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Overcoming barriers to use of nursery run-off water: Understanding plant sensitivity to residual pesticides

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EXECUTIVE SUMMARY:

Programs such as the USDA SCRI-supported Clean WateR3 are providing innovative options for nursery growers to re-use nursery run-off water for irrigation. However, concerns over crop damage from residual pesticides in nursery run-off may prevent growers from adopting emerging technologies for re-using this water. In this study we evaluated the growth and physiological response of three common nursery plants ('Limelight' *Hydrangea paniculata*, "Powell Gardens" *Cornus obliqua* and "Gold Standard" *Hosta*) to irrigation with simulated run-off water that contained pesticides (oxyfluorfen, isoxaben, and chlorpyrifos) at concentrations that have been reported in nursery run-off. Irrigation with simulated run-off containing isoxaben, a pre-emergent herbicide, and chlorpyrifos, an insecticide, did not cause visible injury or affect growth or physiology of any of the species tested. In contrast, exposure to run-off containing oxyfluorfen, an herbicide with post emergent activity, caused visible injury to all three species and reduced growth and photosynthetic capacity of *Hydrangea* and *Hosta*. Nursery growers should follow best management practices, such as minimizing non-target application, to reduce the likelihood that post-emergent herbicides will reach irrigation recycling ponds.

BACKGROUND

According to the USDA Census of Horticulture Specialties, the wholesale value of container-grown nursery crops in Michigan exceeded $71 million in 2014 (USDA 2015). Michigan is among the leading states in the U.S. for nursery crops and ranks 3rd in production of nursery and landscape products in the U.S. (Knudson and Peterson, 2012). Nursery growers often apply irrigation excess of plant water need, which can result in substantial run-off. (Warsaw et al., 2009; Kachenko, 2010). For example, up to 80% of applied water may be lost as run-off in a nursery with #1 containers placed six inches apart (Mathers et al., 2005). Run-off water may contain pesticides which may have an adverse effect on the environment. Moreover, the presence of pesticides in nursery run-off may be an impediment to re-use of this water since growers may be concerned about potential negative impacts on crop growth and quality (Wilson and Broembsen, 2015).

In this study we evaluated the impact of exposure of nursery plant to isoxaben, chlorpyrifos and oxyfluorfen. Each of these pesticides may be found in nursery run-off water and may have an adverse effect on nursery plants (Briggs et al., 2003; Keese et al., 1994).

Isoxaben (Common tradenames: Gallery®, Snapshot®) is a pre-emergence herbicide that works by inhibiting cell wall biosynthesis in dividing cells. This may cause stunted plants and a wide range of nursery plants are susceptible to this herbicide. Chlorpyrifos (Common tradenames: Dursban®, Lorsban™) is an insecticide but may also affect plants by inhibiting activity of enzymes for growth and development hence also causing smaller plants (Parween et al., 2011). Oxyfluorfen (Common tradename; Goal) is widely used pre- and post-emergence herbicide in container nursery production (United States Department of Agriculture and National Agricultural Statistics Service, 2011). It is mostly used for controlling broadleaf weeds and annual grasses (Dow AgroSciences, 2014). It acts by inhibiting protoporphyrinogen "PPO" oxidase which, in turn, destroys cell membranes.

Pesticides may interfere with physiological and biochemical processes in target and non-target plants. Many of these effects are related to photosynthetic function and measuring these responses can indicate the extent of damage caused by pesticides (Krugh and Miles, 1996; Spiers et al., 2008; Venkateswarlu et al., 2012). Although general impacts of isoxaben, chlorpyrifos and oxyfluorfen on plants are described on some studies, the effect of various concentrations of these compounds on common nursery plants has not been clearly documented. Understanding these impacts will ultimately help nursery grows to properly manage run-off water and encourage its re-use. It will also help to identify the impacts of those compounds on nursery plants and facilitate decision making for economical alleviation of those effects.

OBJECTIVES

Determine the sensitivity of common container-grown nursery plants isoxaben, chlorpyrifos and oxyfluorfen applied through irrigation water and develop techniques to identify pesticide sensitivity for different kind of pesticides.

Quantify the effect of those compounds on key physiological processes of nursery plants and outline the threshold level of those compounds on plant productivity.

Conduct foliar leaf analysis for residual pesticide concentration and correlate physiological and morphological responses of nursery plants to the results.

SPECIFIC METHODS AND PROCEDURES

Plant materials and treatments.

We examined plant responses to exposure isoxaben, chlorpyrifos and oxyfluorfen at five different concentration of each pesticide (0, 0.15, 0.35, 0.7 and 1.4 mg L-1 of isoxaben, 0, 0.05, 0.1, 0.2 and 0.4 mg L-1 of chlorpyrifos and 0, 0.005, 0.01, 0.015 and 0.02 mg L-1 of oxyfluorfen). Doses of pesticide were mixed with irrigation water using an injector and sprayed on the plants to simulate an overhead irrigation application. The range of treatments were adjusted to account for minimum to maximum pesticide residue that could be found on collection pond for run-off water. We used 'Limelight' *Hydrangea paniculata,* "Powell Gardens" *Cornus obliqua* and "Gold Standard" *Hosta* for our study. There were six replication per treatment and the experiment was conducted as completely randomized design. Plants were planted in #3 (11 L) container in a standard container mix of pine bark and peat moss (80:20, v:v). Irrigation-pesticide treatments were applied daily for three months.

Measurements

We assessed the response of plants to irrigation with simulated collected nursery run-off water by monitoring growth and detailed analysis of physiological parameters that may be sensitive to pesticide exposure.

Plant growth was monitored by measuring plant height and crown width in two directions (growth index = height + width1 +width2). Photosynthetic responses of each plant was assessed after 3 months of treatment. Photosynthetic gas exchange was measured with a portable photosynthesis system (LI-6400XT, Li-Cor, Inc.). The potential impacts of pesticide exposure on photosynthetic biochemistry were elucidated by developing photosynthetic carbon dioxide response curves (Sharkey et al., 2007). Parameters estimated by fitting these curves provide insights on treatment effects on key biochemical steps in photosynthesis including, maximum carboxylation rate (Vcmax); rate of photosynthetic electron transport (J); triose phosphate use (TPU) and mesophyll conductance (gm). At the end of each experiment, we harvested plants and determined root, stem, and leaf dry weights. A subsample of leaves from three plants from each species and treatment were collected for pesticide residue analysis. Residual levels of isoxaben, chlorpyrifos, and chlorpyrifos were analyzed at a commercial laboratory (Brookside Labs, Laboratories, Inc., New Bremen, OH).

RESULTS

The growth response of nursery plants to pesticide exposure varied depending on the plant type and the pesticide to which they were exposed. Oxyfluorfen generally caused the greatest degree of impact on plants among the pesticides tested. *Hydrangea* plants were the most sensitive to pesticide exposure. Increasing the concentration of oxyfluorfen in irrigation water decreased growth index of *Hydrangea* and *Hosta* but not *Cornus*. (Fig. 1). Exposure to Isoxaben or Chlorpyrifos in irrigation water did not affect growth of any of the species tested (data not shown).

Exposure to oxyfluorfen caused visible injury to all three species examined. Visible injury was most evident on *Hydrangea* and *Hosta*, in which increasing exposure resulted in a dose-rate increase in visible damage. (Fig. 2) Visible symptoms of oxyfluorfen exposure included leaf browning and curling, stunted growth and reduced flower production (Photos 1-3). Exposure to isoxaben or chlorpyrifos did not result in visible injury to the species tested (data not shown).

Irrigating with simulated run-off containing oxyfluorfen affected photosynthetic capacity of *Hosta* and *Hydrangea* (Fig. 3 and Fig. 4). Maximum rates of photosynthesis of *Hosta* were reduced when plants were exposed to 0.01 mg/L or more of oxyfluorfen. Exposure to oxyfluorfen reduced maximum photosynthetic rates of *Hydrangea* plants when were concentrations in irrigation water exceeded 0.015 mg/L. Exposure to oxyfluorfen in irrigation water did not affect photosynthesis of *Cornus* plants. Irrigation with water containing isoxaben or chlorpyrifos did not affect photosynthesis of any of the species tested.

Leaf residual concentration of all three pesticides increased with increasing exposure level (Figs. 5-7). However, species varied in the uptake of each pesticide. *Cornus* plants absorbed relatively high amounts of isoxaben and chlorpyrifos compared to hydrangea and especially hostas. In contrast *Hydrangea* and *Hosta* plants had higher concentrations of oxyfluorfen than cornus plants.

DISCUSSION AND CONCLUSION

In this study the sensitivity of nursery plants to pesticides in irrigation water depended on the pesticide applied and plant species. Among the pesticides examined only exposure to oxyfluorfen resulted in impacts to plant growth, visible injury and photosynthetic capacity. Our observations are consistent with that of growers, who report crop damage following exposure to oxyfluorfen This response likely reflects the fact that oxyfluorfen is an herbicide that has post-emergent activity and therefore has the potential to affect sensitive plants following prolonged low-dose exposure. The other pesticides examined in this study are an insecticide (chlorpyrifos) and an herbicide without post-emergent activity (isoxaben), which may be less likely to impact plant physiological function.

Differences among species in their sensitivity to oxyfluorfen may be due in part to difference in plant uptake. The species that were most impacted by oxyfluorfen exposure, *Hydrangea* and *Hosta*, also had the highest leaf residual concentrations of the compound.

The results of this study also suggest that growth impacts of pesticide exposure in irrigation water are linked to physiological function. The species that had significant reductions in photosynthetic capacity also showed reduced growth.

IMPLICATIONS FOR GROWERS

For nursery growers that are considering using reclaimed water for irrigation, these results suggest that particular care should be used with herbicides that have post-emergent activity. Growers should minimize the amount of pesticides that can run-off into catchment ponds. This includes minimizing non-target application and avoiding applications before heavy rainfall events or irrigation.

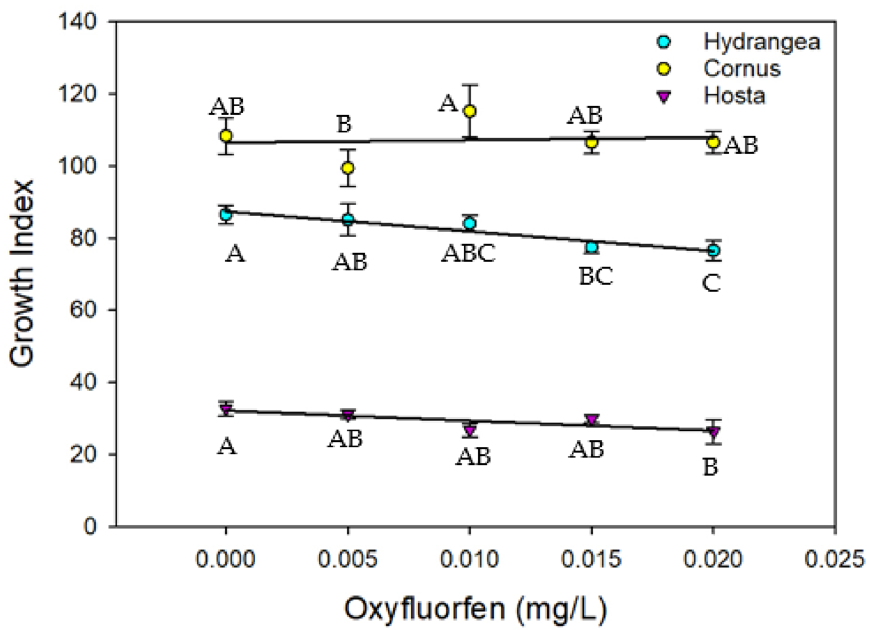


Figure 1. Mean growth index response of *Hydrangea*, *Cornus* and *Hosta* plants irrigated with simulated runoff containing five concentrations of oxyfluorfen for three months. Means within a species followed by the same letter are not iffent at p<=0.05. Mean separation by Tukey's HSD test.

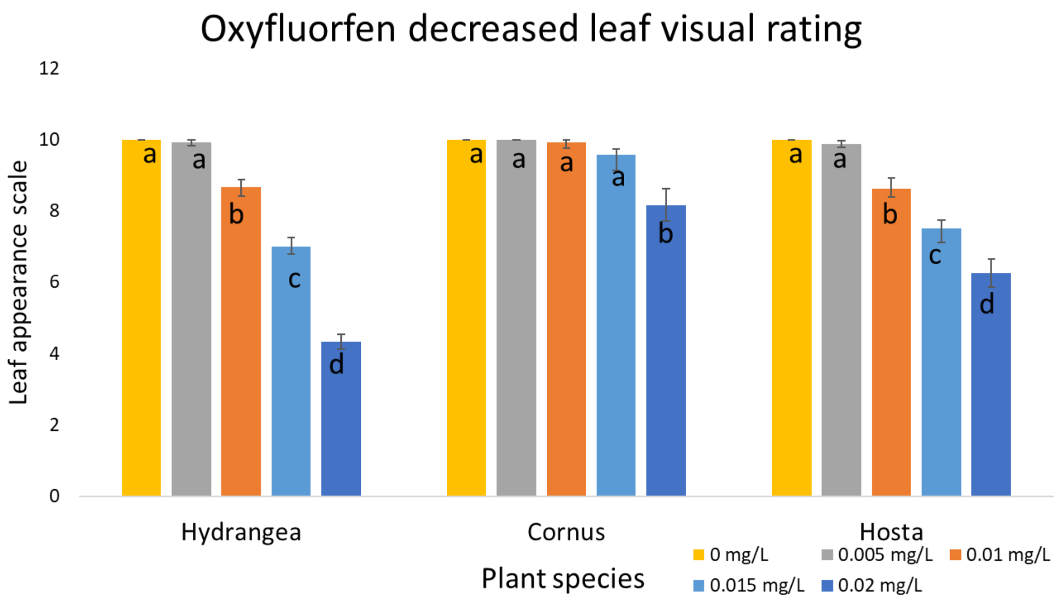
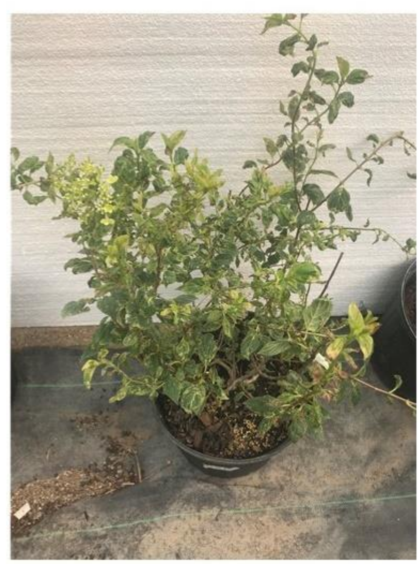


Figure 2. Mean visual rating of *Hydrangea*, *Cornus* and *Hosta* plants irrigated with simulated runoff containing five concentrations of oxyfluorfen for three months. Visual rating based on a scale of 10 = no injury to 0 = dead plant. Means within a species followed by the same letter are not different at p<=0.05. Mean separation by Tukey's HSD test.





Control: 10 Oxy 0.01mg/L: 8.66 Oxy 0.02 mg/L: 4.33

Photo 1. Examples of visual ratings of *Hydrangea* plants irrigated with simulated runoff containing three concentrations of oxyfluorfen for three months. Visual rating based on a scale of 10 = no injury to 0 = dead plant.

Control: 10

Oxy 0.01mg/L: 8.6

Oxy 0.02 mg/L: 6.2

Photo 2. Examples of visual ratings of *Hosta* plants irrigated with simulated runoff containing three concentrations of oxyfluorfen for three months. Visual rating based on a scale of 10 = no injury to 0 = dead plant.

Control: 10

Oxy 0.01mg/L: 9.9

Oxy 0.02 mg/L: 8.1

Photo 2. Examples of visual ratings of Hosta plants irrigated with simulated runoff containing five concentrations of oxyfluorfen for three months. Visual rating based on a scale of 10 = no injury to 0 = dead plant.

Photo 3. Examples of visual ratings of *Cornus* plants irrigated with simulated runoff containing three concentrations of oxyfluorfen for three months. Visual rating based on a scale of 10 = no injury to 0 = dead plant.

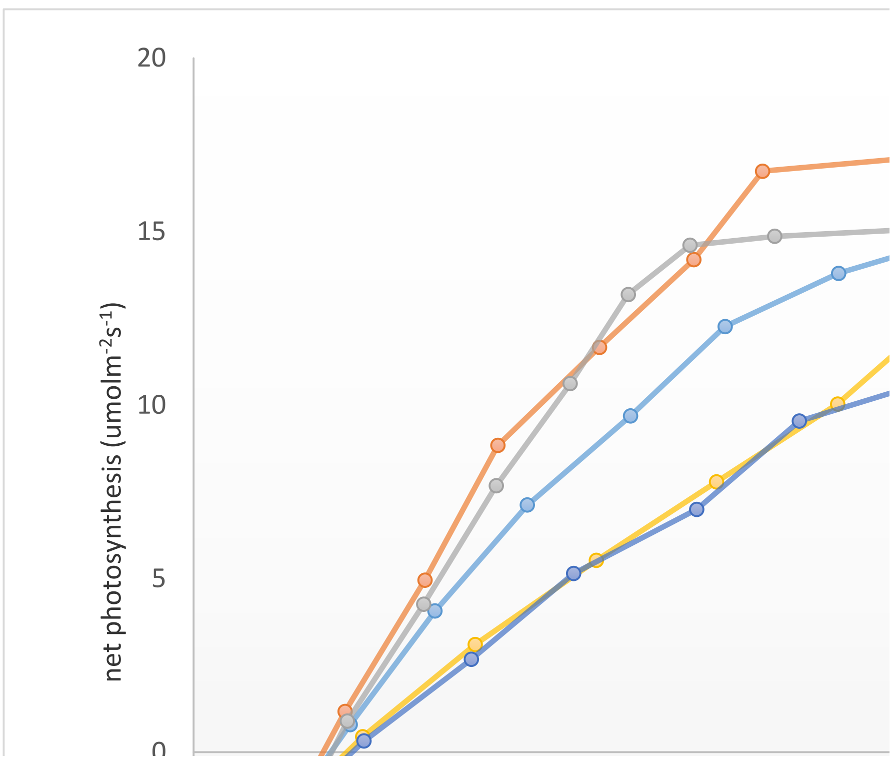


Figure 3. Net photosynthesis of *Hydrangea* plants in response to intercellular CO_2 (Ci) following irrigation with simulated runoff containing five concentrations of oxyfluorfen for three months

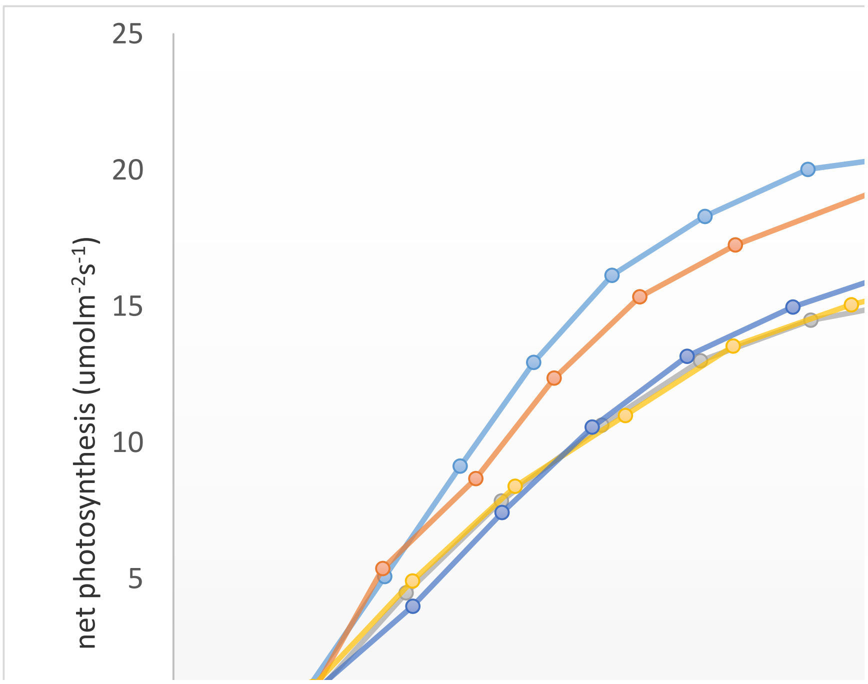


Figure 4. Net photosynthesis of *Hosta* plants in response to intercellular CO2 (Ci) following irrigation with simulated runoff containing five concentrations of oxyfluorfen for three months

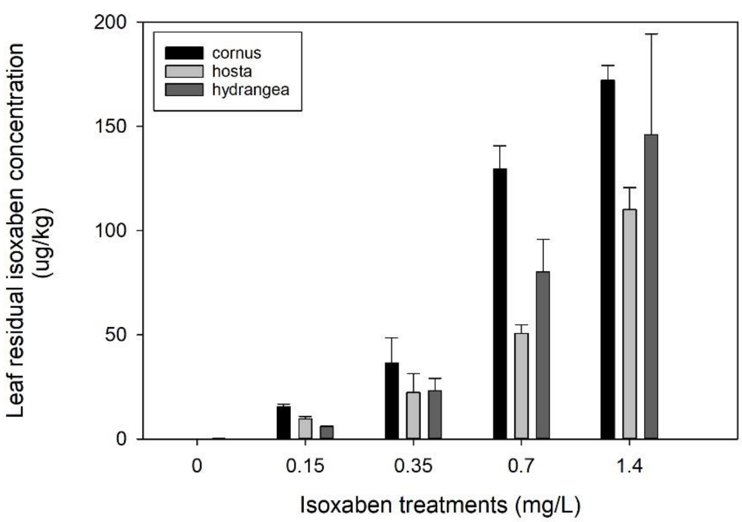


Figure 5. Mean leaf residual concentration of isoxaben of *Cornus*, *Hosta* and *Hydrangea* plants following irrigation with simulated runoff containing five concentrations of isoxaben for three months.

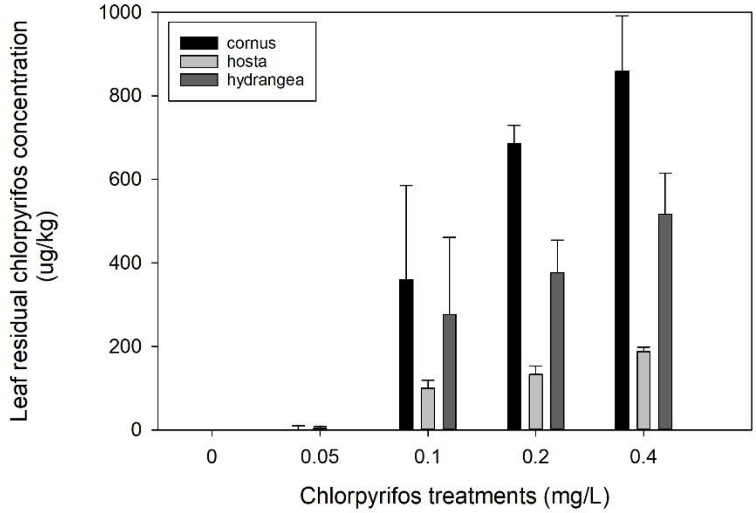


Figure 6. Mean leaf residual concentration of chlorpyrifos of *Cornus*, *Hosta* and *Hydrangea* plants following irrigation with simulated runoff containing five concentrations of chlorpyrifos for three months.

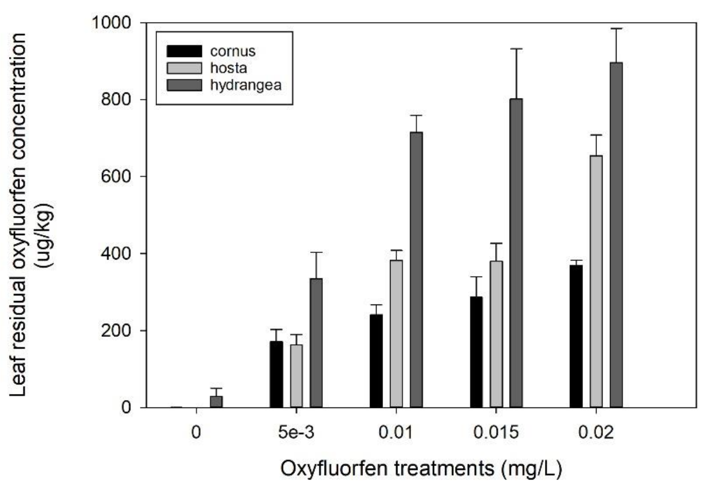


Figure 7. Mean leaf residual concentration of oxyfluorfen of *Cornus*, *Hosta* and *Hydrangea* plants following irrigation with simulated runoff containing five concentrations of oxyfluorfen for three months.

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