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Fertigation: delivering fertiliser in the irrigation water

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Introduction

The delivery of dissolved mineral fertilisers to the roots of crops in the field using irrigation water is known as 'fertigation'. The use of fertigation is gaining popularity because of it's efficiencies in nutrient management, time and labour and potentially a greater control over crop performance.

The supply of dissolved mineral nutrients to plant roots has been a research tool for at least 100 years. The mixture of water and dissolved nutrients is known as the 'nutrient solution', and the concept of growing land plants without soil has become known as 'hydroponics' (from the Greek words for water and labour, namely *hydro* and *ponos*, respectively)[1].

The concept had its first practical application in the 1940s when vegetables were grown in a soilless solution culture. This is still widely practiced in the production of high value annual vegetable crops under protective structures, and is sometimes referred to as nutrient film technique, or NFT. In 'soilless solution' culture, all the plant's mineral nutrient requirements must be supplied in the irrigation water.

Fertigation represents a natural extension of the hydroponics concept, and is now widely practiced in horticultural industries, particularly permanent plantings of crops such as citrus, olives and almonds. Fertigation is most successful when combined with drip irrigation.

Advantages

The advantages of supplying mineral nutrients to crop roots using fertigation include:

- Reduced delivery costs (no need to broadcast fertilisers, leading to less soil compaction in the inter-row areas, less fuel usage and lower labour requirements).
- Greater control over where and when nutrients are delivered, leading to greater fertiliser use efficiency.
- More control over crop behaviour through targeted application of specific nutrients during particular stages of crop development.
- Potential for reduced fertiliser losses (due to immobilisation within or leaching below the rootzone) by supplying small amounts often.

Disadvantages

These include:

- Greater capital costs associated with the equipment needed to dissolve and inject the fertiliser into the irrigation water.
- Higher operating costs associated with using technical grade fertilisers as opposed to agricultural grade fertilisers.
- Chemical reactions between some types of fertilisers when mixed, potentially causing significant equipment blockages.

[1] http://en.wikipedia.org/wiki/Hydroponics

Equipment

The level of sophistication, and associated capital cost of fertigation equipment varies greatly. This aspect will be covered in more detail in another Primefact, but some general comments about mixing tanks and control units are included in this document.

Mixing tanks: Many fertigation systems are designed with three mixing tanks to allow the supply of up to three different fertiliser mixes in a single irrigation, but at different times during that irrigation. Sometimes only a single tank is used, with different fertilisers being supplied in different irrigation shifts (Figure 1).

Using multiple tanks reduces the time required to manage a system, and makes it easier to supply small doses of different fertilisers during every irrigation event without having to frequently replenish each tank. However consideration must be given to allowing sufficient time for one fertiliser to be flushed through the system before another fertiliser is introduced (Figures 2 & 3).

Control systems: Various control units are available that allow irrigation pumps to be turned on at pre-set times, for irrigation sections to be turned on and off according to a pre-determined program, and also systems that control when and how much of each fertiliser mix is to be injected into the irrigation water.

Equipment is also available to monitor and modify the electrical conductivity (EC) and pH of the water/nutrient mix (Figure 4). EC is often used as an indirect measure of the amount of fertiliser being injected into the irrigation water; higher EC readings are indicative of high amounts of fertiliser being injected.

Figure 1. Single fertigation tank in a citrus orchard. This type of equipment is commonly installed down stream of a valve that services a distinct management unit (i.e. block). It generally can only supply a single fertiliser at a time and requires manual operation.

Figure 3. PVC pipes taking separate dissolved fertilisers to the injection point.

Figure 2. Multiple mixing tanks allow the supply of different fertilisers in the one irrigation shift.

Figure 4. Front panel of a fertigation system control unit that allows setting of water/nutrient mix, electrical conductivity (EC) and pH.

Fertilisers Applied

All mineral nutrients can be supplied to plant roots using fertigation. Generally though, it is usually only the major nutrients — nitrogen (N), phosphorus (P) and potassium (K) — that are supplied using this method. However calcium (Ca) and magnesium (Mg) are sometimes supplied. Sulphur (S) is often inadvertently supplied when fertilisers such as potassium sulphate and magnesium sulphate, are used to supply K and Mg, respectively.

Using fertigation to supply the other essential micronutrients such as boron (B), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo) is possible, but these nutrients are generally applied as foliar sprays because only small amounts are needed.

Forms of Fertilisers

Agricultural grade fertilisers are generally not suitable for use in fertigation systems because of the amount of impurities present, which may be insoluble and lead to dripper blockages. For this reason technical grade fertilisers are normally required in fertigation systems because they have fewer impurities and proportionally higher levels of the desired mineral nutrients.

Single, double and triple-strength superphosphate and rock phosphate are unsuitable for use in fertigation systems.

Fertilisers suitable for use in fertigation systems come as technical grade salts (e.g. potassium sulphate), acids (e.g. nitric acid), bases (e.g. potassium hydroxide), polymers (e.g. polyphosphate) or chelates (e.g. iron EDTA). They are almost exclusively injected into the irrigation water already in solution (i.e. pre-dissolved in water).

Insoluble sources of calcium (Ca) are an exception to this rule. For example, gypsum, which is sometimes used to help remove excessive amounts of sodium ions (Na^+) from the soil profile and improve soil structure, can also be introduced into the irrigation water. However it must be very finely ground and the source tank, constantly agitated to prevent settling of the fine particles and to prevent dripper blockages,.

The amount of each fertiliser that can be completely dissolved in a given volume of water is different, and highly dependent on the temperature of the water. Less of a given fertiliser can be dissolved in cold water (i.e. <5°C) than can be dissolved in warm water (i.e. >15°C). There are guides and charts available on the amount of various fertilisers that can be dissolved in a given volume of water as a function of the temperature of that water.

Another potential problem with fertigation systems is with the mixing of fertilisers. There is the potential for negatively charged ions (anions) from one fertiliser to react with positively charged ions (cations) from another fertiliser to form an insoluble precipitate (clump). This can lead to clogging problems in the irrigation system. The major danger lies with calcium (Ca^{2+}) which forms insoluble precipitates with phosphate (PO_4^{3-}) or sulphate (SO_4^{2-}). Compatibility and mixing charts for different fertilisers are available.

Open hydroponics

Fertigation approaches vary from simply using the irrigation water to supply the basic nutrients (i.e. N, P and K) in a few applications per year while still relying on the soil to supply all other nutrients, through to those that supply the crop's complete nutrient needs in small doses sometimes on a daily basis.

In the latter approach (daily irrigations) the soil essentially only provides the mechanical support for the crops' roots and acts as a storage bank for the water and nutrients added. This approach has become known as 'open hydroponics'. Another feature of this approach may include adjusting the pH of the irrigation water/nutrient mix; a practice know as 'pH trimming'.

Some open hydroponic systems have fewer drippers per plant, and water is applied more frequently in very short irrigations (pulsing). This results in a much smaller proportion of the available rootzone being wetted, confining root growth to the wet soil. For example, under open hydroponics, citrus roots can be confined to a root volume as small as 0.5 m^3 compared to 6–10 m^3 under conventional irrigation/fertigation. (Figure 5).

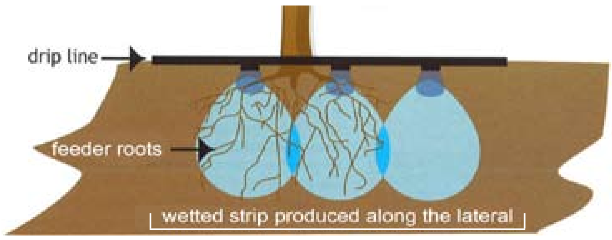

Figure 5. Cross-section along a plant row showing a typical wetting strip pattern under drippers.

The reduced root volume also means that the amount of water held in that soil volume is much less, and so the interval between field capacity and wilting point, i.e. the time interval between irrigation events, is much shorter compared to conventional irrigation. With open hydroponics soil moisture monitoring and the ability to supply water on demand are critical to prevent trees suffering water stress.

The major potential benefit of the open hydroponics approach is – better control over the delivery of water and nutrients to the plant roots due to the restricted volume of wetted soil. However, it is also potentially the weakest link because a very high level of management skill and greater capital investment are required when using open hydroponics compared to simpler approaches. Anything less than best management can very quickly lead to major problems, ranging from reduced yield and quality through to crop death. Cutting corners on equipment may mean that some potential efficiencies are not made.

Using fertigation to manage crop performance needs to be based on a good knowledge of when and to what extent each mineral nutrient is taken up by the crop's roots and how it affects crop growth, development, and yield. With some open hydroponics systems, which essentially ignore soil fertility, this knowledge is even more critical. There is a tendency to assume that all crops behave similarly, but this is not the case. It must be stated that there are still major knowledge gaps in this area for specific crops. Another gap in technology is the ability to measure crop nutrient status in 'real time', and to interpret that information correctly and use it to manage the fertigation system.

Summary

Fertigation potentially offers many advantages over conventional approaches to managing a crop's fertiliser needs.

While fertigation is an exciting and potentially profitable addition to horticultural production systems, it also requires significant investment in equipment, advanced management skills, constant monitoring and an understanding of the specific crop's nutrient needs.

Suggested reading

- Falivene, S 2008, *Soil Solution Monitoring in Australia*, Co-operative Research Centre for Irrigation Futures.
- Giddings, J 2005, *Drip Irrigation – A Citrus Grower's Guide*, NSW Department of Primary Industries, Orange.
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