

Nitrogen leaching in soil amended with biochars produced at low and high temperatures from various feedstocks

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Abstract

Leaching losses of nitrogen (N) from agricultural land are a major source of water pollution in the United States. A greenhouse trial of biochars produced from corn stover, oak wood, paper mill waste, and poultry manure mixed with sawdust at 300°C and 600°C was conducted in order to evaluate the potential of these biochars to reduce N losses to the environment. Nitrate (NO₃) leaching was reduced in the 7% biochar treatment for both 300°C oak and 300°C paper mill waste, while NO₃ leaching increased in the 7% biochar treatment for 300°C poultry manure with sawdust. Ammonium (NH₄) leaching was not reduced in any of the 300°C biochar treatments and an increase was observed in the 300°C corn, paper mill waste, and poultry manure with sawdust treatments. NO₃ leaching was reduced with increasing application rates of 600°C corn and oak biochars. NH₄ leaching was slightly reduced in the 2% and 7% biochar treatments for 600°C paper mill waste and 600°C oak and increased in the 7% biochar treatment for 600°C poultry manure and sawdust treatment. The effect of higher biochar application rates, successive cropping years, and multiple soil types should be investigated in future studies.

Keywords: biochar, nitrate leaching, ammonium leaching, biochar feedstock, nitrate, ammonium.

Introduction

N loss from agricultural soils by leaching can lead to both declines in crop yields and negative environmental impacts including eutrophication of surface waters (Brady and Weil 2008). In addition to the management of vegetation and fertilization, biochar application to soil has been shown to affect the leaching of N through multiple mechanisms (Major *et al.* 2009). In addition to the preexisting physical, chemical, and biological characteristics of the soil to which biochar is applied, the feedstock from which biochar is produced, as well as the temperature at which biochar is produced are important factors related to the effectiveness of a given biochar. Although biochar has been shown to increase soil fertility and carbon sequestration (Glaser *et al.* 2002; Lehmann *et al.* 2003; Lehmann *et al.* 2006), insufficient knowledge exists related to the suitability of pyrolysis feedstocks for biochar production, as well as the ideal pyrolysis conditions for a given pyrolysis feedstock for biochar production (Chan *et al.* 2008).

Methods

Biochar feedstock selection and pyrolysis

An assessment of regionally abundant and available feedstocks was conducted in order to identify the most economically promising pyrolysis feedstocks from which to produce biochar in New York State, USA. These feedstocks included corn stover, oak wood, paper mill waste, and poultry manure mixed with sawdust. The feedstocks were collected, dried to below 10% moisture content, and pyrolyzed using a slow pyrolysis method at a range of temperatures.

Soil type and preparation

A greenhouse trial was conducted in order to evaluate the potential NO₃ and NH₄ leaching reductions achievable with biochars produced from distinct feedstocks at low and high temperatures. True soil was used in the greenhouse trial in order to mimic the biochar-soil interactions that occur in the field. Soil used in the greenhouse trial was Junius loam, Kendaia silt loam, and Lima loam, that was collected from a university research farm in Aurora, NY, USA. The soil pH was 6.85. The soil was continuously cropped in corn for over 50 years preceding collection. The soil was transported to the greenhouse, where it was air-dried. The dried soil was then shredded to break apart clods and sieved to 2mm to maintain uniform particle size. In order to determine the volume of water that was needed to exceed the soil water holding capacity and initiate leaching, the soil water holding capacity was determined. Biochars produced at 300°C and 600°C from corn stover, oak wood, paper mill waste, and poultry manure mixed with sawdust were mixed with field soil at application rates of 0.2, 0.5, 2, and 7% (w/w) using a V mixer and poured into pots. There were 2 replicates of each treatment.

Crop variety and greenhouse conditions

All pots were randomly spaced throughout the greenhouse bench system. Rootworm resistant hybrid corn treated with fungicide was planted. Starter fertilizer was applied at a rate of 2.02 kg N / ha and later supplemented with 22.03 kg N / ha in order to meet crop fertilizer recommendations for the soil used in this trial. Watering was performed when leaf curling was observed in order to avoid hypoxia. The greenhouse temperature was maintained at 24°C during the day and 18°C at night.

Leaching experiment and leachate analysis

All leachate generated during the trial flowed into an enclosed collection system and was collected approximately 24 hours after each leaching event. The leachate was taken from the greenhouse to the laboratory where its volume was recorded and a cumulative subsample (5% by volume) was removed and frozen. After completion of the trial, subsamples were analyzed for NO₃ and NH₄ using colorimetry on a segmented flow analyzer.

Results

NO₃ and NH₄OH leaching in the control pots was observed to be 31.78 kg NO₃/ha and 0.21 kg NH₄OH/ha, respectively. NO₃ leaching was reduced in the 7% biochar treatment to 16.40 and 11.89 kg NO₃/ha for 300°C oak biochar and 300°C paper mill waste biochar, respectively, while NO₃ leaching increased in the 7% biochar treatment for 300°C poultry manure with sawdust biochar to 63.71 kg NO₃/ha (Fig. 1). NH₄ leaching was not reduced in any of the 300°C biochar treatments and an increase in the 7% biochar treatments to 1.43 kg NH₄OH/ha was observed in 300°C corn biochar, 1.08 kg NH₄OH/ha in 300°C paper mill waste biochar, and 1.28 kg NH₄OH/ha in 300°C poultry manure with sawdust biochar treatments (Fig. 2). NO₃ leaching was reduced with increasing application rates of 600°C corn biochar to 6.46 kg NO₃/ha and oak biochar to 15.99 kg NO₃/ha (Fig. 3). NH₄ leaching was slightly reduced in the 2% and 7% biochar treatments for 600°C paper mill waste biochar to 0.04 kg NH₄OH/ha and 0.02 kg NH₄OH/ha, respectively (Fig. 4) NH₄ leaching was reduced in the 0.5%, 2%, and 7% biochar treatments for 600°C oak biochar to 0.03, 0.07, and 0.06 kg NH₄OH/ha, respectively. NH₄ leaching increased in the 7% biochar treatment for 600°C poultry manure and sawdust biochar to 0.62 kg NH₄OH/ha (Fig. 4).

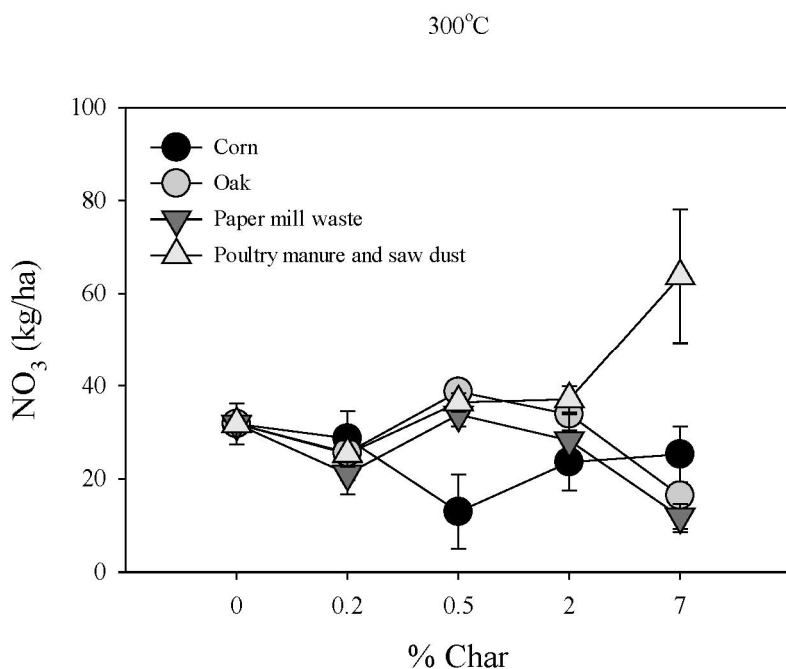


Figure 1. NO₃ lost as leachate from soil amended with biochar produced from various feedstocks at 300°C.

300°C

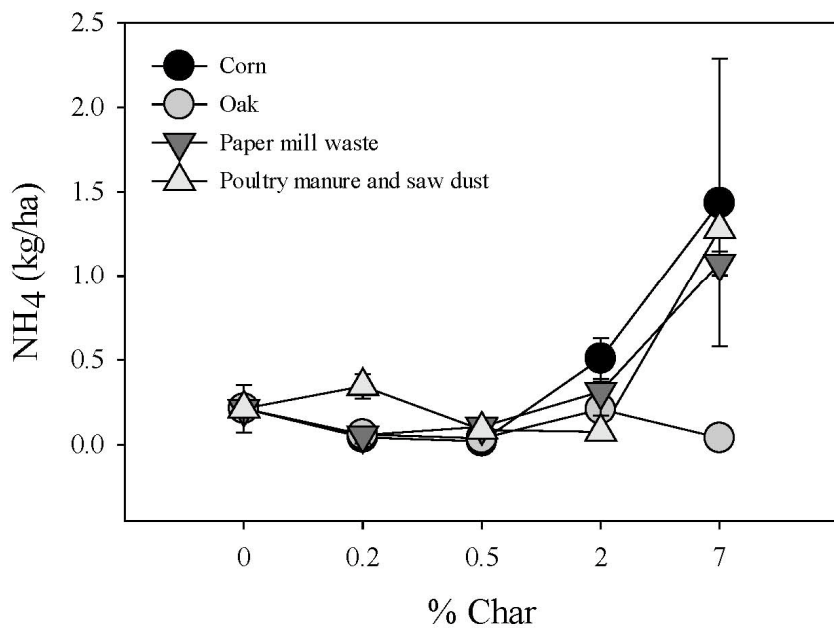


Figure 2. NH_4 lost as leachate from soil amended with biochar produced from various feedstocks at 300°C.

600°C

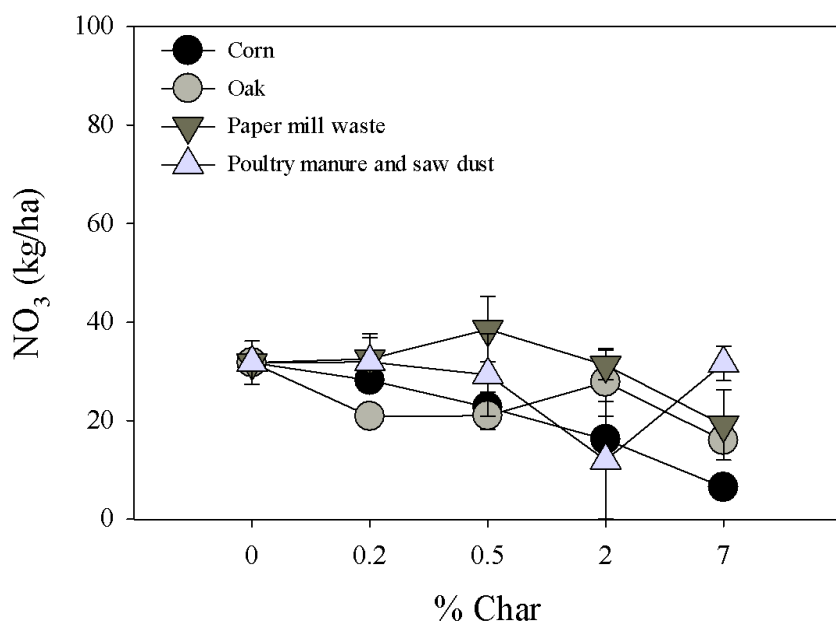


Figure 3. NO_3 lost as leachate from soil amended with biochar produced from various feedstocks at 600°C.

600°C

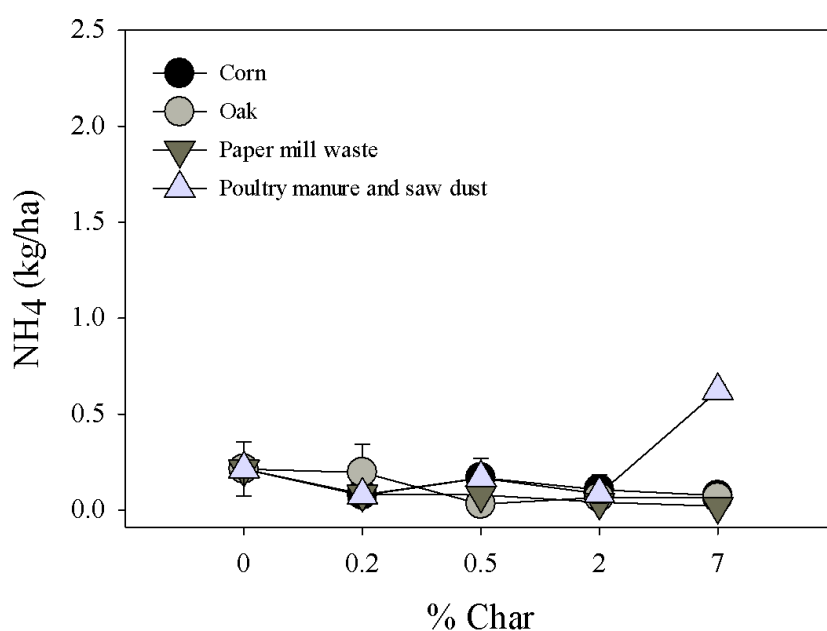


Figure 4. NH₄ lost as leachate from soil amended with biochar produced from various feedstocks at 600°C.

Conclusion

The results of this study showed that biochar application rates, biochar feedstock, and pyrolysis temperature affect the loss of NO₃ and NH₄ from soil by leaching. In order to effectively minimize N losses to the environment, it is necessary to evaluate each biochar individually at multiple application rates.

References

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