Soil, water and plant tissue testing at the Wollongbar DPI environmental laboratory

Teacher's Guide

Video –synopsis

Length: 23 mins 18 secs

This video follows the process of preparation, testing and reporting of results from soil, water and plant tissue samples. The sample results are discussed in reference to application and management in the field. A range of high-tech testing instruments which are used in industry for various sample testing methods are also shown.

Throughout the video, fundamental elements of experimental design are discussed including standardised testing procedures, which allow for accurate results capture and reporting.

The video would be a very useful watching experience to support in class learning and practical testing of soils, water or plant matter or recognition of importance of nutrients present for plant growth and production.

It is recommended that teachers watch the video before showing it to students to assess suitability. There are scientific terms used in the videos that students may not be familiar with and definitions have been provided to allow for student scientific literacy and metalanguage development.

Laboratory testing and service and the DPI

NSW DPI Wollongbar environmental laboratory is one of four nationally accredited DPI testing and service laboratories. The role of NSW DPI laboratory services are to provide quality assured laboratory testing services in the fields of veterinary pathology, analytical chemistry and plant health.

NSW DPI laboratory services undertake diagnostic testing to support surveillance, accreditation, export, diagnostic and emergency activities for animal and plant diseases in NSW and interstate.

NSW DPI laboratory services is a network of National Association of Testing Authorities, Australia (NATA), accredited laboratories across the state with laboratory facilities at Wollongbar, Menangle, Wagga Wagga and Orange. These laboratories are equipped with facilities for organic and inorganic analytical chemistry, (including trace analysis for environmental and pesticide residues), feed testing, olive oil analysis, plant pathology, entomology and veterinary pathology (including the disciplines of serology, histology, parasitology, genetics, bacteriology and anatomical pathology).

Careers highlighted:

- Sarah Morrison – Co-ordinator Analytical Services
- Craig Hunt- Technical Officer
- Murali Samithamby- Technical Officer
- Steven Leahy – Analytical Chemist

Curriculum links

Stage 4 Science and Technology

- ST3-10LW - describes how structural features and other adaptations of living things help them to survive in their environment
- ST3-11LW - describes some physical conditions of the environment and how these affect the growth and survival of living things

Stage 4 Geography

- GE4-5 discusses management of places and environments for their sustainability
- GE4-3 explains how interactions and connections between people, places and environments result in change

Stage 4 Agricultural Technology

- AG4-6 identifies and uses skills to manage the interactions within plant production enterprises
- AG4-8 examines the impact of past and current agricultural practices on agricultural sustainability
- AG4-9 identifies aspects of profitability, technology, sustainability and ethics that affect management decisions
- AG4-11 undertakes controlled experiments in agricultural contexts

Content:

- investigate and analyse soil quality indicators, e.g. soil texture, structure, pH and soil profiles (Core A Plant Production 1)
- design and conduct a controlled agricultural experiment, for example: (ACTDEP049)
    - soil testing to determine the influences on plant growth (Core B Agricultural systems and management)
- draw conclusions from evidence and the analysis of data, for example: (ACTDEP051)
    - identify fertilisers for optimal plant growth (Core B Plant production)
- identify opportunities provided by the agricultural sector, both as an employer and as a user of products (Core B Agricultural systems and management)

Stage 5 Geography

- GE5-3 analyses the effect of interactions and connections between people, places and environments
- GE5-5 assesses management strategies for places and environments for their sustainability

Stage 5 Agricultural Technology

- AG5-6 explains and evaluates the impact of management decisions on plant production enterprises
- AG5-8 evaluates the impact of past and current agricultural practices on agricultural sustainability
- AG5-9 evaluates management practices in terms of profitability, technology, sustainability, social issues and ethics
- AG5-11 designs, undertakes, analyses and evaluates experiments and investigates problems in agricultural contexts

Content:

- investigate and analyse soil quality indicators, e.g. soil texture, structure, pH and soil profiles (Core A Plant Production 1)
- design and conduct a controlled agricultural experiment, for example: (ACTDEP049)
  - soil testing to determine the influences on plant growth (Core B Agricultural systems and management)
- draw conclusions from evidence and the analysis of data, for example: (ACTDEP051)
  - identify fertilisers for optimal plant growth (Core B Plant production 2)
- identify opportunities provided by the agricultural sector, both as an employer and as a user of products (Core B Agricultural systems and management)

Stage 6 Agriculture

Preliminary course

- P1.1 describes the complex, dynamic and interactive nature of agricultural production systems
- P1.2 describes the factors that influence agricultural systems
- P2.1 describes the biological and physical resources and applies the processes that cause changes in plant production systems

Content:

- measure and describe the features of soil including colour, texture, structure, pH, organic matter, parent material and water holding capacity
- identify macro and micro nutrients important for plant growth
- select fertiliser(s) appropriate to the soil and the requirements of the crop/pasture
- research and describe a current technology in plant production or marketing

HSC course

- H1.1 explains the influence of physical, biological, social, historical and economic factors on sustainable agricultural production
- H2.1 describes the inputs, processes and interactions of plant production system

Content:

- describe chemical characteristics of a soil including soil pH, ion exchange capacity, soil carbon and nutrient status
- describe physical characteristics of a soil including soil structure, texture, porosity and bulk density
- perform a first-hand investigation to analyse and report on the physical and chemical characteristics of a soil

Vocabulary used

Aspirate: method whereby matter is drawn into the auto sampler by suction.

Colorimetric reactions: Colorimetric analysis is a method of determining the concentration of a chemical element or chemical compound in a solution with the aid of a colour reagent

Dilution: Dilution is the process of decreasing the concentration of a solute in a solution, usually simply by mixing with more solvent like adding more water to a solution. To dilute a solution means to add more solvent without the addition of more solute.

EC (Electrical conductivity): Electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. EC is measured in units called Siemens per unit area (e.g. mS/cm, or milliSiemens per centimetre), and the higher the dissolved material in a water or soil sample, the higher the EC will be in that material.

Extracting solution: Extractions are a way to separate a desired substance when it is mixed with others. The mixture is brought into contact with a solvent (extracting solution) in which the substance of interest is soluble, but the other substances present are insoluble. For example, Brays No 1 extracting solution extracts Phosphorus from the soil. The extracted phosphorus is measured colourimetrically. Other extracting solutions mentioned throughout the program include Potassium Chloride (KCL), and Colwell Phosphorous.

Homogenous sample: a sample which has similar or identical traits or characteristics

Incubator: an apparatus with a chamber used to provide controlled environmental conditions e.g. temperature, humidity, oxygen etc.

Microbiology: study of micro organisms

NATA (National Association of Testing Authorities, Australia): NATA is a third party auditor that controls the quality assurance of the testing procedures within a laboratory.

Nutrient: a substance that provides nourishment essential for the maintenance of life and for growth.

Optical emission spectrometer: apparatus that carries out Optical Emission Spectroscopy, (OES). OES is a reliable and extensively used analytical technique used to establish the elemental composition of a wide range of metals. OES involves using a high voltage spark to heat a small sample to thousands of degrees Celsius, vaporising it to plasma. The 'excited' plasma metallic atoms within the sample emit light. The wavelengths within the light are separated into element specific wavelengths by the spectrometer. The intensity of light in the wavelength corresponds with the concentration of the metallic element in the sample. OES uses the part of the electromagnetic spectrum, the visible spectrum and part of the ultraviolet spectrum.

pH (potential hydrogen): pH is a measure of the acidity of the water or soil based on its hydrogen ion concentration. The pH of a material ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower pH corresponds with higher [H+], while higher pH is associated with lower [H+].

Plasma: the fourth state of matter. Plasma is a hot, ionised 'gas like' substance. Electrons in plasma move freely among the nuclei of the atoms.

Reagent: a substance used to detect or measure another substance or to convert one substance into another through chemical reaction.

Spectrophotometer: an apparatus for measuring the intensity of light in a part of the spectrum, especially as transmitted or emitted by particular substances.

Substrate: a substance which an enzyme (substance produced by living cells) acts on to produce a chemical reaction.

Quality control: a system or process which aims to maintain or meet quality criteria standards by testing the output or service against the quality criteria.

Transcript of video

Presenter: Sarah Morison, Coordinator Analytical Services

Hi I'm Sarah Morison and I am the Coordinator of Analytical Services at Wollongbar Environmental Lab. So we produce analytical reports that the results help people improve sustainability of agriculture, provide more productive crops and also monitor soil and water as they are really important resources in agriculture.

Receiving samples

So these are our soil and water testing kits, they come in through the post quite often. So we can have farmers send us these in the post for their water and for their soil if they want to know what's going on.

So this is a soil kit, so inside this we will get a bag of soil. So the person that sent it is will have labelled it with an identifier so that we know which soil it was that they want to look at. There will also be paperwork in here that is going to tell us which tests they want. We've organised packages so depending on what the use is for the soils they will be able to pick a particular package. So this one they have picked the horticulture package. So because they have ticked horticulture there is a whole range of tests that we know need to be done for this soil sample.

First thing that we are going to have to do for this soil sample is to log it in to our system so that it gets a unique number so we can follow it all the way through the lab right to when the results and the report are produced.

Out of the water kit we will get a water sample and paperwork as well. So lately because of the drought we have been getting a lot of water samples as people are trying to find a new water source. They might be looking at a new bore or possibly a creek that they didn't use before so we need to test if that water is going to be suitable for the use that they are intending. If you use a water that is too salty for your crop or for your cattle or for your sheep you can do a lot of damage. And it can be really expensive, so if you get sick animals or you block your irrigation system because you used the wrong water that can be really expensive whereas a quick water test will tell you what this water is going to be suitable for. So this one is a dam and they want to know if they use it for their crops and in their house. We are going to do about seven or eight tests on this and then we will be able to tell them.

Sample preparation

OK once a sample arrives at the laboratory and it has been given a unique number in our system, if it is a soil or a plant then we have to bring it down to the shed and that is because we need to dry and grind it before we can analyse it.

So what we will do it we will pour some of the soil – now this one is already quite dry however they don't often come to use like this we can sometimes just get big wet chunks of soil. So this would get put, with its own little number – still the number has to follow it through the whole system – into the oven. Now these get dried at 40 degrees. Now sometimes that can take 24 hours, for a really wet soil it could take three days.

So plants are treated in the same way soil is, so we will often just get the fresh plant material, so sometimes we will get the whole plants of sugar cane, we might get leaves from a bean plant we might get blueberry bushes depending on what the person is looking for. And we get that and we will put that also in the oven, we will dry it, and then we will put it through our mill grinder so that we get a fine powder and then that powder then goes through a similar process of extracting solution into a liquid and then into the instrument.

A water sample is a little bit different, so waters come in and they can usually be analysed without as much preparation as a soil. So most waters can go straight into the analytical equipment without much pre-treatment. Sometimes if it needs a total digest for metals we will have to add some acid to that sample to release all the available metals in that sample. Other than that water samples will tend to just be filtered and tested. Now with water, it's not stable like soils so water should be tested within 24 hours of being sampled so it is really vital that water samples get the laboratory quickly.

OK, so when we have dried a sample, this is some leaf litter, now it's still way too large to put through our analytical equipment so we have to put it through the grinder. So this it is a mill grinder. The sample goes in this area here, we turn it on, the hammers spin around and it comes out the bottom here as a fine powder like that which then we can digest. Now the reason for having fine particles like this from a large sample is that you get a better, repeatable, result. This is called a homogenous sample. If we were trying to analyse something like this… this chunk is going to give a different result to say this bit because the particles are all different and what is going to be in them is going to be different. Once it is ground up to a fine powder you get a much more overall, repeatable result.

So in the laboratory the whole idea is to get a sample with unknown values and find out a known value for that. So how we do that in a laboratory is we use calibrations for a lot of our equipment. Before we run an unknown sample, we run a series of samples through the instrument that have a known value so we can create calibration curve. Then we run the unknown sample through that same calibration curve and wherever they fit along that curve is the value that then we give them. Now another way to ensure that the number that we generate is correct is quality control. So quality control is vital to any laboratory. We run another series of known samples throughout the batch of analytical work that is a known value so that we can always check that we are getting the correct answer. We also run blank samples so that we make sure we are not getting false positives. And we do duplicates to make sure that the methods are repeatable, so we run the same sample twice so that we make sure that we get the same result. If the repeatability is over 15% then we know that something is going on and we might have to repeat the batch because we need the results to be repeatable.

Electrical conductivity and pH

So this is our pH and EC (electrical conductivity) analyser for soil. Now pH is a really, really important test for soil, so it's going to explain how a lot of the other nutrients are reacting within the soil. If you have a really low pH that mobilises a lot of the metals and you can get some toxicity because there is a lot of those metals available. If you have a really high pH it can bind some of those metals up and so you might get deficiencies.

This is just done with a water extract, so we weigh 12 grams of soil and we add water to that. It gets tumbled for an hour and then we have it put on this instrument. It's got EC which is electrical conductivity and a pH probe so we are measuring both at the same time. So we are looking at the salt content and the acidity or the alkalinity of the soil in this test. After it has read a sample it will then go back into the wash so the probes get washed and then into the next sample. You can see here there is a magnetic stirrer, it's stirring the sample and that is to make sure it is getting a nice overall reading of the sample. Now like all laboratory equipment this has been calibrated against known samples before it starts reading the unknown samples. And within these samples we also have a quality control sample which is a soil that we know the pH and the EC of and we test that every 20 samples to make sure that we are getting the correct results.

So you can see this sample here, the pH is around 4.5 and the EC is 650, 660 micro Siemens.

This is the computer program that runs the instrument, and so the individual number that we give each sample is put into this instrument, the ones in green have already been analysed and this is the rest of the run that it still has to do.

So water we also do pH and EC for and we do that on a very similar instrument but we do that on another laboratory. We tend to not mix soils and waters together because waters are a lot cleaner obviously than soils are and so we don't want to get any contamination from the soil sample into the water samples.

Extracting solutions

In the laboratory for soil testing we use a range of different extracting solutions. Now this is because we are trying to show what is available to the plants in the soil. So we don't necessarily want to know the total amount of an element that's in the soil say for nitrogen or phosphorus, we want to know what's available to the plant and therefore what will be affecting the crops. So to do this we use a range of different extracting solutions, so something like a 2 molar KCl or a Brays extracting solution which is for Brays phosphorus.

After the extracting solution has been added and the sample has been tumbled so say for an hour, anywhere between an hour and sixteen hours they will go on these big tumblers it will come out looking like that. Now that can't go through our sensitive analytical equipment so we have to centrifuge it which is spinning it at 3000 rpm for 5 – 10 minutes. So it will come out looking a little bit more like this and you can see the separation between the solid and the liquid. So the analyte that we are now looking for so in this case phosphorus will be in the solution and that's what's going to be plant available. This will now be filtered through an .45 micron filter and then the sample will be placed on the analytical equipment.

Total nitrogen and total carbon

Presenter: Craig Hunt, Technical Officer

This instrument is the Leco total nitrogen, total carbon analyser. It uses a Dumas combustion technique. So this instrument, the Leco, analyses plant and soil samples, it analyses them in a powdered form. So plants are ground and soils are ground to a fine powder. We weigh half a gram of sample into little ceramic boats, just like this. Press the print button and it goes into the computer, that sample is then placed into the carousel for analysis. Then through the autosampler they go into the furnace, the furnace heats the sample up to 1200 degrees, all the gases are captured, it goes through a detector and through the magic of science it gives us total nitrogen, total carbon.

Nutrients

Presenter: Murali Samithamby, Technical Officer

This instrument is called Flow Injection Analyser, the basic principle is spectrophotometer colorimetric method. So in this instrument we run - in water - ammonia, phosphorus, nitrate, nitrite, chloride, total nitrogen and total phosphorus and silica. In soil we run Bray phosphorus – if the soil is acidic - Bray phosphorus and if it is base (more than pH 7) Corwin phosphorus and Olsen phosphorus and if the soil is for sugar cane farmers, we do it for acidic extractable phosphorus. If it is soya beans, we do calcium chloride extractable phosphorus. And we do another two tests mineral nitrogen and nitrate nitrogen in the soil. So that is mainly to determine the nitrogen level in the soil. And also, we do the chloride in the soil to check the salinity. And plants we also test for chloride and nitrate. Nitrate we do because there can be a toxicity for some of the animals, that's why we check the nitrate in the plant. And chloride we check it if there is more salinity there and chloride also it is nutrients for the plant because if it is high it is toxic to the plant. And we can do the fertiliser also for nitrogen, phosphorus, potassium.

So this is a versatile instrument. You can run four chemistries in one line. For example if it is phosphorus, we have a chemical reagent we prepare and pump through the pump and when the pump is pumping the reagents, this water sampler takes from the sample from here, then it's mixed with the reagent, if it's phosphorus it makes a blue colour development. And it goes to the small spectrophotometer and detects the absorbance. And we already apply the known concentration and find out the absorbance and it already has a graph (of the calibration curve). So, if it's an unknown sample it finds out the absorbance only and then it goes directly to the computer and finds out the concentration (by comparing it to the calibration curve). That is the basic principle.

So it is each one minute we get the results. Actually, it's doing a calibration now at the moment. So it is starting to make a calibration curve, so a known concentration is applied, it's found out the absorbance and it has made a graph. If any unknown concentration, any new samples, when we aspirate through the auto sampler it goes to the new graph and finds out the concentration. So from that we calculate the milligram per litre or if it is soils milligram per kilogram. That's the way we do it and for soil samples we have to extract with the different extractions because it is passing through the reagents in a 0.5mm diameter tube.

So all nutrients we do with colorimetric reactions. Earlier, more than 20-25 years back, they did it with manually adding the reagent to the test tubes and shaking and make a coloured development and go to the spectrometer and … this is automated … you can see that each auto sampler is moving and takes the sample and each one minute results is coming.

Presenter: Steven Leahy, Chemist

Hi, I'm Steve I'm the chemist in the lab here. This is one of my instruments called in Inductively Coupled Plasma. This is an Optical Emission Spectrometer, basically what we have here is a plasma that's as hot as the surface of the sun.

You can see here this is sodium in the plasma, it changes it from green to an orange colour in the plasma. You can see that orange tail that's indicative of sodium. I am now going to change to barium, this should change the plasma to a nice blue colour. So this blue is indicative of barium in the plasma.

As you can see we have a series of pumps here that take the sample into the plasma so I can analyse it. I usually receive the samples like this, often digested in acid so it's in a liquid form that can be transported efficiently up into my argon plasma and then through to the detector.

Mainly we test for heavy metals using this. Sixty-five of the elements on the periodic table can be analysed by this instrument. In chemistry it's the old adage that it's the dose that makes the poison, so everything is toxic at a certain concentration so some things aren't toxic until you get a really high concentration and you've got to find that narrow window where it's available enough for a plant but it's not too available that it becomes toxic.

So we measure the different wavelengths, so for sodium we have a number of different wavelengths, so if we look at this wavelength here, it is one of the orange wavelengths. As you add more sodium to the plasma your peak height will increase because there is more sodium. If we add known concentrations of sodium to calibrate, we can then construct a calibration curve and then once we run an unknown sample the intensity can be calculated off this calibration curve to give us the known concentration of the unknown sample.

Microbiology samples

Presenter: Sarah Morison

So I am just taking these out of the incubator, these are our microbiology samples. Now they've been in here for 18 hours and you can see that they are coloured up so we are going to take them over and read them.

Alright so we are going to have a look at some microbiology testing, we only do basic micro here at the lab. We are looking for e-coli which is a bacteria found in the gut of warm blooded animals and it's an indicator of faecal contamination. So e-coli for humans there should be none present in our drinking water. So for stock you can have 100 e-coli per 100mL. Over that and it could cause digestive upset and illness in your stock. So the sample we are looking at today is quite an interesting one, it is from the Hippo lake at Dubbo Zoo. Now they are monitoring that to make sure the e-coli levels don't get too high and make the animals sick. So when we do a test like this we will put a substrate like this into 100mL of a water sample and then we put it into one of these trays. If there is e-coli present you can see these wells will colour up. Now we count these wells and we calculate them off a table and it gives us the number per 100mL. So this one is our quality control and that is e-coli. So here we have the hippo pond, we've had to do a few dilutions because the counts are going to be really high. So this is a x10 dilution and it's all coloured up so we can't get an exact number there. With the 500 dilution we will be able to count that because there are some that have not coloured up. And then we've got a 1000 dilution. Now for this one I would probably choose the 500 and I am going to put it under there and I am going to count the glowing wells and we will be able to work out how much e-coli is in the hippo lake at Dubbo Zoo because when you put it under a fluorescent light it glows

Reporting

OK so after all that process of coming to the laboratory, being dried, ground and extracted and then tested we actually produce a final report. So this is a final soils report for a cropping package, so we've got tests like pH, EC, sulphur, Colwell phosphorus, organic carbon, nitrogen and then all your exchangeable cations. So this is going to give you an overall picture to the general health of your soil. What your pH is, what nutrients are available and whether or not you might have deficiencies in your soil or possibly excesses of some elements in your soil. So this report is from the farm here at Wollongbar. Now I don't know if you can see here but the aluminium saturation here on this sample is 15, so to have an OK level of aluminium it should be under 5 so that one is actually high, so that's getting into the toxic range. Now that's because the pH is quite low so that's releasing the aluminium and causing toxicity in the soil. Whereas when you come along further, this one where the pH is a little higher at 4.8 the aluminium saturation is around about 3 so that's under and it's in the optimum level. So it doesn't take much of a change in pH to have a big effect on what's available in the soil. Something else we can have a look at for this would be the amount of nitrogen in the soil, so typically here we can see there is plenty of nitrogen in the soil. So that indicates that we are not going to need to fertilise these particular paddocks, there's plenty of phosphorus and nitrogen but we are going to have to change the pH. So to do this we are going to lime the soil to try to increase the pH a little bit and hopefully get some of those elements back into balance.

You will also see on our report here that there is a symbol with NATA written on it. Now NATA is a third-party auditor that controls the quality (of the procedures) that go on within a laboratories. Now we are a NATA accredited laboratory. Now what that means, every 18 months NATA come in and they do an audit of every process that we have. They will go through the way we run our instruments, they go through all our methods, they go through how we write things down, they go through what is on our report. So every little bit of everything we touch and do is looked over by NATA so if we are writing something down and we make a mistake we have to put one line through it with a signature and date it so it is right down to that level of scrutiny to ensure that the results that we produce are correct. So having NATA accreditation is really vital to know that the laboratory that you are using has quality results being produced that are, I guess, highly scrutinised for everything that we do.

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