Changes of plankton community structure in pond and stream mesocosms caused by the herbicide metazachlor

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Introduction

A mesocosm study was conducted in the indoor pond and stream mesocosm system of the German Federal Environmental Agency (Mohr et al. 2003) in order to study effects of the herbicide metazachlor on macrophytes and plankton communities. Metazachlor disturbs the synthesis of many chain fatty acids (VLCFA: > 18 C) by an irreversible inhibition of the VLCFA elongation enzyme (Eckermann et al. 2003). This herbicide is toxic to almost all plants and algae seem to react very heterogeneously with EC 50 ranging from 0.031 mg/L for Pseudokircheriella subcapitata to 1.63 mg/L for Chlorella sp. (FAO 1999).

In contrast to higher plants, some algae are capable of replacing the missing VLCFAs in membranes by others or have different fatty acid compositions with few VLCFAs (Schmalfuß et al. 1998; Napolitano 1998). Direct toxic effects on zooplankton or protozoans are rather unlikely since these groups are generally unable to synthesise fatty acids. However, indirect effects may also be impacted by the resulting differences in food quality and quantity. In this study we investigated whether:
- algae with high amounts of VLCFAs are more sensitive to metazachlor than algae with less VLCFAs
- mesocosm studies are suitable to detect sensitive plankton species.

Materials and Methods

Characteristics of the Mesocosm System

Table 1: Nutrient levels of the different mesocosm systems

<table>
<thead>
<tr>
<th>Nutrient Level</th>
<th>Streams</th>
<th>Ponds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (PO₄)</td>
<td>0.01 mg/L</td>
<td>0.005 mg/L</td>
</tr>
<tr>
<td>Nitrite (NO₂)</td>
<td>0.4 - 1.5 NTU</td>
<td>0.5 - 1.5 NTU</td>
</tr>
<tr>
<td>Nitrate (NO₃)</td>
<td>0.9 - 2.0 NTU</td>
<td>0.5 - 2.0 NTU</td>
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Experimental Design

- Contamination of 5 ponds and 5 streams with 5, 20, 80, 200, and 500 µg/L Metazachlor (single application), three systems served as control (Fig. 2 and 3).
- Biweekly measurements of physico-chemical and biological parameters.
- Water sampling for plankton: depth integrated at different positions in the ponds and at a depth of 0.1 m (one position) in the streams.
- Phytoplankton and protozoans were fixed with Lugol’s solution and counted according to Utermöhl (1958).
- Zooplankton was fixed in formaldehyde at a final concentration of 4% and counted under a stereo.
- Plankton community response was analysed by principle response curve (PRC) analysis using CANOCO (version 4.5).

Results: Streams

Fig. 4: PRC-analysis of the reduced phytoplankton data set in the stream mesocosms. Of total treatment variance (21.1 %), 30.5 % is explained by the PRC diagram. Species weights = biak value, arrow indicates date of application.

- Overall, density of phytoplankton and protozoans was very low (<5000 Ind/ml) with few species dominating the systems at each sampling date
- PRC revealed no clear concentration response relationship (Fig. 4).
- Species like Monoraphidium komarckovae (green algae) reacted with a decrease in abundance (Fig. 4, positive species weights; Fig. 5), while species like Fragilaria ulna (diatom) reacted with an increase in abundance (Fig. 4, negative species weights; Fig. 5).
- M. komarckovae directly decreased after Metazachlor application even at lowest concentration (5 µg/L).

Discussion and Conclusions

In this study green algae, which have generally high amounts of VLCFAs (Napolitano 1998), were more sensitive than diatoms and cryptophytes with lower amounts of VLCFAs. However, generalisations concerning sensitive or resistant species are difficult. Even within one species sensitivity towards metazachlor may vary strongly. Schmalfuß et al. (1998) found that a Scedesmus acutus mutant was highly resistant to metazachlor while the wild type was very sensitive. Only the mutant was able to replace the missing VLCFAs in essential membranes or cell wall compounds with <18 fatty acids. The fact that in this study most algal species reacted insensitive or increased in abundance may at least partly result from this capability. Indirect effects like altered habitat structure, changes in competition conditions and food availability were most likely responsible for the changes in the zooplankton communities of the pond mesocosms.

The absence of phytoplankton species like A. excisus. Acroperus harpae or Camptocercus biserratus in the highly contaminated ponds was caused by the strong reduction of macrophyte biomass (Fig. 2), while free swimming species like P. dolichoptera and C. quadrangula increased in abundance.

The occurrence of many indirect effects on the plankton community was probably the reason why the PRC analysis did not reveal a clear concentration response relationship.

General Conclusions

Standard laboratory toxicity tests with few algal species may not be sufficient to cover the whole range of effects of metazachlor on algae since the reactions of algae seem to be very heterogeneous due to the special mode of action of this herbicide. Consequently, for risk assessment mesocosm studies should become a standard in testing chloracaricides or single species tests should be restricted to algae with a high share in <18 VLCFAs.