JANUARY 2013

GRDC
Grains Research & Development Corporation
Your GRDC working with you

BIOCHAR FACT SHEET

NORTHERN, SOUTHERN AND WESTERN REGIONS

UNDERSTANDING BIOCHAR

In some soil types biochar has the potential to enhance soil fertility, increase soil carbon storage and decrease greenhouse gas emissions. However, before biochar can be widely adopted in agriculture, better understanding is needed of its properties and how it interacts – both positively and negatively – with the soil.

KEY POINTS

- Biochar is a purpose-produced charcoal and its composition varies according to the feedstock used and production conditions such as temperature and time.
- There is no single type of biochar.
- Biochar is a stable form of carbon that has potential for carbon sequestration.
- Research suggests it may be useful in decreasing soil greenhouse gas emissions.
- Biochar can alter the physical, chemical and biological properties of a soil and may improve crop productivity.
- Further study is needed on the performance of biochar in a range of soils and environments before it can be accurately predicted where it may have benefits.
- The economic viability of adding biochar is not yet proven. Australian farmers are currently unable to source large quantities cheaply.

PHOTO: DANIEL MURPHY, UWA

Gas chambers are used to measure greenhouse gas emissions from a soil amended with biochar in Western Australia. Although decreased nitrous oxide emissions have been observed in separate trials in New South Wales, in this trial no difference was recorded between the control and the biochar-amended soil.

What is biochar?

Biochar is a solid, carbon-rich material produced when organic matter is heated to very high temperatures in a low-oxygen environment: a process called pyrolysis.

Interest in biochar as a soil amendment has increased due to the growth in the bioenergy industry and interest in how landholders can contribute to carbon sequestration and the reduction of greenhouse gas emissions. Agronomic benefits have sometimes been observed when biochar has been added to a soil as a conditioner.

Results on heavy alkaline soils have been promising, although not consistent. No consistent benefits have been observed on the sandy soils of Western Australia.

Although the term biochar refers to materials produced by pyrolysis, there is no single type of biochar.

Properties such as carbon content, pH and physical and chemical structure vary depending on:

- the feedstock used (manures, energy crops, crop residues, wood chip, municipal waste and so on);
- feedstock preparation;
- the temperature at which it is processed (usually ranging from 450°C to 550°C, however, it can be produced outside this range); and
- the rate and duration of heating.

The type of feedstock used is the most important factor in the variability of the end product.

Different types of biochar have varying potential to sequester carbon or improve

Terra preta soils

Humans have produced biochar (as charcoal) for thousands of years, as evidenced by the terra preta (black earth) soils of the Amazon Basin.

The presence of ancient pottery, manure and animal bones in these soils suggests that charcoal was a by-product of cooking, food preparation and pottery manufacture for the civilisations that lived there.

Terra preta soils are highly fertile and have demonstrated the potential for long-term carbon sequestration.

crop yields. For example, biochar produced from high carbon feedstocks, such as wood waste, at high temperatures are more likely to be better suited to long-term carbon sequestration. However, biochar produced from feedstocks with higher nutrient content, such as animal manures, are more likely to benefit crop productivity.

Feedstock

Biochar can be made from almost any organic material.

The most common feedstocks include wood, crop residues, manures or municipal waste such as food and green waste.

Unlike feedstock material, biochar has a three-dimensional molecular structure of 'aromatic rings'. This structure is difficult for microbes to break down and is very stable over long periods. This is why it has the potential to sequester carbon.

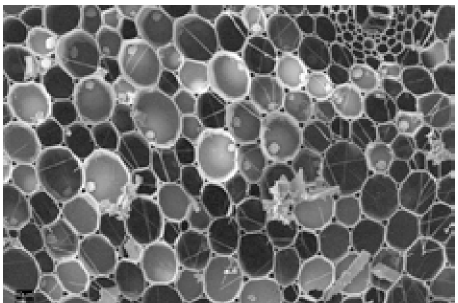


PHOTO: BIOFORSK

Biochar from wheat straw under a scanning electron microscope, demonstrating a porous structure that reflects the parent feedstock.

Pyrolysis

The process of pyrolysis drives off the volatile components of the feedstock and stabilises the remaining material into a carbon-rich solid black material.

These volatile liquids and gases known as synthesis gas, or 'syngas', can be captured and used to power the pyrolysis reaction, with surplus available for bioenergy production.

Characterising the biochar

A range of analytical techniques are employed to understand the structure, composition and interactions of biochar.

The structural aspects can be characterised spectroscopically or by using chemical/thermal analysis and microscopy.

Chemical characteristics can be assessed using laboratory testing. The International Biochar Initiative has published standards and test procedures.

Ecotoxicological testing such as earthworm avoidance assays and plant germination inhibition assays can be used to test ecological safety.

More information on characterisation is available at the Australia and New Zealand Biochar Researchers Network. See Useful Resources.

Biochar's role in soil function

Different types of biochar are suitable for a range of different applications. Research is underway to determine which feedstocks and process conditions produce particular desirable properties such as improved soil structure and nutrient availability.

Some biochar applications have been shown to increase crop (feedstock) production – up to 100 per cent in some glasshouse studies – and improve soils across a range of conditions. However, other research has found no difference or, in some cases, a decline in productivity.

The results depend not only on the type of biochar being used but the way it interacts with a particular soil type, which crop is being grown, the climatic conditions and various other limiting factors to plant growth.

This means that a particular type of biochar needs to be tested for specific crops, soils and environments. This is time-consuming and expensive.

Ongoing research aims to gain a better understanding of the interactions between various types of biochar and differing soil types in a range of environments.

Physical benefits

Applications of biochar to soil have demonstrated improvements in the physical structure of the soil by:

- increasing water-holding capacity (in sandy soils);
- reducing the tensile strength of hard-setting soil;
- altering the soil thermal properties; and
- improving physical conditions for increased earthworm populations.

Chemical and nutritional benefits

Biochar has been shown to deliver nutrients, particularly sulphur and phosphorus to the soil, especially if made from poultry litter. But again, trial results are varied.

Other benefits can include:

- improved nutrient storage and cation exchange capacity (CEC);
- increased soil carbon content;

PHOTO: ZAKARIA SOLAIMAN, UWA

0t/ha	10t/ha	20t/ha	50t/ha	100t/ha
94%	97%	99%	93%	88%

The effect of jarrah biochar on percentage of wheat seed germination. The Petri dish bioassay represents different rates equivalent to 0, 10, 20, 50 and 100 tonnes per hectare based on 10 centimetre field depth.

- increased soil pH (liming value); and
- decreased aluminium toxicity.

Due to altered nutrient storage, CEC, pH and physical changes such as water-holding capacity, fertiliser use efficiency may also improve.

Biological benefits

Changes in microbial communities have been observed following the application of biochar to the soil.

The direct effects of biochar on the physical and chemical functions of soil are likely to have indirect effects on the soil microbial community. Altered biological functions, including carbon and nutrient turnover, are likely to change crop productivity.

In Western Australian studies, biochar has been found to increase mycorrhizal fungi colonisation of wheat plant roots.

The addition of biochar saw 50 to 60 per cent of roots colonised, up from 10 to 20 per cent in soils without biochar.

Improved biological nitrogen fixation by legume/rhizobia systems has also been observed.

Environmental benefits

Biochar has multiple benefits from an environmental perspective.

It can divert organic waste from landfill and convert the material into highly stable forms of carbon, which is likely to have a slow turnover — greater than 100 years.

The production of biochar through pyrolysis generates bioenergy in the form of syngas, which can be used for power generation.

It can also decrease nitrous oxide (N_2O) and methane (CH_4) emissions from the soil. CH_4 is a greenhouse gas that is 25 times more potent than carbon dioxide (CO_2), while N_2O is around 300 times more potent.

Biochar has the potential to play an important role in carbon farming and greenhouse gas mitigation, but its current cost limitations need to be addressed.

Safety

Biochar has several areas in which safety needs to be assured as follows.

Feedstock

Feedstock contaminants can include heavy metals such as lead, zinc and arsenic.

Pyrolysis systems

Toxic byproducts and end products are far more likely to emerge in uncontrolled pyrolysis conditions, so it is important to deal with a reputable producer.

Production systems should meet legislated emission standards, and the safety of all proposed facilities need to to be assessed.

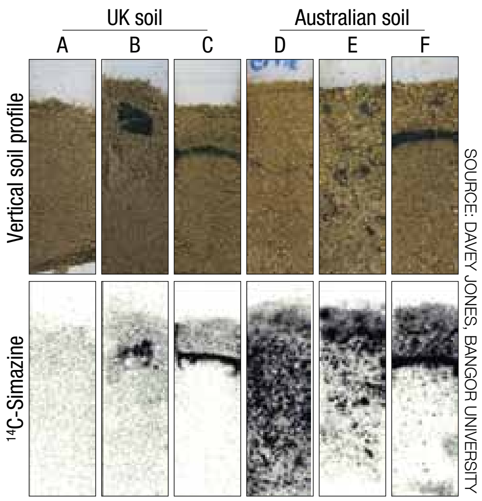
End use

Biochar should meet guidelines for dioxins, heavy metals and polycyclic aromatic hydrocarbons (PAHs). PAHs are atmospheric pollutants, some of which can cause cancer and other health issues. Where biochar is to be used as a soil conditioner it must conform to relevant Australian and international standards for soil amendments.

Earthworm avoidance and plant germination inhibition can be used to test ecological safety. Depending on biochar formulation, dust can be an issue during application.

Pesticide efficacy

Trials have shown that biochar may provide opportunities to reduce phytotoxicity of residual herbicides in crops with susceptible soils. Sorption of atrazine and diuron increased with biochar amendment, but with ageing of biochar in soil this sorption capacity reduces to levels similar to control soils.



Radioactive carbon (^{14}C) tracing of Simazine applied to the soil surface shows that this chemical binds with the biochar that has been added as a single chip (B), applied as a horizontal band (C, F), mixed into the soil (E). In A and D no biochar was added and the Simazine has leached through the soil profile.

Which biochar is right for my system?

Biochar performs differently depending on soil type and climate. Growers wishing to use biochar on their own property should apply a few trial strips and then monitor results in subsequent years.

For example, a biochar suitable for long-term carbon sequestration is likely to be derived from a high carbon feedstock (such as wood waste) and be produced at high pyrolysis temperatures for greater long-term stability.

Manure biochar, and biochar produced from food and garden waste, tends to have greater nutrient content compared to unamended wood waste biochar.

It is important to consider the concentration of available nutrients rather than total nutrients of the biochar.

Sourcing biochar

The increasing interest in biochar, the logistical difficulties of obtaining it and its high cost as an experimental product have naturally led to an interest in small-scale, on-site pyrolysis.

Potential pitfalls of homemade biochar include:

- lack of control of pyrolysis conditions resulting in variability in biochar properties;
- contamination of feedstock with heavy metals;
- lack of characterisation; and
- lack of facilities to capture gases, some of which may be toxic or harmful as greenhouse gases.

The advantages of buying biochar through a reputable established source include:

- the availability of different feedstocks;
- characterisation of its chemical attributes; and
- environmentally sound manufacture in a facility that captures gases and possibly energy.

Economics

Costs are reducing and mobile units are being developed, however, currently the high cost of off-site biochar production, and the logistics of its manufacture and transport, make it uneconomical for broadacre crop application.

PHOTO: ANDREW WHERRETT, UWA

Applying a simulated summer rainfall to biochar-amended field plots assists in assessing the impact of biochar on greenhouse gas emissions.

This may change as a biochar market develops, which is serviced by a new biochar production industry, accompanied by an increase in value of green energy.

Biochar shows great promise in some soils as a method for mitigating climate change, through carbon sequestration and the reduction of greenhouse gas emissions and also through improved soil health.

Before biochar can be broadly adopted, however, more research is needed. Factors such as the cost and logistics of its production must be addressed and its safety with regard to human and environmental health assured.

The body of knowledge around biochar is growing all the time. As we improve our understanding of its various properties and interactions with different soils, we can further refine the potential of biochar across a wide range of applications.

FREQUENTLY ASKED QUESTIONS

How do biochars differ?
The feedstock material and the temperature and time at which it is processed will affect the chemical and physical properties of the biochar produced. The same biochar may also produce different results in different soil types and climatic conditions.

How stable is it?
The terra preta soils of the Amazon Basin indicate that biochar (as charcoal) can be stable in the soil for thousands of years. While it is difficult to estimate the longevity in the soil of newly produced biochar using short-term experiments, it is believed that biochar from wood waste processed at higher temperatures (550°C) could remain stable in the soil for hundreds of years.

What are the agronomic benefits?
The effects of biochar vary according to feedstock, processing temperature and time, and interaction with different soil types. However, some biochars have shown substantial benefits for crop yield, soil fertility, soil pH, available soil phosphorus and CEC.

Root structure analysis has shown healthier root systems in plots where biochar was applied. Glasshouse trials have demonstrated improved water-holding characteristics, reduced tensile soil strength and improved nutrient availability. Biochar can also been have a beneficial impact on low-nutrient and compacted soils and has demonstrated potential for rehabilitating degraded soils.

What is its potential under the *Carbon Credits (Carbon Farming Initiative) Act 2011*?
In May 2012, the Australian government launched a Biochar Capacity Building Program. One of the aims of the program is to facilitate the development of biochar offset methodologies to enable farmers to participate in domestic and international carbon markets through the Carbon Farming Initiative.

This program is also supporting research into the ability of biochar to mitigate greenhouse gas emissions and investigating how biochar may be used on-farm to benefit agricultural activity and improve soil health.

USEFUL RESOURCES

Investigating Biochar: From Source to Sink
www.csiro.au/science/Biochar-Overview

Soil Quality Australia
www.soilquality.org.au

Australia and New Zealand Biochar Researchers Network
www.anzbiochar.org

International Biochar Initiative
www.biochar-international.org

Pacific Pyrolysis
pacificpyrolysis.com

MORE INFORMATION

Annette Cowie, Rural Climate Solutions
annette.cowie@une.edu.au

Lynne Macdonald, CSIRO Land and Water
08 8273 8111
lynne.macdonald@csiro.au

Daniel Murphy, University of Western Australia
08 6488 7083
daniel.murphy@uwa.edu.au

Lukas van Zwieten, NSW Department of Primary Industries
02 6626 1200,
lukas.van.zwieten@dpi.nsw.gov.au

GRDC PROJECT CODES

CSO00041, UWA00130

Acknowledgments: Annette Cowie, Lynne Macdonald, Daniel Murphy, Lukas van Zwieten.

PRODUCED BY **WWW.CORETEXT.COM.AU**