Soils, Nutrient Absorption and Fertilisers

In agriculture much money has been invested in understanding the conditions which crops need to give an economic return from the product. This not the case in bonsai as it is a relatively small market led by “influencers”. So bonsai recommendations evolve from what past bonsai growers have found that works rather than are led by science. So what science from agriculture can we apply to bonsai cultivation?

In this talk I would like to discuss naturally occurring soils, how plants absorb nutrients, different types of soil fertilisers and what to look out for when buying them. We will end with a discussion of how this is applies to bonsai soils.

Mineral Soils

Most of the world’s soils are mineral soils which are formed from rocks over millions of years. To become a soil the rock needs to be broken down into tiny pieces by the action of:

1. Water
2. Ice.
3. Glaciers.
4. Volcanic action

Organic Soils

These are formed from decaying plant material. This can be in the form of peat. The peat forms in areas which are saturated with water for much or all of the year. Few plants can grow in these conditions as there is not enough oxygen for the roots to grow. But mosses thrive on the surface and grow on top of each other over the years. But the absence of oxygen for the roots does not allow rapid breakdown of dead material so the dead plant material is preserved and becomes compressed and, over many years, peat is formed.

Soil Types

Different types of soil can be classified by soil particle size.

Soil Type	*Drainage*	*Soil structure*	*Holds nutrients?*	*Holds Water?*
Grit	Good	None	No	No
Sand	Good	None	No	Little
Silt	Moderate	Good	Yes	Yes

Clay	Poor	Poor	Yes	Yes
Peat	Moderate/Poor	None	No	Yes

Sand Soil

Where this type of soil exists it is termed a hungry soil by farmers meaning that all necessary nutrients must be added by the time the seed is sown. Sand soils can “blow” which occurs when the soil, together with, seed and fertiliser can be blown off the surface of the field into a ditch or neighbouring field. This happens when the soil is dry and has been loosened by cultivation.

Sandy volcanic soils have components such as pumice and lapillo have small and microscopic holes in the particles in which water can be held by surface tension and which roots can reach.

Silt Soil

These soils are formed in the estuaries of muddy rivers. Can have good structure and can drain well. Fertile soils for arable and horticulture crops.

Clay Soil,

Alkaline clay soils contain a lot of Calcium and have good structure, drain well and retain nutrients especially calcium and potassium. Not found locally.

Most clay soils are neutral or acidic, very poorly drained, have a lot of water in the deeper soil all the time but retain a lot of plant nutrients, especially potassium.

The particle structure of clay is like a stack of plates piled together and between the plates is where cations, especially sodium, calcium, magnesium and potassium are held between the clay plates by electrostatic attraction. They can be exchanged for other cations which are brought through the plates in solution with rainwater. The number of cations which a clay can exchange is known as the Cation Exchange Capacity (CEC). Thus clays act as a bank for plant nutrients, and have a big effect on protecting a soil from the acidifying effect of water passing down through the soil.

Acadama is a mined natural soil from Japan which has been dried and graded. It does not have a high CEC but is very root friendly. Most of the other ingredients of bonsai soils would have similar characteristics to grits.

Peat Soil

When peat is drained air can enter the top layers of the soil enabling it to be cultivated. But it also allows bacteria and fungi (soil micro flora) to enter and multiply. These can break down the decaying organic matter, which over many years causes the organic matter to disappear and the peat layer to shrink. Drained peat soil holds no plant nutrients and can also blow.

Most soils are also a mixture of the mineral particles sizes and are described as loams such as sandy clay loam, silty clay loam etc. The different particle size and proportions of water, air and organic matter govern what can grow in it. For example carrots grow well in a sandy soil (with irrigation) and poorly in clay, and vice versa for cereals and grass.

Soil organic matter

All of the mineral soils have a proportion of their content made up by organic matter (1% up to 30%). Organic matter is formed by a continuous process of breakdown of dead plant material. This begins on the soil surface where dead parts of crops form in the top layers also where roots die and are broken down. Action of soil bacteria, fungi and micro organisms begins the process of reducing particle size and enabling it to move further into the soil. All the chemical elements originally present in the plant are eventually broken down (mineralised). The final product is a very small particle size black material which we know as humus. Humus affects soil properties by:

- Improving soil structure
- Increases the ability to attract and retain nutrients and
- Contributes nitrogen, phosphorus and some trace elements.

If crops are removed such as cereals or potatoes less new dead material is available to breakdown and there is less organic matter in the soil compared to a crop such as grass. Organic matter content of soils is important for plant growth and health and to keep the soil open and allowing oxygen to be available to roots.

The organic matter content of soils can be increased by application of farm yard manure and by altering crop rotations to include grass as a crop. This is especially in important in soils with no structure.

Nutrient Absorption

Plants need to absorb a range of nutrients in different quantities to enable them to thrive and grow. The minerals and water are absorbed by tiny structures on roots called root hairs. These have a single layer of cells where the root hair meets soil. Nutrients must be dissolved in water for the root hair to be able to absorb them. The mechanism of absorption is called osmosis where a weaker concentration of the nutrient mixture will move through the membrane at the outside of the root hair towards a more concentrated solution on the inside of the root hair.

The reverse of this process can happen when the soil has a higher concentration of nutrients dissolved in its water such as when too much fertiliser has been applied or spilled. This process is likely to kill the plant by dehydration and is called reverse osmosis.

Once inside the plant the solution of nutrients in water is drawn up the plant in a column in the water transporting cells (xylem cells). This happens because water is continually being lost from pores on the undersides of the leaves in a mechanism which controls the temperature of the plant. In this way the water and dissolved minerals are distributed to the cells where they are needed. In spring and summer this is especially for photosynthesis which gathers the sun's energy in the leaves as sugars and uses it in the cells of the plant to provide energy which the plant can use via its complex biochemical pathways within the cells. In conifers water movement is less than in deciduous due to a smaller leaf area, sunken pores in the needles and a waxy surface to the needles.

Sugars are transported around the plant in phloem cells. In trees phloem and xylem cells are formed from the cambium layer annually.

Soil Microflora

In recent years there has been increased scientific work published which tries to understand how soil microflora (fungi, bacteria, worms and insects) interact with plants in a beneficial way. They have found that plants secrete some of the sugars (10-40%), which they have produced by photosynthesis, into the soil in the vicinity of the root hairs. This enables larger numbers of bacteria to live close to the root hair, the plant can absorb the bacteria close to the tip of the root hair which allows entry inside the root. The presence of the bacteria in the roots stimulates more root hairs to develop which enable the plant to absorb more nutrients and become healthier. Thus there is a continuous cycle of nutrient exchange in the area of the root hair. Some scientists are also claiming better disease resistance from bacterial absorption and distribution throughout the plant.

Fungi are also attracted to the plant sugars secreted around the root hair. Fungi are extensive underground organisms which can bring minerals to the plant from beyond the reach of the roots. In one study of an old woodland it was found that the all the trees in the wood were connected by a network of hyphae from a single fungus! 1 gram of healthy soil can contain 1 kilometre of hyphae if all were placed in a line.

Worms and insects are another important part of the recycling of decaying organic matter. When soil is examined under a microscope there are huge numbers of small insects such as mites and springtails present which all have parts to play in breaking down decaying vegetation into smaller particles which in turn are used as nutrients by the soil microflora and plants. Their action also help to stick the soil particles together. The more open a soil texture is the more oxygen will be present which encourages soil microflora and roots to grow to the benefit of both.

Most soil microflora need oxygen and cannot survive in waterlogged soils.

Major Nutrients

The nutrients which are needed in greatest quantities are:

Nitrogen. This is needed for growth (by making plant protein) and is absorbed by the root hairs as nitrate. This means that nitrogen held in the soil in other chemical forms (such as plant protein in decaying roots) has to be chemically changed to nitrate first before they can be used by the plant. This is done by the soil microflora. Some beneficial soil bacteria can also use nitrogen from the air, releasing it as nitrate into the rhizosphere of the roots, others do the same thing from a symbiotic relationship in root nodules of legumes.

Many nitrogen compounds, including nitrates, are very soluble in water and are easily washed out. Heavy rainfall after application can do this and something we must be aware of when watering bonsai after feeding.

Nitrogen can be stored inside the tree throughout the growing season. The maximum storage takes place in the autumn. Stores are depleted in spring at the time of bud production and growth initiation before the new leaves are fully open and photosynthesis begins. Nitrogen storage sites vary between species and types. Nitrogen is still being stored during the autumn while leaves are dying back.

Type	**Nitrogen storage site**
Deciduous	Woody roots, trunk, branches
Evergreen deciduous	Woody roots, trunk, branches, older leaves

Coniferous	Woody roots, trunk, branches, last year's needles

Potassium

Potassium is needed in large quantities where a plant is needed to grow very vigorously such as grass for silage, or where the crop is a fruit such as apples.

To be absorbed by the root hairs potassium compounds in the soil need to dissolve in water and, unlike nitrogen, they do this slowly. When potassium is applied as a straight fertiliser, such as potash, it is applied in the autumn before the crop is sown next spring to give time for the potassium to move down from the surface to root depth and to change itself from compound to a water soluble form.

Phosphorus

This is used in plant cells in the biochemical processes in the plant cells which give energy to the plant, and is needed structurally to form strong stems.

It is absorbed by the root hairs as solution of phosphate in water. But soil phosphate is often in insoluble forms and, as with potassium, needs to be chemically changed by the soil microflora which happens slowly. Phosphate application as a straight is can also be applied in the autumn to give time to break down to a water soluble form which the root hairs can absorb.

Carbon

This is the element present in the largest quantities in trees and plants. It is not truly a nutrient and we do not have to apply it. It enters the plant through the plant respiration where carbon dioxide is taken in from the air via the pores on the underside of leaves mainly at night.

Magnesium. This is essential for photosynthesis. Chlorophyll is the chemical which makes plants green and is a vital part of the photosynthesis process. A single atom of magnesium forms the centre around which the large chlorophyll molecule is built. No magnesium= no chlorophyll= no photosynthesis= sick plant. This why Epsom Salts turn leaves greener.

Calcium and Sulphur

These are needed to be absorbed by the roots but in smaller quantities than Nitrogen, Phosphorus, and Potassium. They are rarely deficient in soils.

Trace elements

These are chemical elements which are required in smaller quantities and are used for the many different types of metabolism within the cells. Trace element deficiency causes a range of problems for plant growth.

Fertilisers and Biostimulants

There are three types of fertiliser:

a. Organic

These are slow release plant or animal materials such as fishmeal, bonemeal, seaweed or rapeseed meal. They are slowly broken down in the soil by soil micro organisms to convert their chemical constituents to a form which plants can absorb. The process can take some months especially in the colder months when soil microflora work more slowly. The nutrients constituents are not precisely declared and usually contain trace elements, although they may not be declared, as well as NPK. Farm Yard Manure has NPK of approximately 20:10:10 which very concentrated for bonsai use.

b. Manufactured

These can be in three forms:

Prills

These are small white pellets made from materials which easily dissolve in water such as ammonium nitrate (33% N), or urea (46%). The pellets are of very similar size. Because the nutrients in prills are highly concentrated they are intended mainly for agricultural use.

Granular

These are manufactured from by products of the chemical and gas industries and contain N,P and K mainly. Their content will be declared on the label including any trace elements. They are grey granules of equal size and density for even distribution from a fertiliser spreader. There is a wide combination of nutrients for different crops. The concentration of nutrients is greater than organic products. They are widely used in agriculture where research has shown which are the nutrients best suited for each crop and when and how they should be applied.

Blends

Blended fertilisers are similar to granular except they are mixture of the raw materials and so have different colours, grain size and density. They do not distribute as evenly as granular from fertiliser spreaders.

The quantity to be applied is also important to avoid unwanted effects such as leggy, weak growth or reverse osmosis. There should be guidance on the quantity to apply according to the area (acre, square metre, or other). It is the combination of concentration and quantity applied which is important. In bonsai we are looking for health and some growth in our trees but not excessive growth, therefore nutrient concentration of bonsai fertiliser is lower than agricultural fertiliser.

c. Liquid

Liquid fertilisers are rarely used in agriculture as they need specialised equipment to store and apply, but are more commonly used in horticulture and bonsai. Phosphorus and Potassium are present in a water soluble form which makes them more quickly absorbed than, for example, phosphorus in bone meal. The more rapid absorption makes liquid fertilisers useful in the start of the growing season and in the autumn when an organic fertiliser may not break down in time for autumn absorption. It is important to make sure that what is applied is diluted correctly and that just enough is used otherwise too much will go down the drain and nutrients will be wasted.

Fertiliser should be applied just when the tree is beginning to actively grow to avoid nitrogen in the fertiliser being lost when watering.

Reading the Fertiliser Label

Nutrient content declared on the label is covered by statutory legislation which can be used in any claims. The method of declaration can vary between countries.

- Nitrogen is expressed as the available nitrogen content and the form in which the nitrogen content is present e.g. Nitrogen 10% (urea 9%). Plants cannot absorb urea and it has to be converted to ammonium and then to nitrate by a soil enzyme - urease. (Soil enzymes are produced from living and dead soil micro organisms). This happens quickly in warm weather. When urea is present it should be declared on the label and tell us the percentage of nitrogen present as urea.

- Phosphorus (P) and Potassium (K) are expressed as their oxide content, in the UK, (phosphorus pentoxide P_2O_5 and potassium oxide K_2O) followed in brackets by the content of the element e.g phosphorus-P. The amount soluble in water is often declared for phosphate which is what is available to the plant at application. Levels of secondary nutrients present such as magnesium, sulphur, and other trace elements must be declared.
- Levels of any pesticide or moss killing chemicals must be declared.

Vitamins

Plants need vitamins for their metabolism within their cells which they synthesise themselves rather than absorb them through the roots. Vitamins are not added to agricultural fertilisers. There are mixed results from adding vitamins to the soil for root absorption from controlled trials. Vitamin manufacturers will make use of any positive results which help them market their products. Buyer beware!

Biostimulants

Biostimulants (e.g. seaweed extract) are not legally classed as fertilisers and do not need to declare nutrient content unless they are mixed with plant nutrients. They do not have a regulatory framework unless they make direct claims such as effect on pests or diseases.

Bonsai Points

- Most bonsai soils are very shallow and free draining.
- Take care to not overwater to preserve nitrogen in the soil.
- Soil cannot retain nitrogen well other than from applied slow release organic fertilisers.
- Why do we put unhealthy bonsais in the ground?
- Soil bacteria and fungi are vital in making plant nutrients available to the plant. Don’t wash them away by washing roots.
- Bonsai soil is really a misnomer as soil structure, and soil microflora are missing. Bonsai growing medium is a better term.
- Some free draining organic matter in bonsai growing medium is desirable to provide a substrate for bacteria and fungi.
- Bonsai trees do not need the same concentration of fertiliser compared to agricultural and horticultural crops due to their size and we are not aiming for large fruit or seed yields.

- An evenly balanced fertiliser like 4:4:4 is best for most trees where fruit is not required, with most of the P and K in a water soluble form. Trace elements are also essential.
- We do not want to encourage quick growth in older trees.
- Do not add extra fertiliser to poorly growing trees due to the risk of reverse osmosis
- We want healthy trees!

Author

John Runnals from Accrington Bonsai Society