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Effect of Water Temperature on 2,4-D Ester and Carfentrazone-ethyl Applications for Control of Variable-leaf Milfoil

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INTRODUCTION

Variable-leaf milfoil (*Myriophyllum heterophyllum* Michx.) is a submersed plant native to southwestern Quebec and Ontario, to North Dakota and southward to New Mexico and Florida (Godfrey and Wooten 1981). In the Northeastern U.S., variable-leaf milfoil is not native and is considered an invasive and weedy species. As an invasive species, it causes many of the same problems as Eurasian watermilfoil (*Myriophyllum spicatum* L.), including shading out native submersed vegetation and interfering with recreational activities and water supplies (Halstead et al. 2003, NH-DES 2002). Variable-leaf milfoil is an aggressive invader that can grow up to one inch per day under optimal nutrient, temperature, and light conditions and spreads mainly via fragmentation (NH-DES 2002).

Two herbicides that have been shown to effectively control variable-leaf milfoil include 2,4-D ester ([2,4-dichlorophenoxy]acetic acid) and carfentrazone-ethyl (a,2-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1*H*-1,2,4-triazol-1-yl]-4-fluorobenzenepropanoic acid, ethyl ester). In greenhouse studies, 2,4-D ester at 500 and 1500 µg ai L^{-1} exposed for 3, 8, and 24 hours provided 98 to 100% control of variable-leaf milfoil (Netherland and Glomski 2007). Bugbee et al. (2003) also reported that 227 kg ha^{-1} 2,4-D ester as Navigate controlled nearly all the variable-leaf milfoil in treated field sites. Carfentrazone at 100 µg ai L^{-1} for 6 to 30 hours was reported to provide 61 to 81% control of variable-leaf milfoil. Doubling the rate of carfentrazone did not improve efficacy (Glomski and Netherland 2007). While there is no published literature regarding field applications of carfentrazone to control variable-leaf milfoil, recent field trials in North Carolina have demonstrated good control (Rob Richardson, pers. comm.).

The effect of water temperature on efficacy of aquatic herbicide applications is not well documented in the literature. Westerdahl and Getsinger (1988) suggest that aquatic plants have low metabolic activity in cooler waters, and this can inhibit herbicide uptake. Studies done by Netherland et al. (2000) and Poovey et al. (2002) demonstrated that as water

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temperature decreased, diquat and endothall efficacy against curly-leaf pondweed was inhibited; however, biomass and turion formation was significantly reduced with all treatments. Information on the Aquakleen™ (2,4-D ester) and Stingray™ (carfentrazone-ethyl) labels indicate that treatment should take place when weeds are actively growing, yet temperatures are not specified. Many resource agencies have questions regarding the potential efficacy of herbicides if products are applied early in the growing season when plants are actively growing but water temperatures are quite cool. Our objective was to determine the effect of water temperature on efficacy of carfentrazone-ethyl and 2,4-D ester applications for control of variable-leaf milfoil.

MATERIALS AND METHODS

This study was conducted in a greenhouse at the U.S. Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, Texas. Two apical tips of variable-leaf milfoil (15 cm) were planted in each plastic pot (750 mL), filled with LAERF pond sediment amended with 3 g L^{-1} osmocote (16-8-12). Pots were topped with a 1-cm layer of play sand, and four pots were placed in each aquarium (66 L). Aquariums were filled with alum-treated Lake Lewisville water and were situated in 1000-L fiberglass tanks filled with water. Water temperatures in the aquariums were maintained at 18 to 20 C by circulating water in the fiberglass tanks through a Pacific Coast Imports C-1000 1 HP chiller. Carbon dioxide was bubbled into each aquarium once a day to lower the pH to 6.5 to simulate conditions characteristic to the Northeast where variable-leaf milfoil is problematic.

Forty-one days after planting, water temperatures were slowly adjusted to 13, 16, 19, and 22 C in the aquariums. Once temperatures stabilized, tanks were treated at 100 µg ai L^{-1} carfentrazone (Stingray, FMC Corporation, Philadelphia, PA), 250 µg ai L^{-1} 2,4-D ester (Aquakleen, Cerexagri, Philadelphia, PA), or 500 µg ai L^{-1} 2,4-D ester. Treatments were replicated 4 times and included an untreated control. Carfentrazone treatments were static exposures due to the relatively short half-live of carfentrazone, whereas 2,4-D ester applications were 3-h exposures. Rates and exposures chosen for this study were based on previous studies (Glomski and Netherland 2007, Netherland and Glomski 2007). Two days after the herbicide exposure, temperatures were gradually adjusted back to 21 C to stimulate active growth and recovery of the plants.

At 28 d after treatment (DAT) all viable shoot biomass was harvested and dried at 65 C. Data was subjected to a two-way analysis of variance (ANOVA). Where treatment differences were detected, a post hoc test was conducted using the Tukey honestly significant different test ($p < 0.05$).

RESULTS AND DISCUSSION

All plants treated with 2,4-D ester and carfentrazone at 19 and 22 C were beginning to exhibit injury symptoms by 2 DAT. Carfentrazone treated plants had bleached tips and dark red-to-brown stems, while 2,4-D ester treated plants were exhibiting curling stems. In contrast, no injury symptoms were present for plants at 13 and 16 C. At 10 DAT, carfentrazone treated plants at all temperatures were necrotic and starting to collapse. Symptoms of 2,4-D exposure were also now present on plants exposed to 16 C. By 21 DAT, all treated plants at 22 C were dead. At 13, 16, and 19 C only the 250 ppb 2,4-D and the carfentrazone treated plants still had a small amount of viable tissue present.

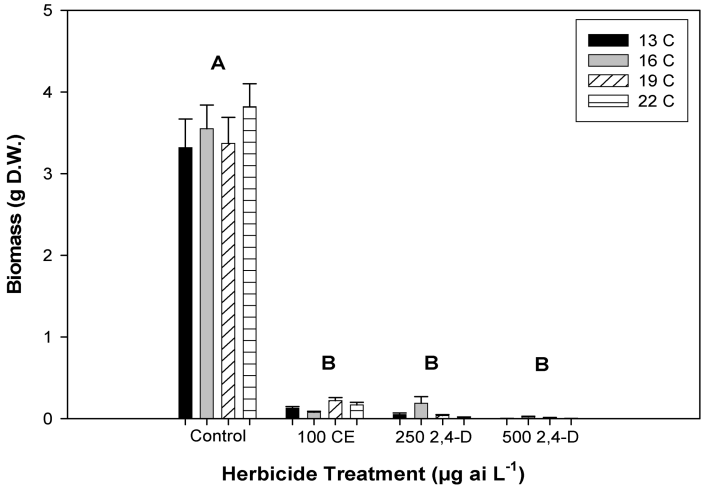

Figure 1. Temperature effect on carfentrazone and 2,4-D ester treatments against variable-leaf milfoil (mean ± SE) dry weight biomass 28 d after treatment. There was no interaction between temperature and treatment and no significant differences among temperatures. There was a significant difference between treatments, and treatments sharing the same letter do not significantly differ from each other ($p < 0.05$).

Biomass data indicated no interaction between herbicide treatment and water temperature and no differences in herbicide treatments among the temperatures tested (Figure 1). All treatments were different compared to the untreated control. All three herbicide treatments reduced variable-leaf biomass by 96 to 100%.

Lack of a temperature effect on 2,4-D applications has also been seen in the field. Bugbee et al. (2003) reported good control of variable-leaf milfoil regardless of the month of application (May, Jun, Jul, and Sep). Results from this study indicate that temperature may cause an initial delay in injury symptoms but overall is not a key factor in carfentrazone or 2,4-D ester efficacy against variable-leaf milfoil. These data suggest that applications to control variable-leaf milfoil could take place in early spring when water temperatures are cooler. Treating the variable-leaf milfoil before it reaches the water surface and before native species begin to actively grow are two advantages to early spring applications.

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