J. Aquat. Plant Manage. 32: 7-11

Response of Hydrilla to Various Concentrations and Exposures of Bensulfuron Methyl[1]

THAI K. VAN AND V. V. VANDIVER, JR.[2]

ABSTRACT

The relationship between herbicide concentration and exposure time was determined for bensulfuron methyl (methyl 2-[[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl] amino]sulfonyl]methyl]-benzoate) and the control of monoecious and dioecious hydrilla *Hydrilla verticillata* (L.f.) Royle] grown in large outdoor tanks. Twenty combinations of bensulfuron methyl concentration and exposure time were tested: concentrations included 0.05, 0.10, and 0.20 mg/l; exposure times ranged from 3 to 42 days. Plant responses to bensulfuron methyl were monitored over a period of 6 months after herbicide application. Severe plant damage was observed in all treatments after 1 month, however, regrowth occurred rapidly in treatments where herbicide exposure was limited to 14 days or less. Greatest reductions in plant growth and tuber production were obtained in treatments with 42 days of exposure. Tuber production after 6 months was reduced by 81 and 93% in the 0.05 mg/l bensulfuron methyl treatments for 42 days in monoecious and dioecious hydrilla, respectively. This long exposure time requirement suggests that caution should be exercised in applications of bensulfuron methyl for control of hydrilla in high water exchange environments.

Key words: Herbicide, chemical control, exposure time, tuber production, *Hydrilla verticillata*, biotypes.

INTRODUCTION

The success of a chemical treatment to submersed aquatic plants depends on both the concentration of the herbicide that comes in contact with the target plant, and the length of time a target plant is exposed to the herbicide. In addition to biological and physical processes of uptake and degradation, herbicide dilution due to diffusion and water movement can reduce both concentration and exposure time to levels less than those required for complete control (Fox et al. 1991). Past research indicates that the concentration and exposure time that are necessary to achieve weed control can vary widely depending on the herbicide used and the weed species involved (Hall and Westerdahl 1984, Van and Conant 1988, Netherland et al. 1991).

Hydrilla is a submersed aquatic plant that causes serious problems in many tropical and sub-tropical areas (Pieterse 1981). One major problem encountered in hydrilla management is the rapid regrowth from vegetative propagules. The subterranean turions, commonly called tubers, are particularly troublesome since they serve as a source of regrowth of new plants soon after the parent plants have been controlled by chemical or mechanical methods. Up to several millions of hydrilla tubers per hectare have been reported in various aquatic sites (Haller et al. 1976, Sutton and Portier 1985).

Both monoecious and dioecious biotypes of hydrilla have been identified in the United States. The dioecious form was first identified in 1959 (Blackburn et al. 1969), and has become a serious weed problem in Florida and other locations in the US. The monoecious form was discovered in 1982 in the Potomac River near Washington, DC (Steward et al. 1984), and is now present in several locations in the northeast. Although the monoecious form is capable of producing seeds, its principal method of reproduction has been established as vegetative (Harlan et al. 1985).

Bensulfuron methyl, currently registered for use in rice, is a member of the sulfonylurea class of herbicides. The sulfonylureas inhibit acetolactate synthase (Beyer et al. 1988), resulting in a loss of production of essential amino acids such as leucine, isoleucine, and valine. Consequently, proteins required for growth and reproductive development are not synthesized. Recent research has shown that bensulfuron methyl is a potent growth regulator with great potential to reduce or regulate hydrilla reproduction at low application rates. Anderson and Dechoretz (1988) observed that vegetative growth of monoecious hydrilla was reduced by early post-emergent applications of bensulfuron methyl at 0.01 mg/l or less. Tuber production also decreased when established hydrilla was exposed to 0.05 mg/l bensulfuron methyl. Duration of exposure required to produce these effects ranged from 7 to 21 days (Anderson 1988). Langeland and Laroche (1992) also reported that exposure of dioecious hydrilla to 0.20 mg/l bensulfuron methyl for 8 days reduced all growth responses to zero. However, these studies addressed only the initial herbicidal effects of bensulfuron methyl, since plant responses were measured within 4 to 6 weeks after herbicide treatment. Van and Vandiver (1992) exposed hydrilla to 0.05 to 0.20 mg/l bensulfuron methyl for 28 days and reduced plant dry weight accrual by as much as 90% after 2 months, but regrowth occurred at various levels in all treatments after this initial inhibition. Other

[1]Part of these data were previously published in the US Army Corps of Engineers Aquatic Plant Control Research Program Bul. Vol. A-91-1 and Misc. Paper A-91-3. Cooperative investigation of the U.S. Department of Agriculture and the University of Florida, Fort Lauderdale Research and Education Center. Published as Journal Series No. R-02967 of the Florida Agricultural Experiment Station. Received for publication February 25, 1993 and in revised form June 1, 1993.

[2]Plant physiologist, ARS, U.S. Department of Agriculture, Ft. Lauderdale, FL 33314; and Associate Professor, University of Florida, IFAS, Fort Lauderdale Research and Education Center, Fort Lauderdale, FL.

studies (Haller et al. 1992, Langeland and Laroche 1992) indicated that control of hydrilla could be maintained for several months with concentrations as low as 0.02 mg/l bensulfuron methyl when exposure to the herbicide was not interrupted, suggesting that a longer exposure to bensulfuron methyl may be necessary to provide hydrilla control over a growing season. In the present study, we investigated the response of hydrilla exposed to various bensulfuron methyl concentrations for up to 42 days. Both biotypes of monoecious and dioecious hydrilla were included for comparison. Plant responses were observed during a period of 6 months after herbicide application to monitor regrowth over a growing season.

MATERIALS AND METHODS

Monoecious and dioecious hydrilla plants used in this study were obtained from stock cultures grown over a period of several months in outdoor concrete tanks. The monoecious hydrilla was established initially from tubers collected from the Potomac River in Virginia. Dioecious hydrilla was established initially from stem apices from Rodeo Lake in Davie, FL.

The investigation consisted of 20 treatment combinations of herbicide concentration and exposure time: concentrations included 0, 0.05, 0.10, and 0.20 mg/l bensulfuron methyl, and exposure times included 3, 7, 14, 28, and 42 days. The herbicide exposures were separated into two independent test runs, conducted in August 1990 and August 1991. Within each run, the herbicide treatments (concentrations X exposures) were arranged as a 4 X 3 factorial with three replicates, and were assigned to the tanks in a randomized complete block design. The 14-day exposure time treatments were included in both test runs. Each experimental run was conducted in 36 outdoor concrete tanks (arranged as 3 rows of 12 tanks) located on the grounds of the Fort Lauderdale Research and Education Center, University of Florida in Fort Lauderdale. The tanks were 0.8 m wide by 2.2 m long (surface area of 1.7 X 10^{-4} ha) and filled with pond water to a depth of 0.6 m. Pond water was from the same source as described previously (Van and Steward 1986). Uniform low water pressure was maintained by constant overflow in a standpipe, and flow to individual tanks was regulated by small petcock valves to provide one water volume change every 24 h. Water temperatures ranged from 15.2 to 33.3 C during the 1990 test run, and 13.8 to 34.5 C during the 1991 run.

Hydrilla tubers of both biotypes were allowed to germinate in pond water at 25 C under continuous light for 3 weeks before planting. Ten sprouted tubers, 10 to 15 cm long, were planted in plastic pots 25 cm in diameter and 20 cm deep. The pots were filled with a rooting medium consisting of approximately 12 kg of potting soil (67% sand, 28% peat, and 5% composted cow manure) enriched with 10 g of a slow release fertilizer[3]. Four pots of each hydrilla biotype were placed in each tank and the plants were allowed to grow for 2 weeks prior to herbicide treatment. Bensulfuron methyl stock solutions was prepared from the commercial formulation Mariner (DuPont, Inc.), dissolved in distilled water. At the time of treatment, the continuous water flow system was turned off and calculated volumes of bensulfuron methyl stock solutions were added to the tanks to provide the desired concentrations. Upon termination of designated exposure times, the tanks were drained and refilled with pond water three times. After rinsing, the flow-through system was reactivated for the duration of the experiment. Hydrilla response to bensulfuron methyl was monitored weekly by visual assessment for a period of 6 months. At the end of 1, 2, 4 and 6 months after herbicide application, one pot of each biotype from each tank was harvested. In the 1991 experiment where longer exposure times were tested, plants were harvested only at 4 and 6 months after herbicide treatment. The harvested biomass was separated into shoots, roots, and tubers, and oven dried at 70 C to a constant weight. The numbers of tubers produced in different treatments were used as estimates of the chemical effect on tuber production since bensulfuron methyl has been reported to have no effect on hydrilla tuber viability and germination (Langeland and Laroche 1992). Data were subjected to analysis of variance using a split-split-plot model with herbicide treatments as main plots, plant biotypes as subplots, and time (harvest dates) as sub-subplots. Because of significant plant biotype by herbicide interaction ($P<0.05$), the model was reduced and data for the two biotypes were analyzed separately. Treatment means within a harvest date were separated using the Waller-Duncan k-ratio t-test ($k=100$) available in SAS[4]. In addition, the Student's t-test was used to compare means between corresponding herbicide treatments with 14 days of exposure that were repeated in the two test runs.

RESULTS AND DISCUSSION

The analyses of variance showed significant effects of time, concentration, and exposure of bensulfuron methyl on plant biomass and tuber production in both monoecious and dioecious hydrilla. The significant concentration by exposure interaction indicated differential levels of plant response to increasing concentrations of bensulfuron methyl when exposure to the herbicide varied. Figure 1 illustrates growth and tuber production of monoecious hydrilla in various treatments of bensulfuron methyl after 1 and 2 months. An exposure to 0.05 mg/l bensulfuron methyl for 3 days resulted in about 35% reduction of plant biomass in monoecious hydrilla after 1 month (Figure 1a). Increasing bensulfuron concentrations up to 0.20 mg/l did not increase the level of control when chemical exposure was limited to 3 days. When exposure to the chemical was extended to 7 days, the 0.05 mg/l bensulfuron treatment provided approximately 70% reduction of plant biomass. Complete inhibition of both plant growth and tuber production in monoecious hydrilla at 1 month after treatment,

[3]Sierra (17-6-10) with an 8- to 9-month release time is manufactured by Sierra Chemical Company, Milpitas, CA 95035. Mention of a trademark or a proprietary product does not constitute a guarantee or warranty of the product by the USDA or the University of Florida and does not imply its approval to the exclusion of other products that also may be suitable.

[4]Statistical Analysis System, SAS Institute Inc., Cary, NC 27511.

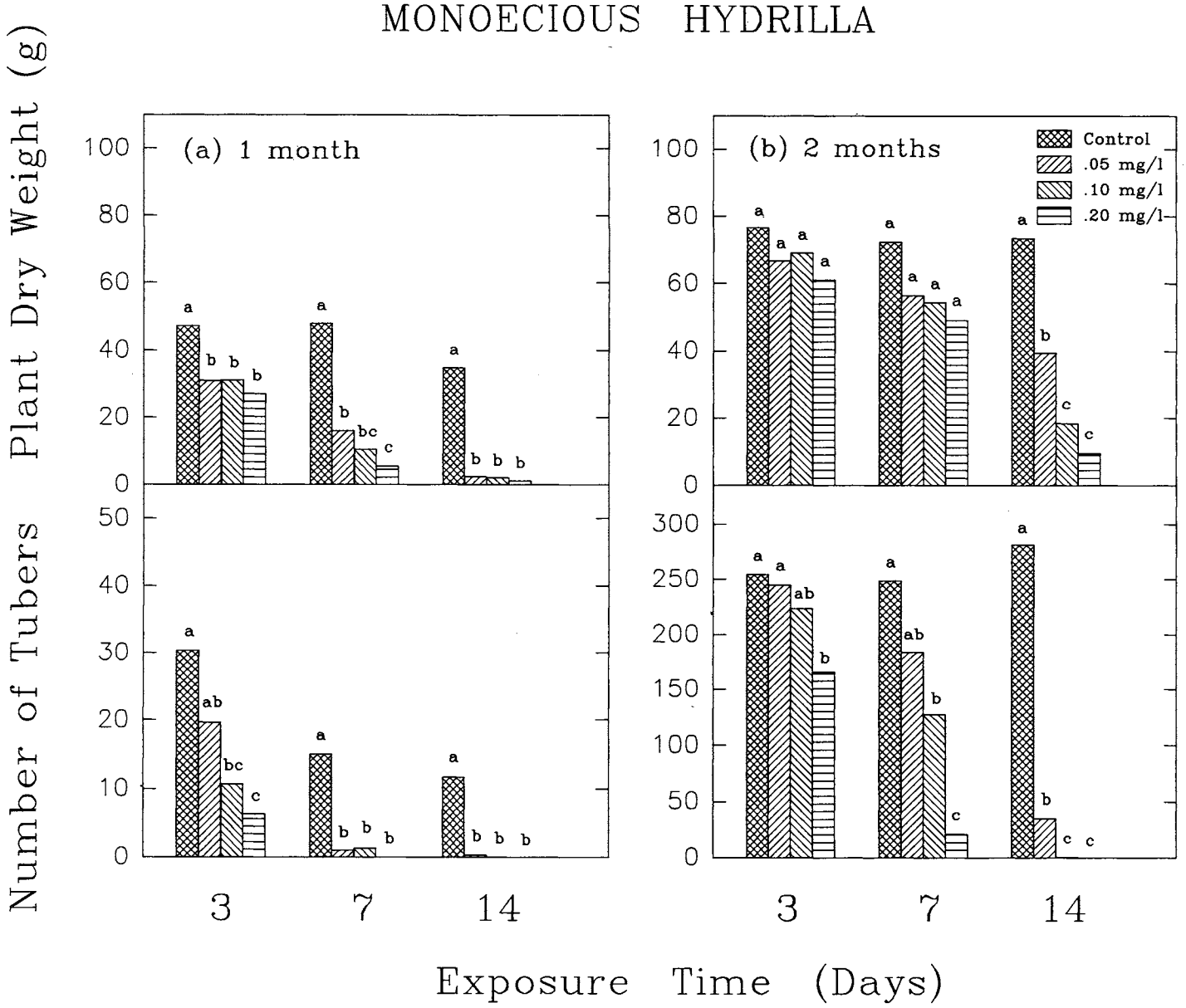

Figure 1. Effects of various concentrations and exposure times of bensulfuron methyl on vegetative growth and tuber production in monoecious hydrilla grown in outdoor tanks in Fort Lauderdale. Herbicide treatments were made on August 01, 1990. Different letters within an exposure time indicate significant differences at P=0.05.

however, required an exposure of 7 days to 0.20 mg/l bensulfuron methyl, or 14 days to the lower herbicide concentration of 0.05 mg/l (Figure 1a).

Severe plant damage, including shoot tip redening and whole plant necrosis, was observed 1 month after exposure of hydrilla to all bensulfuron methyl treatments. Regrowth from injured hydrilla tissue began, however, within 2 months as evidenced by increases in plant weights between harvests after 1 month (Figure 1a) and 2 months (Figure 1b). The levels of regrowth varied depending principally on the different exposure times. Plants recovered almost completely in terms of dry weight after 2 months in all treatments where exposure to the chemical was limited to 3 or 7 days (Figure 1b). The inhibition of tuber production, on the other hand, persisted after 2 months even in treatments where plant biomass had recovered from the initial herbicidal effects of bensulfuron methyl. The 0.10 and 0.20 mg/l treatments with 7 days exposure reduced tuber production by 48 and 92%, respectively. After 2 months, untreated control monoecious hydrilla produced an average of 281 tubers per pot, while no tubers were found in plants treated with 0.10 mg/l bensulfuron and 14 days of exposure. This same treatment of bensulfuron methyl also resulted in no tubers being produced in dioecious hydrilla after 2 months (data not shown).

The reduction of plant growth observed in monoecious and dioecious hydrilla confirms earlier results by Anderson (1988) and Langeland and Laroche (1992) of excellent

initial herbicidal effect of bensulfuron methyl 4 to 6 weeks after treatment. In our 1990 test where herbicide exposure was limited to 14 days or less, plant regrowth occurred rapidly in all treatments after 2 months. Consequently, no significant differences in plant biomass were recorded between the bensulfuron methyl treatments and untreated controls after 4 and 6 months (data not presented). This regrowth of hydrilla from injured tissue suggests that exposure of up to 14 days to 0.05 to 0.20 mg/l bensulfuron methyl was not sufficient to allow adequate uptake and translocation of the herbicide throughout the plant resulting in hydrilla recolonization within 6 months. Similar results were obtained in the 1991 test, as both monoecious and dioecious plants recovered completely in terms of plant weights after 6 months in all treatments with 14 days of herbicide exposure (Figure 2). Plant biomass in monoecious hydrilla treated at 0.05 mg/l bensulfuron methyl for 28 days also recovered after 6 months but the same treatment reduced shoot growth of dioecious hydrilla by 47%. Tuber production after 6 months decreased by 49 and 77% after 6 months in monoecious and dioecious hydrilla exposed to 0.05 mg/l bensulfuron methyl for 28 days, respectively.

We did not measure bensulfuron methyl residue in our tests. However, Langeland and Laroche (1992) found the herbicide half life to be approximately 13 days in North

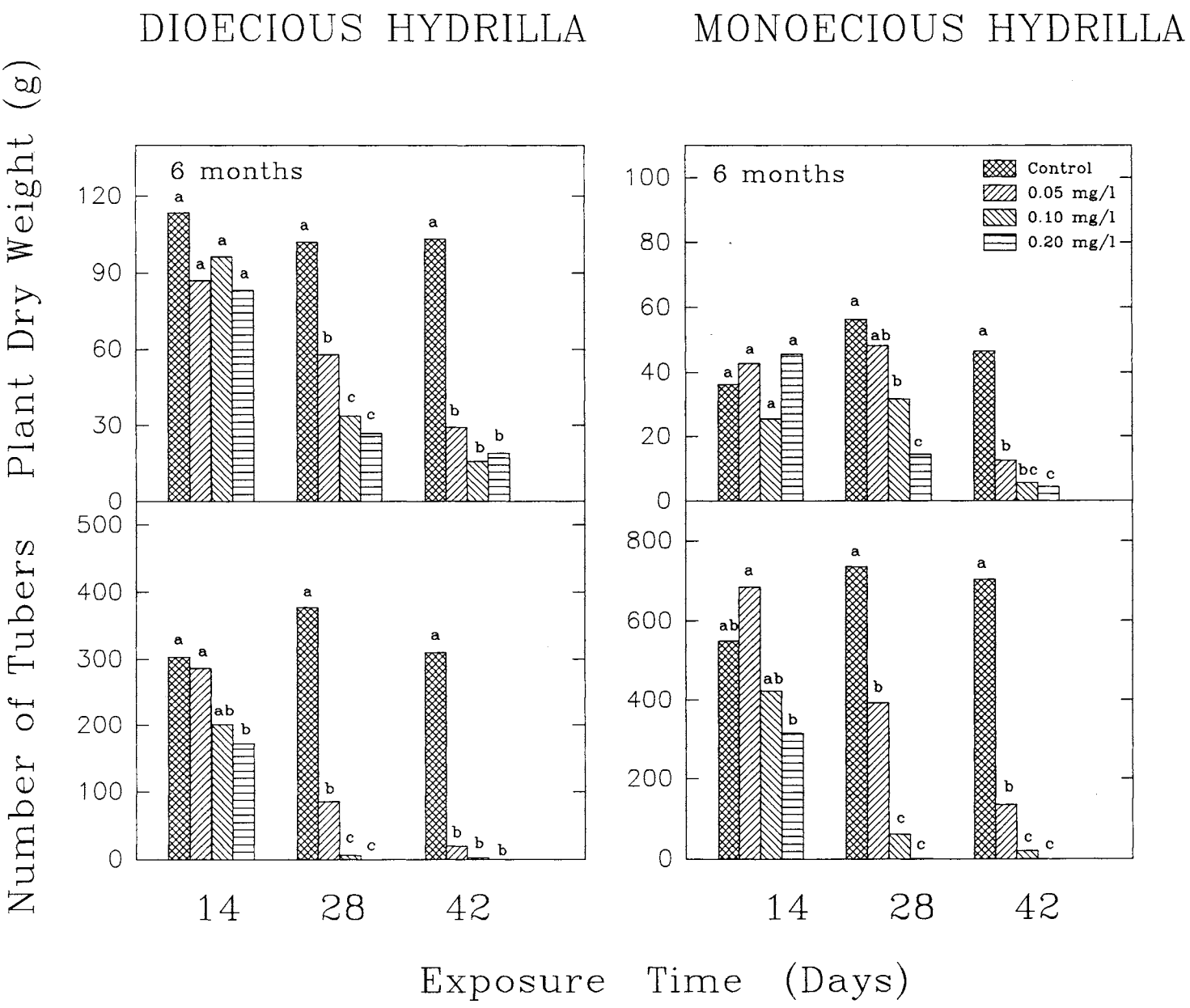

Figure 2. Effects of various concentrations and exposure times of bensufuron methyl on vegetative growth and tuber production in monoecious and dioecious hydrilla grown in outdoor tanks in Fort Lauderdale. Herbicide treatments were made on August 06, 1991. Different letters within an exposure time indicate significant differences at P=0.05.

Florida. Calculations from the decay curve indicate that bensulfuron methyl may remain in water for approximately 44 days after application. In our 1991 test, greatest reductions in plant biomass and tuber numbers of both hydrilla biotypes were recorded in treatments where herbicide exposure was extended to 42 days (Figure 2). Tuber production was more sensitive to bensulfuron methyl and was often reduced to a greater extent than the corresponding reduction of plant biomass exhibited by the same bensulfuron methyl treatment, confirming earlier reports (Anderson 1988, Van and Vandiver 1992). In this study, tuber production after 6 months was reduced by 81 and 93% in treatment of 0.05 mg/l bensulfuron methyl for 42 days in monoecious and dioecious hydrilla, respectively (Figure 2). The long exposure time requirement suggests that caution should be exercised in applications of bensulfuron methyl for control of hydrilla in high water exchange environments.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Michael Mair and Mr. William Maus for their technical assistance. This work was supported in part by the Aquatic Plant Control Research Program, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

LITERATURE CITED

Anderson, L. W. J. 1988. Growth regulator activity of bensulfuron methyl in aquatic plants. In: Chemical Vegetation Management, J. E. Kaufman and H. E. Westerdahl, eds., Plant Growth Regulator Society of America, San Antonio, TX. pp. 127-145.

Anderson, L. W. J. and N. Dechoretz. 1988. Bensulfuron methyl: A new aquatic herbicide. Proc. Aquatic Plant control. Misc. Paper A-88-5. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS., pp. 224-235.

Blackburn, R. D., L. W. Weldon, R. R. Yeo, and R. M. Taylor. 1969. Identification and distribution of certain similar-appearing submersed aquatic weeds in Florida. Hyacinth Control J. 8: 12-21.

Beyer, E. M., M. J. Duffy, J. V. Hay, and D. D. Schlueter. 1988. Sulfunylurea herbicides. In: Herbicides: Chemistry, Degradation, and Mode of Action, Vol. 3, P. C. Kearney and D. D. Kaufman, eds., Marcel Dekker, Inc., NY. pp. 117-189.

Fox, A. M., W. T. Haller, K. D. Getsinger, and W. R. Green. 1991. Characterization of water exchange in hydrilla-infested tidal canals of the Crystal River, Florida. Misc. Paper A-91-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 26 pp.

Hall, J. F. and H. E. Westerdahl. 1984. Growth response of *Myriophyllum spicatum* and *Hydrilla verticillata* when exposed to continuous, low concentrations of fluridone. Technical Report A-84-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 22pp.

Haller, W. T., J. L. Miller, and L. A. Garrard. 1976. Seasonal production and germination of hydrilla vegetative propagules. J. Aquat. Plant Manage. 14:26-29.

Haller, W. T., A. M. Fox, and C. A. Hanlon. 1992. Inhibition of hydrilla tuber formation by bensulfuron methyl. J. Aquat. Plant Manage. 30: 48-49.

Harlan, S. M., G. J. Davis, and G. J. Pesacreta. 1985. Hydrilla in three North Carolina lakes. J. Aquat. Plant Manage. 23:68-71.

Langeland, K. A. and F. A. Laroche. 1992. Hydrilla growth and tuber production in response to bensulfuron methyl concentration and exposure time. J. Aquat. Plant Manage. 30:53-58.

Netherland, M. D., W. R. Green, and K. D. Getsinger. 1991. Endothall concentration and exposure time relationships for the control of Eurasian watermilfoil and hydrilla. J. Aquat. Plant Manage. 29:61-67.

Pieterse, A. H. 1981. Hydrilla verticillata a review. Abstract Trop. Agric. 7(6):9-34.

Steward, K. K., T. K. Van, V. Carter, and A. H. Pieterse. 1984. Hydrilla invades Washington, DC and the Potomac. Amer. J. Bot. 71:162-163.

Sutton, D. L. and K. M. Portier. 1985. Density of tubers and turions of hydrilla in South Florida. J. Aquat. Plant Manage. 23:64-67.

Van, T. K. and K. K. Steward. 1986. The use of controlled-release fluridone fibers for control of hydrilla (*Hydrilla verticillata*). Weed Sci. 34:70-76.

Van, T. K. and R. D. Conant. 1988. Chemical control of hydrilla in flowing water: Herbicide uptake characteristics and concentration versus exposure. Technical Report A-88-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS. 33pp.

Van, T. K. and V. V. Vandiver, Jr. 1992. Response of monoecious and dioecious hydrilla to bensulfuron methyl. J. Aquat. Plant Manage. 30:41-44.