

Effects of rice pesticides on soil & aquatic organisms

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IN A RICE HULL

- ▶ The effect of pesticides on overall soil microbial activity was not significant and no measurable effect on soil biological health could be established under field conditions
- ▶ Laboratory experiments were conducted to avoid the effects of field variability and in these conditions also, overall microbial activity was not adversely affected by pesticide applications, although some potential toxicity of pesticides to soil biological processes was observed
- ▶ Based on a suite of tests, the pesticides were ranked in decreasing order of toxicity: Chlorpyrifos > Fipronil > Thiobencarb > Molinate > Benzofenap > Clomazone. Pesticides when applied in mixtures or together with high salinity levels were found to show greater toxicity to organisms

The impact of pesticides on the biological health of soils (on-site) and impact on ecosystem (off-site) needs to be properly understood to ensure the profitability and sustainability of rice farming systems.

In this project funded by the Rural Industries Research and Development Corporation (RIRDC), we have carried out a series of experiments both in the laboratory and field to examine the ecosystem impacts of five commonly used rice pesticides (molinate, chlorpyrifos, benzofenap, clomazone and thiobencarb).

Key questions addressed in this project

Of pesticides applied in rice bays, a portion sticks to the soil particle (depending on the chemistry of pesticide and soil type), and the remainder may be dissolved in water or dissipate through volatilisation and other processes. In the soil, with time, soil microorganisms will break down the pesticide molecule.

The two important questions we aimed to answer were:

1. Do the pesticides concentrated in the first few centimetres of the soil have any adverse effect on soil microorganisms and their vital functions such as cycling of nutrients in the soil (nitrogen, phosphorus) and soil structural stability?
2. Do the pesticides induce toxicity to aquatic organisms if they enter waterways and riverine systems?

Experimental studies undertaken

To answer the two questions, we conducted field and laboratory experiments to understand the impact, if any, of rice pesticides on ecosystem health, both on-site on soil

microorganisms, and off-site (drainage water and streams) on aquatic organisms.

To understand the effect of pesticides on soil microorganisms, we carried out experiments under field conditions, and simultaneous laboratory experiments were carried out to underpin the field observations. Two types of microbiological tests, as indicators of soil health, were carried out on these soils: one, to establish activity of total microbial community (soil microbial biomass) and two, to establish the activity of specialist nitrifying bacteria and their sensitivity to pesticides. These nitrifiers perform the important function of conversion of ammonium to nitrate, which is the major form of nitrogen taken up by the plants.

Similarly, for investigating off-site effects, we not only tested the toxicity of drainage water to aquatic organisms but also carried out investigations on water and sediment samples collected from associated drains and creeks (eg Little Mirrool Creek, Box Creek and Tuppal Creek). The pesticide residues were measured in samples taken from these creeks and their toxicity to aquatic organisms (eg water flea, midges – used as indicator of aquatic ecosystem health) was tested. Furthermore, through laboratory experiments, we determined the toxicity of rice pesticides (single or mixtures) to a suite of organisms representing different trophic levels and tested if the inherent toxicity of pesticides is affected due to salinity of water.

Salient findings from these investigations

Effect on soil microorganisms

Two years of field experimentation showed little effect on the indicators of soil microbial activities (microbial biomass, respiration, nitrification) in the rice bays. While we noted a



lot of variation from sample to sample, the effect of pesticides on overall soil microbial activity (measured through their respiration) was not observed due to application of pesticides. To avoid field variability effect, we conducted the laboratory experiments testing two situations.

Under laboratory conditions also overall microbial activity (indicated by microbial respiration) was not adversely affected by pesticide applications. However, unlike the soil respiration, the nitrification potential was slightly affected by certain pesticides especially soon after application (molinate and thiobencarb). The other pesticides (chlorpyrifos, benzofenap and clomazone) did not have an inhibitory effect on the nitrification at the recommended rates.

Off-site effects on ecosystem health

A monitoring study assessed the pesticide impacts on the ecological health of seven drains and creeks in the rice growing area. Sampling was carried out four times in the period October 2002–February 2003, representing pesticide pre-spraying, spraying and post-spraying seasons. Each sampling time involved water quality assessment; analyses of pesticides in water and sediment samples, and laboratory bioassays of collected sediments. Molinate, thiobencarb and clomazone were the commonly detected pesticides in the water (< 2 g/L) and sediments (< 0.5 mg/kg) from the channels and creeks. Non-rice pesticides such as diuron, simazine and atrazine were also detected in some drainage and creek systems.

A suite of tests on three different organisms showed some toxicity during the rice-growing season in these creeks but there was significant recovery observed by the end of rice season (Figure 1). High salinity at some sites (eg Box Creek) was also noted to contribute to the overall toxicity to organisms.

To understand how toxicity of drainage water dissipates with time, we used three different test organisms. Not surprisingly, in rice bays toxicity to waterflea, midges and duckweed was observed just after pesticide application. The second application of pesticides, as well as mixtures of

pesticides enhanced toxicity to all test organisms. In general, there was significant recovery observed 7–14 days post-spraying.

Dose-response relationships between rice pesticide residues and toxicity were established using four test organisms (duckweed, waterflea, midges and tadpoles). Based on these, rice pesticides were ranked in the following order of decreasing toxicity: Chlorpyrifos > Fipronil > Thiobencarb > Molinate > Benzofenap > Clomazone.

As pesticides are applied in mixtures, mixture toxicity was also assessed for the commonly detected rice pesticides. Acute bioassays indicated that the binary combinations of some rice pesticides such as thiobencarb, chlorpyrifos and molinate have synergistic effects (the combined effect was greater than the sum of the toxicities of the individual chemicals). Ecotoxicological approaches were used to assess if high salinity in the rice growing areas could further enhance the toxicity to non-target organisms by influencing the bioavailability of pesticides. Some rice pesticides such as thiobencarb (Figure 2) and chlorpyrifos exhibited increased toxicity to waterfleas exposed to high salinities.

Conclusions and recommendations

Some toxicity on organisms due to pesticide residues was observed during the spraying season and recovery was noted with time. While laboratory tests showed some potential toxicity of pesticides to soil biological processes, no measurable effect of soil biological health could be established under field conditions.

Based on a suite of tests, the pesticides were ranked in decreasing order of toxicity: Chlorpyrifos > Fipronil > Thiobencarb > Molinate > Benzofenap > Clomazone. Pesticides when applied in mixtures or together with high salinity levels were found to show greater toxicity to organisms.

It is recommended that a system level approach is developed to minimise off-site impact of pesticides on ecosystem health. Pesticides used in other production

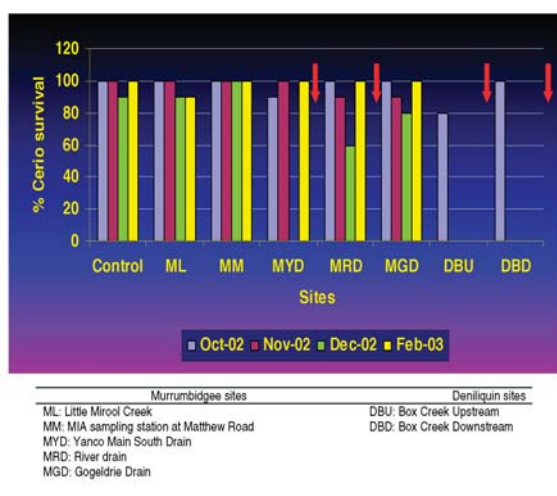


Figure 1 Toxicity of water samples collected from various drainage channels and creeks in rice growing area. Red arrows represent significant mortality in waterfleas.

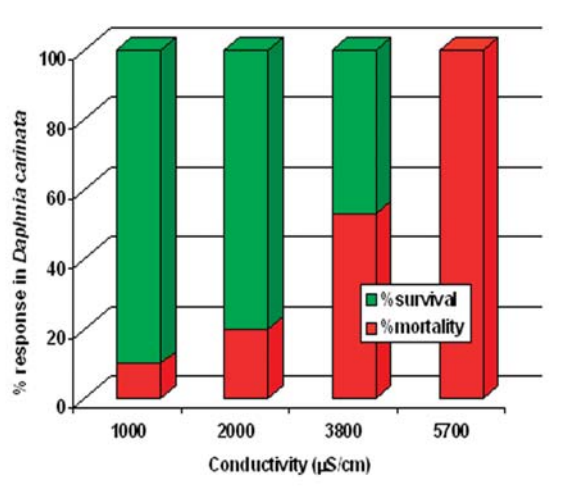


Figure 2 Thiobencarb toxicity to waterflea, *Daphnia carinata*, under the influence of varying salinity



systems in the rice growing areas are also detected in waterways therefore, the rice production should not be considered in isolation but as a part of overall production system. Furthermore, if molinate herbicide is to be replaced by another chemical in future, a search for a suitable indicator compound is a priority. 🌱

RIRDC Project CSL-16A

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Acknowledgements

The authors acknowledge RIRDC for funding this study. A special thanks goes to Wendy Quayle and Sharyn Zrna from CSIRO Griffith site were of great assistance with maintaining field experimental plots and field sampling and Mr Randall Williams and Mr Garry Barden for helping us with the field trials. The authors would also like to thank Mr Mark Neeson, Mr John Sutherland, Mr Mark Robb and Mr Arun Tiwari for providing us drainage water samples for toxicity testing and also for sharing their valuable data with us. We also acknowledge valuable discussions and suggestions made by Dr Mark Stevens, Dr Liz Humphreys, Prof Kath Bowmer and Prof Laurie Lewin during this study.



Figure 3 A field experiment was designed to understand the effects of a range of pesticides on soil microorganisms. Field results were underpinned by results from a simultaneous laboratory study.



Figure 4 Off-site effects of rice pesticides were studied through investigations on water and sediment samples collected from drains and creeks in rice growing areas.