# Biochar potential for soil improvement & soil fertility

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**IN A NUTSHELL**

- Biochar is a form of charcoal resulting from the burning of organic materials at high temperatures under low oxygen conditions.
- There is great interest in biochar production as a means of carbon storage of material that would otherwise be dealt with as waste (and most likely burnt).
- A research project has commenced at CSIRO Griffith to investigate the potential use of local agricultural waste products to produce biochar, and the potential use of the resulting biochar as a soil amendment.

*Biochar is a form of charcoal produced through the heating of natural organic materials (crop wastes, chicken litter, timber) under low oxygen conditions. It has received significant attention recently for its potential as a soil conditioner, a fertiliser and as a means of sustainably storing carbon.*

The carbon in biochar is chemically and biologically more stable than the carbon in the plant residue from which it is made. This makes it difficult to break down, and in some cases, biochar carbon has been known to remain in soil for hundreds or even thousands of years. It is for this reason that biochar potentially offers a way of locking up carbon that may have otherwise been emitted to the atmosphere as carbon dioxide.

In addition to carbon storage, the production of biochar offers a number of benefits. The gases generated, including hydrogen and methane, potentially can be collected and used to produce heat and power. Biochar also provides an opportunity to manage animal and crop wastes by reducing volume and mass and reducing the potential for these wastes to pollute water resources.

The nature of biochar will be dependent on the material that is burnt, and the temperature and rate of the heating process. For example, biochar produced from chicken litter will have a very different nutrient content to biochar made from timber. Biochar produced at 700°C will have different adsorption characteristics to that produced at 400°C.

## Biochar for agricultural soils

The addition of biochar to agricultural soils is receiving a lot of interest due to the agronomic benefits it may produce. Some studies have shown it can improve soil quality and increase fertiliser and water use efficiencies, giving yield benefits. Conversely, in some cases no benefit or negative effects have been observed due to micronutrient deficiency induced by soil pH increases or phytotoxicity resulting from a micronutrient excess in the biochar.

To date there has been little assessment of the characteristics and end use benefits for soils and potential carbon sequestration possibilities of biochar derived from citrus and grape prunings and processing wastes. There are many sources of wastes in the wine and citrus industries that could potentially be used for biochar manufacture. On farm there is a great deal of wood available when old plantings are pulled out. At the moment this wood is generally burnt in the paddock producing no benefit to the farm. In the processing industry there are many waste products such as citrus peel and grape marc.

## Biochar production

Biochar is similar to charcoal. It is made by controlled burning of biomass whilst restricting the air (oxygen) usually at temperatures less than 700°C, a process known as pyrolysis. Biochar is different to charcoal by the fact that it is specifically produced with the intent to be applied to soil as a mean of improving soil productivity, carbon storage or filtration of soil percolating water. The production process, together with its intended use, typically forms the basis for classification as biochar. In contrast, charcoal has no formal classification system. It may be used as fuel for heat, as a filter, as a reductant in iron-making or as a colouring agent in industry or art.

Biochar was produced experimentally at the CSIRO Land and Water Griffith Laboratory in a custom made biochar maker. The construction of the biochar maker is shown in Figure 1.

Approximately 30 kg of feedstock (the biomass or waste product sourced from a local horticultural industry) was placed into a 50 L can (the carbonisation chamber) which was inverted inside a 500 L drum (the combustion chamber) so that an incomplete seal was formed at the base. A temperature sensor was placed in the middle of the feedstock mass inside the carbonisation chamber, and linked to a data logger, which logged temperature every 15 minutes throughout the heating period.

Separating the combustion process from the carbonisation process allows any flammable products generated in the burning of the biomass, such as volatile hydrocarbons and hydrogen, to be burnt as they pass into the combustion chamber producing little soot and smoke. Predominantly, carbon monoxide, carbon dioxide and water vapour are released to the atmosphere during most of the burn.

Once the feedstock and carbonisation chamber were in place, the combustion chamber was filled with pine chips which acted as the combustion fuel. The fuel was lit from the top at various points around the diameter of the combustion chamber to achieve an even burn (Figure 2). A steel lid with a hole in the centre was placed on top of the drum and after a few minutes a chimney was placed on the top of the hole in the lid to achieve sufficient draft for a clean burn. The fuel was then left to burn, converting the feedstock to biochar which could take about 24 hours.

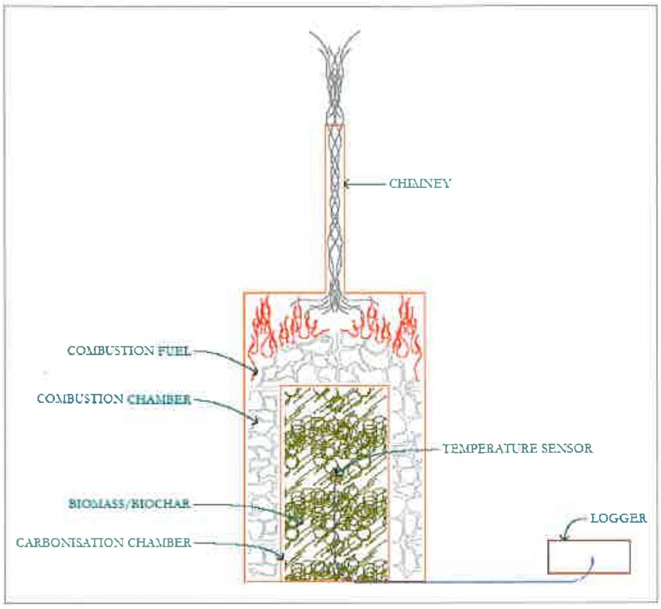


*Figure 1. Diagram of the small scale biochar production plant.*

*Figure 2. The combustion chamber is packed with pine chips that act as the fuel to generate high levels of heat around the inner chamber that contains the biomass that will become biochar.*

The process was repeated four times to produce biochar from:

- grapevine prunings
- orange tree prunings
- grape marc sourced from winery waste
- orange peel sourced from juicing waste.

## Results

Table 1 shows the results of the biochar making process at Griffith. The maximum treatment temperatures achieved were in the range 500–650°C. During the heating process (pyrolysis) most of the feedstock material was burnt, leaving about 21–25% by mass of biochar with little ash. Figure 3 shows the biomass feedstock and the biochar products.

These values are typical for cellulose (plant based material) pyrolysed under reduced oxygen conditions for several hours, in established laboratory work. Yields of up to 30% biochar from cellulose may be attained at lower temperatures (200–300°C). Much lower yields (8%) result if oxygen infiltrates the process.

Elemental analysis shows that the biochars are 67–86% carbon, indicating a 34–83% increase in carbon in the biochar compared with the biomass material burnt as feedstock.

There was also a 166–250% increase in nitrogen, from biomass to biochar. Although the final nitrogen levels were at most, only 3% and we know that only a small fraction of this is available for plant uptake. Previous studies suggest that it is not necessarily the direct nutrient content of the biochar that leads to yield improvement but more the indirect fertility value. Through its adsorption qualities, biochar can reduce leaching and volatilisation of applied nitrogen; reduce soil strength and increase water retention.

The current level of analysis does not allow us to estimate how long the carbon in these specific biochars will be stored in soils. Like other physico-chemical characteristics of biochar, the half life of biochar in soils is dependent on a multitude of factors including the original biomass, production conditions, soil type and climate. Long term storage in soils is difficult to determine in soils from short term studies.

Previous laboratory based studies of different biochars indicate that losses of less than 2% of the carbon occur in the first few

*Table 1. Some production characteristics and properties of different feedstocks and biochars (C = carbon, N = nitrogen)*

| Feedstock | Maximum treatment temperature (°C) | Char yield (%) | Feedstock elemental analysis | | Biochar elemental analysis | |
|---|---|---|---|---|---|---|
| | | | C% | N% | C% | N% |
| Grapevine timber | 562 | 25 | 47 | 0.2 | 86 | 0.5 |
| Orange timber | 650 | 21 | 47 | 0.6 | 82 | 1 |
| Grape marc | 533 | 21 | 50 | 2.1 | 67 | 3 |
| Orange peel | 602 | 22 | 41 | 1.3 | 73 | 2.8 |

months of application through microbial degradation, although these findings are not unequivocal. Biochar as residues from forest fires has frequently been found to be more than 10,000 years old in various soils. However, other losses through soil erosion, wind, and leaching also need to be considered.

## Biochar tests in the field

A trial is currently being conducted at CSIRO Griffith that will test whether the addition to soil (Hanwood Loam) of the biochars produced in this experiment has a beneficial effect on sweetcorn production and what effects the biochar has on soil properties.

Three biochar rates (0, 45 and 90 t/ha) combined by two nitrogen-phosphorus fertiliser rates (0 N:P and 30 kg N/ha: 40 kg P/ha) have been used. The trial continues and the intention is to publish further results in the *Farmers' Newsletter* after the trial is complete.

## Biochar production potential

In the Murrumbidgee Irrigation Area a preliminary estimate suggests that over 600,000 tonnes per year of agricultural organic wastes may be available for biochar production. Assuming a biochar yield of 20%, the mass of waste from these industries might yield 121,530 tonnes of biochar each year. Assuming a soil incorporation depth of biochar of 10 cm and 2.5% incorporation rate (equivalent to 45 t/ha) this amount of biochar would treat approximately 3000 ha/y.

## Summary

The construction and use of a small scale biochar plant was relatively straightforward although gases and particulate organic matter that may be emitted during the process which could impact the environment were not collected and quantified.

The maximum treatment temperatures achieved (approximately 500–650°C) were appropriate for biochar production with relatively little ash. The different feedstocks provided biochar products with a range of carbon and nitrogen contents. Further characterisation of these biochars and the sweetcorn crop trial in which they are used as amendments are ongoing. It is hoped the results will assist in our future understanding of how simple biochar production might fit into a farming system.


*Figure 5.* *Biomass feedstock (upper row) and biochar products (lower row) produced in the small scale biochar maker.*

### Further reading

CSIRO Land and Water Science Report 05/09. 65 pp. *Biochar, climate change and soil: A review to guide future research.* S Sohi, E Lopez-Capel, E Krull and R Bol (2009).

### Acknowledgements

*This work was funded by the CSIRO Land and Water Capability Development Fund. Thanks to Tony Taliano of the Real Juice Co. Pty Ltd for supplying orange processing waste, Tarac Technologies for supplying grape marc and growers local to Griffith for vine and orange tree timber samples. Leo Zandona, Roy Zandona and Alison Fattore (CSIRO, Griffith) are thanked for biochar production and analysis and Evelyn Krull (CSIRO, Urrbrae) for help in project development.*

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