NURSERY PAPERS
November 2011 Issue no.9

The Effect of Biochar Amended Growing Media on Plant Nutrition and Growth

Over the past few years, there has been growing interest in using biochar as soil amendments to improve and maintain soil fertility and to increase soil carbon sequestration. Unfortunately, most of this research has failed to investigate whether biochar behaves similarly when incorporated in growing media. In this Nursery Paper NGIA Environmental & Technical Policy Manager, Dr Anthony Kachenko summarises preliminary research undertaken by Nursery and Garden Industry Australia (NGIA) to assess the effect of biochar amended growing media on plant nutrition and growth. This research was made possible by direct funding from NGIA through the Nursery Industry Research & Development Levy. The research was undertaken at The University of Sydney by Carly Housley as part of her Honours degree in Agricultural Science. Her research was supervised by Associate Professor Balwant Singh and Dr Anthony Kachenko.

Introduction to biochar

Introduction to biochar

Biochar refers to the carbon-rich material produced from heating organic materials (usually 400–600 °C) in the absence of oxygen by a process termed pyrolysis. Organic materials can be sourced from a variety of feedstock's including; plant materials, municipal solid waste, industrial by-products, sewage sludge and animal manures. At these temperatures the feedstock is thermally decomposed and releases a vapour phase and a residual solid phase which is termed biochar.

In the past few years, biochar has gained global importance due to its role in mitigating climate change and variability. It is also considered beneficial in managing soil health by improving and maintaining soil fertility. The application of biochar to soil can potentially:

(i) enhance soil physical, chemical and biological fertility;
(ii) improve fertiliser and water-use efficiencies;
(iii) mitigate emissions of greenhouse gases (GHG), including N_2O; and
(iv) decrease the availability of heavy metals.

One of the distinguishing properties of biochar that allows it to be a long-term carbon sink is its high stability in the environment relative to other types of organic carbon substances. Indeed, biochar resists degradation and can hold carbon in soils for hundreds to thousands of years. Although this appears favourable, it is important to note that the performance of biochar will depend on the feedstock, how it is prepared and pyrolysis conditions under which it was produced. Indeed, it is well documented that the biomass feedstock and the processing conditions such as temperature and heating rate will influence key chemical and physical properties of the biochar.

At present, there is much research being conducted in Australia evaluating the implications of biochar additions to soil in an agricultural and environmental context with many of the studies confirming the aforementioned characteristics of biochar when applied to soil. However, there has been negligible published research conducted in the context of the Australian nursery industry in relation to the effect of biochar additions to growing media.

Research aims

The aims of this preliminary research experiment were to investigate the effect of biochar amended growing media on plant nutrition and growth by:

1) Determining if biochar amended growing media would enhance plant growth and minimise fertiliser inputs.
2) Examining the nutrient uptake and concentration of plants in biochar amended growing media using three different control release fertiliser (CRF) levels (no CRF, half strength CRF, full strength CRF).
3) Investigating the effects on the pH and EC of growing media following the incorporation of biochar.

Methodology

Lilly Pilly (*Acmena smithii*) tube stock, Viola (*Viola v. hybrida*) and Pansy (*Viola x wittrockiana*) plugs were selected for this research. Sydney Blue Gum (*Eucalyptus salinga*) wood (47.9% C, ~0.03% N) was used as the feedstock of the biochar used in this experiment (*Figure 1*).

***Figure 1**. Sydney Blue Gum (Eucalyptus saligna) biochar*

The biochar was produced using slow pyrolysis by BEST Energies, Inc. (Daisy Reactor, Sydney) at temperatures of 550°C. Specifically, the biochar was pyrolysed at 5-10°C/min heating rate and 40 min residence time, and N_2 was then added into the reactor during the cooling-off period to maintain the inert environment. Properties of the biochar are depicted in Table 1.

Table 1. Basic properties of the Sydney Blue Gum (E. saligna) biochar used in the experiment

Biochar treatment	pH (1:5 H_2O)	EC (1:5) (dS/m)	Ash Content (g/kg) 500°C	Ash Content (g/kg) 700°C	Total C (g/kg)	Total N (g/kg)	P (mg/kg)	K (mg/kg)	S (mg/kg)	Ca (mg/kg)	Mg (mg/kg)
550°C, non-activated	8.82	0.16	44	33	836.1	2.6	217	2358	488	21 263	1085

Experimental setup

The experiment was carried out in controlled glasshouse conditions at The University of Sydney (Figure 2). Plastic pots (1.1L) were filled with 650 grams of Premium Grade growing media meeting Australian Standard AS 3743-2003. The experimental design used was a factorial randomised block design with four replications. Pre-plant fertilisers were added to the growing media blend (data not supplied). One week prior to planting, APEX NPK Plus controlled release fertilizer (CRF; N:P:K of 16:2.1:7.4) was added at the recommended rate, half rate or without to create the no CRF, half strength CRF and full strength CRF treatment levels. Biochar was then added to pots at the following rates: 0, 2.5, 5, and 10%. The biochar rates were calculated on a dry weight basis per pot and added manually. Plants were potted up at one plant per pot with a total of 48 pots for each plant species. The pot trial was conducted over a 14 week period with all plants watered twice a day for 10 minutes duration using overhead irrigation.

Figure 2. Experimental setup at The University of Sydney

At the completion of the trial, the above ground biomass of all plants were harvested and dry weights determined. All above ground biomass samples were analysed for an array of plant macro nutrients; phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) and plant micro nutrients; copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe). Carbon (C) and Nitrogen (N) were also determined. A representative sample of growing media from each pot was also analysed for pH and EC. All data were statistically analysed by analyses of variance (two-way ANOVA) using GENSTAT 11th Edition.

Results

Dry matter yield of plants

In general, dry matter yield decreased in all plants in response to a decrease in fertiliser treatments (*Figure 3*). In Lilly Pilly plants there was no significant interaction between biochar and fertiliser treatments. Conversely, in Viola and Pansy plants a significant interaction between biochar and fertiliser treatments was observed. This interaction was due to the fertiliser treatment.

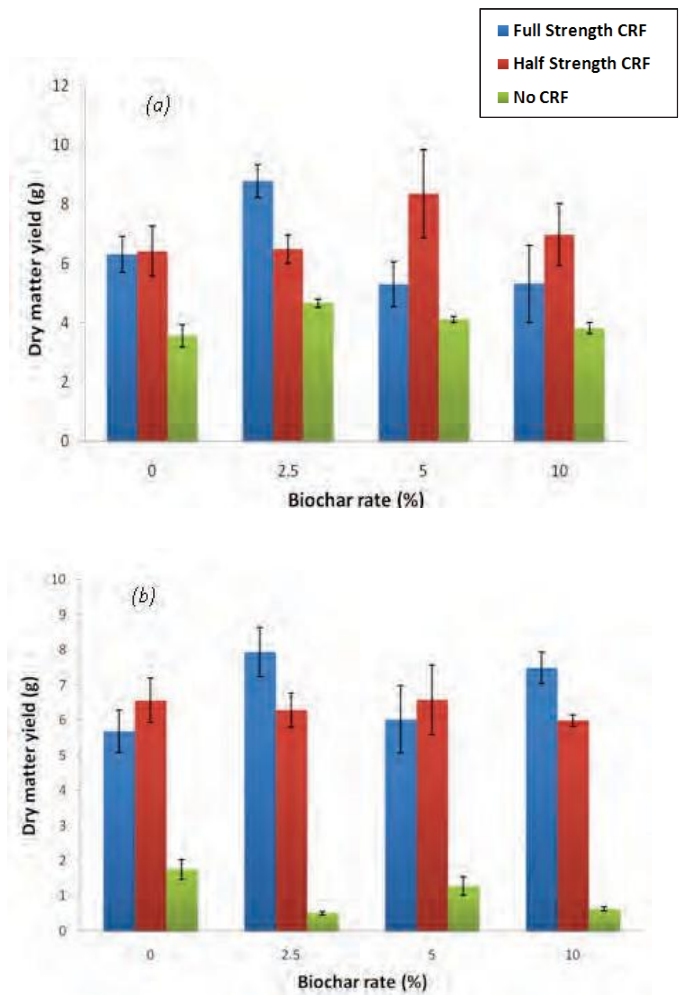

Figure 3. Mean dry matter yield of: (a) Lilly Pilly (b) Pansy and (c) Viola as influenced by the application rates of biochar (0, 2.5, 5 and 10%) and fertiliser treatments (no CRF, half strength CRF and full strength CRF). (n = 4, ± s.e.).

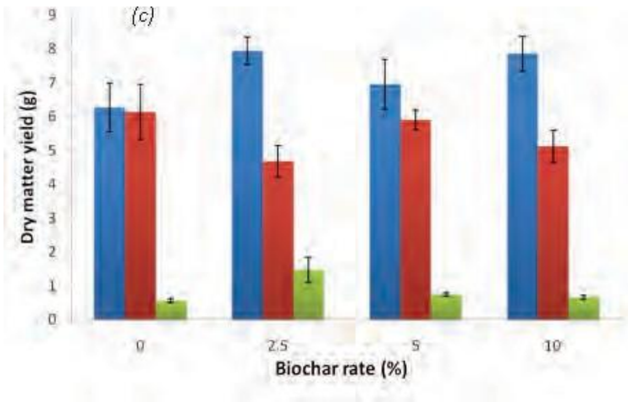

Figure 3. *Continued*

Nutrient concentration

The influence of biochar and fertiliser treatment varied for all three plants investigated. A selection of the data is presented in Figure 4. In Viola plants, there was a significant interaction between biochar and fertiliser treatments for the concentration of C, S, Mn, Na and Zn. In Pansy plants there was a significant interaction between biochar and fertiliser treatments for the concentration of C and Fe. Biochar also had a significant effect on the concentration of S, P and Ca in Pansy plants with the lowest concentration observed at 10% biochar across the three elements respectively. Biochar also had a significant effect on the concentration of C in Pansy plants. In Lilly Pilly plants, there was a significant interaction between fertiliser and biochar rate for the concentration of C, N and Ca. Biochar also had a significant effect on the concentration of C, P, Na and Cu.

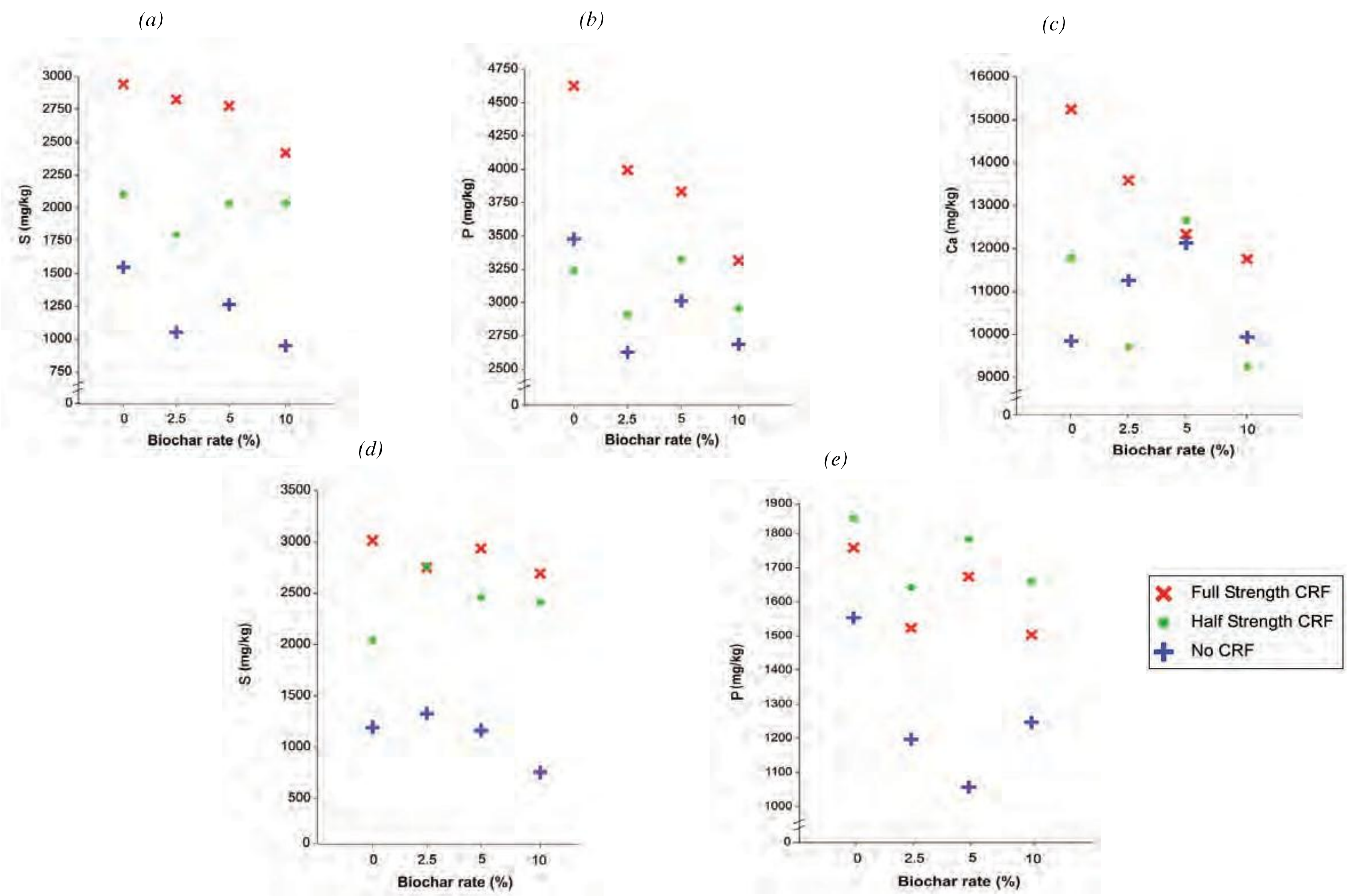

Figure 4*. Selection of means plots where biochar had a significant effect on above ground biomass nutrient concentrations as influenced by the application rates of biochar (0, 2.5, 5 and 10%) and fertiliser treatments (full strength CRF, half strength CRF and no CRF); (a) S in Pansy, (b) P in Pansy, (c) Ca in Pansy, (d) S in Viola and (e) P in Lilly Pilly.*

Growing media pH

In general, growing media pH (1:5 H_2O) after harvest of the plants was observed to decrease in response to an increase in fertiliser treatments; however there was no significant interaction between biochar and fertiliser treatments (date not presented).

Growing media EC

The growing media EC after harvest of the plants had a significant interaction between biochar and fertiliser treatments, biochar treatments and fertiliser treatments (data not presented).

Discussion

The results arising from this preliminary research trial suggest that biochar derived from Sydney Blue Gum (*E. saligna*) wood incorporated in a Premium Grade growing media does not significantly improve the biomass yield of Lilly Pilly, Pansy or Viola plants. In addition, the results from this preliminary research trial make it difficult to ascertain if there is a net gain in optimising Lilly Pilly, Pansy or Viola nutrition by incorporating Sydney Blue Gum biochar in Premium Grade growing media. Indeed, the results from this experiment suggest that the biochar did not appear to enhance CRF efficiency in the experimental plants. In relation to growing media pH, biochar appeared to have had negligible impact at the conclusion of the 14 week trial. In the case of growing media EC, the interaction of fertiliser and biochar appeared significant and requires further investigation.

Although these results appear unfavourable, they must be interpreted with caution due to several reasons including the relatively short duration of the trial and the single Sydney Blue Gum biochar feedstock investigated. Indeed, the properties of biochar are heavily dependent upon the feedstock and manufacturing conditions and thus vary in terms of their ability to influence the properties of growing media. Therefore, a more comprehensive trial should be commissioned to evaluate other feedstock materials over a longer period of time with a wider variety of plant species.

Given the low nutrient content of the Sydney Blue Gum biochar used in this study, the low plant yield observed in the no CRF treatment across the experimental plants was attributed to the absence of fertiliser. This was confirmed by the large yield increase observed in the half strength CRF and full strength CRF treatments across all three plants. In addition, the fertiliser rates used for Lilly Pilly and Pansy showed no significant difference between plant yield for full strength CRF and half strength CRF which suggests that fertiliser application at full strength CRF was higher than required in both species.

It was observed that biochar and fertiliser rates had a significant interaction with maximum plant yield at 2.5% biochar and full strength CRF in all three species. This suggests that there may be an optimum level for the interaction of biochar and fertiliser rates. This aspect should be investigated further using a wider variety of biochar feedstocks. As mentioned earlier, further studies should investigate the effect of biochar using a wider selection of plants as the results from this study suggest that plant response is highly variable.

In summary, it is unclear whether biochar amended growing media offers any real gain in terms of optimising fertiliser and plant nutrition. Indeed, this research highlights several opportunities for further investigation to ascertain if there is a role for biochar in nursery production. Other properties of biochar should also be investigated. For example, due to their increased porosity, biochars may also serve as a useful component in growing media in terms of improving water-holding capacity.

The widespread adoption of biochar application in production nurseries will require further scientific evidence and demonstration of the direct environmental, social and economic benefits to growers. In terms of sequestering carbon, biochar is currently not accepted under the Clean Development Mechanism (CDM) of the Kyoto Protocol hampering recognition in potential gains from carbon trading.

Acknowledgements

The authors thank Tom Savage (The University of Sydney) for his assistance with plant tissue analysis and Michael Nelson (The University of Sydney) for his assistance with statistical analysis.

Further information

Nursery Paper, 2010/8 – Will any growing media suffice to grow the best plants possible? Michael Danelon, NGINA.

Compiled and edited by Matthew Carroll, NGIA Industry Communications; banner photography by Anthony Tesselaar.

Nursery & Garden Industry Australia

Published by NGIA, PO Box 907 EPPING NSW 1710.