe to mix: urea, muriate of potash, potassium nitrate and chelated trace elements.

**Problem products:** Phosphates; sulphates; calcium; magnesium and trace elements as insoluble reaction products may form in the mixing tank.

Due to the manufacture of certain fertiliser products and their purpose of use some contain insoluble impurities, coating agents or granulation:

- These impurities may block filters, emitters and potentially large sections of irrigation infrastructure (drip tape blocks)
- Some fertilisers that may be used in fertigation programs are coated. The coating agents are used to improve the handling characteristics as a dry solid before the products are used. When these products are dissolved in water the coatings begin to break down and may present problems with blockages of filters and small emitters.
- Some fertilisers have a coarse particle size and take a long time to dissolve.

**Solubility**

Not all fertilisers are suitable for fertigation as some are insoluble due to their chemical properties or manufacture.

As a rule of thumb the following chemical properties should be adhered to in determining the solubility of certain fertilisers:

- 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.
Coarse, granular and prilled products can be used provided they do not contain excessive amounts of impurities but may require more agitation. To resolve this source soluble fine or solution grade products that dissolve more quickly

The maximum solubility of a fertiliser in water, while temperature dependent, is a physical constant. As a fertiliser solution becomes more concentrated it becomes increasingly difficult to dissolve more fertiliser. When no more fertiliser can be dissolved regardless of continual agitation the solution is at saturation point. Any remaining undissolved fertiliser has the potential to precipitate. Some fertilisers also cause the temperature of the solution to fall which reduces the solubility. e.g. urea, nitrates.

Fertilisers have different solubilities and therefore need different amounts of water to dissolve and should be completely mixed before being injected. This is where agitation plays an important role in the effectiveness of injection. Agitation is easier in vertical tanks as there is a smaller surface area at the base of tank. It is also essential that you test the mix for corrosion potential and deposition - phosphorous has high corrosion potential when used in galvanised iron which is a particular consideration for CPLM users.

Good agitation and a fine particle size results in a quicker dissolve rate, but the maximum concentration that's able to be dissolved does not change

<table>
<thead>
<tr>
<th>Product</th>
<th>kg / 100 L @ 20° C</th>
<th>Product</th>
<th>kg / 100 L @ 20° C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium nitrate</td>
<td>192</td>
<td>Calcium nitrate</td>
<td>60</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>75</td>
<td>Magnesium sulphate</td>
<td>71</td>
</tr>
<tr>
<td>Mono-ammonium phosphate MAP</td>
<td>37</td>
<td>Magnesium nitrate</td>
<td>71</td>
</tr>
<tr>
<td>Liquifert P (Tech MAP)</td>
<td>20</td>
<td>Soluble boron</td>
<td>9.5</td>
</tr>
<tr>
<td>Mono-potassium phosphate MKP</td>
<td>12</td>
<td>Zinc sulphate</td>
<td>44</td>
</tr>
<tr>
<td>Potassium chloride</td>
<td>34</td>
<td>Liquifert K (KCI)</td>
<td>20</td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>8</td>
<td>Liquifert N (Urea)</td>
<td>25</td>
</tr>
<tr>
<td>Potassium sulphate</td>
<td>10</td>
<td>Urea (water temperature 5° C)</td>
<td>45</td>
</tr>
</tbody>
</table>

If you are considering applying two chemicals at once, test the compatibility with each other and with the irrigation water as a precipitate (sediment) may form. Manufacturers can help out here and are able to advise on the corrosion potential of their products.

Urea, muriate of potash, potassium nitrate & chelated trace elements are generally considered safe to mix. However phosphates, sulphates, calcium, magnesium and trace elements can create problems. When this happens the following can occur:-

- Precipitates may settle to the bottom of the tank or block filters and emitters.
- Precipitates may also form if the water is hard (i.e high in Ca and Mg or contains carbonate).

Therefore the trace elements to avoid are copper, zinc, manganese and iron sulphates. These cannot be mixed with calcium nitrate, MAP, MKP and always use chelated forms of trace elements if mixing products.
### Table 5.7.2. Product compatibility chart

<table>
<thead>
<tr>
<th></th>
<th>Urea</th>
<th>Ammonium nitrate</th>
<th>Ammonium sulphate</th>
<th>Mono-ammonium phosphate MAP</th>
<th>Mono-potassium phosphate MKP</th>
<th>Potassium nitrate</th>
<th>Potassium sulphate</th>
<th>Potassium chloride</th>
<th>Calcium nitrate</th>
<th>Magnesium sulphate</th>
<th>Soluble boron</th>
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</thead>
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<td>YES</td>
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<td>YES</td>
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<tr>
<td>Ammonium nitrate</td>
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<td>YES</td>
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<tr>
<td>Ammonium sulphate</td>
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<td>YES</td>
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<td>YES</td>
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<tr>
<td>Mono-ammonium phosphate MAP</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<td>YES</td>
<td>NO</td>
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<tr>
<td>Mono-potassium phosphate MKP</td>
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<td>YES</td>
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<tr>
<td>Potassium sulphate</td>
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<tr>
<td>Potassium chloride</td>
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<tr>
<td>Calcium nitrate</td>
<td>YES</td>
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<td>Magnesium sulphate</td>
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<tr>
<td>Soluble boron</td>
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<td>YES</td>
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<td>NO</td>
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</tbody>
</table>

The **options for applying Incompatible products** include:

- Apply the fertilisers at different times (e.g. apply MAP or MKP and sulphate fertilisers at different times to calcium fertilisers);
- Alternate between the products each time the crop is irrigated; and,
- use two mixing tanks and injectors - as the concentration of nutrients in the irrigation lines is very dilute and therefore there is less chance of precipitate formation.
System Performance

The performance of fertigation systems depends on the injection type used and the application system. Correct injection rates and an application system that applies water uniformly are crucial to ensure that the distribution of fertiliser is uniform and effective.

To ensure fertiliser is delivered to the field as required it is necessary to understand the hydraulics of your application system. Depending on the size of the irrigated property the application system may be in several components at which point it is beneficial to understand all delivery points. Essentially each irrigated field has an individual hydraulic characteristic.

- The injection of the fertiliser should not start until the flow rate and pressure of the irrigation system reach their normal operating levels. For drip systems this may require running the system for up to one hour prior to commencing the injection.
- Check travel time of overhead irrigation systems and recalculate the fertiliser injection rate for the planned amount of fertiliser.
- 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.
- Avoid injection into empty lines.
- With travelling irrigation systems, the fertiliser solution must be injected continuously at a constant rate (and concentration). For drip systems the fertiliser solution is usually injected in the middle half of the irrigation set time (to ensure the system has reached normal operating levels and for flushing of the system).
- After the fertigation process has started, recheck the fertiliser injection rate.
- Periodically revisit the irrigation system and recheck the operation of the injection meter, operating pressure of the system and water distribution of the irrigation system including the end gun operation on centre pivots.
- At the end of each fertigation application, continue running water through the irrigation system until all of the fertiliser has been discharged from the pipeline of the irrigation system. This will vary depending on the distance between the fertigation tank and the irrigation system. Also run clean water through the injection meter, chemical discharge hose and check valve. Flushing after use prevents scale forming and extends the life of gaskets and metals.
- Maintain a neat storage, mixing and injection area. This promotes safe handling and facilitates early recognition and clean up of any spills and leaks.
- Prevent drainage from the injection/storage area into streams, dams or bores.

Before any test is started, the system must be operating at its normal operational pressure. Once the system is running at the correct pressure commence injecting. There are many indicators to measure performance. Nitrate test strips can be used with a nitrate fertiliser. This is simple as you do not need much nitrate fertiliser in the tank for it to be effective. EC meters (salts), pool test kits (acid and chlorine), molasses and dyes can also be used to check the system.

Injection times and flushing procedure will vary between different irrigation blocks. Select the desired system to check and then start the injection process, being sure to make a note of the injection time (A).

Calculate the time it takes for the fertiliser to reach the first emitter/sprinkler (A – B). If fertiliser injection is done at the actual centre pivot / lateral move/ drip system this time will be minimal but if the fertiliser is injected at the pump some distance away it can take quite a while to get there depending on the sizes of mains/sub-mains.

Now measure the time it takes to get from the first emitter/sprinkler to the last emitter/sprinkler of the centre pivot / lateral move/ drip system (A - C). For most centre pivot / lateral moves and drip systems this time is reasonably quick. Take a note of this time as this is relevant to your injection time at the fertiliser tank.
What do the times mean?

The duration of the fertiliser injection must take at least the same amount of time or longer than it takes for the fertiliser to move from the first emitter to the last emitter. If the injection duration is shorter then not all the areas in the irrigated field will receive the same amount of fertiliser. The uniformity of fertiliser will be uneven with parts of the crop receiving more than others.

Once the fertiliser is injected, the system needs to be flushed for the correct amount of time. This is the same as the time it takes for fertiliser to get from the tank to the last emitter/sprinkler. If the irrigation system is not left running for this time or longer, fertiliser will remain in the main/sub-mains and not be correctly distributed in the block. Worse still you will leave fertiliser (salt) inside the centre pivot/lateral move where it can cause corrosion. It can also block emitters in drip systems particularly if other products are used in subsequent irrigations.

For large irrigation systems such as centre pivots and lateral moves the ability to track fertiliser movement may be difficult given high flow rates.

An alternative to direct measurement is to complete a velocity of flow calculation using the following calculation:

\[ \text{Velocity (m/sec)} = \frac{1.274q}{d^2} \]

where

- \( q \) = Volume flow (m\(^3\)/sec)
- \( d \) = pipe inside diameter (m)

Example

8" pipe and a flow rate of 100 L/sec
8" = 200mm = 0.2m
100 L/sec = 0.1 m\(^3\)/sec

Thus,

\[ V = \frac{(1.274 \times 0.1)}{0.04} \]
\[ V = 3.185 \text{ m/sec} \]

This velocity can be used to estimate the time taken for fertiliser from the injection point to leave the system. If the distance from the injection point to the end of the overhead system is 1000 m then the time taken will be 314 seconds or 5 minutes and 14 seconds (1000 m ÷ 3.185 m/sec).
Application tips

The following application tips are provided with the objective of preventing contamination of nearby water sources, occupational health and safety and handling practices.

- Maintain a neat storage, mixing and injection area. This promotes safe handling, and facilitates early recognition and clean-up of any spills and leaks.
- Prevent drainage from the mixing area into streams, dams or bores.
- 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.
- Allow excess water to re-enter reticulated water supplies for use on other irrigated fields 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,
- Prepare fertiliser solutions as close as possible to the time of use. Do not allow to stand for an extended period of time, e.g. Over night. This can help minimise precipitation and settling in mixing tanks in some instances.
- Inject fertiliser solutions upstream of filters, so that insoluble contaminants are screened out.
- Flush injectors and lines after use, to minimise corrosion and scale formation, and extend the life of gaskets.

Further Reading

Centre pivot and lateral move machines in the Australian cotton industry by J.P. Foley and S.R. Raine (2001). NCEA Publication 1000176/1
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