# Endothall for aquatic weed control in New Zealand

Rohan D.S. Wells and Paul D. Champion
NIWA, PO Box 11-115, Hamilton 3251, New Zealand
Corresponding author: r.wells@niwa.co.nz

**Summary** Dipotassium endothall is widely used as an aquatic herbicide in the USA, particularly for hydrilla control. Endothall gave highly effective control of three of New Zealand's top ranked submersed pest species: hydrilla (*Hydrilla verticillata* (L.f.) Royle), lagarosiphon (*Lagarosiphon major* (Ridley) Moss) and hornwort (*Ceratophyllum demersum* L.). Lagarosiphon and hornwort were eradicated in whole of water body field trials with a single, total water body treatment of endothall. Furthermore, these results were obtained with up to 45 times less herbicide than label rates possibly due to cool water (16°C) contributing to extended exposure times. Hydrilla, however, produces subterranean tubers and aerial turions and is able to recover after endothall treatments.

**Keywords** Endothall, endothal, Aquathol® K, Aquathol® Super K, aquatic weed eradication, aquatic herbicide.

## INTRODUCTION

Dipotassium endothall (referred to hereafter as endothall) is trade marked as Aquathol® K (aqueous) and Aquathol® Super K (pellets) for use as an aquatic herbicide. It has been widely used in the USA, particularly for hydrilla control and has been the focus of studies there since the early 1970s (Sprecher *et al*. 2002). Endothall is the American spelling for endothal, but has been used here to assist keyword searches and because nearly all work on this chemical has been done in the USA.

Endothall was found to be effective in New Zealand tank trials (Wells and Clayton 1993, Hofstra and Clayton 2001) on some of New Zealand's worst aquatic weeds: lagarosiphon, hornwort and hydrilla, but not egeria (*Egeria densa* Planch.) or elodea (*Elodea canadensis* Michx.). All are tall-growing exotic invasive species that displace native submerged vegetation, and can form dense surface-reaching growths (de Winton *et al.* 2009). Aquathol K and Aquathol Super K were subsequently registered for use in New Zealand in 2004. Prior to this, diquat was the only aquatic herbicide registered in New Zealand and endothall appeared to have potential to complement to this herbicide. Endothall is a contact herbicide similar in mode of action to diquat, but complements diquat by working in turbid conditions and is efficacious on some species on which diquat has no effect. In order to field test endothall it was first necessary to gain registration for aquatic use in New Zealand.

This paper reports on selected field trials designed to test efficacy of endothall in New Zealand conditions for New Zealand aquatic weeds: lagarosiphon, hornwort and hydrilla. Lagarosiphon is widespread in the North Island, but is only locally present in the South Island occurring in scattered locations from the top of the island (Nelson/Marlborough) to the bottom (Southland). Hornwort is widespread in the North Island but in the South Island known sites were limited to the vicinity of Motueka in the north (now declared eradicated) and since February 2006 in Centennial Lake, Timaru (lower east coast, SI), above a weir on the Otipua Stream. Hydrilla is restricted to only three Hawke's Bay lakes (lakes Tutira, Waikopiro and Opouahi) in New Zealand and was eradicated from a fourth (Eland's Lake; all sites being located in the middle of the east cost of the North Island) using the herbivorous fish, grass carp. Both hornwort and hydrilla were identified as pests for eradication by the MAFBNZ (Ministry of Agriculture and Forestry Biosecurity New Zealand) National Interest Pests Response Programme initiated in December 2006. Operational plans were developed to manage these species with the goal of eradicating hydrilla nationally and hornwort from the South Island.

## MATERIALS AND METHODS

**Lagarosiphon** Endothall treatments were applied on 5 December 2008 to a series of similar small (200 $m^2$ to 1.4 ha), shallow (<2 m deep) ponds (formed by gravel extraction) containing lagarosiphon at Oreti, Southland, at the bottom of the South Island. A concentration series of 5 (maximum label rate), 2.5, 1, 0.5 and 0.11 ppm endothall and a control were established, with one treatment assigned to each water body. Endothall residues were collected from each treatment at 1, 3, 24 and 72 hours; 7, 14 and 38 days, and 8 months following treatment, and analysed for endothall at the USACE (United States Army Corps of Engineers) laboratories using the immunoassay method. Water temperatures were also recorded when treated and 38 days later (late January, mid-summer). Assessments of the aquatic vegetation (species present,

their height (maximum and average) and percentage cover (maximum and average) were made on scuba assessing the whole water body (using methodology described in Clayton 1983) before treatment, 53 days after treatment and 10 months after treatment. Before treatment, lagarosiphon in the ponds mostly had a maximum height of 1.5 m (average 1.0 m) and was the dominant plant in water >1 m deep with 100% cover and occupying >30% of each pond. This assessment also included casual observations of invertebrates, fish and bird species and abundance.

**Hornwort** Endothall, as both pellet and aqueous formulations, was applied to Centennial Lake (1.6 ha with 2 m average depth) on 18 March 2008 with a total water body treatment of 5 ppm endothall (Wells and Sutherland 2009). Hornwort was of low cover (~15%) but widespread throughout the lake, with some present in the out-flowing stream prior to treatment. Post-treatment scuba inspections assessed underwater vegetation (using the methods described for lagarosiphon) at 1, 8, 12 and 24 months after herbicide application.

**Hydrilla** In Lake Waikopiro (11 ha with a maximum depth of 15 m) hydrilla formed 3.2 ha of dense weed beds around the margins from 1 to 6 m deep with a maximum height of 2 m. In November 2008, 590 L of endothall (aqueous) was applied to 1.34 ha (13% of the lake area) on the north side of the lake to give a calculated 5 ppm treatment to that weed bed (assuming an average depth of 4.5 m). As the herbicide can persist for weeks and lake-wide mixing was likely, the calculation for endothall dispersal through the whole lake volume was ~0.25 ppm. The pre-treatment vegetation assessment was undertaken on 5 fixed profiles evenly spread round the lake prior to herbicide application and a post-treatment inspection was carried out in December 2008 prior to grass carp release.

## RESULTS

**Lagarosiphon** In all treatments residue analyses confirmed target levels of endothall were achieved within 3 days following application. The endothall was persistent in the enclosed ponds maintaining target concentrations for at least 38 days, but was not detectable in the 8 month samples. Water temperatures were cool with 16°C recorded both at the start of the trial and again 38 days later. At 53 days after treatment very high levels of control were evident. All trace of lagarosiphon had gone from the highest treatment (5 ppm endothall) with no fragments above or below sediment level, whereas in the lowest concentration (0.11 ppm) shoots were brown and mostly prostrate, with no re-growth seen anywhere. The roots and basal stem portions were necrotic, so stems were no longer attached. After 10 months only the 0.5 ppm treatment had a few small plants of lagarosiphon re-growing from thick black stem fragments, but in all other treatments, including the 0.11 ppm treatment, no fragments of lagarosiphon were found. The ponds had a wide variety of other species present that were not affected including diverse native emergent macrophytes, amphibious turf species, charophytes and tall-growing vascular plants. There were also a few exotic ubiquitous seed bearing species such as jointed rush (*Juncus bulbosus* L.) and water buttercup (*Ranunculus trichophyllus* Chaix). Damage to the exotic water buttercup and native milfoil (*Myriophyllum triphyllum* Orchard) was noted within 1 month, but no other species were damaged by the treatments. The native milfoil had fully recovered by 10 months post treatment and dominated several of the ponds. No faunal impacts were observed, with similar observations of fish, invertebrate and bird species and abundance noted relative to the control pond and pre-treatment evaluations.

**Hornwort** In Centennial Lake, including the outlet stream, there were no traces of hornwort in any of the post treatment inspections (from 1 month to 2 years). Other species present in the lake such as elodea and curled pond weed (*Potamogeton crispus* L.) were not affected by herbicide and no impacts on waterfowl or fish were observed.

**Hydrilla** Scuba assessments found no vegetative fragments of the 3.2 ha hydrilla weed beds in Lake Waikopiro 1 month post endothall treatment. However, viable tubers were sieved from the mud but introduction of grass carp meant that any subsequent re-growth from tubers would be controlled. No other off-target endothall effects on emergent macrophytes and aquatic fauna were noted.

## DISCUSSION

In these trials endothall was shown to be an effective tool for high level control of vegetative portions of lagarosiphon, hornwort and hydrilla in New Zealand lakes. A single treatment with extended contact times (achieved with total water body treatment) was an effective means of eradicating lagarosiphon and hornwort, which (in New Zealand) do not set seed or form tubers or turions. It would be theoretically possible to eradicate hydrilla with endothall, but hydrilla forms resistant propagules, and it would be impractical, based on costs alone, to continue annual endothall treatments to remove regenerating plants that could

form new tubers and sustain this over at least a 10 year period (the life-span of tubers in New Zealand (Hofstra and Champion 2008)). Grass carp are necessary to eradicate hydrilla and have done so in Lake Elands (Hofstra and Rowe 2008), but the fish are non-selective feeders so this option is associated with removal of most of the non-target aquatic vegetation as well. In contrast, endothall and diquat are highly selective for New Zealand target weed species and have minimal impact on native aquatic vegetation and ecosystems. For endothall, the amphibious turf species and charophytes were not affected and native milfoil was the most susceptible of the native tall-growing species, but recovered during the following growing season.

It was evident from the trial results that endothall concentrations can be greatly reduced if long contact times are achieved, such as for total water body treatments. For example, eradication of lagarosiphon using 0.11 ppm was achieved, which is 45 times less than the maximum label rate, although at these low concentrations results are mixed (e.g. a few plants survived in the 0.5 ppm treatment) so repeat applications may be required. The advantages of a low dose endothall treatment are that whole lake treatments become economically feasible and more acceptable as treatment levels can be less than even the drinking water limit (0.28 ppm). A concentration of 0.5 ppm endothall killed planted shoots of lagarosiphon in tanks given 3–7 days contact time (Wells and Clayton 1993, Hofstra and Clayton 2001) and required 48 and 22 h contact time respectively at 2.5 and 5 ppm to kill lagarosiphon. Long contact times (weeks) for endothall can be achieved at sites where the effects of dissipation are minimal (such as total water body treatments) and when biodegradation rates are slow, such as when temperatures are cool. For example, at 16°C, endothall persisted for weeks and was still effective on lagarosiphon at this temperature in the Southland trial.

Endothall controls some species not susceptible to diquat, such as hydrilla, and likewise diquat effectively controls elodea and egeria, not susceptible to endothall (Hofstra *et al.* 2001). Diquat is rapidly deactivated by organic matter or clays so is of limited use in turbid water and within sediments. Conversely, endothall is not deactivated and can kill the roots of susceptible species making eradication more feasible. Despite this, in a MAF Biosecurity-led programme, diquat has successfully eradicated hornwort (which does not form roots) from Motueka in flowing water with a short contact time (http://www.biosecurity.govt.nz/pests/hornwort), and a double diquat treatment timed to kill regenerating basal portions achieved a very high rate of lagarosiphon removal in Lake Wanaka (Dr J.S. Clayton, NIWA (National Institute of Water and Atmospheric Research Ltd), unpublished data). Thus both herbicides are effective in different situations against different species and both are useful tools for the management of submerged aquatic weeds in New Zealand.

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