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Evaluation of Selected Herbicides for the Control of Exotic Submerged Weeds in New Zealand: I. The Use of Endothall, Triclopyr and Dichlobenil

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ABSTRACT

The aquatic herbicide diquat is the only product registered in New Zealand for controlling the submerged weeds lagarosiphon (*Lagarosiphon major* (Ridley) Wager), hornwort (in New Zealand) or coontail (*Ceratophyllum demersum* L), egeria (*Egeria densa* Planch), and hydrilla (*Hydrilla verticillata* (Lf) Royle). However, diquat can be ineffective under some environmental conditions and it does not control certain submerged weeds. Greenhouse trials were conducted to evaluate the potential of the herbicides, endothall, triclopyr and dichlobenil to control the aforementioned target weeds and to evaluate impacts on the non-target native submerged species *Potamogeton ochreatus* Raoul, *Potamogeton cheesemanii* A. Benn, *Myriophyllum triphyllum* Orchard, *Myriophyllum propinquun* A. Cunn, *Chara corallina* Willd, *Chara globularis* Thuill, *Nitella hookeri* A. Br, *Nitella leptostachys* A. Br, and *Nitella pseudoflabellata* A. Br when using these products. Endothall killed coontail, lagarosiphon and hydrilla and some species of *Myriophyllum* and *Potamogeton* but not egeria or species of *Chara* or *Nitella*. Only transient growth effects were observed in target plants treated with triclopyr and dichlobenil.

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INTRODUCTION

The exotic submerged species hornwort (in New Zealand) or coontail (*Ceratophyllum demersum* L), lagarosiphon (*Lagarosiphon major* (Ridley) Wager), hydrilla (*Hydrilla verticillata* (LF) Royle) and egeria (*Egeria densa* Planch) cause localized problems in lakes, reservoirs, and rivers in New Zealand (Clayton 1996). At present the aquatic herbicide diquat (6,7-dihydrodipyrido (1,2-a:2',1'-c) pyrazinediium dibromide) is the only product registered in New Zealand for controlling these and other submerged plants (Clayton 1986). However diquat is not efficacious on hydrilla or on the other target species under turbid water conditions (Wells and Clayton 1993). The lack of alternative chemical control options and low herbicide efficacy for some New Zealand weed problems led to the evaluation of three herbicides as potential management options for these target weeds. Endothall (7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid), triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) and dichlobenil (2,6-dichlorobenzonitrile), were chosen because they have been reported to control some of these target weeds or related species.

Endothall is a contact herbicide whose desiccant and defoliant properties were first described in the 1950's on terrestrial plants. A number of submerged aquatic plants are also susceptible to endothall, including hydrilla, coontail, lagarosiphon and curly leaved pondweed (*Potamogeton crispus* L) (Wells and Clayton 1993), as well as other species of *Potamogeton* and *Myriophyllum* (Sprecher et al. 1998, Serns 1977).

Triclopyr is a selective systemic herbicide that has traditionally been used for the control of woody and broadleaf plants. More recently it has been used for the control of submerged and marginal aquatic plant species such as *Myriophyllum spicatum* L (Getsinger et al. 1997, Sprecher et al. 1998), *Alternanthera philoxeroides* (Mart.) Griseb (SePRO 2000) and *Myriophyllum aquaticum* (Vell. Conc) Verdc (Anderson 1999), producing a characteristic auxin-like response in growing plants.

Dichlobenil is a systemic herbicide that has been used for the selective control of both terrestrial and aquatic weeds. Aquatic species that are susceptible to dichlobenil include species of *Potamogeton* and *Myriophyllum* as well as coontail, (Walker 1964) and hydrilla (Steward 1980).

The objective of this study was to identify effective concentrations and contact times required to kill the target species and to determine the potential impact on preferred native species of *Myriophyllum, Potamogeton,* and the charophytes, *Chara* and *Nitella*.

MATERIALS AND METHODS

Coontail, lagarosiphon, hydrilla, egeria, *Myriophyllum triphyllum* Orchard, *Myriophyllum propinquum* A. Cunn, *Potamogeton cheesemanii* A. Benn, and *Potamogeton ochreatus* Raoul, were propagated from 20 cm stem fragments, and *Chara corallina* Willd, *Chara globularis* Thuill, *Nitella hookeri* A. Br., *Nitella leptostachys* A. Br., and *Nitella pseudoflabellata* A. Br., from a clump of small rooted plants in 300 ml pots filled with topsoil and covered with a 1 cm layer of sand. Plants were grown for six weeks prior to the start of treatment in 170 L tanks in a greenhouse. Water temperature was 14 to 27C throughout the study and light level was ca. 200 $\mu Em^{-2}s^{-1}$. At least 15 plants were placed in each treatment tank prior to herbicide application.

The herbicides endothall (Aquathol K), triclopyr (Garlon 3A) and dichlobenil (Prefix D) were added at one of four rates of 0, 0.5, 2 and 5 mg/L endothall, 0, 0.25, 1 and 2.5 mg/L triclopyr and 0, 0.5, 1.5 and 2.5 mg/L dichlobenil to four tanks of each plant species.

Tanks were aerated to ensure mixing of the herbicides. Plant appearance was monitored daily and five plants were moved from treatment to recovery tanks (minus herbicide) 3, 7, and 11 days after treatment (DAT) and monitored for signs of recovery till at least 40 DAT, depending on plant condition. Individual plant health (score) was monitored on a 0-5 scale (0 = no effect, 1 = foliage color change/epinastic shoots/shoot deterioration, 2 = loss of turgor, 3 = fragmentation/browning of stem, 4 = plant collapse, 5 = plant kill). Plant recovery was monitored on a similar 0-5 scale (0 = complete recovery, 1 = branching/stem elongation, 2 = two or more new shoots, 3 = one new shoot, 4 = stem integrity, 5 = plant kill). Score data were averaged for plants from the same treatments and data were combined for graphical representation where there was no difference in plant scores between treatments (herbicide concentrations and plant exposure period).

RESULTS AND DISCUSSION

Endothall. Species susceptible to endothall treatment exhibited a variety of symptoms including a dull-green discoloration of leaves, the softening of leaf and stem tissue and stem chlorosis prior to plant collapse. Three of the target species coontail, lagarosiphon and hydrilla, were susceptible to endothall (Figure 1). All concentrations and exposure periods killed coontail within six days, but at the lowest rate (0.5 mg/L) it took an extra day before plants collapsed. Similarly Wells and Clayton (1993) reported control of coontail using endothall with rates as low as 0.5 mg/L in outdoor tank studies. In contrast rates greater than 2 mg/L have been required to control coontail in the USA (J. Skogerboe, U.S. Army Engineer Research and Development Center, pers. comm.).

Lagarosiphon and hydrilla plants in 0.5 mg/L endothall were slow to reveal symptoms, and in the case of lagarosiphon took a day or two longer to completely die. Endothall symptoms were first observed on lagarosiphon plants 3 to 4 DAT, with plant death occurring ca. 15 days. Over 50% of the hydrilla plants were killed when treated at 0.5 mg/L with only three days exposure. At higher rates or longer exposure, all plants were dead within 19 days. No egeria plants were killed, nor were there any obvious symptoms of endothall treatment.

Wells and Clayton (1993) reported lagarosiphon and hydrilla required 48 and 22 hours exposure respectively at 5 mg/L endothall to obtain near zero biomass, while egeria was unaffected at this rate. Their study maintained endothall concentrations at target levels, while the present study allowed natural decline from time zero and this may account for the longer exposure times in the present study. Our results for hydrilla are also in agreement with those reported in US studies. For example, Netherland et al. (1991) controlled (>85% biomass reduction) hydrilla at rates of 3mg/L for 24 hours or 2 mg/L for 48 hours, but at 1 mg/L control was not effective at the maximum exposure time tested (72 hours).

Amongst the native species, while *Myriophyllum* and *Potamogeton* were susceptible to endothall, charophytes were unaffected. The continued vigor and growth of charophytes in the presence of endothall agrees with the results of Wells and Clayton (1993) and Serns (1977). The charophytes used in the present trial (*C. corallina, C globularis, Nitella hookeri, N. leptostachyis,* and *N. pseudoflabellata*), although different to the species tested by Wells and Clayton (1993) (*C. fibrosa* Bruz. and *N. hookeri* A. Br.) showed no injury symptoms or biomass reduction. Serns (1977) also reported chara species to be unaffected by endothall, and eventually spreading over an entire pond where species of milfoil and pondweeds had been controlled. These results contradict Netherland and Turner (1995) who reported greater than 90% control of a chara species with endothall, and Steward (1980) who also reported endothall was effective in controlling chara species prior to regrowth studies with other products.

The milfoil and pondweed species tested varied in their response to endothall and their potential to recover from endothall treatment (Figure 2). *M. triphyllum* exhibited loss of turgor 4-5 DAT and along with the *M. propinquum* and *Potamogeton* species, including those plants removed from treatment after 3 days, started to collapse after 9 days. After a

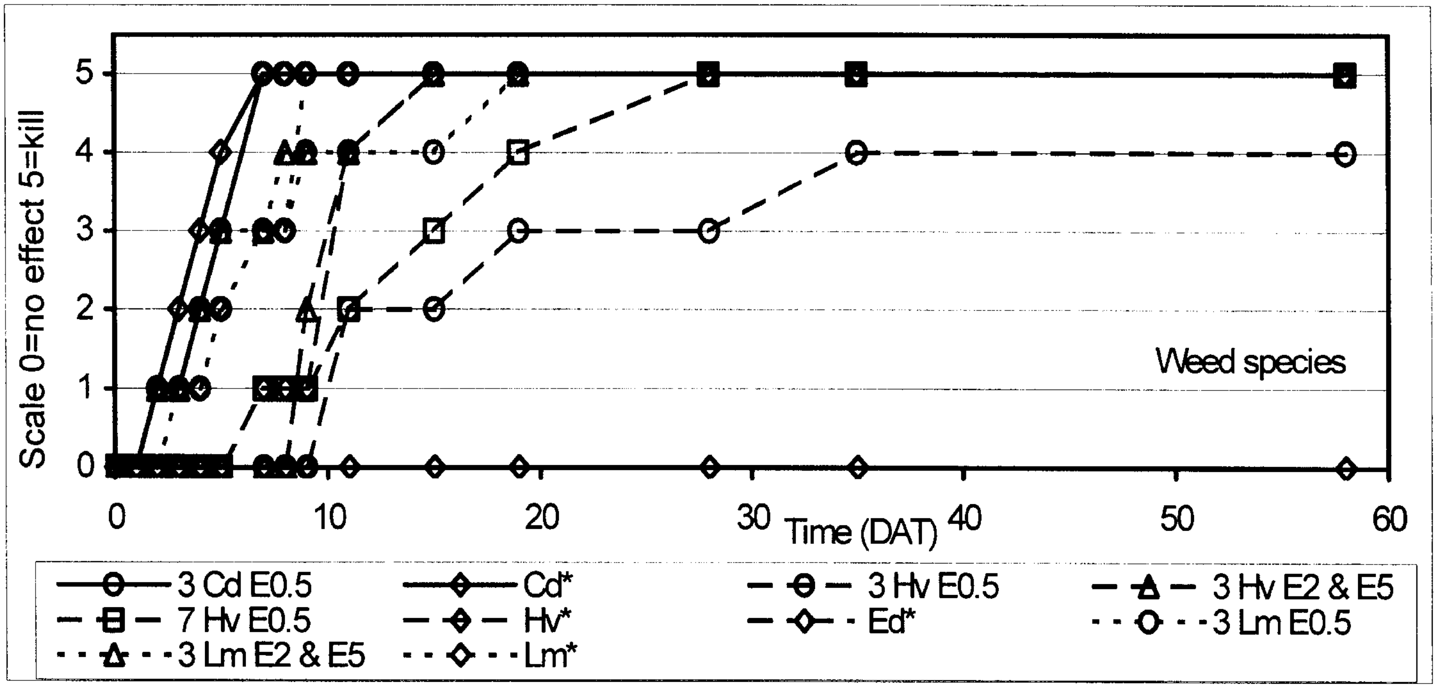

Figure 1. Score data for target weed species treated with endothall at one of three rates 0.5 2.5 or 5 mg/L. Plants are identified in the legend by the first letter of both generic and species names. Endothall concentrations are recorded after the plant label, and numbers preceding the label indicate the time (days) that plants were left in herbicide dosed water. The * represents combined data for all treatments where scores did not differ.

three week recovery period new green shoots were observed amongst *P. ochreatus, M. propinquum* and *M. triphyllum* whereas, *P. cheesemanii* died. Over half of the *P. ochreatus* and *M. propinquum* plants from all treatments recovered, irrespective of concentration or exposure period. *Myriophyllum triphyllum* recovered only from low concentration treatments (0.5 mg/L) and 3 days exposure periods recovered.

Although the effects of endothall on the species of milfoil and pondweed in the present study have not been previously reported, other species of milfoil and pondweeds in the USA are known to be susceptible (Sisneros et al. 1998, Sprecher et al. 1998, Netherland et al. 1991, Serns 1977). For example *P. pectinatus* biomass was reduced (60-98%) along a 5.3 km treatment site within 17 days following treatment with endothall in flowing water (Sisneros et al. 1998). Similarly, *P. crispus* was reduced to near zero biomass in outdoor pond trials (Wells and Clayton 1993, Serns 1977). Although pondweeds in general are susceptible to endothall, there is variation between species in their ability to recover from endothall treatment. Pondweeds such as *P. cheesemanii,* are likely to be controlled along with target vegetation while less susceptible species such as *P. ochreatus* could survive or be expected to recover from endothall treatment, particularly at lower rates. Similarly the non-target milfoils tested in this study exhibit variation between the species in the onset of symptoms and in their ability to recover from endothall treatment. But *M. triphyllum,* like *M. spicatum* was controlled at rates of endothall between 1 and 5 mg/L (Netherland and Turner 1995).

Triclopyr. Triclopyr produced epinastic shoots in all species, except the charophytes, however these growth effects along with some loss of turgor and color change in stems were temporary. For example, coontail had epinastic shoots that were slightly chlorotic 3 to 4 DAT which remained 19 DAT even after plants were in fresh (herbicide free) water. However by 28 DAT plants were recovering and were no different in appearance to control plants by 35 DAT. Lagarosiphon plants took longer than coontail to show symptoms, but were more susceptible in that not all plants recovered. Epinastic shoots and reduced turgor were observed in lagarosiphon 5 DAT and 7 DAT respectively. Plants remaining in triclopyr treated water between 7 and 11 days, or longer at the low concentration (0.25 mg/L) recovered, after a recovery period of ca. 40 to 50 days. However lagarosiphon that remained in triclopyr treated water for 11 days, at the higher rates of 1 and 2.5 mg/L started to fragment at 19 DAT and not all plants recovered. Epinastic shoots were observed in hydrilla and egeria after 4 to 5 DAT. Plants removed after three days treatment showed no symptoms. Some loss of turgor in hydrilla and egeria, and fragmentation in egeria was observed from 7 to 19 DAT, but all plants recovered and had healthy new shoots by 28 to 35 DAT. Similarly the native macrophytes *M. triphyllum, M. propinquum, P. ochreatus* and *P. cheesemanii* had epinastic shoots 4 to 5 DAT, which were particularly apparent in the milfoils, with some loss of turgor 5 to 9 DAT. However, plant recovery was evident by 28 and 35 DAT for pondweeds and milfoils respectively.

In the USA, triclopyr has been used to control *M. spicatum* under an experimental use permit. Triclopyr has demonstrated excellent control of *M. spicatum* at concentrations ranging from 0.25 to 2.5 mg/L when plants were exposed for up to 72 hours (Netherland and Getsinger 1992). Furthermore it has been demonstrated in the field that triclopyr can remove *M. spicatum* and enable *E. canadensis* and coontail to proliferate (Sprecher and Stewart 1995, Getsinger 1995). In

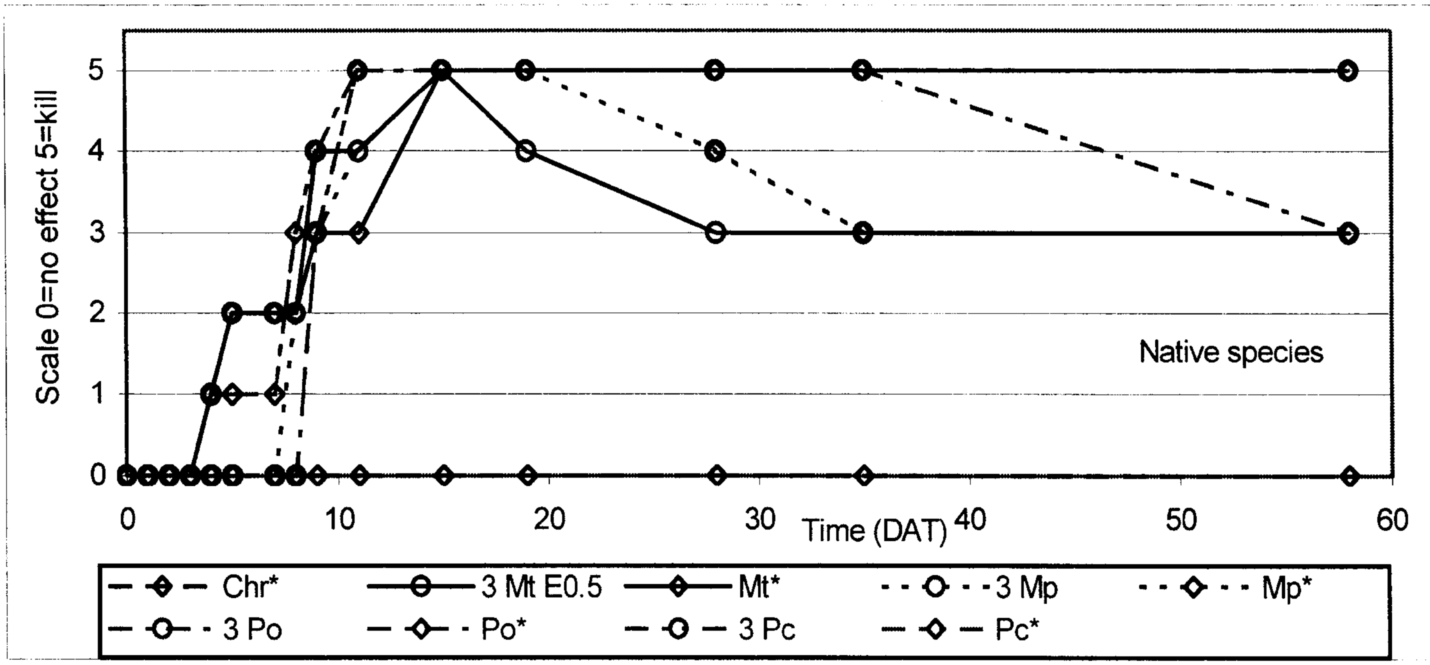

Figure 2. Score data for native species treated with endothall at one of three rates 0.5 2.5 or 5 mg/L. Plants are identified in the legend by the first letter of both generic and species names, except for Chr which represents all charophytes. Endothall concentrations are recorded after the plant label, and numbers preceding the label indicate the time (days) that plants were left in herbicide dosed water. The * represents combined data for all treatments where scores did differ.

the present study although coontail produced transient symptoms from triclopyr treatment it was largely unaffected by the herbicide which is consistent with both USA field and mesocosm studies (Sprecher 1995).

The other target weeds, lagarosiphon, hydrilla and egeria varied in their level of susceptibility to triclopyr, with lagarosiphon the most susceptible. However exposure periods of 11 days at high rates to achieve less than 50% plant kill implies limited potential for use in field applications.

Of the non-target species charophytes were unaffected, and milfoils were more susceptible to triclopyr than pondweeds. Similarly results from other studies indicate that pondweeds could be maintained in the field when using triclopyr to control *M. spicatum* (Sprecher 1995). Sprecher (1995) in a study with two rates of triclopyr (1 and 2.5 mg/L) on *P. pectinatus* observed loss of turgor and reduced chlorophyll in plants at both rates, and reduced biomass of plants treated at the higher rate, and concluded that *P. pectinatus* had good potential for regrowth following triclopyr control of *M. spicatum*. In the present study, neither *P. ochreatus* nor *P. cheesemanii* were effectively controlled by triclopyr although reduced vigor was observed.

The milfoil species *M. triphyllum* and *M. propinquum*, were not controlled by triclopyr, although they exhibited epinastic shoots and reduced vigor. This has important implications for the New Zealand situation because recent trials on marginal aquatic species have also shown that triclopyr has a significant impact on the biomass of *M. aquaticum* (authors observations). Varying susceptibility amongst species within the same genera may enable potential use of triclopyr in New Zealand wetland regions to selectively control *M. aquaticum* where it is considered a serious weed threat.

Dichlobenil. All plants treated with dichlobenil exhibited some loss of vigor when compared to untreated control plants, and some species had more pronounced shoot loss, browning of stems and stem fragmentation, however all symptoms were transient with plant recovery in 35 to 50 DAT. The onset of symptoms was related to dichlobenil concentration rather than exposure time, with all susceptible species exhibiting symptoms irrespective of exposure time, but for some species only at the higher concentration. This is probably due to the long exposure periods of 3 to 11 days, when maximum herbicide concentrations for this formulation of dichlobenil were probably reached in the soil and water several days after application (Ogg 1972, Van Valin 1966).

Of the target species, egeria was the least susceptible with a few soft shoots and some browning of the stems at the higher concentration of 2.5 mg/L, but complete plant recovery within 30 DAT. Lagarosiphon was the most susceptible of the target weeds, with dead shoots and browning stems occurring at 7 DAT followed by stem fragmentation, but plants were recovering by 40 DAT. Coontail was also susceptible to dichlobenil. Shoot apices died and browned at 9 to 10 DAT in all concentrations of dichlobenil, and plants exhibited a distinct lack of vigor for at least 14 days following their removal from treated tanks, after which regrowth was apparent. A lack of vigor in lower dichlobenil concentrations, and dead shoots and apical damage in hydrilla in the 2.5 mg/L treatment was apparent from 9 DAT through to 28 to 35 DAT, with initial signs of plant recovery after ca. one month in freshwater.

In this study none of the target species were killed by the dichlobenil, although with repeat applications some species such as hydrilla may be more susceptible, because a long recovery period in fresh water was required before regrowth was observed. This is consistent with Steward's (1980) observations where dichlobenil controlled regrowth from hydrilla.

Native macrophytes were unaffected at low concentrations, but *P. ochreatus* and *P. cheesemanii* in particular were susceptible at high concentrations of dichlobenil with less than half of the *P. ochreatus* plants and all of the *P. cheesemanii* dying. The milfoils and charophytes exhibited a distinct lack of vigor at 1 and 2.5 mg/L dichlobenil, with shoot deterioration and discoloration of stems in the milfoils, but plant recovery was initiated after ca. three weeks in freshwater. Similar results have been reported for *Potamogeton* and *Myriophyllum* species (Walker 1964). Steward (1980) also observed reduced charophyte regrowth in the presence of dichlobenil.

In conclusion, endothall has shown promising potential for the control of coontail, lagarosiphon and hydrilla. High rates of endothall in this study controlled hydrilla, and importantly did not inhibit the growth of native charophyte species, which are present in hydrilla infested lakes (Hofstra et al. 1999). Endothall was also efficacious against coontail and lagarosiphon in the present study. These two species are readily controlled by diquat in clear water, but endothall may provide effective weed control in more turbid waters (Hofstra et al. 2000).

Based on these results triclopyr and dichlobenil have limited further use in New Zealand for the control of these target submersed weed species. However low efficacy on native pondweeds, milfoils and resistance of charophytes, may enable triclopyr to selectively control problematic growth of marginal *M. aquaticum* with minimal damage to non-target plants in New Zealand wetlands.

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