The Nitrogen Biogeochemical Impacts of Energy Sorghum, a Potential Bioenergy Crop

Mark B. Burnham[1]* (mburnham@illinois.edu), Taylor N. Bozman,[1] Avarna Jain,[1] D.K. Lee,[1] **Evan H. DeLucia**,[1] **Wendy H. Yang**[1]

[1]University of Illinois at Urbana-Champaign, Urbana, IL

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Project Goals: We determined if high-yielding energy sorghum inhibits nitrification and denitrification in its rhizosphere compared to bulk soil and if these effects were changed under different fertilization rates. We also measured if sorghum rhizosphere effects resulted in a change in nitrous oxide flux from sorghum field soils compared to maize.

The net environmental benefit of bioenergy crops depends on how they affect agroecosystem nutrient cycling. Nitrogen (N) fertilizer addition affects ground and stream water by increasing leaching of nitrate (NO_3^-), and increases emissions of nitrous oxide (N_2O), a potent greenhouse gas. Perennial biofuel crops produce high yields with low N fertilizer requirements and small NO_3^- and N_2O losses, but their establishment in the Midwestern United States has been limited. Annual sorghum is more easily incorporated into crop rotations, but high-yielding energy sorghum still requires significant N input. However, sorghum can release compounds into the rhizosphere that cause biological nitrification inhibition (BNI), potentially reducing ecosystem losses of NO_3^- and N_2O compared to maize. We measured potential nitrification and denitrification in rhizosphere and bulk soil across two N fertilization rates (0 and 168 kg N ha^{-1}) in a sorghum agronomy trial at the University of Illinois Energy Farm, and measured soil N_2O emissions in separate sorghum and maize plots. Across all dates, sorghum inhibited potential nitrification by 8.6% in the rhizosphere relative to bulk soil ($P = 0.028$). Mid-growing season, when plants were growing fastest, sorghum inhibited potential nitrification by an average of 16% (± 4.8%). This inhibition was stronger in unfertilized plots (26.8%) compared to fertilized plots (11.6%) ($P = 0.025$). Across all dates, potential denitrification was stimulated by 36.6% in the sorghum rhizosphere compared to bulk soil ($P = 0.01$), and N_2O flux from sorghum fields was higher than from maize. In sorghum fields, carbon-rich root exudates may have stimulated denitrification, a heterotrophic process, causing higher N_2O emissions. The decline of BNI with fertilizer addition indicates that BNI is likely facultatively expressed to reduce N loss as NO_3^- and increase N retention in the soil. As fertilizer rates increase, we expect an exponential increase in NO_3^- leaching as BNI declines.

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