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Fertilizer use could reduce climate benefit of cellulosic biofuels

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(L) A field of switchgrass growing at Michigan State University's Kellogg Biological Station; (R) Phil Robertson, University Distinguished Professor of Ecosystem Science at MSU. A new study out of Robertson's lab led by former MSU graduate student Leilei Ruan, suggests that using nitrogen fertilizer on switchgrass produces a sharp increase in nitrous oxide, a harmful greenhouse gas that contributes to climate change. Credit: US Department of Energy

According to a new, three-year study from the Great Lakes Bioenergy Research Center and Michigan State University (MSU), the use of nitrogen fertilizer on switchgrass crops can produce a sharp increase in emissions of nitrous oxide, a greenhouse gas up to 300 times more harmful than carbon dioxide and a significant driver of global climate change.

Switchgrass is one of several crops poised to become a feedstock for the production of "cellulosic biofuels" – i.e., fuels derived from grasses, wood, or the non-food portion of plants. Though touted for being a clean energy alternative to both fossil fuels and corn ethanol, cellulosic biofuel comes with its share of complexities. A lot of its environmental benefit depends, for starters, on how its crops are grown.

"We've established that the climate benefit of cellulosic biofuels is much greater and much more robust than people originally thought," says Phil Robertson, University Distinguished Professor of Ecosystem Science at MSU and a principle on the study. "But what we're also seeing is that a lot of that climate benefit is dependent. It's dependent on factors such as land use history and – as we're seeing with these results – it's dependent on nitrogen fertilizer use."

Led by former MSU graduate student Leilei Ruan and published this week in *Environmental Research Letters*, the study reports nitrous oxide emissions from switchgrass grown at MSU's Kellogg Biological Station when fertilized at eight different levels.

"What we discovered," says Ruan, "is that there's not a one-to-one relation between adding fertilizer and producing nitrous oxide. It's not a linear relationship. After a certain amount of fertilizer is added, there is, proportionately, a lot more nitrous oxide produced than what you might expect."

The cause of that non-linear relationship can be traced to the soil microbes responsible for converting nitrogen fertilizer to nitrates and then to nitrous oxide. Unlike humans, when some soil microbes are short on oxygen they have the option of using nitrate in place of oxygen. As the microbes respire these nitrates they produce nitrous oxide. Ruan says that fertilizing beyond what the plant can use and needs is likely providing an opportunity for these soil microbes to take up excess nitrate and produce nitrous oxide.

While little nitrous oxide is lost to the atmosphere when the plants are fertilized at appropriate levels, Robertson says the take home is quite simple: "a little bit of over fertilizing hurts a lot." In fact, the disproportionately adverse results of over fertilizing have the potential to effectively change the math on biofuel crops' net climate benefit. An over fertilized switchgrass crop can reduce its climate benefits as much as 50% once the fertilizer's production, use, and nitrous oxide emissions are subtracted from the crop's carbon benefit.

The study also measured the relationship between fertilizer and nitrate leaching, and found – also for the first time – that leaching is also disproportionately greater at high fertilization rates. Soil nitrate not converted to nitrous oxide is also available for loss to groundwater and then eventually to streams, lakes, rivers, and wetlands, where it's once again eligible to be converted into nitrous oxide.

For Ruan, the implications of the study are clear. "If we're ever going to realize the environmental potential of biofuels, we will need to have smart strategies for fertilizing cellulosic crops."

Those strategies could include developing nitrogen use calculators to help farmers determine how much fertilizer to use, or paying farmers for the perceived risk of yield loss as a result of lower fertilization.

Robertson says future research in this area could focus on identifying which soil microbes are responsible for the nitrous oxide increase in order to develop management strategies that suppress them, or – sidestepping the microbes entirely – simply designing a plant capable of more efficient nitrogen use.

More information: Leilei Ruan et al. Nitrogen fertilization challenges the climate benefit of cellulosic biofuels, *Environmental Research Letters* (2016). DOI: 10.1088/1748-9326/11/6/064007

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