

What is biochar?

Biochar is a black, solid substance which bears a strong resemblance to charcoal. It is produced during a process called pyrolysis – heating biomass to a very high temperature in the absence oxygen. Biochar is lightweight, fine-grained and very porous, which are all properties that are useful in its primary usage as a soil amendment. Biochar can be made from all kinds of biomass feedstocks, and each will have its own physio-chemical characteristics, influencing the biochar produced. This means a biochar production facility can tailor their process to create 'designer' biochar. Biochar's use in horticulture, for commercial growers and in landscaping projects is becoming increasingly popular due to its ability to enhance soil quality through improved water holding capacity (WHC) and better nutrient retention, leading to healthier plant growth.

This factsheet will delve into more detail about the properties, benefits and applications of biochar products in soil and provide valuable insights for gardeners, growers and landscapers.

Biochar properties

Biochar products come in lots of forms depending on the material the biochar was made from and what the biochar is blended with. One key feature of biochar is its high carbon content. Depending on what the biochar is made from, the carbon content is likely to be between 50–90% of material. The remainder of the biochar is typically made up of ash, which is important as it can hold reasonably high levels of certain nutrients and is a source of trace elements which are required by plants.

Below are some of the properties of biochar which can positively impact soil health and plant growth:



pH

pH measures how acidic or alkaline a material is. pH ranges from 0 (very acidic) to 14 (very alkaline), with 7 being neutral. Biochar is typically alkaline and can help reduce soil acidity. Most plants like a pH of anywhere between 6 and 7.5 but there are some acid and alkali loving plants which like more extreme conditions.



Biochar surface area

The surface area of biochar is linked to its porosity. Biochar with a high surface area possesses a higher water holding capacity (WHC) and can support greater microbial life (given microbes like to live in biochar pores).

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Cation exchange capacity (CEC)

CEC measures the ability to hold and exchange positively charged ions (cations) like calcium, magnesium, and potassium. Biochar can boost a soil's CEC, leading to better nutrient retention (avoiding leaching) and reliable nutrient supply to plants over time.

Water holding capacity (WHC)

The WHC measures how much water is able to be held as a percentage of the biochar's dry weight, before it is fully saturated. A high WHC indicates that the biochar will remain moist and require less frequent watering. Biochar's high WHC helps soil retain moisture and nutrients.

Electrical conductivity (EC)

EC measures the soil's ability to conduct an electrical current, which is influenced by the concentration of soluble salts (ions) in a material. Higher EC indicates higher salinity and nutrient availability. Biochar can boost the EC of soil, promoting better nutrient uptake.

Hydrogen to carbon ratio (H/C)

The H/C ratio indicates the amount of hydrogen to carbon present in the biochar. The lower the figure, the more stable the biochar is, resulting in the biochar and its carbon remaining in the soil for longer, without breaking down.

Macro & micro nutrient levels

The nutrient levels indicates how much of specific nutrients are available in a material. Macro-nutrients like NPK (Nitrogen, Phosphorus and Potassium) are normally indicated by three numbers such as 5-7-4, meaning the % of each element in the product.

Micro-nutrients are only required in very small quantities. Typically a material may say if they are present or not, rather than providing the quantity present. Examples include Copper, Manganese, Zinc, etc.

Macro & micro nutrient levels

The presence of beneficial microorganisms in a material indicates that the product will increase long term soil health. Microorganisms are able to provide nutrients to plants on an ongoing basis through breaking down organic matter present.

Further reading:



[Blok et al., 2017](#)



[Biochar for circular horticulture](#)



[Royal Horticultural Society](#)



[Biochar as a peat replacement](#)

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As pointed out earlier, not all biochar is created equal. The material it was made from, pyrolysis equipment used, production temperature and retention time will all influence the above properties when making biochar.

The table below shows some of the key properties of biochar and how they differ depending on the material it was made from:

Key properties of raw biochar made from different organic matter	Biochar made from:		
	Woody material	Green waste/ agricultural residues	Animal manures
Water holding capacity (WHC)	High	Medium	Low
pH	Slightly alkaline (7-8)	Neutral (6-8)	Alkaline (8-10)
Cation exchange capacity (CEC)	Moderate	High	Very high
Ash levels	Low	Medium	High
Surface area	Very high	High	Moderate
Macronutrients	Low	Medium	Higher
Micronutrients	Low	Medium	Higher

Meeting Nutrient Requirements

We know that biochar improves nutrient retention and uptake for plants. But what exactly are the nutrient requirements of plants? Plants require light, water, and around 20 elements to grow. These 20 elements are called essential nutrients. An element is classified as essential when:

- A plant cannot complete its life cycle without the element.
- Another element cannot perform the same function as the element in question.
- The element is directly involved in plant nutrition.

Essential elements can be divided into macro-nutrients and micro-nutrients.

Macro & micro-nutrient levels

- Nutrients that plants require in larger amounts are called macro-nutrients. About half of the essential elements are considered macro-nutrients: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur.

- Micro-nutrients, or trace elements, in contrast are only required in very small quantities. The seven main micro-nutrients include boron, chlorine, manganese, iron, zinc, copper, and molybdenum.

Fertilizers

A fertilizer is a substance, either natural or synthetic, that provides nutrients to plants for their growth. Fertilizers enhance the natural fertility of the soil by increasing nutrient levels or replacing nutrients that have been depleted by previous crops. Fertilizers can be blended into other soil products such as composts, or applied as a stand-alone product. Typically fertilizers focus on three key nutrients; nitrogen (N), phosphorus (P), and potassium (K), often referred to as NPK, which are crucial for plant health and productivity.

Micro-organisms

Micro-organisms play a crucial role in soil health and plant growth through various mechanisms. These activities collectively enhance soil structure, fertility, and plant health, contributing to more sustainable and productive growing systems. The key benefits microbes have include:

- **Nutrient cycling:** Microbes are essential for the decomposition of organic matter, which releases nutrients like nitrogen, phosphorus, and potassium back into the soil, making them available for plant uptake.
- **Nitrogen fixation:** Certain bacteria, such as rhizobium, form symbiotic relationships with legumes to fix atmospheric nitrogen into a form that plants can use.
- **Phosphorus solubilisation:** Some soil bacteria and fungi can solubilise phosphorus, making it more accessible to plants.
- **Disease suppression:** Beneficial microbes can outcompete or inhibit harmful pathogens through the production of antibiotics, siderophores, and other compounds.
- **Plant growth promotion:** Microbes like plant growth-promoting rhizobacteria (PGPR) produce hormones such as auxins, cytokinins, and gibberellins, which enhance root growth and overall plant development.
- **Stress tolerance:** Micro-organisms can help plants withstand abiotic stresses like drought and salinity by improving water retention and nutrient uptake.

How to use biochar

Raw biochar

Raw/pure biochar is most effective when nutrients and/or micro-organisms are added to it ahead of end-use in soil. This is known as 'charging' the biochar. Alternatively, biochar needs to be applied 3 months ahead of planting, so the microbes can colonise the biochar.

This is recommended because, if the biochar is placed directly into the soil un-'charged', the biochar will draw in nutrients as the microbes in the soil colonise the biochar. For a period of around 3 months limited nutrients will be available for the plants, after the 3 months the biochar will provide a steady supply of nutrients to the plants.

The easiest way to pre-charge biochar is to blend it with other products such as manures, composts or fertilizers ahead of use. After mixing the biochar it can be used straight away, however if it is left to mature it will be even more effective, as the microbes will have had time to colonise the biochar.

Location and application

Biochar is most effective when located around the roots of plants, typically at a rate of around 10 to 20% by volume. Biochar is a stable product which will remain, once applied in the ground, for many hundreds of years. When using biochar in planting, mixing with substrates is best (digging in the biochar).

If you are using biochar on existing plants and trees, however, the easiest application method is as a top dressing. The biochar will slowly, over a number of months and years, be drawn down into the soil to the root zone.

If using a top dressing method, applying small amounts annually is good practice to enable the biochar to slowly work its way into the soil and build up to around a 10–20% soil volume quantity.

Use in different soil types

Some soils and growing substrates are naturally more fertile than others. Biochar is most effective when improving poor growing media.

The table below shows the expected impact that biochar can have on different soil types:

Soil Type	Description	Expected Biochar Impact
Sandy	Light, dry, warm, low in nutrients and often acidic.	High: Moisture and nutrient retention, and alkalinity of biochar well suited to address drawbacks of sandy soil.
Clay	Heavy, high in nutrients, wet and cold in winter and baked dry in summer.	Medium: Biochar can deliver aeration benefits and increase hydraulic conductivity of the soil.
Loam	Mixtures of clay, sand and silt that avoid the extremes of each type.	Low: Biochar effects more marginal in good soils.
Silt	Fertile, light but moisture-retentive, and easily compacted.	Medium: Biochar can deliver aeration and reduce compaction.
Peaty	Very high in organic matter and moisture.	Low: Biochar effects more marginal in good soils.
Chalky	Very alkaline and may be light or heavy.	Medium: Moisture and nutrient retention beneficial, but soil may remain alkaline.

Glossary

Aeration: The process of introducing air into the soil, which is crucial for healthy root growth. Aeration improves the soil's oxygen supply, necessary for root respiration and overall plant health.

Leaching: The process where water soluble substances are washed out from the soil or compost, often leading to nutrient loss. Biochar can reduce this effect by binding nutrients.

Microbial life: Micro-organisms living in the soil, including bacteria, fungi, and protozoa. These organisms are key to nutrient cycling, breaking down organic matter, and improving soil health and fertility.

Nitrogen fixation: The process by which certain bacteria in soil or plant roots convert nitrogen from the air into a form plants can use for growth.

Nutrient cycling: The process by which nutrients are exchanged between the physical environment and living organisms, including decomposition, absorption, and recycling of nutrients within the soil eco-system.

Biochar in horticulture

The key benefits that have been proven when biochar is used in various horticultural systems include:

Increased microbial activity: Biochar provides a habitat for beneficial soil microbes, which play a crucial role in nutrient cycling and improving plant health.

Enhanced water retention: Biochar's porous structure allows it to retain water effectively, reducing the need for frequent watering and helping plants withstand dry conditions.

Reduced soil acidity: Biochar can help balance the pH levels of acidic soils, making them more conducive to plant growth.

Disease suppression: Biochar has been shown to help suppress certain soil-borne diseases through increased microbial activity, contributing to the overall health of plants.

Carbon sequestration: Adding biochar to soil helps sequester carbon, reducing greenhouse gas emissions and contributing to climate change mitigation.

Improved nutrient availability: Biochar's ability to bind nutrients means less nutrient leaching, leading to more efficient use of fertilizers and less environmental impact as well as increasing nutrient availability for plants.

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Glossary

Nutrient retention: The ability of soil to retain nutrients and prevent them from leaching away with water. Higher nutrient retention means that plants have more prolonged access to essential nutrients.

Phosphorous solubilisation: The process where soil microbes break down phosphorus compounds, making the nutrient available for plants to absorb and use.

Pyrolysis: A thermal decomposition process where organic material is heated to high temperatures in the absence of oxygen, resulting in the production of biochar.

Soil structure: Refers to the arrangement of soil particles and the pore spaces between them. Good soil structure is important for root growth, water movement, and air circulation within the soil.