

Managing iron in nursery irrigation systems

Having a source of good quality water is vital to any professional nursery operation. In this month's Nursery Paper, Victorian Industry Development Officer David Reid examines iron content in nursery irrigation systems, covering why it may be of concern and how best to manage it.

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Iron is one of earth's most common resources, making up at least 5% of the earth's crust. The action of rainfall seeping through this crust dissolves iron and then transports it into natural water sources. The majority of groundwater sources in irrigation systems will exhibit at least some level of dissolved iron.

Although iron in nursery irrigation water could be an essential nutrient, when coming into contact with oxygen in the air it will oxidise, often appearing as an insoluble reddish-brown sediment. Levels of this sediment above 1mg/L of water will ultimately play havoc with a production nursery environment:

- Blocking drippers, filters and spray nozzles through sediment and bacteria that thrive in iron rich environments;
- Contributing to scale build-up in irrigation pipes;
- Decreasing water pressure and overall irrigation efficiency;
- Increasing maintenance and replacement costs over time;
- Staining nursery structures;
- Depositing sediment on foliage, impairing photosynthetic efficiency and ultimately their sale quality (in systems where the level of iron in water exceeds 3-4mg/L).
- Problems may be increased when an iron rich water source is combined with fertigant (calcium salts or unchelated phosphates), accelerating the natural process of iron precipitation considerably.

Water from dams, or surface waterways are unlikely to have iron levels that will contribute to problems within irrigation systems as the iron will have dropped out the water prior to being extracted. The use of a town source or that collected from rainwater are also unlikely to exhibit iron induced problems, unless it comes in contact with degraded steel tanks or pipes.

The problem of iron in irrigation water centres on its extraction from iron-rich groundwater, with bore water a key source. As soil-types are highly variable, groundwater quality at different bore depths will also exhibit variable iron levels.

NB: *The document **Minimum construction requirements for water bores in Australia** suggest numerous methods to mitigate the presence of iron prior to accessing underground water sources.*



As more nurseries look to draw water from sources other than town water or a source with low iron concentration, the following may provide some direction to manage iron levels in your irrigation water.

Types of iron

The presence of iron in a nurseries water source may appear in many different forms; chelated, organic and precipitated, with these forms including:

- **ferrous (Fe²⁺) or dissolved iron**, which is soluble and colourless when dissolved in water. It is this form that can be introduced into an irrigation system.
- **ferric (Fe³⁺)**, which occurs when ferrous iron is moved to the surface and oxidised to highly insoluble or oxidised (rusted) iron, appearing when precipitated as brownish red colored particles

suspended in the water. If this water is left to settle most of the rust particles will sink to the bottom of the storage vessel (tank/dam) over time.

The conversion from the soluble ferrous to the insoluble ferric is affected by numerous factors, with the dominant being:

- **pH** - Iron is more soluble at lower pH values and iron precipitation can be caused by raising the pH.
- **O₂ content** – the ferrous form occurs when oxygen concentration is low (i.e.: bore water). When water is moved from anaerobic (without O₂) to aerobic (with O₂) conditions above ground the ferrous form rapidly converts to ferric, with resulting precipitation. Precipitate usually coagulates near O₂ sources such as leaking pipes or emitters.
- **temperature** – lower temperatures contribute to longer oxidation reaction times

For example, for 90% ferrous iron, oxidation at:

- pH 7.0, it will occur within 1 hour at 21°C and 10 hours at 5°C.
- pH 8.0, it will occur within 30 seconds.
- At pH 6.0, it will occur within 100 hours.

The critical dissolved oxygen concentration is 2mg/L (2ppm). Below this concentration, ferrous iron oxidation occurs very slowly.



Iron precipitate can clearly be seen in this example (picture courtesy of Mr Phil Heath Botanica Nurseries)

So what is the first step to fixing the issue?

Regardless of how clean the water looks, a full elemental water test should be completed on at least a yearly basis to determine iron content.

Not only is it prudent to discover the level of iron that is being sent through your irrigation system and onto your plants, it is vital to your business to identify the presence of other potential contaminants that could compete/react with the iron. Understanding your water's pH, electrical conductivity (EC) and numerous other elemental characteristics are also important, as some of these may inhibit management approaches.

These characteristics may vary greatly between different sites, water sources and times of the year, so regular monitoring is required to ensure your management choices are suitable and able to maintain the quality of your water.

Nutrient and other factor levels in irrigation water for general ornamental plant production.

Based on Hart (1974); Ayres and Westcot (1976), Aikman (1983), Degremont (1991), Yeager et al (1994), Bienbaum 1993.

Factor	Phytotoxic limits
Nitrate (as NO ₃ not N)	<100mg/L (excessive soft growth)
Phosphorus (as phosphate)	<15mg/L for phosphate sensitive plants
Iron (Fe++) (Yeager et al)	5mg/L
Copper	0.2mg/L
Boron	0.3mg/L
Zinc	2.0mg/L
Manganese	0.2mg/L
Aluminium	5.0mg/L
Molybdenum	0.01mg/L
pH (nutrient imbalances)	5.5 to 7.0
Salinity (EC-dS/m)	0.75 to 3.0 (low to severe problem*)
Chloride	200mg/L
Sodium	100mg/L
Alkalinity	40 to 500mg/L CaCO ₃ (low to severe problem)

* Safe salinity limits will depend on the type of crops grown. The optimum levels of nutrients in irrigation

Plugging potential of drip irrigation system water sources

<0.1mg/L	should not present much of an issue
0.1-1.5mg/L	minor to moderate clogging of drippers. Iron bacteria will develop
>1.5mg/L	severe clogging
>3mg/L	iron rust stains and discoloration of foliage plants in overhead application.
>4mg/L	phytotoxicity (this will occur w/ lower value if pH is less than 5.5. Values above this are difficult and expensive to treat.

Before implementing any management options, samples must be taken.

- Draw water sample directly from source
- Place into a plastic container; filling completely.

- Seal tightly to avoid oxidation
- Send off to lab for analysis. Portable test kits are available (speak to IDO in your state for further information).

Clear water samples does not mean that iron is not present, as invisible iron may be present as ferrous bicarbonate ($\text{Fe}(\text{HCO}_3)_2$). However, during sampling and by the time the water sample reaches the laboratory, oxidation of some or all iron can occur and turbidity may show up in the results. Ferrous bicarbonate, when oxidised, changes into ferric hydroxide $\text{Fe}(\text{OH})_3$ producing carbon dioxide and lowering the pH.

Water testing is needed before considering or selecting the appropriate treatment equipment for effective and efficient removal of iron.

Depth of irrigation intake

After identifying that iron content in bore water is causing some of the aforementioned issues, a good first step is to ensure that the irrigation intake is located 50-75cm below the surface of the water. When an intake is too close to the bottom, settled iron sediment will be drawn from the bottom of the pond and those too close to the surface will draw higher levels of the oxidised form and other organisms that flourish on the oxidized from, such as iron fixing bacteria.

Managing emitter blockages /filters

In addition to staining of plants and structures, the blocking of irrigation equipment with iron sediment is a common problem if not managed. This issue of emitter plugging may not be from iron levels alone, but other particulates from soil or water sources. Filters are the first line of defence against particles entering the irrigation system, with the best approach being to install the best filtration system you can afford and regularly maintaining it.

A screen filter is ideal for removing particles from the water source prior to distributing them throughout the irrigation system, with multiple screens system recommended for surface water sources. Disc filters trap particulates on adjacent discs as water flows from outside edges toward the inside of the discs, with filtered water exiting through the central conduit.

Filtration alone does not remove iron efficiently as it only removes particles of oxidised iron. A sand media filter is the most appropriate filter for removing ferric oxide.

The recommended treatment to remove iron is oxidation, sedimentation and filtration, with the use of settling, aeration, chlorination and even potassium permanganate. Aeration and oxidation should take upstream of the filter.

Aeration and settling to precipitate iron

Where iron concentration is above 1mg/L, aeration and settling is recommended prior to use in irrigation systems. Pumping water from the bore and spraying it into the air over a dam (or into a tank) is a reliable way to remove the iron. Another option is cascading the bore water over baffles. Allowing the water to flow over a large surface such as rocks, a corrugated surface or baffle plates will encourage aeration, before settling in a dam. As previously mentioned, during the aeration process the iron is oxidised into is insoluble form that can then be settled in the



Bore pump Iron precipitate can decrease pump performance and lead to pump failure

dam/tank. A clear disadvantage is that the water must be double pumped, with an extra pressurisation required after aeration.

If you wish to settle it in a tank, it is ideal to draw the water off from a high level outlet and into another storage tank, with a regular drawing off of the iron rich sludge from the settling tank via a bottom outlet plug.

Chlorination to control iron

Chlorination can be utilised as a further control following aeration and sedimentation. As well as controlling zoospores and spores of particular pathogens, if the pH is below 6.5 and the iron concentration is less than 3.5mg/L chlorination can also manage iron content.

NB: If pH is above 6.5, the iron concentration must be below 1.5mg/L.

Chlorination can be considered as a treatment method, especially when iron exists in organic form. Chlorination breaks down the organic complexes, and the iron then may be oxidised and precipitated by aeration and pH adjustment. Iron is more soluble at lower pH, with the ideal precipitation value is likely to occur at a pH of 7.2, so it may require the addition of hydrate lime to raise pH. Prudent use of lime is encouraged as too much will create hard water.

Furthermore, chlorination also kills iron bacteria (a type of brown-reddish slime that precipitates from water that contains iron) on contact. The bacteria can live on iron or sulphur and produce a mass of slime that quickly attach to PVC and polyethylene tubing and clogs emitters and filters. This slime can also act as an adhesive to bind other solids together to exacerbate clogging. They can also cause soluble iron and sulphur to precipitate out of the water. A continuous residual rate of 1-2ppm of free available chlorine at the distant end of the irrigation system should be sufficient. (Bucks and Nakayama 1980)

Ion exchange / softeners filters

A further option is through softeners to remove the ferrous bicarbonate in water. The simplest method (but not necessarily the most cost effective) is to remove ferrous bicarbonate iron from the water by passing it through an air tight water softener containing a resinous cation exchanger: an insoluble matrix normally in the form of small (1–2mm diameter) beads, fabricated from an organic polymer substrate with a surface that easily traps and releases ions in a sodium ion exchange using coated resin beads or zeolite process called ion exchange. The capacity for removing iron depends on the capacity of resin.

By using a basic softener regenerated with sodium chloride, iron can be removed along with calcium and magnesium. Filters such as these require regular backwashing to maintain effectiveness.

Potassium permanganate

This compound is another option for iron removal from irrigation water, often combined with manganese greensand, acting as a filter to capture ferrous oxide, by oxidising the iron into an insoluble oxide (1:1.06mg/L) The main advantage is the high rate of reaction, many times faster than that of chlorine. The reaction is also not sensitive to pH within the range of 5 to 9.

After backwashing to remove the insoluble iron oxide, regeneration with potassium permanganate solution is carried out to maintain the process. The greensand is recharged until pink water flows out of the greensand media. The flow is then decreased until a slight pink colour appears. There should be no pink colour after filtration.

Other products such as zeolites and birm can be used instead of greensand and potassium permanganate to improve the oxidation process.

Complexing the iron to stop oxidation

If the iron in the water is complexed to stop oxidation, precipitate will not form and blockages are not likely to occur.

A simple means of complexing the iron is to add sodium silicate to the water with an injection pump located near the main pump. Sodium silicate is a dense sticky liquid available in 200L drums. Each litre of sodium silicate contains 450g of silicate. To help mix it sodium silicate may be pre-mixed with water to make it less sticky, but do not dilute with more than two parts of water to one part of sodium silicate.

The amount of sodium silicate required depends on the amount of iron in the water. The recommended rate is 7g of silicate per 1g of iron. This is the equivalent to 0.015L of sodium silicate, per 1mg/L of iron, per 1kL of water.



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