NSW GOVERNMENT | Department of Primary Industries

FACTSHEET

Soil solution analysis

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Introduction

Soil salinity can cause salt burn, affect crop quality and reduce yield. Incorrect soil nitrate levels affect crop growth, quality and yield and excessive nitrogen applications are wasteful and can result in contamination of water tables and waterways. It is essential that soil salinity and nitrate levels be monitored throughout the crop cycle to ensure optimum crop growth.

The extraction and analysis of soil solutions is a quick and easy way to monitor both soil salinity and nitrate levels. The sample can be analysed on site using an electrical conductivity (EC) meter and nitrate test strips.

What is the soil solution?

The water that is held in the soil is known as the soil solution. It contains a mix of nutrients. Salts and nitrogen are taken up by the roots from this soil solution. Soil solution analysis should be used in conjunction with a soil moisture monitoring program.

How can monitoring the soil solution help irrigated crop management?

Analysing soil solutions can help identify excessive nutrient and salinity levels in the soil and nutrient leaching past the root zone.

Monitoring the soil solution within and below the root zone can identify incorrect nitrogen application. Excessive nitrogen application can be identified by an accumulation of nitrate in the soil solution collected from within the root zone. Nitrate is a highly mobile nutrient and can be easily leached below the main root zone where it becomes unavailable to the plant. Analysing the soil solution below the root zone can identify possible nitrogen waste through nitrate leaching.

Nitrate is the main nutrient of concern, however excessive levels of potassium and calcium have also been found in highly intensive nutrition programs in light textured soils. Nutrient accumulation can cause root burn and salinity issues.

Soil salinity is usually monitored using an annual soil test and observations of plant leaves for symptoms of salt burn. By the time symptoms appear on leaves, yield and/or crop quality effects may have already occurred. In contrast, the soil solution can be tested throughout the growing season and soil salinity levels monitored. Corrective action, such as increased irrigation, can be taken to maintain salinity levels within acceptable limits before yields or crop quality are affected.

What are the limitations of soil solution analysis?

It is normal to experience site variability. Readings from a number of probes within a single block may be highly variable. At least three sites may initially need to be installed to assess site variability. Due to this normal site variability, soil analysis readings should be viewed as a tool to enhance nutrient management not as a definitive measure of overall soil nutrient status.

A time commitment is required if deciding to implement a soil solution monitoring program.

Nitrate and salinity levels are the key focus of soil solution monitoring. The monitoring of other nutrients such as potassium, calcium, magnesium and phosphorus is not recommended. These nutrients are bound to soil particles and their levels as measured in the soil solution do not provide a reliable indication of their supply and availability to the crop.

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Soil solution sampling devices

The devices used to extract soil solution are called lysimeters. There are two types of lysimeter, active and passive.

Ceramic suction cups are active lysimeters. They draw water out of the soil through negative air pressure (suction) exerted within the ceramic cup.

Passive lysimeters intercept the downward flow of water (the wetting front) during an irrigation or rainfall event and direct the water into a collection vessel. The FullStop® Wetting Front Detector is an example of a passive lysimeter.

The two types of lysimeter are suited to different situations, and have different installation and operational procedures. The advantages and disadvantages of each are outlined below. Users should assess which type of device best suits their needs and management style.

Ceramic cup samplers

There are two types of ceramic cup samplers, soil solution extraction tubes (SSET) and ceramic cylinder samplers.

The ceramic tips come in high or low flow models. High flow tips are better suited to sandy/loam soils and low flow tips are more suited to clay soil types. Automated ceramic samplers are also available for scientific applications.

Soil Solution Extraction Tubes (SSET)

Soil solution extraction tubes are generally supplied in two diameters, 40 mm and 20 mm (Figures 1 & 2). Both sizes operate equally well. Some users prefer the 20 mm units because the PVC tube protrudes out of the ground and is easy to re-install when required. This sized tube is also slightly easier to install and less soil is disturbed during installation. Both the 20 mm and 40 mm wide tubes provide similar volumes of soil solution.

Figure 1. Example of a 40 mm diameter SSET.

Figure 2. Example of a 20 mm diameter SSET.

Advantages

- Ceramic cup samplers are easy to install and only disturb a small volume of soil.
- Reliable sampling can be conducted after a number of irrigation cycles.
- Samples can be taken at slightly drier soil moisture levels than the FullStop® Wetting Front Detector.
- Ceramic cup samplers can be placed at any depth.
- Ceramic cup samplers may be inexpensive if assembled by the user.

Disadvantages

- Ceramic cup samplers need to be primed by applying suction one or two days before the sample is extracted
- The device will not operate if the ceramic tip loses contact with the soil due to poor installation and/or dry soil, or if there are air leaks due to a possible cracked tip or poor manufacture. Air leaks can be checked prior to installation by pushing air into the tube and checking for escaping air bubbles. Very fine air bubbles can be expected but large air bubbles are a sign of air leaks.
- The ceramic tip can become blocked with silt in clay or loamy soils or with fine calcium carbonate particles.

Ceramic Cylinder Samplers

Ceramic cylinder samplers are the cheapest commercially available samplers and they can also be handmade. The volume of the ceramic cylinder alone is too small to contain an adequate amount of soil solution. A disposable syringe is attached to the microtube to increase the capacity (Figure 3).

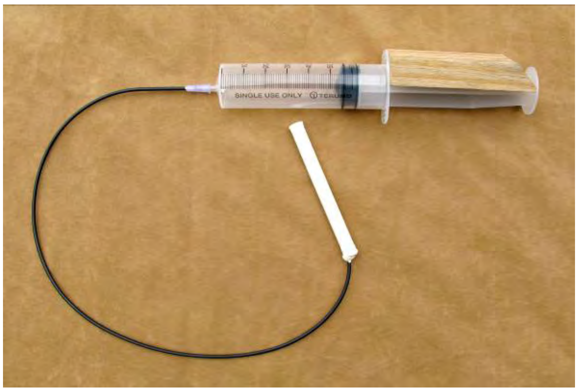

Figure 3. Example of a ceramic cylinder sampler

To take a sample, the syringe plunger is pulled back to cause negative air pressure and held in place with a small piece of dowel or a wooden block. The soil solution is removed from the syringe within a couple of days of priming.

Advantages (compared to ceramic samplers)

- Ceramic cylinder samplers are pre-assembled and the component parts are inexpensive to manufacture.

Disadvantages (compared to ceramic samplers)

- It can be difficult to get good soil contact during installation.
- A syringe needs to be attached to the device during sampling.
- The soil solution must not be stored in the syringe for an extended period as microbial growth may occur and distort the results.

Wetting front detector (FullStop®)

The FullStop® wetting front detector (Figure 4) is simple in design and application. It can be used to monitor the soil solution and also the depth of irrigation.

Advantages

- The FullStop® does not require priming to collect a sample.
- It takes and stores a sample at the same soil moisture content range (0 to –3 kPa) at each sampling event.
- It can be used both as an irrigation management tool to identify when an irrigation event has reached a certain soil depth and as a soil solution sampler.
- It links water monitoring (wetting front depth) and solute monitoring
- Samples of up to 50 mL can be obtained immediately after a strong wetting front moves past the device. A 5 mL sample is stored in the device after it drains which is enough to conduct a salinity and nitrate test.

Disadvantages

- It is not suitable for use at depths greater than 500 mm for drip and 400 mm for sprinkler systems.
- A large hole (200 mm diameter) needs to be dug to install the device and 1–2 months of settling is required before reliable results can be obtained.
- In some circumstances clay may permeate through the sand filter and cause muddy samples.
- It only collects a sample after an irrigation or rainfall event
- The indicator is susceptible to breakage and needs to be frequently inspected and replaced as necessary.

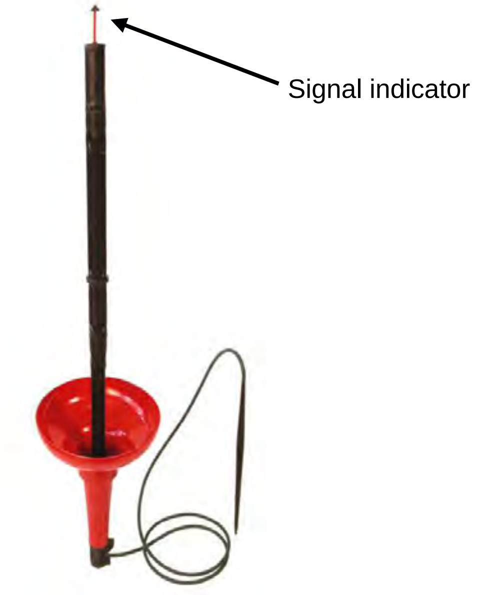

Figure 4. A FullStop® wetting front detector
Source: www.fullstop.com.au

Maintenance

To ensure reliable operation, ceramic samplers and the FullStop® require regular maintenance.

Both devices contain rubber tubing that can be chewed or damaged by animals. If damaged, the ceramic sampler tubing must be shortened. The full stop tube can be fixed or extended with a 2.5 mm irrigation joint and hosing.

The ceramic sampler tips can become clogged with silt, clay or calcium carbonate. Samplers can be easily tested by placing the tips in a bucket of water and priming the tubes. They should be able to collect about 50 mL within 20 minutes. If the ceramic tip is underperforming, soak and prime the tube in a bucket with a mild acid solution (*i.e.* diluted concrete cleaning acid) to dissolve the calcium carbonate deposits. Flush with fresh water three times to remove acid residues from the ceramic tip. Tips clogged with silt deposits may need replacing.

It is very important to maintain the signal indicator on the FullStop® (Figure 4). If the indicator breaks, replace immediately or seal the top with some sticky tape to prevent ant intrusion. Ants can deposit soil in the reservoir and can cause tube blockages. The reservoir can be cleaned by back flushing. If clay is still present in the soil solution after back flushing, reinstall the FullStop® with clean sand.

Insects can also enter the tubing of the ceramic sampler and FullStop®. Ceramic samplers come with a stopcock that can be sealed. The FullStop® comes with a plastic rod to plug the tube. The rod can permanently expand the rubber hose making it difficult to obtain a good seal when using a syringe to extract a sample. It is advisable to either taper down the diameter of the plastic (using sandpaper) or use another plug that will not stretch the pipe. Alternatively, install a stopcock similar to that used in ceramic samplers.

Installation

There are various ways to install soil solution devices and these are explained in videos located on the NSW Department of Primary Industries (NSW DPI) YouTube® site under the title 'Soil Solution Analysis'. The videos describe the installation of 40 mm and 20 mm wide SSET units. FullStop® installation information is available at www.fullstop.com.au

Soil solution analysis results can be variable due to differences in root density within the root zone and the possible irregular movement of water in the soil. It is important to install at least three sets of soil solution tubes on each individual site to enable some assessment of site variability. If results are consistent then the number of sampling sites may be able to be reduced. For research purposes at least five sites per treatment is recommended.

Analysis methods

To ensure suitable samples can be extracted from the site the soil must have recently been wetted either from rainfall or irrigation. Soil solution samples can then either be analysed on-site or sent to a laboratory.

On-site measurement involves the use of a salinity meter and nitrate test strips. Other nutrients including potassium, calcium, magnesium and phosphorus can also be measured concurrently. However, in contrast with chloride and nitrate ions, these nutrients are more difficult to estimate accurately.

Salinity

Salinity is measured with a hand held electrical conductivity (EC) meter (Figure 5). These meters are relatively inexpensive and reliable. The meters should be calibrated regularly to ensure accurate results.

Figure 5. Electrical conductivity (EC) meter.

Nitrate and other nutrients

Nitrate test strips are cheap and easy to use. The strips change colour when they react with nitrate. The colour can be compared against a scale for an approximate estimate of nitrate content (Figure 6) or read by an instrument for a more accurate estimate.

Colour scale comparison test strips indicate nitrate levels in 50 to 100 ppm (mg/L) increments for low readings and 250 ppm increments for high readings. For most field applications they provide a useful indication of the nitrate level in the soil solution. It is important to be aware that muddy samples can mask the colour of test strips making them difficult to read.

Figure 6. Reading a nitrate result from a test strip using a colour chart.

For more accurate nitrate measurements the nitrate test strips can be read by an inexpensive Merck RQ Easy® meter (Figure 7).

Figure 7. Reading a nitrate result from a test strip using an RQ Easy® meter

The Merck RQ Flex® meter (Figure 8) is a laboratory grade testing device that provides a greater level of accuracy and it can also be used in the field. It reads test strips in the same manner as the Merck RQ Easy® meter with the added advantage of being able to read test strips for pH and other nutrients such as calcium, phosphate and magnesium.

The Horiba Cardy® nitrate meter (Figure 9) provides a variable level of accuracy. A limitation of the meter is that the level of accuracy is reduced when readings fall below 62 ppm. The sensor also responds to chloride and organic ions which can elevate readings. The sensor requires changing annually and as it begins to wear out it becomes unstable leading to inaccurate readings. Horiba also manufacture sodium and potassium meters.

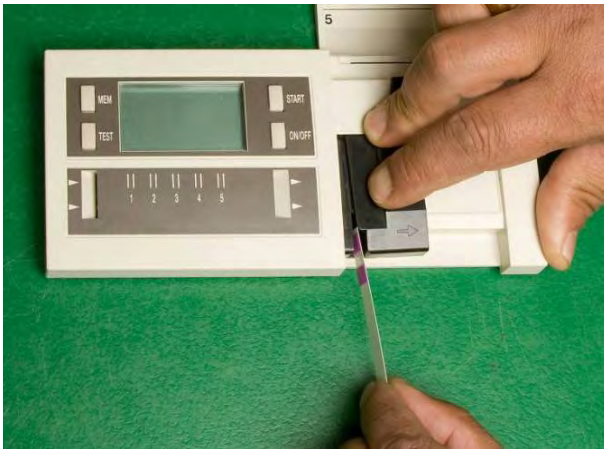

Figure 8. Inserting a test strip into the Merck RQ Flex® meter to take a nitrate reading.

Figure 9. Horiba Cardy® nitrate meter

Wet chemistry

Wet chemistry kits (eg Aquaspex®, Aquamerck®) are similar to chlorine pool test kits. They are very easy to use and give an indication of nutrient levels at a similar or slightly better level of accuracy than test strips read against a colour chart. Wet chemistry kits are available for measuring most nutrients. Read all warnings and information on test kits to ensure all safety procedures are followed.

pH

pH meters require regular calibration with special buffer solutions to ensure continued accuracy. When comparing pH meter readings from various brands of instrument, be aware that results can differ up to 0.5 pH units. Some meters also need probe or internal gel replacement within a set period of time. Measurements take several minutes to stabilise.

pH test strips are less accurate than a pH meter but can still provide an acceptable indication of pH.

Laboratory analysis

Samples can also be sent to a laboratory for analysis. It usually takes between 7 and 10 days for results to become available. Laboratory analysis is more costly however it allows for a wider range of nutrients to be accurately measured. It is best to choose an accredited laboratory. These laboratories are independently assessed for technical competence and reliability. Always contact the laboratory to find out how to store and transport your sample prior to sending.

Interpretation of results

Analysis of the soil solution is one tool that can help you make decisions about your irrigation and nutrition management program. Site variability must also be considered when assessing results from a limited number of soil solution samples. It is important to realize that there are no interpretation standards available, only some general guidelines. Results should be interpreted by comparing trends from season-to-season and block to block with crop performance indicators such as yield and fruit quality.

Long-term soil solution monitoring provides the most useful information for improving crop management.

Nitrate interpretation

Nitrogen content in soil solution can be expressed in two ways; nitrate (NO_3) or nitrate nitrogen (NO_3-N). Most tests report nitrate. Nitrate nitrogen readings indicate the total nitrogen component of nitrate, whilst nitrate readings indicate the total weight of the nitrogen and oxygen in nitrate. To convert nitrate nitrogen to nitrate multiply by 4.43 (*e.g.* 1 ppm nitrate nitrogen = 4.43 ppm nitrate).

A general guide for nitrate levels in soil solution for irrigated horticulture crops are provided in **Table** .

Table 1. General guide for interpreting soil solution nitrate levels for irrigated horticulture crops.

Soil solution nitrate level	**Nitrate ppm**
Very low	Below 10
Low	25–100
medium	100–250
high	Above 500

Salinity interpretation

Soil salinity (EC_e) threshold charts have been developed for different crops (Figure 10). The salinity threshold value is the average salinity at which salt begins to affect growth. These can be used to derive salinity thresholds for the soil solution. Multiply the recommended soil salinity threshold by 0.5 to convert to a soil solution threshold. For example, using **Table 2** the soil salinity threshold for oranges is 1.7 $EC_{e.}$ So 1.7 multiplied by 0.5 gives a soil solution threshold of 0.85. Soil salinity (EC_e) tables are available from State Departments of Agriculture and can also be sourced from the internet.

Note: High levels of salt can interfere with nitrate and other nutrient tests. Check the instructions on the analysis kit for information about the interference from salts or organic ions.

Figure 10. Extract from the NSW DPI slide-out chart displaying salinity thresholds for various crops.

Table 2. Examples of soil salinity thresholds provided by salinity threshold charts.

Crop	**Soil Salinity EC_e**	
	Threshold	25% yield loss
Almond	1.5	2.8
Broccoli	2.8	5.5
Carrot	1	2.8
Orange	1.7	3.2

Analysis of other nutrients

Analysis for other nutrients such as potassium, calcium, magnesium and phosphorus is possible but the results can be inconsistent and not reflective of fertiliser applications. This is due to the way the nutrients are stored in the soil. The soil holds these nutrients on the clay particles, until they are released into the soil solution. This process buffers the soil solution from dramatic changes in nutrient concentration. In some sandy soils with very low amounts of clay and a poor buffering capacity, analysis for these nutrients is possible and can help identify shortages and excessive application.

Further information

A workshop on soil solution analysis has been developed and can be held on request. Enquiries should be directed to Steven Falivene. More information on case studies and contacts for equipment and component parts is available from the *Soil Solution Monitoring in Australia* report available on the NSW DPI website.

References

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