Comparative effects of pesticides on South Australian soil microbial functions

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Key messages

- **This study will deliver South Australian farmers with information to aid decision making on the use of pesticides by investigating the effect of 20 pesticides, including insecticides, herbicides and fungicides on soil microbial function in three South Australian (SA) soils.**
- **The information on cumulative effects and persistence of negative effects on selected soil-pesticide combinations could be instrumental in safeguarding the long-term productivity and profitability of SA grain growers.**
- **Understanding the correlation between a pesticide's mode of action and its effects on soil function may aid in the development of new active ingredients and/or the reformulation of current pesticides.**
- **The insights into lab-field transferability will provide greater understanding of how the complexities of environmental factors affect pesticide impacts on soil functions.**

Why do the trial?

This project will deliver essential information to South Australian farmers for identifying the best soil-pesticide combinations for maintaining healthy, well-functioning soil microbial communities in their soils.

Crop protection products, such as pesticides, have contributed to the profitability of the agriculture sector, contributing $20.6 billion to the annual harvested crop in Australia. However, pesticides can affect soil microbial community structure and function and hence vital, microbially-driven ecosystem services such as nutrient cycling, soil structural stability and plant pathogen control.

There are several factors that influence the effect that a pesticide will have on soil microorganisms and soil fertility. Such factors include the chemical structure, concentration and toxicity of the pesticide and soil properties. Different pesticides will therefore affect soil microbial communities differently depending on soil type, but these interactions are not well understood. Most past studies have only investigated the effect of a single pesticide on a single nutrient cycle (mostly the nitrogen cycle), using a limited number of soil types. For example, 15 previous studies have investigated the effect of pesticides on nitrate production in soil, and most of these studies only tested one pesticide in one soil. More importantly, of these 15 studies, only one used an Australian soil; a Queensland sugarcane cropping soil. Therefore, there is a scarcity of information regarding the potential effects of pesticides on the soil microbial communities of southern Australian agricultural soils.

One of the aims of this study is to investigate the comparative effect of 20 commercial agricultural pesticides on soil functions driven by microbial and enzymatic activities in three different SA soil types. The cumulative effects and persistence of negative impacts of selected soil-pesticide combinations will also be further studied to ensure ongoing pesticide performance and benefit. Overall, this project will aid farmers in the selection of future pesticide strategies that maximise farm outputs while retaining, or even improving, SA soil fertility.

How was it done?

During the first 12 months of this three-year project, we have carried out laboratory experiments testing 20 commercialised pesticides, with different modes of action (Table 1), on three SA soil types. The pesticides include four insecticides, eight herbicides, and four fungicides, all supplied by six agrochemical companies; Bayer, BASF, Syngenta, FMC, Nufarm and ADAMA. The three SA soil types are 1) a grey calcareous sandy soil from Piednippie, Eyre Peninsula 2) a clay-loam soil from the Hart Field site in the Clare Valley where a field trial will also be conducted in 2020, and 3) a sodic soil from Pine Hill, South East SA.

Table 1. Pesticides selected for targeted investigation.

Pesticide	Class	Mode of action	Product name	Supplier	Concentration of active ingredient
Chlorpyrifos	Insecticide	AChE inhibitor	Chlorpyrifos 500EC	Nufarm	500g/L
Fipronil	Insecticide	Chloride channel blocker	Legion	Nufarm	500 g/L
Alphacypermethrin	Insecticide	Sodium channel blocker	Astound Duo	Nufarm	100 g/L
Imidacloprid	Insecticide	nAChR modulator	Gaucho®	Bayer	600 g/L
Chlorsulfuron	Herbicide	ALS inhibitor	TACKLE®	ADAMA	750 g/kg
Imazamox	Herbicide	ALS inhibitor	Raptor	BASF	700 g/kg
Atrazine	Herbicide	PS II inhibitor	Atragranz	Nufarm	900 g/kg
Trifluralin	Herbicide	Microtubule inhibitor	Triflur X	Nufarm	480 g/L
Propyzamide	Herbicide	Microtubule inhibitor	Rustler® 900WG	FMC	900 g/L
Prosulfocarb	Herbicide	Lipid synthesis inhibitor	Countdown®	Adama	800 g/L
Metolachlor	Herbicide	VLCFA inhibitor	Bouncer® 960S	Nurfam	960 g/L
Pyroxasulfone	Herbicide	VLCFA inhibitor	Sakura 850WG	Bayer	850 g/kg
Isoxaflutole	Herbicide	HPPD inhibitor	Balance® 750WG	Bayer	750 g/kg
Clopyralid	Herbicide	Synthetic auxin	Archer 750	Nufarm	750 g/L
Paraquat	Herbicide	PS I inhibitor	Shirquat 250	Nufarm	250 g/L
Glyphosate	Herbicide	EPSP inhibitor	Weedmaster® DST	Nufarm	470 g/L
Flutriafol	Fungicide	Sterol biosynthesis inhibitor	Intake® HiLoad Gold	Nufarm	500 g/L
Metalaxyl-M	Fungicide	RNA polymerase I	ApronXL	Syngenta	350 g/L
Penflufen	Fungicide	SDH inhibitor	EverGol Prime	Bayer	240 g/L
Azoxystrobin	Fungicide	Ubiquinol oxidase inhibitor	Supernova 250 SC	Nufarm	250 g/L

The 20 pesticides were tested on the three soil types at two different doses (equivalent to one and five times the recommended dose) and incubated for four weeks under controlled conditions (i.e. constant temperature, and humidity) to give 120 treatments prepared in triplicate. At the end of each incubation period, a suite of high-throughput molecular tools was used to monitor the structure, diversity and function of soil microbial communities involved in three nutrient cycles: carbon cycle, nitrogen cycle and phosphorus cycle. We further investigated effects on the nitrogen cycle by measuring potential nitrification (a test that indicates the potential for ammonium to be converted to nitrite; one of the most important steps in the nitrogen cycle), and, the expression of functional genes involved in this process (i.e. *amoA* genes).

All statistical analyses are being carried out using GraphPad Prism 8.2.0. In the middle of the second year, this study will assess lab-field transferability of the experimental data by establishing a field trial that will be conducted over two years at the Hart Field Site. The field trial will test three to five selected soil-pesticide combinations of special interest to growers. The cumulative effects and persistence of the selected pesticides will also be investigated in laboratory experiments that will run in parallel to the field trial. Repeat applications will be applied every six months and samples will be collected two weeks after pesticide application, just before the next application. The fate of the pesticides will also be tested in parallel throughout the experiment using ^{14}C-labelled compounds. For the correlation of a pesticides' mode of action to any negative impacts on non-target organisms, multiple pesticides of interest with similar modes of action will be further investigated to determine the presence of any possible relationship.

What happened?

Data have been collected from the laboratory experiments in the first year of the project (2019) and are currently being analysed. More laboratory work will be continued in the second year of the project and more results will be collected from the Hart field trial, which will start in May 2020.

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