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Evaluation of Selected Herbicides for the Control of Exotic Submerged Weeds in New Zealand: II. The Effects of Turbidity on Diquat and Endothall Efficacy

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ABSTRACT

Diquat is the only herbicide registered in New Zealand for the control of submerged invasive weeds such as hornwort or coontail (*Ceratophyllum demersum* L). However, under turbid conditions, binding to clay and charged particles in the water may deactivate diquat. To determine whether endothall achieved better control of Coontail under turbid conditions, both diquat and endothall were applied at maximum label rates, for three different exposure periods (1, 2 and 8 days) to tanks of varying turbidity (0 to 40 NTU). All plants exposed to endothall were killed irrespective of turbidity or exposure period, whereas diquat only achieved complete control (kill) at the maximum exposure when there was no turbidity.

Keywords: Ceratophyllum demersum, hornwort, lake sediment.

INTRODUCTION

Diquat (6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinediium dibromide) is a contact herbicide that was first used on submerged aquatic weeds in New Zealand in the 1960s (Clayton, 1986) and is currently the only herbicide registered for aquatic use in New Zealand. Diquat is commonly used to control the invasive weeds lagarosiphon (*Lagarosiphon major* Ridley) Wager) and hornwort or coontail (*Ceratophyllum demersum* L), however it is rapidly deactivated by clay and charged sediment particles in the water or on plant surfaces (Weber et al. 1965, Coats et al. 1966, Weber and Weed 1968, Akhavein and Linscott 1968, Simsiman et al. 1976). Adsorption of diquat to clay minerals and organic matter may hinder its bio-availability for weed control as well as its microbial degradation (Simsiman et al. 1976).

Unlike diquat, endothall (7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid) does not bind to charged particles in the water column and recent studies with endothall show promising results for the control of coontail. Coontail was first recorded in New Zealand in 1963 and has presented a major management problem for power generation and recreational use of infested waterbodies (Clayton 1996). The primary objective of this study was to determine whether endothall is more efficacious than diquat in turbid water on the target species coontail.

MATERIALS AND METHODS

Coontail was propagated from stem fragments 20 cm long in 300 ml pots filled with topsoil and covered with a 1 cm layer of sand. Plants were grown for one month prior to the start of treatment in 120 L tanks in the greenhouse. Water temperature ranged from 15 to 21C throughout the study and the incident light was ca. 200 $\mu Em^{-2}s^{-1}$. At time zero five plants were removed and dry weights were recorded to establish pre-treatment biomass. At least 25 plants were in each treatment tank prior to turbidity and herbicide application.

Sediment from Lake Waahi (a turbid lake in the lower Waikato River catchment, 37°34'S, 175°08'E) was used to create turbid conditions in the treatment and recovery tanks. In each tank turbidity (nephelometric turbidity units, NTU) was measured daily using a Hach (Boulder, Colorado, USA) 18900 meter, and a mean of three readings per tank recorded. Turbidity was maintained at one of three levels, zero, low (ca. 10 NTU) or high (ca. 25 NTU) through the addition of sediment slurry as necessary. Tanks were aerated continually to ensure uniform mixing of water and prevent sediment from settling out of the water column. Lake Waahi sediment was analyzed to determine cation exchange capacity (CEC), clay content and clay mineral component.

Herbicide was added at the maximum label rate of either 2 mg/L diquat or 5 mg/L endothall to all treatment tanks, except the untreated reference. Five plants were removed from each of the treatment tanks and placed in recovery tanks with similar NTU readings (minus herbicide), and three were harvested and dry weights recorded after one day (24 hours) and 2 days (48 hours) of herbicide exposure. The remaining plants stayed in the treatment tanks for eight days. Plant appearance was recorded daily, and after eight days the remaining plants were harvested from all treatment and recovery tanks, and dry weights obtained. One additional tank at ca. 40 NTU, had the maximum label rate of endothall with seven plants as a reference point. Biomass data from herbi-

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cide and turbidity control tanks were analyzed using analysis of variance (ANOVA) and plant survival data was analyzed using Fisher's exact test.

RESULTS AND DISCUSSION

Turbidity levels ranged over the duration of the study from 0-1 NTU for the control tanks, 8-15 NTU for the low level treatment tanks, 19-30 NTU for the high level treatment tanks and 32-68 NTU for the reference tank (Figure 1). The CEC of the Lake Waahi sediment slurry was 10 me/100g and the sediment was comprised principally of kaolinite and quartz with minor amounts of K-feldspar.

All plants in control tanks (with 0, 10 and 25 NTU) continued to grow and exceeded the pre-treatment biomass after eight days, with no significant differences between plant biomass in the control and turbidity only tanks.

The level of control (based on % plant survival) achieved in endothall tanks compared with diquat tanks was significantly different. Coontail was killed in all endothall treatments irrespective of the recovery period or turbidity level including the reference tank at 40 NTU. Foliage discoloration and loss of tissue integrity were noted after 24 hours. Three and four days after treatment plants had completely collapsed, and by day eight there was zero plant survival and biomass (Figure 2). These results are in agreement with those previously recorded for endothall efficacy on coontail in clear water conditions (Hofstra and Clayton 2000).

By comparison, diquat only killed all plants after eight days exposure under clear water conditions. Damaged shoot tips were noted 48 hours post treatment, followed by plant fragmentation on days three and four. In turbid water (10, 25 NTU) potential plant recovery (firm and intact stems) was evident following all exposure periods (Figure 2). Percentage plant survival was significantly lower after two and eight days than after one, and differed significantly for all diquat treatment tanks with time. Based on percentage plant survival data there was no significant turbidity effect within diquat treatments.

Coontail biomass was generally greater in turbid diquat tanks than in the clear water diquat tank (Figure 2). In turbidity tanks, after two days, less viable plant biomass was recovered from all diquat tanks than one day after treatment, however more viable plant biomass was recovered after the eight day period than after two days. This surprising result could be attributed to larger biomass recovered from single plants (Figure 2).

Clay content and CEC are significant indicators of the sediments ability to adsorb diquat (Weber and Coble 1968). For example, turbidity generated from sediments with higher CEC values will reduce diquat efficacy and result in greater plant biomass than those of lower CEC. In a study with bentonite clay (CEC of 100 me/100g) and Texas (USA) sediment (CEC of 35 me/100g), using diquat (2 mg/L) and turbidity of 30 NTU, egeria (*Egeria densa* Planch) post-treatment biomass with the bentonite was twice that with Texas turbidity. A negative trend of diquat in the water column was reported in response to bentonite turbidity (Getsinger, unpublished data). In Australian irrigation canals, adsorption by suspended sediments completely inactivated diquat at concentrations of up to 0.8 mg/L (Bowmer 1982a, b). However, Bowmer concludes that diquat could provide effective submerged weed control if sufficient herbicide were used to saturate suspended sediments, and attain a surplus of free di-

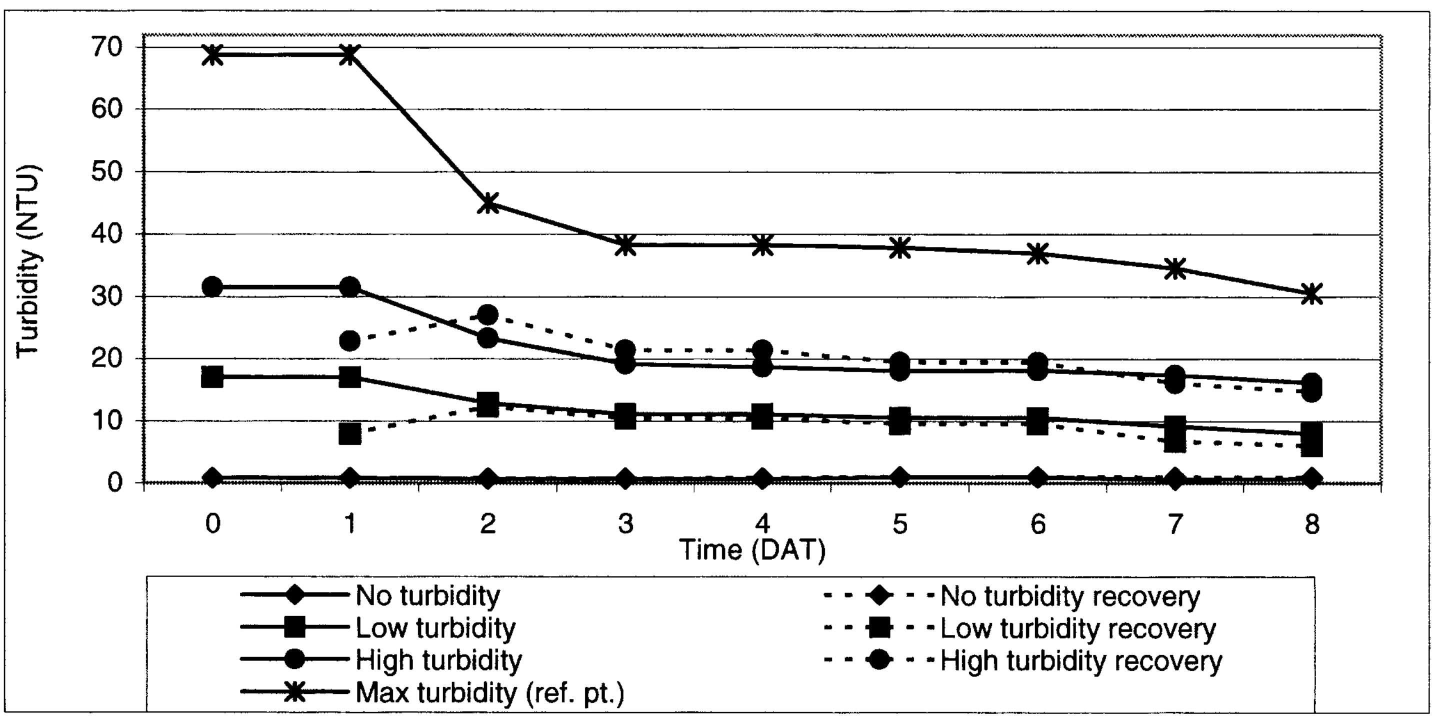

Figure 1. Mean turbidity levels in treatment and recovery tanks. The standard error was 5% or less, and DAT refers to days after treatment.

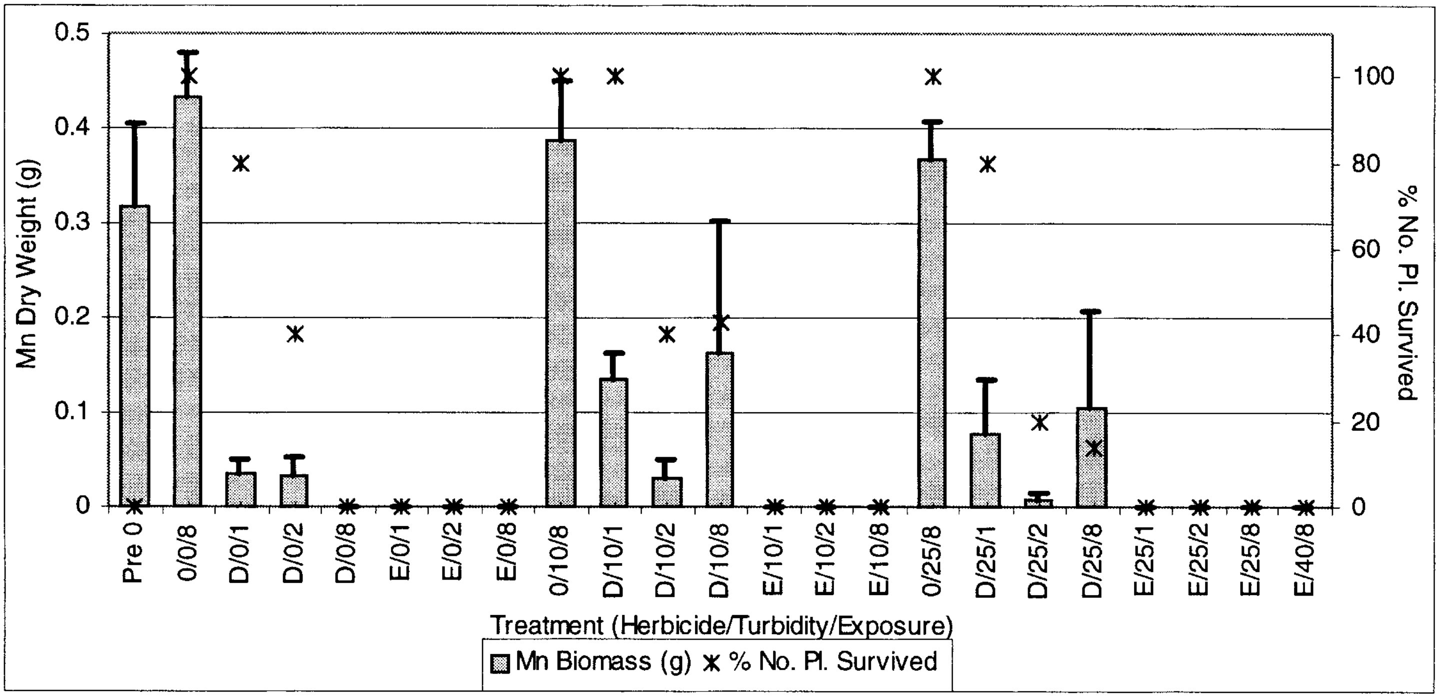

Figure 2. *Ceratophyllum demersum* biomass and plant survival after exposure to diquat and endothall. On the x-axis treatments are represented by 0, D, or E for none, diquat, or endothall respectively, turbidity is either 0, 10, 25 or 40 (NTU) and the exposure period is either one, two or eight days. Grey bars are mean dry weights (± standard error) and the (*) represent the percentage of plants that survived each treatment.

quat concentration equivalent to that which was required in clear water. In the present study, the low CEC and consequentially low binding potential of the Lake Waahi sediment slurry, may account for the limited effect of turbidity on plant survival within diquat treatment tanks.

Irrespective of time or turbidity with diquat, endothall efficacy was significantly greater based on plant survival. The efficacy of endothall for coontail under both clear and turbid water supports the potential benefit of this herbicide in New Zealand, particularly in field situations where diquat has limited or no effect.

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