Do aphids biomagnify Cd and Zn as a defence against predation?

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Introduction

It is well established that aphids can biomagnify Cd and Zn and that this phenomenon is not confined to contaminated environments; it is also seen in environments with low background concentrations of these metals (1,2). What benefit do aphids gain by accumulating two potentially toxic elements? Work on other herbivorous insects feeding on Ni hyperaccumulating plants indicates that Ni obtained from the plants plays a role in protecting the insects from predation (3). Could this be the reason behind metal biomagnification in aphids? This works investigates this possibility.

Method

Grain aphids (*Sitobion avenae* L.) were harvested from wheat plants that had been grown in soil amended with sewage sludge at rates equivalent to 0, 10 or 100 t (dry solids) ha^{-1}. Harvested aphids were stored frozen for subsequent feeding to ladybirds. Thirty 7-spot ladybirds (*Coccinella septempunctata* L.) were isolated individually in 9 cm Petri dishes placed in a controlled environment cabinet. The ladybirds were allowed to acclimatise for 72 hrs, during which time no food was given. Groups of 10 Ladybirds were randomly assigned to a diet of aphids harvested from one of the three sludge treatments. Each ladybird was fed a known weight of defrosted aphids. After 24 hrs, uneaten aphids were removed and weighed to determine the mass of aphids eaten. This was repeated for 6 days, with freshly thawed aphids given to the ladybirds at the start of each 24 hr period. Samples of soil, plants and aphids taken from each pot were digested in HNO_3 and analysed for Cd and Zn content by AAS at the end of the experiment.

Results

• Cd concentrations were significantly elevated in the soil ($F = 215$, $P < 0.001$) and wheat shoots ($F = 123$, $P < 0.001$), but not in aphids ($F = 1.9$, $P = 0.18$; Figure 1).

• Zn concentrations were significantly elevated in the soil ($F = 548$, $P < 0.001$), in wheat shoots ($F = 55.2$, $P < 0.001$) and in aphids ($F = 14.0$, $P < 0.001$; Figure 2).

• Aphids did not biomagnify Cd compared to wheat shoots (Figure1), but biomagnified Zn to a concentration approximately twice that of the shoots in all treatments (Figure 2).

• Fresh mass of aphids consumed by ladybirds decreased significantly with increasing sludge amendment ($F = 4.2$, $P = 0.03$; Figure 3).

• There was no significant correlation between Cd concentrations in aphids and the mass of aphids consumed by ladybirds ($r_s = -0.31$, $P = 0.94$).

• There was a significant, negative correlation between Zn concentration in aphids and the mass of aphids consumed by ladybirds ($r_s = -0.50$, $P = 0.005$).

Figure 1. Cadmium concentrations (mg kg^{-1}) in soil, wheat shoots and grain aphids following the amendment of soil with sewage sludge (mean ± 1 SE).

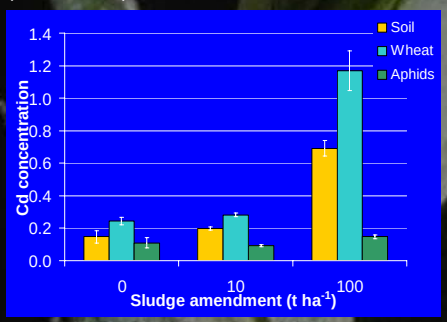


Figure 2. Zinc concentrations (mg kg^{-1}) in soil, wheat shoots and grain aphids following the amendment of soil with sewage sludge (mean ± 1 SE).

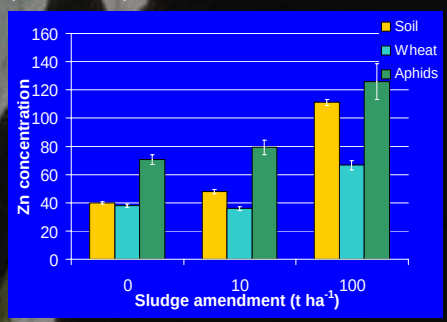
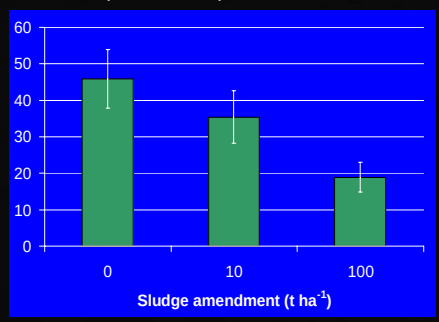


Figure 3. Mean mass of aphids (mg f.w.) consumed by ladybirds over a 6 day period in control and sewage sludge contaminated treatments (mean ± 1 SE).



Discussion and Conclusions

• Amending soil with sewage sludge more than halved the fresh mass of aphids consumed by ladybirds.

• Results do not support the view that the highly zootoxic metal Cd played a role in reducing the mass of aphids consumed by ladybirds.

• The biomagnification of Zn by aphids together with the negative correlation between Zn concentration in aphids and the mass of aphid material consumed by ladybirds provided evidence that Zn may have played a role in reducing the consumption of aphids by ladybirds.

• The reduced consumption of aphids by ladybirds may be a mechanism to prevent the ingestion of potentially toxic concentrations of Zn.

• In conclusion, this work provides evidence that aphids biomagnifiy Zn as a mechanism to protect themselves from predators. This may have a negative effect on the biological control of aphids when soils are contaminated with Zn from sewage sludge amendments.

References

1. Merrington, G., Winder, L., Green, I., 1997. The bioavailability of Cd and Zn from soils amended with sewage sludge to winter wheat and subsequently to the grain aphid *Sitobion avenae*. The Science of the Total Environment 205, 245-254.
2. Merrington, G., Winder, L., Green, I., 1997. The uptake of Cd and Zn by the bird cherry oat aphid *Rhopalosiphum padi* (Homoptera: Aphididae) feeding on wheat grown on sewage sludge amended agricultural soil. Environmental Pollution 96, 111-114.
3. Boyd, R.S., Wall, M.A., 2001. Responses of generalist predators fed high-Ni *Melanotrichus boydi* (Heteroptera : miridae): Elemental defence against the third trophic level. American Midland Naturalist 146 (1), 186-198.