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Influence of Dilute Acetic Acid Treatments on American Pondweed Winter Buds in the Nevada Irrigation District, California

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ABSTRACT

American pondweed (*Potamogeton nodosus* Poir.) is commonly found in northern California irrigation canals. The purpose of this study was to test the hypothesis that exposure of American pondweed winter buds to dilute acetic acid under field conditions would result in reduced subsequent biomass. The treatment consisted of adding either 1703 or 3406 L of 2.3% acetic acid per 83-m^2 plot. Acetic acid was applied using either drip tape or soaker hoses. We collected nine samples 6 weeks after treatment from each plot for biomass determination. American pondweed biomass was reduced by the acetic acid application. The reduction was observed for samples collected from the sides as well as the canal bottom when 3406 L per plot were applied. At the lower rate, there was slightly more biomass on the sides of the canal. These results confirm findings from earlier laboratory/greenhouse experiments, and suggest that application of a 2.3% acetic acid solution by drip irrigation tape may be useful in the management of American pondweed in systems that can have the water removed temporarily.

Key words: aquatic weeds, irrigation canal, drip tape, sediment treatments, *Potamogeton nodosus.*

INTRODUCTION

American pondweed is a common weed in northern California irrigation systems. It reproduces by fragmentation, stolons, subterranean winter buds, and seeds. Like many other weedy aquatic species (van Vierssen 1993), the underground vegetative propagules are particularly important to American pondweed's long-term survival in a particular habitat. To date there have been few attempts to manage this important life cycle stage. Some have suggested that it may be possible to disrupt propagule formation or dormancy (Ogg et al. 1969, Spencer and Ksander 1992, MacDonald et al. 1993, van Vierssen 1993) but, there have been few attempts to manipulate their survival in the sediment (Ogg et al. 1969, Haller et al. 1976, Godfrey and Anderson 1994, Godfrey et al. 1994).

Previous work (Spencer and Ksander 1995, 1997) indicated that 0.1 to 5% solutions of the natural sediment component, acetic acid, (Ponnamperuma 1972, Miller et al. 1979, King and Klug 1982, Sansone and Martens 1982) greatly reduced survival and sprouting of vegetative propagules of pondweeds (*Potamogeton* spp.) and hydrilla (*Hydrilla verticillata* (L.f.) Royle) in laboratory and greenhouse trials. Spencer and Ksander (1999) demonstrated reduced survival of monoecious hydrilla tubers in the Oregon House Canal following treatment of either 2.5% or 5% acetic acid to plants in plots with dimension of 1 by 1 m. Recently, Tenuta et al. (2002) demonstrated that dilute solutions of acetic acid present in liquid swine manure killed microsclerotia of the wilt fungus, *Verticillium dahliae* Kleb., when applied to soils.

The purpose of this study was to evaluate the efficacy of 2.3% acetic acid at reducing American pondweed winter bud survival and subsequent growth when applied at two rates 1703 or 3406 L per 83-m^2 plot using drip tape or soaker hoses under field conditions.

MATERIALS AND METHODS

Part of this research was conducted in the Nevada Irrigation District's Wolf Hannaman Canal located in Nevada County, California, about 100 km northeast of Sacramento. The approximate location is 39°02' 43.18928" N, 121°12' 31.41053" W and the altitude is approximately 270 m. This is a shallow canal with a mean water depth 1 m which typically conveys water between April 15 and October 15. American pondweed is the dominant plant growing in the canal although elodea (*Elodea canadensis* Michx.) plants occur occasionally during the period when flowing water is present. Elodea plants are apparently from fragments that enter the canal when water is introduced in the spring.

On April 11 and 12, 2002 we applied dilute acetic acid of 2.3% to nine plots measuring 16.6 by 5 m. Three plots each received one of the following treatments: 1703 L of solution applied using drip tape; 3406 L of solution applied using drip tape; or 1703 L of solution applied using soaker hoses, or untreated. The acetic acid solution was prepared by adding 197 L of 80% acetic acid to 6624 L of water in water tanker truck. Mixing occurred as the truck was driven to a site adjacent to the canal. Approximately 946 L of the solution were transferred to 1230 L polyethylene tanks mounted in the bed of pickup trucks. Using pumps that maintained 68 to 83 kPa, the acetic acid solution was pumped from these tanks into tubing connected to either drip tape or soaker hoses placed in the canal. An in-line flow meter recorded the volume of material applied to each plot (1703 L required about

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90 minutes to apply; 3406 L required about 3 hr to apply). Ten 16.6 m sections of drip tape (TSX5XX-08-670, T-Tape North America) were arranged in the canal bottom so that the entire bottom from the water-line (i.e., indicated by the presence of terrestrial plants on the side of the canal) on each side was treated (Figure 1).

To verify that the acetic acid solution actually soaked into the ground, we measured soil moisture content with a Hydrosense Moisture Meter with 12 cm long probes (Campbell Scientific Inc., Logan, UT) prior to and shortly after the acetic acid solution was applied. We collected data from the center and from each side of the canal as shown in Figure 2.

At the time the treatments were applied terrestrial forms of American pondweed were present in the canal (Spencer and Ksander 1992). Prior to application, we estimated their abundance by counting the number present in 60 randomly deployed square quadrats (25 cm by 25 cm). One week after this treatment nine sediment samples were collected from each plot. Samples were collected from each side of the canal and in the middle. The sediment samples were returned to the laboratory facility, placed in plastic containers with dimensions of 25 cm in length by 18 cm in width by 12 cm in depth, and placed in a large outdoor container filled with water to a depth of 65 cm. These samples were exposed to ambient conditions for 11 weeks. Samples were harvested, washed over 2-mm mesh metal screens to separate plant material from the soil. Plant material was separated by species and dried at 80 C for 48 hr and weighed.

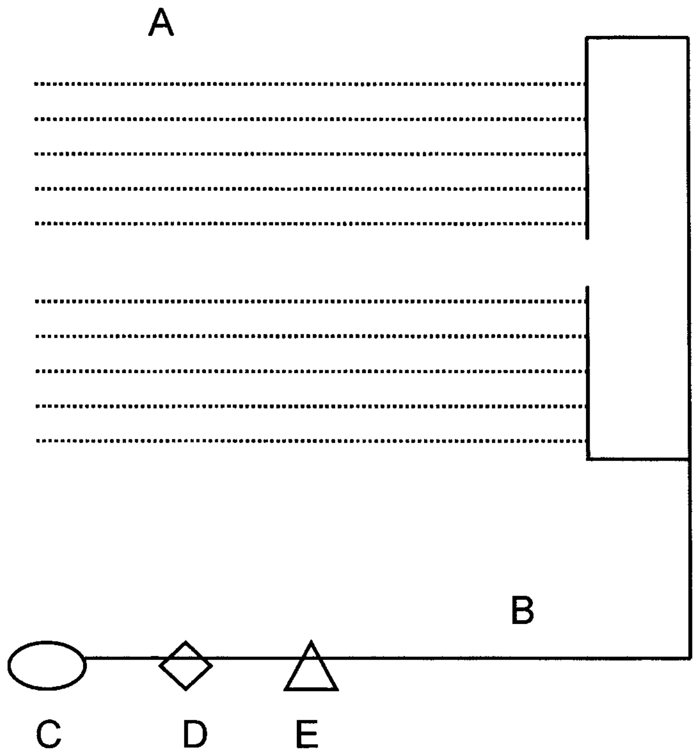

Figure 1. Diagram of drip tape arrangement for applying acetic acid solution. The drip tape sections (A) were 0.3 m apart. The flexible tape could be adjusted to fit the canal width by overlapping the two sections of drip tape. Drip tape was connected by carrier tubes (B) to the polyethylene tank (C), the pump (D), and the in-line flow meter (E).

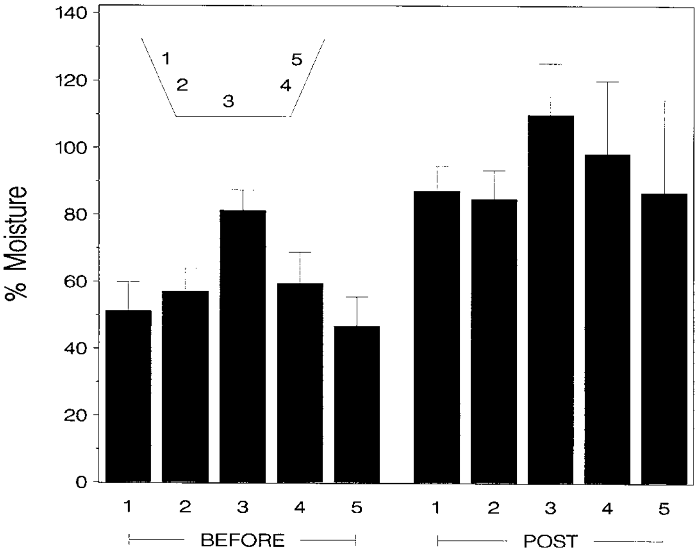

Figure 2. Soil Moisture (%) to 12 cm deep before and after acetic acid solutions were applied. Locations correspond to those illustrated in the canal cross section diagram.

Six weeks following the treatments we collected nine 15-cm diameter cores from each plot and from adjacent non-treated canal sections which served as controls. Within each plot three cores were collected from the center and either side of the canal. The cores were transported to the laboratory facility in Davis, California and washed over 2-mm mesh metal screens to separate plant material from the soil. Plant material was dried at 80 C for 48 hr and weighed. Dry weight per sample was subjected to analysis of variance with treatment method (i.e., drip tape and volume) and location as the treatment factors.

RESULTS AND DISCUSSION

At the time these treatments were made there were 486 ± 120 plants m^{-2} (N = 60). Based on previous reports for a closely related species this represents from 34 to 96% of the total number of winter buds present (Spencer and Ksander 1992). The moisture content of treated sediments increased to levels characteristic of saturated soils indicating the acetic acid solution was penetrating the soil to at least 12 cm deep (Figure 2). Pondweed winter buds and tubers have been reported to occur at greater sediment depths (Spencer and Ksander 1990, Spencer 1987) but these were for samples collected from the canal bottom and not on the sides of the canal.

American pondweed biomass 6 weeks after treatment (Figure 3) was significantly reduced by the 2.3% acetic acid applications (ANOVA, $P < 0.001$). The greatest reduction was for plots that received 3406 L applied with drip tape. For this treatment biomass was greatly reduced on the canal sides as well as on the bottom. Plots which received 1703 L whether by drip tape or soaker hoses had somewhat greater biomass, especially on the canal sides, indicated by the significant effect of location (ANOVA, $P = 0.03$). The acetic acid by location interaction was not significant ($P = 0.14$).

Results from samples placed in outdoor tanks and allowed to grow for 11-week period are shown in Figures 4 and 5.

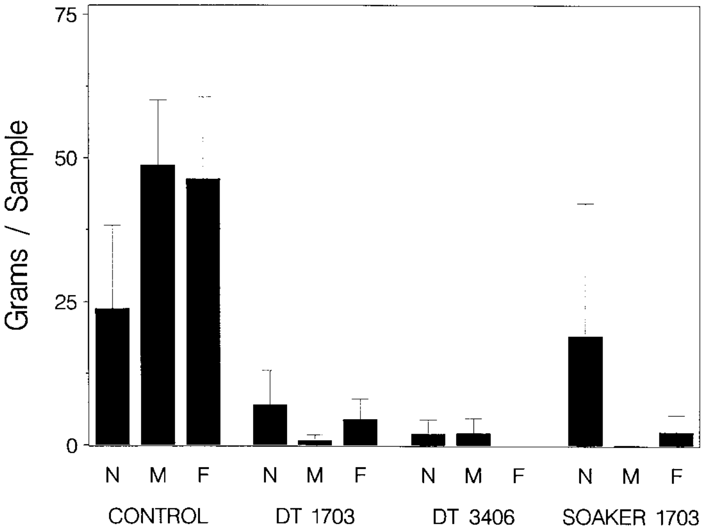

Figure 3. American pondweed biomass six weeks after treatment at three locations (either side, N (near), F (far), or M (middle)) within plots that received different acetic acid treatments (DT = drip tape, soaker = soaker hoses, 1703 L per plot and 3406 L per plot). Plotted values are the mean and 95% confidence intervals. Effects of the acetic acid treatment were significant (ANOVA, P < 0.001) as were those of location (P = 0.03). The acetic acid by location interaction was not significant (P = 0.14).

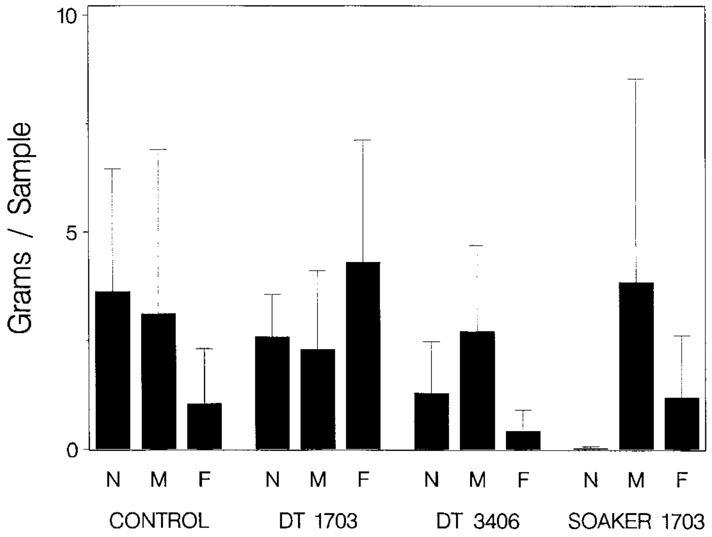

Figure 5. Spikerush biomass after 11 weeks in an outdoor tank in Davis, California. Samples were collected from three locations (either side, N or F, or middle, M) within plots that received different acetic acid treatments. Plotted values are the mean and 95% confidence intervals. Effects of the acetic acid treatment were not significant (ANOVA, P = 0.72). The effects of location (P = 0.61) and the acetic acid by location interaction were not significant (P = 0.75).

American pondweed biomass was significantly reduced by the dilute acetic acid treatments. The effect of location was not significant in this case (P = 0.99) perhaps due to the longer growing period compared to the samples collected from the canal. Likewise, the acetic acid by location interaction was not significant (P = 0.19). Interestingly, growth of another aquatic plant, spikerush (*Eleocharis sp.*), in these samples was unaffected by the acetic acid treatments (Figure 5). This confirms the differential susceptibility of aquatic plants to dilute acetic acid solutions noted previously (Spencer and Ksander 1995) and further suggests the possibility of enhancing the growth of spikerush which is considered to be a more desirable species in irrigation systems (Ashton and Bissell 1987, Yeo and Thurston 1984).

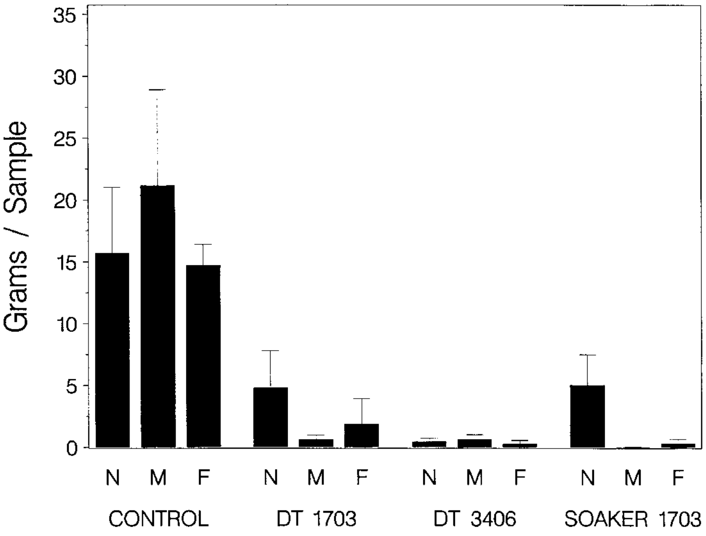

Figure 4. American pondweed biomass after 11 weeks in an outdoor tank in Davis, California. Samples were collected from three locations (either side, N (near), F (far), or M (middle)) within plots that received different acetic acid treatments. Plotted values are the mean and 95% confidence intervals. Effects of the acetic acid treatment were significant (ANOVA, P < 0.001). The effects of location (P = 0.99) and the acetic acid by location interaction were not significant (P = 0.19).

These results suggest that using drip irrigation tape to apply dilute solutions of acetic acid in irrigation canals that have had the water removed may be a practical method for treating canal sides as well as the bottom. Previous work applied the material by flooding the canal. This required more water and consequently more acetic acid. The use of drip irrigation tape and perhaps soaker hoses allowed the material to be applied at a slower rate over a longer period of time and to saturate the soil in the treated area. This not only killed sufficient winter buds to greatly reduce subsequent pondweed biomass, but also reduced the amount of material required for the treatment. The slightly higher biomass in samples collected from the canal sides may be partly explained by the irregular topography of the canal sides in this canal. The canal traverses an area used by cattle and as a result some of the plots had deep footprints in the sides and bottom. We noticed that the acetic acid solution tended to collect in these depressions and this may have prevented the material from spreading in the sediment as it did in other plots that did not have so many cattle footprints. In our experience, most irrigation canals are not impacted by cattle in this way and thus greater efficacy might be expected if these canals received similar treatments.

Underground vegetative propagules are important to the long-term survival of some species of aquatic plants and, appear to be particularly important in the life cycles of weedy species (van Vierssen 1993). To date, attempts to manage this important life cycle stage have been aimed at disrupting their formation or dormancy (Ogg et al. 1969, Spencer and Ksander 1992) and we know of few attempts to manipulate tuber survival in the sediment (Haller et al. 1976, Godfrey and Anderson 1994, Godfrey et al. 1994). Results of this study indicate that a 2.3% solution of acetic acid, equivalent to slightly less than one-half the strength of vinegar, was effective in reducing survival of American pondweed winter buds under the conditions prevalent in this field test. These results imply that it may be possible to develop a novel method for managing this important life-cycle stage by manipulating the sediment environment, as has been suggested by Gunnison and Barko (1989) and Kremer (1993). Use of a naturally occurring, short-lived, low molecular weight organic compound, such as acetic acid may be especially attractive in this regard. Continued evaluation of this approach in additional habitats with different sediment characteristics such as clay content, organic content, porosity, and other characteristics may be illuminating and are essential to understanding the broader applicability of this approach.

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