PP100: AN ALTERNATIVE FORMULATION OF DIQUAT FOR CONTROL OF SUBMERGED AQUATIC WEEDS

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SUMMARY

PP100 is a new experimental gel formulation of diquat for use in the control of submerged aquatic weeds. When applied to water it forms gelatinous strings or droplets which sink and adhere to submerged plants. PP100 was compared with aqueous diquat and results suggest that it was better able to control deep weed growth, although water drift was still significant. Factors affecting herbicidal efficacy are discussed. These include water temperature, depth, movement, and volume treated, plant morphology, height, age, and degree of metabolic activity.

INTRODUCTION

The bipyridyl contact herbicides diquat and paraquat are the only chemicals registered for submerged weed control in New Zealand. Diquat is the most commonly used aquatic herbicide. Recent water rights for the use of diquat have specified that agents to minimise dispersion should be added since a number of problems have been recognised in the use of aqueous formulations.

These include:

- (i) Aerial drift of fine sprays.
- (ii) Inadequate control of placement in static waters due to wind generated surface and subsurface currents, and thermal density barriers.
- (iii) Limitations to use in flowing water.

This lack of predictability has lead to unfavourable consequences in non-target areas, hindered the achievement of required concentrations and contact times, and limited the control of deeper-growing weeds.

In this paper we report on PP100 an experimental gel formulation of diquat developed by ICI (UK), and discuss a number of factors influencing the efficacy of herbicides in water.

PP100 FORMULATION

PP100 is a dark viscous sodium-alginate formulation containing 10% diquat. Formulation details are given by Barrett (1978). When extruded into water PP100 forms gelatinous strings or droplets which sink and are claimed to cling to submerged weeds thereby allowing a significant improvement in the localisation of weed control in both static and flowing water. This product has been field tested overseas since 1977 on a limited range of species. It is however, expected that it will be active against the same range of species as aqueous diquat and meet the same environmental specifications. Because of its sinking properties and localisation within the weed bed it is claimed that doses may be applied on a surface area basis irrespective of depth (ICI 1981). Recommended rates of application are 10 ml product/m², giving a theoretical water concentration of 1 ppm diquat in a depth of 1 m.

METHODS

Field sites representative of a range of water qualities, depths, temperatures, and submerged weed species were selected to test PP100 efficacy and compare it to aqueous diquat. Trials were carried out between 25.9.81 and 16.4.82 in Hamilton Lake, a turbid, mesotrophic lake; and Lakes Okataina and Rotoma, both clear-water, oligotrophic lakes in the Rotorua area. Five metre square quadrats (25m²) were marked with corner

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buoys in areas of complete plant cover. Ten metre square quadrats (100m²) were chosen for some of the aqueous diquat trials to allow for the greater dispersion expected.

Observations on water depth, community composition and canopy height were made in each quadrat using scuba. Sites chosen in Hamilton lake contained a mosaic of the three plants lagarosiphon (*Lagarosiphon major*), egeria (*Egeria densa*), and Canadian pondweed (*Elodea canadensis*). Those in Lakes Okataina and Rotoma contained only lagarosiphon.

PP100 and aqueous diquat were applied evenly over the water surface of the plots in all 5 x 5 m quadrats using 50 ml plastic syringes. Aqueous diquat was applied in the 10 x 10 m plots using a knapsack sprayer with a 2 mm open nozzle allowing a spray range of up to 10 m. Observations were made using scuba at 7, 20 and 45 days after spraying. Final scoring of herbicidal effect was based on a four point scale. The area of herbicidal effect outside the quadrats was also noted as an indication of the extent of drift.

RESULTS

Results of diquat applications in the three lakes treated are summarised in the Table.

Lake Okataina

No effect was apparent at normal rates of aqueous diquat application (0.7 g/m²) in Lake Okataina during September 1981. PP100 applied at half the recommended rate (0.5 g ai/m²) had no visible effect. Only minimal plant effects were observed when the rate of application was increased to recommended and twice recommended rates. Despite calm sunny weather (water temperature 14°C), only around half of the lagarosiphon shoots showed terminal scorching of the top 4-5 cm followed by decay of these portions. Small lesions were occasionally apparent where PP100 had adhered to lower portions of the plants.

Lake Rotoma

In February 1982, higher rates of aqueous diquat were applied (1.0 and 2.0 g/m²) in order to compare directly with recommended and twice recommended rates of PP100. Water temperatures were warmer (22°C) and weather conditions favourable for herbicide application. Only taller plants of lagarosiphon were affected by aqueous diquat. Shoots below a water depth of 1.3 m were not visibly influenced, while shoots above this depth scored sub-lethal effects with only the terminal portions subsequently decaying. Although vertical temperature readings were not taken, this result was attributed to temperature stratification preventing vertical mixing of aqueous diquat below a depth of 1.3 m. This effect was widespread, even beyond the treated plots in shallower water where sub-lethal effects were noted on most plants growing in water shallower than 1.3 m.

PP100 was applied on the same day and at equivalent rates and conditions as aqueous diquat, except that smaller plots were used. Lagarosiphon did score more visible damage from PP100 than from aqueous diquat. Sub-lethal effects were observed for all plots sprayed. Any thermal density barrier that might have been present did not provide an obstacle to the depth of gel penetration. Strong winds 2 months after treatment subsequently resulted in the collapse of vegetation only in the PP100 treated plots.

Since PP100 was reported to be containable within weeds beds and to work in fast flowing water of up to 80 cm/sec (Barrett 1981a and b) a further application was made at recommended rates during light windy conditions with a water movement of only around 4 cm/sec. Only minimal effects were observed on the plants within the treated areas and for a large area beyond the plots.

Hamilton Lake

Trials using PP100 at recommended and twice recommended rates had lethal effects on all three weed species present. Total vegetation collapse occurred within 1 week in treated plots and up to 10 m beyond. Sub-lethal effects were apparent for a considerable distance.

Further trials compared PP100 with aqueous diquat during a light wind and with a water movement of around 4 cm/sec. Plot sizes and application rates were the same. Both treatments scored sub-lethal effects on all weed species present. Considerable drift was apparent using both formulations.

TABLE 1: Herbicidal effects of two formulations of diquat (PP100 and aqueous) in three lakes between 25.9.81 and 16.4.82 with different rates of application; water temperature, movement and depth; plant height and species composition.
(N.B. Rate g/m² is equivalent to a theoretical concentration expressed as g/m ha or ppm/top ha m).

Form- ulation	Rate (g/m ²)	Water column conc. (g/m ³)	Surface water temp. (°C)	Water movement	Water depth (m)	Vegetation height (m)	Species	Final score
Okataina (oligotrophic)								
P	0.5	0.14	14	C	3.5	1.5	a	0
P	1.0	0.29	14	C	3.5	1.5	a	1
P	2.0	0.60	14	C	3.5	1.5	a	1
A*†	0.7	0.20	12	C	3.5	1.5	a	0
Rotoma (oligotrophic)								
P	1.0	0.33	22	D	3.0	1.5	a	1
P	1.0	0.33	22	C	3.0	1.5	a	2-3
P	2.0	0.67	22	C	3.0	1.5	a	2-3
A*	1.0	0.33	22	C	3.0	1-2	a	0-2
A	2.0	0.67	22	C	3.0	1-2		0-2
Hamilton (mesotrophic)								
P	1.0	0.33	19	C	3.0	2	abc	3
P†	2.0	0.67	19	C	3.0	2	abc	3
P†	2.0	1.0	23	D	2.0	1.5	ab	2
P†	2.0	1.0	23	D	2.0	1.5	ab	2

P — PP100
A — Aqueous
C — calm, no wind, water movement negligible
D — disturbed, light wind, water movement 4 cm/sec
a — lagarosiphon
b — egeria
c — Canadian pondweed
* — 10 x 10 m plot, all others 5 x 5 m
† — two plots, all others single

0 — no effect; 1 — minimal effect (low incidence of apical effect); 2 — sublethal (majority apices affected); 3 — (total stand collapse)

DISCUSSION

A number of factors appear to influence the efficacy of PP100 and aqueous diquat.

Plot size

Although Barrett (1978, 81a and b) reported localisation effect in 2 m² plots, such small plots have a large edge effect in relation to the volume of water treated. This would result in greater dilution of any outward drift and possibly give a false impression of herbicidal containment. The 25 and 100 m² plot sizes used in these trials had a smaller edge in relation to volume treated. Outward drift would therefore become more apparent due to the reduced effect of dilution.

Water movement

Calm conditions with negligible water movement gave best results. Moderate water movement of around 4 cm/sec significantly reduced the efficacy of both PP100 and aqueous diquat.

Water temperature

Best results were obtained when diquat was applied to warmer water, provided water movement was minimal. Because of its sinking properties PP100 also appears to be more effective than aqueous diquat if vertical temperature stratification exists.

Water depth

The depth of water determines the dilution of herbicides. PP100 did appear to be more successful than aqueous diquat in deeper water.

Vegetation height

Water movement beneath the plant canopy is significantly lower than in the open water above. The proportion of the water column occupied by vegetation, and the path length between the water surface and the canopy, affects the amount of herbicide penetration into the canopy and also drift from the target area.

Weed species

All three weed species present in the Hamilton lake trials were controlled. Lagarosiphon and Canadian pondweed are known to be susceptible to diquat, however, there have been few attempts to control *Egeria* using diquat. *Egeria* was particularly sensitive to PP100 and aqueous diquat, and also showed the effects from drift further than the other two species. Characean algae were not visibly affected by any of the diquat treatments.

Plant morphology

The morphology of weed species appeared to have an important impact on the attachment of gel formulations. Lagarosiphon has strongly recurved leaves which form a smooth surface to any downward moving strings or drops of gel. This resulted in little attachment or sticking of PP100 onto the lagarosiphon shoots. *Egeria* has larger leaves which face outwards and provide better attachment sites.

Plant age

The age and metabolic activity of the treated plants may also have influenced the results. The trial sites in Lake Okataina had not previously been sprayed and the lagarosiphon had a high proportion of older stems with little recent growth evident. The success of the Hamilton lake trials might have been partly attributable to the younger age of the plant regrowth since the lake was sprayed in 1979.

CONCLUSIONS

PP100 has the potential to reduce a number of the problems associated with aqueous formulations of diquat. There is no aerial drift, better placement is possible, and deeper growing weed can be controlled. Problems of drift in water still exist however, even when water movement is negligible.

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