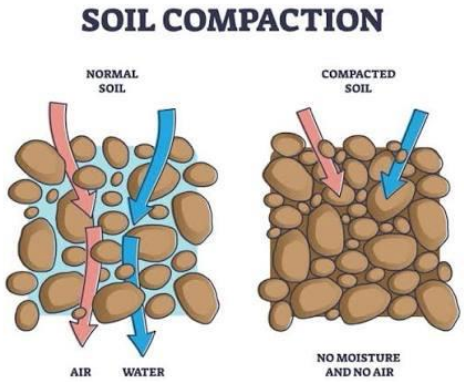
SOILCRATES FARMER'S TOOLBOX

SOIL COMPACTION FACT SHEET

WHAT IS COMPACTION?

Healthy agricultural soil looks and functions like a sponge. They consist of approximately 50% soil particles and 50% pore space, which is filled with air and water.



Pressure on the soil surface, from a tractor or poached by animals, compresses the soil particles and can break the structure of soil aggregates. This results in a reduction of pore space, so the soil becomes denser and there is less space for air and water to move freely.

Principal causes of compaction are heavy machinery, animals trampling the soil, and tillage. Soils are particularly vulnerable to compaction when managed in wet conditions.

EFFECTS OF COMPACTION

Restricted root & microbial activity: denser soil reduced pore space and limits oxygen availability. This oxygen deficiency negatively impacts soil biodiversity, including earthworms, arthropods, and beneficial microorganisms, and impairing pasture and crop health and yield. Poor Drainage & Environmental risks: Reduced water infiltration leads to waterlogging, which causes anaerobic conditions, effectively preventing plant roots from breathing. Excessive runoff increases erosion, nutrient loss, downstream flooding, and pollution in nearby water catchments

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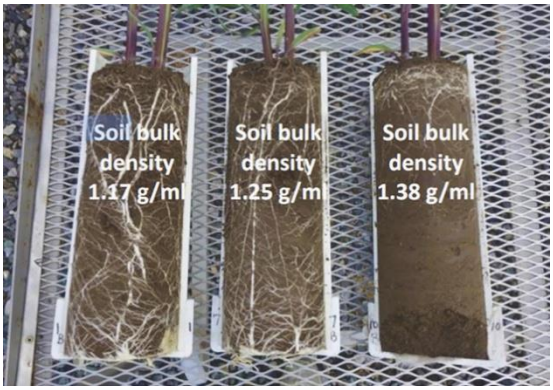

HOW TO DIAGNOSE SOIL COMPACTION

VISUAL INDICATIONS

Soil surface:

- **Water pooling** on the ground, often seen around farm gates, around troughs, in tractor wheelings, etc.
- **Runoff** - restricted water infiltration causes runoff on sloping land. The runoff can be observed through the presence of rills or gullies in the soil or the accumulation of sediment in ditches or at the bottom of slopes.
- **Plant growth** - stunted, uneven, and patchy growth, or specific weeds (like plantains or docks) may indicate compaction.
- **Nutrient deficiency** can occur even after fertiliser use and may be due to roots being unable to absorb nutrients in compacted soil.
- **Hard ground**, which is difficult to work, whether it is wet or dry.

Underground:

Dig a hole to a depth of 30-50 cm and look at the following:

Root growth – growth may be restricted at a specific depth, or roots may grow sideways as they hit a compacted layer of soil.
Soil structure may be platy (large flat chunks) or blocky (large square chunks) and hard to break up by hand. A healthy soil should have a crumbly texture.
Soil colour – grey or orange patches may indicate waterlogging and poor aeration.
Lack of earthworms and other visible soil life.
Resistance to digging – a sudden increase in resistance may be encountered.

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SMELL the soil

Take a handful of soil and smell it - a bad smell (i.e., smell of rotten eggs) may indicate anaerobic conditions which could be a result of waterlogging due to compaction. Healthy soil should have a nice 'earthy' smell.

MECHANICAL RESISTANCE

Resistance is affected by SOIL MOISTURE and SOIL TEXTURE

When is the best time to test the resistance?

The best time to test mechanical resistance is when soil moisture is at ***'Field Capacity'***. This is when excess water has drained away under the influence of gravity after rain. In freely draining sandy soils, this may occur a few hours after rainfall, but in clay-rich soils it may take a few days. Soil must be nearly but not completely dry for the best testing conditions.

DRY SOILS - the soil particles are pulled tightly together, and the soil will be harder and give greater resistance, even when uncompacted.

WET SOILS - water fills the pore spaces, pushing soil particles away from each other. This reduces friction, and there may be little resistance, even in compacted soils.

Know your soil texture

SANDY SOILS – when dry, sandy soil particles don't bind together (aggregate) readily, so readings will be less variable at different moisture contents.

CLAY SOILS – even with a small reduction in water content, soils with a high clay content can have a very large increase in penetration resistance.

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Equipment required

A **PENETROMETER** is the main tool used for testing compaction in agricultural soils. It consists of a pressure gauge attached to a metal rod with a tip, designed to mimic the resistance a plant root faces when pushing through the soil.

The metal rod may have markings every 10 cm to easily measure the depth of penetration or may come with an O-ring which will move up the rod as it's pushed into the ground, indicating the final depth.

The penetrometer may come with more than one metal tip. Follow the instructions, or if unsure, start with the smaller tip. If this moves through the soil easily, try the larger tip. N.B. There are different gauges for different-sized tips.

ALTERNATIVES – a **tile probe** is cheaper than a penetrometer and is sufficient to locate the depth of compaction. Alternatively, use a **long metal rod with a pointy tip**, such as a **pigtail or similar**, anything that can be easily pushed into the soil. Be aware that compaction is often found at a depth of 25-30 cm. Be aware of the stones and try to test in many locations to understand the whole picture.

MEASURING THE DEPTH OF COMPACTION

- Steadily push the penetrometer, tile probe, etc., vertically into the soil and note the depth where you meet a lot of resistance. If you hit a stone, try again. (You will learn the 'feel' of a stone compared to compacted soil.

- Take multiple readings across the site and compare them with undisturbed areas (i.e., hedgerows).

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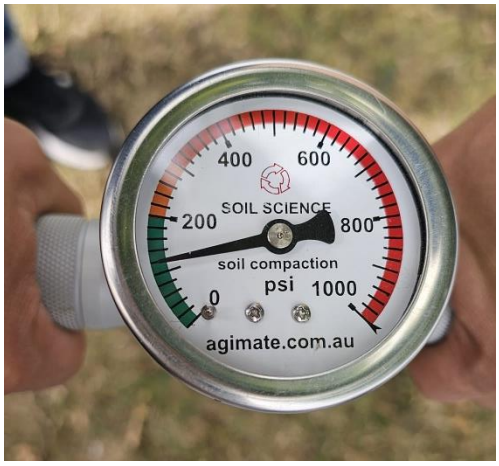
For more detailed information, the gauge on the penetrometer will indicate the resistance pressure encountered by a plant root. Remember that this will be influenced by the soil moisture on any given day. Refer to the dial colours below.

- Green – no restriction to root growth. Uncompacted. (0-150 psi / 0-1,034 kPa)



- Yellow – some restriction to root growth. Moderate compaction. (150-300 psi / 1,034-2,068 kPa)

- Red – badly compacted soils (300+ psi / 2,068+ kPa)

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HOW TO MEASURE SOIL INFILTRATION RATE

A water infiltration test will help to understand the speed at which water enters the soil during a rain event, showing how well the soil soaks up the rainfall and allows it to percolate down through the soil. It is a simple method for comparing fields of similar soil types, serving as a good indicator of soil structure, and highlighting potential areas of compaction.

Be aware of your **SOIL TEXTURE** and the **SOIL MOISTURE,** as these will influence the results.

EQUIPMENT REQUIRED

- Metal can (open at both ends) – no less than 10 cm diameter (wider is better)

Wooden block
- Mallet
- Water (see below for calculations)
- Measuring jug, or pre-marked container
- Stopwatch
- Plastic sheet (large enough to line the can) for bare soil
- Scissors or knife to trim vegetation

BEFORE TESTING

Soil shouldn't be saturated, so wait a few days after a heavy rainfall.

METHODs

Cut surface vegetation to near ground level. Try not to alter the soil surface.

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Insert the can into the soil to a depth where the water doesn't leak out – about 3 cm is usually enough. You may need to use the wooden block and mallet to bang it in. Trial and error will show!!
Insert a plastic sheet into the can, pour in the water and then slide out the plastic sheet as you start the stopwatch (especially on bare soil).
OR
Pour in a volume of water to a depth of 2.5 cm (see next page) and immediately start the stopwatch.
When there is no remaining water above the soil surface, stop the stopwatch.
If soils are dry, repeat in the same spot (the second run may give a much more accurate reading of how your soil handles sustained rain)
Take a few readings across the site for comparison and compare to the hedgerows area where your soil is in much better condition.

RESULTS

Results are not static and will be influenced by soil moisture at the time of testing, vegetation cover (roots), organic matter content, etc., and will vary across one field. However, it is a useful method to compare different fields or areas with the same soil type. Across your site, faster infiltration rates indicate better porosity, less compaction, improved soil structure, and a higher proportion of organic matter.

The following infiltration rates from FAO data are intended as a guideline.

How to calculate your water infiltration rate:

Soil type	***Infiltration rate (mm/hour)***
Sand	*>30*
Sandy loam	*20-30*
Loam	*10-20*
Clay loam	*5-10*
Clay	*1-5*

Volume of water required for each repetition = the area of the can x 2.5 cm

Area of a circle (A). A = $\Pi r2$

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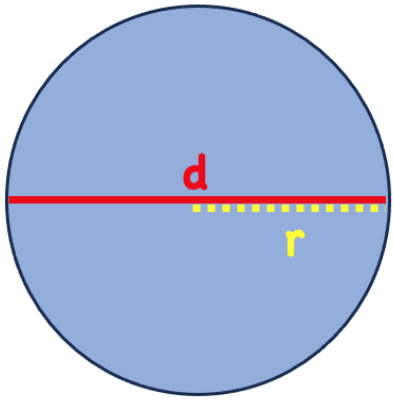
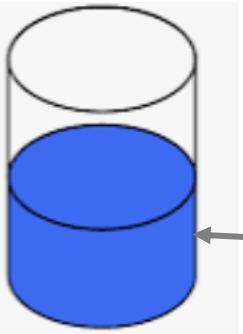


Example given for 15mm diameter can

1. Measure across the can for the diameter (d) 15 cm, and half it (r)= **7.5 cm**
2. Multiply it by itself 7.5 x 7.5 = **56.25 cm^2**
3. Multiply by 3.14 (P - π) 56.25 x 3.14 = **176.625 cm^2**
4. Multiply by the depth of water – 2.5 cm 176.625 **x 2.5 = 441.6 cm^3 ≈462 (ml)**



You can round this up to 450 ml of water if you like

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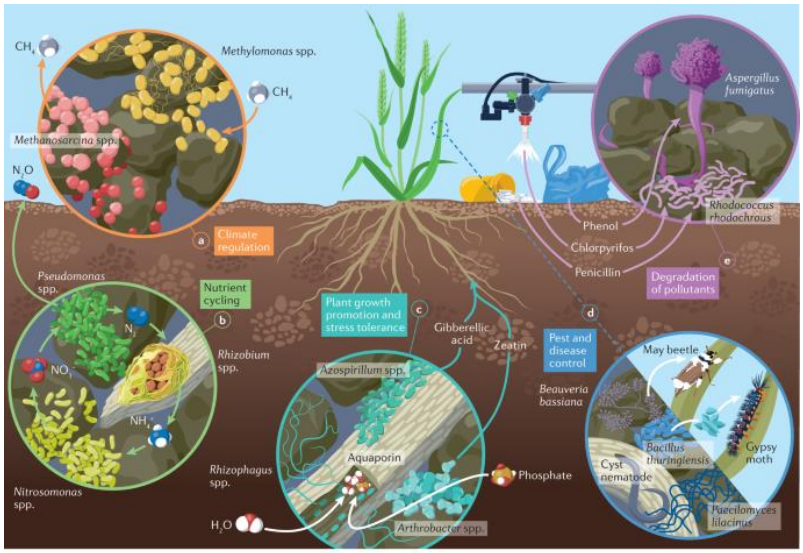
SOIL BIODIVERSITY (MICROBIAL ACTIVITY) FACT SHEET

What is soil microbial biodiversity

Healthy, living soil is filled with billions of microscopic organisms. Soil microbial activity is essentially the collective 'work' and life processes of the billions of microbes living in soil. If you think of the soil as a massive, underground city, microbes, including bacteria, fungi, actinomycetes, algae and protozoa, are the busy workforce. Their daily activities (eating, breathing, moving, and reproducing) drive the cycles that keep the entire ecosystem alive and productive.



These microbes perform important tasks:
Decomposition: Microbes break down crop residues, manure, and organic materials (like your cotton strip), releasing locked-up nutrients back into the soil for plants to eat.
Nutrient Cycling: They act as tiny processing plants, converting all elements into plant-available forms (e.g., transforming organic nitrogen into nitrate).
Humus Formation: As they process carbon, they leave behind stable organic matter (humus) that glues soil particles into healthy, crumbly aggregates.

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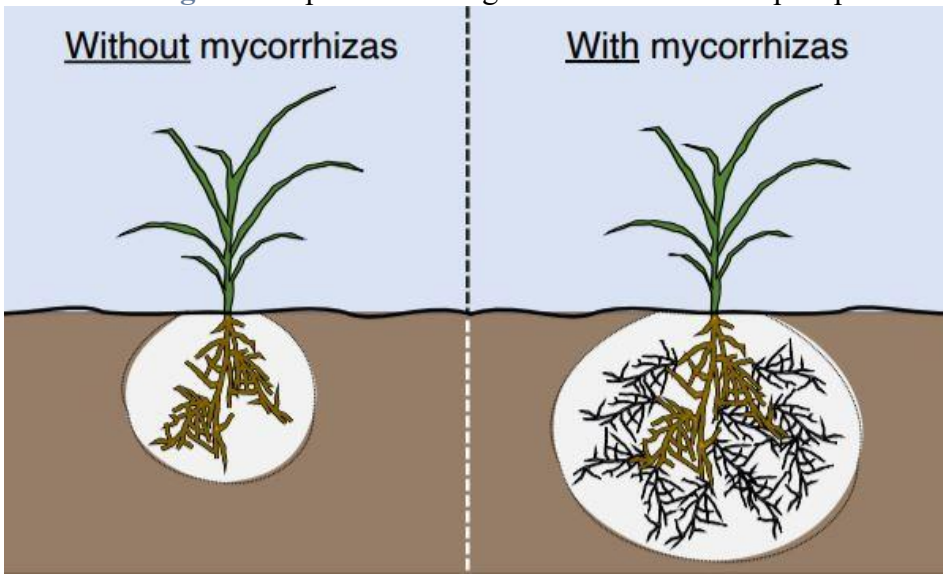
Symbiotic Partnerships:

- **Mycorrhizal fungi** extend plant roots to grab distant water and phosphorus.



- **Rhizobia bacteria** on legume roots capture nitrogen directly from the air for plants to consume.

How to measure soil microbial activity on your farm

Microbes and other organisms in biologically active soil need food, and their favourite meal is cellulose, the natural plant fibre that makes, for example, up 100% of cotton.
By burying a piece of 100% cotton in your field, you are setting up a 'microbe buffet'. How fast and how much of the cotton fabric disappears tells you exactly how active and healthy your soil biology is. Conversely, intact cotton fabric suggests low microbial activity, potentially pointing to issues like compaction, poor organic matter, or disrupted soil ecosystems.

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Equipment required

- 100% untreated cotton (i.e., Unbleached Calico, t-shit, underpant)
    - N.B. you need to know the area of the cotton strip you are going to bury beforehand

- A spade or shovel (to dig)
- A marker flag or stake (to locate the site)

Before testing

Choose a time when the soil is warm and active (ideally during late spring or early summer). Do not test in frozen, waterlogged, or bone-dry soil, as soil biology goes inactive under these extreme conditions.
DO not test directly after application of fertiliser or slurry -increased nitrogen can produce a false activity; wait for at least 2 weeks after fertilisation.

Method

- Dig a trench: dig a flat-bottomed shovel trench about 15cm deep. This is the active root zone where most soil biology lives.
- Bury the cotton: lay the fabric flat in the trench so the cotton has maximum contact with the soil.
- Cover and mark: fill the trench back in with the soil you dug out, patting it down gently to ensure good soil contact with the fabric. Mark the spot with a flag or stake. It's easy to lose track of where you buried it.
- Wait and let them eat: leave the fabric in the soil for 6 weeks. Go about your regular farming practices on top.
- Retrieve: after 6 weeks, carefully shovel around the site to exhume the fabric. Do not yank them out, as degraded fabric will tear and fall apart. Gently rinse off the excess dirt in a bucket of water.

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Results & Interpretation

Once the retrieved fabric is dry, evaluate how much of it has been eaten away:

- Virtually nothing is left (excellent): the fabric has completely disappeared, leaving only a few loose threads or nothing at all. Your soil is incredibly healthy and thriving with active microbes
- The fabric is full of holes, shredded, and thin (good): moderate to high microbial activity. Your soil organisms are actively working to break down organic matter.
- The fabric is intact and just stained/dirty (poor): low microbial activity. This is a strong indicator of compacted, sterile, or oven-tilled soil with very little microbial life.

N.B. This test is highly susceptible to temperature and time. We recommend that you do a few cotton strips across your field so that you can get an even result and place some of the pieces at the hedgerow to compare with undisturbed soil.

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EARTHWORM COUNTING FACT SHEET

Why count earthworms?

Earthworms are the ultimate soil engineers. They chew up crop residues, mix organic matter deep into the ground, and dig extensive tunnels that naturally break up compaction. Beyond their soil-building work, they are a vital food source for birds and mammals, making them an excellent indicator of overall soil health. An earthworm count is a simple, effective way to compare and measure soil health across your different fields.

Effects of earthworms

- Natural aeration and drainage: worm tunnels act as ready-made pathways for plant roots, rainwater, and fresh air to penetrate deep into the subsoil, reducing waterlogging.
- Reduced compaction: deep-burrowing worms can tunnel several meters down, cracking open hard clay and plough pans that mechanical equipment struggles to reach.
- Enhanced nutrient cycling: earthworm casting (their poop) is packed with concentrated, plant-available nutrients like nitrogen, phosphorus, and potassium, which are easier for crops to absorb.

Earthworm ecological groups

Endogenic (topsoil earthworms)

- Colours: pale-grey, pink, or green
- Size: small to medium
- Role: soil aggregation and nutrient mineralisation
- Where to find them: upper soil layers, they are relatively resilient and can withstand soil disturbance

Epigenic (litter-dwelling earthworms)

- Colour: red pigmented
- Size: small to medium
- Role: organic matter breakdown and carbon cycling
- Where to find them: on or near the soil surface in the leaf litter.

Anicic (deep burrowing earthworm)

- Colour: red/brown pigmented with a noticeably darker head.
- Size: large (longer than 10 cm in length, or 5 cm in diameter)

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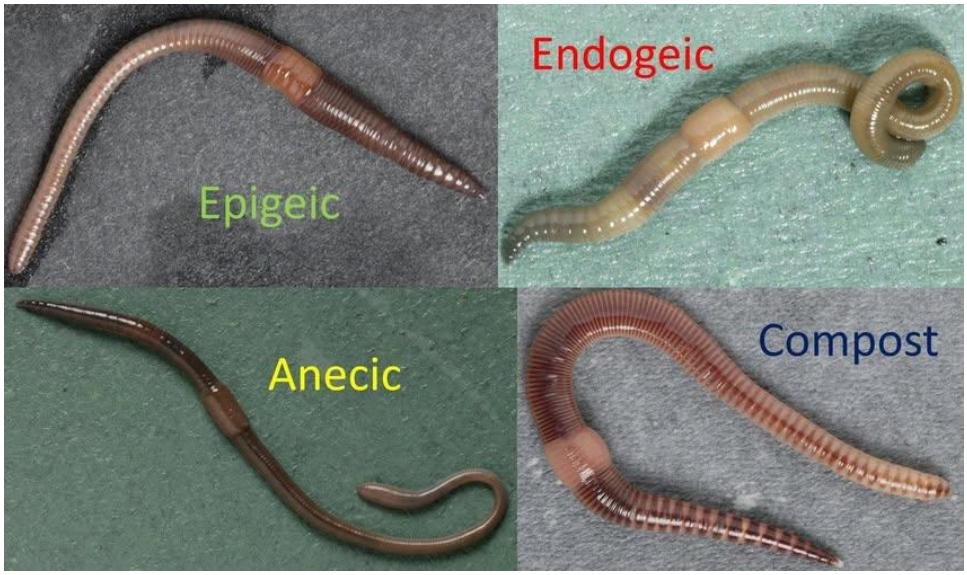
- **Role:** deep burrowing, which improves aeration, water drainage, and root penetration

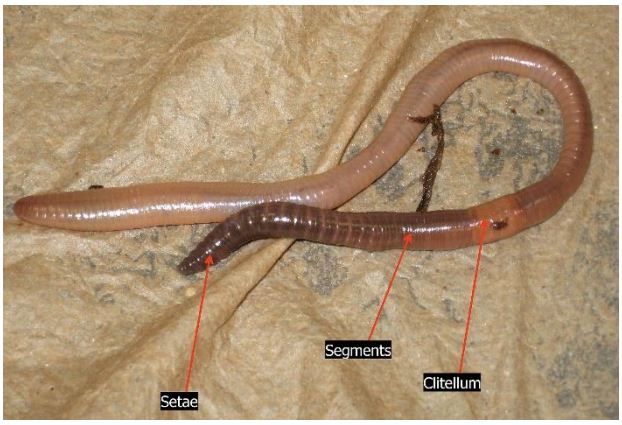
Where to find them: they leave tell-tale signs of their deep vertical tunnels by creating 'middens' (tiny piles of cast material and organic debris) on the soil surface



Earthworms: adult and juvenile

We have 28 native earthworm species in Ireland; size alone is not a reliable way to tell if a worm is fully grown. Some adult species are only 1 cm long, while others reach 20 cm. To determine the maturity of the earthworms that you found in your soil, look for the **saddle (clitellum).**

- Adult earthworms have a developed 'saddle' (clitellum). This is a unique, raised band located near the head end of the worm, which is part of its reproductive system.
- Juveniles: will not have this raised band. Their bodies are completely smooth from head to tail.



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How to count earthworms

Equipment:

- Spade
- Tray/Mat
- Container with lid
- Record sheet

Before testing

Only test when the soil is moist but not wet and warm (spring or autumn). Do not test during a freezing winter, baking summer, or right after an intensive rainfall event, as earthworms will have burrowed deep underground or will be going up to the surface for respiration, as the environment has been changed.

Method

- Dig out a soil block of 20cm × 20cm × 20cm (W × L × D), and place the soil on the tray/mat
- Gently hand-sort the soil, removing all earthworms from the soil and putting it into the container
- Count the total number of earthworms. Separate the adult and the juvenile earthworms. Record the numbers on the record sheet.
- Return the earthworms and soil to the ground after you have finished counting

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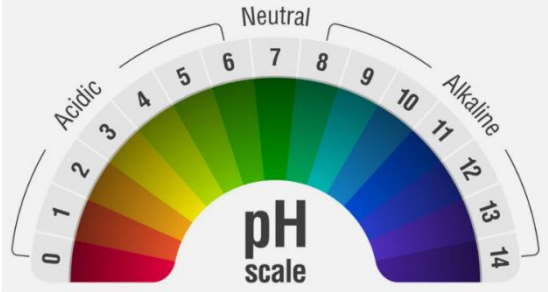
SOIL pH AND N, P, K TEST FACT SHEET

What is soil pH?

Soil pH is a measure of how acidic or alkaline your soil is. The pH scale ranges from 0 to 14.



Why is soil pH important?

Soil pH strongly influences how easily plants' roots can take up nutrients from the soil. If the pH is too high or too low, plants cannot take them up even if nutrients are present in the soil. Maintaining the proper pH ensures the right nutrients are available when crops need them.

Correct soil pH helps because:

- Roots grow more efficiently to absorb moisture and nutrients.
- Plants develop stronger immune systems and resilience to weather and disease stress
- Fertilisers are used more effectively, minimising input costs and waste
- Crop yields and overall quality can improve

Effects of soil pH

When soil pH is too acidic (low pH) or too alkaline (high pH), some nutrients become unavailable, while some nutrients can reach toxic levels (i.e., aluminum and manganese). In addition, fertiliser efficiency decreases, affecting overall plant growth and crop yield. When soil pH is optimal, essential nutrients become accessible, supporting stronger root development and making crops more resilient to stress. A balanced pH also boosts beneficial soil microorganisms, creating a healthier, more active soil ecosystem for your crops.

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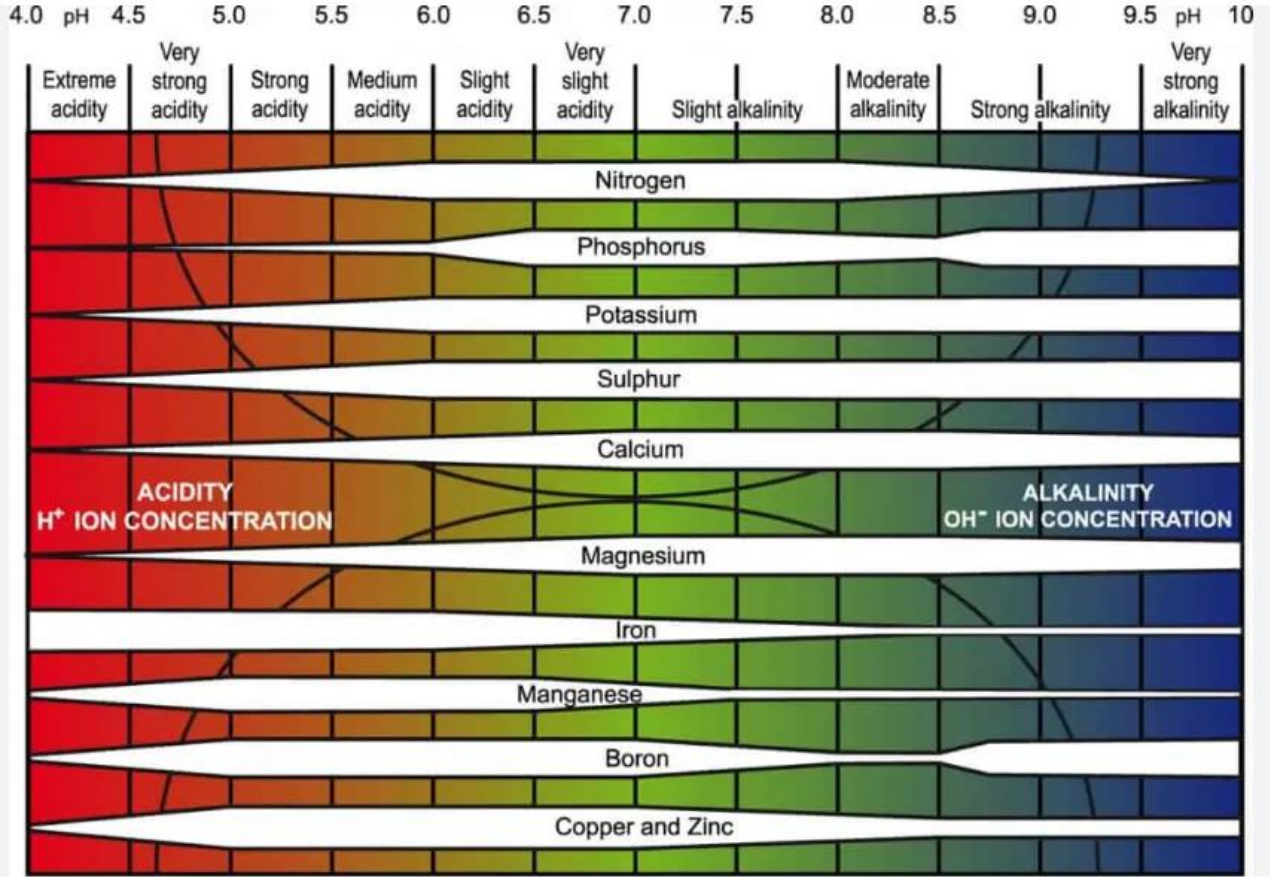

When should soil pH be measured?

Soil pH can be measured at any time of the year, but it's best to mean your soil pH before planting and before fertiliser applications. This provides an accurate picture of the soil's initial condition. For consistency, it is recommended to sample at approximately the same time each year and under similar soil moisture conditions. Avoid measuring pH when soils are extremely dry or waterlogged, as these conditions can make sampling more difficult.

Equipment required

- Soil test kit
- Spade or shovel (to dig)
- Clean container for soil sample
- Teaspoon
- Bottled water
- Dropper

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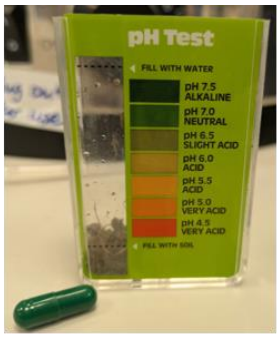
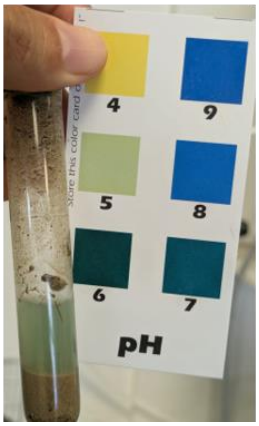
Before testing

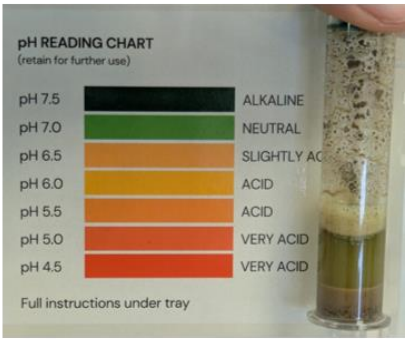
Test different areas of a field as it may differ due to underlying soil differences or localized conditions. Place the soil sample into a clean container. Break the sample up with the trowel or spoon. Remove small stones, organic material such as grass, weeds, or roots. Crumble the sample finely and mix thoroughly.

Method

- Depending on the soil test kit, remove the cap from the box or test tube.
- Fill the box or test tube with soil to the recommended level, approximately the amount equivalent to half a teaspoon.
- Carefully add the full content of the pH reagent(s) to the soil sample in the box or test tube.
- Using a dropper (usually provided in the kit), add bottled water to the water fill line.
- Cap the box or test tube. Make sure it is sealed properly and shake thoroughly.
- Allow soil to settle and colour to develop. Depending on the kit, this can take up to 5 minutes.
- Compare the colour of the solution to the pH chart provided with the kit.







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What is N, P and K?

Nitrogen (N), phosphorus (P) and potassium (K) are the three primary nutrients required by plants to grow and are commonly supplied through fertilisers. Each nutrient plays a different role in plant development. Nitrogen promotes leafy growth, supports chlorophyl production and gives plants a healthy green colour. Phosphorus is essential for proper root development, early plant establishment, and production of flowers and seeds. Potassium makes the plants resilient to stress by helping water regulation within the plant, improving resistance to drought, pests and diseases. A balanced supply of these nutrients is important for healthy plant growth and good crop yields.

Why measure soil NPK?

Measuring soil NPK provides valuable information about the nutrients available to support plant growth. Understanding the nutrient availability of the soil helps make informed fertiliser use decisions, ensuring that crops receive the nutrients they need while avoiding unnecessary applications. This can improve fertiliser efficiency, reduce input costs, and minimise nutrient losses to the environment through leaching or runoff. Regular soil testing helps monitor soil fertility over time, supporting sustainable soil management and productive soils for future cropping.

Effects of Nitrogen (N)

Nitrogen is the nutrient most closely associated with leafy growth and plant vigour. When nitrogen levels are too low, plants often appear pale green or yellow, grow slowly, produce lower yields and overall growth is sparse.
Nitrogen promotes healthy green leaves, vigorous growth, and good crop productivity. However, excessive nitrogen can result in lush, leafy growth at the expense of flowers or grain. Furthermore, excess nitrogen can lower soil pH (acidify the soil), and lead to nitrate leaching, reducing fertiliser efficiency and increasing the risk of environmental pollution.

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Effects of Phosphorus (P)

Phosphorus plays a key role in root development, energy transfer, and early plant growth. In pastures, phosphorus deficiency can produce purple discoloration, and tips of older halms become yellow-reddish colour and may die off. Low levels of phosphorus lead to poor root systems, slow establishment, delayed maturity, and reduced yields. Acidic soils decrease phosphorus availability. When phosphorus levels are adequate, crops establish quickly, develop strong roots, and are better able to support flowering, seed production, and overall growth. Although excess phosphorus rarely harms crops directly, it can accumulate in the soil and increase the risk of phosphorus loss to rivers and lakes through runoff, contributing to poor water quality and representing an unnecessary fertiliser expense.

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Effects of Potassium (K)

Potassium helps plants regulate water use, strengthen stems, and improve resistance to environmental stresses. Low potassium levels can result in weak stems, poor drought tolerance, greater susceptibility to pests and diseases, and reduced crop quality. In pastures, older leaves show brown blotches along the blade of the leaf and are reduced in length. Adequate potassium supports healthy plant growth, improves water-use efficiency, enhances tolerance to stress, and contributes to higher-quality yields. Excessive potassium is uncommon but may interfere with the uptake of other nutrients, particularly magnesium and calcium, leading to nutrient imbalances and unnecessary fertiliser costs.

When should NPK be measured, and how?

Soil NPK should ideally be measured before planting or before applying fertilisers, as this provides the most accurate assessment of the nutrients already available in the soil. Testing before fertiliser application helps ensure that nutrients are only added where they are needed, improving fertiliser efficiency and reducing unnecessary costs. Avoid sampling immediately after fertiliser or manure has been applied, as this can give misleadingly high nutrient readings. For consistent monitoring over time, collect samples at approximately the same time each year and under similar field conditions. To obtain a representative result for the entire field, collect several soil samples from different locations and combine them into one sample before carrying out the test.

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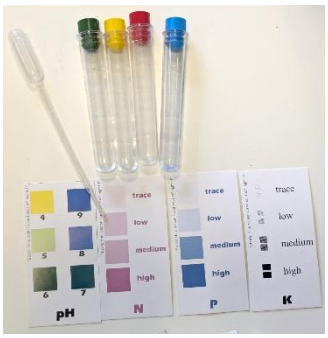
Equipment required

- Soil test kit
- Spade or shovel (to dig)
- Clean container for soil sample
- Clean container for mixing soil and water
- Bottled water
- Dropper



Before testing

Test different areas of a field as it may differ due to underlying soil differences or localised conditions. Place the soil sample into a clean container. Break the sample up with the trowel or spoon. Remove small stones and organic material such as grass, weeds or roots. Crumble the sample finely and mix thoroughly.

Method

- Fill a clean container with 1 cup of soil and 5 cups of bottled water, or measure the ratio of soil and water is 1:5.
- Thoroughly shake or stir the soil and water together for one minute, then allow the mixture to settle for 1 to 24 hours, depending on the type of soil. Allowing the water to clear yields better results.
- Select the appropriate box or test tube for the test you wish to run, depending on the soil test kit.
- Use the dropper (usually provided by the soil test kits) fill the test chamber or test tube to the fill line with solution from the soil sample. Avoid disturbing sediment. Transfer only liquid.
- Carefully add the full content of the appropriate test reagent to the solution sample in the box or test tube.
- Cap the box or test tube. Make sure it is sealed properly and shake thoroughly.
- Allow Colour to develop. Depending on the kit and test, this can take up from 5 to 10 minutes.

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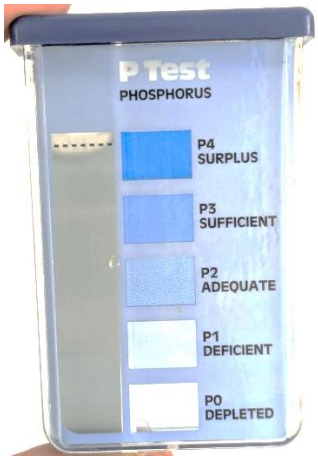
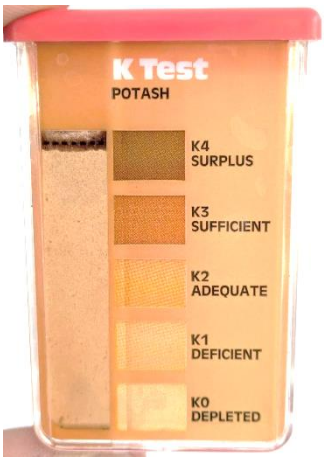
Reading the results

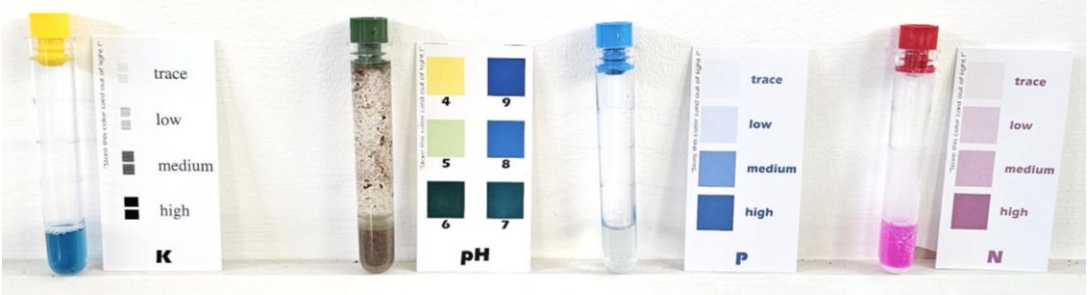
- Phosphorus (P): If flakes of blue colour appear to have settled to the bottom of the phosphorus test during the 10-minute developing period, shake the box or test tube to suspend them in the solution.



- Potassium (K): if flakes of orange or brown colour appear to have accumulated at the top of the test chamber of the potassium box or test tube, do not re-shake. Read the Colour of the solution only.



- Compare the colour of the solution in the test to the colour chart provided by the kit.



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