J. Aquat. Plant Manage. 44: 67-69

NOTES

Effect of Carfentrazone-ethyl on Three Aquatic Macrophytes

LEE ANN M. GLOMSKI[1], ANGELA G. POOVEY[2], AND KURT D. GETSINGER[2]

INTRODUCTION

Carfentrazone-ethyl (ethyl 2-chloro-3-[2-chloro-4-fluoro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1*H*-1,2,4-triazol-1-yl]phenyl]propionate) is a phenyl triazolinone herbicide used for post-emergent control of terrestrial broadleaf weeds. It is a contact herbicide that inhibits protoporphyrinogen oxidase in the chlorophyll biosynthetic pathway, causing plants to become necrotic within hours of treatment (WSSA 2002). Carfentrazone-ethyl, hereafter called carfentrazone, is converted to the chloropropionic acid via pH dependent hydrolysis (Ngim and Crosby 2001). Under laboratory conditions, Ngim and Crosby (2001) reported a first order half-life ($t_{1/2}$) of 3.4 h at pH 9, whereas at pH 7, $t_{1/2}$ was 131 h. Even though carfentrazone is rapidly converted to the chloropropionic acid, the acid has been demonstrated to be just as phytotoxic as carfentrazone in leaf-disc assays (Dayan et al. 1997).

Carfentrazone plus the chloropropionic acid have been shown to rapidly dissipate from the water column. A half-life of 83 h was reported for a 0.08 ha carfentrazone treated pond (water pH ranging from 6.9 to 9.6) and after 168 h, no residues were detected (Koschnick et al. 2004). Koschnick et al. (2004) also found no accumulation of carfentrazone or the chloropropionic acid in sediments. Due to rapid degradation of carfentrazone in the aquatic environment, no accumulation in the sediment, low use rates and the fact that it does not pose a hazard to mammals or other non-target organisms (WSSA 2002), it received approval for use in aquatic sites from the U.S. Environmental Protection Agency in 2004, and is marketed by the trade name, Stingray® (FMC Corporation, Philadelphia, PA). The reduced risk nature of this herbicide may make it a candidate for use near potable water intakes and in environmentally sensitive sites.

While carfentrazone can be efficacious on certain floating plants (Koschnick et al. 2004), there is currently no published literature on the efficacy of carfentrazone against submersed plants. The objective of this study was to determine the efficacy of carfentrazone on three submersed plants, Eurasian watermilfoil (*Myriophyllum spicatum* L., hereafter called milfoil), parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc.), and sago pondweed (*Stukenia pectinatus* (L.) Boerner), that cause problems in water bodies in many regions of the United States.

[1]Analytical Services, Inc., U.S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, 201 E. Jones St., Lewisville, TX 75057; e-mail: glomskl@wes.army.mil.

[2]U.S. Army Engineer Research and Development Center, 3909 Halls Ferry Rd., Vicksburg, MS 39180. Received for publication June 24, 2005 and in revised form November 3, 2005.

MATERIALS AND METHODS

This study was conducted in 12 outdoor mesocosms, each with a volume of 1600-L and a depth of 1 m, located at the US Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility, Texas from May to July 2003. On 12 May, 3 apical 15-cm stems of milfoil and parrotfeather and 3 tubers of sago pondweed were planted in 5-L plastic containers (separated by species) and filled with clay-based kitty litter, amended with 3 g L^{-1} Osmocote® (18-6-12). Filtered water from nearby Lake Lewisville was used to fill the mesocosms to a depth of 60 cm. Eight planted containers of each species were placed in each mesocosm.

On 17 June, when apical stems of the plants reached the water surface and before canopy formation, carfentrazone was applied evenly to the water column. Treatments included 50, 100, and 200 µg active ingredient (ai) L^{-1} and untreated controls for a static exposure of 28 days, ending on 15 July. Treatments were randomly assigned to the mesocosms and replicated three times.

At the time of application, all treatments were exposed to full summertime sunlight. Seven days after application, a shade cloth was arranged 3 m above the mesocosms to mitigate high water temperatures that can be caused by exposure to full sunlight. Environmental measurements, such as water temperature, conductivity and pH in the water column were taken weekly.

Herbicide efficacy was assessed through visual ratings and changes in shoot biomass. Four containers of each species were harvested pretreatment (PRE) and 28 days post treatment (POST). In each case, biomass was clipped at the sediment surface, harvested, and dried to a constant weight at 70°C. Percent control was calculated using shoot biomass data and was analyzed using a one-way analysis of variance (ANOVA) to test for herbicide concentration effects. Means were compared using the Student-Newman-Kuels Method (S-N-K; $p \leq 0.05$).

RESULTS AND DISCUSSION

The average water temperature was 28 ± 0.29 C. The minimum water temperature of 24 C was recorded at herbicide application on 17 June, and maximum water temperature of

31 C was reached the following week on 23 June. The average pH was 9.2 ± 0.03 throughout the study, indicating that carfentrazone was likely hydrolyzed to the chloropropionic acid within several hours of treatment (Ngim and Crosby 2001). Water pH in this study fell within the range reported by Koschnick et al. (2004) therefore, a half-life of 83 h or less would be expected for carfentrazone plus the chloropropionic acid. Mean water conductivity was 314 ± 4.58 µmho cm^{-1}.

Milfoil was moderately susceptible to carfentrazone following treatment at concentrations of 100 and 200 µg ai L^{-1}, and was controlled by 71 and 68%, respectively (Table 1). The 100 and 200 µg ai L^{-1} rates significantly reduced milfoil biomass compared to 50 µg ai L^{-1} (54%). However, doubling the rate from 100 to 200 µg ai L^{-1}, was not very effective in improving efficacy for milfoil which may suggest a level of tolerance to the herbicide. Moreover, observations indicated these treatments severely injured milfoil at 21 days POST (Table 1). By 28 days POST, plants had deteriorated, but some viable tissue was still present indicating potential for regrowth. Although the carfentrazone concentration of 50 µg ai L^{-1} partially controlled milfoil (Table 1), plant recovery and re-growth was apparent 28 days POST.

Susceptibility of parrotfeather to carfentrazone was variable with no statistical differences between application rates, as control ranged from 29 to 54% (Table 1). Although shoot growth was suppressed for all treatments, foliage above and below the water surface was still viable at 28 days POST (Table 1). Although submersed application of carfentrazone was not successful in adequately controlling parrotfeather, direct surface application to apical meristems above the water surface might improve control against this species

Sago pondweed was intermediately susceptible to carfentrazone. Both the higher concentrations (100 and 200 µg ai) controlled sago pondweed by greater than 50%, while the lowest concentration, 50 µg ai L^{-1}, provided only 31% control (Table 1). However, all treatments were statistically similar (ANOVA, p = 0.085). Similar to milfoil, increasing the rate from 100 to 200 µg ai L^{-1} did not improve efficacy for sago pondweed. Sago pondweed did not exhibit herbicide effects for any treatment until 21 days POST, when some foliage discoloration was observed. Like parrotfeather, growth of sago pondweed was suppressed, but remaining biomass was viable at 28 days POST with re-growth observed.

The marginal control of the submersed species used in this study could have been due to rapid degradation of the herbicide, application technique or species sensitivity. Alkaline water conditions could have caused a rapid degradation of carfentrazone from the water column. With a half-life estimated at 3.5 d, aqueous levels of initial herbicide residues would be reduced approximately 95% by 14 days POST. Better control of species such as milfoil may require longer exposure periods. Longer exposure periods in alkaline water may require re-application several days after the initial treatment. An alternative strategy for controlling milfoil and parrotfeather, both dicots, would be to apply carfentrazone in combination with dicot-selective, auxin-like products, such as 2,4-D and triclopyr. In terrestrial systems, when carfentrazone is combined with low levels of auxin-like products, efficacy of targeted broadleaves has been improved (Boydston 2004). If these auxins can improve efficacy when added at rates that fall below drinking water levels of concern (70 µg ai L^{-1} for 2,4-D and 400 µg ai L^{-1} for triclopyr), then the reduced risk advantage offered by using carfentrazone should be maintained. Future research should also focus on the efficacy of carfentrazone on milfoil in water with acidic to neutral pH regimes, or on other species, such as variable-leaf watermilfoil (*Myriophyllum heterophyllum* Michx.), which can grow to nuisance levels in low pH waters (Kimball and Baker 1983; Getsinger et al. 2003).

TABLE 1. MEAN PERCENT CONTROL (±1 SE) OF EURASIAN WATERMILFOIL, PARROTFEATHER, AND SAGO PONDWEED AFTER CARFENTRAZONE APPLICATION (50, 100 AND 200 µG AI L^{-1}) AT 28 DAYS POST TREATMENT. DIFFERENT LETTERS WITHIN A COLUMN DENOTE SIGNIFICANT DIFFERENCES BETWEEN TREATMENT MEANS FOR EACH SPECIES (S-N-K METHOD, P ≤ 0.05).

	Percent Control		
Carfentrazone-ethyl µg ai L^{-1}	Eurasian watermilfoil	Parrot feather	Sago pondweed
50	53.7 ± 4.2 b	42.4 ± 8.5 a	31.4 ± 10.1 a
100	71.3 ± 4.4 a	29.5 ± 7.7 a	54.0 ± 5.6 a
200	67.6 ± 4.9 a	54.0 ± 6.5 a	51.4 ± 6.2 a

Thompson and Nissen (2000) reported that carfentrazone is a selective herbicide. The different response between the three species evaluated in this study suggests that carfentrazone may have selective properties for submersed plant control. Species selectivity on floating plants was observed by Koschnick et al. (2004) who reported that carfentrazone could control water hyacinth (*Eichhornia crassipes* (Mart.) Solms), water lettuce (*Pistia stratiotes* L.), and salvinia (*Salvinia minima* Baker), but did not control landoltia (*Landoltia punctata* (G. Mey.) Les & D. J. Crawford). In environmentally sensitive areas, a 50% reduction in milfoil at 50 µg ai L^{-1} would be acceptable if there is minimal injury to non-target species. However, carfentrazone is a new product in the aquatic plant management arena and therefore, the effect of carfentrazone on most non-target species is unknown. More work is needed to determine rate responses on target and non-target plants.

In these mesocosm studies, carfentrazone provided 55 to 70% control of milfoil and less than 55% control of parrotfeather and sago pondweed. Based on previous experience, levels greater than 85% control obtained in herbicide efficacy mesocosm studies usually correspond to control of target plants in field situations (Netherland et al. 1997; Getsinger et al. 2001; Getsinger et al. 2002). Better control of milfoil and parrotfeather might be achieved with different treatment strategies, which requires further investigation.

ACKNOWLEDGMENTS

The authors would like to thank FMC Corporation and the Aquatic Ecosystem Restoration Foundation for sponsoring this project. The authors would also like to thank Chetta Owens and Judy Shearer for early reviews of this manuscript. Permission was granted by the Chief of Engineers to publish on this information. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

LITERATURE CITED

Boydston, R. A. 2004. Managing volunteer potato (*Solanum tuberosum*) in field corn (*Zea mays*) with carfentrazone-ethyl and dicamba. Weed Tech. 18:83-87.

Dayan, F. E., S. O. Duke, J. D. Weete and H. G. Hancock. 1997. Selectivity and mode of action of carfentrazone-ethyl, a novel phenyl triazolinone herbicide. Pestic. Sci. 51:65-73.

Getsinger, K. D., J. D. Madsen, T. J. Koschnick, M. D. Netherland, R. M. Stewart, D. R. Honnell, A. G. Staddon and C. S. Owens. 2001. Whole-lake applications of Sonar for selective control of Eurasian watermilfoil. ERDC/EL TR-01-7, U.S. Army Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. 58 pp.

Getsinger, K. D., R. M. Stewart, J. D. Madsen, A. S. Way, C. S. Owens, H. A. Crosson and A. J. Burns. 2002. Use of whole-lake fluridone treatments to selectively control Eurasian Watermilfoil n Burr Pond and Lake Hortonia, Vermont. ERDC/EL TR-02-39, U.S. Army Engineer Research and Development Center, Vicksburg, MS. 79 pp.

Getsinger, K. D., S. L. Sprecher and A. P. Smagula. 2003. Effects of triclopyr on variable-leaf watermilfoil. J. Aquat. Plant Manage. 41:124-126.

Kimball, K. D. and A. L. Baker. 1983. Temporal and morphological factors related to mineral composition in *Myriophyllum heterophyllum* Michx. Aquat. Bot. 16:189-205.

Koschnick, T. J., W. T. Haller and A. W. Chen. 2004. Carfentrazone-ethyl pond dissipation and efficacy on floating plants. J. Aquat. Plant Manage. 42:103-108.

Netherland, M. D., Getsinger, K. D, and Skogerboe, J. G. 1997. Mesocosm evaluation of the species-selective potential of fluridone. J. Aquat. Plant Manage. 35:41-50.

Ngim, K. K. and D. G. Crosby. 2001. Fate and kinetics of carfentrazone-ethyl herbicide in California, USA, flooded rice fields. Environ. Toxicol. Chem. 20:485-490.

Thompson, W. M. and S. J. Nissen. 2000. Absorption and fate of carentrazone-ethyl in *Zea mays*, *Glycine max*, and *Abutilon theophrasti*. Weed Sci. 48:15-19.

Weed Science Society of America. 2002. Herbicide Handbook—Eight Edition. W. K. Vencill (ed.). Lawrence, KS. 493 pp.