Impact of biochar and nitrogen management on nitrous oxide emissions in aerobic rice cropping system

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Introduction

The increase in nitrogen prices and demand for sustainable production gave importance to studies about strategies that increase nitrogen use efficiency. Besides contributing to carbon (C) sequestration, some studies have suggested that biochar can be used as amendment in soil to improve the uptake by plants of NPK fertilizer, consequently increasing plant growth and grain yield, as well as to reduce nitrous oxide (N_2O) emissions from agricultural fields [1].

The average yield achieved by aerobic rice based cropping systems in Brazilian savannas has been around 1.8 ton ha^{-1}. The high climatic variability is the main cause for that low grain production. Hence, two long term experiments were implemented aiming to test the effect of charcoal on nitrogen use efficiency and N_2O emissions in aerobic rice production systems under two different areas in Brazilian savannas (Figure 2 and 3).

One was implemented on a sandy Haplic Cambisol, in summer 2008/2009, testing two doses of N (0 and 110 kg ha^{-1}) and four doses of charcoal (0, 8, 16, 32 Mg ha^{-1}) from Cerrado (legalized), whose composition was 49.06% of C and 0.66% of N. Another was implemented on a clayey Haplic Ferralsol, in summer 2009/2010, testing four doses of N (0, 30, 60 and 90 kg ha^{-1}) in combination with four doses of charcoal (0, 8, 16, 32 Mg ha^{-1}) from eucalyptus (*Eucalyptus* sp.), whose composition was 75.89% of C and 0.78% of N.

The charcoal was incorporated to 15 cm in the soil right before sowing rice. The variety of aerobic rice (*Oryza sativa*) used was 'Primavera'. Fifty per cent of the N fertilizer (urea) was applied at sowing and 50% at 45-35 days after sowing. In both experiments, each plot of 40m^2 had a static chamber used to collect the N_2O fluxes afterwards analyzed in a gas chromatography, during all the rice cycle. The fluxes were log transformed and the total emissions were calculated by interpolation of the mean fluxes and interpolation over the time [2]. Both experiments are still ongoing. The results presented here are from the first year of evaluation.

Results and Discussions

For both areas, the highest N_2O fluxes were observed for the treatments with the highest doses of N and charcoal, around the 2nd day after sowing, meaning 13,459 μg m^{-2} dia^{-1} in sandy soil (treatment 110/32) and 616 μg m^{-2} dia^{-1} in clayey soil (treatment 90/32). Moreover, in sandy soil the fluxes were almost 4 times higher than in clayey soil. Pay attention at the scale in axis Y in Figure 1. Also, the average of temperature in the soil at layer 0-10 cm was higher in the area of sandy soil (30ºC) than in the area of clayey soil (25ºC). Consequently, the highest total emissions were 1.2 kg ha^{-1} in sandy soil (treatment 110/32) and 0.134 kg ha^{-1} in clayey soil (treatment 90/32). Besides the doses 0 of N and 0 of biochar, the lowest total emission was observed for the treatments 110/16 in sandy soil, 0.657 kg ha^{-1}, and for the treatment 30/16 in clayey soil, 0.081 kg ha^{-1}. However, in clayey soil there was no statistical difference ($p \leq 5\%$) between emissions. The average rice yield was 2,600 kg ha^{-1} in clayey soil and 759 kg ha^{-1} in sandy soil, where the rice plants faced periods of drought during the end of the cycle. The agronomic efficiency (AE) [3] in clayey soil was higher for the treatment 30/32 and lower for the treatment 90/0. In the sandy soil the AE showed unexpected behavior, meaning that the charcoal effect on the rice yield was much greater than the N itself, probably due the hydric stress. The highest emission factor (F) in clayey soil was 0.09% for treatment 90/32 and in the sandy soil 1.1% for the treatment 110/32. The recognized F by IPCC [4] is 1% of N applied.

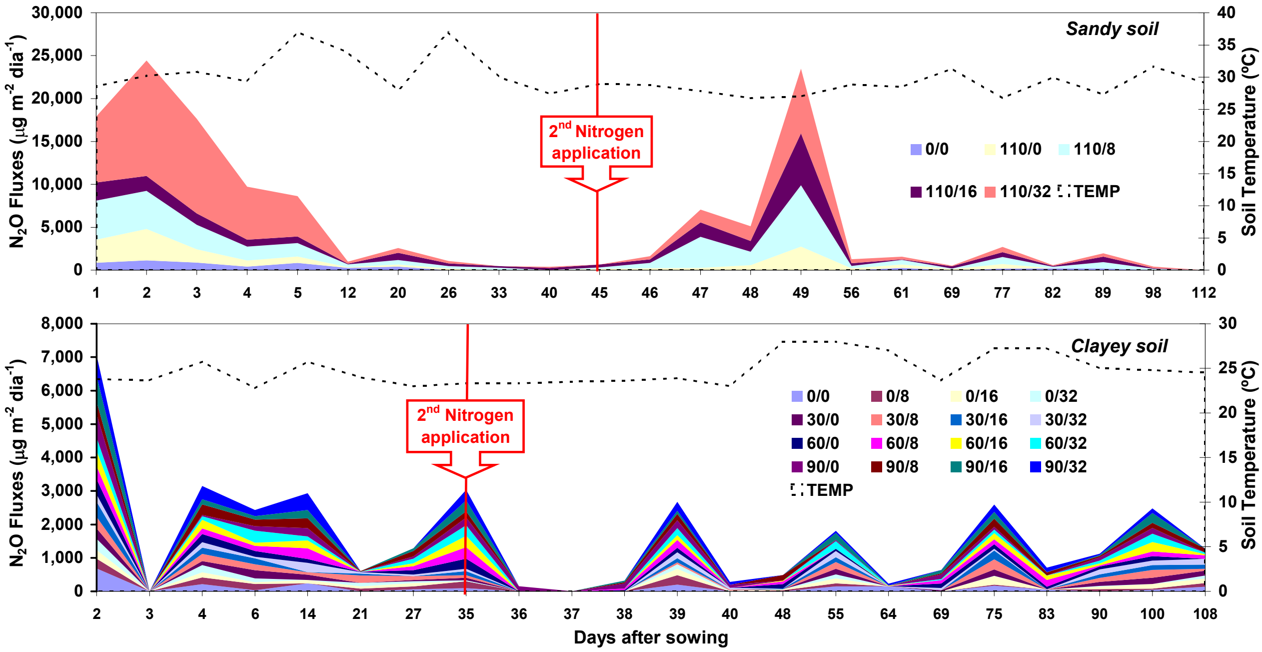

Figure 1. Nitrous oxide fluxes and soil temperature at layer 0 to 10 cm observed during all the cycle of aerobic rice cropping system (112-108 days after sowing) cultivated under sandy Haplic Cambisol and clayey Haplic Ferralsol in Brazilian savannas.

Conclusions

In summary, in clayey Ferralsol, charcoal had positive effect on rice yield, no effect on N_2O emission, increasing AE and decreasing F. In sandy Cambisol, charcoal had positive effect on rice yield, but it caused higher N_2O emission, resulting in greater F.

Therefore, the pros and contras of charcoal application to soil has to be carefully considered since its overall effect, yield, AE, F, N_2O emission, can be positive, however, depending on environmental characteristics acting on water-soil-plant-atmosphere system, contras may weight more in the balance.

Hence, long term assessment, considering specificity of local conditions, must be done before recommendation of biochar as a soil amendment in agricultural systems.

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Figure 2. Biochar incorporated in clayey Haplic Ferralsol at Capivara Farm (16°29'17" S and 49°17'57" W) (Photo by Holger Meinke, February, 2010).

Figure 3. Biochar incorporated in sandy Haplic Cambisol at Estrela do Sul Farm (14°34'50" S and 52°24'01" W) (Photo by Beata E. Madari, February, 2009).

[1] Fowles, M. 2007. *Biomass and Bioenergy*, *31*, pp. 426-432.
[2] Velthof, G. L. 1997. *Nitrous oxide emissions from intensively managed grasslands.* (PhD Thesis). Wageningen University.
[3] Fageria, N. K.; Slaton, N.A.; Baligar, V.C. 2003. *Advances in Agronomy*, 80, pp. 63-152.
[4] IPCC. 2006. *Guidelines for National Greenhouse Gas Inventories, 4*, 54.