CSIRO PUBLISHING
www.publish.csiro.au/journals/ajsr *Australian Journal of Soil Research*, 2010, **48**, i–iv

Preface to Special Issue: Proceedings from the 1st Asia-Pacific Biochar Conference, 2009, Gold Coast, Australia

Evelyn Krull[A], *Balwant Singh*[B], *and Stephen Joseph*[C]

[A]CSIRO Land and Water, PMB 2, Glen Osmond, SA 5064, Australia.
[B]Faculty of Agriculture, Food and Natural Resources, The University of Sydney, NSW 2006, Australia.
[C]School of Material Science and Engineering, University of NSW, Sydney, NSW 2052, and Anthroterra Pty Ltd, 31 Pile Road, Somersby, NSW 2250, Australia.

Background

Since the first formal gathering of scientists, engineers, producers, and users interested in biochar in 2007 in Terrigal, NSW, Australia, the understanding and knowledge as well as public awareness of biochar has increased tremendously. Some 107 participants from 13 countries attended this first international biochar meeting, hosted by the International Agrichar initiative (now the International Biochar initiative). The 2nd International Biochar Conference followed in Newcastle, UK, in 2008. Attendance at this event increased to over 225 attendees from 31 different countries, which is testimony to the rapidly expanding field of biochar and its roles in the urgent need to find solutions to abate climate change and in exploring alternative ways of maintaining high agricultural productivity without increasing the use of fertilisers.

It was from these two international conferences that momentum in biochar research was gathering in different parts of the world, and the need became apparent to host regional conferences that addressed the needs, products, and application types characteristic for the region.

This spawned the idea for hosting an Asia-Pacific Biochar conference. With the help of the Australian and New Zealand Biochar Researchers Network (ANZBRN: www.anzbiochar.org/index.html) and the Japan Biochar association (www.geocities.jp/yasizato/JBA.htm), planning and coordination of the event for May 2009 on the Gold Coast, Australia, commenced. This Asia-Pacific conference (www.anzbiochar.org/2009presentations.html) was matched in the Northern Hemisphere with the North American Biochar conference (http://cees.colorado.edu/northamericanbiochar.html) in Boulder, CO, in August 2009, followed by the US Biochar 2010 Conference in June 2010 in Iowa (www.biorenew.iastate.edu/biochar2010). Organisation of the next International Biochar conference was hosted in September 2010 in Rio de Janeiro, Brazil (www.ibi2010.org/).

Organisation and sponsorship of the 1st Asia-Pacific Biochar conference

The conference was organised by an international committee comprising Lukas van Zwieten (Convenor; NSW DII), Annette Cowie (UNE), Adriana Downie (UNE/Pacific Pyrolysis), Stephen Joseph (IBI/UNSW/Anthroterra), Steven Kimber (NSW DII), Evelyn Krull (CSIRO Land and Water), Jerome Matthews (Australian Biochars), Attilio Pigineri (Massey University, NZ), Akira Shibata (Ritsumeikan University), and Yoshiyuki Shinogi (National Institute for Rural Engineering). This multi-cultural committee, together with the help from our sponsors, allowed for stimulating presentations from over 30 nations while ensuring assistance for students and attendees from developing countries. In fact, the help from our sponsors was critical to the success of the conference and we sincerely thank these organisations for their contributions: Crucible Carbon Pty Ltd, BEST Energies (now Pacific Pyrolysis) Pty Ltd, Richmond Landcare Inc., Primary Industries Innovation Centre, EternaGreen, Queensland Government, NSW Department of Primary Industries (now Industry & Investment NSW), Anthroterra Pty Ltd, Australian Biochars Pty Ltd, BioSol, Transfield Services Pty Ltd, SoilCare Inc., Northern Rivers CMA, Gansel Australia Pty Ltd and the New Zealand Biochar Research Centre.

Attendance, program, and presentations

Attendance of the 1st Asia-Pacific biochar conference exceeded the organisers' expectations as the conference venue was able to hold 200 delegates and all available places were filled. Representatives from 10 countries (including 7 delegates from developing countries) attended, and the diversity of research from the different parts of the world provided a stimulating environment for discussion and exchange of ideas.

The Sunday night Welcome Reception was opened by the Hon. Malcolm Turnbull, and the conference was formally opened on Monday morning by the Hon. Brett Raguse (member for Forde). The scientific program comprised 56 presentations, and keynote addresses were given by Prof. Dr Johannes Lehmann (Cornell University, USA), entitled 'Biochar: Science and policy' and Prof. Dr Makoto Ogawa (Ogawa institute of Technology, Japan): 'Charcoal use in agriculture in Japan'.

The 2-day conference included sessions on 'Biochar characterization', 'Biochar production and technologies', 'Business models for commercialization', 'Environmental benefits of biochar including greenhouse gas mitigation', 'Effects of biochar utilization', and 'Policy issues for the biochar industry'. The full conference schedule can be found at www.biochar-international.org/sites/default/files/AP%20Bio

 10.1071/SRv48i7_PR 0004-9573/10/07000i

Char%20Conference-may09.pdf. Where permission was granted, pdf copies of posters and presentations can be found on these websites: www.biochar-international.org/regional/conference/australia2009 and www.anzbiochar.org/2009presentations.html#one.

The conference was followed by a 1-day field trip to experience some current biochar trials in the region. The post-conference field trip was attended by almost 100 delegates; unfortunately, the Gold Coast experienced one of its worst storms that year, resulting in floods and severe winds and causing the field trip to be cut short.

Awards

Best oral presentation was awarded to Dr Hirowaka from the international Charcoal Co-op Association, Japan for his presentation 'Charcoal application for poultry farming'. The best student poster was presented to Prakashh Srinivasan from Landcare Research NZ for his poster 'Retention capacity of three types of biochar for estrogenic steroid hormones in dairy farm soil'.

This Special Issue—Overview of papers

The closing session of the conference comprised concluding remarks by the conference organisers and solicited feedback for the publication of a special journal issue, containing proceedings from this conference. The response was very encouraging and the high interest confirmed that a special issue was not only possible but would also contain a sizeable number of papers. The papers in this Special Issue cover a wide scope of biochar topics, including biochar characterisation, application in the field and impacts on crop productivity, estimation of C sequestration potential, effect of biochar on contaminants, and processes occurring in the soil–biochar interface. We were fortunate to have a large delegation of biochar scientists from Japan present, where charcoal has been applied to soils for centuries. Fittingly, the first paper of this issue by Professors Ogawa and Okimori provides a summary of the history of biochar utilisation in Japan since the 17th Century. They discuss in detail the research that has been undertaken since 1980, utilising wood, nut shells, bark, bamboo, and rice husk biochar and wood vinegar. They also provide a summary of the results of trials with different biochars in Indonesia and the Philippines. They note that many of the studies found increase in crop yields and/or increase in microbial activity, stimulation of root nodule formation in leguminous plants, and improvements in soil properties. Issues related to carbon sequestration, economics of utilisation, and rehabilitation of land are also discussed.

Joseph *et al.* (2010) provide a thorough review of the reactions, interactions, and changes of biochar in soil. In particular, they discuss micro-scale processes associated with pores and biochar surfaces, microbe and root interactions. Their data indicate that different biochars undergo complex reactions in soil that vary and depend on the specific properties of the biochars and the types of soils involved. Factors that can impact the nature of biochar reaction include nutrient composition, organic matter content, soil mineralogy, pH/Eh conditions, presence of toxins, soil biota, the type of plants grown, the proximity of the biochars to the rhizosphere, and the temporal variation in soil moisture.

A comprehensive chemical characterisation and associated methods are discussed in the paper by Singh *et al.* (2010). In this study, 11 biochars from 5 different feedstocks were evaluated with regard to their nutrient and soil-specific properties. The authors found that wood-derived biochars had a higher C content, and lower ash content, nutrient content, and CEC than manure-based biochars. Biochar made from paper sludge did not fit either group as it was characterised by very high Ca content. This paper also highlights the need for the development of biochar-specific analytical methods as standard soil or plant methods are sometimes inadequate for biochars.

Chen *et al.* (2010) examined the effectiveness of biochar produced from biosolids and bagasse in reducing nutrient run-off from fields where sugarcane was grown in a Shimajiri maji soil. Results indicate that bagasse charcoal decreased soil density and increased available moisture, which resulted in increased yields and decreased nitrate-N concentration. Although nitrate-N concentration in the biosolids charcoal plot was higher than in the control plot, percolating water level was reduced by 12% with biosolids charcoal use, and yield increases were greater than those for bagasse.

The study by Blackwell *et al.* (2010) analysed the potential to reduce fertiliser use through application of biochar in bands underneath wheat seeds. Trials were carried out using different types of biochar and different application rates of chemical fertiliser at 4 locations. Three different types of wood biochar were used. Changes in yield, P and N uptake, and mycorrhizal root colonisation from trials in 2 locations are reported in detail. An economic analysis of the benefits of banding biochar was also undertaken. The authors conclude that banding biochar underneath wheat seeds has the potential to significantly reduce the requirement for P fertilisers and/or increase yields. This is most likely due to the improved performance of mycorrhizae to obtain more water and/or nutrients at important times for crop growth. The authors also conclude that a maximum total biochar cost of about AU$170/ha is viable if it provides a 10% yield benefit over 12 years.

Solaiman *et al.* (2010) investigated the direct and residual effects of oil mallee biochar application to a sandy clay loam soil on mycorrhizal root colonisation, and growth and nutrition of wheat in field and glasshouse experiments. Biochar application at 6 t/ha combined with half of the recommended rate of soluble fertiliser produced significant increases in wheat yield, and significant yield increases were also observed when biochar treatments (1.5, 3.0, 6.0 t/ha) were applied with inoculated mineral fertiliser. The yield increases with biochar application were attributed to increased mycorrhizal colonisation in wheat roots. The study highlights the need for undertaking several bioassays throughout the cropping season to properly evaluate complex soil–biochar interactions in relation to mycorrhizal colonisation, microbial activity, and availability of nutrients.

Biochar has been implicated in the potential reduction of N_2O emission from soil. The paper by van Zwieten *et al.* (2010*a*) investigates the effect of different biochars on N_2O emission from soils in a microcosm incubation experiment. Soils were amended with 5 different biochars and urea was added to the soils, which were subsequently flooded. Most N_2O emissions occurred during the flooding phase. Compared with the control soil, which released 15% of N as N_2O, the soil amended with 5% biosolid-biochar released only 2.2% of the applied N as N_2O. The authors suggest that the reduction in N_2O emissions from the biochar-amended soils could be attributed to increased adsorption of NO_3^- but further studies are necessary to confirm this.

van Zwieten *et al.* (2010*b*) conducted a glasshouse experiment to determine the effects of a greenwaste biochar on the yield and nitrogen uptake of wheat and radish. Plant biomass increased significantly with increasing biochar addition when applied in combination with lower N application rates. Application of biochar at the highest rate resulted in significantly more NO_3-N in the soil. Application of biochar also increased microbial activity and available P in the soil. The authors emphasise the need for a long-term study to evaluate the influence of biochar on N-use efficiency in soil.

The paper by Kimetu and Lehmann (2010) investigates an important aspect of biochar dynamics in soil: how the addition of biochar compared with other organic matter additions interacts with the natural soil organic matter. Some studies have suggested a faster decomposition of native soil organic matter with biochar addition. This study conclusively showed that biochar addition, particularly in low-C soils, results in reduced mineralisation losses of existing soil C and greater stabilisation of the pre-existing C.

Kameyama *et al.* (2010) used data from a pilot sugarcane bagasse carbonisation plant to assess the net carbon-sequestration potential of bagasse biochar. They took into account fossil fuel consumption during biochar production and transport, as well as the C-sequestration potential of different feedstocks when applied to soil. They found that the estimated net C-sequestration potential of dry feedstock was 0.3 t CO_2/t DW, which corresponds to 70% of the carbon stabilised as bagasse biochar. While fossil fuel consumption was the major contributor to CO_2 emissions during biochar production, low moisture content feedstock required almost no extra fuel once the process was initiated.

The paper by Chia *et al.* (2010) reports the results of microscopic and spectroscopic characterisation of biochar–clay complexes, or synthetic Terra Preta (STP), produced at 220 and 240°C. The degree of interaction between organic and mineral components increased with increasing temperature, and thus no clear phase boundaries existed between these phases in the STP processed at 240°C. Microstructure of STP processed at 240°C showed some similarities to the Amazonian Terra Preta, such as the presence of long thin tubes. However, the structures of STPs were more complex, suggesting differing processing conditions to Terra Preta. The authors suggest that various biotic and abiotic processes operating over the time might have also contributed to the difference in properties of Terra Preta in comparison to the STPs.

Hina *et al.* (2010) examined changes in the properties of waste pine and eucalyptus bark treated with alkaline tannery waste (at 2 different concentrations) and subsequently pyrolysed at 550°C. Carbon yields were slightly lower for the treated eucalyptus samples than the untreated samples, but little difference was noted for the treated and untreated pine samples. Pre-treatment of the bark with alkaline tannery slurry prevented the development of internal microporous surfaces of the biochars, and thus lowered the total surface area. Despite the decreased internal surface area, the treated biochars had more surface functional groups (particularly carboxyl and carbonyl groups) and greater NH_4^+ absorption capacity than the untreated chars. The authors conclude that the resultant activated biochar has potential as a product for the treatment of waste streams and, once saturated with NH_4^+, could also be used as a slow-release fertiliser.

The paper by Fuertes *et al.* (2010) examines some of the principle differences in corn stover char produced by hydrothermal carbonisation (250°C at 4 MPa for 4 h) and thermal carbonisation (550°C, heating rate 40°C/min, for 15 min). Various techniques and parameters were used to characterise these 2 materials: SEM imaging, solid-state ^{13}C NMR, FT-IR, Raman spectroscopy, XPS, elemental composition, cation exchange capacity, acid group contents, BET, and yield. The hydrochar had a low ash content and low pH (4.7) and only about half of the C was aromatic. Atomic O/C and H/C ratios in the hydrochar were higher than in the biochar. The biochar had higher ash content than the hydrochar, and higher pH (~10) (lime equivalence ~40 kg $CaCO_3$/t). The C recovery was lower in the biochar than in the hydrochar, although most of the C recovered was aromatic. The authors conclude that both chars could be used as soil amendments but for different soil types and purposes.

Kookana (2010) reviews the role of biochar in modifying the environmental fate, bioavailability, and efficacy of pesticides in soils. The author highlights the lack of research in this area; however, limited research suggests that biochar can reduce the bioavailability and efficacy of pesticides in soils. Biochar has been shown to inhibit the microbial degradation of pesticides and thus can influence the potential accumulation and ecotoxicological impact of pesticides in soil. The author emphasises the need for further research on pesticides interaction with biochars produced from various feedstocks, especially using aged biochars. The off-site migration of pesticides with biochar particles through surface runoff or wind erosion also needs to be evaluated in order to determine the impact of such processes on the receiving environments.

To date, little research exists on the influence of biochar on the bioavailability of trace elements to plants. Namgay *et al.* (2010) evaluated the availability of As, Cd, Cu, Pb, and Zn to maize plants with and without biochar. They found that the effect of biochar on trace element uptake and availability varied depending on the type of trace element and biochar application rate. The concentrations of As, Cd, and Cu in the plant decreased with biochar application, whereas the effects of biochar on Pb and Zn were inconsistent. Biochar application increased extractable As and Zn, did not influence extractable Cu, decreased extractable Pb, and produced inconsistent effects on extractable Cd in soil.

The paper by Sarmah *et al.* (2010) reports on laboratory results for the retention capacity of biochar-amended New Zealand dairy farm soil for an estrogenic steroid hormone, estradiol, and its primary metabolite, estrone. All 3 biochars (corn cob, pine sawdust, and greenwaste) substantially increased the soil sorption capacity for the hormones, and soil amended with 1% pine sawdust biochar had the highest sorption capacity for estradiol. The authors attribute the higher sorption capacity of biochar-amended soils to the greater specific surface area and the abundance of functional groups of biochars.

Acknowledgments

On behalf of the organising committee of the 1st Asia-Pacific biochar conference, we wish to express our appreciation of the inputs of the various sponsors and individuals, which, together with the speakers, poster presenters, and leaders of the field trip, made for a relaxed, informative, and highly successful conference. We hope that the next Asia-Pacific Biochar conference will continue this trend in growth and expansion of knowledge.

Lastly, as guest editors, we wish to acknowledge the guidance, support, and help we have received from the Managing Editor Jenny Fegent in compiling this Special Issue of the *Australian Journal of Soil Research*.

References

Blackwell P, Krull E, Butler G, Herbert A, Solaiman Z (2010) Effect of banded biochar on dryland wheat production and fertiliser use in south-western Australia: an agronomic and economic perspective. *Australian Journal of Soil Research* **48**, 531–545.

Chen Y, Shinogi Y, Taira M (2010) Influence of biochar use on sugarcane growth, soil parameters, and groundwater quality. *Australian Journal of Soil Research* **48**, 526–530.

Chia CH, Munroe P, Joseph S, Lin Y (2010) Microscopic characterisation of synthetic Terra Preta. *Australian Journal of Soil Research* **48**, 593–605.

Fuertes AB, Camps Arbestain M, Sevilla M, Maciá-Agulló JA, Fiol S, López R, Smernik RJ, Aitkenhead WP, Arce F, Macias F (2010) Chemical and structural properties of carbonaceous products obtained by pyrolysis and hydrothermal carbonisation of corn stover. *Australian Journal of Soil Research* **48**, 618–626.

Hina K, Bishop P, Camps Arbestain M, Calvelo-Pereira R, Maciá-Agulló JA, Hindmarsh J, Hanly JA, Macías F, Hedley MJ (2010) Producing biochars with enhanced surface activity through alkaline pretreatment of feedstocks. *Australian Journal of Soil Research* **48**, 606–617.

Joseph SD, Camps-Arbestain M, Lin Y, Munroe P, Chia CH, Hook J, van Zwieten L, Kimber S, Cowie A, Singh BP, Lehmann J, Foidl N, Smernik RJ, Amonette JE (2010) An investigation into the reactions of biochar in soil. *Australian Journal of Soil Research* **48**, 501–515.

Kameyama K, Shinogi Y, Miyamoto T, Agarie K (2010) Estimation of net carbon sequestration potential with farmland application of bagasse charcoal: Life cycle inventory analysis through a pilot sugarcane bagasse carbonisation plant. *Australian Journal of Soil Research* **48**, 586–592.

Kimetu JM, Lehmann J (2010) Stability and stabilisation of biochar and green manure in soil with different organic carbon contents. *Australian Journal of Soil Research* **48**, 577–585.

Kookana RS (2010) The role of bicohar in modifying the environmental fate, bioavailability, and efficacy of pesticides in soils: a review. *Australian Journal of Soil Research* **48**, 627–637.

Namgay T, Singh B, Singh BP (2010) Influence of biochar application to soil on the availability of As, Cd, Cu, Pb, and Zn to maize (*Zea mays*L.). *Australian Journal of Soil Research* **48**, 638–647.

Ogawa M, Okimori Y (2010) Pioneering works in biochar research, Japan. *Australian Journal of Soil Research* **48**, 489–500.

Sarmah AK, Srinivasan P, Smernik RJ, Manley-Harris M, Antal MJ Jr, Downie A, van Zwieten L (2010) Retention capacity of biochar-amended New Zealand dairy farm soil for an estrogenic steroid hormone and its primary metabolite. *Australian Journal of Soil Research* **48**, 648–658.

Singh B, Singh BP, Cowie AL (2010) Characterisation and evaluation of biochars for their application as a soil amendment. *Australian Journal of Soil Research* **48**, 516–525.

Solaiman ZM, Blackwell P, Abbott LK (2010) Direct and residual effect of biochar application on mycorrhizal root colonisation, growth and nutrition of wheat. *Australian Journal of Soil Research* **48**, 546–554.

van Zwieten L, Kimber S, Morris S, Downie A, Berger E, Rust J, Scheer C (2010*a*) Influence of biochars on flux of N_2O and $CO_2$from Ferrosol. *Australian Journal of Soil Research* **48**, 555–568.

van Zwieten L, Kimber S, Downie A, Morris S, Petty S, Rust J, Chan KY (2010*b*) A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. *Australian Journal of Soil Research* **48**, 569–576.