Biochar in Agriculture
-Perspectives for Germany and Malaysia-

2nd Public-Newsletter – March 2014

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Editorial

Dear Reader,

Welcome to the second issue of the SAW-Biochar Public-Newsletter.
Within this newsletter we will keep you informed about the recent progress of our biochar research.

For some years the application of biochar to agricultural fields has been suggested as an effective method to simultaneously sequester carbon in the soil, decrease GHG emissions from the soil and improve soil fertility. Until now effects on soil fertility and mitigation of greenhouse gases have been identified primarily in the tropics on weathered soils with low soil fertility. Many soils in Brandenburg also face limited fertility due to low cation exchange capacity and low precipitation, which triggered the idea to identify the potentials for biochar applications in these soils. To enable a comparison of biochar applications in the tropics and in temperate zones a research network was established with partners in Berlin-Brandenburg and the University of Putra Malaysia. Clearly, depending on the biomass material and the conversion technology used, the resulting biochar products differ substantially in their chemical, physical and biological properties and thus in their impacts on soil fertility and yield response, presumably. These effects are analyzed in field experiments and pot experiments in Germany and Malaysia.

Regular Meetings

During the last year the German Institute for Economic Research (DIW), Humboldt-Universität zu Berlin (HU) and the Leibniz-Institute for Agricultural Engineering Potsdam-Bornim e.V. (ATB) organized PhD Student meetings of the Biochar-Project, to maintain an intensive professional exchange between PhD students and to discuss and create new cooperation between the varying scientific disciplines. Additionally, ATB arranged the 2nd annual meeting of all project partners to present recent results and to coordinate the progress of the project.

The following contributions summarize the respective research progress of the project partners in Germany and Malaysia. We present the first results of the impact of biochars and hydrochar, digestate and fertilizer add-ons on soil fertility in terms of yield potential, water holding capacity, nutrient dynamics and soil biology.

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This project is funded by the **Leibniz Association** as a *Joint Initiative for Research and Innovation*

Effects of biochar on the Soil-Plant-System

Frank Ellmer, Heiko Vogel, Katharina Reibe (Humboldt-Universität zu Berlin)

To quantify the influence of the biochars and the hydrochar as well as the addition of digestate and/or nitrogen fertilizer on the yield of different crops we conducted a 3-factorial pot experiment with 4 replications. The factor char was included with four levels (“without”, “Pyro”, “Pyreg”, “HTC”). The two factors digestate and nitrogen fertilizer were included with two levels (“with” and “without”). Four crops were planted in sequence: spring wheat - spring barley - rapeseed - corn. While significant differences between the treatments on yield of spring wheat were observed, treatments with only char and without any addition showed no yield increase in comparison to the corresponding treatments without char. To investigate the effects of chars and the addition of digestate, the pots were all fertilized after harvest of spring wheat. Spring barley and rapeseed showed no differences in plant biomass between the treatments.

To compare effects of the chars on root growth of spring wheat, two rhizobox experiments were set up where physical contact of roots with chars was prevented using nylon gauze. Rhizoboxes were filled with unamended soil as a control or with three different soil-char mixtures (Pyro, Pyreg and HTC). Shoots and roots of two spring wheat seedlings were harvested before flowering and at tillering in the first and second experiment, respectively. Chemical soil properties (N_t, K, C_t, pH) were affected differently by the different chars, whereas P levels were not significantly influenced. Both above-ground and below-ground dry matter were affected differently by biochars and the hydrochar. Pyro-char had particularly positive effects on root development and shoot growth.

To analyze the effects of different biochar types (Pyro, Pyreg, HTC, treated HTC) on the collembolan Protaphorura fimata we exposed 150 individuals for 5 weeks to 2.5 kg defaunated soil mixed with the different biochars. There were no significant differences between the treatments. In a second experiment which is currently ongoing we varied the amount of chars.

Short-term incubation studies on degradation of biochar in soil

Stephan Wirth, Jürgen Kern**, Giacomo Lanza** (*The Leibniz Centre for Agricultural Landscape Research, **Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)*

Biochar stability is an essential property for the assessment of the environmental and economical suitability of biochar as a soil amendment.

The evaluation of biochar stability in soil is complicated by the impact of external factors thus as soil moisture and temperature, soil nutrient status and moreover by extended decay timescales. To overcome these difficulties, we performed dynamic incubation experiments under laboratory conditions, using a multi-channel, automated infra-red gas analysis system (Figure 1) at 20°C for up to 10 days to detect CO_2 emission over time. Our aim was to compare the decay dynamics of different biochar preparations added to our field experiments, i.e. HTC-char and Pyro-char from maize silage with and without biological post-processing (anaerobic digestion), as compared to unmodified maize straw. Digestate from a maize silage-fed anaerobic biogas reactor was also tested.

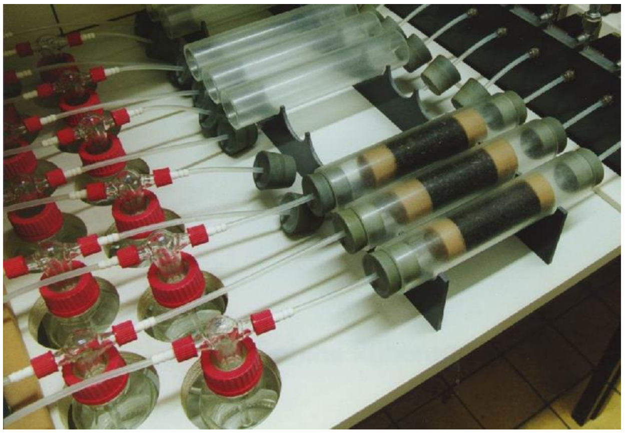

Figure 1 Multi-channel, automated infra-red gas analysis system

As a result, the addition of charred or digested materials to soil resulted in much lower CO_2 emission rates as compared to the unmodified maize straw, proving stability of biochar carbon compounds. Pyro-char showed to be the most stable of all substrates added, as the CO_2 emission was hardly distinguishable from that of the control soil. Soil enriched with HTC-char emitted significantly more CO_2 compared to soil enriched with Pyro-char, but the post-processing was effective in reducing the emissions. Furthermore, HTC-char showed a two-step decay kinetics, which cannot apparently be explained with a simple double-pool model.

In conclusion, the short-term incubation approach was effective to highlight differences in decomposition dynamics between the considered substrates in soil, and confirmed the effectiveness of the charring process to increase the stability of organic substrates in soil. More investigations are necessary to reveal the impact of readily available substrates and nutrients on degradation of biochar in soil, and to clarify the mechanisms responsible for the observed kinetics in order to derive a suitable process model.

Effects of biochar on the dynamics of soil aggregation

Martin Kaupenjohann, Frederick Büks (Technische Universität Berlin)

1. Enzymatic Treatment for Soil Aggregate Dispersion

We designed an enzymatic method – using α-glucosidase, β-galactosidase and lipase – for gentle biofilm detachment effecting a decrease in soil aggregate stability. Currently we try to optimize the method to use an enzyme concentration as little as possible.

2. Influence of Nematode Life Cycle on Soil Aggregate Stability

Acrobeloides buetschlii is a grazing nematode living in soils. We started to test the effect of feeding and motion on soil aggregate stability. Recently we started to cultivate nematodes for the experiment.

3. Second Long Term Experiment for Soil Aggregate Geometry

On the basis of a first soil column experiment we identified different bacterial and fungal growth dynamic as well as aggregate size and amount. By a second experiment we hope to identify the influence of both parameters biochar and microbial activity on the size, amount, geometry and stability of aggregates. The aggregate stability will be determined by means of ultrasonication with and without foregoing selective enzymatic biofilm detachment.

4. Application on the field experiment (Berge)

Physical and biological methods for soil aggregate disaggregation will be applied to samples from the field experiment in Berge/Germany. We are going to determine influences of fertilization and types of applied biochar on biofilms as well as other factors of aggregate stability in local agricultural soils.

Impact of biochar on soil biota and microbial activities

Peter Lentzsch, Monika Joschko, Stephan Wirth, Philip Rebensburg (The Leibniz Centre for Agricultural Landscape Research)

In 2013, we adapted a promising ecotyping method which makes use of taxon-specific DNA quantification by means of qPCR for analysis of soil microbial dynamics, which allows to compare relative abundance of selected bacterial and fungal groups and thus yields an ecological footprint of the soil sample involving Eubacteria, Fungi, Archaea, Alphaproteobacteria, Betaproteobacteria, Actinobacteria and Acidobacteria. The taxon-specific qPCR approach was tested in several experiments that were run in 2013 or are still running (longterm pot experiment at ZALF, Berge field trial). In one experiment run by Frederick Büks (TU Berlin) which addresses the formation of soil aggregates and biofilms in a closed container environment under the influence of Pyreg biochar as well as the role of manganic precipitations in soil aggregate stabilization, microbial population dynamics were analyzed using the method described above. The same was done in another experiment run by Giacomo Lanza (ATB Potsdam) which had the goal of assessing microbial biomass, trace gases and microbial population structure under the influence of Pyro-char and HTC-char.

Moreover, in a long term pot experiment with strawberry plants assessing the influence of biochar on microbial polulation dynamics, soil samples for soil DNA analysis were collected and fruit mass and number of fruit per plant as well as plant vitality were monitored.

Figure 2 Long term pot experiment with strawberry plant

On the field experiment site at Berge, soil samples were taken in the last week of August for taxon specific qPCR and earth worm abundance was monitored by means of handsieving in the second week of October for selected plots. There is a cross-plot abundance of earthworms of the species A. caliginosa ranging from 34-76 worms/m². L. terrestris was not found. In tendency, there was an increase of worm number and biomass per worm in pyrolysis biochar plots as opposed to control plots.

Effect of biochars on crop yields (LCA and farm economic evaluation of biochar)

Andreas Meyer-Aurich, Anja Sänger (Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Within the field experiment in Berge near Potsdam the impact of different biochars from pyrolysis and hydrothermal carbonization (HTC) technology, digestate and fertilizer add-ons on soil fertility for a typical soil of Brandenburg is investigated. In the years 2012/2013 the first crop of a trinomial crop rotation (winter wheat – winter rye – maize) was grown. At present, the second crop (winter rye) is cultivated with an expected harvest in July/August 2014. One year after the biochar application no significant differences in grain yield response of winter wheat to treated and untreated biochars was found. The impact of nitrogen fertilization (0, 75, 150 and 195 kg N ha^{-1}) could be proven statistically.

However, the interactions of fertilizer application with biochars and digestate incorporation showed no statistically significant effects. Taking soil properties into account resulted in a statistically significant yield increasing effect of biochar in a multiple regression approach. The application of digestate did not result in higher yields compared to control soils without any application of digestate or biochar. This might be due to a higher amount of less degradable organic compounds in this substrate based on whole crop maize. Possibly, these compounds as well as accumulated nutrients in the biochars may be mineralized within the following vegetation periods and might increase the yields of winter rye and maize.

Welfare analysis

Claudia Kemfert, Isabel Teichmann (German Institute for Economic Research)

Germany has ambitious targets for the reduction of its greenhouse gas emissions. Compared to the 1990 level, it aims to reduce its annual emissions by 55% by 2030 and 80-95% by 2050. Against this background, the German Institute for Economic Research (DIW Berlin) has conducted an economic assessment of greenhouse gas sequestration and mitigation through biochar soil incorporation in Germany for the time horizons 2030 and 2050. In particular, it has calculated the greenhouse gas sequestration-mitigation potential and associated costs of slow-pyrolysis biochar from a wide variety of feedstocks, mainly ranging from forestry residues, other waste wood, cereal straw and certain types of green waste to sewage sludge, animal manure and digestates. Depending on the baseline scenario, the scale of the biochar production technology, and the type of fossil fuels offset by the energetic use of the liquid and gaseous pyrolysis by-products, the study finds that approximately one percent of Germany's greenhouse gas reduction target for 2030 could be met using biochar. To a great extent, however, this potential could be realized only at a cost of over a hundred euros per tonne of carbon-dioxide equivalent. Ultimately, the potential for reducing greenhouse gas emissions with the help of biochar soil incorporation is limited by the availability of biomass for biochar production.

Pot Experiment on N-Fertilizer Leaching and Crop Uptake

Azni Idris, Rosenani Abu Bakar, Tinia Idaty Mohd. Ghazi, Mohd Amran Mohd Salleh, Sherwin Lee Chan Kit (University Putra Malaysia)

The aim of our study is to determine the effects of oil palm empty fruit bunch (EFB) biochar on nitrogen (N) fertilizer recovery, crop uptake, and N leaching using ^{15}N labelled fertilizer. A pot experiment was conducted under a rain shelter using maize as the test crop and soil type used for planting was clayey sandy soil. The experimental design was random complete block (RCBD) with 6 blocks and treated with four rates of EFB biochar; 0 (control), 5, 10, and 20 t/ha. After incubating the soils in the pots for 2 weeks, EFB biochar was applied at the top 20 cm of the soil and only one maize was planted per pot. The maize plants were fertilized at 10 days old with ammonium sulphate $[(^{15}NH_4)_2SO_4]$ labelled with ^{15}N, triple superphosphate (TSP), and muriate of potash (MOP) at the rate of 30:30:30. The same fertilizer rate was applied again when the maize reached 20 days old and final fertilization at the rate of 20:20:20 was applied at the age of 35 days old. Induced leaching was started 2 days after the first fertilization and continuously done once after every 4 days until silking stage of the maize. The total leachate was measured while ammonium (NH_4^+) and nitrate (NO_3^-) concentration in leachate was analyzed using steam distillation method with MgO and Devarda's alloy, respectively (Bremner, 1965). At silking stage (56 days old), tissue sample was harvested to be analyzed for dry matter weight, ^{15}N content, total N, P, K, Ca, and Mg, while pot soil will be analyzed for ^{15}N content, total N, C, P, pH, electrical conductivity (EC), cation exchange capacity (CEC), and exchangeable cations (K, Ca, and Mg). From the results obtained so far, EFB biochar has the ability to increase water holding capacity (Laird et al., 2010) and reduces leaching. Hence, the volume and frequency of watering can be reduced and lesser nitrogen (N) fertilizer will be lost due to leaching. The biochar acts like a cache for water and indirectly holds more soluble plant nutrients, especially N. This could be the reason why maize that were treated with EFB biochar have greater biomass than the control (Figure 3). Future work of analyzing ^{15}N in the maize tissue and pot soil using isotope ratio mass spectrometer (IRMS) will support this theory.

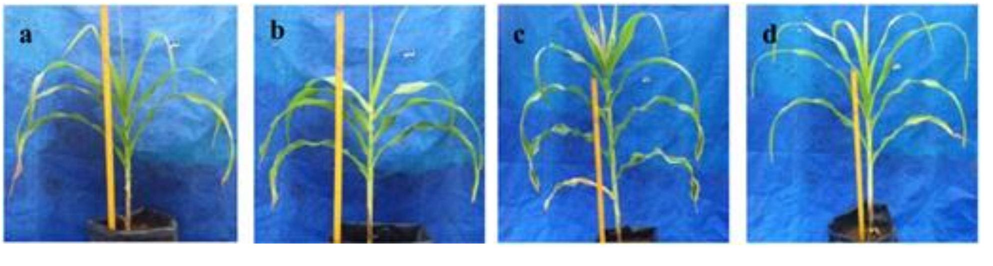

Figure 3 The maize growth performance with different rates of EFB biochar:
(a) 0 t/ha (control);
(b) 5 t/ha;
(c) 10 t/ha;
(d) 20 t/ha

Biochar network

Coordination and dissemination; Life cycle assessment and farm economic evaluation of biochar
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Dr. Anja Sänger
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Research station Berge
Dr. Andreas Muskolus
(Institute of Agricultural and Urban Ecological Projects)

Gas flux measurements at the research station Berge
Dr. Jürgen Kern
Christiane Dicke – PhD Student
Giacomo Lanza – PhD Student
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

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Effects of biochar on the dynamics of soil aggregation
Prof. Dr. Martin Kaupenjohann
Frederick Büks – PhD Student
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Field experiment with biochar in Selangor, Malaysia
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Assoc. Prof. Dr. Rosenani Abu Bakar
Assoc. Prof. Dr. Tinia Idaty Mohd. Ghazi
Dr. Mohd Amran Mohd Salleh
Sherwin Lee Chan Kit – PhD student
(University of Putra Malaysia)

Welfare analysis
Prof. Dr. Claudia Kemfert,
Isabel Teichmann – PhD Student
(German Institute for Economic Research)

Char materials (Pyro- and HTC char)
Dr. Jan Mumme
Dr. Mamadou Diakité
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Impact of biochar application on soil nematodes
Stefanie Menzel – PhD Student
(Humboldt-Universität zu Berlin)

Contributions in 2013/2014

Publications:

Teichmann, I. (2014): "Climate Protection Through Biochar in German Agriculture: Potentials and Costs." DIW Economic Bulletin 4(4): 17-26.

Teichmann, I. (2014): „Klimaschutz durch Biokohle in der deutschen Landwirtschaft: Potentiale und Kosten." DIW Wochenbericht 1+2/2014: 3-13.

Reibe, K., Ellmer F. (2013): "Einfluss von Biokohle und deren Behandlung auf die Ertragsbildung von Kulturpflanzen." Mitt. Ges. Pflanzenbauwissenschaften Band 25, 315-316.

Presentation:

Teichmann, I. (2014): "An Economic Assessment of Biochar in Germany" by Isabel Teichmann, Second Mediterranean Biochar Symposium, Palermo, Italy, 16-17 January 2014

Reibe, K., Döring, T. F., Ellmer, F. (2013): "Root growth and yield of spring wheat influenced by different biochars." BCD Conference, October 2013, Bari, Italy

Lanza, G. (2013): "Studies on biochar stability through isotopic measurements" BioPhys Spring 2013, 21.-23. Mai 2013, Lublin, Poland

Reibe, K., Ellmer, F. (2013): "Einfluss von Biokohle und deren Behandlung auf die Ertragsbildung von Kulturpflanzen" Agrosnet Doktorandentag, Berlin, Germany

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