AHDB HORTICULTURE

Robert Irving, ADAS

Understanding and measuring conductivity in soilless substrate grown soft fruit crops

Conductivity is a useful measurement of total salt content of a soilless substrate and provides growers with an indication of the strength of feed solution within a container grown crop (Figure 1). This factsheet explains what conductivity is and how best to measure and manage it. By measuring it regularly, growers will avoid unexpected problems developing within the delivery system, such as nutrient wastage, nutrient accumulation and possibly background conductivity problems in the water source.

Figure 1. Measuring the conductivity of a soilless substrate strawberry crop

Action points

- Calibrate your conductivity meter with standard solutions from the manufacturer at least once a year
- Sample the feed solution, run-off or substrate conductivity in a consistent manner. It is best if the same person carries out the sampling each time
- Know the acceptable electrical conductivity (EC) ranges for your crop and sampling method. The values will vary between farms and between the sampling methods chosen
- Plot measurements on a spreadsheet. A graph provides a good insight of trends and covers for individual small imperfections in both the sampling and the meter. The trend in conductivity levels is the most useful information
- Adjust the feed by small amounts as you observe these trends. You may also choose to conduct a laboratory feed or substrate analysis if there is something hard to explain
- Well-collected data is valuable when reviewing the crop performance ahead of the next crop.

What is conductivity

The electrical conductivity (EC or sometimes referred to as cF) is a measure of the total salt content of a solution. In a laboratory analysis, it is sometimes reported as microsiemens per cm (µS/cm) at 20°C. It is more commonly expressed as µS or its multiple mS (1,000µS = 1mS). On a portable conductivity meter, it is frequently abbreviated to µS or mS.

A conductivity measurement will vary according to the temperature of the solution. Most portable meters automatically compensate to the default temperature of 20°C. This is also the standard temperature for a laboratory analysis where methods and calibration are maintained to a very high standard.

What creates conductivity?

Conductivity is created by water and salts that form ions (ions are sometimes called electrolytes – see Further Information section). Fertiliser ingredients contribute significantly to the salt content, in addition to the salts that naturally occur in the water source.

Water itself has both H+ and OH- ions. All of these ions combine to produce a total conductivity reading of the solution. The more of them there are (mg/l), the higher the conductivity (µS).

Deionised water (the equivalent of distilled water) has a conductivity close to zero. Carefully collected rainwater is also close to zero. Both water types are salt free.

Conductivity of the water source

The conductivity of the water source is referred to as 'background' conductivity. Water sources will contain some useful nutrients and, while some will be inert, some may possibly be harmful, if present in high quantities. Only a laboratory analysis will identify these factors. You can expect a laboratory analysis of your water source to be a useful reference for 1–2 years in most cases.

The most common contributors to high conductivity (EC) in a water source are carbonate, sulphate, chloride and nitrate ions. Poorly managed water with a high EC can give rise to an accumulation of salts in the substrate, which leads to root damage. Regular measurement of the conductivity in the feed 'run-off' (which drips out of the bag/container) will give an early warning of accumulating salts around the root zone.

Background conductivity varies from site to site and depends upon the water source used. Table 1 displays a range of background conductivity measurements recorded in water analyses at different commercial soft fruit production sites. A typical EC of mains water is 500µS. Uncontaminated rainwater is close to zero. Note that boreholes are highly variable and that water over 850µS should be avoided or diluted with water of a lower EC, using rain or mains water. Background EC can vary from a river or borehole over time and is highly variable between different boreholes, even on the same farm.

A full water analysis also indicates water safety. It is possible to have a good conductivity, while still having levels of sodium or chlorine, for example, which are harmful to crops.

Table 1. Examples of water source (background) conductivities found on fruit farms

Source	µS/cm	Source	µS/cm
Borehole	293	Mains water	223
Borehole	372	Mains water	376
Borehole	475	Mains water	434
Borehole	490	Mains water	566
Borehole	556	Surface water	557
Borehole	556	Surface water	637
Borehole	646	Surface water	661
Borehole	721	Surface water	880
Borehole	764	Rainwater	5
Borehole	837	Borehole (unused)	1,770
Borehole	845	Borehole (unused)	1,810
Borehole	863	Borehole (unused)	8,685

Blending water sources to reduce background conductivity

High background conductivity can be reduced by blending with water sources with lower levels of conductivity to resolve the problem. Given the very low background conductivity of rainwater, this is the ideal source to use when blending with a high EC source from a borehole, for example.

The importance of measuring conductivity within the feeding system

The injectors and dilutors in the pump house are set up to deliver a designated feed plan to a bag/container grown crop. It is important to regularly check that what you think is happening, is actually happening. The feed plan must be seen to be working correctly to ensure that the crop is receiving the correct strength of solution. The delivery system can break down and give rise to either a high nutrient overdose or else an insufficient feed strength.

A high nutrient overdose can cause excessive growth then ultimately stunted dark green growth. If this is caused by unwanted salts, the plant exhibits a senescent appearance with 'tired' looking foliage and an autumnal appearance (Figure 2). An examination of the roots will reveal an 'off-white' colour.

Figure 2. A crop exhibiting symptoms of high conductivity caused by saline water

A very low conductivity will give rise to a smaller crop canopy (Figure 3), exhibiting pale leaf colour and possibly green leaf veins (this could also be caused by high pH). The berries will have a noticeably poor flavour.

Figure 3. A crop exhibiting symptoms of low conductivity feed solution

Measuring conductivity is a quick way to monitor the overall nutrient strength of the feed. It is less detailed than a laboratory analysis but offers a valuable technique for detecting early changes in the feed, should a system error occur.

The conductivity should, ideally, be checked within the crop at least once a week throughout the growing season. This 'little and often' approach avoids nutrient imbalances developing that are hard to resolve. You can adjust the frequency to fortnightly at the cooler ends of the season. Similarly, at key stages of cropping, conductivity can be checked daily, when small changes in conductivity can have a greater impact on fruit quality.

Measuring the conductivity of the feed solution

It is important to measure the conductivity of both the feed solution entering the bag/container (input) and the solution dripping through the drainage holes (output).

Conductivity of feed solution (input)

The conductivity of the feed solution (Figure 4) is the total of the 'background' and fertiliser solution conductivity. This provides a day-to-day statement of input EC. It should be noted that only a full laboratory analysis will provide detailed information of the exact composition of the constituents of the feed solution.

Be careful when comparing your own readings with the EC used on other farms or in trials data, as the background conductivities can be so variable. Table 2 (overleaf) provides guideline conductivity levels that strawberry growers should aim for in soilless substrate grown strawberries.

Figure 4. Collecting input feed

Table 2. Optimum conductivity levels in strawberry feeds

Starter/vegetative feed	Conductivity of input feed* (μS/cm at 20°C)
First 10–14 days feeding	1,400
After 14 days	1,600

Fruiting feed	Conductivity of input feed* (μS/cm at 20°C)
From first fruit set	1,600
From start of picking	1,800

**Including background conductivity of water at 500μS/cm at 20°C.*

Conductivity of run-off solution (output)

The conductivity of the run-off solution (Figures 5a and 5b) reflects the irrigation and fertigation practice and so it can vary enormously over the course of the season. It is always higher than the feed solution, typically by 10–20%.

Figure 5a. Collecting run-off solution from strawberry

Figure 5b. Collecting run-off solution from raspberry

A high run-off conductivity is commonly recorded during hot weather, when the irrigation frequency does not match the volume of water removed by crop uptake. This will lead to an increase in salt levels in the compost, resulting in prolonged high conductivity readings from the run-off solution.

High conductivity readings in the run-off solution can warn of potential problems in crop growth. An increase in total volume of salts (which gives rise to high conductivity) can restrict water uptake via the roots. The symptoms of this can vary according to the salt constituents.

High chloride and sodium levels can cause root death. Healthy young roots should always be bright white, especially at their tips (Figure 6). Where run-off conductivity readings are high, it is worth examining the plant's root system to check for any root death (Figure 7). High carbonate and bicarbonate levels will cause crop leaf yellowing, but not root death (Figure 8).

Figure 6. Healthy root system

Figure 7. Dark or brown coloured roots displaying symptoms of root death

Figure 8. Typical leaf chlorosis symptoms caused by high carbonate and bicarbonate levels

What does a conductivity meter actually tell you about your feed solution?

A conductivity meter reading does not tell you everything about your feed solution. Be aware of what it does and what it doesn't tell you.

- **It does** provide a measure of the total volume of salts in the compost, input or output solution. This provides a useful guide of the strength of your feed
- **It does** offer an indication of the total useful nutrients (eg nitrogen, potassium, phosphorous) and background salts. These background salts (eg associations of chloride, carbonate) may be harmless, but can be harmful at high levels
- **It doesn't** provide a measure of the quantity of each ion. Only a full laboratory analysis can provide the exact levels of each N, P, K, Cl and other ions
- **It doesn't** provide an assessment of pH level.

Understanding dilution and conductivity

When growers construct feeding programmes for soft fruit crops grown in soilless substrates, a stock solution is normally formed and then diluted to provide the final feed solution to the plant. It is important to understand the effect that the dilution has on the conductivity of the final feed solution.

Different fertilisers have different conductivity properties. The conductivity of the feed solution (minus background) is directly proportional to the quantity of feed in solution.

For example, a stock solution of potassium nitrate at 150g/l can be diluted at different ratios as illustrated in Table 3. Deionised (distilled) water was used as the background water for the readings in the top line. If the background water is changed to 500μS, then the readings change to those listed in the bottom line.

This direct relationship with electrolytes and conductivity demonstrates how easy it is to adjust conductivity with dilution, if needed. A water source of too high a conductivity can be successfully blended with another low conductivity, eg rainwater.

Table 3. Effect of diluting a stock solution of potassium nitrate (150g/l) using different water sources

Dilution water	Dilution rate		
	1:100	1:200	1:400
Conductivity reading in μS (using 0μS deionised water)	1,890	940	450
Conductivity reading in μS (using 500μS background water)	2,390	1,440	950

Conductivity meters

There are two types of portable meter that are widely used on farms. Both use different mechanisms.

Two probe devices (Figure 9) are available from several manufacturers that measure conductivity and temperature. These are commonly used for measuring the conductivity of solutions.

Figure 9. Typical two probe conductivity meter

Figure 10. Typical three probe conductivity meter

Three probe devices (Figure 10) are also available from various manufacturers that measure capacitance, resistance and temperature. These are mostly used for measuring the conductivity of water in compost pores within the substrate. They can also measure conductivity in solution.

Where and how to measure conductivity

The sampling method and frequency is very important. A meter may be slightly inaccurate, but you will still get useful insight from the trend of values from a sequence of readings.

In compost

Compost is a combination of solids and solution. The compost conductivity is commonly measured with a three probe meter. Positioning and testing time with the probe can give varying results.

- Fully insert the probes and do not wobble them (Figure 11)
- Avoid an unusually dry crop for testing
- The pore water conductivity is measured, so there will be a higher reading in a drier sample of the same compost
- A good time to sample is within half an hour of a liquid feed application, to be sure of an evenly wetted compost.

Figure 11. Probe inserted in side of raspberry container

It is possible to use a traditional meter using an extracted compost sample of a known volume, diluted in a standardised solution. This would be comparatively time-consuming but accurate and is the approach used in the laboratory method.

In solution

The traditional two probe conductivity meter is most commonly used for this, although a three probe meter can also be used. Measuring the input or run-off solution (Figure 12) provides a perfect indication of the conductivity around the roots.

Figure 12. Two probe meter dipped into a solution in a beaker

A root-zone that receives fertigation for prolonged periods (well watered) will reflect the conductivity of the input solution, as all salts are rinsed through the compost profile. There are no probe placement or timing factors to consider when measuring an input or run-off solution.

Understanding and interpreting the conductivity levels

The conductivity of a liquid feed solution is typically in the range of 1,000–2,000µS. On its own, this means little unless you know the background conductivity (water source). This background conductivity typically ranges from 300–700µS. The difference between the two is the amount that your fertiliser injection system is responsible for. Be careful when comparing conductivities where different water sources are used. Nearby boreholes on the same farm can be quite different.

Conductivities quoted in conversation and trials commonly miss an insight into the background conductivity. Two solutions of the same conductivity are likely to have different levels of nutrients.

In practice, crops can cope quite well within a moderate range of water conductivities. A laboratory analysis of the water gives an important understanding of the quantity of each ion involved. Frequently, a large component of a high conductivity is high alkalinity (carbonates and bicarbonates), which are not phytotoxic. Less frequently, there can be high levels of sodium or chloride present, which are harmful. Use a laboratory analysis of your water source to identify if such harmful ions are present before you use it.

Once you have ascertained that your water source is safe to use and you start to feed your crop, you should be checking your input and output solutions at least once a week. You will then be well placed to spot problems early on and remedy in good time.

- Maintain your meter well by storing carefully according to the manufacturer's instructions
- Check its accuracy monthly, using a calibration solution from your supplier.

Tables 4 and 5 list a series of conductivity readings and scenarios that are commonly encountered in the input and run-off solutions in commercial production systems. For each one, a potential cause is provided, along with suggested action that must be taken or solutions to the problem. These assume that no pest or disease problems are giving rise to the problem.

Table 4. Input solution – typical scenarios encountered and remedial action required

Scenario	Cause/Action required
High background water conductivity (eg over 850µS)	Conduct laboratory analysis of water source. It could be an alkalinity problem or more serious. There may be a need to change/mix with water from other sources.
High input conductivity (eg > 2,000µS)	Very probably a dilution problem.
Low input conductivity (eg < 1,000µS)	Very probably a dilution problem.
Good input conductivity (eg 1,500–1,800µS) and well watered but crop exhibiting poor growth	Check conductivity of water. Analyse your feed solution and maybe source water. Something has probably changed (eg high alkalinity, toxic ions).

Table 5. Run-off solution – typical scenarios encountered and remedial action required

Scenario	Cause/Action required
High output conductivity (eg > 2,000µS)	Assuming input is good, it could be a sign of previous under irrigation, resulting in background levels of salts accumulating, a common event in hot weather. Gently reduce feed strength by 10% and increase its frequency and amount to rinse out the accumulation.
Low output conductivity (eg < 1,800µS)	Quite rare except in early season overwintered bags. The crop is probably underfed. Check your input records.
Good output conductivity (eg 1,800–2,000µS) but crop exhibiting poor growth	Something has probably changed (high alkalinity, toxic ions). Check the conductivity of water and feed solution, then analyse your feed solution and possible source water.

Further information

Other useful publications

AHDB Horticulture Factsheet 06/07: 'Principles of strawberry nutrition in soilless substrates'.

AHDB Horticulture Factsheet 15/06: 'Water quality for the irrigation of ornamental crops'.

AHDB Strawberry nutrient feed calculator.

AHDB Strawberry analysis chart – optimum ranges.

Image credits

Glossary

Electrolyte – an electrolyte is another word for an ion that makes up a salt. In feed solutions, a salt is mostly the fertiliser component.

For example:

Potassium sulphate (potassium and sulphate ions, $K^+ + SO_4^-$)

Ammonium nitrate (ammonium and nitrate ions, $NH_4^+ + NO_3^-$)

Calcium carbonate (calcium and carbonate ions, Ca^{2+} & CO_3^{2-})

These ions carry positive and negative charges within the water and feed solution, which also contains H+ and OH- ions.

These charges combine and create the conductivity reading of the solution. The more of them there are (mg/l), the higher the conductivity (µS).

Want to know more?

If you want more information about AHDB Horticulture, or are interested in joining our associate scheme, you can contact us in the following ways...

horticulture.ahdb.org.uk

AHDB Horticulture, Stoneleigh Park,
Kenilworth, Warwickshire CV8 2TL

T: 024 7669 2051 E: hort.info@ahdb.org.uk

@AHDB_Hort

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