Eurasian Watermilfoil and Parrotfeather Control Using Carfentrazone-ethyl

CODY J. GRAY¹, J. D. MADSEN², R. M. WERSAL² AND K. D. GETSINGER³

ABSTRACT

Two invasive weed species, Eurasian watermilfoil (Myriophyllum spicatum L.) and parrotfeather [Myriophyllum aquaticum (Vell.) Verdc.], were grown in outdoor mesocosms to determine the efficacy of carfentrazone-ethyl (a,2-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]-4-fluorobenzenepropanoic acid, ethyl ester), alone and in combination with 2,4-D, a herbicide routinely used for watermilfoil control. Eurasian watermilfoil control was ≥98% when carfentrazone rates were applied alone at ≥150 µg ai L⁻¹. Carfentrazone alone initially controlled parrotfeather; however, tissue viability 3 weeks after treatment suggested plant recovery was likely. Both Eurasian watermilfoil and parrotfeather control was 100% when 2,4-D was applied at 1000 µg ae L⁻¹; however, when 2,4-D rate was reduced to 100 µg ae L⁻¹ control declined to <50%. Herbicide applications containing carfentrazone with low rates of 2,4-D resulted in 100% death of both plant species. These results indicate that Eurasian watermilfoil control can be obtained using carfentrazone alone; but the addition of low levels of 2,4-D may be needed to achieve desired parrotfeather control.

Key words: Myriophyllum spicatum, Myriophyllum aquaticum, herbicide, biomass reduction, protox inhibitor.

INTRODUCTION

Eurasian watermilfoil and parrotfeather are two exotic invasive dicot species found in freshwater lakes, ponds, and irrigation and drainage canals in the northern and western United States. Both species reproduce vegetatively, usually via stem fragmentation. Fragments are easily spread by boats, trailers, water movement, and by dumping aquarium plants in water sources (Madsen and Smith 1997, Madsen 1997a). Until 2005, only eight herbicides have been registered with Section 3 labels in the United States for use in aquatic sites. Due to increased problems with newly introduced invasive plants and the development of herbicide resistance, additional chemistries and active ingredients are being developed and evaluated for invasive species management in aquatic and wetland systems (Netherland et al. 2005).

Carfentrazone-ethyl (hereafter referred to as carfentrazone) is one such herbicide that is being evaluated in aquatic plant management. In November 2004 the US Environmental Protection Agency granted full Federal registration of carfentrazone for use in aquatic sites (FMC 2005).

Carfentrazone controls plants by disrupting chlorophyll biosynthesis via inhibition of protoporphyrinogen oxidase, leading to subsequent buildup of phytotoxic intermediates (Vencill 2002). Rapid foliar desiccation results in limited symplastic phloem movement of carfentrazone. In terrestrial use, carfentrazone is absorbed rapidly by the foliage and...
plants become necrotic and die within a few days after treatment. Environmentally, carfentrazone is non-volatile (Vencill 2002) and rapidly metabolized in plants (Dayan et al. 1997). Elmarakby et al. (2001) reported rapid conversion of the parent ester to carfentrazone-chloropropionic acid in less than 2 days under aerobic aquatic conditions, while Koschnick et al. (2004) showed that both the parent molecule and the chloropropionic acid metabolite degraded rapidly from the aquatic environment (half-lives = 83 h) with no accumulation in the sediment.

Carfentrazone is a broad-spectrum herbicide primarily used for aquatic weeds. It is labeled for use in a number of agricultural crops including corn (Zea mays L.), soybean [Glycine max (L.) Merr.], and small grain crops (Boydston 2004, Nandula and Manthey 2002, Thompson and Nissen 2000). The product has also been evaluated as an alternative to methyl bromide fumigants in strawberry production (Manning and Fennimore 2001).

Carfentrazone has been reported to control floating species such as waterlettuce (Pistia stratiotes L.), waterhyacinth [Eichhornia crassipes (Mart.) Solms], and common salvinia [Salvinia minima Baker]; however, submersed species control was not evaluated (Koschnick et al. 2004). Glomski et al. (2006) reported only 55 to 70% control of three submersed species, Eurasian watermilfoil, parrotfeather and sago pondweed (Stukenia pectinata (L.) Böerner) when treated with carfentrazone and suggested combining low levels of 2,4-D ((2,4-dichlorophenoxy)acetic acid) with carfentrazone to improve control of watermilfoils. Carfentrazone is combined with low levels of auxin-like products such as 2,4-D and triclopyr ((3,5,6-trichloro-2-pyridinyl) oxy)acetic acid) to enhance performance against terrestrial dicots (Boydston 2004). Therefore, the objective of this research was to evaluate the efficacy of carfentrazone for control of the submersed macrophytes, Eurasian watermilfoil and parrotfeather, alone and in combination with 2,4-D.

**MATERIALS AND METHODS**

Experiments were conducted in 1100-L outdoor mesocosm tanks that measured 1.6 m in length and 1.75 m in width, each tank was 0.6 m deep. The experiments were located at the R. R. Foil Plant Research Facility (North Farm), Mississippi State, MS. On 15 September 2004, two apical plant cuttings (15 cm in length) of a single species were propagated in 3.9 L plastic containers containing approximately 2 L of topsoil. Osmocote fertilizer (19-6-12) was incorporated into the topsoil at a rate of 2 g/L of soil. A layer of pea gravel was placed on top of the soil to minimize topsoil from leaching into the water column. In Experiment #1, six containers of each species were placed in each mesocosm tank and plants were allowed to grow for four weeks. While in Experiment #2, one container of each species was placed in each mesocosm tank and plants were allowed to grow for six weeks. At the time of herbicide applications, plants were healthy and apical tips were at or just below the surface of the water.

Treatments in the first experiment consisted of carfentrazone (100 µg ai L⁻¹) and 2,4-D (1000 µg ae L⁻¹) applied alone and in combination (carfentrazone:2,4-D = 100:250, 100:500, 100:1000 and 100:2000) and an untreated control. Treatments in the second experiment were selected to augment rates from the first experiment and consisted of carfentrazone (150 and 200 µg ai L⁻¹) and 2,4-D (100 µg ae L⁻¹), and in combination (carfentrazone:2,4-D = 100:100 µg ai L⁻¹), and an untreated control. A concentrated aqueous solution was applied to each mesocosm tank such that, when diluted in 1100 L, it provided the desired herbicide concentration throughout the water column. Plants remained in the herbicide exposed tanks throughout the study. Visual ratings were taken weekly based upon a scale of 0 (no control) to 100% (death of plant). Shoot biomass was harvested 3 weeks after treatment (WAT) and dried to a constant weight in a forced air oven at 70°C.

The study was set-up as a randomized complete block design, where mesocosm tanks were aligned in three rows (blocks) of seven tanks each, with a treatment replicate randomly located within each row (n = 3). A block design was used to ensure any differences in plant biomass were due to our treatments and not other factors (Steel et al. 1997). A data logger was placed at random in one mesocosm tank per block to measure water temperature throughout the study.

Analysis of variance (ANOVA) was used to determine block and treatment effects. No differences occurred between blocks for all analysis procedures. Treatment means were analyzed using Fisher’s least significant difference test (p < 0.05). Water temperatures were pooled across blocks and days into respective weeks after treatment for each experiment.

**RESULTS AND DISCUSSION**

Water temperatures ranged from 20.8 to 24.5°C in the first experiment and from 13.2 to 16.1°C in the second experiment. These values reflect the range of temperatures that are conducive for healthy growth of Eurasian watermilfoil and parrotfeather (Barko and Smart 1981, Sutton 1985, Madsen 1997b, Moreira et al. 1999).

In the first experiment, Eurasian watermilfoil control 1 WAT was >90% for all treatments containing a combination of carfentrazone and 2,4-D (Table 1). At this time interval, control was significantly lower for carfentrazone or 2,4-D alone at 82 and 78%, respectively. Eurasian watermilfoil control was 100% 3 WAT for all treatments except carfentrazone alone (70%). Shoot biomass was reduced by nearly 50% compared to the untreated control. These results are comparable to those found by Glomski et al. (2006), where rates of 50 to 200 µg ai L⁻¹ carfentrazone provided 54 to 71% control at 28 days after treatment (DAT) when applied to Eurasian watermilfoil.

Parrotfeather control 1 WAT was ≥90% for all treatments except for the 72% control from 2,4-D alone (Table 1). At 3
alone was applied from 50 to 200 µg ai L$^{-1}$ in outdoor mesocosms in Texas, when carfentrazone (2006) also found limited control of parrotfeather (29 to 54%) in outdoor mesocosms in Texas, when carfentrazone alone (70%). Glomski et al. (1990, Parsons et al. 2001). Parrotfeather control was 100% for all treatments with the exception of carfentrazone alone (55%) (Table 2). At 3 WAT treatment, Eurasian watermilfoil biomass results showed that parrotfeather, although initially suppressed, can recover and survive applications of carfentrazone alone.

In the second experiment, Eurasian watermilfoil control 1 WAT was 95% for all treatments with the exception of 2,4-D alone (55%) (Table 2). At 3 WAT treatment, Eurasian watermilfoil control with 2,4-D alone decreased to 43%, while control with respect to all other treatments ranged from 88 to 100%. Shoot biomass was significantly lower compared to the untreated control (10 g/pot). Rates of 2,4-D used for controlling Eurasian watermilfoil in the field typically exceed 1000 µg ai L$^{-1}$ and the rate used in this evaluation is below threshold levels (500 to 750 µg ai L$^{-1}$) required to achieve acceptable control (Green and Westerdahl 1990, Parsons et al. 2001).

Parrotfeather control 1 WAT was ≥90% for all treatments except for the 62% control from 2,4-D alone (Table 2). Parrotfeather control with 2,4-D 3 WAT decreased to 53% while all other treatments were statistically the same, with control ranging from 88 to 100%. Parrotfeather shoot biomass was reduced for all treatments compared to the untreated control, and only carfentrazone plus 2,4-D completely reduced shoot biomass. Moreira et al. (1999) suggested the most effective active ingredient for parrotfeather control was 2,4-D at 6.5 kg ai/ha, yielding 640 µg ai L$^{-1}$ in the water column immediately after treatment.

Parrotfeather shoot recovery was visible with carfentrazone applied alone and evident in shoot biomass (Tables 1 and 2). The combination of the visual control ratings and biomass results showed that parrotfeather, although initially suppressed, can recover and survive applications of carfentrazone alone.

### Table 1. Eurasian Watermilfoil and Parrotfeather Percent Control and Biomass Reduction Using Carfentrazone Alone and in Combination with 2,4-D for Experiment #1.

<table>
<thead>
<tr>
<th>Herbicide treatment</th>
<th>Rate$^a$</th>
<th>Control$^b$</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/L</td>
<td>1 WAT</td>
<td>2 WAT</td>
</tr>
<tr>
<td>Carfentrazone</td>
<td>100</td>
<td>82 b</td>
<td>78 b</td>
</tr>
<tr>
<td>2,4-D</td>
<td>1000</td>
<td>78 c</td>
<td>98 a</td>
</tr>
<tr>
<td>Carfentrazone + 2,4-D</td>
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<td>93 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Carfentrazone + 2,4-D</td>
<td>100 + 500</td>
<td>97 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Carfentrazone + 2,4-D</td>
<td>100 + 1000</td>
<td>97 a</td>
<td>100 a</td>
</tr>
<tr>
<td>Carfentrazone + 2,4-D</td>
<td>100 + 2000</td>
<td>92 ab</td>
<td>100 a</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>0 d</td>
<td>0 c</td>
<td>0 c</td>
</tr>
</tbody>
</table>

$^a$Visual ratings were assessed based on a scale of 0 (no control) to 100% (death of plant).

$^b$Carfentrazone (in µg ai/L): 2,4-D (in µg ae/L).

$^c$Means within a column followed by the same letter are equivalent according to Fisher’s protected LSD test P = 0.05.

### Table 2. Eurasian Watermilfoil and Parrotfeather Percent Control and Biomass Reduction Using Carfentrazone Alone and in Combination with 2,4-D for Experiment #2.

<table>
<thead>
<tr>
<th>Herbicide treatment</th>
<th>Rate$^a$</th>
<th>Control$^b$</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µg/L</td>
<td>1 WAT</td>
<td>2 WAT</td>
</tr>
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<td>97 a</td>
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<td>95 a</td>
<td>100 a</td>
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<tr>
<td>2,4-D</td>
<td>100</td>
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<td>47 b</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>0 c</td>
<td>0 c</td>
<td>0 c</td>
</tr>
</tbody>
</table>

$^a$Visual ratings were assessed based on a scale of 0 (no control) to 100% (death of plant).

$^b$Carfentrazone (in µg ai/L): 2,4-D (in µg ae/L).

$^c$WAT = weeks after treatment.

$^d$Means within a column followed by the same letter are equivalent according to Fisher’s protected LSD test P = 0.05.
trazone alone. The herbicide treatment was applied evenly throughout the water column, rather than over the top of emergent shoots, an application technique that is commonly used in the field. Therefore, over-the-top broadcast applications of carfentrazone for the control of parrotfeather need to be studied further.

Results from these studies suggest carfentrazone applied with low rates of 2,4-D will completely control both Eurasian watermilfoil and parrotfeather. Eurasian watermilfoil control may be obtained using a carfentrazone rate of 150 µg ai L⁻¹ or greater. Carfentrazone applied alone initially controlled parrotfeather; however, tissue viability at 3 WAT indicated that plant recovery was likely.

ACKNOWLEDGMENTS

This research was supported by the Aquatic Ecosystem Restoration Foundation and the FMC Corporation. Permission was granted by the Chief of Engineers to publish this information. This manuscript has been approved for publication as Journal Article No. J-0000 of the Mississippi Agricultural and Forestry Experiment Station, Mississippi State University.

LITERATURE CITED