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# *Crassula helmsii*: attempts at elimination using herbicides

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## Abstract

The high resistance to control by herbicides of stands of the aggressively-invasive water plant *Crassula helmsii* (Australian swamp stone crop or New Zealand Pygmy Weed, also sold as *Tillaea recurva*) was shown during a series of tank and field trials aimed at:

firstly, selecting the most appropriate UK-approved herbicide showed that diquat, either directly or in alginate form was effective on submerged plants particularly at low biomass, whereas for emergent stands, although glyphosate was initially selected as effective, diquat was subsequently recommended;

secondly, the efficacy of the herbicides selected under a range of conditions of biomass, season of application and, particularly, field conditions showed that whilst low biomasses could be controlled and the plant could probably be eliminated, elevated or multiple applications would be necessary at the very high biomasses (up to 45 kg fresh weight per $m^2$) achieved by this plant, unless the bulk of the biomass could be physically reduced prior to herbicide application; further trials were considered necessary to meet legal current constraints.

## Introduction

The aggressively-invasive water plant *Crassula helmsii* (T. Kirk) Cockayne which continues to invade ponds and lakes in Britain and to outcompete native flora, has plant stands which show a high resistance to control by herbicides (Dawson, 1988, 1989). Other methods have been attempted such as grass carp and shade material, but these have proved either difficult to implement over the range of conditions, ineffective, aesthetically displeasing or prone to damage (Dawson & Warman, 1987). Herbicides were therefore considered essential to any control strategy and particularly in nature reserves where the absence of control may often lead to rapid suppression or loss of the rarer flora (Cooke, 1986; Dawson, 1994).

The plant has an amphibious habit with growth forms adapted to a wide range of habitats from drying soils surrounding temporary pools to submerged growing from depths of 3 m in Britain. Maximum biomasses were found in emergent stands at the margins of nutrient-rich static waters (Dawson, 1994).

The objectives of this study were to:

(1) determine, in tank and field trials, which were the most effective herbicides to control submerged and marginal/emergent stands of *C. helmsii*, and to

(2) extend recommendations for the use of the selected herbicides to eliminate this plant from nature reserves by amending existing guidelines.

## Methods and materials

The methods, experimental design and work programme included:

(a) tank-trials on the control of both emergent and submerged stands of *C. helmsii* using proprietary UK-approved aquatic herbicides; and

(b) field trials over a representative range of water levels.

## Herbicide selection trials

### *Tank trials*

Plant material of *C. helmsii* was collected as turves of 0.25 by 0.25 m in area, from shallow (emergent form) and deeper (submerged form) water from Mockbeggar Pond, adjacent to the New Forest, Hampshire, UK, in September 1988 and grown as emergent (7) and submerged (7) stands respectively in large domestic water tanks (0.6 × 1.0 × 0.55 m deep, 300 l) in an almost unshaded area protected from the wind, away from normal access and without direct drainage. Turves were transported sealed in suitably-sized thick polythene bags and placed in pairs in each of the tanks. Turves from emergent stands were supported on wooden boards fitted 0.25 m from the top of the tanks to create shallow-water but to avoid excessive shading from the tanks sides; turves from submerged stands, were placed upon the bottom of the tanks. Tanks were filled with calcareous tap water to near the top.

Water levels were maintained by addition of tap water as necessary; plant nutrients were monitored and replenished to maintain good plant growth, typically c. 10 ml of a commercial general fertilizer (8-4-4 NPK) every ten days.

Plant material for further trials was collected in January and July 1989. Subsequent trials were also undertaken in 1993–1994, following the culture from 1991 of sufficient 'sediment-free' plant material from that material previously used as 'controls' in 1989, on stands typical of natural 'high' biomass stands (30–50 kg $m^{-2}$ fresh weight).

### *Field trials*

Three types of site were selected to include the habitat range of this plant, firstly, on the basis of the uniformity and extent of plant stand to allow for adjacent single plots for each herbicide separated by control areas and secondly, on relevant permission being available:

(i) stands drying in summer with the plant growing as a short turf of 0.02–0.1 m in height around the margins of a shallow gravel lake, (2 m × 2 m);
(ii) emergent stands of 0.3–0.6 m in height growing at the margins of a lake in water depths from about 0.2 m depth up to the moist margins (10 m × 10 m); and
(iii) submerged stands at water depths of about 1 m in a lake (10 m × 10 m).

### *Herbicide application*

In the initial 'low' biomass herbicide-selection trials (13–16 kg $m^{-2}$ fresh weight, 7% dry weight) in October 1988, July 1989 and July 1990, single doses of herbicides (emergent – asulam, 2,4-D amine, dalapon & glyphosate, submerged – dichlobenil, diquat & terbutryne, were applied in an appropriate manner and at the maximum 'permitted' dose rates to field sites and to the tanks after 'good growth' had re-established following transfer (minimum 6 weeks). Subsequent trials in March 1993, May 1993 and May 1994, on plant material cultured in tanks to 'higher' biomasses (up to 50 kg $m^{-2}$), were treated in an attempt to achieve full control with a series of elevated dose rates up to × 50 with both glyphosate, with and without adjuvant (Mixture B) to optimise efficacy, and diquat as supplied, diluted to highest water volumes (× 50) and in the alginate formulation. Dose rates were calculated according to individual tank volumes for submerged stands or surface areas of tanks for emergent because of tank flexibility.

### *Assessment*

After the initial trial, the plant material in each tank was weighed prior to and at intervals after treatment by sliding the plant mat onto a large pre-weighed wire frame, draining for five minutes before weighing using a large spring balance (0–50 kg) and returning it to its tank. At the conclusion of a trial (5–12 weeks), plant material was removed for assessment of living material, fresh and dry weight (105 °C); dried samples were sorted, by hand, to remove any stones, etc. originating from field sites and the weights corrected.

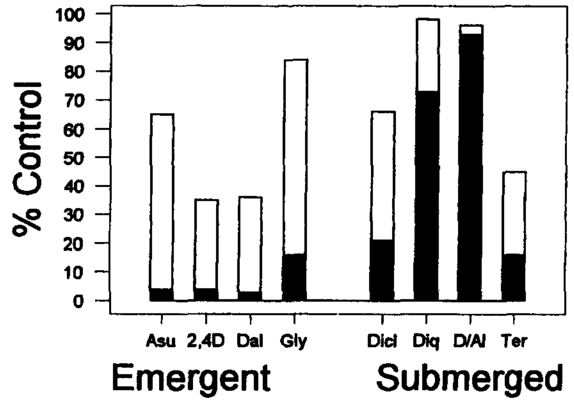


*Figure 1.* Comparison of the reduction in plant biomass, as percentage control in 'low biomass' trials (13–16 kg $m^{-2}$) with differing UK-approved herbicides during autumn (lower lines) and spring or summer (upper lines) at approved concentrations of herbicides as specified on the product label. Key: Asu = Asulam; 2,4D = 2,4 diamine; Dal = Dalapon; Gly = Glyphosate; Dicl = Dichlobenil; Diq = Diquat; D/Al = Diquat alginate; Ter = Terbutryne.

## Results

### *Tank trials*

The environment of the tanks. The water temperature varied daily and seasonally but no heat stress was observed in any plants; some plant stems and leaves were however killed when crushed in ice during winter when temperatures fell to −7 °C. Changes in water chemistry were never excessive compared to local ponds. Nutrient additions were never enough to cause more than minor algal growth.

## 'Low' biomass trials 1988–89

### *Submerged plants*

In tank trials at biomasses of 3–5 kg fresh weight, diquat and diquat-alginate were both rapid and effective in killing the majority of the plant and reducing the biomass to 0.1 kg fresh weight within a few weeks (Figure 1). Dichlobenil and terbutryne were considerably slower and only partially reduced biomasses to 1–2 kg, as might be expected by their mode of action and the time of application in the growing season. Material treated with dichlobenil was brittle, easily fragmented and had poor roots.

### *Emergent plants*

At biomasses of 8–10 kg, glyphosate was the most effective reducing biomass to 1.6 kg by December 1988, although little lasting control was found in the repeat trials of August 1989 and at higher biomasses in July 1990, apart from direct scorching showed rapidly regenerated; this was also observed at the field sites. However the biomass in several of the treated tanks was lower than the control tanks, particularly with glyphosate, indicating some degree of reduction in growth rates and therefore some control (1–2 kg).

Correction of the July 1989 results for growth of the plants compared to the controls showed that whereas glyphosate was only partially effective, diquat was very effective with reductions to 0.5–0.1 kg followed by dichlobenil (to ~1 kg) and terbutryne (to 0.7 kg).

### *Field trials*

Field trials on the short drying turves were inconclusive with much scorching but reductions in biomass appeared to show a similar pattern to the tank trials. Plant stands were however almost entirely killed in the deeper water trials, but differing degrees of control between herbicides were not observed as material may have drifted into or out of the areas under wind action and water movements may have occurred creating a herbicide 'cocktail' despite the use of buffer zones.

### *High biomasses tank trials*

Trials at 'higher' biomasses (30–45 kg $m^{-2}$ fresh weight) in May 1993 and July 1994 in which glyphosate and diquat were applied at higher than the normal application rates, resulted in more reliable reductions in biomass particularly at the × 5 and × 10 concentrations (Figure 2a & b). Diquat was effective when tested at higher concentrations but even when tested at a single dose rate of × 50, plant material was not fully killed at the highest biomasses of 45 kg $m^{-2}$ fresh weight. However a disproportionally higher quantity of dead material remained compared to low biomass trials, some of which remained viable in the waste pit even after several months under black polythene.

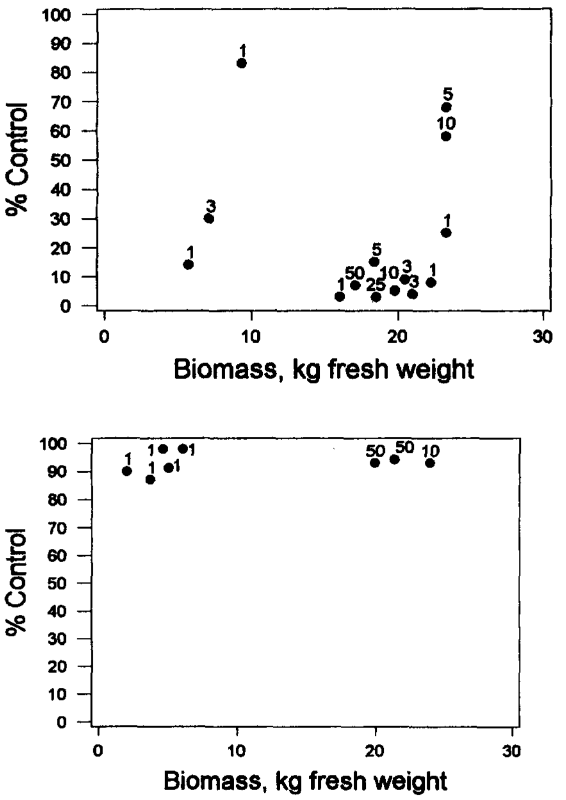


*Figure 2.* Comparison of the reduction in plant material at differing biomass with (a) Glyphosate and (b) Diquat and diquat alginate at different concentrations of herbicide. The concentrations, × 1 to × 50, are indicated by the numbers by each symbol.

## Discussion, conclusion and recommendations

The results are discussed in relation to the objectives of this study:

1. determining from tank and field trials the most effective and acceptable herbicide to control both submerged and marginal/emergent stands of *C. helmsii*;

2. extending recommendations for the use of herbicides to eliminate this plant from nature reserves, and amending existing guidelines.

The 'comparison of the effectiveness of different aquatic herbicides' in tank trials showed conclusive results for tank trials but not for field trials particularly on emergent stands. In initial trials, both untreated emergent and underwater stands showed that the degree of control varied with the type of herbicide but that low biomass underwater stands (up to 10 kg $m^{-2}$) were best controlled by diquat and diquat-alginate. Emergent stands were however only partially susceptible to one herbicide glyphosate at normal concentrations despite the addition of adjuvant.

Hydrogen peroxide (100 volume, 100 ml $m^{-2}$), a potentially environmentally-acceptable chemical was also tested in field and tank trials and was quite effective initially but its effect was limited to a direct kill or scorching effect.

Comparison of the normal requirements of weed control with those of elimination illustrate two problems both of which through 'legal' constraint lead to limitation in the effectiveness of control:

(i) the typical biomass of a maturing emergent stand of *Crassula helmsii* is considerably higher during the approved application period (50 kg $m^{-2}$) fresh weight, than for normal aquatic 'weeds'; this results in an unusually low ratio of herbicide to 'weed' biomass,

(ii) elimination of this plant is desired not merely the firm control as required for most other aquatic sites.

These problems are exemplified by the field trials on both drying turves and emergent stands, in which a single application at the approved dose limited biomass but produced little observable effect; underwater stands, typically lower in biomass, were far more successful controlled if the problem of die-back to shoot tips and release of fragments of differing viability for recolonisation, is neglected. (Fine wire-mesh enclosures were previously recommended to contain these fragments).

Dose rate and timing have been investigated in the tank trials on both glyphosate and diquat in anticipation of 'off-label' trials at higher concentrations but even ten times the normal maximum dose was insufficient to give more than two-thirds control in a single application. If eradication of this plant from nature reserves is to be achieved, multiple applications are indicated and these should be fully tested in further tank and field trials.

The second objective, that of extending the existing recommendations for use of herbicides to eliminate this plant from nature reserves by synthesizing the results of herbicide tank and field trials with the variety of conditions and range of sites to prevent the further continuing spread of *Crassula helmsii*, indicated:

1. different guidelines are required for sites with differing degrees of dominance, e.g. 'low' versus 'high' biomass areas or sites, and

2. noting that some techniques were ineffective or counter-productive.

Thus for example

(i) manual or mechanical normally results in the increase in the number of viable fragments within the wet area with a consequential loss of local flora and also an increase in the risk of spread to other sites, e.g. on operators boots, equipment or machinery.

(ii) herbicides should be applied as effectively as possible on the first application because reduced or subsequent applications only causes the loss of other more susceptible species effectively enhancing the dominance of *C. helmsii.* However alternatives available including the application of herbicide in winter when native species are less common may cause adverse less effect and the natural seed bank can help to regenerate the local flora.

Recommendations for further work on the control of *Crassula helmsii* include:

1. Improving the control of emergent stands by
   (i) using glyphosate in an off-label way for the UK,
   (ii) optimizing the concentration of surfactant or 'adjuvant' additive,
   (iii) undertaking new user trials with glyphosate, to determine appropriate concentrations or
   (iv) extending the recommended use of diquat to emergent plants as well as submerged.

Further research to assess the herbicidal properties and by-products of simple chemical compounds for use in nature reserves (or by the use of other herbicides) could be undertaken. The use of hydrogen peroxide in these trials resulted in some direct control but this was not exploited; further investigation of 'peroxygen' generating compounds, in particular, is suggested.

2. Trials on (i) multiple doses of herbicide diquat at intervals of 2–4 weeks and (ii) in a concentration appropriate to the biomass present, as part of a considered elimination strategy for this plant.

3. Continuation of the study of the primary and secondary dispersion of this plant, both by man and other mechanisms to reduce the invasion of important and rare natural site, and to reduce the invasion of large site in which control is likely to be impractical eg Cumbrian lakes and Scottish locks.

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