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Herbicide Trials for the Control of Parrotsfeather

DEBORAH E. HOFSTRA[1], P. D. CHAMPION[1], AND T. M. DUGDALE[2]

ABSTRACT

Parrotsfeather (*Myriophyllum aquaticum* (Vell. Conc.) Verdc.) is an introduced aquatic weed that forms nuisance growths in drainage systems, wetlands and shallow lakes and is a species with limited or ineffectual control options in New Zealand. In the first year of trials five different herbicides were tested for their efficacy against parrotsfeather under culture conditions. The triethylamine salt of triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) was the most effective product and in the second and third trial years it was compared with glyphosate (*N*-(phophonomethyl) glycine) (the product currently used in New Zealand for parrotsfeather control) and evaluated over a wider range of concentrations. Results indicate that triclopyr is effective at controlling parrotsfeather under contained experimental conditions, reducing biomass to zero (or near), with little or no plant recovery in contrast to the results for glyphosate. Under field conditions triclopyr has successfully reduced the cover and presence of parrotsfeather.

Key words: Parrotsfeather, *Myriophyllum aquaticum*, triclopyr, endothall, dichlobenil, glyphosate.

INTRODUCTION

Parrotsfeather is a robust stoloniferous perennial that grows rapidly in aquatic habitats as a submerged or sprawling emergent plant. A native of South America, it has been widely naturalized in North America, southern Africa and parts of Europe where it is considered a major weed (Guillarmod 1979, Murphy et al. 1993, Systma and Anderson 1993). In New Zealand parrotsfeather occurs in the North Island from Northland to Wellington, with scattered infestations in the northern part of the South Island (Nelson and Marlborough, and one site in Westland). Until its inclusion on the national list of plants banned from sale and distribution under the Biosecurity Act (1993) it was often cultivated in ornamental garden ponds from which it escaped, with subsequent spread by contaminated drain clearing machinery. It is an aggressive and troublesome weed in drainage systems and shallow lakes (Coffey and Clayton 1988) and is ranked as one of the worst aquatic weeds in New Zealand (Champion and Clayton 2001).

Parrotsfeather can be controlled by mechanical harvesting, which provides immediate and localized clearance, but also results in fragmentation and potential spread of the weed (Machado and Rocha 1998). Several potential biocontrol agents have been investigated in a number of countries for use against parrotsfeather. For example, flea beetles (*Lysathia ludoviciana* and *L. flavipes*) have been considered as potential biocontrol candidates for parrotsfeather (Habeck and Wilkerson 1980, Cordo and DeLoach 1982, Cilliers 1998). Fungal pathogens have also been isolated in South America which damage parrotsfeather and have biocontrol potential, in addition to an isolate of *Pythium carolinianum* isolated from parrotsfeather that causes root and stem rot and leaf wilt (Bernhardt and Duniway 1984). Grass carp (*Ctenopharyngodon idella*) too has shown potential as a biocontrol agent for parrotsfeather (Pine and Anderson 1991, Armellina et al. 1998, Brunson 1998, Moreira et al. 1998). Of these potential biocontrol agents only grass carp are available in New Zealand, and they are seldom effective in a drainage environment (Wells et al. 2003).

Chemical applications have been more effective for longer-term control than mechanical techniques. Excellent control has been reported when using endothall (7-oxabicyclo [2.2.1] heptane-2,3-dicarboxylic acid), diquat (6,7-dihydrodipyrido [1,2-α:2',1'c] pyraninediium ion) and 2,4-D ((2,4-dichlorophenoxy)acetic acid) against parrotsfeather in the US (Westerdahl and Getsinger 1988), and triclopyr has provided promising results in California (Anderson 1999). Glyphosate control of parrotsfeather ranges from fair to excellent (Machado and Rocha 1998, Westerdahl and Getsinger 1988) to not recommended (Langeland 1993, Moreira et al. 1998). Dichlobenil (2,6-dichlorobenzonitrile) has shown some efficacy for parrotsfeather with fair control in the US (Westerdahl and Getsinger 1988) and in Australia (Ripper and Milvain 1989).

In New Zealand only two products, diquat and endothall are registered for use on submerged aquatic weeds. Glyphosate is registered for use where contamination of water may occur, and an application with ERMA (Environmental Risk Management Authority) has recently been lodged for triclopyr for similar use (i.e., the control of marginal aquatic plant species). Of these products diquat has previously been trialled on parrotsfeather but was not efficacious (NIWA unpublished data). Currently glyphosate is used to control parrotsfeather but several repeat applications are usually required to give adequate control even at the maximum label rate.

Parrotsfeather is currently regarded by waterway managers as a problematic plant that has limited or ineffective control options available. In this study alternative chemical options to glyphosate were evaluated for parrotsfeather control in contained and field trials, using a range of products selected for their efficacy on parrotsfeather and/or reported selectivity.

MATERIALS AND METHODS

Contained Trials. Parrotsfeather was cultivated in 31 tubs during the summer of 1999 to 2000 and treated with endothall (Aquathol® K), triclopyr (Garlon® 3A), dichlobenil

[1]Institute of Water and Atmospheric Research Ltd., P.O. Box 11-115, Hamilton, New Zealand; e-mail: D.Hofstra@niwa.co.nz.

[2]School of Botany, University of Melbourne, Parkville, Victoria 3010, Australia. Received for publication May 31, 2005 and in revised form Jan. 10, 2006.

(Prefix®-D), fluridone (Sonar® AS) or clopyralid (Versatill®). During the second summer (2000 to 2001) parrotsfeather was grown in 27 tubs and treated with triclopyr (the product that gave the best results from year one and field trials) or glyphosate (Roundup® G2).

Each year (i.e., each trial) healthy root-stock and basal stem material of parrotsfeather was planted in 60 L plastic tubs that were two-thirds filled with topsoil and a ca 10 cm layer of sand and then filled completely with water. Plants were grown outdoors for the duration of the study, with an initial establishment period of about two months before herbicide was applied.

In the first year herbicide was sprayed onto the plants at concentrations of 8.8 and 14.8 kg ai/ha endothall, 2.0 and 4.0 kg ai/ha triclopyr, 0.1 and 0.5 kg ai/ha fluridone and 1.5 kg ai/ha clopyralid with a water rate of 200 L/ha (sufficient to visibly wet all shoots). Dichlobenil (granular form of Prefix®-D) was scattered onto tanks at a rate of either 6.75 or 20.25 kg ai/ha. There were three replicates of each treatment and four untreated controls that were randomly assigned to tubs of parrotsfeather. In the second year herbicide was sprayed onto plants at concentrations of 2.0, 4.0 or 8.0 kg ai/ha triclopyr and 3.2 kg ai/ha glyphosate (Roundup®) (plus Uptake® adjuvant oil). There were six replicates of each herbicide treatment and three untreated controls that were randomly assigned to tubs.

Plants were monitored weekly for eight weeks after treatment (WAT) and then every two weeks in the first year study, and every two weeks for 20 WAT and then monthly in the second year study. Percent plant cover and shoot number were recorded in the first year, but because these two measures of plant growth showed the same trends shoot numbers were not counted routinely in the second year study and are not included in the dataset presented. In the first year plants were harvested at the end of the summer (17 WAT). In the second year plants were harvested a year after treatment. Harvesting was carried out in three sections keeping separate the emergent shoots, the submerged shoots, and below ground portions of the plants. All plant biomass was dried to constant weight, and dry weights (±0.1 g) were recorded.

Plant biomass and percent cover data were analyzed using ANOVA (analysis of variance) with Dunnett and Tukey post hoc tests. Rank transformed data were used for comparison between trials from the two years using ANOVA. All mention of statistical significance refers to $P < 0.05$.

During the third spring and summer a low rate triclopyr trial was undertaken in a controlled temperature (20 C ± 1 C) and light (ca. 100 µE m^2/s) growth room. Stem fragments of parrotsfeather (15 cm in length) were planted into pots (7 cm by 7 cm across and 9 cm deep) that were two thirds full with topsoil and a 1 cm layer of fine sand, and then covered in water. Plants grew for six weeks prior to triclopyr application, at which time the mean biomass of three randomly selected pre-treatment plants was 2.4 gm (± 0.4 gm std dev). Triclopyr was sprayed onto the plants at one of seven different rates (2, 1, 0.5, 0.25, 0.1, 0.05 and 0.025 kg ai/ha) with 6 replicates of each treatment, and 6 untreated controls that were randomly assigned to the pots of parrotsfeather. Plants were monitored every two weeks for a period of 18 WAT. At each monitoring period plants were visually assessed and assigned a score based on their health (appearance of triclopyr symptoms/plant recovery). The scores were as follows; 5 = healthy shoots and no triclopyr symptoms; 4 = curled, wilted or bent leaves/many new shoots, and few triclopyr symptoms; 3 = stems bent or wilted in appearance/many new shoots, but over half of the plant is still has triclopyr symptoms; 2 = leaf drop/at least one new shoot; 1 = leaf drop and stem drop/turgid stem; 0 = dead.

Although the scores assigned to plant health provide the best indication of triclopyr efficacy in this smaller scale pot study, percent cover of parrotsfeather was also assessed fortnightly to provide a routine estimate of growth for comparison with plants in the earlier larger tub trials.

Plants were harvested keeping the above ground and below ground biomass separate. Plant biomass was oven dried till constant and dry weights (±0.1 g) were recorded. Plant biomass data were analyzed using ANOVA with Dunnett and Tukey post hoc tests. All mention of statistical significance refers to $P < 0.05$.

Field Trials. During the summer of 2000 and 2001 a field trial was undertaken in the Kaituna Wildlife Management Reserve (a wetland in the Bay of Plenty (North Island)), to evaluate the field use of the best herbicides from the first year of the contained herbicide trial for parrotsfeather control.

Eighteen treatment plots of 5 by 5 m (triplicates for each treatment) and three untreated reference plots were marked out in a region of the wetland that contained dense parrotsfeather (95 to 100% cover) in a water depth of ca 30 cm. Each herbicide (endothall (Aquathol® K), dichlobenil (Prefix® D) and triclopyr (Garlon® 3A)) was applied at two rates referred to as high or low. The concentrations were 8.8 and 14.8 kg ai per ha of endothall, 2.0 and 4.0 kg ai per ha triclopyr and 6.8 and 20.3 kg ai per ha dichlobenil. Application of the endothall and triclopyr was made with a knapsack sprayer using a water rate of 500 L per hectare, and the dichlobenil (in granular form) was broadcast over treatment plots. The plots were treated in early summer (December) 2000.

A re-spray of the plots was carried out 51 days after the initial treatment, following a large drop in water level one month after treatment and greater exposure of (and accessibility to) the parrotsfeather. The rates used during the respray were the same as those used initially. Vegetation was assessed visually (species present and percent vegetation cover) prior to the application of herbicides, and the impact of herbicide application on parrotsfeather and other wetland vegetation was assessed at 1, 4, 7, 11, 30 and 54 WAT from the initial application.

A second field trial on parrotsfeather was carried out in two drains in the Bay of Plenty (North Island) in conjunction with Environment Bay of Plenty (the regional authority). This field trial was conducted during the spring (October) and summer of 2002 to 2003 in the Omeheu and East Drains, using triclopyr at a rate of 4 kg ai/ha.

The treated section of Omeheu Drain was 3 m wide and 2 km long, with a low density cover of emergent parrotsfeather that occupied a total cover of 35 m^2 at the time of treatment. The treated section of East Drain was ca 1 km long with the first half (498 m) of the drain being wide (ca 3 m) and the second half narrow (ca 1 m), and had a high density cover of parrotsfeather of 86 m^2 and 42 m^2 in the two sections respectively.

Post spray monitoring (plant species present and percent vegetation cover of parrotsfeather) was carried out 1, 4, 12 and 25 WAT. However at 8 WAT substantial re-growth of associate drain weed species and parrotsfeather in Omeheu Drain resulted in intervention by local management authorities and Omeheu Drain was cleared. Therefore only the first two datasets from Omeheu Drain will be described here.

RESULTS AND DISCUSSION

Contained Trials. In the first year trial plants in control tubs continued to increase in percent cover and shoot number during the seventeen-week trial period as did the fluridone treated plants. The fluridone treated plants had symptomatic development of pink and chlorotic shoots within the first 2 WAT, although this did not appear to impact on percent cover (Figure 1a) and did not result in reduced biomass (Figure 1b). Plants treated with clopyralid showed some initial loss of vigor, with reduced cover (and shoot number) for approximately 8 WAT. By 17 WAT the percent plant cover in the clopyralid tubs was within 20% of that observed in the control tubs, and the biomass did not differ significantly from control plants.

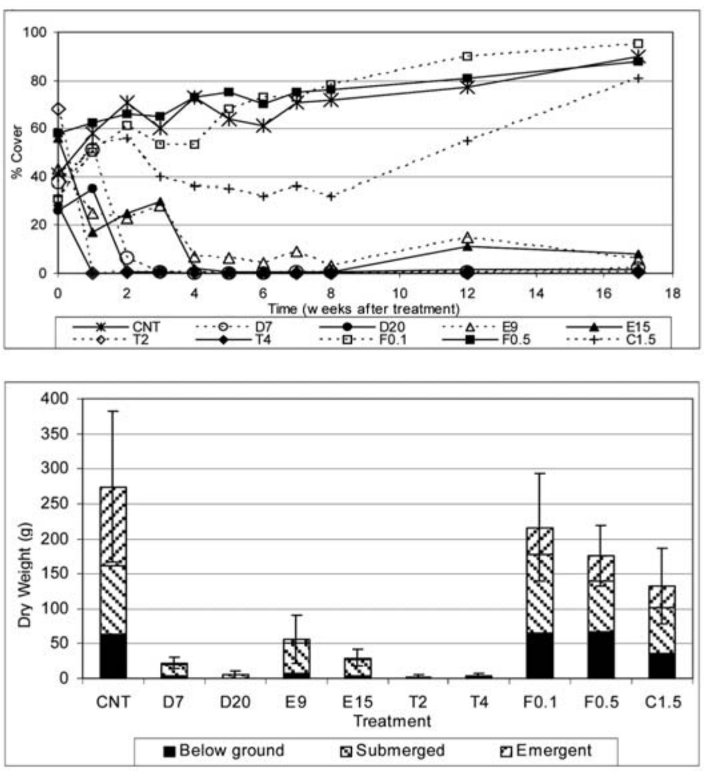

Figure 1. a) Percent vegetation cover of parrotsfeather in the year one contained trial, b) parrotsfeather biomass from the year one contained trial. Each line or bar represents the mean from replicate treatments (n = 3 for herbicide treatments and n = 4 for untreated controls). Vertical lines on each bar in Figure 1b, represent the standard deviation for the total biomass. Legend abbreviations are as follows: CNT, D, E, T, F and C represent control, dichlobenil, endothall, triclopyr, fluridone and clopyralid respectively. The numbers following each letter represents the rate at which each product was applied in kg ai/ha.

Clopyralid was selected in this study because it provides selective control of a range of dicot species with little damage to monocots. The advantage of this for a drain-weed herbicide is that ditch bank grasses will not be damaged and continue to provide or maintain bank stability in the absence of other vegetation. Fluridone was selected because some authors have reported fair control of parrotsfeather (Langeland 1993). In the present study, clopyralid and fluridone were of limited use for the control of parrotsfeather, and were not evaluated further.

In contrast to clopyralid and fluridone, parrotsfeather treated with endothall and triclopyr exhibited distinct herbicide symptoms (wilting) 7 hours after treatment, and by 5 days after treatment the plants were brown, and those treated with dichlobenil were yellowing and chlorotic in appearance. This was followed by a sharp decline in percent plant cover within 4 WAT from which only the endothall treated plants showed some signs of recovery (new shoot development) by 17 WAT (Figure 1a). This is also illustrated by the plant biomass data at harvest (Figure 1b). Plant biomass from dichlobenil, triclopyr and endothall treated tubs was significantly lower than the biomass of plants from control tubs (Figure 1b). Similarly, excellent control of parrotsfeather with endothall (Westerdahl and Getsinger 1988), and fair control with dichlobenil has been recorded in the US (Westerdahl and Getsinger 1988) and in Australia (Ripper and Milvain 1989).

Triclopyr, dichlobenil and endothall were all promising in reducing parrotsfeather cover and biomass in the first year contained trial. In the subsequent (second year) contained trial however, only triclopyr was evaluated because it was more efficacious than endothall (i.e., less plant recovery as determined by percent cover and biomass at harvest. In addition dichlobenil was seen as less likely to be an acceptable choice of product for parrotsfeather control compared with triclopyr, due to the longer persistence of dichlobenil.

Results from the second contained trial show a substantial decline in the percent cover of triclopyr and glyphosate treated plants within the first 5 WAT, however, the glyphosate treated plants showed signs of recovery (increased percent cover) within 10 WAT (Figure 2a). By comparison, recovery was only evident in plants treated with the lowest rate of triclopyr after ca 30 WAT (Figure 2a). All triclopyr treatments had significantly lower percent cover than glyphosate tubs from 15 WAT. This trend continued for the duration of the study and is reflected in the biomass data at harvest (Figure 2b). Therefore, triclopyr provided substantially better control of parrotsfeather than glyphosate.

Similar results were obtained in the first and second year contained trials for the same rates of triclopyr (2 and 4 kg/ha), with significantly lower parrotsfeather biomass in triclopyr treated tubs than in control tubs (Figures 1b and 2b). The second year contained trial also shows no plant recovery when treated with the two highest rates of triclopyr (4 and 8 kg/ha), even with the longer potential recovery period of a year.

The low rate contained trial (third year) was undertaken to determine the lowest concentration at which triclopyr would effectively control parrotsfeather, and so indicate threshold levels for triclopyr treatment that could minimize the environmental load of chemicals and the associated costs.

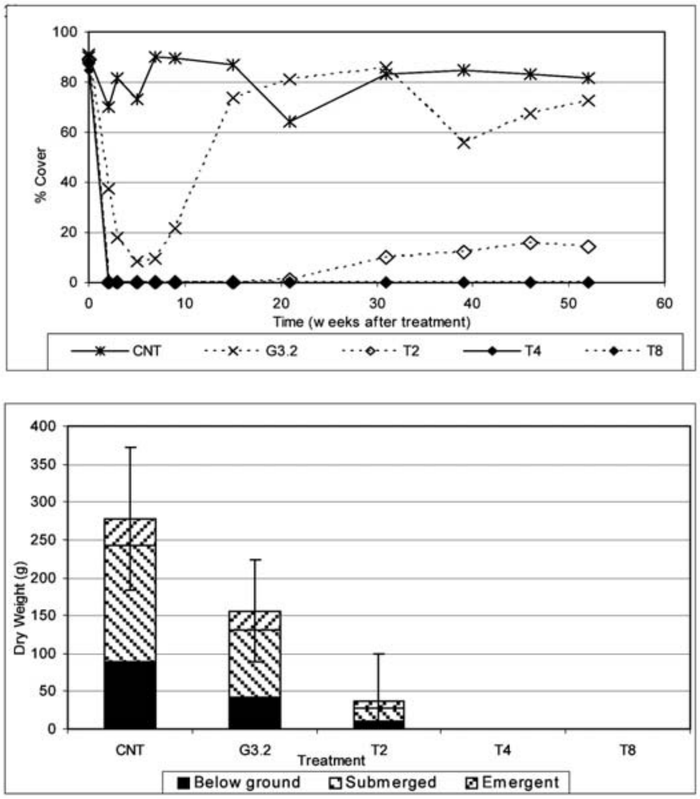

Figure 2. a) Percent vegetation cover of parrotsfeather in the year two contained trial, b) parrotsfeather biomass from the year two contained trial. Each line (2a) and bar (2b) represents the mean from replicate treatments (n = 6 for herbicide treatments and n = 3 for untreated controls). Vertical lines on each bar represent the standard deviation for the total biomass. Legend abbreviations are as follows: CNT, T and G represents the control, triclopyr and glyphosate treatments respectively. The numbers after each treatment represent the herbicide rate in kg ai/ha.

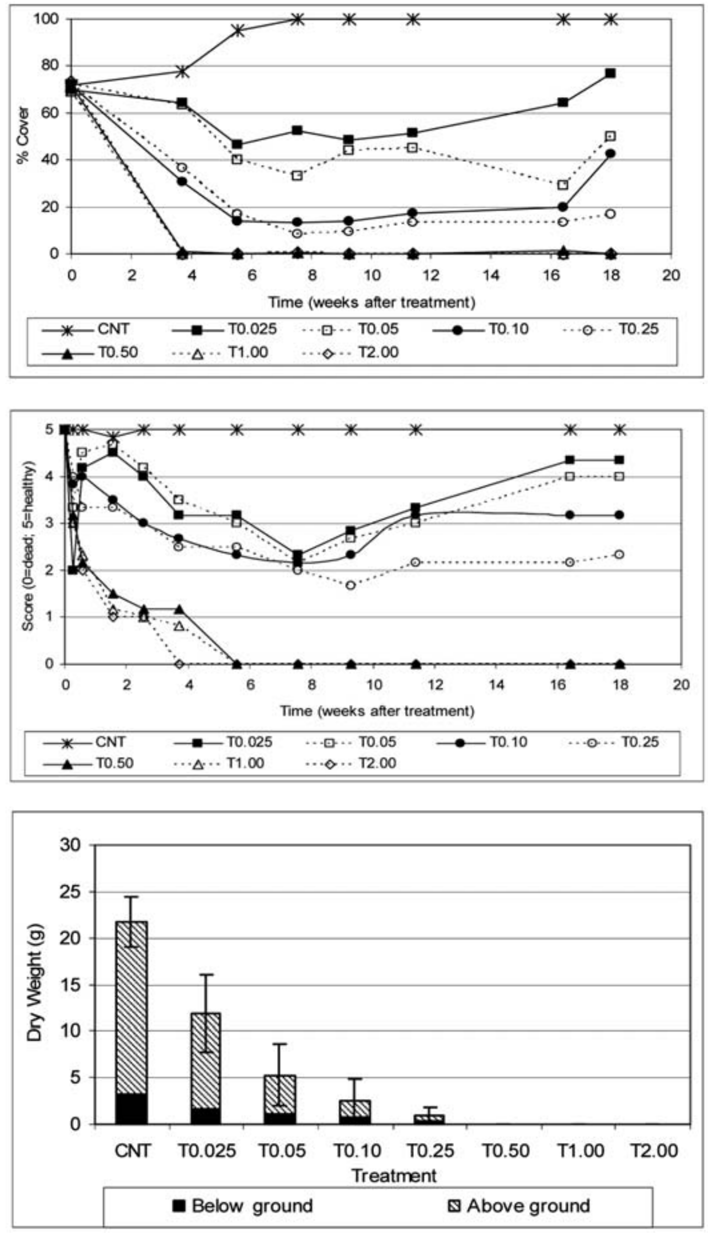

Figure 3. a) Percent vegetation cover parrotsfeather in the low rate contained trial (year three), b) mean scores for parrotsfeather decline or recovery from triclopyr treatment in the low rate contained trial (year three), c) Parrotsfeather biomass from the low rate contained trial (year three). Lines and bars represent the mean from replicate treatments (n = 6). Vertical lines on each bar in Figure 3c, represent the standard deviation for the total biomass. Legend abbreviations are as follows: CNT represents the control, T0.025 through to T2.00 represent the seven different rates of triclopyr in kg ai/ha.

Parrotsfeather treated with rates of 0.5 and 1 kg ai/ha differed from the 2 kg ai/ha treated plants only in the speed of onset of symptoms, and from 6 WAT these plants were all dead (Figure 3a, b). This compares well with the two previous contained trials where larger plants treated with 2 kg ai/ha triclopyr were dead by at least 6 WAT (Figures 1a, 2a), although some recovery was later evident in the second contained trial. Triclopyr symptoms were evident on all treated plants 24 hours following application, with wilt of leaves and stems by two days post treatment (Figure 3b). By 18 WAT plants treated with the lowest two rates (0.025 and 0.05 kg ai/ha) did not differ in appearance from control plants at the time of harvest, while those treated with the mid rates (0.1 and 0.25 kg ai/ha) still had some bent, wilted shoots and only moderate regrowth (Figure 3b). All rates even those as low as 0.025 kg ai/ha triclopyr significantly reduced the biomass of parrotsfeather at harvest (18 WAT) (Figure 3c).

Although a high level of control (significant reduction in biomass) and total plant death was achieved with these higher rates (2 to 8 kg ai/ha) of triclopyr, these results show that rates lower than 2 kg ai/ha were effective at controlling parrotsfeather under experimental conditions, and indicate that triclopyr may be efficacious on field populations of parrotsfeather at lower rates, where translocation of triclopyr is facilitated, because rapid wilting or shoot burn is limited. Because triclopyr is a systemic herbicide that is absorbed by the leaves and roots and then translocated throughout the plant (Getsinger et al. 2003), it has been suggested that high rates that cause the rapid development of symptoms may reduce a plants ability to translocate the herbicide and result in resprouting (Gardner and Grue 1996), and conversely that translocation throughout the plant will prevent resprouting (Langeland 1986). For instance, triclopyr treated purple loosestrife that exhibited rapid wilting and yellowing, was found to stimulate new growth on existing root-stock (Gardner and Grue 1996). Similarly, observations of parrotsfeather control in California also indicate that rapid uptake of triclopyr (i.e., with the use of surfactants) may limit the efficacy in the same way (Shaun Hyde, SePRO, pers com). By comparison, earlier work with triclopyr on alligatorweed suggested that translocation throughout the plant was apparent because axillary buds did not resprout and no living rhizomes were found (Langeland 1986).

It is possible that in the present study, the complete death of parrotsfeather achieved at the highest rates of 4 and 8 kg ai/ha was due not only to the concentration, but to the high level of triclopyr contact that could be achieved in the contained trial so that translocation was not as important as it may be in field sites where contact can be more difficult to maintain. By comparison a similarly high level of triclopyr contact would also have been achieved with the 2 kg ai/ha treatment plants in culture, but this rate may have been sufficient to cause the rapid symptoms in the outer tissues (within 8 hours) yet was insufficient to completely kill the plants, or enable adequate translocation, resulting in the basal stem resprout (Figure 2b). If this is the case then lower concentrations than 2 kg ai /ha may better enable translocation and be as efficacious as the higher rates (4 and 8 kg ai/ha).

Field Trials. Based on initial (% cover) results from the first contained trial, the Kaituna field trial was designed to evaluate the three best products at that time, i.e., triclopyr, dichlobenil and endothall. However the subsequent field trial in the Omeheu and East Drains only evaluated triclopyr, which was then considered the best control option (less plant recovery evident in contained trials).

At Kaituna there was an initial reduction of parrotsfeather in all treatment plots, however by 4 WAT recovery (new shoot development) was substantial (Figure 4). This coincided with a drop in water level in the wetland, such that there was little (5 cm) or no surface water and subsequent exposure of new parrotsfeather shoots and stems (rhizome), which facilitated an effective re-spray. Following the re-spray, successful control of parrotsfeather was maintained for a longer period of time than the initial spray, with percent cover in treatment plots increasing to between 60 and 90% cover by 30 WAT (150 days after re-spray), largely as a result of encroaching plants from outside of the spray zone rather than recovery from within the treatment plots. Similarly, in a field evaluation of triclopyr to control Eurasian watermilfoil it was also noted that transport of healthy milfoils stem fragments from plants growing outside of the treatment areas were responsible for regrowth that occurred in the plots (Getsinger et al. 1996, Getsinger et al. 1997, Petty et al. 1998).

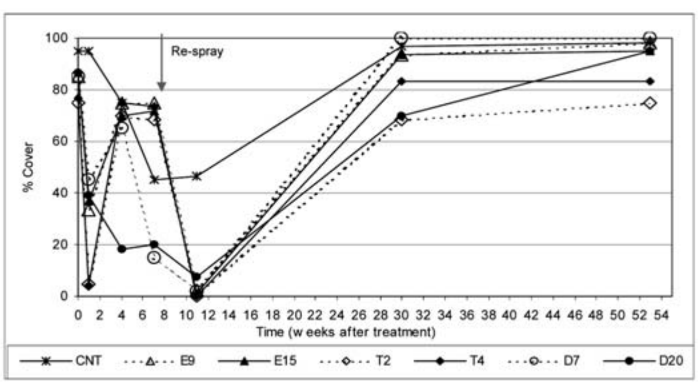

Figure 4. Percent cover of parrotsfeather in Kaituna wetland plots. Legend abbreviations are as follows: CNT, E, T and D represent control, endothall, triclopyr and dichlobenil respectively. Numbers after each treatment represent the rate of application in kg ai/ha. Timing of the re-spay is indicated.

Control of parrotsfeather in the field trial was similar to that obtained for those herbicides used in contained trials, with triclopyr being the most efficacious. However, the initial recovery of parrotsfeather was faster in the Kaituna field trial for all herbicide treated plots compared to contained trials. For example in the second year contained trial it was 30 WAT at the lowest triclopyr rate (T2) before there was 10% cover (or recovery), compared with the same rate in the field trial which had over 10% cover by 2 WAT and 6 to 7 weeks after the re-spray (Figures 2a and 4). This could be a result of product dissipation into the water and away from the targeted trial plot, resulting in lower concentrations and shorter contact time and hence faster plant recovery than in the contained trials where there was no water exchange/movement, and also the potential incursion of parrotsfeather from outside the treatment plots. Although, differences in recuperative capacity could also be expected between mature plants that occur in the field as opposed to younger plants cultivated for experimental purposes (Netherland and Getsinger 1992). However, better control of parrotsfeather following the re-spray was no doubt facilitated by the exposure of basal stems that were then severely damaged and no longer viable. As with other milfoil species severe damage of the root crowns following triclopyr treatment can impede regrowth (Getsinger et al. 1997).

In the Omeheu and East Drains pretreatment areas of parrotsfeather were 35m^2 and 128m^2 respectively. Initial symptoms of shoot wilt from triclopyr were evident on parrotsfeather plants within eight hours of treatment. One WAT dense mats of parrotsfeather in both drainage systems were brown, desiccated and dying. By comparison parrotsfeather in an untreated drain (adjacent to East Drain) was dense and continued to grow throughout the summer. However in Omeheu Drain the control of parrotsfeather (decreased cover of parrotsfeather) was generally poor (i.e., cover was reduced from an area of 35m^2 to 22m^2 by 4 WAT). At the time of application there were low covers of emergent parrotsfeather with the majority of this species present as submerged vegetation. At discrete sites, where mats of emergent parrotsfeather were present pre-treatment, reduction in plant cover was large and sustained for at least 4 WAT (e.g., 90% reduction at one site).

In East Drain a substantial reduction in the cover of parrotsfeather was achieved following triclopyr application. Initial reduction in parrotsfeather was over 90% over the entire area of the drain (i.e., from 128 m^2 to 2 m^2) by 4 WAT and was sustained for 12 WAT. By 25 WAT there were a few patches of parrotsfeather regrowth in the narrow section of East Drain. Results at East Drain were better than at Omeheu, most likely due to the low cover of emergent parrotsfeather at the time of application in Omeheu compared with East Drain where dense vegetation facilitated better contact and herbicide uptake, and hence better control.

In addition to the successful control of parrotsfeather in the field trials, triclopyr also showed selective control. For example, in East Drain non-target native species such as *Potamogeton cheesemanii* and *Persicaria decipiens* were either not impacted or recovered rapidly (within 4 WAT) following application of triclopyr. No damage to bank grasses or floating sweet grass (*Glyceria declinata*) was noted.

These trial results demonstrate that triclopyr can provide a better level of parrotsfeather control than glyphosate (which is currently used in New Zealand) at rates from 4 to 8 kg ai per ha, and that rates lower than 2 kg ai per ha also have potential application. Applications of triclopyr provide selective control of parrotsfeather.

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