Title: Comparing the effects of imidacloprid and its alternatives on soil biological communities in turfgrass through different routes of exposure

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Abstract: We are currently investigating the ecological consequences of imidacloprid and its alternatives on soil biological communities in order to develop practices that achieve pest management goals without compromising belowground ecological services. The aim of the proposed project is to identify the routes of exposure through which imidacloprid affects soil invertebrates and microbial communities. By tracking pesticide residues in the field and by measuring how soil biota respond to imidacloprid, we can better inform stakeholders about non-target effects of imidacloprid, highlight the importance of beneficial biota in soil ecological services and provide information about developing alternatives to imidacloprid for turfgrass. Our findings indicated that both imidacloprid and cyantraniliprole were detectable in soils soon after and up to 12 months following soil application. Our work also shows that imidacloprid had stronger effects on soil biota but that imidacloprid and cyantraniliprole are capable of having both stimulatory and suppressive effects on soil microbial decomposition activity that vary based on pesticide concentration.

Background and justification: The balance between plant protection and soil health is a key component of sustainable agriculture; however, the potential interactions between these two factors are often overlooked. For instance, neonicotinoid insecticides such as imidacloprid can compromise non-target, beneficial arthropods. Given the importance of soil microarthropods and microbes in the maintenance of soil processes such as decomposition and soil fertility, reductions in their density or activity may lead to the loss of unique ecological functions and the subsequent loss of ecosystem services (e.g. Zaller et al. 2016).

Imidacloprid is one of the most widely used neonicotinoid insecticide in the United States (Jeschke et al. 2011). Despite its proven effectiveness against white grubs and other soil-dwelling pests in turfgrass, imidacloprid can also decrease the abundance and activity of beneficial microbes and invertebrates in soil (Peck 2009, Gan and Wickings 2017). On-going research in our lab is comparing the effects of imidacloprid with those of chemical, biological, and bio-based alternatives on beneficial soil biota in lawn turf. Our findings indicate that imidacloprid, applied at recommended label rates, suppresses soil microbes and key invertebrate decomposers up to four months following application (Bray and Wickings, unpublished). In contrast, the chemical, biological, and bio-based alternatives as well as lower than label rates appear to have fewer negative impacts.

While awareness of the negative impacts of imidacloprid on soil organisms is growing, many aspects of the insecticide-soil biology interaction remain unclear. It is unknown whether the impacts result from direct contact between imidacloprid and soil organisms, and how this relates to the persistence of the product in soil. Elucidating the underlying details of the interactions between imidacloprid and its alternatives and soil biota will increase knowledge about the full ecological cost of neonicotinoid use in lawn turf and will be critical for developing IPM alternatives to imidacloprid that are both efficacious and sustainable.

Objectives:

Objective 1: Quantify the presence and persistence of imidacloprid and cyantraniliprole, a current alternative product, in soil and plant residues over the course of two growing seasons.

Objective 2: Compare the effects of imidacloprid on soil microbes and invertebrates through distinct routes of exposure (treated plant residues, treated soil).

Objective 3: Project Evaluation

Results and discussion:

Results – Soil samples collected from plots receiving imidacloprid and cyantraniliprole were submitted for analysis to the pesticide residue testing lab in Ithaca, NY. Positive detections were made for both compounds and their breakdown products. Both products were detectable at as early as one week following application during both years of the study (Figure 1 a-d). As expected, concentrations of both products decreased in soil overtime, however, they were both detectable through the end of each respective season, especially when applied at high label rates. Surprisingly, we also detected both products, at all three application rates, the following spring, a full twelve months after application. This indicates that the products remain present within the soil environment considerably longer than assumed. Also of note, was the observation that soil concentrations of both products differed significantly by year, despite being applied at the same three rates both years of the study. In fact, peak imidacloprid concentration in year one was close to 10x that of year two. While the drivers of this difference are not fully known, we attribute it to differences in precipitation between the two study years that may have influenced uptake efficiency of the products by turf.

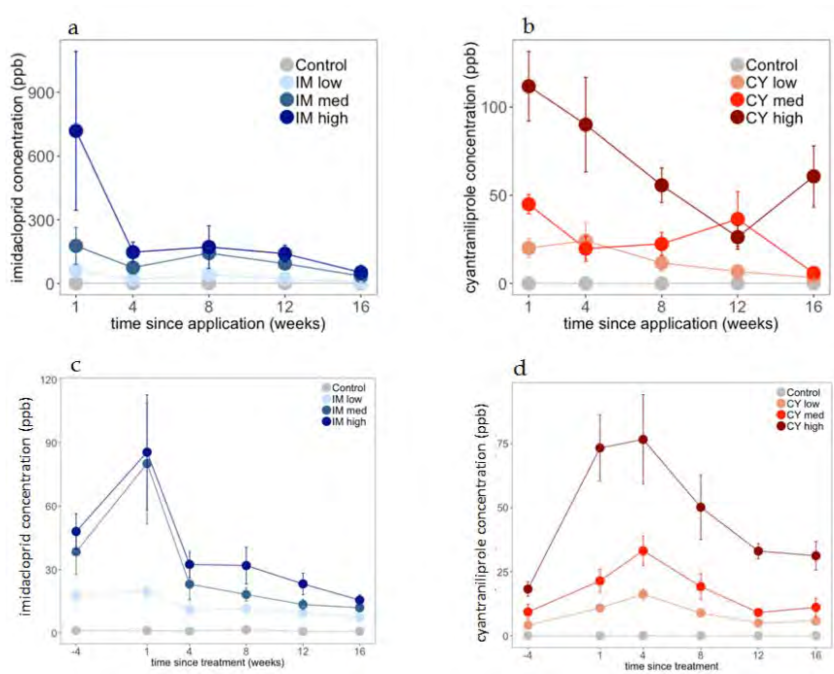

Figure 1. Concentrations (ppb) of imidacloprid (a, c) and cyantraniliprole (b, d) in soil one through 16 weeks following product application to turf soils in 2016 (a, b) and 2017 (c, d).

We were unable to fully address the second objective outlined in our grant due to an increase in pesticide residue analysis costs and difficulty in establishing microbial and soil animal treatments within the lab. We will continue to pursue this aspect of the proposal using different funds this coming summer, likely with the assistance of a summer research scholar. However, our additional study of soil biotic responses to the use of these two products has revealed very few impacts of cyantraniliprole on soil biota, regardless of application rate or route (applied to turf residue or introduced as a systemic via soil drench. Imidacloprid on the other hand suppressed collembolan densities when applied as a soil drench but had no impact on collembolan colonization or decomposition rate of decomposing grass clippings. The response of microbial enzyme activities to imidacloprid and cyantraniliprole application was the most difficult to interpret, however, upon correlation of enzyme activities with soil concentrations of both products we found positive relationships. Interestingly, at low concentrations, both products appeared to have a suppressive effect on enzyme activity while at high concentrations, the effect appears stimulatory (Figure 2a,b). This suggests that while the products may hinder some

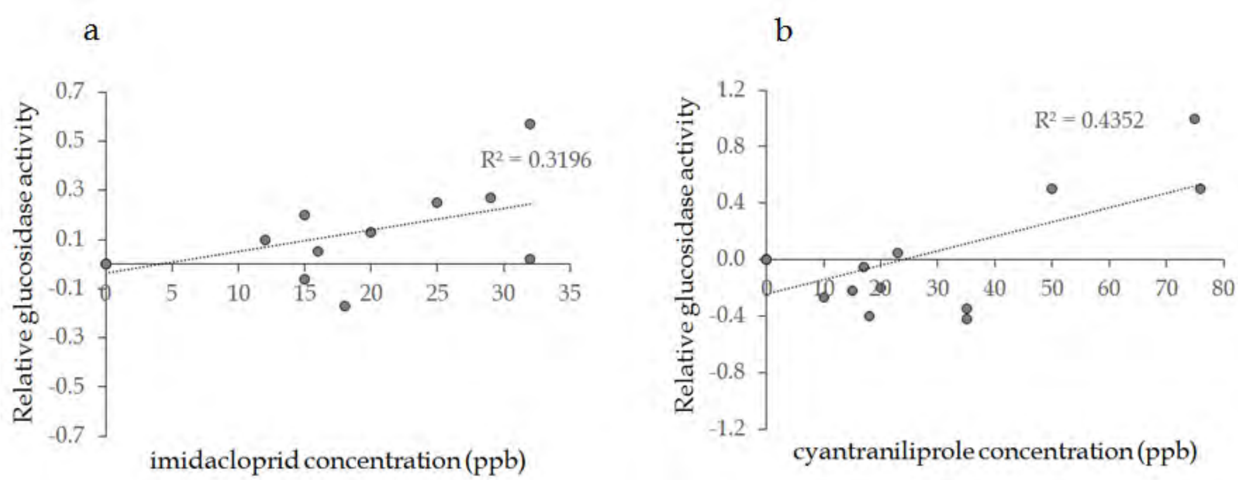

Figure 2. Concentrations (ppb) of imidacloprid (a) and cyantraniliprole (b) correlated with the relative activity of the cellulose-degrading enzyme beta-glucosidase.   Enzyme activities were scaled relative to activity levels measured in untreated plots to show magnitude and direction (positive or negative) or the relative pesticide impact on enzyme activity.

microbial taxa, they may also serve as a potential resource for microbes that are insensitive to the products. This mechanisms underlying this interaction will need to be explored further as they may relate to many aspects of product efficacy and sustainability including uptake efficiency and non-target impacts on soil food webs.

Current and expected impact – To date, the results of our work have been very useful in my extension programming efforts to introduce turfgrass stakeholders to soil biological health. One long-term goal of my extension program in turfgrass is to seek a balance between pest management and soil health management goals. I am also interested in helping turf managers identify opportunities for increasing reliance on soil ecosystem services for achieving plant health. The data generated by this project provides a much needed linkage between our current pesticide use practices and downstream effects on beneficial soil biota and I have been using it as key rationale for why we need to rely more heavily on IPM principles in making decisions about pesticide use.

I have had the opportunity to present this work to over 100 stakeholders recently in White Plains NY. The group was comprised of turf managers from diverse sectors of the industry including school grounds managers, golf turf managers, and lawn and landscape professionals. Many lawn and landscape professionals approached me following my seminar to discuss a growing interest among their customers in organic and low-input approaches to lawn management and indicated that the material in the seminar was very useful as they consider the limitations and benefits of this management approach. With lawn care companies servicing just under 10 percent of turfgrass acres in NY State (~280,000 acres), I believe that a change in mindset and knowledge about balancing soil and plant health in the management of lawns could make a substantial impact on the industry.

Future efforts – To ensure this work is used and that the industry's awareness increases, I intend to continue offering extension programming on this topic, and already have another seminar scheduled for March of 2019 at the Western Regional Meeting of the NY State Turfgrass Association in Buffalo, NY. During this meeting I intend to implement the pre- and post- seminar surveys outlined in our proposal to assess awareness of how pesticides impact soil health and the benefits of soil biological health for turfgrass. I also intend to continue pursuing funding to support future work in this area in my lab. Currently, two additional graduate students are conducting similar research in field and vegetable cropping systems in my lab and I intend to continue this work in turfgrass as well.

Project location: Cornell AgriTech, Geneva, NY

Samples of resources developed:

Extension seminars

Wickings, K. Optimizing pest management to enhance soil biological health. New York State Turf and Landscape Association winter meeting, White Plains NY, January 15, 2019

- 130 participants, 1 hour
- In this seminar I reported results of our work and used the results as a springboard to discuss how proper scouting, insect identification, reliance on action thresholds, and product selection can allow for achieving pest management goals while preserving and harnessing soil biological activity.

Wickings, K. Optimizing pesticide use practices to meet pest management goals without compromising soil health, NYSTA Western Regional Conference, March 25, 2019

Academic presentations

Bray, N., Wickings, K. Comparing the effects of chemical and biological insecticides on soil biological diversity and function in managed grass systems. New York City Urban Soil Symposium, Manhattan, NY, December 6-7, 2018.

Publications in prep

Bray, N., Wickings, K. Comparing the effects of chemical and biological insecticides on soil biological diversity and function in managed grass systems. – *In prep*