Enhanced Carbon Storage and Nitrate Retention in Soils Following Biochar and Biosolid Application

Britt Fossum, Katja Koehler-Cole - Nebraska Extension, Arindam Malakar - University of Nebraska-Lincoln Nebraska Water Center and School of Natural Resources, Michael Kaiser - Department of Agronomy & Horticulture, University of Nebraska-Lincoln**

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Introduction

Biochar is produced by pyrolyzing waste biomass under low oxygen conditions. It is used as a soil conditioner containing >70% organic carbon[1] that can reliably increase carbon content in soil. It can also enhance nutrient retention.

Biosolids are a form of organic fertilizer sourced from wastewater treatment containing both nutrients and organic carbon.[2] Organic fertilizers can impact carbon and nutrient cycling in soil.

Carbon fractions isolated from bulk soil can provide additional information about carbon dynamics. Carbon is stored in particulate organic matter, as dissolved organic matter, and in physically protected fractions (aggregate-occluded and mineral associated).

Materials & Methods

Table 1. Fertilizer and amendment application by treatment. Both biosolid and mineral fertilizer were applied in Spring 2023.

Treatments (four field replicates, 1 acre size per plot)			
MAP: Monoammonium phosphate (MAP) 91 kg ha^{-1} + 136 kg ha^{-1} Potash	Biochar: 20 Mg ha^{-1} Biochar + MAP 91 kg ha^{-1} + 136 kg ha^{-1} Potash	Biosolid: 60 Mg ha^{-1} Biosolid	Biochar+Biosolid: 20 Mg ha^{-1} Biochar + 60 Mg ha^{-1} Biosolid

16 acre field experiment located at Lincoln North East Wastewater Treatment Facility.

Sampling and Analysis

- Annually post-harvest: soil sampled to a depth of one meter, with 0-10 cm and 10-30 cm samples analyzed for plant-available nutrients (Timberline Instruments).
- Spring samples analyzed for OC content and used for soil carbon fractionation.
- Annual response in corn or soybean yield.

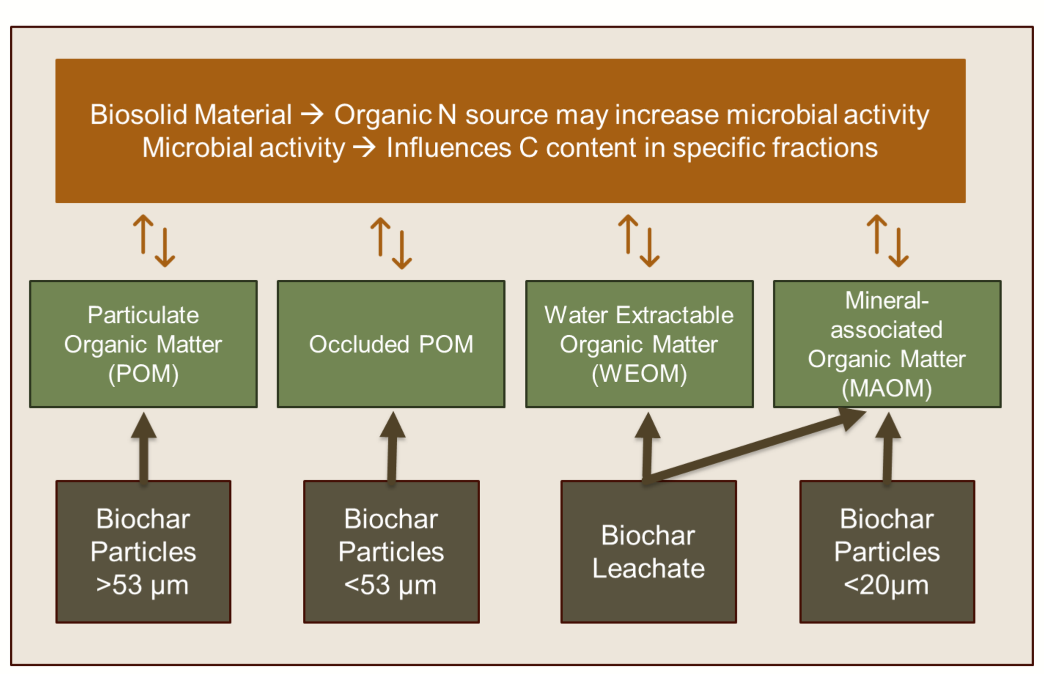

Fig. 2 Conceptual scheme of soil carbon fractions. A combined physical-chemical fractionation method is used to access carbon fractions relevant for carbon storage dynamics. Biochar and biosolid can both influence how carbon is stored in soil.

Results: Yield Response

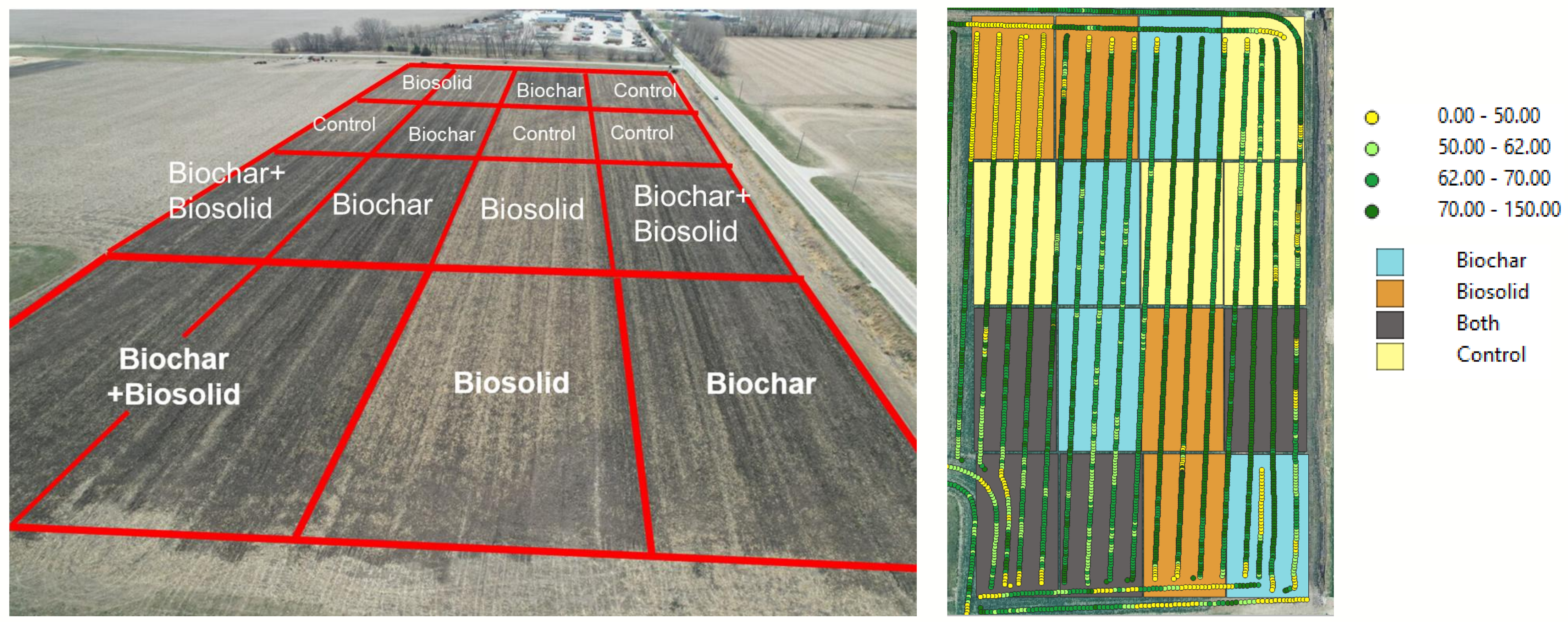

Fig. 3 Post-Application Field Assessment and Soybean Yield Response. Aerial survey after incorporation of biochar and biosolid, with labeled treatments (Photo Credit: Ann Powers). Yield response was mapped using combine data, and yield was assessed using pre-harvest biomass sampling and with post-harvest combine data.

→ No significant difference was observed in soybean yield (2024). Average yield for the field was 62 bushel/acre,

Soil Nutrient Content

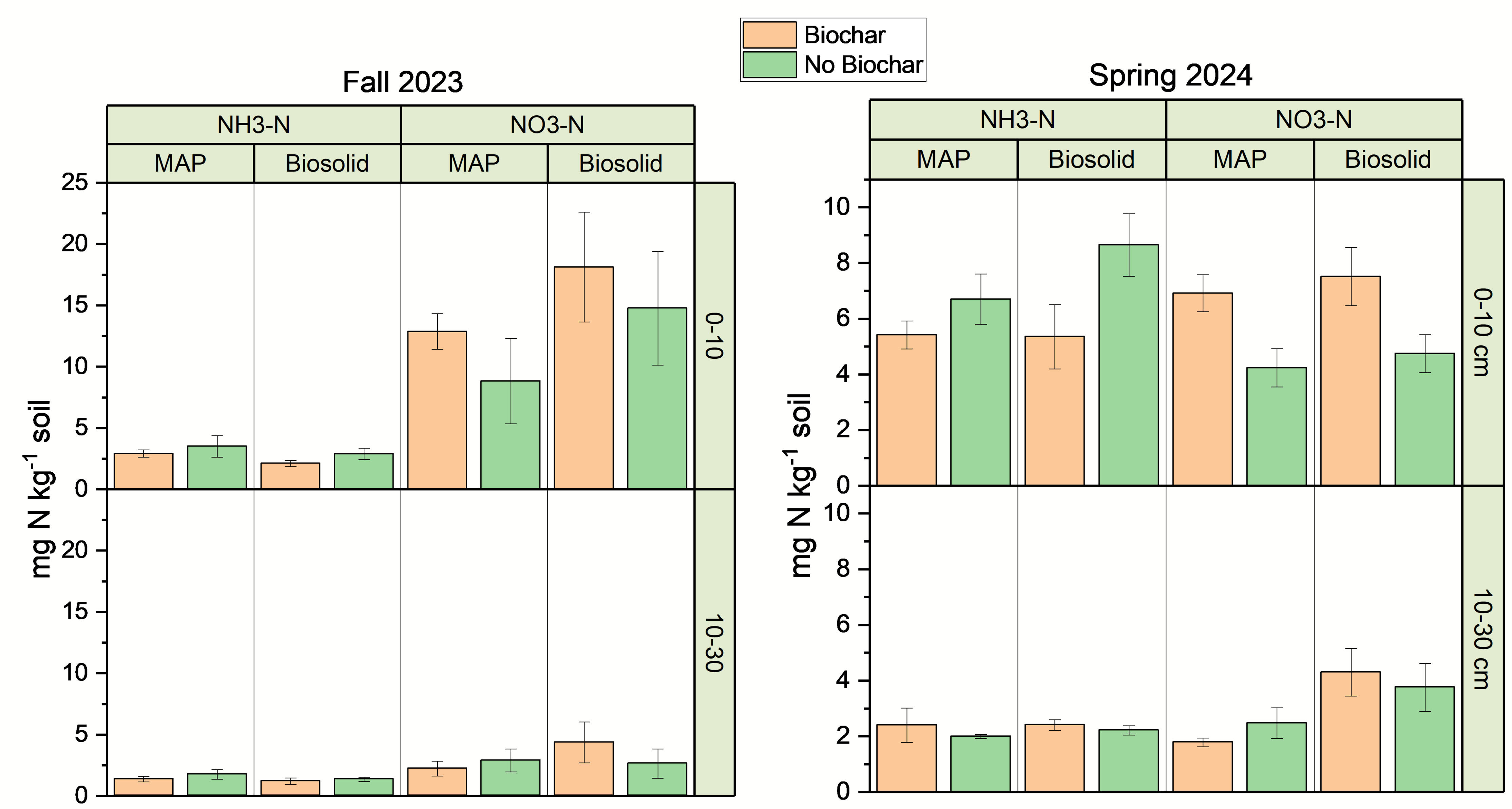

Fig. 4: NH_3-N and NO_3^--N in soil extracts in Fall 2023 (post-harvest) and Spring 2024 prior to soybean planting. Significantly higher nitrogen was found in post-harvest samples receiving biosolids as fertilizer compared to mineral nitrogen source monoammonium phosphate (MAP). NH_3^+-N was overall higher at spring sampling date, with lower amounts of ammonium for plots receiving biochar from both nitrogen sources. Biochar significantly increased nitrate-N content for spring soil samples at the 0-10 centimeter soil depth, indicating that biochar improved retention of nitrate in topsoil over winter

Carbon Fractionation

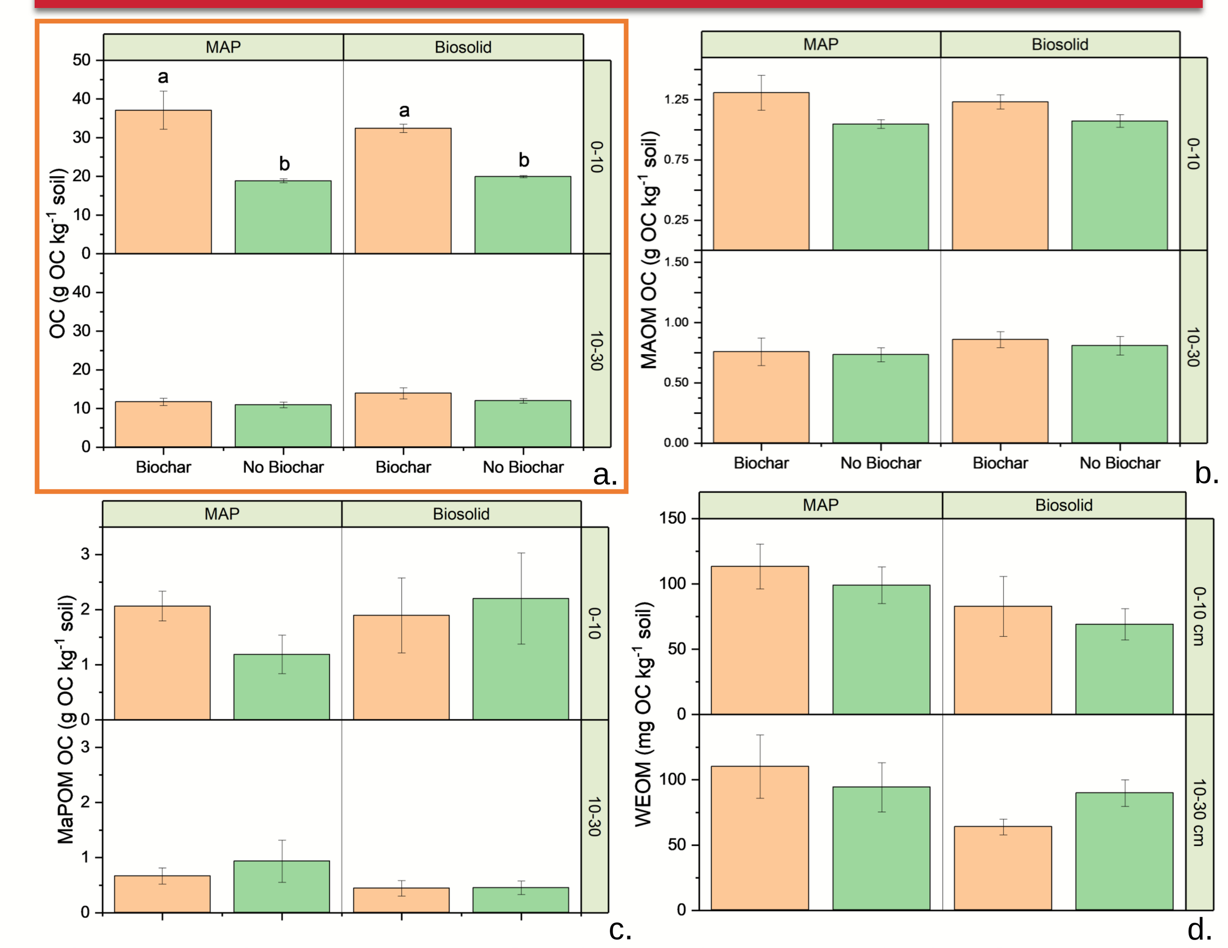

Fig. 5: Carbon content of soil fractions. Clockwise from top left, figures show a. Bulk soil OC; b. Mineral associated OC; c. Macroaggregate-occluded particulate organic matter OC; d. Water-Extractable organic matter OC.

- OC stored in topsoil (0-30 cm) increased by 18 Mg ha^{-1} g (Biochar+MAP) and 19 Mg ha^{-1} (Biochar+Biosolid).
- Biochar application at 20 Mg ha^{-1} → Expected OC increase of 16 Mg ha^{-1}
- OC content in fractions was not significantly different by treatment omitting POM fraction, which is expected to contain majority of biochar-OC.
- Biosolid fertilizer did not impact carbon storage.

→ Large-scale application resulted in 100% recover of applied biochar carbon

Conclusions

Nitrate retention was enhanced by biochar application immediately after harvest, with nitrate retained into the following growing season.

High carbon recovery following biochar application was not impacted by fertilizer choice and did not impact storage in MAOM, oPOM, or WEOM fractions.

References

1. Joseph, S.et al. How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar. *GCB Bioenergy* 2021, *13*, 1731–1764.
2. Schroder et al. 2008. The effect of long-term annual application of biosolids on soil properties, phosphorus, and metals. SSSAJ 72, 73-82.

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