J. Aquat. Plant Manage. 39: 125-128

Control of Dioecious New Zealand Hydrilla using Fluridone in Mesocosms

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ABSTRACT

Hydrilla verticillata (L.f.) Royle was treated with fluridone at initial concentrations of 0, 10, 20, 50, and 150 µg/L in growth tanks at two different light levels (90% shade and 30% shade) for five months over the summer of 1998-1999. Plants were harvested monthly to assess biomass and potential recovery. Differences in plant appearance and biomass were apparent between treatment and control tanks after one month, however biomass was not different between the different fluridone treatment tanks at any stage. After five months in treatment tanks, plant biomass was about four to six times less than that of control plants, but was similar to that of initial biomass. Light level had no effect on biomass in treatment tanks, after the first month. Plants remained viable in all fluridone treatments, however recovery took at least two months (at autumn temperatures) for plants that had been in fluridone treatments as long as five months. These results indicate that fluridone significantly inhibits growth of hydrilla, but plant death would require longer contact times under the conditions tested.

Key words: *Hydrilla verticillata*, fluridone efficacy.

INTRODUCTION

Hydrilla verticillata (L.f.) Royle has been in New Zealand since the 1960s, and is established in four lakes in the Hawke's Bay Region. Since its introduction, several programs have been implemented to control and potentially eradicate hydrilla, including the use of grass carp (Clayton et al. 1992), weed matting and diquat (the only herbicide registered for aquatic use in New Zealand). Following successful reports of hydrilla control with fluridone in the U.S.A., trials were also conducted in New Zealand in the 1980s to evaluate the efficacy of fluridone on hydrilla and other selected weed species (Wells et al. 1986). Fluridone was evaluated at concentrations of 0.1, 1, 10 and 100 mg/L for 60 days contact time commencing in late spring. Wells et al. (1986) reported that fluridone was not effective at controlling hydrilla or a range of troublesome aquatic weeds tested. Fluridone produced a transient albescence in growing tissues and produced little damage to older plant tissue in the 0.1, 1 and 10 mg/L treatments. They concluded from the results of mesocosm and field trials that fluridone "is of low herbicidal activity and is therefore unlikely to be registered as a broad spectrum aquatic herbicide for use in this country" (Wells et al. 1986).

Variable success in the use of fluridone at different concentrations and exposure times for control of submerged macrophytes has been described by a number of authors. Dechoretz and Frank (1978), for example, observed some phytotoxic effects using 10 µg/L fluridone, but concluded that it was generally ineffective on established plants of *Pota-*

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mogeton species and *Elodea canadensis*. Whereas McCowen et al. (1979) tested fluridone at rates of 0.25, 0.5, 1, 2 and 4 mg/L, on a number of submerged macrophytes including *Potamogeton* and hydrilla, and reported excellent control, even at the lowest dose tested. Grant et al. (1979) evaluated fluridone control of hydrilla in a pond at rates of 0.75 to 2 lbs per acre. Fluridone injury symptoms (chlorotic leaves) began to appear on hydrilla three to six days after treatment, but very little control was noticed until four to six weeks after treatment when the percentage of open water increased (Grant et al. 1979). Hall and Westerdahl (1983) also reported a lack of total hydrilla control based on percent injury and chlorophyll results, although greater than 50% control was achieved at a concentration of 20 µg/L fluridone.

Failure to effectively control hydrilla with fluridone has been attributed to insufficient contact time (Netherland and Getsinger 1995b). Both fluridone concentration and exposure time requirements were evaluated for Eurasian milfoil and hydrilla under controlled conditions (Netherland et al. 1993). Although fluridone inhibited growth and reduced biomass at rates of 12, 24 and 48 µg/L, removal of plants from fluridone at 30 and 60 days resulted in extensive regrowth following a 30 day recovery period. These results indicate that maintaining fluridone concentration as low as 12 µg/L for greater than 60 days is critical for successful fluridone treatment (Netherland et al. 1993). Similarly, Fox et al. (1996) reported that the control of hydrilla in Lake Harris resulted from the long exposure (over 25 weeks due to the split application) to fluridone concentrations of 2 µg/L, well below the maximum label recommendation. However, control of hydrilla at such low concentrations has not been successful in other lakes (Fox et al. 1996).

Although fluridone is effective at inhibiting growth of submerged macrophytes at concentrations ranging from 1 to 10 µg/L, plant control is not achieved at these rates unless there is an extended contact time of greater than 10 weeks (Netherland and Shearer 1996). Hence, in the New Zealand study by Wells et al. (1986) which used the previously recommended (Lilly Res. Lab. 1981) 60 day contact time, insufficient exposure may account for the failure of fluridone to kill hydrilla, despite the use of high fluridone concentrations. The objective of the present study was to determine the concentration and contact times of fluridone necessary to achieve control (a significant reduction in biomass) of New Zealand hydrilla, by evaluating a range of concentrations, and contact times that exceed the label recommended contact time.

MATERIALS AND METHODS

Dioecious hydrilla was treated with fluridone (Sonar AS) for up to five months during the summer of 1998/1999. The fluridone treatment concentrations were 0, 10, 20, 50 and 150 µg/L, with four 1500 L tanks at each concentration. Half of the tanks were covered with 30% neutrally absorbing shade cloth and the other half with 90% shade cloth. Water depth was maintained at 1.4 m and the tanks were aerated. The degradation of fluridone in all tanks was monitored monthly by SePRO using FASTest. Light levels and temperatures were recorded within each tank at monthly intervals throughout the study.

Hydrilla was propagated from stem fragments in 300-ml pots filled with lake sediment and covered with a 10-mm layer of sand. The lake sediment was excavated from Lake Waikapiro, a Hawke's Bay lake with hydrilla. Plants were acclimated for 6 weeks prior to the start of the treatment. At time zero, nine plants were removed and dry weights recorded as estimates of pre-treatment biomass. At least 90 plants in each tank were subject to treatment with fluridone.

The growth and appearance of plants was assessed weekly for the first month and fortnightly thereafter. Growth (stem elongation and branching) was recorded as; (0) for no new growth, and (1) if new growth was evident. Appearance was recorded on a (0-5) scale where: (0) was no effect, (1) was chlorotic new growth, (2) was some necrosis in young leaves, (3) was all apices are necrotic, (4) was some necrotic mature leaves and (5) was plant kill (Wells et al. 1986).

Each month, eighteen plants were removed at random from each tank, nine of which were put into a recovery tank of similar light levels, without fluridone and nine were harvested and dry weights determined. At each harvesting period the number of tubers (subterranean turions) and turions (axillary turions) present were also recorded. Plants in the recovery tank were visually assessed fortnightly. Recovery was deemed to be the production of new healthy green shoots. The final harvest of all plants remaining in the tanks occurred five months (142 days) following treatment with fluridone.

Plant dry weights were analyzed using analysis of variance (ANOVA). All statements of significance are made at the 5% level or less.

RESULTS AND DISCUSSION

Chlorotic growth and pink shoots were observed on at least half of the plants in all of the treatment tanks within one week of treatment with fluridone. Plant growth continued in the presence of fluridone, with pink chlorotic shoots up to 700 mm in length recorded in the 10 and 20 µg/L tanks after 2 months treatment. Plants in higher concentrations (50 and 150 µg/L) developed necrotic apices after 2 to 3 months, but this was not apparent in the majority of plants at the two lower concentrations until the third and fourth months. Even after five months at the highest concentrations, plants were not killed. Plants in the control tanks were healthy and continued to grow throughout the study (Figure 1). Male flowers were present on plants in all tanks from January (mid summer), but were more abundant in the control and lower concentration tanks than in the highest treatment tank.

Biomass data were significantly different between the control and treatment tanks from one month through to the conclusion of the study, but did not differ between treatments (concentration). The occurrence of significant differences in biomass after only one month was similar to other reported results. Netherland and Getsinger (1995a) treated hydrilla at concentrations between 0 to 25 µg/L, and report significant difference in shoot biomass between treatments of 1 to 25 µg/L and control plants after one month. In the present study, chlorotic growth continued in all treatments, but plant biomass between treatment concentrations was not different to each other at any harvest period (Figure 1). These results are similar to U.S. studies in that growth inhibition and con-

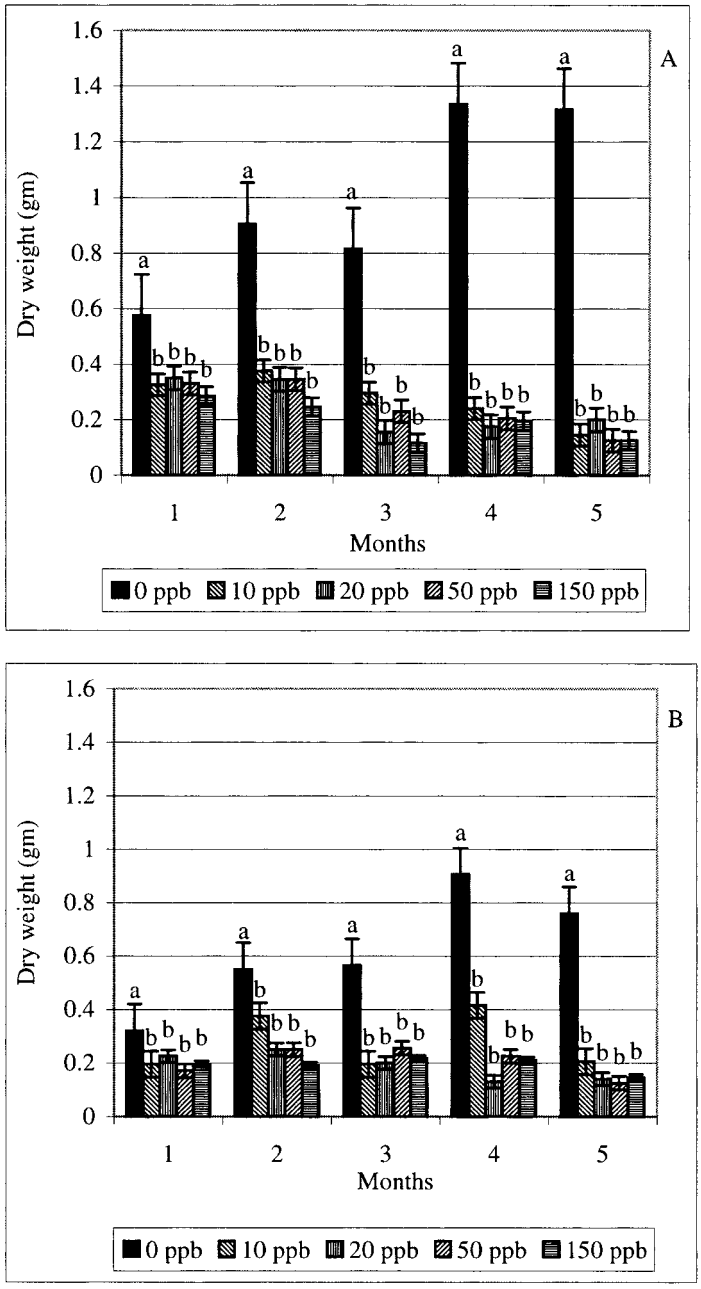

Figure 1. Effects of fluridone on hydrilla biomass over five months at two shade levels (A) = 30% and (B) = 90% shade. Bars represent the mean plant biomass (n = 18) from all tanks at the treatment concentration (µg/L or ppb). Vertical lines on each bar indicate the standard error. Bars with different letters at each month are significantly different from each other ($p < 0.05$). The mean plant dry weight at time zero was 0.18 gm (SE = 0.026, and n = 9).

trol of hydrilla for exposure times beyond ten weeks have been reported at concentrations equal to or less than those used in the present study (Netherland and Shearer 1996).

Hydrilla recovered within one or two months of having been placed in fresh water when exposure to fluridone was between one to three months. These recovery results are in general agreement with other studies in that once plants are removed from the fluridone, particularly after only 60 days treatment or less, they do recover (Netherland et al. 1993, Wells et al. 1986). Use of a 60 day contact time would explain the results reported by Wells et al. (1986), where the quick recovery of plants led to the conclusion that fluridone was ineffective. After five months of fluridone treatment plant recovery still occurred, although it took more than two months. The length of time to recover was presumably a function of the longer exposure to fluridone, but the termination of this study also coincided with the onset of autumn and cooler temperatures, which is associated with lower growth rates in hydrilla (Clayton et al. 1992). A steady decline in monthly temperatures can be seen in the harvest temperature data. Diel water temperature ranges for the three days preceding each harvest date were 24 to 27C in December, 21 to 29C in January, 21 to 25C in February, 21 to 25C in March and 15 to 17C in April.

Shade had an effect on plant biomass in treatment tanks for the first harvest only. Plant biomass was greater under high light (30% shade, about 400 $\mu Em^{-2}s^{-1}$) conditions than low light (90% shade, about 100 $\mu Em^{-2}s^{-1}$). Plants were taller when grown under 90% shade and particularly towards the end of the study they were healthier in appearance, and without the epiphytic algal growths that were present in the 30% shade tanks. Several studies have described a reduction in chlorophyll levels after treatment with fluridone that was more pronounced under high light rather than low light conditions (Devlin et al. 1978, Bartels and Watson 1978, Anderson 1981). Plants growing under high light conditions would normally produce more carotenoids to offset the increase in light generated oxidative stress. The effect of fluridone would therefore be exacerbated under high light intensity due to a higher rate of photo-oxidation and growth (Doong et al. 1993). In this study, the more chlorotic and necrotic plants under high light conditions were not associated with a decrease in biomass of these plants compared with low light plants. However, hydrilla and many other submersed aquatic macrophytes persist in areas of very low light intensity yet fluridone still provides good control (Doong et al. 1993).

After two months of treatment, a total of 17 tubers and 18 turions were produced in the four control tanks, and 10 tubers and 1 turion in the fluridone treated tanks. Although viable tubers and turions were produced in the presence of fluridone, the tissue produced following germination was chlorotic, which is consistent with the literature (McCowen et al. 1979, Arnold 1979). Once in recovery tanks, plants 'grew out' of the chlorotic appearance.

Similar initial fluridone concentrations were obtained between replicate tanks, and there was little fluridone degradation, irrespective of shade level, with more than half of the initial concentration remaining in all treatments after five months (Figure 2). The rate of photo degradation is largely a function of sunlight duration and intensity, and water turbidity and depth. In particular, it is the UV-B portion of the light spectrum that fluridone is susceptible (Mossler et al. 1989, MacDonald et al. 1996). Twenty days is the average half-life of fluridone in treated ponds (West et al. 1983, Tarver 1986), with half-lives ranging from 5 to 60 days reported in the literature (Netherland and Getsinger 1995b). The half-life in this present study was long compared with those usually reported in U.S. studies, but not compared to Wells et al. (1986) where

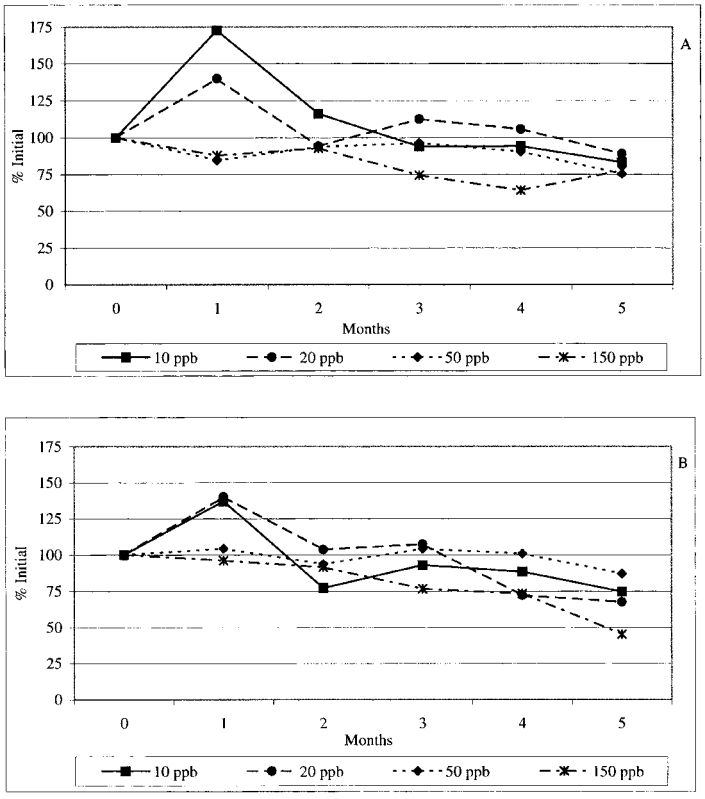

Figure 2. Percentage fluridone remaining in treated tanks at monthly intervals. Data are mean percentages (n = 2) per concentration (µg/L or ppb). Graph (A) = 30% shade and (B) = 90% shade.

more than 50% of the initial dose remained in all treatments at the end of the trial (60 days). Therefore, it seems unlikely that rapid fluridone degradation by photolysis could account for a lack of efficacy in earlier fluridone trials in New Zealand as suggested by MacDonald et al. (1996).

The results of this study demonstrate that even after five months continuous exposure to fluridone at concentrations reported to control hydrilla, biomass may be reduced without resulting in plant death. The ability of hydrilla to recover after five months treatment and to develop propagules in the presence of fluridone, may indicate greater fluridone tolerance of the New Zealand hydrilla biotype compared to the U.S. biotypes. The New Zealand biotype is readily distinguished from the U.S. plants (Hofstra et al. 2000, Madiera et al. 1997).

Experimental studies have the advantage that herbicide concentrations and contact times can be controlled and plant response carefully monitored. Although results from this study indicated fluridone may require more than five months contact to kill hydrilla, it is likely that field trials may present different results. Inevitably, it would be difficult to maintain concentration or contact time equivalent to experimental treatments. This would indicate that natural infestations of the New Zealand hydrilla biotype may not show a significant reduction in biomass or plant death in field trials using fluridone. However, it is also possible that mitigating factors (e.g. grazing by swans) may predispose field populations of hydrilla to be more susceptible than predicted from experimental results.

ACKNOWLEDGMENTS

This research was conducted with funding assistance from the New Zealand Foundation for Research and Scientific Technology. The authors would also like to thank R. D. S. Wells and M. Netherland for their contribution to the study, N. Cox for the statistical analysis, and SePRO Corporation for the provision of Sonar and FasTEST analysis.

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